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THE ROLE OF CORE COLLAPSE SUPERNOVAE IN THE CONTEXT OF DUST PRODUCTION IN THE EARLY UNIVERSE

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The role of core collapse supernovae in the context of dust production in the early universe

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Declaration of Authorship

I, Mikkel Juhl Hobert, declare that this thesis titled, “The role of core collapse supernovae in the context of dust production in the early universe” and the work presented in it are my own. I confirm that:

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Date:

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"Thanks to my solid academic training, today I can write hundreds of words on virtually any topic without possessing a shred of information, which is how I got a good job in journalism."

Dave Barry

UNIVERSITY OF COPENHAGEN

Abstract

Faculty of Science

Niels Bohr Institute

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The role of core collapse supernovae in the context of dust production in the early universe

by Mikkel Juhl Hobert

Recent research based on infrared observations of high-z galaxies have confirmed the presence of significant amounts of dust in the early universe, only a few hundred million years after the onset of the first stars. This poses a problem to our current physical understanding of the environmental circumstances under which the dust is formed, since it suggests that the dust must have been produced and injected into the interstellar medium at an incredibly fast rate. Because of their lifetimes of only a few million years, core collapse supernovae of high mass stars may play a crucial role in the context of early dust production. So far, however, observations have failed to detect the necessary dust yields in order to explain the large dust masses we see in the young galaxies. It wasn't until quite recently that a massive dust reservoir of up to $\sim 1\,M_{\odot}$ of cold dust was observed in the SN1987A in the Large Magellanic Cloud using far infrared measurements from the Herschel Space Observatory.

Motivated by this recent observation, in this project I aim to study a sample of young type II supernova remnants in the Magellanic Clouds. My goal is to estimate the largest possible amount of cold dust that can possibly have been produced by each remnant, mainly based on the far infrared and sub millimeter surveys done by the Herschel Open Time Key Programme HERITAGE, with the inclusion of mid infrared observations from the MIPS instrument on the Spitzer Space Telescope.

My sample consists of the young and relatively isolated core collapse supernova remnants, N11L, N23, N132D, 0N49 and N63A with the inclusion of the previous results of SN1987A in the Large Magellanic Cloud. By performing careful measurements of each remnant using aperture photometry, I extract the flux densities for each remnant over the mid and far infrared and sub millimeter regimes. I then fit the spectral energy distributions with a two component modified blackbody spectrum for three distinct dust models of silicates and amorphous carbon. Using the ATCA, SHASSA and MAGMA surveys of neutral, ionized and molecular hydrogen and local dust-to-gas mass ratios in order to account for the swept-up dust mass from the interstellar medium.

I find that the average cold dust yield per supernova is still fairly uncertain. At first sight, the three remnants N11L, N23 and N132D does not appear to contain significant amounts of cold dust with $M_d/M_\odot \sim 0$. The total dust masses in N49 and N63A are upwards of $M_d/M_\odot \sim 10 - 20$. Using the gas surveys I suspect that the dust masses observed in N49 may be mostly swept-up material. N63A, however, is peculiar and the high flux densities may partly be due to significant contributions from synchrotron radiation and atomic lines, neither which I accounted for.

All in all I find that the total dust masses strongly depend on the chosen dust model and that the measurements are highly limited by difficulties in the background subtraction. However, the data weakly suggests that, on average, that core collapse supernovae may not by themselves be the key contributors to dust in the early universe.

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ACAR	Amorphous carbon, **ACAR** sample
AS	**A**stronomical **S**ilicates
ATCA	**A**ustralia **T**elescope **C**ompact **A**rray
BE	Amorphous carbon, **BE** sample
CC	**C**ore **C**ollapse
ESA	**E**uropean **S**pace **A**gency
FIR	**F**ar **I**nfra**r**ed
HIPE	**H**erschel **I**nteractive **P**rocessing **E**nvironment
IPAC	**I**nfrared **P**rocessing and **A**nalysis **C**enter
IRAF	**I**mage **R**eduction and **A**nalysis **F**acility
IRSA	**I**nfra**r**ed **S**cience **A**rchive
ISM	**I**nter**s**tellar **M**edium
LBV	**L**uminous **B**lue **V**ariable
LMC	**L**arge **M**agellanic **C**loud
MAGMA	The **Mag**ellanic **M**opra **A**ssessment
MC	**M**olecular **C**loud
MIPS	**M**ultiband **I**maging **P**hotometer for **S**pitzer
MIPS 24	**MIPS** 24 µm band
MIPS 70	**MIPS** 70 µm band
MIR	**M**id **I**nfra**r**ed
NASA	**N**ational **A**eronautics and **S**pace **A**dministration
NIR	**N**ear **I**nfra**r**ed
NOAO	**N**ational **O**ptical **A**stronomy **O**bservatory
PACS	**P**hotometric **A**rray **C**amera and **S**pectrometer
PACS 100	**PACS** 100 µm band
PACS 160	**PACS** 160 µm band
SED	**S**pectral **E**nergy **D**istribution
SHASSA	The **S**outhern **H**-**A**lpha **S**ky **S**urvey **A**tlas
SMC	**S**mall **M**agellanic **C**loud
SN	**S**uper**n**ova
SNR	**S**uper**n**ova **R**emnant

SPIRE	**S**pectral and **P**hotometric **I**maging **Re**ceiver
SPIRE 250	**SPIRE** 250 µm band
SPIRE 350	**SPIRE** 350 µm band
SPIRE 500	**SPIRE** 500 µm band
submm	**Sub** **Mi**lli**m**eter
WR	**W**olf-**R**ayet
YSO	**Y**oung **S**tellar **O**bject

Unit Conversions

Arcminute	$1' = 1/60^\circ$
Arcsecond	$1'' = 1/3600^\circ$
Erg	$1\,\mathrm{erg} = 10^{-7}\,\mathrm{J}$
Gigahertz	$1\,\mathrm{GHz} = 10^{9}\,\mathrm{Hz}$
Jansky	$1\,\mathrm{Jy} = 10^{-26}\,\mathrm{W\,m^{-2}\,Hz^{-1}}$
Micron	$1\,\mu\mathrm{m} = 10^{-6}\,\mathrm{m}$
Parsec	$1\,\mathrm{pc} = 3.09 \times 10^{16}\,\mathrm{m}$
Rayleigh	$1\,R = 10^{6}/4\pi\,\mathrm{photons\,s^{-1}\,cm^{-2}\,sr^{-1}}$
Solar mass	$1\,M_\odot = 1.989 \times 10^{30}\,\mathrm{kg}$
Steradian	$1\,\mathrm{sr} = 3282.8\,\mathrm{deg}^2$

Dedicated to my friends and family, whom I wouldn't have come this far today without.

Chapter 1

Introduction

Large amounts of dust have been observed in quasars and galaxies at redshifts $z \gtrsim 6$, most notably the quasar SDSS J1148+5251 (Robson et al., 2004; Beelen et al., 2006) when the universe was $\lesssim 1\,\mathrm{Gyr}$ old. The epoch of reionization and the onset of the first stars is believed to have taken place at around $z \gtrsim 10$ (Greif and Bromm, 2006; Planck Collaboration et al., 2014) when the universe was only $\sim\ 400\,\mathrm{Myr}$ old. Together these observations suggest that the universe had only around $\sim 400 - 500\,\mathrm{Myr}$ to produce the large amounts of dust and inject it back into the ISM in the early galaxies. It's therefore assumed that it must have been produced by one or more short-lived stellar processes.

For a long time it has been suggested that CC SNe may be the primary sources of early dust enrichment due to their short lifespans of a few hundred Myr or less and their large production of metals. However CC SNe most likely play a dual role in the evolution of interstellar dust since during the collapse they can either produce large amounts of metals and dust or destroy surrounding dust grains by thermal sputtering and evaporation.

In this project I'm going to investigate the role that CC SNe play in the context of dust production. My aim is to attempt to accurately estimate the net production of some given type of dust in each SN event. In particular I'm going to look at already known young type II SNRs in the nearby SMC and LMC satellite galaxies in the Local Group mainly due to their well-determined distances.

My thesis will be structured like so; Firstly I'm going to give a brief introduction of and context on the late stages and deaths of high mass stars, SN events and general classifications of SNe. Secondly I'm going to introduce the theory relevant to the various aspects I used in my research. Thirdly I'll give a description of my methods I used to obtain my results. Finally I'm going to apply my theory and methods to specific SNRs in the Magellanic Clouds to reach a discussion and conclusion of my results as well as my suggestions for further investigations.

1.1 Late stages of stellar evolution of high-mass stars

The stellar lifetime of a star from birth to death is highly dependent on its mass. It spends most of its life on the main sequence fusing hydrogen to helium in its core where only about $10\,\%$ of its total mass is burned as fuel and only $0.7\,\%$ of that mass is converted to energy in the nuclear process (Christensen-Dalsgaard, 2008, chap. 1). For a star of mass M and average luminosity L, a rough estimate of its lifetime is therefore

$$\begin{aligned} t_{\text{nuc}} &\sim 7 \cdot 10^{-4} \frac{Mc^2}{L} \\ &\sim 10^4\,\text{Myr} \left(\frac{M}{M_\odot}\right) \left(\frac{L}{L_\odot}\right)^{-1}, \end{aligned} \tag{1.1}$$

where the nuclear timescale t_{nuc} is the time it takes for the star to exhaust its hydrogen core. For a massive star the mass-luminosity relation is approximately $L \propto M^3$ so $t_{\text{nuc}} \propto M^{-2}$. If the mass is of order $M \sim 10\,M_\odot$ then

$$t_{\text{nuc}} \sim 10^2\,\text{Myr}, \tag{1.2}$$

so the typical lifetime for a high-mass star with $8\,M_\odot \lesssim M \lesssim 100\,M_\odot$ is only a few million years.

A star with $M \gtrsim 8\,M_\odot$ goes through several nuclear burning phases

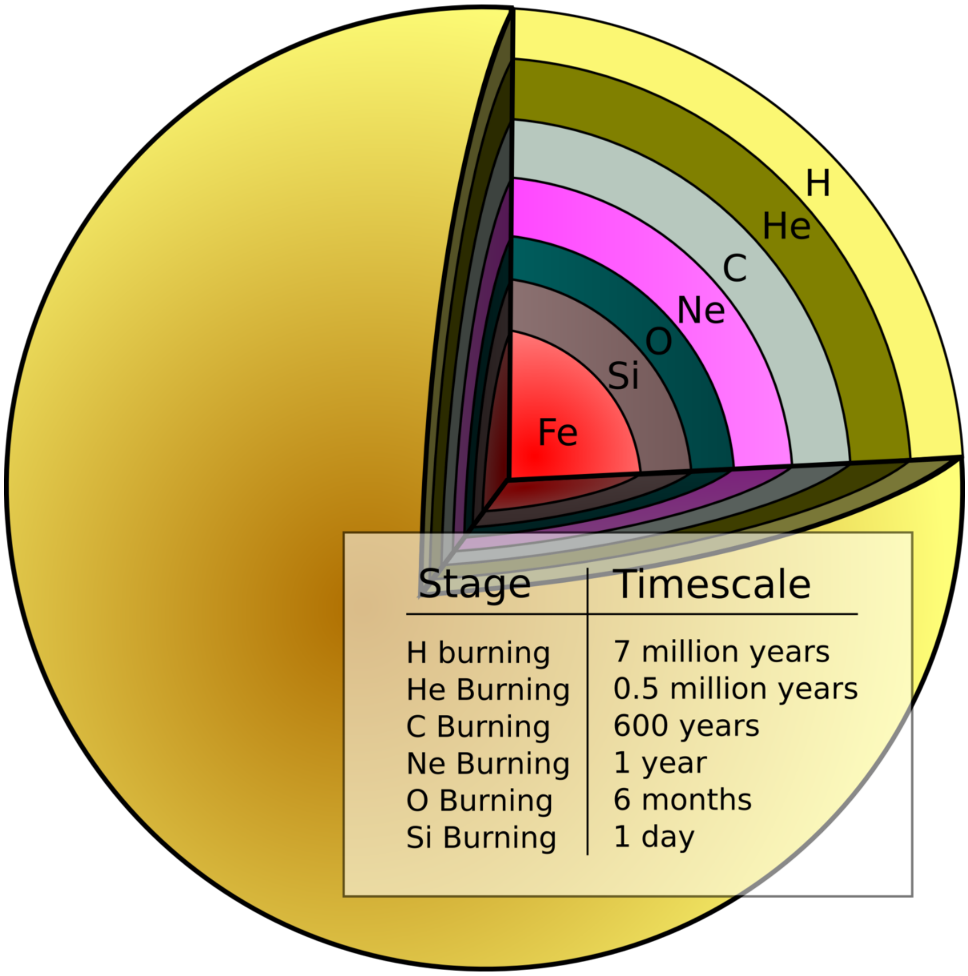


FIGURE 1.1: Schematic of the onion-like structure of a massive star with typical timescales for the different nuclear fusion processes in the core, here calculated for a 25 $M_\odot$ star. Source: Phillips (1999).

fusing different elements throughout its interior in an onion-like structure all the way up to iron-fusion in its core (see Figure 1.1).

At some point the star has fused its silicon to iron. Since iron fuse is an energy consuming process, the star can no longer maintain its hydrostatic equilibrium in which gravity is balanced by thermal pressure by burning fuel in its core. Hence it reaches the end of its lifetime and ends with a violent collapse under its own gravity.

As the star collapses, neutrons and neutrinos are created at a rapid rate by electron captures and further neutrino/anti-neutrino pairs are created by various high-energetic processes in the core. Because of their low cross-sections, the core initially cools rapidly by releasing a large amount of neutrinos which carries away a huge amount of kinetic energy typically with a luminosity of $\sim 10^{52}\,\mathrm{erg\,s^{-1}}$ for several seconds. At some point, however, the density becomes so large that even the neutrinos start to scatter on the nuclei and get trapped. The neutrino-nucleon interactions then heat the matter in the collapse enough to overcome the gravitational potential and so matter is finally expelled from the core leaving behind a neutron star or a black hole in a CC SN explosion.

Progenitor stars of mass $8\,M_{\odot} \lesssim M \lesssim 30\,M_{\odot}$ usually leave behind a neutron star while the most massive stars with $M \gtrsim 30\,M_{\odot}$ leave behind a black hole.

1.2 Classification of supernovae

SNe events are most generally divided into two subclasses, type I and type II. The type II is defined by the presence of hydrogen emission lines in its spectrum and the type I is defined by the lack thereof. The two types of SNe are then further divided into several subclasses depending on their spectral features and light curve shape. A schematic of the subtype classifications is shown in Figure 1.2. Type Ia SNe are associated with thermonuclear runaways of accreting white dwarves in binary systems while the rest are CC SNe of high-mass stars.

1.2.1 Type Ia supernovae

The type Ia SN shows no hydrogen lines in the spectrum because the progenitor has shed its hydrogen layers prior to the explosion as a thermally pulsing AGB-star. The spectrum contains silicon as it's the nuclear product of carbon and oxygen fusion which is the end-stage reaction for low- and intermediate mass stars during the thermonuclear runaway. Type Ia SNe are therefore associated with white dwarves in binary systems that have accreted enough mass from its

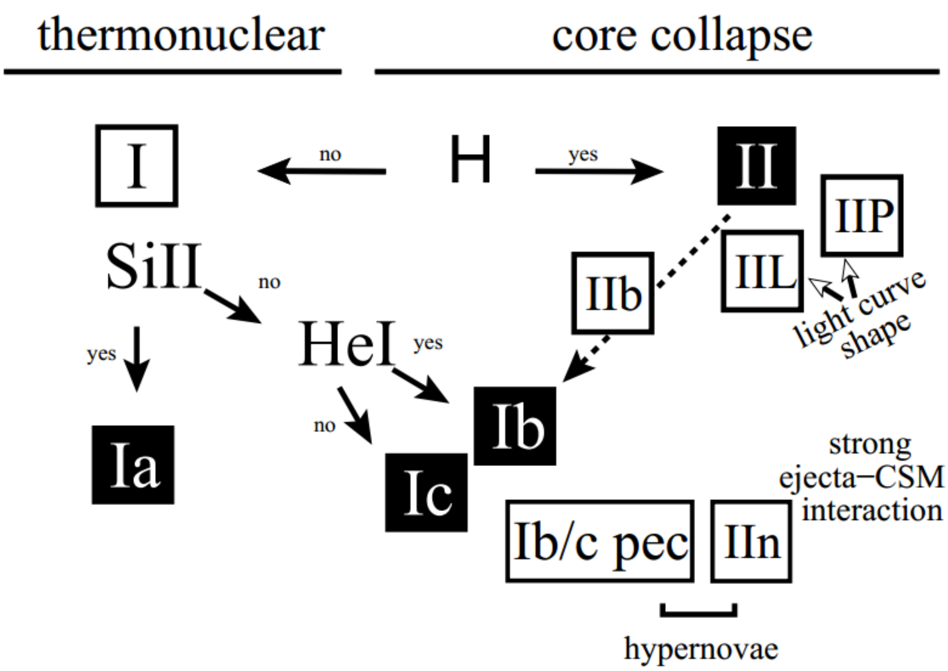


FIGURE 1.2: Schematic of the different types and subtypes of SNe. The type Ia supernova is associated with the thermonuclear explosion of a white dwarf while the other types are believed to be the CC of stars with a mass $M \gtrsim 8\,M_{\odot}$ or higher. Source: Turatto (2003).

companion to exceed a $1.4\,M_\odot$ threshold which starts a runaway nuclear reaction of carbon and oxygen in the electron degenerated core that rips the remnant apart entirely.

1.2.2 Type Ib/Ic supernovae

Like the type Ia, the type Ib/Ic SNe spectra show no hydrogen line features which indicates that they have also undergone mass losses by strong stellar winds. Unlike the type Ia, they both lack strong silicon features since most of the abundance resides in the collapsed core. Type Ib differs from type Ic in that excited helium lines can be found in the spectrum. The type Ib progenitor has shed its hydrogen layer prior to the collapse revealing its underlying helium layer whereas the type Ic has lost both its hydrogen-rich and helium-rich shells. Due to steep spectral indices in their radio emissions which indicates strong shock interactions and synchrotron radiation from electrons accelerated in the shock, the type Ib/Ic are both associated with CC SNe.

1.2.3 Type II supernovae

Type II supernovae are classified by the presence of hydrogen lines in the spectra and are all associated with the massive stars due to their rapid evolution and collapse so there is a large amount of gas in the outer layers that haven't undergone shell burning or considerable mass losses by thermal pulsations. The type II class is typically divided into four subcategories.

Type IIP and IIL SNe both have very blue and almost featureless spectra. The type IIP light curve plateaus ("P") shortly after its maximum while the type IIL declines linearly ("L").

Type IIb SNe usually show early time spectra similar to the type II SNe containing strong hydrogen features but late time spectra more similar to type Ib/c (hence "IIb").

TABLE 1.1: Definitions of the different SNe types. Source: Gall et al. (2011)

SN type	Defining characteristics	Progenitor mass range ($M_\odot$)
Type II	Hydrogen present	
Type IIP	Blue, almost featureless spectrum, light curve plateaus	$8 - 25$
Type IIL	Blue, almost featureless spectrum, light curve declines linearly	$\sim 15 - 25$
Type IIn	Narrow emission lines	$\gtrsim 25 - 30$
Type IIb	Early-time spectrum similar to type II, late-time spectrum similar to type I	$\gtrsim 25 - 30$
Type I	Hydrogen absent,	
	Silicon present	
Type Ia	Thermonuclear explosion	$\lesssim 8$
	Silicon absent	
Type Ib	Helium present	> 25
Type Ic	Helium absent	> 25

Type IIn SNe are identified by their narrow emission lines ("n") probably owing to the ejecta interacting with a dense circumstellar medium which transforms kinetic energy into thermal energy and radiation.

A few SNe don't fall into any of these categories and are generally categorized as "peculiar".

The variety of CC SNe types can generally be attributed to gradually increasing progenitor masses ordered from IIP, IIL, IIn, IIb, Ib and Ic, although the classifications also owe to many other factors like the stellar winds, shell stripping and mass transfer by companion stars. The general definitions and properties of all the SN types are summarized in Table 1.1.

1.3 The dynamical evolution of SNRs

The dynamical evolution of the SNR following the explosion or a CC can generally be divided into three distinct phases:

The free expansion phase

After the initial explosion a shock front propagates outwards in the surrounding ISM. The expanding shockwave is unaffected by the pressure of the interstellar gas so the ejection velocity only depends on the initial kinetic energy of the SN ejecta.

The adiabatic/Sedov-Taylor phase
After some time enough mass from the ISM has accumulated behind the shock front that it starts to affect the SNR. At some point the density contrast between the accumulated mass and the SN ejecta becomes so large that a reverse shock starts to travel inwards heating up the SN ejecta to high temperatures. The energy loss by radiation processes are negligible so the SNR expands adiabatically.

The radiative/snowplough phase
When the SNR becomes cool enough due to adiabatic expansion, ionized atoms begin to recombine and radiative cooling becomes dominant. The expansion rate decreases even further as the internal thermal pressure drops and more mass is accumulated in a snowplough manner until the SNR finally disperses into the surrounding medium.

In the following sections I will focus on the first two phases and derive analytical equations that are most likely too simplistic but nonetheless give an idea of scaling relations between as well as orders of magnitude estimates of the dynamical quantities.

1.3.1 The free expansion phase

In this phase the SN ejecta of mass M_e is free to expand as the shockwave propagates outwards unaffected by the surrounding ISM. The expansion velocity v_e of the ejecta therefore depends only on the initial kinetic energy of the SN explosion $E_{\rm SN}$ (excluding the energy carried away by the neutrinos which is many times larger),

$$\begin{aligned} E_{\rm SN} &= \frac{1}{2} M_e v_e^2 \\ v_e &= \left(\frac{2E_{\rm SN}}{M_e} \right)^{1/2}, \end{aligned} \tag{1.3}$$

and the shock radius R_s at some time t is

$$R_s = v_e t. \tag{1.4}$$

For a typical type II SN, the kinetic energy is $E_{\rm SN} \sim 10^{51}\,{\rm erg}$ and the ejecta mass is $M_e \sim 5\,M_\odot$ (Chevalier, 1977) and so the expansion velocity is $v_e \sim 5000\,{\rm km\,s^{-1}}$.

1.3.2 The adiabatic/Sedov-Taylor phase

The free expansion phase by definition ends when the swept-up ISM mass is equal to the mass of the ejecta. This happens at a radius $R_{\rm SW}$ when

$$M_e = \frac{4\pi}{3} R_{\rm SW}^3 \rho_0$$
$$\Updownarrow$$
$$R_{\rm SW} = \left(\frac{3}{4\pi}\frac{M_e}{\rho_0}\right)^{1/3}, \tag{1.5}$$

where ρ_0 is the initial density of the ISM. This radius is reached after a sweep-up time $t_{\rm SW}$

$$t_{\rm SW} = \frac{R_{\rm SW}}{v_e}. \tag{1.6}$$

Using a typical ISM density of $10^{-24}\,{\rm g\,cm^{-3}}$, the sweep-up time is of the order $t_{\rm SW} \sim 10^2 - 10^3\,{\rm yr}$. At this time a reverse shock begins travelling inwards as a result of the contact discontinuity between the accumulated ISM mass and the SN ejecta, conveying the presence of the surrounding ISM material to the ejecta. The reverse shock heats the ejecta to temperatures so high that the gas eventually becomes ionized and unable to recombine so cooling by radiative losses in this phase is negligible. The ejecta therefore only cools adiabatically due to the expansion of the shell.

Let R_s denote the radius of the expanding shell of the swept-up ISM with mass density ρ_0. If the shell expands adiabatically due to some internal pressure P, the equation of motion can be written as

$$F = \frac{d}{dt}\left(M_s \dot{R}_s\right) = \frac{d}{dt}\left(\frac{4\pi}{3} R_s^3 \rho_0 \dot{R}_s\right) = 4\pi R_s^2 P. \tag{1.7}$$

In an adiabatic process we have the relation

$$P = \frac{E}{V}(\gamma - 1). \tag{1.8}$$

If the energy is conserved during the expansion then we can set $E = E_{\mathrm{SN}}$ as kinetic energy is converted to internal energy in the gas and set the volume to $V = (4\pi/3)R_s^3$. If we assume that $\gamma = 5/3$ which is true for a monoatomic gas with 3 degrees of freedom, then we can write

$$\frac{d}{dt}\left(R_s^3 \dot{R}_s\right) = \frac{3}{2\pi\rho_0}\frac{E_{\mathrm{SN}}}{R_s}. \tag{1.9}$$

Making the assumption that $R_s = At^\eta$, we find that

$$\begin{aligned}\frac{d}{dt}\left(R_s^3 \dot{R}_s\right) &= \eta A^4 \frac{d}{dt}\left(t^{4\eta-1}\right) \\ &= (4\eta - 1)\,\eta A^4 t^{4\eta-2} \propto t^{4\eta-2} \\ &= \frac{3}{2\pi\rho_0} E_{\mathrm{SN}} A^{-1} t^{-\eta} \propto t^{-\eta}.\end{aligned} \tag{1.10}$$

The two sides of (1.10) must scale equally and hence

$$\begin{aligned}4\eta - 2 &= -\eta \\ \eta &= \frac{2}{5}.\end{aligned} \tag{1.11}$$

Putting this value back into (1.10), cancelling the time dependency and rearranging terms we see that

$$A^5 = \frac{25}{4\pi\rho_0} E_{\mathrm{SN}}. \tag{1.12}$$

Hence we conclude that

$$\begin{aligned}\eta &= \frac{2}{5} \\ A &= \left(\frac{25 E_{\mathrm{SN}}}{4\pi\rho_0}\right)^{1/5},\end{aligned}$$

which means that

$$R_s = \left(\frac{25E_{\rm SN}}{4\pi\rho_0}\right)^{1/5} t^{2/5} \propto t^{2/5}, \tag{1.13}$$

$$v_s = \frac{2}{5}\left(\frac{25E_{\rm SN}}{4\pi\rho_0}\right)^{1/5} t^{-3/5} \propto t^{-3/5}. \tag{1.14}$$

The adiabatic phase ends once the shell has become cold enough that the ionized atoms in the gas can effectively capture free electrons and release energy through the emission of highly energetic photons. At this point, when radiative cooling becomes dominant, the thermal pressure in the shell and hence the expansion rate decreases.

From shock physics a time-temperature and velocity-temperature relation in the shell during the adiabatic phase can be estimated as (Hamilton et al., 1983)

$$T_s \approx 1.4 \times 10^7 \left(\frac{v_s}{1000\,{\rm km\,s^{-1}}}\right)^2 {\rm K}, \tag{1.15}$$

which implies

$$T_s \propto t^{-6/5}. \tag{1.16}$$

The post-shock temperature in the beginning of the adiabatic phase is of order $T_s \sim 10^8\,{\rm K}$ for an initial shock velocity of $v_s \sim 5000\,{\rm km\,s^{-1}}$ when the SNR is a few 100 years old. The phase ends when the temperature has dropped to a critical point of around $T_s \sim 10^6\,{\rm K}$. Using the temperature-time relation, a typical timescale for the adiabatic phase is then $t_{age} \sim (T_2/T_1)^{-5/6} t_1 = 10^{5/3} t_1 \sim 2 \times 10^4\,{\rm yr}$ for $t_1 = 500\,{\rm yr}$.

Chapter 2

Theory

2.1 The evolution of dust in early galaxies

In this section my aim is to describe the evolution of dust and the total dust yield per SN event required to explain the observed amount in the early universe assuming that CC SNe during this period are the only contributors, stellar and non-stellar, closely based on the work done by Dwek et al. (2007).

We'll start with the total gas mass in a galaxy, M_g. If the galaxy is sufficiently young, we can assume that the stellar ejecta from SNe events are instantaneously recycled back into the ISM. If we denote the star formation rate (SFR) $\psi(t)$ as the mass of stars formed per unit time and the fraction of stellar mass that is recycled back to the ISM by SNe explosions R then the rate of change in the gas mass is

$$\frac{dM_g}{dt} = -(1-R)\psi(t) + \left(\frac{dM_g}{dt}\right)_{in} - \left(\frac{dM_g}{dt}\right)_{out}, \quad (2.1)$$

where the first term represents the change of gas due to the formation of stars and the second and third term are due to the infall and outflow of gas in the galaxy respectively.

We will consider a closed-box model where there's no infall or outflow of gas and so the last two terms $\dot{M}_{g_{in}} = \dot{M}_{g_{out}} = 0$. We will also assume that the SFR can be parametrized as a power-law proportional to the gas mass as

$$\psi(t) = \psi_0 \left(\frac{M_g(t)}{M_0}\right)^k$$
$$= \psi_0 \mu_g(t)^k, \tag{2.2}$$

where ψ_0 and M_0 denote the SFR and total mass of the system at $t = 0$ and $\mu_g(t)$ denotes the fractional gas mass at some time t. Putting this into (2.1) gives

$$\frac{d\mu_g}{dt} = -(1-R)\left(\frac{\psi_0}{M_0}\right)\mu_g^k, \tag{2.3}$$

which for the initial condition that the total mass at $t = 0$ consists of gas alone ($\mu_g = 1$) gives the solutions

$$\mu_g(t) = \begin{cases} \exp\left[-(1-R)\left(\frac{\psi_0}{M_0}\right)t\right], & k = 1 \\ \left[1-(1-R)(1-k)\left(\frac{\psi_0}{M_0}\right)t\right]^{1/(1-k)}, & k \neq 1 \end{cases}. \tag{2.4}$$

Suppose the average dust yield in a CC SN event in the galaxy is $\hat{Y}_d$ and that the SN rate R_{SN} is given by

$$R_{\mathrm{SN}} = \frac{\psi(t)}{m_\star}, \tag{2.5}$$

where $\psi(t)$ is the SFR and $m_\star$ is the mass of all stars born per SN event. Then the evolution of the dust mass M_d in the galaxy can be described by

$$\frac{dM_d}{dt} = -Z_d\psi(t) + \hat{Y}_d R_{\mathrm{SN}} - \frac{M_d}{\tau_d}, \tag{2.6}$$

where Z_d is the dust-to-gas mass ratio and τ_d is the average lifetime of dust grains against destruction due to the SN shocks. The first term on the RHS describes the amount of dust that is consumed during stellar formation, the second term is the rate of injection of dust back into the ISM the third term describes the change in dust mass in the galaxy due to grain destruction.

If $\langle m_{\mathrm{ISM}}\rangle$ denotes the total ISM mass (gas+dust) that is completely cleared of dust in a single SN event, the average lifetime of the dust grains is then given by

$$\tau_d = \frac{M_g}{\langle m_{\rm ISM}\rangle R_{\rm SN}}. \tag{2.7}$$

We can now rearrange (2.6) into

$$\frac{dM_d}{dt} = -\left(\frac{\psi(t)}{M_g}\right)\left(1 + \frac{\langle m_{\rm ISM}\rangle}{m_\star}\right) M_d + \hat{Y}_d \frac{\psi(t)}{m_\star}. \tag{2.8}$$

Using (2.3) we can describe the evolution of dust mass M_d as a function of the fractional gas mass μ_g:

$$\frac{dM_d}{d\mu_g} = \left(\frac{\nu}{\mu_g}\right) M_d - \hat{Y}_d \frac{M_0}{(1-R)m_\star}, \tag{2.9}$$

where

$$\nu \equiv \frac{\langle m_{\rm ISM}\rangle + m_\star}{(1-R)m_\star}. \tag{2.10}$$

The solution to this equation is

$$\mu_d(\mu_g) = \left(\frac{\hat{Y}_d}{\langle m_{\rm ISM}\rangle + Rm_\star}\right) \mu_g \left(1 - \mu_g^{\nu-1}\right), \tag{2.11}$$

where μ_d is the fractional dust mass $\mu_d \equiv M_d/M_0$. This equation can be rearranged to find the average dust yield per SN event as a function of the dust-to-gas mass ratio for a given gas mass fraction

$$\hat{Y}_d = Z_d \left(\frac{\langle m_{\rm ISM}\rangle + Rm_\star}{1 - \mu_g^{\nu-1}}\right). \tag{2.12}$$

The total mass of all stars per SN event $m_\star$ is related to the stellar initial mass function (IMF) $\phi(m)$ by

$$m_\star \equiv \frac{\langle m\rangle}{f_{\rm SN}}, \tag{2.13}$$

where the average stellar mass $\langle m \rangle$ and the fraction of stars that become CC SNe $f_{\rm SN}$ are given by

$$\langle m \rangle = \int_{m_l}^{m_u} m\phi(m)dm, \tag{2.14}$$

$$f_{\rm SN} = \int_{m_W}^{m_{\rm SN}} \phi(m)dm, \tag{2.15}$$

where $[m_l, m_u]$ is the stellar mass range and m_W and $m_{\rm SN}$ are the lower and upper mass limits of stars that become CC SNe. The IMF, the fractional number of stars between the interval $m + dm$, is normalized in the stellar mass range so that

$$\int_{m_l}^{m_u} \phi(m)dm = 1. \tag{2.16}$$

Usually the IMF is parametrized as $\phi(m) \propto m^{-\alpha}$ and a Salpeter-like IMF with $\alpha \approx 2.35$ is preferred where the number of massive stars drop fast, but in the early universe we will typically prefer more top-heavy IMFs with a lower exponent that favours more heavy stars and so typically in this epoch we pick $\alpha \approx 1.50$.

For a Salpeter-like IMF, the average stellar mass $\langle m \rangle$ is typically low but so is the fraction of stars that become CC SNe and so a typical value of $m_\star$ is $m_\star = \langle m \rangle / f_{\rm SN} \sim 150\, M_\odot$. In a top-heavy IMF, $\langle m \rangle$ is typically much larger and likewise is $f_{\rm SN}$ and so $m_\star \sim 50\, M_\odot$ is much smaller.

Dwek et al. (2007) applied (2.12) to the observations of the highly redshifted quasar SDSS J1148+5251 at $z = 6.4$ for which they inferred a fractional gas mass $\mu_g = 0.60$ and dust-to-gas mass ratio $Z_d = 6.7 \cdot 10^{-3}$. They assumed that half of the stellar mass is returned to the ISM, $R = 0.5$, and estimated $m_\star = 147\, M_\odot$ for a Salpeter IMF and $m_\star = 50\, M_\odot$ for a top-heavy IMF. The results are shown in Figure 2.1.

In a scenario where grain destruction is negligible, that is $\langle m_{\rm ISM} \rangle = 0$, at least an average dust yield of $\hat{Y}_d \sim 0.4\, M_\odot$ per SN for a top-heavy IMF is required to explain the observed dust-to-gas mass ratio of SDSS J1148+5251 for the chosen parameters if CC SNe are the only sources of dust in this epoch.

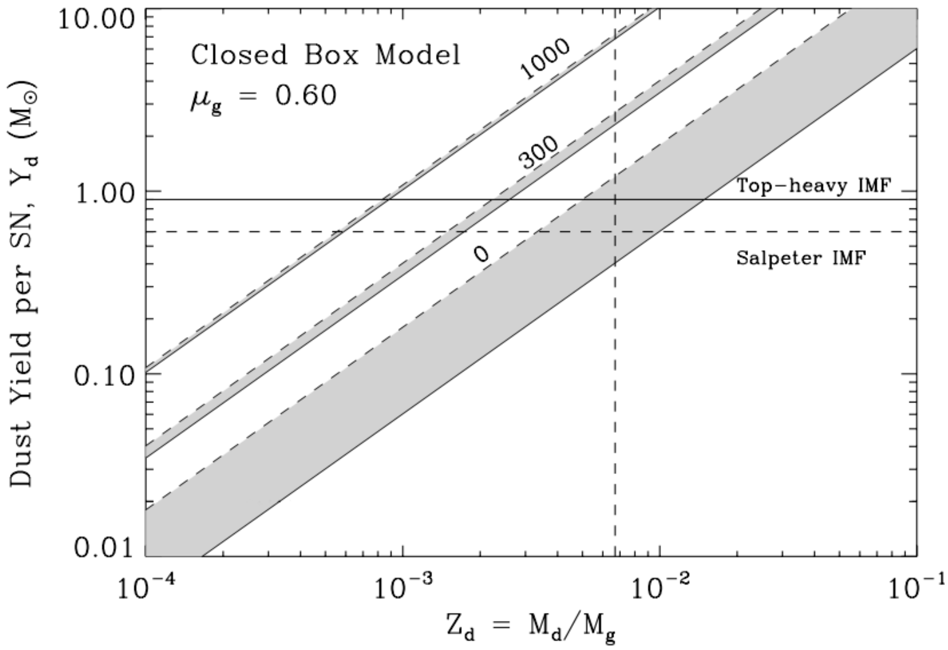


FIGURE 2.1: The average dust yield per SN as a function of dust-to-gas mass ratio (2.12) for a given fractional gas mass $\mu_g = 0.6$. The curve labels represent different values for the grain destruction efficiency $\langle m_{\rm ISM}\rangle/M_\odot$. For a given curve, the solid line denotes the top-heavy IMF result and the dashed curve denotes the Salpeter IMF. The vertical dotted line represents $Z_d = 6.7 \cdot 10^{-3}$ at $\mu_g = 0.6$, the measured dust and gas quantities for SDSS J1148+5251. The top two horizontal lines represent the IMF-averaged theoretical dust yields for the two IMFs. Source: Dwek et al. (2007)

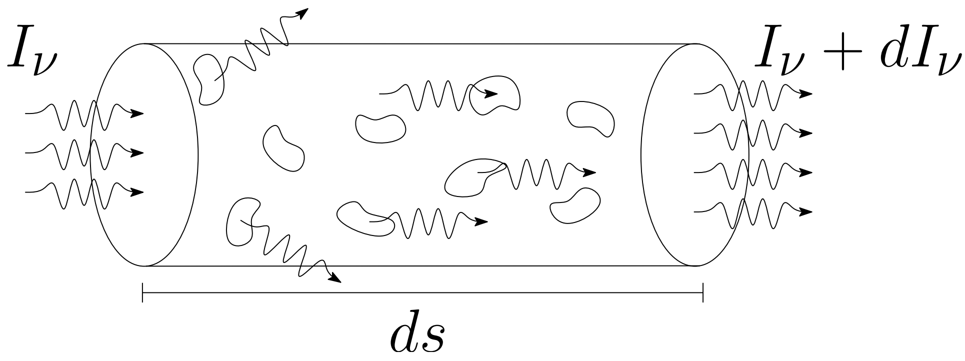


FIGURE 2.2: Extinction and emission of a radiation field with intensity I_ν due to dust.

2.2 Dust emission

2.2.1 Radiative Transfer Equation

Imagine an incident radiation field of intensity I_ν through a slab of width ds consisting of dust particles with mass density ρ_d, opacity κ_ν and emissivity j_ν (Figure 2.2). The change in I_ν due to extinction and emission by the dust as the radiation passes through the slab is then

$$dI_\nu = -I_\nu \rho_d \kappa_\nu ds + j_\nu ds. \tag{2.17}$$

If we define the optical depth τ_ν through

$$d\tau_\nu = \rho_d \kappa_\nu ds, \tag{2.18}$$

we can rewrite (2.17) as

$$\frac{dI_\nu}{d\tau_\nu} = -I_\nu + S_\nu, \tag{2.19}$$

where $S_\nu \equiv \frac{j_\nu}{\rho_d \kappa_\nu}$ is the "source function".

(2.19) is called the "Radiative Transfer Equation" (RTE) and the formal solution can be found as such:

$$\frac{dI_\nu}{d\tau_\nu} = -I_\nu + S_\nu$$
$$\Updownarrow$$
$$\frac{dI_\nu}{d\tau_\nu}e^{\tau_\nu} + I_\nu e^{\tau_\nu} = S_\nu e^{\tau_\nu}$$
$$\frac{d}{d\tau_\nu}\left(I_\nu e^{\tau_\nu}\right) = S_\nu e^{\tau_\nu}$$
$$\Updownarrow$$
$$\left(I_\nu(\tau_\nu')e^{\tau_\nu'}\right)\Big|_0^{\tau_\nu} = \int_0^{\tau_\nu} S_\nu(\tau_\nu)e^{\tau_\nu'}d\tau_\nu'$$
$$I_\nu(\tau_\nu)e^{\tau_\nu} - I_\nu(0) = \int_0^{\tau_\nu} S_\nu(\tau_\nu)e^{\tau_\nu'}d\tau_\nu'$$
$$\Updownarrow$$
$$I_\nu(\tau_\nu) = I_\nu(0)e^{-\tau_\nu} + \int_0^{\tau_\nu} S_\nu(\tau_\nu)e^{-(\tau_\nu-\tau_\nu')}d\tau_\nu', \tag{2.20}$$

where $I_\nu(0)$ is the incident intensity upon entering the slab. (2.20) is usually referred to as the Formal Transfer Equation (FTE).

2.2.2 Dust emission and modified blackbody spectra

It is common to assume that the dust is in *local thermodynamic equilibrium* (LTE) which means that the source function $S_\nu = B_\nu(T)$ where $B_\nu(T)$ is the Planck function at temperature T. (2.20) then becomes

$$I_\nu(\tau_\nu) = I_\nu(0)e^{-\tau_\nu} + B_\nu\left(T\right)\left(1 - e^{-\tau_\nu}\right). \tag{2.21}$$

If we now imagine we observe a region of dust in LTE with uniform temperature T_d and with no background source shining through it ($I_\nu(0) = 0$), then the total intensity due to dust emission alone will be

$$I_\nu(\tau_\nu) = B_\nu\left(T_d\right)\left(1 - e^{-\tau_\nu}\right). \tag{2.22}$$

If the dust is optically thin, $\tau_\nu \ll 1$, then $e^{-\tau_\nu} \approx 1 - \tau_\nu$ and so

$$I_\nu(\tau_\nu) \approx B_\nu(T_d)\tau_\nu. \tag{2.23}$$

The flux we observe at some distance D from the region of dust is the intensity integrated over the solid angle $d\Omega = dA/D^2$

$$\begin{aligned} F_\nu &= \int_\Omega I_\nu d\Omega \\ &= \int_A B_\nu(T_d)\tau_\nu dA/D^2 \\ &= \int_A B_\nu(T_d)\rho_d\kappa_\nu ds dA/D^2 \\ &= B_\nu(T_d)\kappa_\nu \int_V \rho_d dV/D^2 \\ &= B_\nu(T_d)\kappa_\nu M_d/D^2, \end{aligned} \tag{2.24}$$

where M_d is the total dust mass. It's assumed that the temperature T_d and opacity κ_ν are uniform over the observed region.

In the FIR and submm regime the opacity, or *mass extinction coefficient*, κ, usually which is a measure of can usually be closely parametrized as

$$\kappa_\nu = \kappa_0 \left(\frac{\nu}{\nu_0}\right)^\beta, \tag{2.25}$$

where κ_0 is the mass extinction coefficient at some reference wavelength ν_0 and β is the dimensionless power-law slope and is usually between $1-2$.

Since the Planck function $B_\nu \propto \nu^2$ for $h\nu \ll kT$ we see from (2.24) that the flux in the infrared regime of some region of dust with $\kappa_\nu \propto \nu^\beta$ will not behave as a blackbody ($F_\nu \propto \nu^2$) but a *modified blackbody* with

$$F_\nu \propto \nu^{2+\beta}, \tag{2.26}$$

where β depends on the geometry and type of dust under consideration.

2.2.3 Mie theory

Mie theory, named after German physicist Gustav Mie who in 1908 applied Maxwell's equations to spherical gold particles, generally describes the scattering of electromagnetic waves by spherical particles.

The theory provides analytical solutions for the scattering of electromagnetic radiation by homogeneous dielectric spherical particles in terms of infinite series. They describe among other quantities the extinction, scattering and absorption of the incident light in terms of the *efficiency coefficients* $Q_{\rm ext}(\lambda, a)$, $Q_{\rm sca}(\lambda, a)$ and $Q_{\rm abs}(\lambda, a)$ which are related by

$$Q_{\rm ext}(\lambda, a) = Q_{\rm sca}(\lambda, a) + Q_{\rm abs}(\lambda, a), \tag{2.27}$$

where a is the grain radius and λ is the wavelength of the incident light.

Mie theory is usually applicable in three regimes, defined by the dimensionless parameter x which describes the size of the grains relative to the incident light by

$$x \equiv \frac{2\pi a}{\lambda}, \tag{2.28}$$

Rayleigh scattering is the long wavelength regime where $x \ll 1$, *Mie scattering* is when $x \sim 1$ and *Geometric scattering* is the short wavelength regime for which $x \gg 1$. Here I'm going to present an approximate solution in the Rayleigh regime. A full outline of the theory applied to interstellar dust can be found in van de Hulst (1957).

In Rayleigh scattering where $x \ll 1$, the solutions to the scattering and absorption efficiency coefficients $Q_{\rm sca}(\lambda, a)$ and $Q_{\rm abs}(\lambda, a)$ are given by (see Tielens, 2005, chap. 5)

$$Q_{\rm sca}(\lambda, a) = \frac{8}{3} x^4 \, \mathrm{Re} \left[\frac{\epsilon - 1}{\epsilon + 2} \right]^2, \tag{2.29}$$

$$Q_{\rm abs}(\lambda, a) = -4x \, \mathrm{Im} \left[\frac{\epsilon - 1}{\epsilon + 2} \right], \tag{2.30}$$

where $\epsilon = \epsilon_1 + i\epsilon_2$ is the *dielectric constant* of the material. It depends on the optical properties of the material through the *complex index of refraction*, m, which is given by the refractive indices, n and k, which are the real and imaginary parts of the incident wavelength function through

$$m = n + ik. \tag{2.31}$$

The complex index of refraction is related to the dielectric constant by

$$\epsilon = m^2, \tag{2.32}$$

with

$$\epsilon_1 = n^2 - k^2, \tag{2.33}$$

and

$$\epsilon_2 = 2nk. \tag{2.34}$$

Hence the efficiency coefficients depend on the optical properties of the material which are usually measured in the laboratory and are typically given by the refractive indices n and k.

The extinction efficiency coefficient $Q_{\text{ext}}(\lambda, a)$ is related to the optical depth τ_ν and the mass extinction coefficient κ_{ext} by

$$d\tau_\nu = \rho_d \kappa_{\text{ext}} ds = n_d C_{\text{ext}} ds = n_d Q_{\text{ext}} \sigma_d ds, \tag{2.35}$$

where C_{ext} is the *extinction cross section* and σ_d is the *geometrical cross section* of the dust with n_d, the number of dust grains per unit volume. Hence Q_{ext} is a measure of the extinction to the geometrical cross section

$$Q_{\text{ext}} = \frac{C_{\text{ext}}}{\sigma_d}. \tag{2.36}$$

Using that $\sigma_d = \pi a^2$ for some spherical dust grain with radius a we see that

$$\kappa_{\text{ext}} = \frac{Q_{\text{ext}} \pi a^2}{m_{gr}} = \frac{3}{4} \frac{Q_{\text{ext}}}{a \rho_{gr}}, \tag{2.37}$$

where $m_{gr} = \rho_d / n_d$ is the mass of a single dust grain which is related to the volumetric mass density ρ_{gr} by $m_{gr} = (4/3)\pi a^3 \rho_{gr}$.

2.3 The interstellar medium and hydrogen gas densities

Much of the interstellar dust resides in the ISM. Generally, by number, the ISM consists of about $99.9\,\%$ gas of which rougly $90.8\,\%$ is hydrogen and $9.1\,\%$ is helium while the last $0.1\,\%$ is heavier elements and compound molecules in the form of metals and dust (Ferrière, 2001).

The ISM hydrogen gas comes in three forms. Neutral atomic hydrogen, denoted by H I, ionized hydrogen, denoted by H II and molecular hydrogen, H_2. Later in my project it's going to important to distinguish between the dust that's been produced in the CC and the dust from the swept-up ISM material. The later is related to the hydrogen gas by the *dust-to-gas* mass ratio, Z_d, by

$$Z_d = \frac{m_d}{m_g}. \tag{2.38}$$

Therefore it's relevant to examine the three forms of ISM hydrogen gas densities and how to measure them.

2.3.1 Neutral atomic gas, H I - The 21 cm line

Neutral hydrogen in the ISM is usually measured by the radio $21\,\mathrm{cm}$ line at a wave frequency of $1420\,\mathrm{MHz}$. This emission line comes from the spin flip transition between the electron and proton spin alignments (see Figure 2.3) which splits the 1s ground state into two distinct energy levels. This energy splitting of the ground state is known as the hyperfine structure and is illustrated in Figure 2.4.

In a cloud of neutral hydrogen, the $21\,\mathrm{cm}$ line can be used to determine the column density $N_{\mathrm{H\,I}}$ if the cloud is optically thin ($\tau_\nu \ll 1$). Here all the emitted photons escape the cloud without being reabsorbed and so the number of photons tells us what the column density is. A rigorous treatment of the equations governing the optical

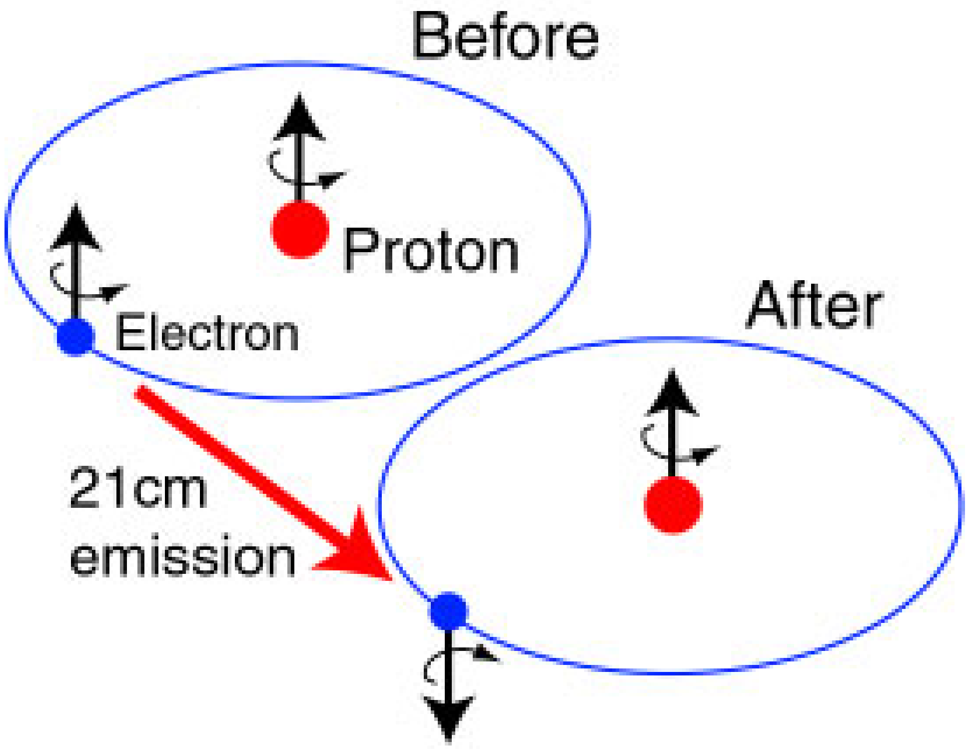


FIGURE 2.3: Illustration of the 21 cm spin flip transition in the hydrogen atom.

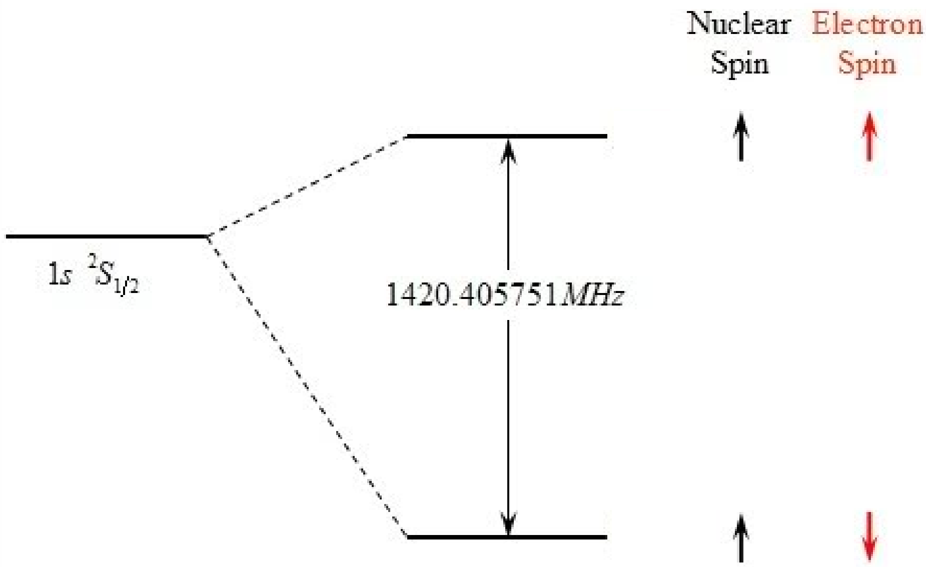


FIGURE 2.4: Illustration of the hyperfine splitting of the hydrogen 1s ground state.

depth and the gas column density can be found in various literatures (see e.g. Klein and Kerp, 2008). In the Rayleigh-regime, where $h\nu_{21\,\mathrm{cm}}/kT_b \ll 1$, we have that

$$\frac{N_{\mathrm{H\,I}}}{\mathrm{cm}^{-2}} = 1.823 \times 10^{18} \int_0^\infty \frac{T_b(v)}{\mathrm{K}} \frac{dv}{\mathrm{km\,s}^{-1}}, \tag{2.39}$$

where T_b is the brightness temperature of the hydrogen measured at a Doppler broadening interval dv.

2.3.2 Hot ionized gas, H II - The $\mathrm{H}\alpha$ recombination line

If the gas is hot enough, the hydrogen will be ionized and able to recombine with the electrons to some excited state, n. One way of measuring this recombination rate is by the $n = 3 \rightarrow 2$ transition known as the $\mathrm{H}\alpha$ line in the Balmer series since it's a fraction of the total number of recombinations.

The *Emission Measure (EM)* through some ionized cloud of thickness ds with electron density n_e is a quantity defined as

$$EM \equiv \int n_\mathrm{e}^2 ds, \tag{2.40}$$

and is usually given in the units of $\mathrm{cm}^{-6}\mathrm{pc}$.

The $\mathrm{H}\alpha$ line intensity $I(\mathrm{H}\alpha)$ depends upon whether the line is optically thin (case A) or thick (case B) to the Lyman continuum. For most studied H II regions the line is found to be optically thick (Osterbrock, 1989). A semi-empirical relation between the line intensity and emission measure for case B in the electron temperature range $T_\mathrm{e} = 5000 - 20\,000\,\mathrm{K}$ is (Valls-Gabaud, 1998)

$$\frac{I(\mathrm{H}\alpha)}{\mathrm{erg\,cm^{-2}\,s^{-1}\,sr^{-1}}} \overset{\text{case B}}{=} 9.41 \times 10^{-8} T_4^{-1.017} 10^{-0.029/T_4} \left(\frac{EM}{\mathrm{cm}^{-6}\mathrm{pc}}\right), \tag{2.41}$$

where T_4 is the electron temperature measured in units of $10^4\,\mathrm{K}$.

If we assume that the gas is fully ionized then $n_\mathrm{e} = n_\mathrm{H\,II}$ and so the emission measure is directly related to the ionized gas density

$$n_\mathrm{H\,II} = \left(\frac{dEM}{ds}\right)^{0.5}. \tag{2.42}$$

As a final note on the ionized gas component, a useful unit convention that will become relevant later is the Rayleigh unit, denoted R, which measures the photon flux over a column. It is defined such that $1\,R$ is equivalent to 10^{10} photons per column per square metre per second, or similarly,

$$1\,R = 10^6/4\pi\,\mathrm{photons\,s^{-1}\,cm^{-2}\,sr^{-1}}. \tag{2.43}$$

For the Hα-line at the wavelength $\lambda = 656.28\,\mathrm{nm}$ we have that one photon has the energy

$$E = \frac{hc}{\lambda} = 3.03 \times 10^{-12}\,\mathrm{erg}, \tag{2.44}$$

which means that

$$1R(\mathrm{H}\alpha) = 2.41 \times 10^{-7}\,\mathrm{erg\,s^{-1}\,cm^{-2}}. \tag{2.45}$$

2.3.3 Molecular gas, $\mathrm{H_2}$ - CO collisional excitation

Because of its atomic symmetry and hence lack of a dipole moment and high dissociation energy, molecular hydrogen (H_2) only radiates directly in hot regions, e.g. in the vicinity of stars. Therefore in the cold ISM, indirect tracers of the gas molecule which can be more easily measured must be used.

One such tracer is carbon monoxide (CO), the second most abundant molecule. Even though it's far less abundant than H_2, its rotational excitation levels absorb and radiate much more effectively and so even a few CO molecules is an indicator for a large amount of H_2. CO is coupled with H_2 through collisional excitations between the molecules and a constant factor $X_{\rm CO}$, which can be derived from a Virial analysis (e.g. Klein and Kerp, 2008), is usually applied to convert between the $\rm H_2$ column density, $N_{\rm H_2}$, and integrated $\rm CO$ intensity, $W_{\rm CO}$. Similar to (2.42), if

$$W_{\rm CO} = \int T_b dv, \tag{2.46}$$

for $\rm CO$, then the conversion factor to $N_{\rm H_2}$ is given through

$$N_{\rm H_2} = X_{\rm CO} W_{\rm CO}. \tag{2.47}$$

The conversion factor, $X_{\rm CO}$, is often the centre for a heated discussion. It may very likely not be a constant at all. For example, many studies suggest that it increases significantly with decreasing metallicity. For the sake of simplicity, however, I will assume a constant value across the Magellanic Clouds. Typical values range between $X_{\rm CO} \sim 1 - 7 \times 10^{20}\,{\rm cm^{-2}\,K^{-1}\,km^{-1}\,s}$. I'm going to adopt the value from Fukui et al. (2008),

$$X_{\rm CO} = 7 \times 10^{20}\,{\rm cm^{-2}\,K^{-1}\,km^{-1}\,s}. \tag{2.48}$$

Chapter 3

Methods

3.1 Locating targets

The first thing I want to do was to search for valid SNR candidates for my project. I focused on SNRs in the SMC & LMC because of a) their well-determined distances ($60\,\mathrm{kpc}$ and $50\,\mathrm{kpc}$ with about $2\,\%$ accuracy respectively (Hilditch et al., 2005; Pietrzyński et al., 2013)) and b) their spatial orientations to us (both being almost planar with a slight inclination), which makes our line-of-sight (LOS) almost unobscured by the gas and dust in the galaxies.

I used the criteria that the SNR progenitor must be a core-collapsed star (which excludes type Ias) and the remnant must be relatively young because I was interested in ones that haven't yet started to significantly disperse into the surrounding ISM. From the analytical treatment and the order-of-magnitude estimates of the SNR phases I derived in section 1.3, this means that I'm interested in SNRs that are still either freely or adiabatically expanding and hence are no more than a few thousand years old.

Having very accurate distance measurements to the SMC & LMC, this age requirement translates into an approximate maximum angular extend of the sources on the sky. Consider an observer $\mathcal{O}$ looking at a spherical SNR of radius r a distance D away as sketched in Figure 3.1.

Assuming that the SNR has been expanding freely with velocity v for a time t, we can express the radius as $r = vt$. The angular extend

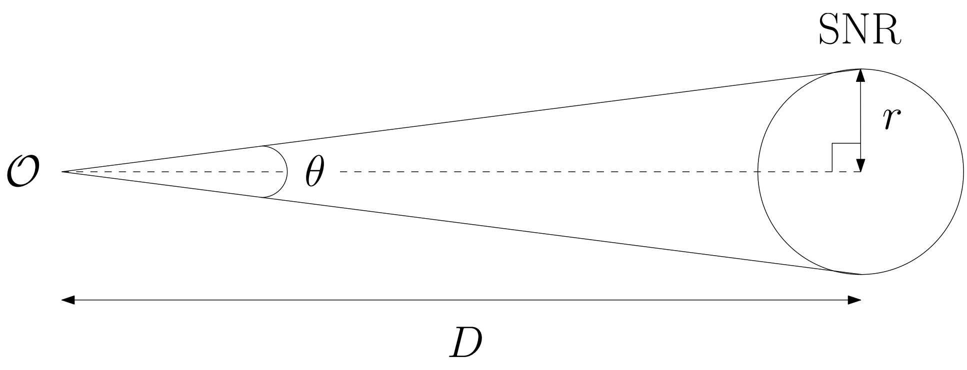


FIGURE 3.1: Schematic of the geometrical interpretation of a spherically symmetric SNR of radius r at a distance D away from an observer $\mathcal{O}$. The SNR extends an angle θ on the sky as seen by the observer.

θ is then

$$\tan\left(\frac{\theta}{2}\right) = \frac{vt}{D}$$
$$\Updownarrow$$
$$\theta = 2\arctan\left(\frac{vt}{D}\right). \tag{3.1}$$

3.2 Aperture photometry

After having picked a target of interest, my next step is to estimate the flux coming from that target. The usual procedure is to do aperture photometry. Aperture photometry is the simple task of counting all the photons received within an area (aperture) centred on an object. Other methods like calculating the flux from the point-spread function (PSF) in an image are sometimes used, but the method of PSF-fitting is more complicated for extended sources and I choose not to go into more details with it here.

Measuring the flux using aperture photometry is typically done by performing the following steps:

Subtracting the background from the target

In an image, one's target usually sits on top of some background. The background contains emission from various things in the field behind and around the target that is not the target itself, e.g. an MC structure. Therefore the first thing one would like to do to estimate that flux coming from the target alone is to subtract the background behind it. Depending on what the surrounding field consists of, this step can be arbitrarily difficult and is usually the source of most systematic and statistical errors. For a stellar field with a uniform sky level with no nearby significant or bright objects, the usual procedure is to determine some constant value for the background by placing an annulus around the target as shown in Figure 3.2 and subtract that value for each pixel across the aperture.

However, it's not always possible to estimate the background by some constant value. For my SNRs, for example, the targets are usually embedded in or near the edges of MCs where there is typically a statistically significant gradient across the aperture and so I will often choose to remove the background by using a median filter which I will describe in more details in section 3.2.2.

Choosing a suitable aperture size

After having decided on one's method of background subtraction, the next step is to decide on a suitable aperture size, that is, how large an area one wants to measure the flux from. Typically, one would like to choose the aperture that covers the target entirely and don't include other objects. Since the flux measures the amount of energy through some surface per second per unit area, we have that $F \propto r^{-2}$, one normally uses *curves of growth* to decide on a suitable aperture size. To make a curve of growth, one measures the flux in increasing aperture sizes. At first, more and more emission is included from the target and so the flux goes up. When the aperture becomes large enough so that the whole target is in it, no additional emission is included and so the flux starts to drop with r^{-2}. An example is illustrated on Figure 3.3. It's then typical to pick the aperture radius at which the flux is the largest.

Sometimes, one will have to settle for an aperture size by other methods mostly given by the physical circumstances in one's image and the field around the target. For example, because the SNRs I examine are often embedded in MCs, increasing the aperture size will include additional flux from the surrounding medium together with the source so I will often have to choose an aperture size by other criteria, e.g. other scientific papers or plain visual inspection.

Counting flux and estimating the statistical error
When the background has been subtracted and a suitable aperture size has been chosen, the flux can be measured by summing over the photon counts in the aperture (if it hasn't already been done after making the curve of growth). After that it's also necessary to determine the error on one's flux measurement. The error will typically have a contribution from both the original, background-included image and from the method by which the background has been subtracted, unless one contribution dominates the other. The method for determining the statistical flux error then depends on how the background was subtracted.

The procedure is repeated for all colour bands and the resulting plot is the *SED* function which describes the flux F_ν, usually measured in units of Jy, as a function of the frequency ν (or interchangeably, the wavelength λ).

3.2.1 Flux and error propagation with the background subtracted with an annulus

Say you want to perform aperture photometry and subtract the background with an annulus as indicated in Figure 3.2. Let S_A denote the total integrated flux coming from some aperture of N_A pixels and let S_B denote the total integrated flux coming from some annulus of N_B pixels. The flux coming from the source alone, F_{src}, will then be the total flux with the mean background level, $\bar{B} = S_B/N_B$ subtracted

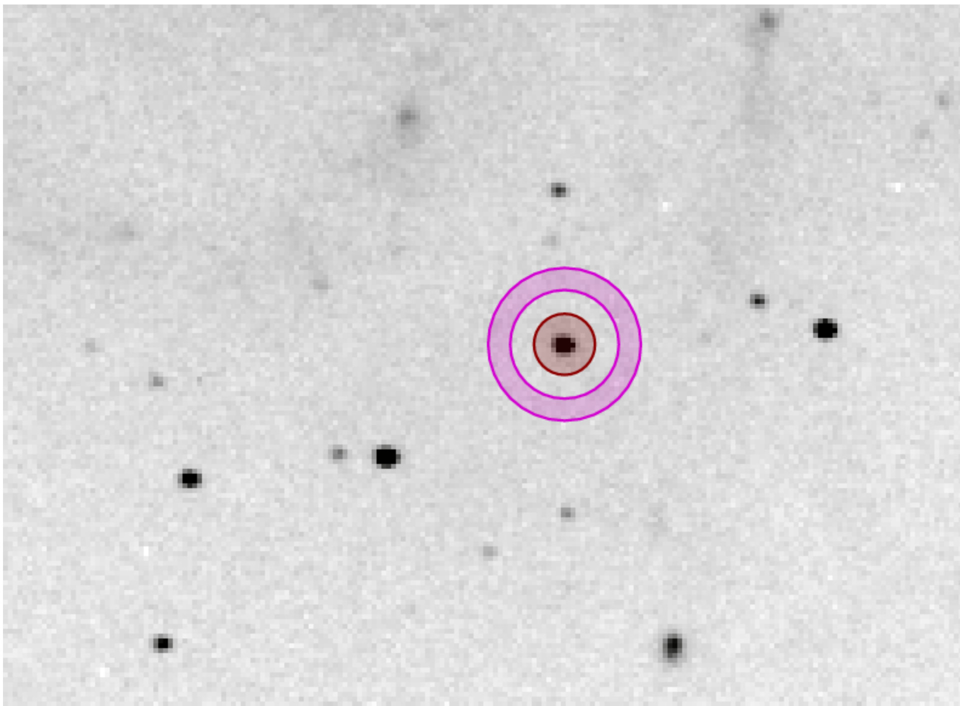


FIGURE 3.2: A typical way to perform aperture photometry where the background is removed from the target by estimating some averaged constant value from the annulus (purple) which is then subtracted from the aperture (dark red).

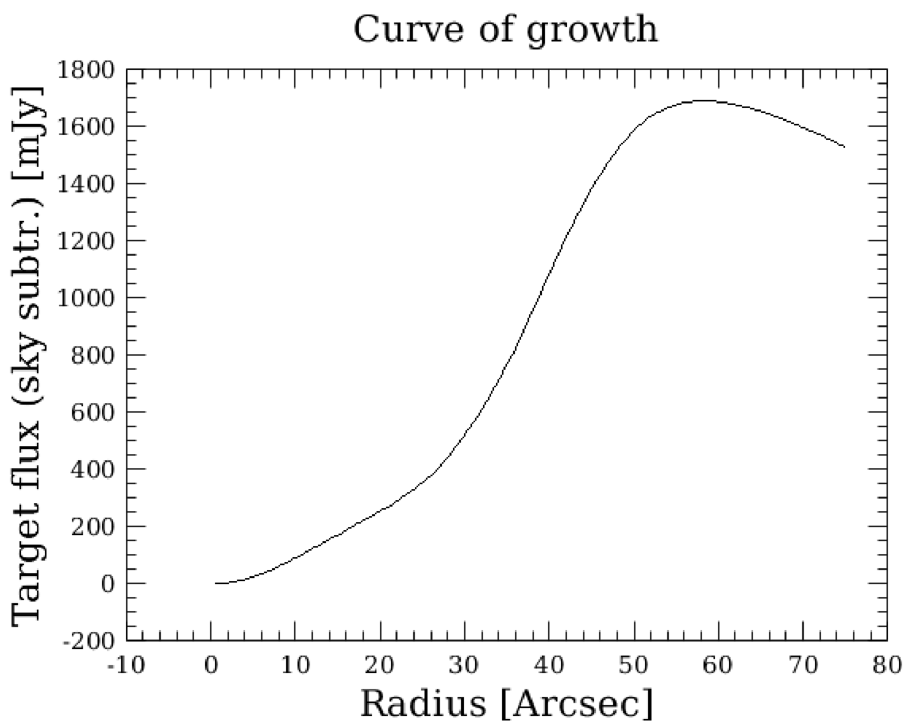


FIGURE 3.3: A curve of growth of a target where the total flux in the aperture increases at first and then drops after the area (indicated by the aperture radius) has enclosed the majority of the source at around $r = 58''$.

for all pixels across the aperture,

$$\begin{aligned} F_{\text{src}} &= S_A - N_A \bar{B} \\ &= S_A - \frac{N_A}{N_B} S_B. \end{aligned} \tag{3.2}$$

Using standard error propagation, the statistical error on the integrated source flux, σ_{src}, is

$$\sigma_{\text{src}}^2 = \sigma_A^2 + \frac{N_A}{N_B}\sigma_B^2, \tag{3.3}$$

where σ_i^2 is the total variance of the i'th region ($i = \{A, B\}$).

If the i'th region consists of N_i pixels, then the total variance σ_i^2 is given by

$$\sigma_i^2 = \sum_{j=1}^{N_i} \sigma_{i,j}^2, \tag{3.4}$$

where $\sigma_{i,j}^2$ is the pixel-to-pixel variance for the j'th pixel in the i'th region. If $\sigma_{i,j}^2$ is equal to some constant value, $\sigma_i'^2$, for all the pixels, we can write

$$\sigma_i^2 = N_i \sigma_i'^2, \tag{3.5}$$

and hence

$$\sigma_{\text{src}}^2 = N_A \left(\sigma_A'^2 + \frac{N_A}{N_B} \sigma_B'^2 \right). \tag{3.6}$$

From (3.6) we see that $\sigma_{\text{src}} \propto \sqrt{N_A}$ which means that the signal-to-noise ratio (SNR) $F_{\text{src}}/\sigma_{\text{src}} \propto \sqrt{N_A}$ and that the last term, which is the statistical error in the background subtraction, falls off as $1/\sqrt{N_B}$. This implies that 1) it is favourable to have a large spatial resolution (many pixels N_A in the aperture) to get a high SNR and 2) if the chosen annulus is very big and well-determined ($N_A/N_B \ll 1$ and

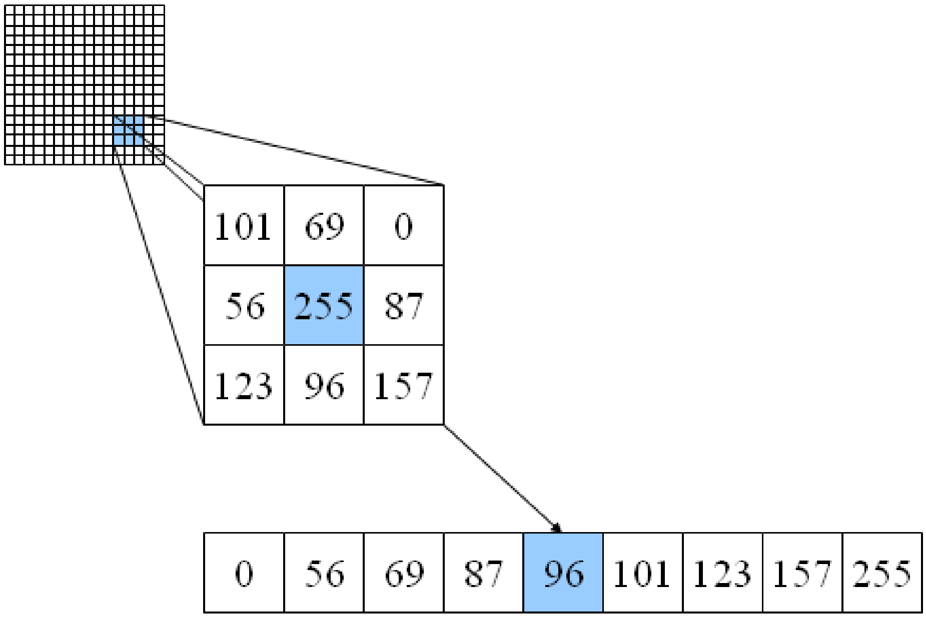


FIGURE 3.4: A schematic of median filtering an image.

σ_B is small) then the term eventually becomes negligible small and the total variance σ^2_{src} is minimized. However, some of the pitfalls from choosing a big annulus (N_B large) are simultaneously that the variance σ'^2_B may increase and that you eventually include additional emission which is not from the sky level itself.

3.2.2 Background subtraction by a median filter

Median filtering an image is the process of ordering the discrete pixels within some $m \times n$ window, then setting the center pixel value to the median in the distribution as illustrated in Figure 3.4 and then repeat it across the entire image.

Creating a median filter of an image is a way to simulate structures on the $m \times n$ window scale or larger while preserving small scale variations. This makes it suitable to imitate the background in an image where a smaller source lies on top of some large scale structure, in my case a SNR on top of a MC of statistically significant varying intensity. One weakness though is that it cannot account deal with background variations smaller than the source. Sometimes the SNR may also be situated in a area where the bulk MC structure is smaller

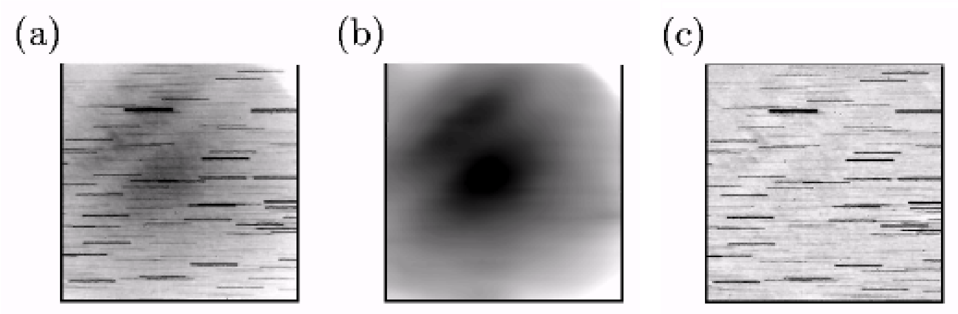


FIGURE 3.5: Subtracting the background from an image by using a median filter. (a) Original image; (b) median filter; (c) background subtracted image.

than the SNR itself. These are both sources of uncertainty. Likewise, the median filter doesn't account for the Gaussian noise in the image which then propagates to the summed photon counts when estimating the flux. A schematic procedure of subtracting a median filtered background from an image is shown in Figure 3.5.

3.2.3 Flux and error propagation for a source in a median filtered image

Let F_{tot} denote the total flux coming from some aperture containing a source and let F_{bgr} denote the flux coming from the background in that aperture. The flux from the source alone F_{src} is then

$$F_{\mathrm{src}} = F_{\mathrm{tot}} - F_{\mathrm{bgr}}, \tag{3.7}$$

and hence the statistical error σ on the measurement is

$$\sigma^2_{\mathrm{src}} = \sigma^2_{\mathrm{tot}} + \sigma^2_{\mathrm{bgr}}, \tag{3.8}$$

where σ_i^2 denotes the total variance of the i'th component in the aperture with $i = \{\mathrm{src}, \mathrm{tot}, \mathrm{bgr}\}$.

If the background is subtracted with a median filter as illustrated in Figure 3.5, then the flux and variance from the background can be measured directly from the median filter. If the area of the aperture consists of N pixels, then the total variance σ_i^2 for i'th component is

$$\sigma_i^2 = \sum_{j=1}^{N} \sigma_{i,j}^2, \tag{3.9}$$

where $\sigma_{i,j}^2$ is the individual pixel variance for the j'th pixel.

If we assume that the individual pixel variations $\sigma_{i,j}^2$ are equal to some constant value $\sigma_i'^2$ across the aperture, we can write

$$\sigma_i^2 = N\sigma_i'^2. \tag{3.10}$$

(3.8) can then be expressed as

$$\sigma_{\text{src}}^2 = N\left(\sigma_{\text{tot}}'^2 + \sigma_{\text{bgr}}'^2\right). \tag{3.11}$$

Like in (3.6), because the variance $\sigma_{\text{src}} \propto \sqrt{N}$, then the SNR $\propto \sqrt{N}$, which implies that a good spatial resolution with many pixels inside the aperture (N large) results in a high SNR. This time, however, the statistical background error and hence the final error is limited by the pixel-to-pixel variations in the image and cannot be minimized by using a larger annulus and may easily be the dominating error depending on the degree of background contamination.

3.3 Dust models and extinction coefficients

From section 2.2.3, we saw how the extinction coefficient κ_{ext} depends on the optical and geometrical properties of the dust; the refractive indices n and k (or dielectric functions ϵ_1 and ϵ_2) as well as the grain size a (under the assumption that the grains are spherically symmetric) and the volumetric mass density ρ_{gr}. The optical properties are usually measured in the laboratory as a function of the emission wavelength λ for some given dust model while the geometrical properties are assumed.

A lot of authors have measured a large variety of dust compositions. In my project, I'm mainly going to adopt and compare two distinct dust models that are typically (but not necessarily) assumed to be prominent in CC SNe and the ISM. The first model is *astronomical silicates* from Draine and Lee (1984) (see Draine, 1985). The second model is *amorphous carbon* from Zubko et al. (1996). The first model is a mix of various silicate compounds, molecules consisting largely of silicon (Si) and oxygen (O) atoms. The second model is primarily free, reactive carbon (C) produced under various conditions, and which doesn't have any diamond- og graphite-like structure, e.g. coal and soot.

My motivation for using these particular dust models consisting mainly of C, O and Si is based on current knowledge about nucleosynthesis for a high mass star and the following CC, in which these elements are produced and most likely released in large quantities (e.g. Woosley and Weaver, 1995) and so it's reasonable to expect that the dust is largely composed in some way or another of these elements.

With the tabulated data about the optical properties and for some assumed geometrical grain size and density, κ_{ext} can be calculated by (2.37). To do this, I've adopted the **BHMIE algorithm** (originally published in Bohren and Huffman, 1998, to compute the infinite series of the Mie scattering theory), which takes the dimensionless size parameter x (2.28) and the complex refraction index m (2.31) and computes, among other quantities, the extinction efficiency coefficient Q_{ext}. Calculating κ_{ext} as a function λ for a given size and density is then straight forward.

Finally I parametrize κ_{ext} in the FIR regime with (2.25) by fitting a linear model of the form $y(x) = mx + b$ of the log-log function,

$$\log\left[\kappa_{\text{ext}}\right]\left(\log\left[\nu\right]\right) = \beta \log\left[\nu\right] + \log\left[\kappa_0\right] - \beta \log\left[\nu_0\right], \qquad (3.12)$$

to determine the model parameters κ_0 and β at a given reference frequency ν_0.

3.4 Fitting the SED with a double component modified blackbody spectrum

After having performed aperture photometry for the various bands to determine the SED function, F_ν, I will assume that the measured FIR emission is due to dust.

If a significant part of the ambient ISM has been heated by the shock, it's reasonable to assume that the SED is best modelled by a double modified blackbody spectrum describing two significant and distinct dust components, one warm and the other cold. This double component signature is indeed indicated by the SEDs of many of my SNRs as we shall later see.

If F_ν describes the combined SED from the emitting warm (w) and cold (c) dust, then from (2.24) we have that

$$F_\nu = F_\text{w} + F_\text{c} = \frac{B_\nu(T_1)\kappa_{\text{ext},1}(\nu)M_1}{D^2} + \frac{B_\nu(T_2)\kappa_{\text{ext},2}(\nu)M_2}{D^2}, \tag{3.13}$$

where T_1, M_1, T_2 and M_2 are the temperatures and total dust masses of the warm and cold components respectively. The total dust mass is then $M_d = M_1 + M_2$. For simplicity I will assume that the two dust components consist of the same type of dust, e.g. $\kappa_{\text{ext},1} = \kappa_{\text{ext},2} = \kappa_\text{ext}$.

It's also interesting to note that we can roughly relate the dust mass of component i to the peak of the modified blackbody spectrum at $\nu = \nu_\text{max}$ by $M_d \propto F_{\nu_\text{max}}/B_{\nu_\text{max}}(T)\nu^\beta_\text{max}$. In the FIR regime where $h\nu \ll kT$, the Rayleigh-Jeans approximation says that $B_\nu(T) \propto \nu^2 T$. Furthermore Wien's displacement law says that $\nu_\text{max} \propto T$ and hence $M_d \propto F_\text{max} T^{-(3+\beta)}$ where typically $\beta \sim 1-2$. In other words, a slight temperature difference between T_1 and T_2 of a warm and cold dust component respectively result in a much larger cold dust mass, $M_2 \gg M_1$, if the distinct SEDs are comparable, $F_\text{w} \sim F_\text{c}$, and we can often attribute the total dust mass as the mass from the cold component alone, $M_d \approx M_2$.

From this anaylsis, my main motivation of using two dust components becomes more clear. My goal is to fit with a lower temperature for the cold dust compared to the result of fitting with a single component, to estimate the maximum possible dust mass, that can possibly account for the FIR SED, which will be largely dominated by the cold component.

3.5 Gas densities and ISM dust mass

In order to distinguish between the produced dust from a given SNR and the dust that already resides in the ISM, I'm going to estimate the total swept-up ISM dust mass $M_{d,\text{ISM}}$ in a spherical volume V by measuring the total swept-up ISM gas mass $M_{g,\text{ISM}}$. The two quantities are related through the dust-to-gas mass ratio, Z_d, given by (2.38). If the average gas number density is n throughout the volume, $M_{d,\text{ISM}}$ is then given by,

$$\begin{aligned} M_{d,\text{ISM}} &= Z_d M_{g,\text{ISM}} \\ &= Z_d m_\text{p} V n \\ &= Z_d m_\text{p} \frac{4}{3} \pi r^3 \frac{dN}{ds}, \end{aligned} \tag{3.14}$$

where

$$N = \int_L n ds, \tag{3.15}$$

is the gas column density measured over the line-of-sight, L, and m_p is the proton mass. As I have discussed in section 2.3, the gas column number density, N, will have three contributions from neutral atomic hydrogen, $N_{\text{H I}}$, ionized hydrogen, $N_{\text{H II}}$, and molecular hydrogen, $N_{\text{H}_2} = n_{\text{H}_2} L$,

$$N = N_{\text{H I}} + N_{\text{H II}} + 2 n_{\text{H}_2} L, \tag{3.16}$$

where the last factor 2 is because molecular hydrogen contains two H-atoms. The three terms on the RHS are determined by eq. (2.39), (2.42) and (2.47) respectively.

If we assume that N is approximately constant throughout L and equal to the column density in the volume, then we can approximate,

$$M_{d,\mathrm{ISM}} = Z_d m_\mathrm{p} \frac{4}{3} \pi r^3 \frac{N}{L}, \tag{3.17}$$

and with this it's possible to distinguish the swept-up ISM dust, $M_{d,\mathrm{ISM}}$, from the dust produced by the CC, M_d, as long as the total gas column density, N, is measured in the area.

Chapter 4

Data Processing & Results

4.1 Observations and surveys

4.1.1 Dust content - HERITAGE and SAGE

For my SEDs, F_λ, I'm going to use the data provided by the Herschel Space Observatory open time key programme *HERschel Inventory of The Agents of Galaxy Evolution (HERITAGE) in the Magellanic Clouds* (Meixner et al., 2013) as well as the data provided by the Spitzer Space Telescope open key time programme, *Surveying the Agents of a Galaxy's Evolution (SAGE)* (Meixner et al., 2006). The HERITAGE data is publicly available from ESA in Herschel's User. Provided Data Products. The SAGE data is publicly available on NASA/IPAC's IRSA.

HERITAGE consists of two full imaging survey maps of the LMC and SMC taken with the parallel mode by the FIR and submm instruments PACS and SPIRE. In the parallel mode, the PACS instrument observes in two wavelength bands at $100\,\mu m$ ("PACS 100") and $160\,\mu m$ ("PACS 160"). while SPIRE observes at $250\,\mu m$ ("SPIRE 250"), $350\,\mu m$ ("SPIRE 350") and $500\,\mu m$ ("SPIRE 500"). The absolute photometric uncertainties of PACS 100 and PACS 160 are $10\,\%$ and $20\,\%$ respectively (Poglitsch et al., 2010, Table 5). The absolute photometric uncertainties for the three SPIRE bands are $15\,\%$ (Swinyard et al., 2010).

SAGE consists of a full imaging survey map of the LMC taken with the instruments IRAC and MIPS, of which I will only be using the latter. MIPS observes in three wavelength bands; $24\,\mu\mathrm{m}$, $70\,\mu\mathrm{m}$ and $160\,\mu\mathrm{m}$. I will only be using the two former bands at $24\,\mu\mathrm{m}$ ("MIPS 24") and $70\,\mu\mathrm{m}$ ("MIPS 70"). The absolute photometric uncertainty of MIPS 24 is $2\,\%$ (Engelbracht et al., 2007). The absolute photometric uncertainty of MIPS 70 is $5\,\%$ (Gordon et al., 2007).

4.1.2 Gas components - ATCA, SHASSA and MAGMA

For my three gas components, H I, H II and H_2, I used the survey maps provided by ATCA (Kim et al., 2003), SHASSA (Gaustad et al., 2001) and MAGMA (Wong et al., 2011) respectively.

The ATCA survey contains individual 3d data cubes for each SNR of various pixel resolutions containing spatial brightness temperature maps of the 21-cm atomic line transition for a heliocentric velocity range of $v_{\mathrm{HEL}} = 190 - 387\,\mathrm{km\,s^{-1}}$ and velocity resolution of $dv = 1.649\,\mathrm{km\,s^{-1}}$.

The SHASSA survey consists of 2168 images covering 542 fields of which one o9f the fields covers the LMC. There are four images for each field. Hα, Continuum, Continuum-Corrected and Smoothed Continuum-Corrected. I use the Continuum-Corrected image for the LMC field to measure the Hα-emission, which is the emission for which the foreground and sky continuum has been subtracted.

The MAGMA data, like the ATCA survey, contains a 3d cubed survey map of the LMC consisting of spatial brightness temperature maps of the CO(1-0) atomic line transition for velocity channels of resolution $dv = 0.526\,\mathrm{km\,s^{-1}}$ spanning a total range of $v_{\mathrm{HEL}} = 190 - 349\,\mathrm{km\,s^{-1}}$. Unfortunately the survey doesn't cover the entire LMC and some of my targets are not covered by the survey.

4.2 Sample selection

For my sample of SNRs, I'm going use the catalogues from Seok et al. (2013, Table 1) and Badenes et al. (2010, Table 1). For the dust produced by the CC to not have significantly mixed with the surrounding ISM, I want the SNRs to be relatively young, e.g. they should be somewhere in the free expansion phase or early adiabatic phase in their evolutionary time lines. I'm also going to impose the arbitrary criteria that the SNR should be readily distinguishable from the background, i.e. if it's either too embedded in strongly emitting MCs or doesn't show any significant emission in any of the wavelength bands, I'm excluding it because it's too difficult to determine and subtract and suitable background.

With the following criteria above and motivated by the analysis in section 1.3, I assume the parameters $t = 2000\,\mathrm{yr}$ and $v = 6000\,\mathrm{km\,s^{-1}}$ for a typical remnant to be in its early evolutionary phases. For the Magellanic Clouds, this yields

$$\theta \approx \begin{cases} 101'', & \mathrm{LMC}\ (D = 50\,\mathrm{kpc}) \\ 84'', & \mathrm{SMC}\ (D = 60\,\mathrm{kpc}). \end{cases} \tag{4.1}$$

I will make the assumption that remnants at approximately this size or smaller have not yet dispersed significantly into the surrounding ISM.

Figure 4.1 shows the SNRs from CC SNe in the LMC that satisfy the age criteria generally imposed by (4.1). The survey map is a combined RGB image from HERITAGE with PACS 100 (blue), PACS 160 (green) and SPIRE 250 (red). The names marked in red are the remnants I further excluded since they are either embedded in a too noisy area or indistinguishable from the background in all the wavelength bands in general. The names marked in green are the ones I included for further investigation. Unfortunately, there were no SNRs included in my final sample from the SMC. The final sample is listed in Table 4.1.

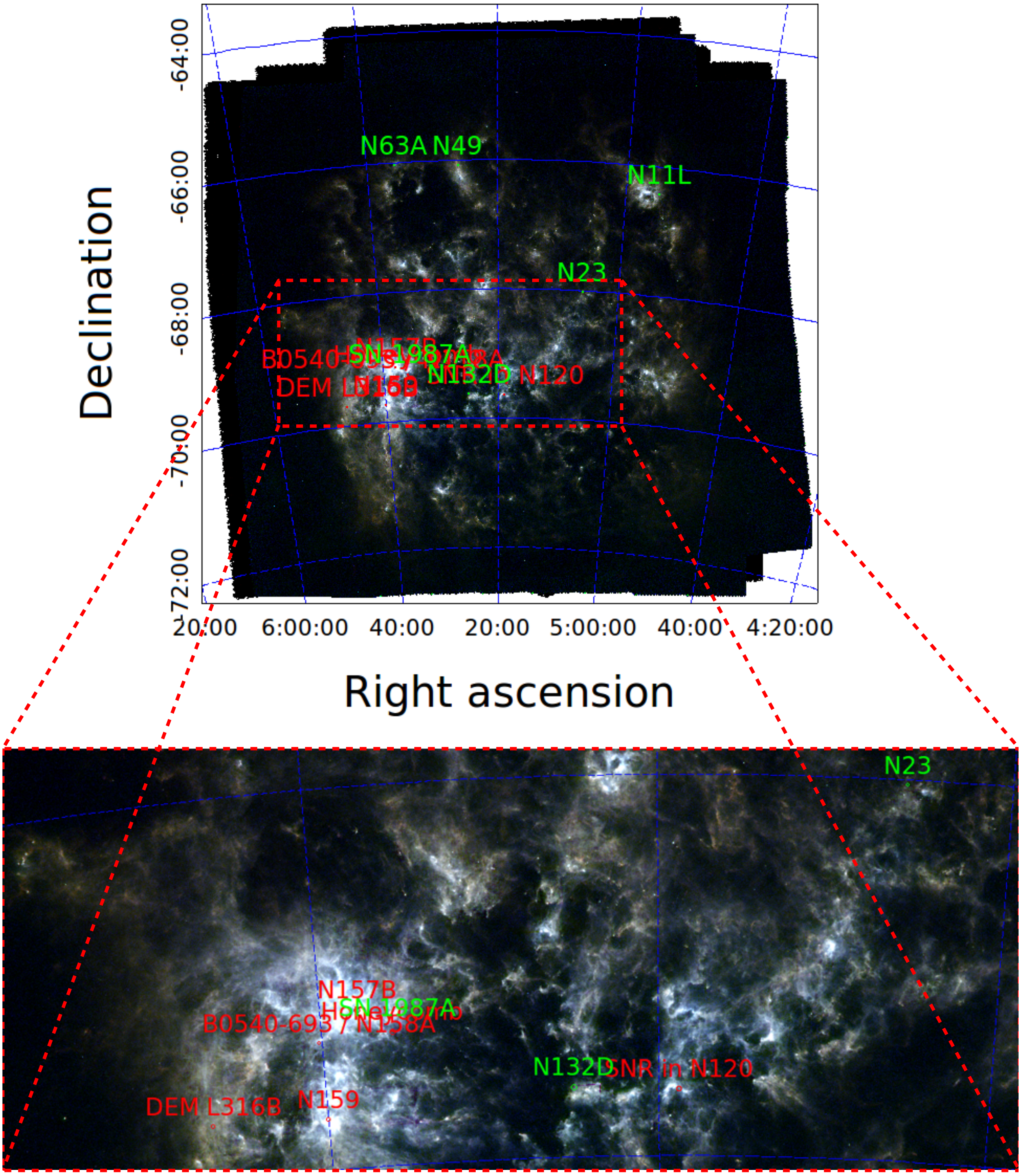


FIGURE 4.1: Combined RGB image of the LMC from the HERITAGE survey (Meixner et al., 2013) with the type II SNRs in the LMC that match my age criteria imposed by (4.1) included (Seok et al., 2013; Badenes et al., 2010). Blue is PACS 100, green is PACS 160 and red is SPIRE 250. The green names indicate the targets included in my sample.

TABLE 4.1: List of SNRs included in the sample.

SNR B1950	Other name	Position RA(J2000)	Dec(J2000)	Age (kyr)[a]	Diameter ($''$)	Progenitor mass ($M_\odot$)
0535–69.3	SN1987A	05:35:28	-69:16:11	0.029	1.6	≈ 20[1]
0454–66.5	N11L	04:54:48	-66:25:50	$7-15$	72	...
0506–68.0	N23	05:05:55	-68:01:47	~ 4.6	51	...
0525–69.6	N132D	05:25:03	-69:38:35	~ 3.15	104	~ 50[2]
0525–66.1	N49	05:26:00	-66:04:57	~ 6.6	100	~ 20[3]
0535–66.0	N63A	05:35:44	-66:02:14	$2-5$	78	$\gtrsim 40$[4]

Notes. [a] The listed ages are quoted directly from Seok et al. (2013, Table 1).

References. [1] Woosley et al. (1987) ; [2] France et al. (2009) ; [3] Hill et al. (1995) ; [4] Chu et al. (1999) .

4.3 Extraction of the flux densities

Following the procedures described in section 3.2, I'm going to extract the flux densities for the SEDs for all the bands and for each SNR. To visibly and quantitatively inspect the targets, I use the software SAOImage DS9. For the annulus background subtraction, I use the *annular sky aperture photometry* procedure in the HIPE software to extract the flux densities. For the background subtractions with a median filter, I use the `median` package inside NOAO's IRAF environment to create the median filters and the `imarith` package to subtract it.

To measure the statistical statistical errors in both the original and median filtered images I use DS9's in-built *region* function and proceed accordingly to section 3.2. The quantities N_A, N_B and $\sigma_i'^2$ can all be read from the regions statistics. However, as mentioned previously, each band has an absolute flux calibration error. This means that even if the region i is completely uniform so the statistical error $\sigma_i = 0$, there would still be an uncertainty corresponding to a percentage of the flux, e.g. $10\,\%$ for PACS 100. Hence, to estimate the total standard deviation in a measurement, σ, I add the absolute flux calibration error, $\sigma_F = F_{\lambda=100\,\mu\text{m}}/10$, in quadrature to the statistical errors from (3.6) and (3.11), so that

$$\sigma^2 = \sigma_{\text{src}}^2 + \sigma_F^2. \tag{4.2}$$

If the source and sky are very uniform then the standard deviation will be dominated by the absolute flux calibration of the instrument.

4.3.1 Infrared imaging, morphology and photometry of the sample

I treated each SNR in the sample separately with different methods of background subtractions depending on the structure of the remnant and the morphology of the ambient medium. My method of reduction for each individual case is described below. The measured flux densities are listed in Table 4.2. SN1987A has already been extensively covered by Matsuura et al. (2011) and so I will only quote the flux densities from this article for this SNR. I will discuss it more rigorously in chapter 5.

N11L

The N11L remnant is located at the outskirts of the N11 H II region and is shown in Figure 4.2. Apart from some barely noticeable emission at $24\,\mu\mathrm{m}$ and $70\,\mu\mathrm{m}$ from which the aperture was defined, it has no clearly visible observations in any of the IR or submm bands. The surrounding MC is very eminent, however, and starts to overlap with the remnant a lot in the PACS and SPIRE bands. I estimated the background with an annulus, since the MC features seen to the south-east are at a scale comparable to the size of the remnant, which makes it difficult to subtract with a median filter.

The SED was extracted from an aperture radius of $36''$. The background was estimated with the median pixel value from an annulus with inner and outer radii of $40''$ and $50''$ respectively.

N23

At $24\,\mu\mathrm{m}$ the morphology is highly asymmetric showing bright IR emission to the south-east. This asymmetry is likely due to the SNR ejecta's interaction with the significant density gradient from the partly

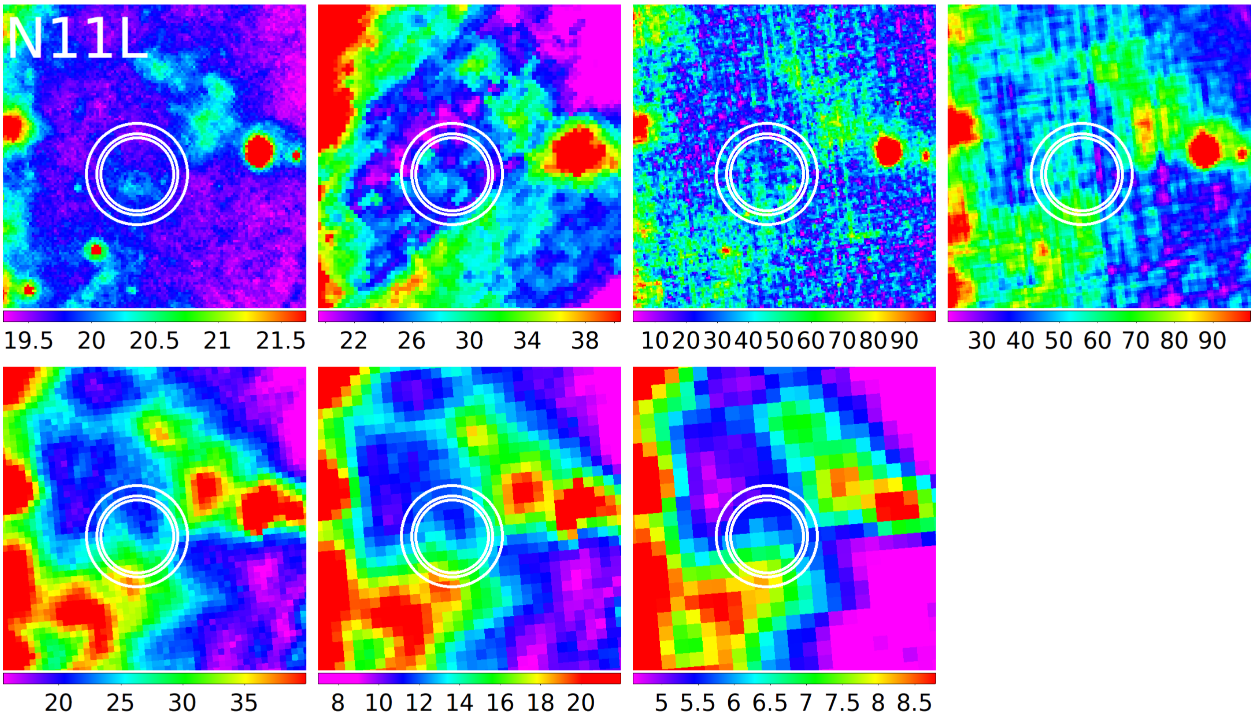


FIGURE 4.2: FIR and submm images from the HERITAGE and SAGE surveys of the N11L SNR. Top row: MIPS 24, MIPS 70, PACS 100, PACS 160. Bottom row: SPIRE 250, SPIRE 350, SPIRE 500. North is up and east is left. The white aperture indicates the area from which the flux densities were extracted. The median pixel value from the area indicated by the white annulus was used for the background subtraction. The colour scales are in units of $\mathrm{MJy\,sr^{-1}}$.

overlapping cloud complex. This gradient is much more prominent in FIR regime at wavelengths $\gtrsim 70\,\mu\mathrm{m}$. The SNR at these wavelengths becomes almost indistinguishable from the background. The remnant is shown in Figure 4.3.

Due to the significance of the gradient, I removed the background with a median filtered image created with a box size larger than the maximum IR extension of the SNR seen in MIPS 24, $72'' \times 72''$, in an attempt to preserve the small-scale structure. The aperture radius from which the flux densities were extracted was set to $25.5''$ for which the PACS 100 and PACS 160 bands, the essential bands for a cold dust component, contained the maximum emission.

N132D

The IR morphology of this SNR is similar to N23. A shell-like structure is easily distinguishable in the $24\,\mu\mathrm{m}$ MIPS band with brighter emission to the south, probably due to the interaction with the ambient molecular cloud to the south-west. The SNR becomes almost indistinguishable from the background in the FIR and submm bands at around $\sim 160\,\mu\mathrm{m}$ and above. The remnant is shown in Figure 4.4.

Again, due to the significant gradient of the partly overlapping MC, I removed the background emission with a median filter created with a box size of $120'' \times 120''$, the approximate size of the largest structure related to the SNR. The flux densities were extracted from a circular aperture of radius $52.0''$ which was chosen to include as much as the IR emission from the SNR as possible while excluding the emission from the molecular complex to the south based on the PACS 100 band.

N49

Like the previous remnants, N49, shown in Figure 4.5, is also embedded in a prominent MC. The shell-like structure is clearly seen in the MIPS 24 band. The south-eastern limb shows much brighter emission than the rest of the remnant indicating a density gradient in the

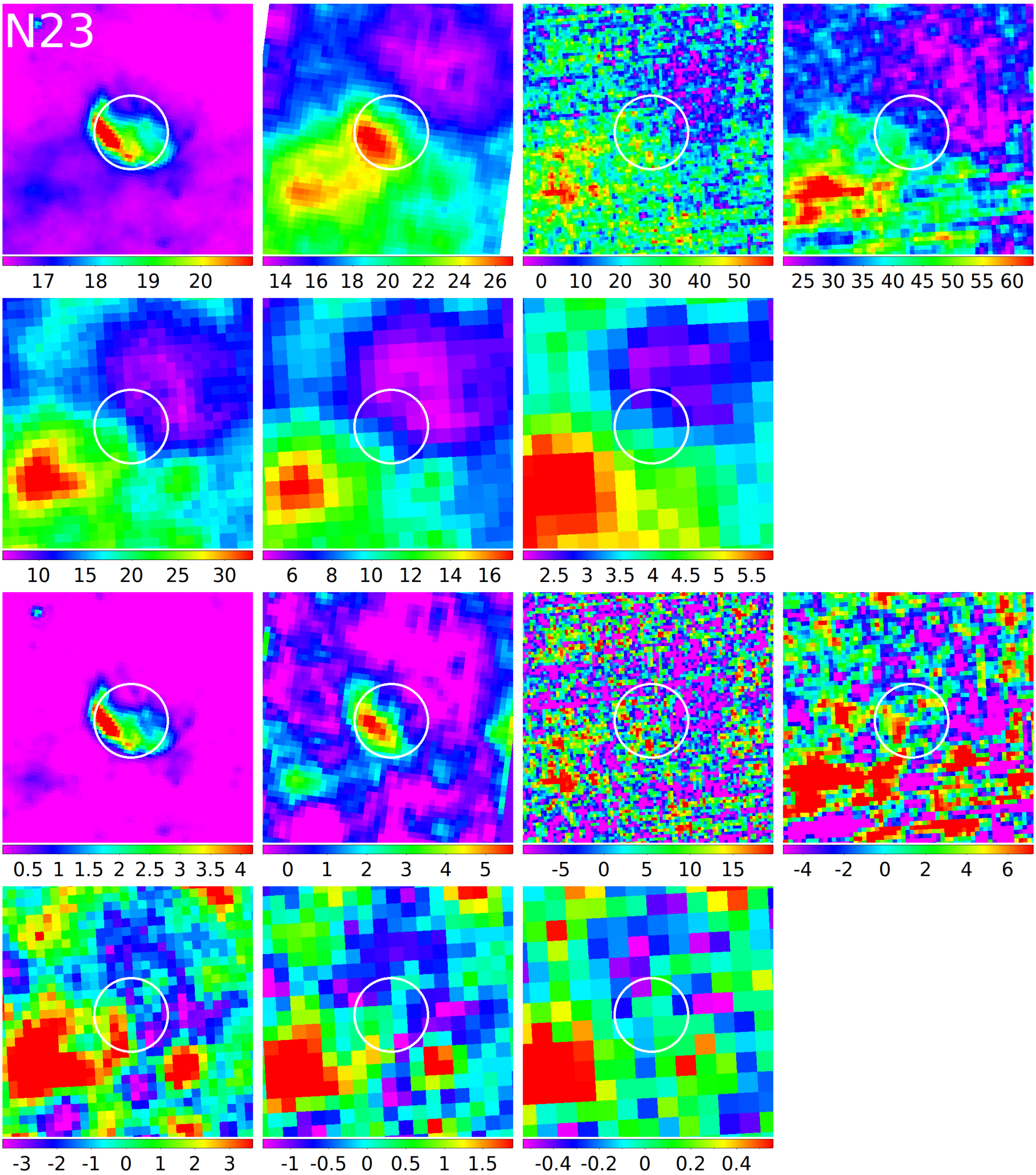


FIGURE 4.3: FIR and submm images from the HERITAGE and SAGE surveys of the N23 SNR. First row: MIPS 24, MIPS 70, PACS 100, PACS 160. Second row: SPIRE 250, SPIRE 350, SPIRE 500. Third and fourth rows are the corresponding median subtracted images. North is up and east is left. The white aperture indicates the area from which the flux densities were extracted. The colour scales are in units of $\mathrm{MJy\,sr^{-1}}$.

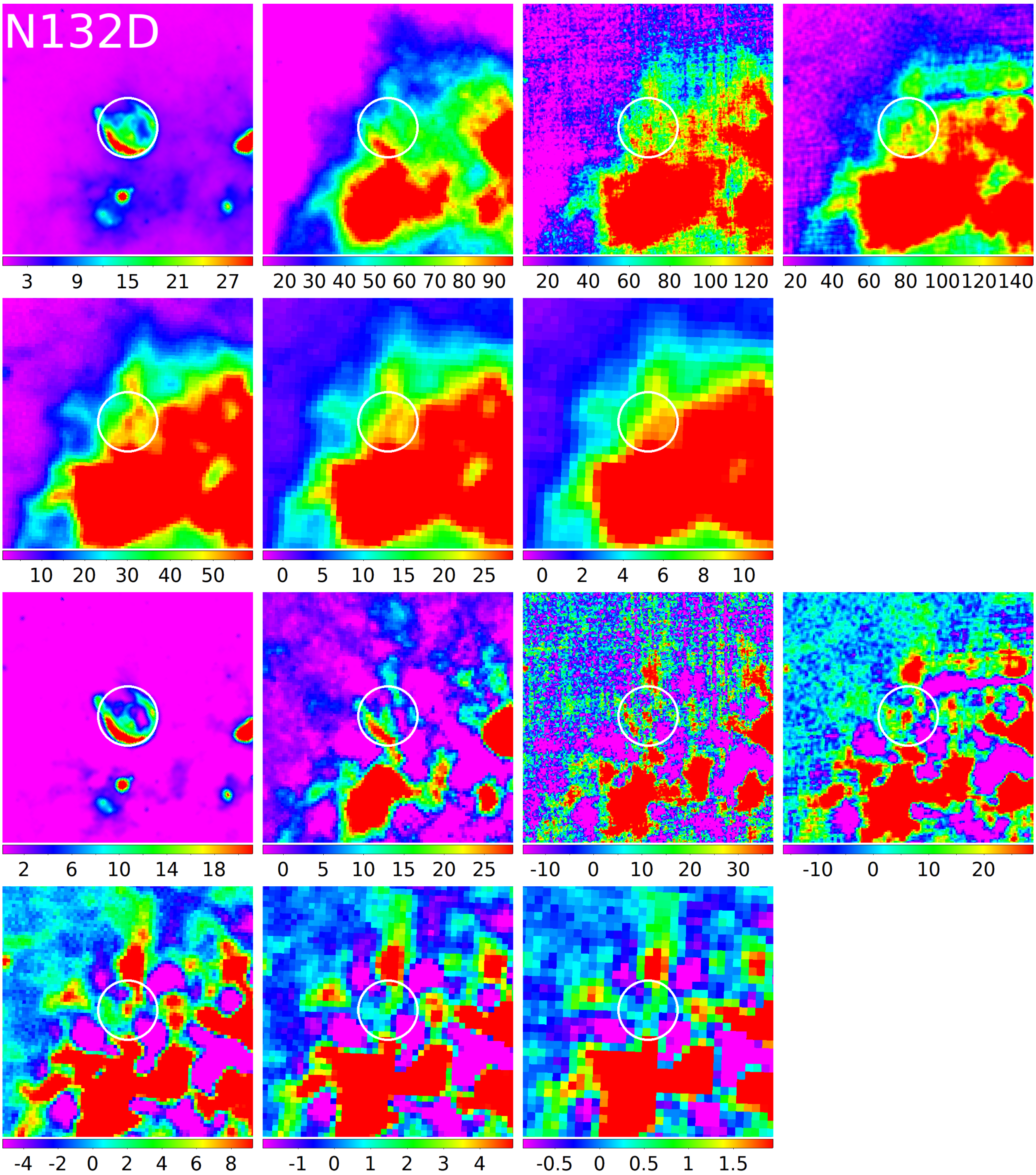


FIGURE 4.4: FIR and submm images from the HERITAGE and SAGE surveys of the N132D SNR. First row: MIPS 24, MIPS 70, PACS 100, PACS 160. Second row: SPIRE 250, SPIRE 350, SPIRE 500. Third and fourth rows are the corresponding median subtracted images. North is up and east is left. The white aperture indicates the area from which the flux densities were extracted. The colour scales are in units of $\mathrm{MJy\,sr^{-1}}$.

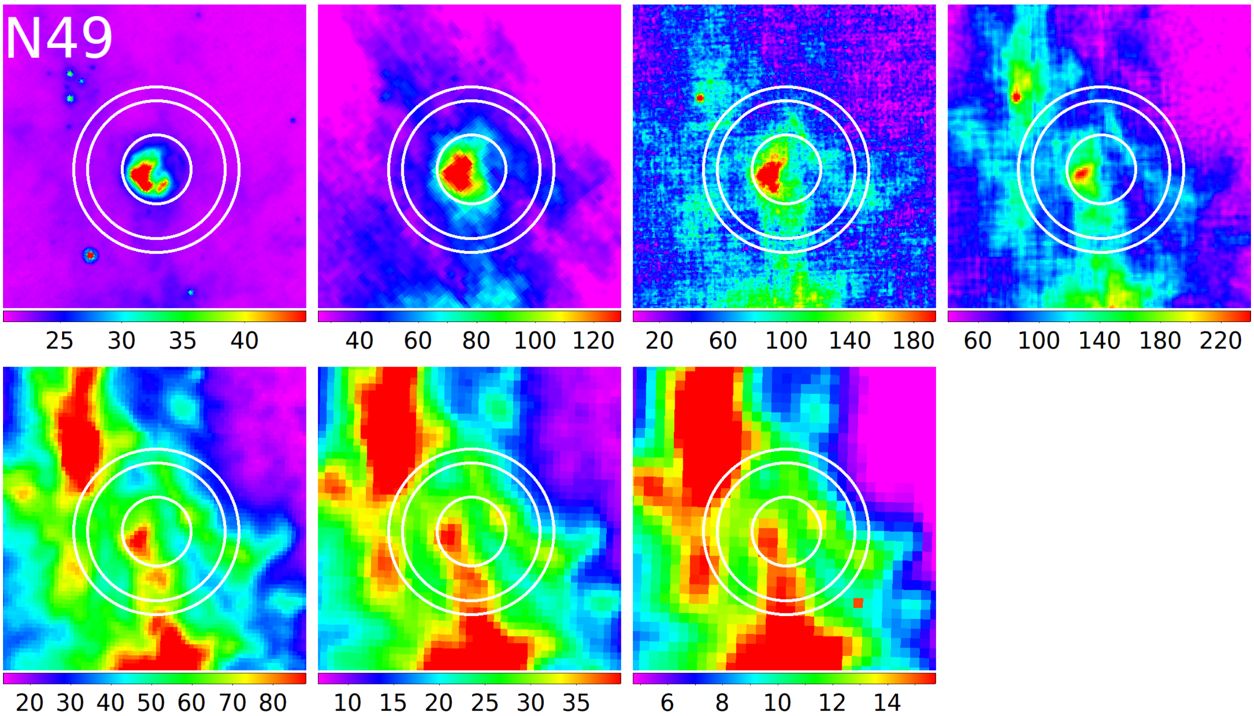


FIGURE 4.5: FIR and submm images from the HERITAGE and SAGE surveys of the N49 SNR. Top row: MIPS 24, MIPS 70, PACS 100, PACS 160. Bottom row: SPIRE 250, SPIRE 350, SPIRE 500. North is up and east is left. The white aperture indicates the area from which the flux densities were extracted. The median pixel value from the area indicated by the white annulus was used for the background subtraction. The colour scales are in units of $\mathrm{MJy\,sr^{-1}}$.

ambient medium which increases from the north-west to the south-east with which it may be interacting. The IR morphology is similar in all bands. In the submm regime at $\gtrsim 350\,\mu\mathrm{m}$ the morphology is similar, but becomes more indistinguishable from the surrounding MC, probably owing to the increasingly lower resolution of the images.

Based on the shell-like morphology visible in MIPS 24, I used an aperture radius of $50''$. Unlike N23 and N13D the scale of the MC around N49 is comparable to the remnant itself. I therefore chose to subtract the background using with the median pixel value of an annulus of inner and outer radii of $100''$ and $120''$ respectively.

TABLE 4.2: The measured flux densities of the sample.

SNR	MIPS 24 (mJy)	MIPS 70 (mJy)	PACS 100 (mJy)	PACS 160 (mJy)	SPIRE 250 (mJy)	SPIRE 350 (mJy)	SPIRE 500 (mJy)
SN1987A[a]	...	...	70.5 ± 8.5	125.3 ± 16.1	131.7 ± 12.1	49.3 ± 6.5	$< 57.3^{b}$
N11L	11.8 ± 0.8	73.5 ± 23.8	154.6 ± 57.4	-147.5 ± 78.3	33.9 ± 59.5	-11.7 ± 50.3	35.5 ± 31.4
N23	84.4 ± 4.1	103.8 ± 17.6	93.9 ± 21.0	51.6 ± 25.3	-11.7 ± 35.7	-12.5 ± 21.9	-5.3 ± 12.1
N132D	1781.7 ± 57.5	1635.8 ± 218.3	1180.2 ± 174.5	523.6 ± 218.7	179.3 ± 174.9	56.7 ± 138.4	26.1 ± 79.4
N49	1596.1 ± 55.5	9608.5 ± 550.8	11597.7 ± 1180.9	6117.4 ± 1249.0	1806.4 ± 335.7	591.4 ± 165.2	201.2 ± 80.0
N63A	2260.1 ± 101.4	8444.6 ± 691.3	13953.6 ± 1663.2	7858.7 ± 1757.2	2739.3 ± 569.0	916.2 ± 258.0	319.3 ± 88.8

Notes. $^{(a)}$ Matsuura et al. (2011) ; $^{(b)}$ 3σ upper limit.

N63A

N63A lies within another H II region. It's shown in Figure. 4.6. The shell-like structure of the SNR is clearly visible in the MIPS 24 band. The bright emission to the west is due to a three-lobed structure which are nearly indistinguishable in all the IR and submm bands. A young stellar object (YSO) to the north-east and a background galaxy to the south-east are visible in the edge of the remnant in all the bands.

Based on the infrared structure in the MIPS 24 image, I chose an aperture radius of $39''$ to extract the flux densities from. The radius was chosen to exclude most of the emission from the YSO. The aperture was still overlapping with the bright background galaxy to the south-east which I therefore attempted to remove using a model PSF created with the `DAOPHOT` procedure in IRAF. This was possible up until $250\,\mu\mathrm{m}$ from where the galaxy starts to blend in almost entirely with the background. I used the median value of the pixels distribution inside an annulus of inner and outer radii $80''$ and $100''$ centred on the remnant to subtract the background.

4.4 Dust models

For my project I adopt three dust models as mentioned in section 3.3. Astronomical silicates (AS) from Draine and Lee (1984) and the amorphous carbon, ACAR and BE (ACAR and BE) samples from Zubko et al. (1996) motivated by various nucleosynthesis models in high mass stars for which the elements C, O and Si are produced in

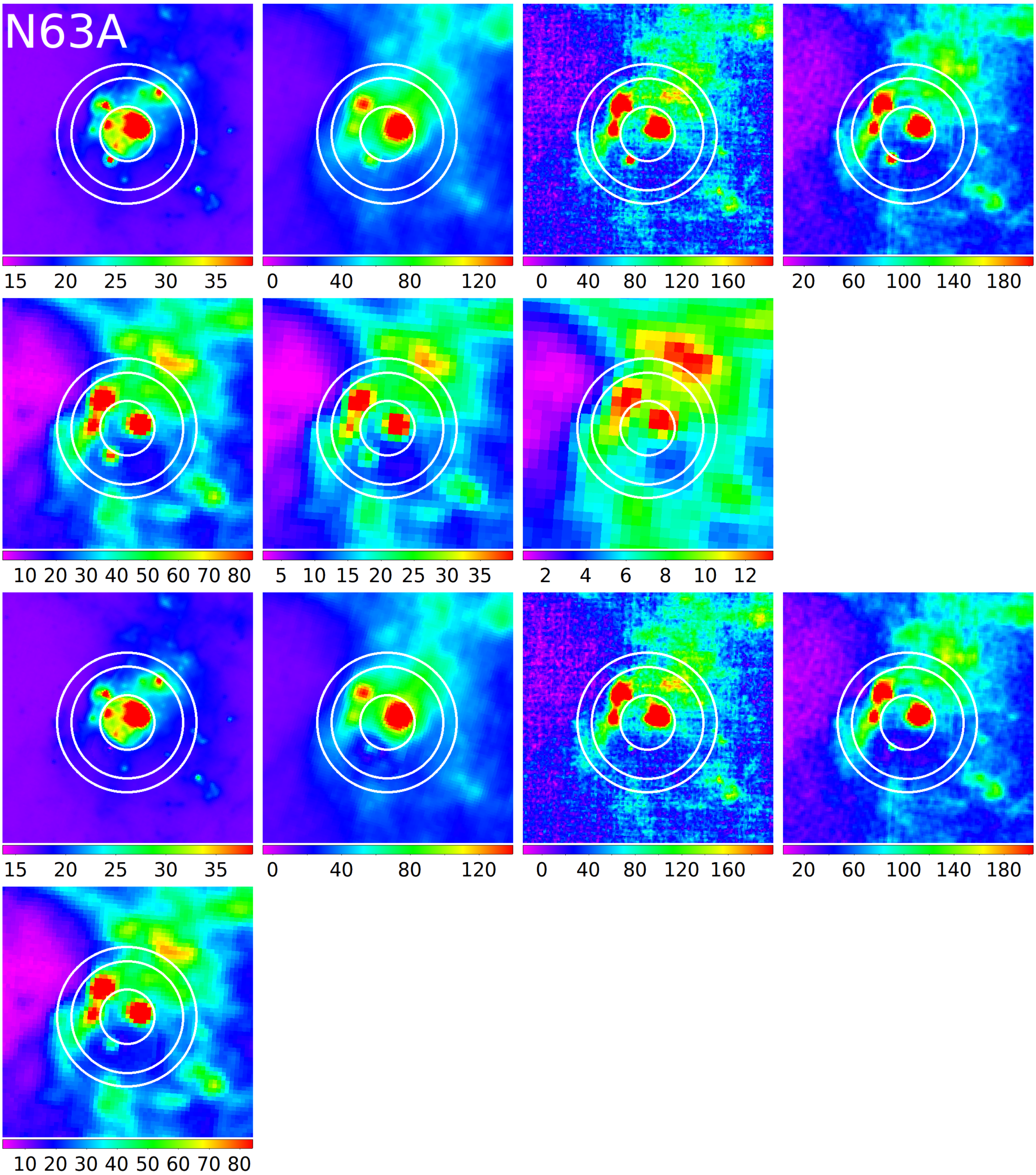


FIGURE 4.6: FIR and submm images from the HERITAGE and SAGE surveys of the N63A SNR. First row: MIPS 24, MIPS 70, PACS 100, PACS 160. Second row: SPIRE 250, SPIRE 350, SPIRE 500. Third and fourth rows are the corresponding bands up to SPIRE 250 with the young stellar object at the south-western edge of the aperture subtracted. North is up and east is left. The white aperture indicates the area from which the flux densities were extracted. The median pixel value from the area indicated by the white annulus was used for the background subtraction. The colour scales are in units of $\mathrm{MJy\,sr^{-1}}$.

TABLE 4.3: Dust models for a single grain size $a = 0.1\,\mu\text{m}$ and the best fit parameters found at the reference frequency $\nu_0 = 2997.92\,\text{GHz}$ ($\lambda_0 = 100\,\mu\text{m}$).

Dust model	Abbreviation	ρ_{gr} $(\text{g}\,\text{cm}^{-3})$	κ_0 $(\text{cm}^2\,\text{g}^{-1})$	β	Reference
Astronomical silicates	AS	3.5[a]	30.46	2.03	1
Amorphous carbon, ACAR sample	ACAR	1.85[b]	53.17	1.40	2
Amorphous carbon, BE sample	BE	1.85[b]	38.55	1.57	2

Notes. The grain densities are adopted from: [(a)] Weingartner and Draine (2001) ; [(b)] Rouleau and Martin (1991) .

References. (1) Draine and Lee (1984); (2) Zubko et al. (1996).

large quantities (e.g. Woosley and Weaver, 1995). The complex refractive index, $m = n + ik$, for AS is publicly available and published as online material by Bruce T. Draine, Dept. of Astrophysical Sciences, Princeton University. The ACAR and BE dielectric functions were provided to me by Anja C. Andersen, Dark Cosmology Center, Niels Bohr Institute, Copenhagen University. All three models are listed in Appendix A.

I calculated the extinction efficiency coefficients, Q_{ext} of the three models with the **BHMIE algorithm** for spherical grains of radius a using a single grain size $a = 0.1\,\mu\text{m}$. To calculate the mass extinction coefficient, κ_{ext}, I adopted a grain density $\rho_{\text{gr}} = 3.5\,\text{g}\,\text{cm}^{-3}$ for AS from Weingartner and Draine (2001) and $\rho_{\text{gr}} = 1.85\,\text{g}\,\text{cm}^{-3}$ for the ACAR and BE samples from Rouleau and Martin (1991). I also tried to vary the grain size by a factor 10, but it didn't change κ_{ext} or the total dust masses, M_d, significantly.

Finally I parametrized κ_{ext} as (2.25) and used a least squares fitting method using (3.12) at a reference frequency $\nu_0 = (\lambda_0 = 100\,\mu\text{m})^{-1}c = 2997.92\,\text{GHz}$ over the FIR range $100 - 500\,\mu\text{m}$, to determine κ_0 and β. The results are listed in Table 4.3. The results are shown in Figures 4.7-4.9.

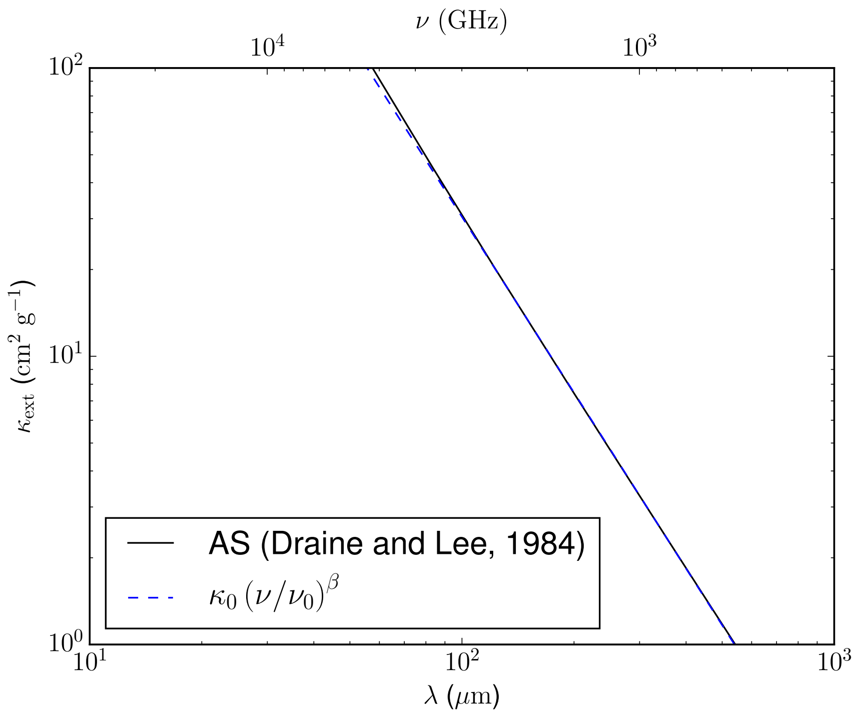


FIGURE 4.7: Mass extinction coefficient, $\kappa_{\rm ext}$, for AS dust (Draine and Lee, 1984), calculated for a single grain size, $a = 0.1\,\mu$m. The full black line is the experimental coefficient. The dashed blue line is the parametrization fitted over the wavelength range $\lambda = 100 - 500\,\mu$m at a reference frequency, $\nu_0 = 2997.92$ GHz ($\lambda_0 = 100\,\mu$m), with the best fit parameters listed in Table 4.3.

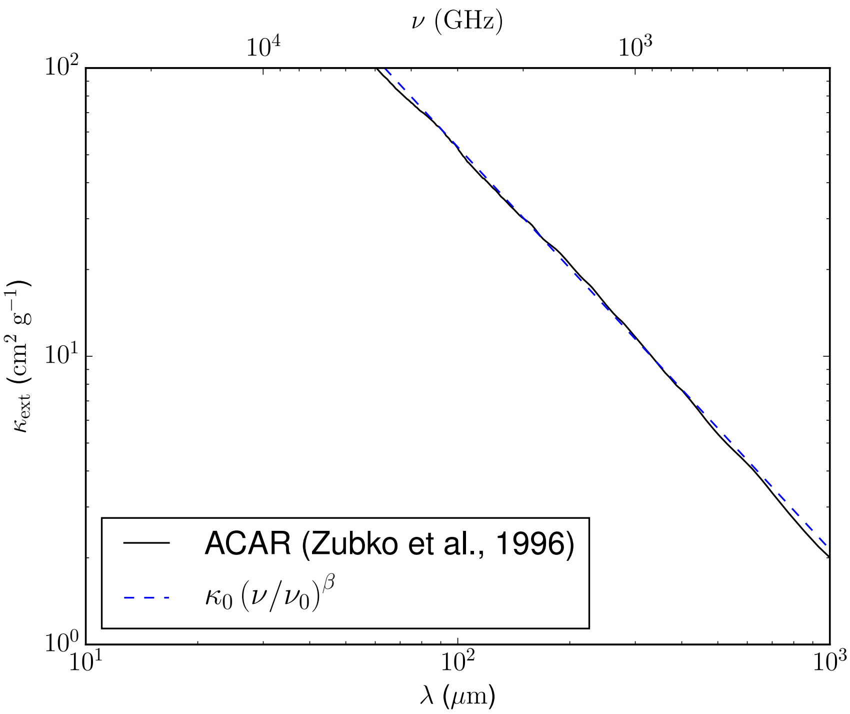


FIGURE 4.8: Mass extinction coefficient, κ_{ext}, for ACAR dust (Zubko et al., 1996), calculated for a single grain size, $a = 0.1\,\mu\text{m}$. The full black line is the experimental coefficient. The dashed blue line is the parametrization fitted over the wavelength range $\lambda = 100 - 500\,\mu\text{m}$ at a reference frequency, $\nu_0 = 2997.92\,\text{GHz}$ ($\lambda_0 = 100\,\mu\text{m}$), with the best fit parameters listed in Table 4.3.

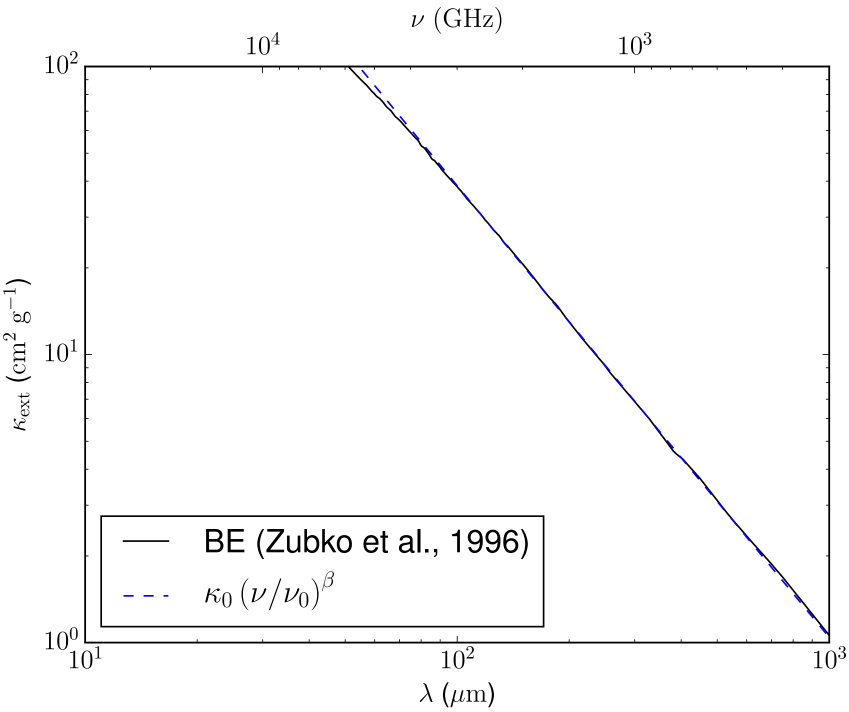


FIGURE 4.9: Mass extinction coefficient, κ_{ext}, for BE dust (Zubko et al., 1996), calculated for a single grain size, $a = 0.1\,\mu\text{m}$. The full black line is the experimental coefficient. The dashed blue line is the parametrization fitted over the wavelength range $\lambda = 100 - 500\,\mu\text{m}$ at a reference frequency, $\nu_0 = 2997.92\,\text{GHz}$ ($\lambda_0 = 100\,\mu\text{m}$), with the best fit parameters listed in Table 4.3.

4.5 Total dust masses

With the SEDs and dust models in hand, I'm finally ready to measure the total dust masses, M_d, for a given dust model. I'm going to fit with a double component model as described in section 3.4 and run Monte Carlo simulations for $n = 100\,000$ model spectra with a least squares fitting method for each remnant using the flux densities and standard deviations from Table 4.2. Of the $n = 100\,000$ samples of the warm and cold dust components, M_1, T_1, M_2 and T_2, I will quote the median as the true parameters. As the standard deviation, I will assume that 1σ contains $68.27\,\%$ around the median, i.e. the lower and upper limits cover $34.135\,\%$ away from the median of the distribution.

Since the remnants N11L, N23 and N132D have relative large uncertainties in the long wavelength bands at $\gtrsim 160\,\mu\mathrm{m}$ (which I will discuss more thoroughly in chapter 5), running the Monte Carlo simulations unconstrained resulted in an unphysically low cold dust temperature at $T_2/\mathrm{K} \ll 1$ and hence an unrealistically large cold dust mass $M_2/M_\odot \gg 1$. I therefore assumed that the cold dust mass is at a similar temperature with the surrounding ISM dust (Bernard et al., 2008, Figure 7) and constrained the lower parameter limit of T_2 to $18\,\mathrm{K}$.

For all the remnants, the total dust mass is completely dominated by the cold dust mass, $M_d = M_1 + M_2 \approx M_2$, and since I only used the MIPS 24 band to guide the shape of the warm component, the warm dust mass and temperature is too unrestrained. However, if $T_1 \gg T_2$ then $M_1 \gg M_2$ and so I will assume that the dust in the remnant is dominated by the cold component, $M_d = M_2$ and $T_d = T_2$.

The results are summarized in Table 4.4 and shown in Figures 4.10-4.15.

TABLE 4.4: Median value and 1σ lower and upper limits of the cold dust. Calculated for $n = 100\,000$ Monte Carlo simulations for the three dust models described in Table 4.3.

SNR	AS		ACAR		BE	
	M_d $(M_\odot)$	T_d (K)	M_d $(M_\odot)$	T_d (K)	M_d $(M_\odot)$	T_d (K)
SN1987A	$3.0^{+0.5}_{-0.4}$	$17.1^{+0.5}_{-0.5}$	$0.6^{+0.09}_{-0.08}$	$19.8^{+0.6}_{-0.6}$	$1.1^{+0.2}_{-0.1}$	$19.0^{+0.6}_{-0.6}$
N11L[a]	$0.05^{+0.1}_{-0.05}$	$30.5^{+6.8}_{-12.0}$	$0.03^{+0.2}_{-0.03}$	$18.0^{+16.2}_{-0.02}$	$0.03^{+0.2}_{-0.03}$	$23.0^{+13.3}_{-5.0}$
N23[a]	$0.08^{+0.1}_{-0.05}$	$30.4^{+7.2}_{-12.4}$	$0.02^{+0.02}_{-0.02}$	$35.4^{+7.8}_{-17.4}$	$0.03^{+0.05}_{-0.02}$	$35.7^{+7.0}_{-17.6}$
N132D[a]	$0.9^{+2.1}_{-0.5}$	$30.8^{+10.7}_{-8.6}$	$0.2^{+0.4}_{-0.1}$	$40.7^{+11.3}_{-15.9}$	$0.3^{+0.8}_{-0.2}$	$37.6^{+11.3}_{-13.4}$
N49	$9.5^{+1.8}_{-1.5}$	$32.1^{+1.1}_{-1.3}$	$1.9^{+0.3}_{-0.3}$	$40.4^{+1.5}_{-1.4}$	$3.5^{+0.6}_{-0.5}$	$37.7^{+1.3}_{-1.2}$
N63A	$18.2^{+3.3}_{-2.9}$	$28.7^{+0.9}_{-0.9}$	$3.4^{+0.6}_{-0.5}$	$35.5^{+1.2}_{-1.1}$	$6.5^{+1.1}_{-1.0}$	$33.3^{+1.1}_{-1.0}$

Notes. [(a)] The lower limit of the cold dust temperature T_2 was constrained to 18 K (see text) .

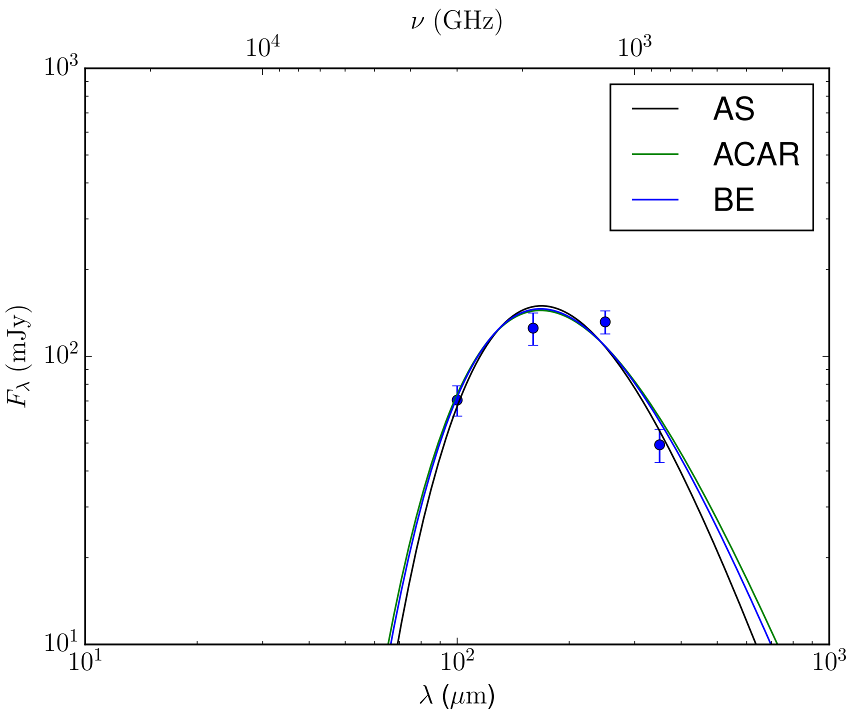


FIGURE 4.10: SED of SN1987A fitted with a modified blackbody for the three dust models. Fit parameters are summarized in Table 4.3 and 4.4.

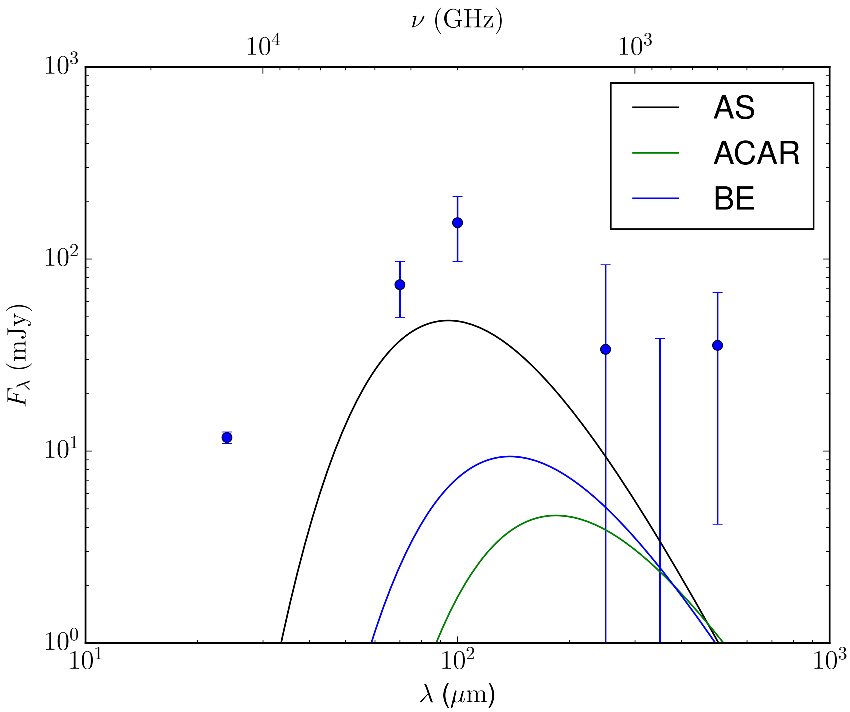


FIGURE 4.11: SED of N11L fitted with a modified blackbody for the three dust models. Fit parameters are summarized in Table 4.3 and 4.4. Note that the PACS 160 band flux plus upper limit is below zero.

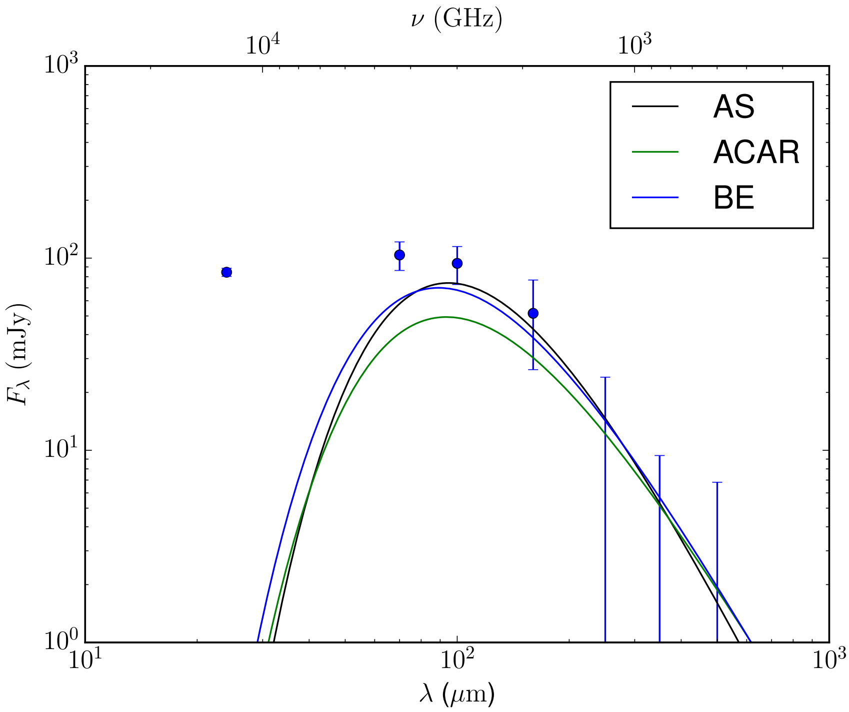


FIGURE 4.12: SED of N23 fitted with a modified blackbody for the three dust models. Fit parameters are summarized in Table 4.3 and 4.4.

4.6 Dust mass in the ISM

To determine how much of the total dust mass comes from the swept up ISM mass, I'm going to calculate the ISM gas number densities for the three components H I, H II and H_2 using the ACTA, MAGMA and SHASSA surveys and transform them into a swept-up ISM mass, $M_{d,\mathrm{ISM}}$. using the dust-to-gas mass ratio, Z_d. If we assume that the column densities N_i, which I measure from the survey maps, is constant over the LMC disk thickness L, the volume densities n_i can be approximated as $n_i = N_i/L$.

I assume an LMC disk thickness $L = 400\,\mathrm{pc}$ and the dust-to-gas mass ratios for each SNR from Temim et al. (2015, Table 1).

To measure the column density $N_{\mathrm{H\,I}}$, I calculate the integral in (2.39) by integrating each data cube in the ACTA survey over the velocity range and measure the mean pixel value of the SNR region on the integrated map. I use the same procedure for $N_{\mathrm{H_2}}$ and (2.47)

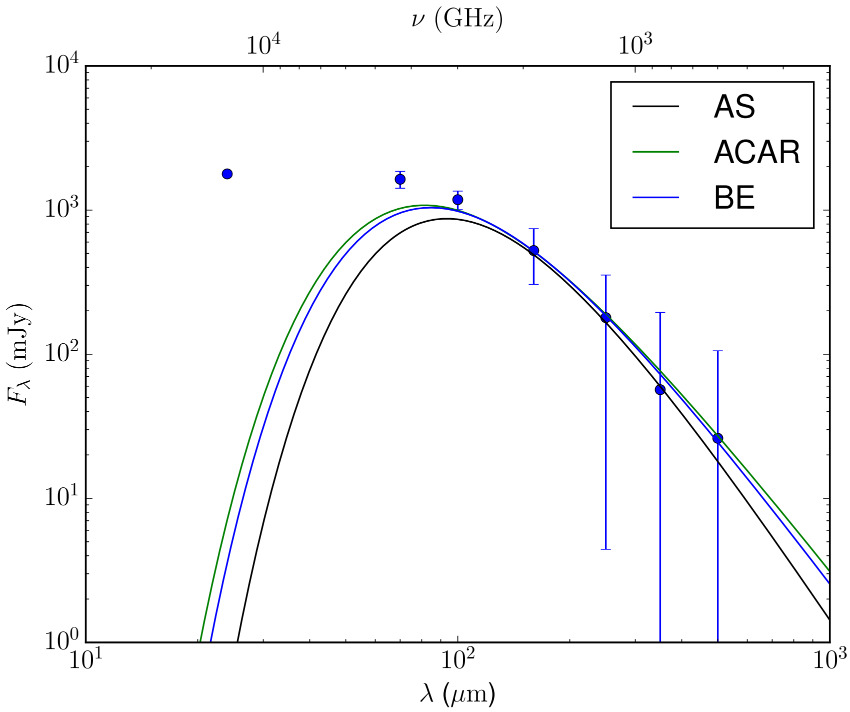


FIGURE 4.13: SED of N132D fitted with a modified blackbody for the three dust models. Fit parameters are summarized in Table 4.3 and 4.4.

using the MAGMA data and adopt $X_{\rm CO} = 7 \times 10^{20}\,{\rm cm^{-2}\,K^{-1}\,km^{-1}\,s}$ (Fukui et al., 2008). Unfortunately the N11L, N23 and N63A regions aren't covered by the survey so I make the crude assumption that the molecular gas content here is negligible.

To measure the volume density $n_{\rm H\,II}$, I use (2.42) for an assumed electron temperature $T_e = 10^4\,$K. The SHASSA map is in units of Rayleigh, so I use the factor (2.45) for Hα emission to convert it into the convenient unit. I use the mean pixel value over the SNR region to estimate the volume density for H II.

Finally, I measure the total gas column density $N_{\rm H}$ in accordance with (3.16) and use my assumed disk thickness L to estimate the volume density $n_{\rm H}$. The results are shown in Figures 4.16-4.20 and listed in Table 4.5.

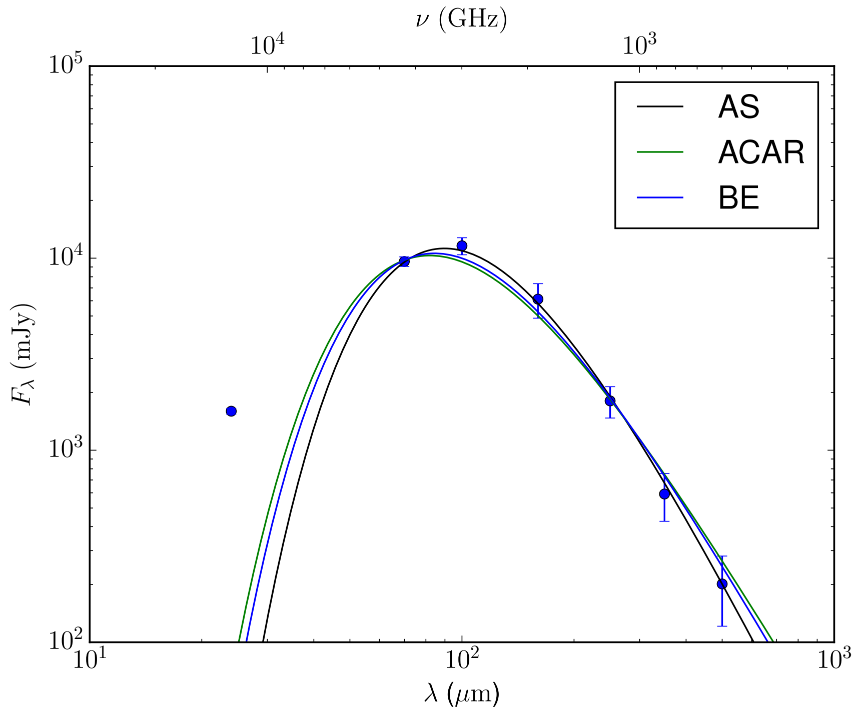


FIGURE 4.14: SED of N49 fitted with a modified blackbody for the three dust models. Fit parameters are summarized in Table 4.3 and 4.4.

TABLE 4.5: ISM gas volume densities at the SNRs and total swept-up dust masses.

SNR	$n_{\mathrm{H\,I}}$ (cm^{-3})	$n_{\mathrm{H\,II}}$ (cm^{-3})	$n_{\mathrm{H_2}}$ (cm^{-3})	n_{H} (cm^{-3})	Volume (pc^3)	$D2G^a$ (10^{-3})	$M_{d,\mathrm{ISM}}$ ($M_\odot$)
SN1987A	...	...	...	1^b	3.06×10^{-2}	4.15	6×10^{-6}
N11L	2.64	0.81	...	3.45	2784	4.17	1.0
N23	1.38	0.66	...	2.04	989.3	4.44	0.2
N132D	1.34	0.87	0.21	2.63	8389	8.26	4.5
N49	3.14	1.96	0.13	5.36	7458	6.25	6.2
N63A	0.28	2.1	...	2.38	3539	9.62	2.0

Notes. $^{(a)}$ Temim et al. (2015) ; $^{(b)}$ Matsuura et al. (2011) .

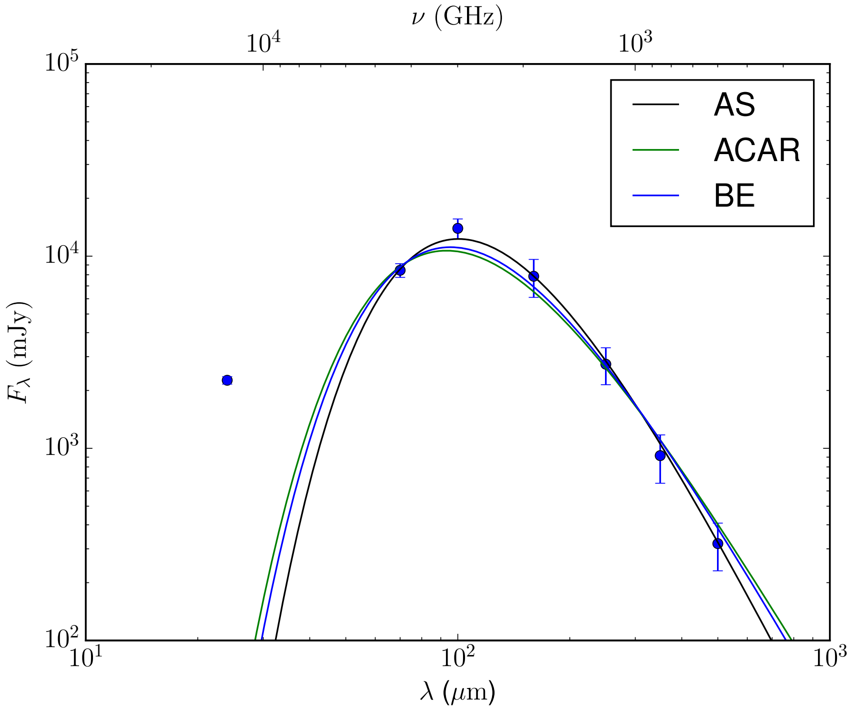
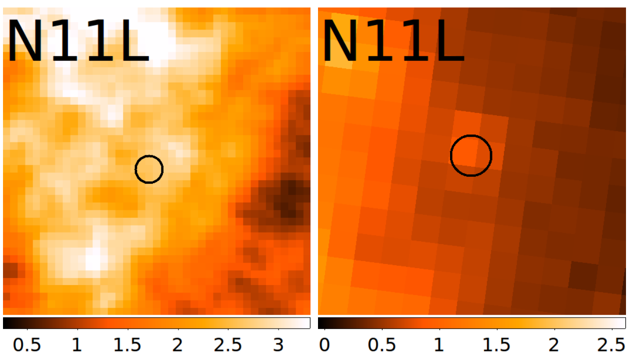
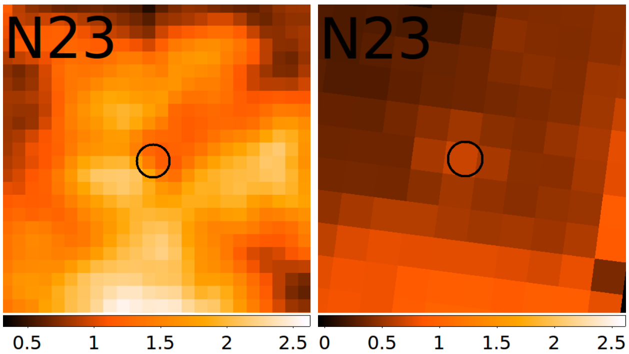


FIGURE 4.15: SED of N63A fitted with a modified blackbody for the three dust models. Fit parameters are summarized in Table 4.3 and 4.4.



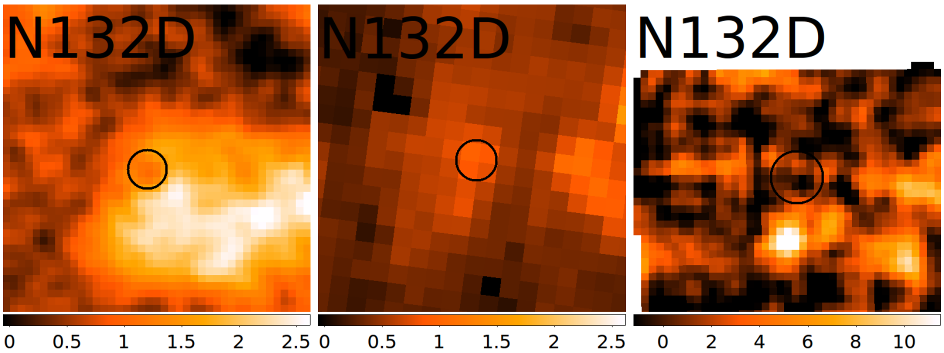
(A) $n_{\mathrm{H\,I}}$ (B) $n_{\mathrm{H\,II}}$

FIGURE 4.16: Number volume densities for the various gas components around N11L. The colour scales are in units of cm^{-3}.



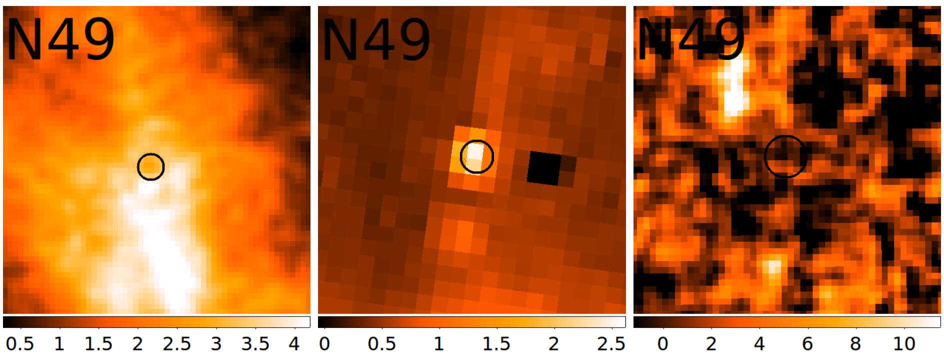
(A) $n_{\mathrm{H\,I}}$ (B) $n_{\mathrm{H\,II}}$

FIGURE 4.17: Number volume densities for the various gas components around N23. The colour scales are in units of cm^{-3}.



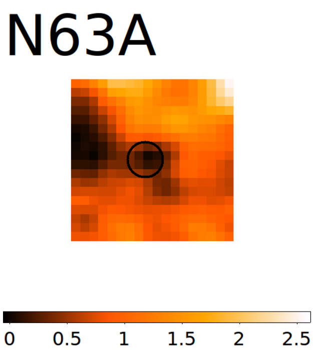
(A) $n_{\mathrm{H\,I}}$ (B) $n_{\mathrm{H\,II}}$ (C) $n_{\mathrm{H_2}}$

FIGURE 4.18: Number volume densities for the various gas components around N132D. The colour scales are in units of cm^{-3}.

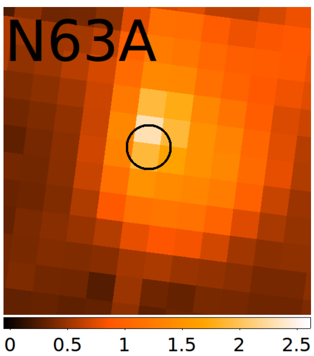


(A) $n_{\mathrm{H\,I}}$ (B) $n_{\mathrm{H\,II}}$ (C) $n_{\mathrm{H_2}}$

FIGURE 4.19: Number volume densities for the various gas components around N49. The colour scales are in units of cm^{-3}.



(A) $n_{\text{H I}}$



(B) $n_{\text{H II}}$

FIGURE 4.20: Number volume densities for the various gas components around N63A. The colour scales are in units of cm^{-3}.

Chapter 5

Discussion & Conclusion

Initially there are three important things to notice from Table 4.4. Firstly, the measured dust masses vary significantly for the given dust models, even between the ACAR and BE samples. Secondly, about half the sample, mainly SN1987A, N49, and arguably N132D, contain a large amount of total dust while the rest contain almost none. Thirdly, the lower mass and temperature limits for N11L and N23 and are driven by the lower parameter boundary, $T_2 \geq 18\,\mathrm{K}$.

SN1987A is the first remnant from a CC SN in which a significant amount of cold dust, contributed to the remnant itself, has been detected (Matsuura et al., 2011), in agreement with the theory that each SN must produce, on average, at least $0.4\,M_\odot$ of dust (Dwek et al., 2007). Within the uncertainties my result also agrees with this, although I measure a slightly larger true dust mass with a slightly lower temperature than Matsuura et al. (2011) owing to the fact that I used two dust components, which reduces the cold dust temperature and hence increases the cold dust mass, as well as my grain densities from Table 4.3 being slightly larger than the ones quoted by Matsuura et al. (2011). The swept-up ISM dust in SN1987A is negligible (see Table 4.5). Matsuura et al. (2011) also ruled out the possibility of the emission coming from a light echo from interstellar dust grains behind the remnant as well as the possibility of the measured dust being produced in the red supergiant progenitor prior to the collapse. They concluded that the cold dust must have been produced after the SN event and that CC SNe may be significant contributors of dust if it's not significantly destroyed during its injection back into the ISM. This conclusion has also been the driving motivation in my project to measure the maximum possible amount of cold dust masses that may have been produced by other CC SNe.

One of the largest uncertainties with my results, by far, is the difficulty with determining the background accurately. Many of the SNRs are deeply embedded in emitting MCs with which they may be interacting, which often results in high sky levels and with large density gradients. For the remnants N11L, N23 and N132D in particular, it's evident from Figures 4.2-4.4 that I overestimate the background, especially in the long wavelength bands where the remnants blend in with the background entirely. N11L is the eldest of the sample which together with its angular size indicates that it has probably collapsed into a dense medium slowing the expansion rate significantly. The age indicates that it's probably near the ends of its adiabatic expansion phase. Hence the potential dust has become much more indistinguishable from the background. This is eminent in Figure 4.2 where the remnant becomes almost entirely indistinguishable from its surroundings at wavelengths $\gtrsim 100\,\mu\mathrm{m}$. In these bands it's entirely dominated by the features in the sky emission. The same is evident with N23 in Figure 4.3 where it has no clearly defined features from wavelengths $\gtrsim 100\,\mu\mathrm{m}$. The results of this can be seen in the SEDs in Figures 4.11 and 4.12 and partly for N132D in Figure 4.4 in the SPIRE bands.

On the other hand, the two remnants N49 and N63A, for which the highest dust masses were measured, lie within much more isolated and uniform regions. The background here is much more well defined and more easily determined. For N49 the measured total dust mass ranges from $1.9 - 9.5\,M_\odot$ depending on the dust model. The crudely estimated swept-up ISM dust is fairly large, $\sim 6\,M_\odot$. For N63A the total dust mass is as high as $3.4 - 18.2\,M_\odot$ with a much lower estimated swept-up mass of $\sim 2\,M_\odot$. In reality, the dust is probably a mix of silicates and some type of amorphous carbon as well as other compounds unexplored in this project (e.g. iron, ices etc.). This means that the total mass for a mix of dust models is probably in between this upper and lower limit from the AS and ACAR models. It is therefore likely that most of the dust measured in N49 is swept-up ISM dust. Under all circumstances, without further knowledge about what type of dust dominates the emission, it's difficult to conclude exactly how large an amount may have been produced by this remnant.

For N63A, even when accounting for the crudely estimated swept-up material, there is undoubtedly a significant amount of IR emission. This emission requires *at least* $\sim 1\,M_\odot$ order of magnitude, even for pure amorphous carbon, and as high as $\sim 10\,M_\odot$ (order of magnitude) for a silicates dominated material. Nuclear synthesis models of massive stars up to $\sim 40\,M_\odot$ indicate that up to $\sim 10\,M_\odot$ of metals may be synthesized during the collapse (Woosley and Weaver, 1995), with up to $\sim 8\,M_\odot$ of oxygen (O). Hence it requires nearly $100\,\%$ of the synthesized elements to combine to dust which I think is highly unlikely. It's more probable that the IR emission is either due to dust emitted by the surrounding material which suggests that I have underestimated the background. Another possibility is that the IR emission is dominated by another component than dust. Most notably is the contribution due to synchrotron radiation that I haven't accounted for in any the SEDs. Synchrotron radiation is mostly dominant in the submm and radio waves regime and since most of the SED shapes are driven by the mid- and far IR MIPS and PACS bands, I expect that the contribution due to synchrotron radiation is negligible. However, this may not be the case for N63A. If synchrotron radiation dominates the FIR SPIRE bands then the dust temperature is expected to be driven lower for the modified blackbody fits unless this is properly accounted for. Levenson et al. (1995) also noted that the western lobe, which dominates the IR emission in all bands, is due to photoionization indicative of a dense H II region. This may suggest that a) the number density of H II across the lobe may be much higher than the average number in the SNR (Table 4.5) which suggests that I may have underestimated the swept-up mass and b) that the synchrotron radiation from this lobe may very well be quite significant. A third option is that some or more of the bands may also be dominated by atomic line emissions. All in all, I think it's likely that the IR emission measured in N63A is either entirely due to dust related to the remnant or that I've significantly accounted for the background or swept-up material.

The conclusion of this project is as follows. There appears to be a significant amount of dust related to the remnants SN1987A, N49 and N63A although it's difficult to conclude the amount coming from N49 and N63A exactly. The remnants N11L, N23 and N132D doesn't show significant signs of cold dust. However, the accuracy of the temperatures and dust estimates is highly dominated by the accuracy of the background estimations. SN1987A, N49 and N63A are all fairly isolated targets and in relatively uniform mediums whilst N11L, N23 and N132D are much more dominated by features in the regions and the MCs in which they are embedded. The measured dust masses are also highly dependent on the dust models and it even varies significantly between different models for amorphous carbon. I'm therefore led to the conclusions that

- Initially it doesn't appear that there's a significant amount of cold dust produced, on average, by each CC SN, but
- The detectable total dust mass is to a high degree limited by the difficulties related to the background subtraction and
- Our limited knowledge about the dust composition that may be produced in the SNe events is a crucial factor to understand and interpret the nature of and amount coming from cold dust emission.

With the results of this project, it's still uncertain whether the CC SNe may be the major contributors to the large dust masses in the early universe. The difficulties in the background subtractions and our limited understanding of the interstellar dust including particularly, but not limited to, the chemical composition, grain size and distribution and the environmental circumstances for its formation, are currently the largest sources of uncertainties in the true dust mass and temperature estimations.

Whether or not each CC SN, on average, injects $0.1-1.0\,M_{\odot}$ of dust back into the ISM is hence still uncertain. The remnants N132D, N49 and particularly N63A as well as the newborn SN1987A still deserve careful examinations. Previous works suggest that the progenitors of all the three priorly mentioned remnants were highly massive supergiants while the progenitor mass of SN1987A is also at the same order of magnitude. A possible, yet still inconclusive scenario, is that the average dust yield of very high mass progenitors may be particularly large, with cold dust formations to upwards of $\gtrsim 1\,M_\odot$.

Another active area of research in the context of this project is the dust destruction rate, the rate at which dust is destroyed by the SNRs before it can be injected back into the ISM. Temim et al. (2015) and Lakićević et al. (2015) both argue that the areas of the SNRs are generally more void of dust than their surroundings. Under the assumption that the dust is sputtered and not merely pushed away, this indicates that the dust destruction rates are large enough that CC SNe in fact may destroy more dust than they averagely produce.

If further research agrees with this conclusion, then there must be other candidates for the dust in the early universe. Some likely candidates are either the pulsating AGB stars or dust-shells due to outbursts observed around the late-evolved and highly massive Wolf-Rayet (WR) stars and Luminous Blue Variables (LBV), although previous observations of the former have yet to detect the required amount of dust. However, recent research based on FIR observations of the WR stars and LBVs suggests that they may possibly be major contributors of dust (e.g. Boyer et al., 2010) if the dust observed in the shells is effectively injected back into the ISM and is not significantly destroyed during the following collapse.

Appendix A

Dust models

A.1 Astronomical silicates

```
Wed Jun  2 12:11:56 EDT 1993
Astronomical silicate
B.T.Draine, Princeton Univ.
(cf Laor, A., & Draine, B.T. 1993, ApJ 402,441)

1.000E-01 = radius (micron)
1201 1.000E+03 1.000E-03 = NWAV, w_1 (micron), w_NWAV (micron)
w(micron)  Re(eps-1)  Im(eps)    Re(m-1)    Im(m)
1.000E+03  1.064E+01 3.384E-01  2.412E+00 4.958E-02
9.886E+02  1.064E+01 3.423E-01  2.412E+00 5.016E-02
9.772E+02  1.064E+01 3.462E-01  2.412E+00 5.074E-02
9.661E+02  1.064E+01 3.502E-01  2.412E+00 5.133E-02
9.550E+02  1.064E+01 3.543E-01  2.412E+00 5.192E-02
9.441E+02  1.064E+01 3.584E-01  2.412E+00 5.252E-02
9.333E+02  1.064E+01 3.625E-01  2.412E+00 5.313E-02
9.226E+02  1.064E+01 3.667E-01  2.412E+00 5.375E-02
9.120E+02  1.064E+01 3.710E-01  2.412E+00 5.437E-02
9.016E+02  1.064E+01 3.753E-01  2.412E+00 5.500E-02
8.913E+02  1.064E+01 3.796E-01  2.412E+00 5.564E-02
8.810E+02  1.064E+01 3.840E-01  2.412E+00 5.628E-02
8.710E+02  1.064E+01 3.885E-01  2.412E+00 5.693E-02
8.610E+02  1.064E+01 3.930E-01  2.412E+00 5.759E-02
8.511E+02  1.064E+01 3.975E-01  2.412E+00 5.826E-02
8.414E+02  1.064E+01 4.021E-01  2.412E+00 5.893E-02
8.318E+02  1.063E+01 4.068E-01  2.412E+00 5.962E-02
8.222E+02  1.063E+01 4.115E-01  2.411E+00 6.031E-02
8.128E+02  1.063E+01 4.162E-01  2.411E+00 6.101E-02
8.035E+02  1.063E+01 4.211E-01  2.411E+00 6.171E-02
7.943E+02  1.063E+01 4.259E-01  2.411E+00 6.243E-02
7.852E+02  1.063E+01 4.309E-01  2.411E+00 6.315E-02
7.762E+02  1.063E+01 4.359E-01  2.411E+00 6.388E-02
7.674E+02  1.063E+01 4.409E-01  2.411E+00 6.462E-02
7.586E+02  1.063E+01 4.460E-01  2.411E+00 6.537E-02
7.499E+02  1.063E+01 4.512E-01  2.411E+00 6.613E-02
7.413E+02  1.063E+01 4.564E-01  2.411E+00 6.690E-02
7.328E+02  1.063E+01 4.617E-01  2.411E+00 6.767E-02
7.244E+02  1.063E+01 4.670E-01  2.411E+00 6.846E-02
7.161E+02  1.063E+01 4.724E-01  2.411E+00 6.925E-02
7.079E+02  1.063E+01 4.779E-01  2.411E+00 7.005E-02
6.998E+02  1.063E+01 4.834E-01  2.411E+00 7.086E-02
6.918E+02  1.063E+01 4.890E-01  2.411E+00 7.169E-02
6.839E+02  1.063E+01 4.947E-01  2.411E+00 7.252E-02
6.761E+02  1.063E+01 5.004E-01  2.411E+00 7.336E-02
6.683E+02  1.063E+01 5.062E-01  2.411E+00 7.421E-02
6.607E+02  1.063E+01 5.121E-01  2.411E+00 7.507E-02
6.531E+02  1.063E+01 5.180E-01  2.411E+00 7.594E-02
6.457E+02  1.063E+01 5.240E-01  2.411E+00 7.682E-02
6.383E+02  1.063E+01 5.301E-01  2.411E+00 7.771E-02
6.310E+02  1.063E+01 5.363E-01  2.411E+00 7.861E-02
6.237E+02  1.063E+01 5.425E-01  2.411E+00 7.952E-02
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6.166E+02	1.063E+01	5.488E-01	2.411E+00	8.044E-02
6.095E+02	1.063E+01	5.551E-01	2.411E+00	8.138E-02
6.026E+02	1.063E+01	5.615E-01	2.411E+00	8.232E-02
5.957E+02	1.063E+01	5.681E-01	2.411E+00	8.328E-02
5.888E+02	1.063E+01	5.746E-01	2.411E+00	8.424E-02
5.821E+02	1.062E+01	5.813E-01	2.411E+00	8.522E-02
5.754E+02	1.062E+01	5.880E-01	2.411E+00	8.621E-02
5.689E+02	1.062E+01	5.948E-01	2.411E+00	8.721E-02
5.623E+02	1.062E+01	6.017E-01	2.410E+00	8.822E-02
5.559E+02	1.062E+01	6.087E-01	2.410E+00	8.924E-02
5.495E+02	1.062E+01	6.158E-01	2.410E+00	9.028E-02
5.433E+02	1.062E+01	6.229E-01	2.410E+00	9.132E-02
5.370E+02	1.062E+01	6.301E-01	2.410E+00	9.238E-02
5.309E+02	1.062E+01	6.374E-01	2.410E+00	9.345E-02
5.248E+02	1.062E+01	6.448E-01	2.410E+00	9.454E-02
5.188E+02	1.062E+01	6.523E-01	2.410E+00	9.563E-02
5.129E+02	1.062E+01	6.598E-01	2.410E+00	9.674E-02
5.070E+02	1.062E+01	6.675E-01	2.410E+00	9.787E-02
5.012E+02	1.062E+01	6.752E-01	2.410E+00	9.900E-02
4.955E+02	1.062E+01	6.830E-01	2.410E+00	1.001E-01
4.898E+02	1.062E+01	6.909E-01	2.410E+00	1.013E-01
4.842E+02	1.062E+01	6.989E-01	2.410E+00	1.025E-01
4.786E+02	1.061E+01	7.070E-01	2.410E+00	1.037E-01
4.732E+02	1.061E+01	7.152E-01	2.410E+00	1.049E-01
4.677E+02	1.061E+01	7.234E-01	2.409E+00	1.061E-01
4.624E+02	1.061E+01	7.318E-01	2.409E+00	1.073E-01
4.571E+02	1.061E+01	7.403E-01	2.409E+00	1.086E-01
4.519E+02	1.061E+01	7.488E-01	2.409E+00	1.098E-01
4.467E+02	1.061E+01	7.575E-01	2.409E+00	1.111E-01
4.416E+02	1.061E+01	7.662E-01	2.409E+00	1.124E-01
4.365E+02	1.061E+01	7.751E-01	2.409E+00	1.137E-01
4.315E+02	1.060E+01	7.841E-01	2.409E+00	1.150E-01
4.266E+02	1.060E+01	7.931E-01	2.408E+00	1.163E-01
4.217E+02	1.060E+01	8.023E-01	2.408E+00	1.177E-01
4.169E+02	1.060E+01	8.116E-01	2.408E+00	1.191E-01
4.121E+02	1.060E+01	8.210E-01	2.408E+00	1.204E-01
4.074E+02	1.060E+01	8.305E-01	2.408E+00	1.218E-01
4.027E+02	1.060E+01	8.401E-01	2.408E+00	1.233E-01
3.981E+02	1.060E+01	8.499E-01	2.408E+00	1.247E-01
3.936E+02	1.060E+01	8.597E-01	2.408E+00	1.261E-01
3.890E+02	1.060E+01	8.697E-01	2.408E+00	1.276E-01
3.846E+02	1.060E+01	8.798E-01	2.408E+00	1.291E-01
3.802E+02	1.059E+01	8.900E-01	2.408E+00	1.306E-01
3.758E+02	1.059E+01	9.003E-01	2.407E+00	1.321E-01
3.715E+02	1.059E+01	9.108E-01	2.407E+00	1.336E-01
3.673E+02	1.059E+01	9.213E-01	2.407E+00	1.352E-01
3.631E+02	1.059E+01	9.320E-01	2.407E+00	1.368E-01
3.589E+02	1.059E+01	9.428E-01	2.407E+00	1.384E-01
3.548E+02	1.059E+01	9.538E-01	2.407E+00	1.400E-01
3.508E+02	1.059E+01	9.648E-01	2.407E+00	1.416E-01
3.467E+02	1.058E+01	9.760E-01	2.407E+00	1.432E-01
3.428E+02	1.058E+01	9.873E-01	2.406E+00	1.449E-01
3.388E+02	1.058E+01	9.987E-01	2.406E+00	1.466E-01
3.350E+02	1.058E+01	1.010E+00	2.406E+00	1.483E-01
3.311E+02	1.058E+01	1.022E+00	2.406E+00	1.500E-01
3.273E+02	1.058E+01	1.034E+00	2.406E+00	1.518E-01
3.236E+02	1.057E+01	1.046E+00	2.405E+00	1.535E-01
3.199E+02	1.057E+01	1.058E+00	2.405E+00	1.553E-01
3.162E+02	1.057E+01	1.070E+00	2.405E+00	1.571E-01
3.126E+02	1.057E+01	1.083E+00	2.405E+00	1.590E-01
3.090E+02	1.057E+01	1.095E+00	2.405E+00	1.608E-01
3.055E+02	1.056E+01	1.108E+00	2.404E+00	1.627E-01
3.020E+02	1.056E+01	1.121E+00	2.404E+00	1.646E-01
2.985E+02	1.056E+01	1.134E+00	2.404E+00	1.665E-01
2.951E+02	1.056E+01	1.147E+00	2.404E+00	1.685E-01
2.917E+02	1.056E+01	1.160E+00	2.404E+00	1.704E-01
2.884E+02	1.055E+01	1.174E+00	2.404E+00	1.724E-01
2.851E+02	1.055E+01	1.187E+00	2.403E+00	1.744E-01
2.818E+02	1.055E+01	1.201E+00	2.403E+00	1.765E-01
2.786E+02	1.055E+01	1.215E+00	2.403E+00	1.785E-01
2.754E+02	1.055E+01	1.229E+00	2.403E+00	1.806E-01
2.723E+02	1.054E+01	1.243E+00	2.403E+00	1.827E-01
2.692E+02	1.054E+01	1.258E+00	2.402E+00	1.848E-01
2.661E+02	1.054E+01	1.272E+00	2.402E+00	1.870E-01
2.630E+02	1.054E+01	1.287E+00	2.402E+00	1.892E-01
2.600E+02	1.054E+01	1.302E+00	2.402E+00	1.914E-01
2.570E+02	1.053E+01	1.317E+00	2.402E+00	1.936E-01

2.541E+02	1.053E+01	1.332E+00	2.401E+00	1.959E-01
2.512E+02	1.053E+01	1.348E+00	2.401E+00	1.982E-01
2.483E+02	1.053E+01	1.364E+00	2.401E+00	2.005E-01
2.455E+02	1.052E+01	1.379E+00	2.400E+00	2.028E-01
2.427E+02	1.052E+01	1.395E+00	2.400E+00	2.052E-01
2.399E+02	1.052E+01	1.412E+00	2.400E+00	2.076E-01
2.371E+02	1.051E+01	1.428E+00	2.399E+00	2.100E-01
2.344E+02	1.051E+01	1.444E+00	2.399E+00	2.125E-01
2.317E+02	1.051E+01	1.461E+00	2.399E+00	2.150E-01
2.291E+02	1.050E+01	1.478E+00	2.398E+00	2.175E-01
2.265E+02	1.050E+01	1.495E+00	2.398E+00	2.200E-01
2.239E+02	1.049E+01	1.512E+00	2.398E+00	2.226E-01
2.213E+02	1.049E+01	1.530E+00	2.397E+00	2.252E-01
2.188E+02	1.049E+01	1.548E+00	2.397E+00	2.278E-01
2.163E+02	1.048E+01	1.565E+00	2.396E+00	2.305E-01
2.138E+02	1.048E+01	1.584E+00	2.396E+00	2.332E-01
2.113E+02	1.047E+01	1.602E+00	2.395E+00	2.359E-01
2.089E+02	1.047E+01	1.620E+00	2.395E+00	2.386E-01
2.065E+02	1.046E+01	1.639E+00	2.394E+00	2.414E-01
2.042E+02	1.046E+01	1.658E+00	2.394E+00	2.443E-01
2.018E+02	1.045E+01	1.677E+00	2.393E+00	2.471E-01
1.995E+02	1.045E+01	1.696E+00	2.393E+00	2.500E-01
1.972E+02	1.044E+01	1.716E+00	2.392E+00	2.529E-01
1.950E+02	1.044E+01	1.736E+00	2.392E+00	2.559E-01
1.928E+02	1.044E+01	1.756E+00	2.391E+00	2.589E-01
1.905E+02	1.043E+01	1.776E+00	2.391E+00	2.619E-01
1.884E+02	1.043E+01	1.797E+00	2.390E+00	2.650E-01
1.862E+02	1.042E+01	1.817E+00	2.390E+00	2.680E-01
1.841E+02	1.041E+01	1.838E+00	2.389E+00	2.712E-01
1.820E+02	1.041E+01	1.860E+00	2.389E+00	2.744E-01
1.799E+02	1.040E+01	1.881E+00	2.388E+00	2.776E-01
1.778E+02	1.040E+01	1.903E+00	2.388E+00	2.808E-01
1.758E+02	1.039E+01	1.925E+00	2.387E+00	2.841E-01
1.738E+02	1.039E+01	1.947E+00	2.387E+00	2.874E-01
1.718E+02	1.038E+01	1.969E+00	2.386E+00	2.908E-01
1.698E+02	1.037E+01	1.992E+00	2.385E+00	2.942E-01
1.679E+02	1.037E+01	2.015E+00	2.385E+00	2.977E-01
1.660E+02	1.036E+01	2.038E+00	2.384E+00	3.011E-01
1.641E+02	1.035E+01	2.062E+00	2.383E+00	3.047E-01
1.622E+02	1.035E+01	2.085E+00	2.383E+00	3.083E-01
1.603E+02	1.034E+01	2.109E+00	2.382E+00	3.119E-01
1.585E+02	1.033E+01	2.134E+00	2.381E+00	3.155E-01
1.567E+02	1.032E+01	2.158E+00	2.380E+00	3.193E-01
1.549E+02	1.032E+01	2.183E+00	2.379E+00	3.230E-01
1.531E+02	1.031E+01	2.208E+00	2.379E+00	3.268E-01
1.514E+02	1.030E+01	2.234E+00	2.378E+00	3.306E-01
1.496E+02	1.029E+01	2.259E+00	2.377E+00	3.345E-01
1.479E+02	1.028E+01	2.285E+00	2.376E+00	3.385E-01
1.462E+02	1.027E+01	2.312E+00	2.375E+00	3.425E-01
1.445E+02	1.026E+01	2.338E+00	2.374E+00	3.465E-01
1.429E+02	1.025E+01	2.365E+00	2.373E+00	3.506E-01
1.413E+02	1.025E+01	2.392E+00	2.372E+00	3.547E-01
1.396E+02	1.024E+01	2.420E+00	2.371E+00	3.589E-01
1.380E+02	1.023E+01	2.447E+00	2.370E+00	3.631E-01
1.365E+02	1.022E+01	2.475E+00	2.369E+00	3.674E-01
1.349E+02	1.020E+01	2.504E+00	2.368E+00	3.717E-01
1.334E+02	1.019E+01	2.532E+00	2.367E+00	3.761E-01
1.318E+02	1.018E+01	2.561E+00	2.366E+00	3.805E-01
1.303E+02	1.017E+01	2.590E+00	2.364E+00	3.850E-01
1.288E+02	1.016E+01	2.620E+00	2.363E+00	3.895E-01
1.274E+02	1.015E+01	2.650E+00	2.362E+00	3.940E-01
1.259E+02	1.014E+01	2.680E+00	2.361E+00	3.987E-01
1.245E+02	1.012E+01	2.710E+00	2.359E+00	4.034E-01
1.230E+02	1.011E+01	2.741E+00	2.358E+00	4.081E-01
1.216E+02	1.010E+01	2.772E+00	2.357E+00	4.129E-01
1.202E+02	1.008E+01	2.803E+00	2.355E+00	4.177E-01
1.189E+02	1.007E+01	2.835E+00	2.354E+00	4.226E-01
1.175E+02	1.006E+01	2.867E+00	2.352E+00	4.276E-01
1.161E+02	1.004E+01	2.899E+00	2.351E+00	4.326E-01
1.148E+02	1.003E+01	2.932E+00	2.350E+00	4.376E-01
1.135E+02	1.001E+01	2.965E+00	2.348E+00	4.428E-01
1.122E+02	9.997E+00	2.998E+00	2.346E+00	4.480E-01
1.109E+02	9.980E+00	3.031E+00	2.345E+00	4.532E-01
1.096E+02	9.963E+00	3.065E+00	2.343E+00	4.585E-01
1.084E+02	9.945E+00	3.099E+00	2.341E+00	4.639E-01
1.072E+02	9.927E+00	3.134E+00	2.339E+00	4.693E-01
1.059E+02	9.908E+00	3.168E+00	2.337E+00	4.747E-01

1.047E+02	9.889E+00	3.203E+00	2.335E+00	4.803E-01
1.035E+02	9.869E+00	3.238E+00	2.332E+00	4.859E-01
1.023E+02	9.849E+00	3.274E+00	2.330E+00	4.915E-01
1.012E+02	9.829E+00	3.310E+00	2.328E+00	4.973E-01
1.000E+02	9.809E+00	3.346E+00	2.326E+00	5.030E-01
9.886E+01	9.788E+00	3.383E+00	2.324E+00	5.089E-01
9.772E+01	9.766E+00	3.420E+00	2.321E+00	5.148E-01
9.661E+01	9.744E+00	3.457E+00	2.319E+00	5.208E-01
9.550E+01	9.720E+00	3.494E+00	2.316E+00	5.268E-01
9.441E+01	9.696E+00	3.532E+00	2.314E+00	5.329E-01
9.333E+01	9.672E+00	3.569E+00	2.311E+00	5.390E-01
9.226E+01	9.646E+00	3.607E+00	2.308E+00	5.452E-01
9.120E+01	9.621E+00	3.646E+00	2.305E+00	5.515E-01
9.016E+01	9.595E+00	3.685E+00	2.303E+00	5.578E-01
8.913E+01	9.569E+00	3.724E+00	2.300E+00	5.642E-01
8.810E+01	9.542E+00	3.763E+00	2.297E+00	5.707E-01
8.710E+01	9.513E+00	3.802E+00	2.293E+00	5.772E-01
8.610E+01	9.484E+00	3.841E+00	2.290E+00	5.837E-01
8.511E+01	9.454E+00	3.881E+00	2.287E+00	5.904E-01
8.414E+01	9.424E+00	3.921E+00	2.283E+00	5.970E-01
8.318E+01	9.393E+00	3.961E+00	2.280E+00	6.038E-01
8.222E+01	9.361E+00	4.001E+00	2.276E+00	6.106E-01
8.128E+01	9.328E+00	4.041E+00	2.272E+00	6.175E-01
8.035E+01	9.294E+00	4.082E+00	2.269E+00	6.244E-01
7.943E+01	9.259E+00	4.122E+00	2.265E+00	6.313E-01
7.852E+01	9.224E+00	4.163E+00	2.261E+00	6.384E-01
7.762E+01	9.189E+00	4.204E+00	2.257E+00	6.454E-01
7.674E+01	9.154E+00	4.245E+00	2.253E+00	6.525E-01
7.586E+01	9.118E+00	4.285E+00	2.248E+00	6.596E-01
7.499E+01	9.080E+00	4.326E+00	2.244E+00	6.668E-01
7.413E+01	9.041E+00	4.367E+00	2.240E+00	6.740E-01
7.328E+01	9.001E+00	4.408E+00	2.235E+00	6.813E-01
7.244E+01	8.959E+00	4.449E+00	2.230E+00	6.887E-01
7.161E+01	8.916E+00	4.489E+00	2.225E+00	6.960E-01
7.079E+01	8.872E+00	4.529E+00	2.220E+00	7.034E-01
6.998E+01	8.830E+00	4.570E+00	2.215E+00	7.108E-01
6.918E+01	8.783E+00	4.611E+00	2.209E+00	7.183E-01
6.839E+01	8.734E+00	4.650E+00	2.203E+00	7.258E-01
6.761E+01	8.686E+00	4.689E+00	2.197E+00	7.333E-01
6.683E+01	8.638E+00	4.729E+00	2.192E+00	7.408E-01
6.607E+01	8.592E+00	4.769E+00	2.186E+00	7.483E-01
6.531E+01	8.544E+00	4.808E+00	2.180E+00	7.559E-01
6.457E+01	8.492E+00	4.847E+00	2.174E+00	7.635E-01
6.383E+01	8.437E+00	4.884E+00	2.167E+00	7.711E-01
6.310E+01	8.382E+00	4.922E+00	2.160E+00	7.786E-01
6.237E+01	8.328E+00	4.959E+00	2.154E+00	7.862E-01
6.166E+01	8.273E+00	4.996E+00	2.147E+00	7.937E-01
6.095E+01	8.217E+00	5.032E+00	2.140E+00	8.013E-01
6.026E+01	8.161E+00	5.068E+00	2.133E+00	8.088E-01
5.957E+01	8.104E+00	5.103E+00	2.126E+00	8.163E-01
5.888E+01	8.045E+00	5.138E+00	2.118E+00	8.238E-01
5.821E+01	7.985E+00	5.172E+00	2.111E+00	8.313E-01
5.754E+01	7.923E+00	5.205E+00	2.103E+00	8.387E-01
5.689E+01	7.861E+00	5.237E+00	2.095E+00	8.461E-01
5.623E+01	7.798E+00	5.268E+00	2.086E+00	8.535E-01
5.559E+01	7.733E+00	5.299E+00	2.078E+00	8.608E-01
5.495E+01	7.669E+00	5.329E+00	2.070E+00	8.680E-01
5.433E+01	7.603E+00	5.358E+00	2.061E+00	8.752E-01
5.370E+01	7.537E+00	5.386E+00	2.052E+00	8.823E-01
5.309E+01	7.471E+00	5.414E+00	2.043E+00	8.894E-01
5.248E+01	7.404E+00	5.440E+00	2.034E+00	8.964E-01
5.188E+01	7.337E+00	5.466E+00	2.025E+00	9.034E-01
5.129E+01	7.269E+00	5.491E+00	2.016E+00	9.102E-01
5.070E+01	7.199E+00	5.514E+00	2.007E+00	9.170E-01
5.012E+01	7.129E+00	5.537E+00	1.997E+00	9.237E-01
4.955E+01	7.058E+00	5.558E+00	1.987E+00	9.302E-01
4.898E+01	6.987E+00	5.578E+00	1.977E+00	9.367E-01
4.842E+01	6.915E+00	5.597E+00	1.967E+00	9.431E-01
4.786E+01	6.842E+00	5.615E+00	1.957E+00	9.495E-01
4.732E+01	6.769E+00	5.633E+00	1.947E+00	9.558E-01
4.677E+01	6.696E+00	5.649E+00	1.936E+00	9.619E-01
4.624E+01	6.622E+00	5.664E+00	1.926E+00	9.680E-01
4.571E+01	6.548E+00	5.679E+00	1.915E+00	9.741E-01
4.519E+01	6.473E+00	5.692E+00	1.904E+00	9.800E-01
4.467E+01	6.398E+00	5.705E+00	1.893E+00	9.859E-01
4.416E+01	6.323E+00	5.716E+00	1.882E+00	9.917E-01
4.365E+01	6.247E+00	5.727E+00	1.871E+00	9.974E-01

4.315E+01	6.171E+00	5.735E+00	1.860E+00	1.003E+00
4.266E+01	6.095E+00	5.743E+00	1.848E+00	1.008E+00
4.217E+01	6.019E+00	5.749E+00	1.837E+00	1.013E+00
4.169E+01	5.943E+00	5.753E+00	1.825E+00	1.018E+00
4.121E+01	5.866E+00	5.755E+00	1.813E+00	1.023E+00
4.074E+01	5.788E+00	5.750E+00	1.800E+00	1.027E+00
4.027E+01	5.711E+00	5.746E+00	1.788E+00	1.030E+00
3.981E+01	5.634E+00	5.741E+00	1.776E+00	1.034E+00
3.936E+01	5.558E+00	5.735E+00	1.763E+00	1.038E+00
3.890E+01	5.483E+00	5.730E+00	1.751E+00	1.041E+00
3.846E+01	5.408E+00	5.723E+00	1.739E+00	1.045E+00
3.802E+01	5.334E+00	5.717E+00	1.726E+00	1.048E+00
3.758E+01	5.261E+00	5.710E+00	1.714E+00	1.052E+00
3.715E+01	5.196E+00	5.708E+00	1.704E+00	1.056E+00
3.673E+01	5.131E+00	5.705E+00	1.693E+00	1.059E+00
3.631E+01	5.065E+00	5.702E+00	1.682E+00	1.063E+00
3.589E+01	4.999E+00	5.699E+00	1.672E+00	1.067E+00
3.548E+01	4.933E+00	5.695E+00	1.661E+00	1.070E+00
3.508E+01	4.866E+00	5.690E+00	1.649E+00	1.074E+00
3.467E+01	4.799E+00	5.685E+00	1.638E+00	1.077E+00
3.428E+01	4.731E+00	5.679E+00	1.627E+00	1.081E+00
3.388E+01	4.663E+00	5.673E+00	1.615E+00	1.085E+00
3.350E+01	4.595E+00	5.666E+00	1.604E+00	1.088E+00
3.311E+01	4.521E+00	5.658E+00	1.591E+00	1.092E+00
3.273E+01	4.447E+00	5.649E+00	1.578E+00	1.096E+00
3.236E+01	4.372E+00	5.639E+00	1.565E+00	1.099E+00
3.199E+01	4.297E+00	5.628E+00	1.552E+00	1.103E+00
3.162E+01	4.221E+00	5.616E+00	1.539E+00	1.106E+00
3.126E+01	4.144E+00	5.602E+00	1.525E+00	1.109E+00
3.090E+01	4.067E+00	5.587E+00	1.511E+00	1.112E+00
3.055E+01	3.990E+00	5.570E+00	1.497E+00	1.116E+00
3.020E+01	3.912E+00	5.553E+00	1.482E+00	1.118E+00
2.985E+01	3.835E+00	5.532E+00	1.468E+00	1.121E+00
2.951E+01	3.760E+00	5.507E+00	1.453E+00	1.122E+00
2.917E+01	3.685E+00	5.481E+00	1.439E+00	1.124E+00
2.884E+01	3.610E+00	5.454E+00	1.424E+00	1.125E+00
2.851E+01	3.535E+00	5.426E+00	1.409E+00	1.126E+00
2.818E+01	3.460E+00	5.397E+00	1.394E+00	1.127E+00
2.786E+01	3.386E+00	5.368E+00	1.379E+00	1.128E+00
2.754E+01	3.312E+00	5.337E+00	1.364E+00	1.129E+00
2.723E+01	3.237E+00	5.310E+00	1.348E+00	1.130E+00
2.692E+01	3.162E+00	5.281E+00	1.333E+00	1.132E+00
2.661E+01	3.087E+00	5.253E+00	1.318E+00	1.133E+00
2.630E+01	3.012E+00	5.224E+00	1.302E+00	1.135E+00
2.600E+01	2.937E+00	5.194E+00	1.286E+00	1.136E+00
2.570E+01	2.863E+00	5.164E+00	1.271E+00	1.137E+00
2.541E+01	2.788E+00	5.133E+00	1.255E+00	1.138E+00
2.512E+01	2.714E+00	5.102E+00	1.239E+00	1.140E+00
2.483E+01	2.640E+00	5.061E+00	1.222E+00	1.139E+00
2.455E+01	2.568E+00	5.008E+00	1.204E+00	1.136E+00
2.427E+01	2.497E+00	4.954E+00	1.186E+00	1.133E+00
2.399E+01	2.431E+00	4.916E+00	1.171E+00	1.132E+00
2.371E+01	2.363E+00	4.874E+00	1.154E+00	1.131E+00
2.344E+01	2.290E+00	4.822E+00	1.136E+00	1.129E+00
2.317E+01	2.226E+00	4.773E+00	1.120E+00	1.126E+00
2.291E+01	2.163E+00	4.730E+00	1.104E+00	1.124E+00
2.265E+01	2.093E+00	4.692E+00	1.087E+00	1.124E+00
2.239E+01	2.012E+00	4.643E+00	1.067E+00	1.123E+00
2.213E+01	1.929E+00	4.581E+00	1.045E+00	1.120E+00
2.188E+01	1.861E+00	4.513E+00	1.025E+00	1.114E+00
2.163E+01	1.800E+00	4.450E+00	1.007E+00	1.109E+00
2.138E+01	1.737E+00	4.392E+00	9.890E-01	1.104E+00
2.113E+01	1.666E+00	4.329E+00	9.686E-01	1.100E+00
2.089E+01	1.597E+00	4.258E+00	9.474E-01	1.093E+00
2.065E+01	1.533E+00	4.184E+00	9.267E-01	1.086E+00
2.042E+01	1.472E+00	4.116E+00	9.070E-01	1.079E+00
2.018E+01	1.396E+00	4.052E+00	8.844E-01	1.075E+00
1.995E+01	1.316E+00	3.968E+00	8.587E-01	1.067E+00
1.972E+01	1.242E+00	3.857E+00	8.306E-01	1.053E+00
1.950E+01	1.179E+00	3.742E+00	8.040E-01	1.037E+00
1.928E+01	1.128E+00	3.626E+00	7.793E-01	1.019E+00
1.905E+01	1.088E+00	3.511E+00	7.570E-01	9.992E-01
1.884E+01	1.060E+00	3.394E+00	7.365E-01	9.772E-01
1.862E+01	1.043E+00	3.269E+00	7.172E-01	9.517E-01
1.841E+01	1.035E+00	3.143E+00	6.999E-01	9.243E-01
1.820E+01	1.037E+00	3.020E+00	6.852E-01	8.960E-01
1.799E+01	1.048E+00	2.908E+00	6.740E-01	8.686E-01

1.778E+01	1.066E+00	2.800E+00	6.653E-01	8.408E-01
1.758E+01	1.093E+00	2.693E+00	6.587E-01	8.117E-01
1.738E+01	1.125E+00	2.588E+00	6.543E-01	7.822E-01
1.718E+01	1.164E+00	2.489E+00	6.525E-01	7.531E-01
1.698E+01	1.207E+00	2.401E+00	6.536E-01	7.260E-01
1.679E+01	1.256E+00	2.318E+00	6.569E-01	6.995E-01
1.660E+01	1.308E+00	2.236E+00	6.616E-01	6.727E-01
1.641E+01	1.365E+00	2.158E+00	6.683E-01	6.466E-01
1.622E+01	1.427E+00	2.087E+00	6.776E-01	6.221E-01
1.603E+01	1.494E+00	2.025E+00	6.893E-01	5.995E-01
1.585E+01	1.565E+00	1.969E+00	7.027E-01	5.782E-01
1.567E+01	1.636E+00	1.917E+00	7.170E-01	5.581E-01
1.549E+01	1.712E+00	1.870E+00	7.329E-01	5.395E-01
1.531E+01	1.793E+00	1.831E+00	7.512E-01	5.229E-01
1.514E+01	1.880E+00	1.800E+00	7.716E-01	5.081E-01
1.496E+01	1.968E+00	1.775E+00	7.925E-01	4.952E-01
1.479E+01	2.061E+00	1.756E+00	8.153E-01	4.837E-01
1.462E+01	2.168E+00	1.746E+00	8.419E-01	4.738E-01
1.445E+01	2.282E+00	1.753E+00	8.712E-01	4.684E-01
1.429E+01	2.404E+00	1.783E+00	9.034E-01	4.683E-01
1.413E+01	2.525E+00	1.839E+00	9.365E-01	4.748E-01
1.396E+01	2.639E+00	1.926E+00	9.694E-01	4.890E-01
1.380E+01	2.736E+00	2.039E+00	9.991E-01	5.100E-01
1.365E+01	2.803E+00	2.175E+00	1.023E+00	5.377E-01
1.349E+01	2.841E+00	2.322E+00	1.041E+00	5.690E-01
1.334E+01	2.850E+00	2.465E+00	1.052E+00	6.006E-01
1.318E+01	2.836E+00	2.605E+00	1.058E+00	6.327E-01
1.303E+01	2.809E+00	2.742E+00	1.062E+00	6.649E-01
1.288E+01	2.762E+00	2.880E+00	1.061E+00	6.985E-01
1.274E+01	2.689E+00	3.018E+00	1.056E+00	7.338E-01
1.259E+01	2.597E+00	3.141E+00	1.046E+00	7.677E-01
1.245E+01	2.487E+00	3.242E+00	1.031E+00	7.982E-01
1.230E+01	2.374E+00	3.329E+00	1.014E+00	8.265E-01
1.216E+01	2.254E+00	3.415E+00	9.964E-01	8.552E-01
1.202E+01	2.108E+00	3.496E+00	9.730E-01	8.860E-01
1.189E+01	1.950E+00	3.548E+00	9.446E-01	9.122E-01
1.175E+01	1.787E+00	3.568E+00	9.123E-01	9.329E-01
1.161E+01	1.637E+00	3.571E+00	8.810E-01	9.492E-01
1.148E+01	1.499E+00	3.568E+00	8.512E-01	9.635E-01
1.135E+01	1.353E+00	3.568E+00	8.203E-01	9.800E-01
1.122E+01	1.200E+00	3.555E+00	7.861E-01	9.951E-01
1.109E+01	1.043E+00	3.522E+00	7.486E-01	1.007E+00
1.096E+01	8.954E-01	3.478E+00	7.112E-01	1.016E+00
1.084E+01	7.458E-01	3.429E+00	6.724E-01	1.025E+00
1.072E+01	5.847E-01	3.371E+00	6.293E-01	1.034E+00
1.059E+01	4.131E-01	3.278E+00	5.784E-01	1.038E+00
1.047E+01	2.565E-01	3.146E+00	5.239E-01	1.032E+00
1.035E+01	1.376E-01	2.987E+00	4.721E-01	1.015E+00
1.023E+01	5.916E-02	2.832E+00	4.288E-01	9.911E-01
1.012E+01	3.710E-03	2.694E+00	3.927E-01	9.674E-01
1.000E+01	-4.715E-02	2.574E+00	3.598E-01	9.466E-01
9.886E+00	-1.055E-01	2.461E+00	3.254E-01	9.286E-01
9.772E+00	-1.693E-01	2.343E+00	2.877E-01	9.096E-01
9.661E+00	-2.364E-01	2.211E+00	2.456E-01	8.877E-01
9.550E+00	-2.935E-01	2.061E+00	2.010E-01	8.579E-01
9.441E+00	-3.299E-01	1.897E+00	1.579E-01	8.190E-01
9.333E+00	-3.419E-01	1.728E+00	1.196E-01	7.716E-01
9.226E+00	-3.292E-01	1.562E+00	8.885E-02	7.175E-01
9.120E+00	-2.947E-01	1.408E+00	6.774E-02	6.594E-01
9.016E+00	-2.431E-01	1.270E+00	5.721E-02	6.006E-01
8.913E+00	-1.816E-01	1.151E+00	5.610E-02	5.449E-01
8.810E+00	-1.166E-01	1.051E+00	6.212E-02	4.947E-01
8.710E+00	-5.455E-02	9.677E-01	7.199E-02	4.513E-01
8.610E+00	-3.700E-04	8.967E-01	8.225E-02	4.143E-01
8.511E+00	4.267E-02	8.307E-01	8.990E-02	3.811E-01
8.414E+00	7.755E-02	7.612E-01	9.473E-02	3.477E-01
8.318E+00	1.115E-01	6.825E-01	9.903E-02	3.105E-01
8.222E+00	1.582E-01	5.978E-01	1.094E-01	2.694E-01
8.128E+00	2.149E-01	5.145E-01	1.257E-01	2.285E-01
8.035E+00	2.755E-01	4.398E-01	1.456E-01	1.920E-01
7.943E+00	3.439E-01	3.758E-01	1.703E-01	1.606E-01
7.852E+00	4.170E-01	3.215E-01	1.979E-01	1.342E-01
7.762E+00	4.934E-01	2.762E-01	2.272E-01	1.125E-01
7.674E+00	5.672E-01	2.401E-01	2.555E-01	9.562E-02
7.586E+00	6.380E-01	2.116E-01	2.825E-01	8.249E-02
7.499E+00	7.065E-01	1.917E-01	3.084E-01	7.324E-02
7.413E+00	7.704E-01	1.784E-01	3.322E-01	6.696E-02

7.328E+00	8.298E-01	1.705E-01	3.542E-01	6.294E-02
7.244E+00	8.835E-01	1.663E-01	3.737E-01	6.052E-02
7.161E+00	9.317E-01	1.637E-01	3.911E-01	5.883E-02
7.079E+00	9.747E-01	1.635E-01	4.065E-01	5.813E-02
6.998E+00	1.014E+00	1.636E-01	4.203E-01	5.758E-02
6.918E+00	1.050E+00	1.641E-01	4.329E-01	5.728E-02
6.839E+00	1.083E+00	1.648E-01	4.443E-01	5.705E-02
6.761E+00	1.113E+00	1.654E-01	4.547E-01	5.684E-02
6.683E+00	1.141E+00	1.658E-01	4.643E-01	5.662E-02
6.607E+00	1.167E+00	1.659E-01	4.733E-01	5.632E-02
6.531E+00	1.192E+00	1.659E-01	4.815E-01	5.598E-02
6.457E+00	1.215E+00	1.656E-01	4.892E-01	5.559E-02
6.383E+00	1.236E+00	1.651E-01	4.964E-01	5.516E-02
6.310E+00	1.257E+00	1.643E-01	5.032E-01	5.466E-02
6.237E+00	1.276E+00	1.634E-01	5.097E-01	5.411E-02
6.166E+00	1.295E+00	1.622E-01	5.159E-01	5.350E-02
6.095E+00	1.313E+00	1.608E-01	5.218E-01	5.283E-02
6.026E+00	1.331E+00	1.594E-01	5.276E-01	5.218E-02
5.957E+00	1.348E+00	1.581E-01	5.330E-01	5.155E-02
5.888E+00	1.364E+00	1.567E-01	5.383E-01	5.093E-02
5.821E+00	1.379E+00	1.554E-01	5.433E-01	5.035E-02
5.754E+00	1.394E+00	1.542E-01	5.481E-01	4.979E-02
5.689E+00	1.408E+00	1.530E-01	5.527E-01	4.925E-02
5.623E+00	1.422E+00	1.518E-01	5.570E-01	4.875E-02
5.559E+00	1.435E+00	1.508E-01	5.613E-01	4.828E-02
5.495E+00	1.448E+00	1.498E-01	5.654E-01	4.784E-02
5.433E+00	1.461E+00	1.489E-01	5.693E-01	4.743E-02
5.370E+00	1.473E+00	1.480E-01	5.731E-01	4.704E-02
5.309E+00	1.484E+00	1.472E-01	5.768E-01	4.667E-02
5.248E+00	1.495E+00	1.464E-01	5.804E-01	4.633E-02
5.188E+00	1.506E+00	1.457E-01	5.838E-01	4.601E-02
5.129E+00	1.517E+00	1.451E-01	5.871E-01	4.572E-02
5.070E+00	1.527E+00	1.446E-01	5.903E-01	4.545E-02
5.012E+00	1.537E+00	1.440E-01	5.934E-01	4.520E-02
4.955E+00	1.546E+00	1.436E-01	5.962E-01	4.498E-02
4.898E+00	1.555E+00	1.431E-01	5.990E-01	4.476E-02
4.842E+00	1.563E+00	1.427E-01	6.017E-01	4.456E-02
4.786E+00	1.572E+00	1.423E-01	6.043E-01	4.436E-02
4.732E+00	1.580E+00	1.420E-01	6.068E-01	4.418E-02
4.677E+00	1.587E+00	1.417E-01	6.092E-01	4.402E-02
4.624E+00	1.595E+00	1.413E-01	6.115E-01	4.386E-02
4.571E+00	1.602E+00	1.410E-01	6.137E-01	4.370E-02
4.519E+00	1.609E+00	1.408E-01	6.159E-01	4.355E-02
4.467E+00	1.616E+00	1.405E-01	6.180E-01	4.341E-02
4.416E+00	1.622E+00	1.402E-01	6.200E-01	4.328E-02
4.365E+00	1.629E+00	1.400E-01	6.218E-01	4.317E-02
4.315E+00	1.634E+00	1.398E-01	6.237E-01	4.305E-02
4.266E+00	1.640E+00	1.396E-01	6.254E-01	4.293E-02
4.217E+00	1.645E+00	1.393E-01	6.271E-01	4.282E-02
4.169E+00	1.651E+00	1.391E-01	6.287E-01	4.271E-02
4.121E+00	1.656E+00	1.388E-01	6.302E-01	4.258E-02
4.074E+00	1.661E+00	1.385E-01	6.317E-01	4.244E-02
4.027E+00	1.665E+00	1.381E-01	6.331E-01	4.229E-02
3.981E+00	1.670E+00	1.378E-01	6.345E-01	4.214E-02
3.936E+00	1.674E+00	1.374E-01	6.359E-01	4.198E-02
3.890E+00	1.679E+00	1.370E-01	6.372E-01	4.183E-02
3.846E+00	1.683E+00	1.366E-01	6.384E-01	4.167E-02
3.802E+00	1.687E+00	1.362E-01	6.396E-01	4.153E-02
3.758E+00	1.691E+00	1.358E-01	6.408E-01	4.138E-02
3.715E+00	1.694E+00	1.354E-01	6.420E-01	4.123E-02
3.673E+00	1.698E+00	1.350E-01	6.430E-01	4.108E-02
3.631E+00	1.701E+00	1.346E-01	6.441E-01	4.094E-02
3.589E+00	1.705E+00	1.342E-01	6.451E-01	4.079E-02
3.548E+00	1.708E+00	1.338E-01	6.460E-01	4.064E-02
3.508E+00	1.711E+00	1.334E-01	6.469E-01	4.049E-02
3.467E+00	1.713E+00	1.330E-01	6.478E-01	4.034E-02
3.428E+00	1.716E+00	1.325E-01	6.486E-01	4.019E-02
3.388E+00	1.719E+00	1.321E-01	6.494E-01	4.004E-02
3.350E+00	1.722E+00	1.316E-01	6.502E-01	3.987E-02
3.311E+00	1.724E+00	1.311E-01	6.510E-01	3.970E-02
3.273E+00	1.727E+00	1.306E-01	6.518E-01	3.952E-02
3.236E+00	1.729E+00	1.300E-01	6.525E-01	3.932E-02
3.199E+00	1.732E+00	1.293E-01	6.532E-01	3.911E-02
3.162E+00	1.734E+00	1.287E-01	6.539E-01	3.891E-02
3.126E+00	1.736E+00	1.281E-01	6.546E-01	3.872E-02
3.090E+00	1.738E+00	1.276E-01	6.553E-01	3.854E-02
3.055E+00	1.741E+00	1.271E-01	6.559E-01	3.838E-02

3.020E+00	1.743E+00	1.267E-01	6.566E-01	3.823E-02
2.985E+00	1.745E+00	1.262E-01	6.572E-01	3.807E-02
2.951E+00	1.747E+00	1.257E-01	6.578E-01	3.792E-02
2.917E+00	1.749E+00	1.253E-01	6.584E-01	3.777E-02
2.884E+00	1.751E+00	1.248E-01	6.590E-01	3.762E-02
2.851E+00	1.753E+00	1.244E-01	6.596E-01	3.748E-02
2.818E+00	1.755E+00	1.240E-01	6.601E-01	3.734E-02
2.786E+00	1.757E+00	1.235E-01	6.607E-01	3.719E-02
2.754E+00	1.758E+00	1.231E-01	6.612E-01	3.706E-02
2.723E+00	1.760E+00	1.227E-01	6.617E-01	3.692E-02
2.692E+00	1.762E+00	1.223E-01	6.622E-01	3.678E-02
2.661E+00	1.763E+00	1.219E-01	6.627E-01	3.665E-02
2.630E+00	1.765E+00	1.215E-01	6.631E-01	3.651E-02
2.600E+00	1.766E+00	1.211E-01	6.636E-01	3.638E-02
2.570E+00	1.767E+00	1.207E-01	6.640E-01	3.626E-02
2.541E+00	1.769E+00	1.203E-01	6.644E-01	3.613E-02
2.512E+00	1.770E+00	1.199E-01	6.647E-01	3.601E-02
2.483E+00	1.771E+00	1.195E-01	6.651E-01	3.589E-02
2.455E+00	1.772E+00	1.192E-01	6.654E-01	3.578E-02
2.427E+00	1.774E+00	1.188E-01	6.658E-01	3.567E-02
2.399E+00	1.775E+00	1.185E-01	6.661E-01	3.556E-02
2.371E+00	1.776E+00	1.182E-01	6.665E-01	3.545E-02
2.344E+00	1.777E+00	1.178E-01	6.668E-01	3.534E-02
2.317E+00	1.778E+00	1.175E-01	6.671E-01	3.523E-02
2.291E+00	1.779E+00	1.171E-01	6.674E-01	3.512E-02
2.265E+00	1.780E+00	1.168E-01	6.677E-01	3.501E-02
2.239E+00	1.781E+00	1.164E-01	6.680E-01	3.490E-02
2.213E+00	1.782E+00	1.161E-01	6.682E-01	3.480E-02
2.188E+00	1.782E+00	1.158E-01	6.684E-01	3.469E-02
2.163E+00	1.783E+00	1.154E-01	6.686E-01	3.459E-02
2.138E+00	1.784E+00	1.151E-01	6.688E-01	3.449E-02
2.113E+00	1.784E+00	1.148E-01	6.690E-01	3.440E-02
2.089E+00	1.785E+00	1.145E-01	6.692E-01	3.431E-02
2.065E+00	1.786E+00	1.142E-01	6.694E-01	3.422E-02
2.042E+00	1.786E+00	1.139E-01	6.696E-01	3.412E-02
2.018E+00	1.787E+00	1.136E-01	6.698E-01	3.403E-02
1.995E+00	1.788E+00	1.133E-01	6.700E-01	3.394E-02
1.972E+00	1.788E+00	1.131E-01	6.702E-01	3.385E-02
1.950E+00	1.789E+00	1.128E-01	6.704E-01	3.376E-02
1.928E+00	1.790E+00	1.125E-01	6.705E-01	3.367E-02
1.905E+00	1.790E+00	1.122E-01	6.707E-01	3.358E-02
1.884E+00	1.791E+00	1.119E-01	6.709E-01	3.350E-02
1.862E+00	1.791E+00	1.117E-01	6.711E-01	3.341E-02
1.841E+00	1.792E+00	1.114E-01	6.712E-01	3.333E-02
1.820E+00	1.792E+00	1.111E-01	6.714E-01	3.325E-02
1.799E+00	1.793E+00	1.109E-01	6.715E-01	3.317E-02
1.778E+00	1.793E+00	1.106E-01	6.717E-01	3.310E-02
1.758E+00	1.794E+00	1.104E-01	6.718E-01	3.303E-02
1.738E+00	1.794E+00	1.102E-01	6.719E-01	3.296E-02
1.718E+00	1.795E+00	1.100E-01	6.720E-01	3.290E-02
1.698E+00	1.795E+00	1.098E-01	6.721E-01	3.284E-02
1.679E+00	1.795E+00	1.096E-01	6.722E-01	3.278E-02
1.660E+00	1.795E+00	1.095E-01	6.723E-01	3.273E-02
1.641E+00	1.796E+00	1.093E-01	6.723E-01	3.267E-02
1.622E+00	1.796E+00	1.091E-01	6.724E-01	3.262E-02
1.603E+00	1.796E+00	1.090E-01	6.724E-01	3.257E-02
1.585E+00	1.796E+00	1.088E-01	6.724E-01	3.252E-02
1.567E+00	1.796E+00	1.086E-01	6.725E-01	3.248E-02
1.549E+00	1.796E+00	1.085E-01	6.725E-01	3.243E-02
1.531E+00	1.796E+00	1.083E-01	6.726E-01	3.237E-02
1.514E+00	1.797E+00	1.081E-01	6.726E-01	3.232E-02
1.496E+00	1.797E+00	1.079E-01	6.727E-01	3.226E-02
1.479E+00	1.797E+00	1.077E-01	6.727E-01	3.221E-02
1.462E+00	1.797E+00	1.076E-01	6.728E-01	3.215E-02
1.445E+00	1.797E+00	1.074E-01	6.728E-01	3.210E-02
1.429E+00	1.797E+00	1.072E-01	6.728E-01	3.205E-02
1.413E+00	1.797E+00	1.071E-01	6.729E-01	3.200E-02
1.396E+00	1.798E+00	1.069E-01	6.729E-01	3.195E-02
1.380E+00	1.798E+00	1.067E-01	6.729E-01	3.190E-02
1.365E+00	1.798E+00	1.066E-01	6.729E-01	3.185E-02
1.349E+00	1.798E+00	1.064E-01	6.730E-01	3.179E-02
1.334E+00	1.798E+00	1.062E-01	6.730E-01	3.174E-02
1.318E+00	1.798E+00	1.060E-01	6.731E-01	3.169E-02
1.303E+00	1.798E+00	1.059E-01	6.731E-01	3.163E-02
1.288E+00	1.798E+00	1.057E-01	6.731E-01	3.158E-02
1.274E+00	1.798E+00	1.055E-01	6.731E-01	3.154E-02
1.259E+00	1.798E+00	1.054E-01	6.731E-01	3.150E-02

1.245E+00	1.798E+00	1.053E-01	6.731E-01	3.146E-02
1.230E+00	1.799E+00	1.052E-01	6.732E-01	3.143E-02
1.216E+00	1.799E+00	1.051E-01	6.732E-01	3.141E-02
1.202E+00	1.799E+00	1.050E-01	6.733E-01	3.138E-02
1.189E+00	1.799E+00	1.049E-01	6.733E-01	3.135E-02
1.175E+00	1.799E+00	1.049E-01	6.734E-01	3.133E-02
1.161E+00	1.799E+00	1.048E-01	6.734E-01	3.130E-02
1.148E+00	1.799E+00	1.047E-01	6.734E-01	3.128E-02
1.135E+00	1.800E+00	1.046E-01	6.735E-01	3.125E-02
1.122E+00	1.800E+00	1.045E-01	6.735E-01	3.123E-02
1.109E+00	1.800E+00	1.044E-01	6.735E-01	3.121E-02
1.096E+00	1.800E+00	1.044E-01	6.735E-01	3.118E-02
1.084E+00	1.800E+00	1.043E-01	6.735E-01	3.116E-02
1.072E+00	1.800E+00	1.042E-01	6.735E-01	3.113E-02
1.059E+00	1.800E+00	1.041E-01	6.735E-01	3.111E-02
1.047E+00	1.800E+00	1.041E-01	6.735E-01	3.109E-02
1.035E+00	1.800E+00	1.040E-01	6.735E-01	3.107E-02
1.023E+00	1.800E+00	1.039E-01	6.735E-01	3.104E-02
1.012E+00	1.800E+00	1.038E-01	6.735E-01	3.102E-02
1.000E+00	1.800E+00	1.038E-01	6.735E-01	3.100E-02
9.886E-01	1.800E+00	1.037E-01	6.735E-01	3.098E-02
9.772E-01	1.800E+00	1.036E-01	6.735E-01	3.096E-02
9.661E-01	1.799E+00	1.036E-01	6.734E-01	3.094E-02
9.550E-01	1.799E+00	1.035E-01	6.734E-01	3.092E-02
9.441E-01	1.799E+00	1.034E-01	6.734E-01	3.091E-02
9.333E-01	1.799E+00	1.034E-01	6.734E-01	3.089E-02
9.226E-01	1.799E+00	1.033E-01	6.734E-01	3.087E-02
9.120E-01	1.799E+00	1.033E-01	6.734E-01	3.085E-02
9.016E-01	1.799E+00	1.032E-01	6.734E-01	3.083E-02
8.913E-01	1.799E+00	1.031E-01	6.734E-01	3.081E-02
8.810E-01	1.799E+00	1.031E-01	6.734E-01	3.080E-02
8.710E-01	1.800E+00	1.030E-01	6.735E-01	3.078E-02
8.610E-01	1.800E+00	1.029E-01	6.735E-01	3.076E-02
8.511E-01	1.800E+00	1.029E-01	6.735E-01	3.074E-02
8.414E-01	1.800E+00	1.028E-01	6.736E-01	3.072E-02
8.318E-01	1.800E+00	1.028E-01	6.736E-01	3.070E-02
8.222E-01	1.800E+00	1.027E-01	6.737E-01	3.068E-02
8.128E-01	1.800E+00	1.026E-01	6.737E-01	3.066E-02
8.035E-01	1.801E+00	1.026E-01	6.738E-01	3.064E-02
7.943E-01	1.801E+00	1.025E-01	6.738E-01	3.062E-02
7.852E-01	1.801E+00	1.024E-01	6.739E-01	3.060E-02
7.762E-01	1.801E+00	1.024E-01	6.740E-01	3.058E-02
7.674E-01	1.802E+00	1.023E-01	6.741E-01	3.056E-02
7.586E-01	1.802E+00	1.022E-01	6.741E-01	3.054E-02
7.499E-01	1.802E+00	1.022E-01	6.742E-01	3.051E-02
7.413E-01	1.802E+00	1.021E-01	6.743E-01	3.049E-02
7.328E-01	1.803E+00	1.020E-01	6.744E-01	3.047E-02
7.244E-01	1.803E+00	1.020E-01	6.745E-01	3.045E-02
7.161E-01	1.803E+00	1.019E-01	6.746E-01	3.043E-02
7.079E-01	1.804E+00	1.019E-01	6.747E-01	3.041E-02
6.998E-01	1.804E+00	1.018E-01	6.748E-01	3.039E-02
6.918E-01	1.804E+00	1.017E-01	6.749E-01	3.037E-02
6.839E-01	1.805E+00	1.017E-01	6.750E-01	3.035E-02
6.761E-01	1.805E+00	1.016E-01	6.750E-01	3.033E-02
6.683E-01	1.805E+00	1.015E-01	6.751E-01	3.031E-02
6.607E-01	1.805E+00	1.015E-01	6.752E-01	3.029E-02
6.531E-01	1.806E+00	1.014E-01	6.754E-01	3.027E-02
6.457E-01	1.807E+00	1.014E-01	6.755E-01	3.026E-02
6.383E-01	1.807E+00	1.014E-01	6.757E-01	3.025E-02
6.310E-01	1.808E+00	1.013E-01	6.759E-01	3.023E-02
6.237E-01	1.808E+00	1.013E-01	6.761E-01	3.022E-02
6.166E-01	1.809E+00	1.013E-01	6.763E-01	3.020E-02
6.095E-01	1.810E+00	1.012E-01	6.765E-01	3.019E-02
6.026E-01	1.810E+00	1.012E-01	6.767E-01	3.017E-02
5.957E-01	1.811E+00	1.012E-01	6.769E-01	3.016E-02
5.888E-01	1.812E+00	1.011E-01	6.771E-01	3.015E-02
5.821E-01	1.813E+00	1.011E-01	6.773E-01	3.013E-02
5.754E-01	1.813E+00	1.011E-01	6.776E-01	3.012E-02
5.689E-01	1.814E+00	1.010E-01	6.778E-01	3.011E-02
5.623E-01	1.815E+00	1.010E-01	6.781E-01	3.009E-02
5.559E-01	1.816E+00	1.010E-01	6.783E-01	3.008E-02
5.495E-01	1.817E+00	1.009E-01	6.786E-01	3.007E-02
5.433E-01	1.818E+00	1.009E-01	6.789E-01	3.006E-02
5.370E-01	1.819E+00	1.009E-01	6.792E-01	3.004E-02
5.309E-01	1.820E+00	1.009E-01	6.795E-01	3.003E-02
5.248E-01	1.821E+00	1.009E-01	6.798E-01	3.002E-02
5.188E-01	1.822E+00	1.008E-01	6.801E-01	3.001E-02

5.129E-01	1.823E+00	1.008E-01	6.804E-01	2.999E-02
5.070E-01	1.824E+00	1.008E-01	6.808E-01	2.998E-02
5.012E-01	1.825E+00	1.008E-01	6.811E-01	2.997E-02
4.955E-01	1.826E+00	1.008E-01	6.815E-01	2.996E-02
4.898E-01	1.828E+00	1.007E-01	6.818E-01	2.995E-02
4.842E-01	1.829E+00	1.007E-01	6.822E-01	2.994E-02
4.786E-01	1.830E+00	1.007E-01	6.826E-01	2.992E-02
4.732E-01	1.832E+00	1.007E-01	6.831E-01	2.991E-02
4.677E-01	1.833E+00	1.007E-01	6.835E-01	2.990E-02
4.624E-01	1.835E+00	1.007E-01	6.840E-01	2.989E-02
4.571E-01	1.837E+00	1.007E-01	6.845E-01	2.988E-02
4.519E-01	1.838E+00	1.006E-01	6.850E-01	2.987E-02
4.467E-01	1.840E+00	1.006E-01	6.855E-01	2.985E-02
4.416E-01	1.842E+00	1.006E-01	6.860E-01	2.984E-02
4.365E-01	1.844E+00	1.006E-01	6.867E-01	2.983E-02
4.315E-01	1.846E+00	1.006E-01	6.874E-01	2.982E-02
4.266E-01	1.848E+00	1.006E-01	6.879E-01	2.981E-02
4.217E-01	1.850E+00	1.006E-01	6.885E-01	2.980E-02
4.169E-01	1.852E+00	1.006E-01	6.892E-01	2.979E-02
4.121E-01	1.855E+00	1.006E-01	6.898E-01	2.978E-02
4.074E-01	1.857E+00	1.006E-01	6.905E-01	2.977E-02
4.027E-01	1.859E+00	1.006E-01	6.912E-01	2.975E-02
3.981E-01	1.862E+00	1.006E-01	6.919E-01	2.973E-02
3.936E-01	1.864E+00	1.006E-01	6.927E-01	2.971E-02
3.890E-01	1.867E+00	1.006E-01	6.935E-01	2.969E-02
3.846E-01	1.870E+00	1.005E-01	6.943E-01	2.967E-02
3.802E-01	1.873E+00	1.005E-01	6.952E-01	2.964E-02
3.758E-01	1.876E+00	1.005E-01	6.961E-01	2.962E-02
3.715E-01	1.879E+00	1.004E-01	6.970E-01	2.960E-02
3.673E-01	1.882E+00	1.004E-01	6.980E-01	2.957E-02
3.631E-01	1.886E+00	1.004E-01	6.990E-01	2.955E-02
3.589E-01	1.889E+00	1.004E-01	7.000E-01	2.953E-02
3.548E-01	1.893E+00	1.004E-01	7.011E-01	2.952E-02
3.508E-01	1.897E+00	1.004E-01	7.022E-01	2.950E-02
3.467E-01	1.901E+00	1.004E-01	7.034E-01	2.947E-02
3.428E-01	1.905E+00	1.004E-01	7.046E-01	2.945E-02
3.388E-01	1.909E+00	1.004E-01	7.058E-01	2.942E-02
3.350E-01	1.913E+00	1.004E-01	7.071E-01	2.940E-02
3.311E-01	1.918E+00	1.003E-01	7.084E-01	2.937E-02
3.273E-01	1.922E+00	1.003E-01	7.097E-01	2.934E-02
3.236E-01	1.927E+00	1.003E-01	7.111E-01	2.931E-02
3.199E-01	1.932E+00	1.003E-01	7.125E-01	2.929E-02
3.162E-01	1.937E+00	1.003E-01	7.140E-01	2.926E-02
3.126E-01	1.942E+00	1.003E-01	7.156E-01	2.923E-02
3.090E-01	1.948E+00	1.003E-01	7.172E-01	2.920E-02
3.055E-01	1.954E+00	1.003E-01	7.190E-01	2.917E-02
3.020E-01	1.960E+00	1.003E-01	7.208E-01	2.913E-02
2.985E-01	1.967E+00	1.003E-01	7.227E-01	2.910E-02
2.951E-01	1.974E+00	1.002E-01	7.246E-01	2.906E-02
2.917E-01	1.981E+00	1.002E-01	7.267E-01	2.902E-02
2.884E-01	1.988E+00	1.002E-01	7.287E-01	2.899E-02
2.851E-01	1.995E+00	1.002E-01	7.307E-01	2.895E-02
2.818E-01	2.002E+00	1.002E-01	7.330E-01	2.891E-02
2.786E-01	2.010E+00	1.002E-01	7.353E-01	2.887E-02
2.754E-01	2.019E+00	1.002E-01	7.378E-01	2.883E-02
2.723E-01	2.028E+00	1.002E-01	7.403E-01	2.878E-02
2.692E-01	2.037E+00	1.002E-01	7.430E-01	2.874E-02
2.661E-01	2.047E+00	1.002E-01	7.458E-01	2.868E-02
2.630E-01	2.057E+00	1.001E-01	7.487E-01	2.863E-02
2.600E-01	2.068E+00	1.001E-01	7.517E-01	2.857E-02
2.570E-01	2.079E+00	1.001E-01	7.548E-01	2.853E-02
2.541E-01	2.090E+00	1.001E-01	7.581E-01	2.848E-02
2.512E-01	2.102E+00	1.001E-01	7.615E-01	2.840E-02
2.483E-01	2.115E+00	9.963E-02	7.651E-01	2.822E-02
2.455E-01	2.128E+00	9.877E-02	7.689E-01	2.792E-02
2.427E-01	2.143E+00	9.756E-02	7.729E-01	2.751E-02
2.399E-01	2.158E+00	9.604E-02	7.772E-01	2.702E-02
2.371E-01	2.176E+00	9.558E-02	7.823E-01	2.681E-02
2.344E-01	2.195E+00	9.565E-02	7.876E-01	2.676E-02
2.317E-01	2.215E+00	9.627E-02	7.932E-01	2.684E-02
2.291E-01	2.237E+00	9.715E-02	7.993E-01	2.700E-02
2.265E-01	2.261E+00	9.884E-02	8.059E-01	2.737E-02
2.239E-01	2.285E+00	1.031E-01	8.127E-01	2.843E-02
2.213E-01	2.310E+00	1.101E-01	8.196E-01	3.027E-02
2.188E-01	2.336E+00	1.178E-01	8.267E-01	3.223E-02
2.163E-01	2.362E+00	1.263E-01	8.339E-01	3.444E-02
2.138E-01	2.388E+00	1.360E-01	8.410E-01	3.693E-02

2.113E-01	2.415E+00	1.469E-01	8.484E-01	3.975E-02
2.089E-01	2.442E+00	1.575E-01	8.557E-01	4.244E-02
2.065E-01	2.469E+00	1.681E-01	8.630E-01	4.511E-02
2.042E-01	2.497E+00	1.799E-01	8.707E-01	4.810E-02
2.018E-01	2.527E+00	1.931E-01	8.788E-01	5.140E-02
1.995E-01	2.560E+00	2.074E-01	8.875E-01	5.495E-02
1.972E-01	2.595E+00	2.224E-01	8.970E-01	5.863E-02
1.950E-01	2.632E+00	2.398E-01	9.068E-01	6.288E-02
1.928E-01	2.670E+00	2.597E-01	9.169E-01	6.773E-02
1.905E-01	2.709E+00	2.821E-01	9.273E-01	7.319E-02
1.884E-01	2.749E+00	3.097E-01	9.378E-01	7.991E-02
1.862E-01	2.789E+00	3.405E-01	9.485E-01	8.739E-02
1.841E-01	2.830E+00	3.739E-01	9.594E-01	9.540E-02
1.820E-01	2.872E+00	4.098E-01	9.705E-01	1.040E-01
1.799E-01	2.915E+00	4.482E-01	9.818E-01	1.131E-01
1.778E-01	2.958E+00	4.872E-01	9.932E-01	1.222E-01
1.758E-01	3.003E+00	5.288E-01	1.005E+00	1.319E-01
1.738E-01	3.048E+00	5.731E-01	1.017E+00	1.421E-01
1.718E-01	3.095E+00	6.203E-01	1.029E+00	1.528E-01
1.698E-01	3.144E+00	6.709E-01	1.042E+00	1.643E-01
1.679E-01	3.198E+00	7.297E-01	1.057E+00	1.774E-01
1.660E-01	3.255E+00	7.945E-01	1.072E+00	1.918E-01
1.641E-01	3.316E+00	8.663E-01	1.088E+00	2.075E-01
1.622E-01	3.384E+00	9.496E-01	1.106E+00	2.254E-01
1.603E-01	3.460E+00	1.046E+00	1.126E+00	2.459E-01
1.585E-01	3.568E+00	1.133E+00	1.154E+00	2.631E-01
1.567E-01	3.666E+00	1.261E+00	1.179E+00	2.892E-01
1.549E-01	3.743E+00	1.442E+00	1.202E+00	3.274E-01
1.531E-01	3.788E+00	1.729E+00	1.223E+00	3.891E-01
1.514E-01	3.767E+00	2.066E+00	1.232E+00	4.629E-01
1.496E-01	3.670E+00	2.449E+00	1.230E+00	5.492E-01
1.479E-01	3.432E+00	2.792E+00	1.199E+00	6.349E-01
1.462E-01	3.046E+00	3.055E+00	1.135E+00	7.155E-01
1.445E-01	2.600E+00	3.059E+00	1.040E+00	7.496E-01
1.429E-01	2.244E+00	2.910E+00	9.497E-01	7.464E-01
1.413E-01	2.014E+00	2.663E+00	8.755E-01	7.100E-01
1.396E-01	2.006E+00	2.384E+00	8.496E-01	6.444E-01
1.380E-01	2.091E+00	2.276E+00	8.614E-01	6.115E-01
1.365E-01	2.168E+00	2.278E+00	8.801E-01	6.058E-01
1.349E-01	2.187E+00	2.334E+00	8.891E-01	6.177E-01
1.334E-01	2.159E+00	2.396E+00	8.873E-01	6.347E-01
1.318E-01	2.078E+00	2.420E+00	8.700E-01	6.471E-01
1.303E-01	2.009E+00	2.410E+00	8.527E-01	6.505E-01
1.288E-01	2.011E+00	2.362E+00	8.491E-01	6.388E-01
1.274E-01	2.037E+00	2.365E+00	8.556E-01	6.371E-01
1.259E-01	2.057E+00	2.443E+00	8.669E-01	6.542E-01
1.245E-01	2.038E+00	2.531E+00	8.697E-01	6.768E-01
1.230E-01	1.976E+00	2.607E+00	8.618E-01	7.001E-01
1.216E-01	1.899E+00	2.669E+00	8.492E-01	7.217E-01
1.202E-01	1.814E+00	2.710E+00	8.331E-01	7.392E-01
1.189E-01	1.729E+00	2.737E+00	8.158E-01	7.536E-01
1.175E-01	1.648E+00	2.747E+00	7.977E-01	7.641E-01
1.161E-01	1.579E+00	2.750E+00	7.816E-01	7.718E-01
1.148E-01	1.519E+00	2.751E+00	7.677E-01	7.781E-01
1.135E-01	1.483E+00	2.750E+00	7.590E-01	7.818E-01
1.122E-01	1.449E+00	2.764E+00	7.523E-01	7.885E-01
1.109E-01	1.417E+00	2.793E+00	7.478E-01	7.988E-01
1.096E-01	1.378E+00	2.856E+00	7.458E-01	8.181E-01
1.084E-01	1.324E+00	2.933E+00	7.416E-01	8.421E-01
1.072E-01	1.234E+00	3.012E+00	7.297E-01	8.707E-01
1.059E-01	1.105E+00	3.071E+00	7.070E-01	8.996E-01
1.047E-01	9.546E-01	3.104E+00	6.767E-01	9.256E-01
1.035E-01	8.083E-01	3.092E+00	6.417E-01	9.418E-01
1.023E-01	6.720E-01	3.056E+00	6.055E-01	9.516E-01
1.012E-01	5.648E-01	3.008E+00	5.741E-01	9.554E-01
1.000E-01	4.734E-01	2.955E+00	5.452E-01	9.562E-01
9.886E-02	3.927E-01	2.910E+00	5.197E-01	9.574E-01
9.772E-02	3.176E-01	2.867E+00	4.955E-01	9.585E-01
9.661E-02	2.409E-01	2.825E+00	4.709E-01	9.605E-01
9.550E-02	1.645E-01	2.781E+00	4.456E-01	9.620E-01
9.441E-02	8.861E-02	2.731E+00	4.192E-01	9.621E-01
9.333E-02	1.568E-02	2.672E+00	3.918E-01	9.599E-01
9.226E-02	-5.752E-02	2.601E+00	3.618E-01	9.550E-01
9.120E-02	-1.140E-01	2.524E+00	3.343E-01	9.457E-01
9.016E-02	-1.287E-01	2.426E+00	3.133E-01	9.238E-01
8.913E-02	-1.425E-01	2.347E+00	2.955E-01	9.060E-01
8.810E-02	-1.467E-01	2.320E+00	2.894E-01	8.995E-01

8.710E-02	-1.449E-01	2.333E+00	2.923E-01	9.027E-01
8.610E-02	-1.517E-01	2.342E+00	2.921E-01	9.062E-01
8.511E-02	-1.673E-01	2.345E+00	2.887E-01	9.100E-01
8.414E-02	-1.921E-01	2.344E+00	2.820E-01	9.142E-01
8.318E-02	-2.262E-01	2.337E+00	2.720E-01	9.188E-01
8.222E-02	-2.796E-01	2.319E+00	2.547E-01	9.241E-01
8.128E-02	-3.490E-01	2.287E+00	2.307E-01	9.293E-01
8.035E-02	-4.206E-01	2.249E+00	2.046E-01	9.336E-01
7.943E-02	-4.940E-01	2.204E+00	1.764E-01	9.369E-01
7.852E-02	-5.690E-01	2.153E+00	1.460E-01	9.393E-01
7.762E-02	-6.452E-01	2.094E+00	1.133E-01	9.406E-01
7.674E-02	-6.995E-01	2.035E+00	8.567E-02	9.371E-01
7.586E-02	-7.453E-01	1.974E+00	5.939E-02	9.315E-01
7.499E-02	-7.864E-01	1.910E+00	3.341E-02	9.243E-01
7.413E-02	-8.227E-01	1.845E+00	7.729E-03	9.155E-01
7.328E-02	-8.542E-01	1.778E+00	-1.762E-02	9.051E-01
7.244E-02	-8.834E-01	1.712E+00	-4.271E-02	8.943E-01
7.161E-02	-9.109E-01	1.647E+00	-6.771E-02	8.832E-01
7.079E-02	-9.351E-01	1.580E+00	-9.261E-02	8.709E-01
6.998E-02	-9.561E-01	1.514E+00	-1.174E-01	8.574E-01
6.918E-02	-9.740E-01	1.446E+00	-1.420E-01	8.427E-01
6.839E-02	-9.907E-01	1.378E+00	-1.672E-01	8.272E-01
6.761E-02	-1.004E+00	1.309E+00	-1.925E-01	8.102E-01
6.683E-02	-1.013E+00	1.238E+00	-2.174E-01	7.911E-01
6.607E-02	-1.018E+00	1.167E+00	-2.419E-01	7.699E-01
6.531E-02	-1.018E+00	1.096E+00	-2.659E-01	7.463E-01
6.457E-02	-1.015E+00	1.017E+00	-2.921E-01	7.183E-01
6.383E-02	-1.004E+00	9.407E-01	-3.156E-01	6.872E-01
6.310E-02	-9.860E-01	8.673E-01	-3.361E-01	6.532E-01
6.237E-02	-9.619E-01	7.967E-01	-3.536E-01	6.163E-01
6.166E-02	-9.241E-01	7.272E-01	-3.648E-01	5.724E-01
6.095E-02	-8.756E-01	6.631E-01	-3.679E-01	5.245E-01
6.026E-02	-8.268E-01	6.068E-01	-3.658E-01	4.785E-01
5.957E-02	-7.768E-01	5.571E-01	-3.584E-01	4.342E-01
5.888E-02	-7.258E-01	5.190E-01	-3.438E-01	3.955E-01
5.821E-02	-6.783E-01	5.062E-01	-3.213E-01	3.729E-01
5.754E-02	-6.328E-01	4.986E-01	-2.977E-01	3.550E-01
5.689E-02	-5.885E-01	4.972E-01	-2.731E-01	3.420E-01
5.623E-02	-5.480E-01	5.000E-01	-2.497E-01	3.332E-01
5.559E-02	-5.226E-01	4.941E-01	-2.369E-01	3.238E-01
5.495E-02	-5.012E-01	4.885E-01	-2.264E-01	3.157E-01
5.432E-02	-4.842E-01	4.833E-01	-2.181E-01	3.091E-01
5.370E-02	-4.698E-01	4.784E-01	-2.112E-01	3.032E-01
5.309E-02	-4.537E-01	4.729E-01	-2.035E-01	2.969E-01
5.248E-02	-4.388E-01	4.674E-01	-1.964E-01	2.908E-01
5.188E-02	-4.252E-01	4.620E-01	-1.900E-01	2.852E-01
5.129E-02	-4.127E-01	4.566E-01	-1.842E-01	2.798E-01
5.070E-02	-4.010E-01	4.510E-01	-1.788E-01	2.746E-01
5.012E-02	-3.901E-01	4.455E-01	-1.738E-01	2.696E-01
4.955E-02	-3.801E-01	4.399E-01	-1.693E-01	2.648E-01
4.898E-02	-3.706E-01	4.343E-01	-1.651E-01	2.601E-01
4.842E-02	-3.616E-01	4.287E-01	-1.611E-01	2.555E-01
4.786E-02	-3.532E-01	4.231E-01	-1.575E-01	2.511E-01
4.732E-02	-3.454E-01	4.175E-01	-1.541E-01	2.468E-01
4.677E-02	-3.380E-01	4.119E-01	-1.510E-01	2.425E-01
4.624E-02	-3.310E-01	4.062E-01	-1.481E-01	2.384E-01
4.571E-02	-3.245E-01	4.007E-01	-1.453E-01	2.344E-01
4.519E-02	-3.182E-01	3.951E-01	-1.427E-01	2.305E-01
4.467E-02	-3.122E-01	3.896E-01	-1.403E-01	2.266E-01
4.416E-02	-3.065E-01	3.841E-01	-1.380E-01	2.228E-01
4.365E-02	-3.011E-01	3.785E-01	-1.358E-01	2.190E-01
4.315E-02	-2.958E-01	3.730E-01	-1.337E-01	2.153E-01
4.266E-02	-2.909E-01	3.674E-01	-1.317E-01	2.116E-01
4.217E-02	-2.861E-01	3.619E-01	-1.299E-01	2.080E-01
4.169E-02	-2.815E-01	3.564E-01	-1.281E-01	2.044E-01
4.121E-02	-2.772E-01	3.509E-01	-1.264E-01	2.008E-01
4.074E-02	-2.730E-01	3.455E-01	-1.248E-01	1.974E-01
4.027E-02	-2.689E-01	3.400E-01	-1.233E-01	1.939E-01
3.981E-02	-2.650E-01	3.346E-01	-1.218E-01	1.905E-01
3.935E-02	-2.612E-01	3.292E-01	-1.203E-01	1.871E-01
3.890E-02	-2.574E-01	3.239E-01	-1.189E-01	1.838E-01
3.846E-02	-2.538E-01	3.185E-01	-1.175E-01	1.805E-01
3.802E-02	-2.504E-01	3.132E-01	-1.162E-01	1.772E-01
3.758E-02	-2.470E-01	3.079E-01	-1.150E-01	1.739E-01
3.715E-02	-2.437E-01	3.026E-01	-1.137E-01	1.707E-01
3.673E-02	-2.405E-01	2.974E-01	-1.125E-01	1.676E-01
3.631E-02	-2.373E-01	2.922E-01	-1.114E-01	1.644E-01

3.589E-02	-2.343E-01	2.871E-01	-1.102E-01	1.613E-01
3.548E-02	-2.312E-01	2.820E-01	-1.090E-01	1.583E-01
3.508E-02	-2.282E-01	2.770E-01	-1.079E-01	1.552E-01
3.467E-02	-2.253E-01	2.720E-01	-1.068E-01	1.522E-01
3.428E-02	-2.224E-01	2.670E-01	-1.056E-01	1.493E-01
3.388E-02	-2.195E-01	2.621E-01	-1.045E-01	1.463E-01
3.350E-02	-2.167E-01	2.572E-01	-1.034E-01	1.434E-01
3.311E-02	-2.139E-01	2.523E-01	-1.023E-01	1.405E-01
3.273E-02	-2.111E-01	2.475E-01	-1.012E-01	1.377E-01
3.236E-02	-2.084E-01	2.427E-01	-1.001E-01	1.349E-01
3.199E-02	-2.058E-01	2.380E-01	-9.907E-02	1.321E-01
3.162E-02	-2.031E-01	2.333E-01	-9.800E-02	1.293E-01
3.126E-02	-2.005E-01	2.286E-01	-9.694E-02	1.266E-01
3.090E-02	-1.979E-01	2.241E-01	-9.588E-02	1.239E-01
3.055E-02	-1.953E-01	2.196E-01	-9.480E-02	1.213E-01
3.020E-02	-1.928E-01	2.152E-01	-9.373E-02	1.187E-01
2.985E-02	-1.902E-01	2.108E-01	-9.265E-02	1.162E-01
2.951E-02	-1.877E-01	2.065E-01	-9.157E-02	1.136E-01
2.917E-02	-1.851E-01	2.021E-01	-9.049E-02	1.111E-01
2.884E-02	-1.826E-01	1.978E-01	-8.942E-02	1.086E-01
2.851E-02	-1.801E-01	1.936E-01	-8.834E-02	1.062E-01
2.818E-02	-1.776E-01	1.894E-01	-8.725E-02	1.037E-01
2.786E-02	-1.751E-01	1.853E-01	-8.614E-02	1.014E-01
2.754E-02	-1.726E-01	1.813E-01	-8.502E-02	9.909E-02
2.723E-02	-1.701E-01	1.774E-01	-8.389E-02	9.682E-02
2.692E-02	-1.676E-01	1.735E-01	-8.275E-02	9.459E-02
2.661E-02	-1.651E-01	1.696E-01	-8.163E-02	9.236E-02
2.630E-02	-1.626E-01	1.658E-01	-8.050E-02	9.017E-02
2.600E-02	-1.602E-01	1.620E-01	-7.935E-02	8.801E-02
2.570E-02	-1.576E-01	1.583E-01	-7.819E-02	8.589E-02
2.541E-02	-1.551E-01	1.547E-01	-7.701E-02	8.381E-02
2.512E-02	-1.525E-01	1.511E-01	-7.580E-02	8.177E-02
2.483E-02	-1.499E-01	1.476E-01	-7.456E-02	7.976E-02
2.455E-02	-1.473E-01	1.442E-01	-7.330E-02	7.778E-02
2.427E-02	-1.446E-01	1.408E-01	-7.200E-02	7.584E-02
2.399E-02	-1.418E-01	1.374E-01	-7.067E-02	7.394E-02
2.371E-02	-1.390E-01	1.341E-01	-6.932E-02	7.207E-02
2.344E-02	-1.360E-01	1.309E-01	-6.783E-02	7.021E-02
2.317E-02	-1.321E-01	1.277E-01	-6.589E-02	6.836E-02
2.291E-02	-1.285E-01	1.289E-01	-6.394E-02	6.885E-02
2.265E-02	-1.275E-01	1.261E-01	-6.350E-02	6.731E-02
2.239E-02	-1.259E-01	1.234E-01	-6.277E-02	6.584E-02
2.213E-02	-1.240E-01	1.208E-01	-6.186E-02	6.439E-02
2.188E-02	-1.220E-01	1.183E-01	-6.087E-02	6.299E-02
2.163E-02	-1.199E-01	1.158E-01	-5.986E-02	6.161E-02
2.138E-02	-1.180E-01	1.134E-01	-5.891E-02	6.025E-02
2.113E-02	-1.159E-01	1.110E-01	-5.791E-02	5.893E-02
2.089E-02	-1.138E-01	1.087E-01	-5.685E-02	5.762E-02
2.065E-02	-1.115E-01	1.064E-01	-5.572E-02	5.635E-02
2.042E-02	-1.091E-01	1.042E-01	-5.452E-02	5.509E-02
2.018E-02	-1.065E-01	1.020E-01	-5.324E-02	5.387E-02
1.995E-02	-1.039E-01	9.988E-02	-5.189E-02	5.267E-02
1.972E-02	-1.010E-01	9.782E-02	-5.045E-02	5.151E-02
1.950E-02	-9.802E-02	9.582E-02	-4.894E-02	5.037E-02
1.928E-02	-9.488E-02	9.388E-02	-4.735E-02	4.927E-02
1.905E-02	-9.177E-02	9.200E-02	-4.577E-02	4.821E-02
1.884E-02	-9.289E-02	9.840E-02	-4.618E-02	5.158E-02
1.862E-02	-9.325E-02	9.615E-02	-4.643E-02	5.041E-02
1.841E-02	-9.282E-02	9.396E-02	-4.627E-02	4.926E-02
1.820E-02	-9.228E-02	9.183E-02	-4.604E-02	4.813E-02
1.799E-02	-9.163E-02	8.974E-02	-4.576E-02	4.702E-02
1.778E-02	-9.088E-02	8.771E-02	-4.541E-02	4.594E-02
1.758E-02	-8.987E-02	8.576E-02	-4.494E-02	4.490E-02
1.738E-02	-8.875E-02	8.386E-02	-4.440E-02	4.388E-02
1.718E-02	-8.758E-02	8.201E-02	-4.383E-02	4.288E-02
1.698E-02	-8.636E-02	8.019E-02	-4.324E-02	4.191E-02
1.679E-02	-8.509E-02	7.842E-02	-4.262E-02	4.096E-02
1.660E-02	-8.377E-02	7.670E-02	-4.197E-02	4.003E-02
1.641E-02	-8.249E-02	7.501E-02	-4.134E-02	3.912E-02
1.622E-02	-8.124E-02	7.336E-02	-4.072E-02	3.824E-02
1.603E-02	-7.999E-02	7.174E-02	-4.010E-02	3.737E-02
1.585E-02	-7.874E-02	7.014E-02	-3.948E-02	3.651E-02
1.567E-02	-7.748E-02	6.859E-02	-3.886E-02	3.568E-02
1.549E-02	-7.623E-02	6.706E-02	-3.824E-02	3.487E-02
1.531E-02	-7.500E-02	6.556E-02	-3.763E-02	3.406E-02
1.514E-02	-7.377E-02	6.407E-02	-3.702E-02	3.327E-02
1.496E-02	-7.253E-02	6.261E-02	-3.640E-02	3.249E-02

1.479E-02	-7.128E-02	6.118E-02	-3.578E-02	3.172E-02
1.462E-02	-7.003E-02	5.977E-02	-3.515E-02	3.098E-02
1.445E-02	-6.875E-02	5.839E-02	-3.452E-02	3.024E-02
1.429E-02	-6.745E-02	5.702E-02	-3.386E-02	2.951E-02
1.413E-02	-6.611E-02	5.569E-02	-3.319E-02	2.880E-02
1.396E-02	-6.474E-02	5.437E-02	-3.250E-02	2.810E-02
1.380E-02	-6.333E-02	5.309E-02	-3.180E-02	2.742E-02
1.365E-02	-6.154E-02	5.182E-02	-3.089E-02	2.673E-02
1.349E-02	-5.949E-02	5.056E-02	-2.985E-02	2.606E-02
1.334E-02	-5.821E-02	5.195E-02	-2.917E-02	2.676E-02
1.318E-02	-5.817E-02	5.070E-02	-2.917E-02	2.611E-02
1.303E-02	-5.736E-02	4.947E-02	-2.877E-02	2.547E-02
1.288E-02	-5.572E-02	4.826E-02	-2.794E-02	2.482E-02
1.274E-02	-5.513E-02	4.916E-02	-2.763E-02	2.528E-02
1.259E-02	-5.490E-02	4.794E-02	-2.752E-02	2.465E-02
1.245E-02	-5.454E-02	4.675E-02	-2.736E-02	2.403E-02
1.230E-02	-5.405E-02	4.557E-02	-2.712E-02	2.342E-02
1.216E-02	-5.344E-02	4.442E-02	-2.682E-02	2.282E-02
1.202E-02	-5.270E-02	4.329E-02	-2.645E-02	2.223E-02
1.189E-02	-5.184E-02	4.217E-02	-2.602E-02	2.165E-02
1.175E-02	-5.085E-02	4.108E-02	-2.553E-02	2.108E-02
1.161E-02	-4.974E-02	4.001E-02	-2.497E-02	2.052E-02
1.148E-02	-4.848E-02	3.895E-02	-2.434E-02	1.996E-02
1.135E-02	-4.708E-02	3.793E-02	-2.363E-02	1.942E-02
1.122E-02	-4.555E-02	3.692E-02	-2.286E-02	1.889E-02
1.109E-02	-4.388E-02	3.593E-02	-2.201E-02	1.837E-02
1.096E-02	-4.206E-02	3.497E-02	-2.109E-02	1.786E-02
1.084E-02	-3.873E-02	3.403E-02	-1.940E-02	1.735E-02
1.072E-02	-3.492E-02	3.310E-02	-1.747E-02	1.684E-02
1.059E-02	-3.468E-02	4.240E-02	-1.726E-02	2.157E-02
1.047E-02	-3.947E-02	4.131E-02	-1.971E-02	2.107E-02
1.035E-02	-4.041E-02	4.024E-02	-2.020E-02	2.054E-02
1.023E-02	-4.062E-02	3.920E-02	-2.032E-02	2.001E-02
1.012E-02	-4.067E-02	3.818E-02	-2.035E-02	1.949E-02
1.000E-02	-4.067E-02	3.717E-02	-2.036E-02	1.897E-02
9.886E-03	-4.062E-02	3.618E-02	-2.035E-02	1.846E-02
9.772E-03	-4.052E-02	3.520E-02	-2.030E-02	1.797E-02
9.661E-03	-4.036E-02	3.424E-02	-2.023E-02	1.748E-02
9.550E-03	-4.015E-02	3.331E-02	-2.013E-02	1.699E-02
9.441E-03	-3.984E-02	3.239E-02	-1.998E-02	1.653E-02
9.333E-03	-3.948E-02	3.150E-02	-1.981E-02	1.607E-02
9.226E-03	-3.909E-02	3.062E-02	-1.962E-02	1.562E-02
9.120E-03	-3.867E-02	2.977E-02	-1.941E-02	1.518E-02
9.016E-03	-3.820E-02	2.893E-02	-1.918E-02	1.475E-02
8.913E-03	-3.770E-02	2.811E-02	-1.893E-02	1.433E-02
8.810E-03	-3.719E-02	2.732E-02	-1.867E-02	1.392E-02
8.710E-03	-3.670E-02	2.653E-02	-1.843E-02	1.352E-02
8.610E-03	-3.620E-02	2.577E-02	-1.818E-02	1.312E-02
8.511E-03	-3.569E-02	2.502E-02	-1.792E-02	1.274E-02
8.414E-03	-3.516E-02	2.430E-02	-1.766E-02	1.237E-02
8.318E-03	-3.462E-02	2.359E-02	-1.739E-02	1.200E-02
8.222E-03	-3.408E-02	2.290E-02	-1.712E-02	1.165E-02
8.128E-03	-3.354E-02	2.223E-02	-1.685E-02	1.130E-02
8.035E-03	-3.299E-02	2.157E-02	-1.657E-02	1.097E-02
7.943E-03	-3.242E-02	2.093E-02	-1.629E-02	1.064E-02
7.852E-03	-3.184E-02	2.031E-02	-1.599E-02	1.032E-02
7.762E-03	-3.125E-02	1.972E-02	-1.570E-02	1.002E-02
7.674E-03	-3.059E-02	1.913E-02	-1.537E-02	9.713E-03
7.586E-03	-2.990E-02	1.855E-02	-1.502E-02	9.417E-03
7.499E-03	-2.917E-02	1.799E-02	-1.465E-02	9.129E-03
7.413E-03	-2.800E-02	1.745E-02	-1.406E-02	8.849E-03
7.328E-03	-2.768E-02	1.850E-02	-1.389E-02	9.379E-03
7.244E-03	-2.789E-02	1.795E-02	-1.400E-02	9.100E-03
7.161E-03	-2.768E-02	1.740E-02	-1.390E-02	8.824E-03
7.079E-03	-2.740E-02	1.688E-02	-1.376E-02	8.556E-03
6.998E-03	-2.705E-02	1.637E-02	-1.358E-02	8.298E-03
6.918E-03	-2.669E-02	1.588E-02	-1.340E-02	8.046E-03
6.839E-03	-2.631E-02	1.539E-02	-1.321E-02	7.800E-03
6.761E-03	-2.592E-02	1.492E-02	-1.301E-02	7.560E-03
6.683E-03	-2.552E-02	1.446E-02	-1.282E-02	7.326E-03
6.607E-03	-2.513E-02	1.402E-02	-1.262E-02	7.098E-03
6.531E-03	-2.472E-02	1.358E-02	-1.242E-02	6.877E-03
6.457E-03	-2.432E-02	1.317E-02	-1.221E-02	6.666E-03
6.383E-03	-2.391E-02	1.276E-02	-1.200E-02	6.459E-03
6.310E-03	-2.350E-02	1.237E-02	-1.180E-02	6.257E-03
6.237E-03	-2.310E-02	1.198E-02	-1.160E-02	6.061E-03
6.166E-03	-2.270E-02	1.161E-02	-1.140E-02	5.872E-03

6.095E-03	-2.230E-02	1.126E-02	-1.120E-02	5.691E-03
6.026E-03	-2.191E-02	1.091E-02	-1.100E-02	5.514E-03
5.957E-03	-2.152E-02	1.057E-02	-1.081E-02	5.341E-03
5.888E-03	-2.114E-02	1.023E-02	-1.061E-02	5.171E-03
5.821E-03	-2.075E-02	9.907E-03	-1.042E-02	5.005E-03
5.754E-03	-2.037E-02	9.590E-03	-1.023E-02	4.844E-03
5.689E-03	-1.999E-02	9.281E-03	-1.004E-02	4.688E-03
5.623E-03	-1.962E-02	8.983E-03	-9.849E-03	4.536E-03
5.559E-03	-1.925E-02	8.697E-03	-9.663E-03	4.391E-03
5.495E-03	-1.889E-02	8.419E-03	-9.479E-03	4.250E-03
5.433E-03	-1.853E-02	8.148E-03	-9.297E-03	4.112E-03
5.370E-03	-1.817E-02	7.886E-03	-9.118E-03	3.979E-03
5.309E-03	-1.782E-02	7.632E-03	-8.940E-03	3.850E-03
5.248E-03	-1.747E-02	7.386E-03	-8.765E-03	3.726E-03
5.188E-03	-1.713E-02	7.150E-03	-8.593E-03	3.606E-03
5.129E-03	-1.679E-02	6.921E-03	-8.424E-03	3.490E-03
5.070E-03	-1.646E-02	6.696E-03	-8.258E-03	3.376E-03
5.012E-03	-1.613E-02	6.478E-03	-8.093E-03	3.265E-03
4.954E-03	-1.581E-02	6.266E-03	-7.932E-03	3.158E-03
4.898E-03	-1.549E-02	6.061E-03	-7.773E-03	3.054E-03
4.842E-03	-1.518E-02	5.863E-03	-7.616E-03	2.954E-03
4.786E-03	-1.488E-02	5.672E-03	-7.463E-03	2.857E-03
4.732E-03	-1.458E-02	5.487E-03	-7.311E-03	2.764E-03
4.677E-03	-1.428E-02	5.306E-03	-7.162E-03	2.672E-03
4.624E-03	-1.399E-02	5.130E-03	-7.015E-03	2.583E-03
4.571E-03	-1.370E-02	4.960E-03	-6.870E-03	2.497E-03
4.519E-03	-1.342E-02	4.796E-03	-6.728E-03	2.414E-03
4.467E-03	-1.314E-02	4.637E-03	-6.588E-03	2.334E-03
4.416E-03	-1.287E-02	4.484E-03	-6.451E-03	2.256E-03
4.365E-03	-1.260E-02	4.334E-03	-6.316E-03	2.181E-03
4.315E-03	-1.233E-02	4.189E-03	-6.183E-03	2.108E-03
4.266E-03	-1.207E-02	4.048E-03	-6.052E-03	2.036E-03
4.217E-03	-1.182E-02	3.912E-03	-5.924E-03	1.968E-03
4.169E-03	-1.157E-02	3.780E-03	-5.798E-03	1.901E-03
4.121E-03	-1.132E-02	3.654E-03	-5.674E-03	1.837E-03
4.074E-03	-1.108E-02	3.530E-03	-5.553E-03	1.775E-03
4.027E-03	-1.084E-02	3.410E-03	-5.433E-03	1.714E-03
3.981E-03	-1.061E-02	3.293E-03	-5.315E-03	1.655E-03
3.935E-03	-1.038E-02	3.181E-03	-5.200E-03	1.599E-03
3.890E-03	-1.015E-02	3.072E-03	-5.087E-03	1.544E-03
3.846E-03	-9.929E-03	2.967E-03	-4.976E-03	1.491E-03
3.802E-03	-9.711E-03	2.865E-03	-4.866E-03	1.440E-03
3.758E-03	-9.497E-03	2.766E-03	-4.759E-03	1.390E-03
3.715E-03	-9.287E-03	2.671E-03	-4.653E-03	1.342E-03
3.673E-03	-9.080E-03	2.578E-03	-4.550E-03	1.295E-03
3.631E-03	-8.877E-03	2.489E-03	-4.448E-03	1.250E-03
3.589E-03	-8.676E-03	2.402E-03	-4.347E-03	1.206E-03
3.548E-03	-8.479E-03	2.318E-03	-4.248E-03	1.164E-03
3.508E-03	-8.286E-03	2.237E-03	-4.151E-03	1.123E-03
3.467E-03	-8.097E-03	2.158E-03	-4.056E-03	1.084E-03
3.428E-03	-7.912E-03	2.083E-03	-3.963E-03	1.045E-03
3.388E-03	-7.731E-03	2.009E-03	-3.873E-03	1.009E-03
3.350E-03	-7.554E-03	1.938E-03	-3.784E-03	9.727E-04
3.311E-03	-7.380E-03	1.869E-03	-3.696E-03	9.382E-04
3.273E-03	-7.210E-03	1.803E-03	-3.611E-03	9.049E-04
3.236E-03	-7.042E-03	1.740E-03	-3.527E-03	8.730E-04
3.199E-03	-6.876E-03	1.678E-03	-3.443E-03	8.420E-04
3.162E-03	-6.712E-03	1.618E-03	-3.361E-03	8.117E-04
3.126E-03	-6.550E-03	1.559E-03	-3.280E-03	7.823E-04
3.090E-03	-6.394E-03	1.503E-03	-3.202E-03	7.541E-04
3.055E-03	-6.246E-03	1.452E-03	-3.128E-03	7.281E-04
3.020E-03	-6.100E-03	1.401E-03	-3.054E-03	7.025E-04
2.985E-03	-5.954E-03	1.351E-03	-2.981E-03	6.775E-04
2.951E-03	-5.809E-03	1.302E-03	-2.908E-03	6.530E-04
2.917E-03	-5.664E-03	1.255E-03	-2.836E-03	6.291E-04
2.884E-03	-5.521E-03	1.208E-03	-2.764E-03	6.058E-04
2.851E-03	-5.378E-03	1.163E-03	-2.692E-03	5.831E-04
2.818E-03	-5.236E-03	1.119E-03	-2.621E-03	5.611E-04
2.786E-03	-5.095E-03	1.077E-03	-2.551E-03	5.398E-04
2.754E-03	-4.956E-03	1.036E-03	-2.481E-03	5.192E-04
2.723E-03	-4.829E-03	9.964E-04	-2.417E-03	4.994E-04
2.692E-03	-4.699E-03	9.583E-04	-2.352E-03	4.803E-04
2.661E-03	-4.568E-03	9.216E-04	-2.287E-03	4.619E-04
2.630E-03	-4.436E-03	8.864E-04	-2.220E-03	4.442E-04
2.600E-03	-4.302E-03	8.527E-04	-2.153E-03	4.273E-04
2.570E-03	-4.166E-03	8.206E-04	-2.085E-03	4.112E-04
2.541E-03	-4.028E-03	7.901E-04	-2.016E-03	3.959E-04

2.512E-03	-3.889E-03	7.614E-04	-1.946E-03	3.814E-04
2.483E-03	-3.748E-03	7.344E-04	-1.876E-03	3.679E-04
2.455E-03	-3.543E-03	7.063E-04	-1.773E-03	3.538E-04
2.427E-03	-3.313E-03	6.790E-04	-1.658E-03	3.401E-04
2.399E-03	-3.065E-03	6.530E-04	-1.534E-03	3.270E-04
2.371E-03	-2.799E-03	6.282E-04	-1.400E-03	3.146E-04
2.344E-03	-2.513E-03	6.048E-04	-1.257E-03	3.028E-04
2.317E-03	-2.412E-03	1.555E-03	-1.207E-03	7.783E-04
2.291E-03	-2.790E-03	1.504E-03	-1.396E-03	7.532E-04
2.265E-03	-2.898E-03	1.455E-03	-1.450E-03	7.287E-04
2.239E-03	-2.933E-03	1.408E-03	-1.467E-03	7.050E-04
2.213E-03	-2.928E-03	1.362E-03	-1.465E-03	6.819E-04
2.188E-03	-2.919E-03	1.316E-03	-1.460E-03	6.592E-04
2.163E-03	-2.906E-03	1.272E-03	-1.454E-03	6.370E-04
2.138E-03	-2.888E-03	1.229E-03	-1.445E-03	6.152E-04
2.113E-03	-2.866E-03	1.186E-03	-1.434E-03	5.939E-04
2.089E-03	-2.840E-03	1.145E-03	-1.421E-03	5.732E-04
2.065E-03	-2.809E-03	1.104E-03	-1.405E-03	5.530E-04
2.042E-03	-2.769E-03	1.066E-03	-1.385E-03	5.336E-04
2.018E-03	-2.727E-03	1.028E-03	-1.364E-03	5.148E-04
1.995E-03	-2.682E-03	9.916E-04	-1.342E-03	4.964E-04
1.972E-03	-2.633E-03	9.560E-04	-1.317E-03	4.786E-04
1.950E-03	-2.581E-03	9.216E-04	-1.291E-03	4.614E-04
1.928E-03	-2.526E-03	8.883E-04	-1.264E-03	4.447E-04
1.905E-03	-2.468E-03	8.562E-04	-1.235E-03	4.286E-04
1.884E-03	-2.415E-03	8.246E-04	-1.208E-03	4.128E-04
1.862E-03	-2.360E-03	7.940E-04	-1.181E-03	3.975E-04
1.841E-03	-2.303E-03	7.645E-04	-1.152E-03	3.827E-04
1.820E-03	-2.243E-03	7.360E-04	-1.122E-03	3.684E-04
1.799E-03	-2.181E-03	7.087E-04	-1.091E-03	3.547E-04
1.778E-03	-2.116E-03	6.825E-04	-1.059E-03	3.416E-04
1.758E-03	-2.042E-03	6.568E-04	-1.021E-03	3.288E-04
1.738E-03	-1.957E-03	6.319E-04	-9.791E-04	3.162E-04
1.718E-03	-1.866E-03	6.079E-04	-9.335E-04	3.042E-04
1.698E-03	-1.767E-03	5.849E-04	-8.841E-04	2.927E-04
1.679E-03	-1.551E-03	5.624E-04	-7.757E-04	2.814E-04
1.660E-03	-1.616E-03	9.877E-04	-8.083E-04	4.942E-04
1.641E-03	-1.701E-03	9.520E-04	-8.507E-04	4.764E-04
1.622E-03	-1.730E-03	9.174E-04	-8.653E-04	4.591E-04
1.603E-03	-1.748E-03	8.837E-04	-8.745E-04	4.422E-04
1.585E-03	-1.756E-03	8.509E-04	-8.781E-04	4.258E-04
1.567E-03	-1.752E-03	8.191E-04	-8.761E-04	4.099E-04
1.549E-03	-1.736E-03	7.882E-04	-8.683E-04	3.945E-04
1.531E-03	-1.712E-03	7.585E-04	-8.565E-04	3.796E-04
1.514E-03	-1.678E-03	7.298E-04	-8.392E-04	3.652E-04
1.496E-03	-1.632E-03	7.023E-04	-8.161E-04	3.514E-04
1.479E-03	-1.606E-03	7.467E-04	-8.030E-04	3.737E-04
1.462E-03	-1.612E-03	7.194E-04	-8.061E-04	3.600E-04
1.445E-03	-1.601E-03	6.935E-04	-8.007E-04	3.470E-04
1.429E-03	-1.584E-03	6.683E-04	-7.924E-04	3.344E-04
1.413E-03	-1.566E-03	6.437E-04	-7.835E-04	3.221E-04
1.396E-03	-1.547E-03	6.199E-04	-7.739E-04	3.102E-04
1.380E-03	-1.527E-03	5.967E-04	-7.637E-04	2.986E-04
1.365E-03	-1.504E-03	5.745E-04	-7.524E-04	2.875E-04
1.349E-03	-1.481E-03	5.530E-04	-7.408E-04	2.767E-04
1.334E-03	-1.457E-03	5.322E-04	-7.287E-04	2.663E-04
1.318E-03	-1.432E-03	5.121E-04	-7.163E-04	2.562E-04
1.303E-03	-1.407E-03	4.928E-04	-7.036E-04	2.466E-04
1.288E-03	-1.382E-03	4.743E-04	-6.912E-04	2.373E-04
1.274E-03	-1.357E-03	4.563E-04	-6.788E-04	2.283E-04
1.259E-03	-1.333E-03	4.388E-04	-6.665E-04	2.195E-04
1.245E-03	-1.308E-03	4.218E-04	-6.542E-04	2.110E-04
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1.216E-03	-1.260E-03	3.905E-04	-6.299E-04	1.953E-04
1.202E-03	-1.235E-03	3.755E-04	-6.179E-04	1.879E-04
1.189E-03	-1.212E-03	3.609E-04	-6.059E-04	1.806E-04
1.175E-03	-1.188E-03	3.467E-04	-5.940E-04	1.735E-04
1.161E-03	-1.164E-03	3.330E-04	-5.822E-04	1.666E-04
1.148E-03	-1.141E-03	3.196E-04	-5.704E-04	1.599E-04
1.135E-03	-1.117E-03	3.068E-04	-5.587E-04	1.535E-04
1.122E-03	-1.094E-03	2.945E-04	-5.472E-04	1.473E-04
1.109E-03	-1.071E-03	2.828E-04	-5.359E-04	1.415E-04
1.096E-03	-1.049E-03	2.715E-04	-5.246E-04	1.358E-04
1.084E-03	-1.026E-03	2.606E-04	-5.133E-04	1.304E-04
1.072E-03	-1.004E-03	2.501E-04	-5.021E-04	1.251E-04
1.059E-03	-9.818E-04	2.400E-04	-4.910E-04	1.200E-04
1.047E-03	-9.596E-04	2.303E-04	-4.799E-04	1.152E-04

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1.035E-03 -9.376E-04 2.211E-04 -4.689E-04 1.106E-04
1.023E-03 -9.153E-04 2.120E-04 -4.577E-04 1.061E-04
1.012E-03 -8.929E-04 2.032E-04 -4.465E-04 1.016E-04
1.000E-03 -8.705E-04 1.947E-04 -4.353E-04 9.738E-05
```

A.2 Amorphous carbon, ACAR sample

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# wavelength in micron, 'n' and 'k'
# of amorphous carbon
#
# ACAR sample
#
# Reference:
# Zubko V.G., Mennella V., Colangeli L., Bussoletti E., 1996,
# MNRAS, 282, 1321

  w(micron)  n          k
  4.008e-02  9.092e-01  7.918e-02
  4.043e-02  9.026e-01  8.402e-02
  4.078e-02  8.982e-01  8.883e-02
  4.114e-02  8.946e-01  9.357e-02
  4.149e-02  8.915e-01  9.824e-02
  4.186e-02  8.888e-01  1.029e-01
  4.222e-02  8.865e-01  1.074e-01
  4.259e-02  8.843e-01  1.119e-01
  4.296e-02  8.824e-01  1.164e-01
  4.334e-02  8.807e-01  1.208e-01
  4.372e-02  8.791e-01  1.252e-01
  4.410e-02  8.776e-01  1.295e-01
  4.448e-02  8.762e-01  1.338e-01
  4.487e-02  8.749e-01  1.381e-01
  4.526e-02  8.737e-01  1.424e-01
  4.566e-02  8.726e-01  1.467e-01
  4.605e-02  8.716e-01  1.509e-01
  4.646e-02  8.706e-01  1.552e-01
  4.686e-02  8.697e-01  1.594e-01
  4.727e-02  8.688e-01  1.637e-01
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  4.937e-02  8.651e-01  1.851e-01
  4.980e-02  8.644e-01  1.894e-01
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  5.292e-02  8.610e-01  2.209e-01
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  5.723e-02  8.595e-01  2.650e-01
  5.773e-02  8.596e-01  2.702e-01
  5.823e-02  8.597e-01  2.755e-01
  5.874e-02  8.600e-01  2.808e-01
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  5.977e-02  8.606e-01  2.918e-01
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  6.189e-02  8.630e-01  3.147e-01
  6.243e-02  8.639e-01  3.206e-01
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  6.463e-02  8.686e-01  3.448e-01
  6.520e-02  8.701e-01  3.509e-01
  6.577e-02  8.718e-01  3.571e-01
  6.634e-02  8.736e-01  3.633e-01
  6.692e-02  8.755e-01  3.695e-01
  6.750e-02  8.775e-01  3.758e-01
  6.809e-02  8.797e-01  3.821e-01
  6.869e-02  8.820e-01  3.884e-01
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7.174e-02	8.955e-01	4.198e-01
7.236e-02	8.985e-01	4.261e-01
7.299e-02	9.017e-01	4.324e-01
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7.427e-02	9.085e-01	4.450e-01
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7.558e-02	9.157e-01	4.576e-01
7.624e-02	9.195e-01	4.639e-01
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7.893e-02	9.361e-01	4.892e-01
7.962e-02	9.407e-01	4.956e-01
8.032e-02	9.454e-01	5.020e-01
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8.244e-02	9.609e-01	5.213e-01
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8.610e-02	9.917e-01	5.523e-01
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8.761e-02	1.006e+00	5.639e-01
8.837e-02	1.013e+00	5.693e-01
8.914e-02	1.021e+00	5.746e-01
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9.981e-02	1.132e+00	6.181e-01
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1.033e-01	1.167e+00	6.225e-01
1.042e-01	1.176e+00	6.229e-01
1.051e-01	1.185e+00	6.231e-01
1.061e-01	1.194e+00	6.230e-01
1.070e-01	1.202e+00	6.227e-01
1.079e-01	1.211e+00	6.221e-01
1.089e-01	1.219e+00	6.212e-01
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1.401e-01	1.384e+00	5.113e-01
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1.983e-01	1.224e+00	5.494e-01
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2.053e-01	1.225e+00	5.884e-01
2.071e-01	1.226e+00	5.981e-01
2.089e-01	1.227e+00	6.078e-01
2.107e-01	1.228e+00	6.178e-01
2.126e-01	1.230e+00	6.282e-01
2.144e-01	1.231e+00	6.388e-01
2.163e-01	1.233e+00	6.496e-01
2.182e-01	1.236e+00	6.607e-01
2.201e-01	1.239e+00	6.720e-01
2.220e-01	1.243e+00	6.834e-01
2.239e-01	1.247e+00	6.950e-01
2.259e-01	1.252e+00	7.064e-01
2.279e-01	1.258e+00	7.178e-01
2.299e-01	1.264e+00	7.289e-01
2.319e-01	1.271e+00	7.397e-01
2.339e-01	1.278e+00	7.501e-01
2.359e-01	1.285e+00	7.604e-01
2.380e-01	1.293e+00	7.705e-01
2.401e-01	1.301e+00	7.807e-01
2.422e-01	1.309e+00	7.910e-01
2.443e-01	1.318e+00	8.013e-01
2.464e-01	1.328e+00	8.114e-01
2.486e-01	1.339e+00	8.210e-01
2.507e-01	1.350e+00	8.298e-01
2.529e-01	1.362e+00	8.378e-01
2.551e-01	1.374e+00	8.450e-01
2.573e-01	1.387e+00	8.514e-01
2.596e-01	1.399e+00	8.572e-01
2.619e-01	1.411e+00	8.625e-01

2.641e-01	1.423e+00	8.674e-01
2.664e-01	1.435e+00	8.719e-01
2.688e-01	1.447e+00	8.759e-01
2.711e-01	1.459e+00	8.795e-01
2.735e-01	1.471e+00	8.827e-01
2.759e-01	1.483e+00	8.853e-01
2.783e-01	1.495e+00	8.874e-01
2.807e-01	1.507e+00	8.888e-01
2.832e-01	1.519e+00	8.894e-01
2.856e-01	1.529e+00	8.896e-01
2.881e-01	1.539e+00	8.896e-01
2.906e-01	1.549e+00	8.896e-01
2.932e-01	1.558e+00	8.900e-01
2.957e-01	1.567e+00	8.907e-01
2.983e-01	1.576e+00	8.916e-01
3.009e-01	1.585e+00	8.925e-01
3.035e-01	1.594e+00	8.933e-01
3.062e-01	1.603e+00	8.940e-01
3.089e-01	1.612e+00	8.947e-01
3.116e-01	1.620e+00	8.952e-01
3.143e-01	1.629e+00	8.957e-01
3.170e-01	1.638e+00	8.961e-01
3.198e-01	1.647e+00	8.964e-01
3.226e-01	1.656e+00	8.966e-01
3.254e-01	1.664e+00	8.967e-01
3.282e-01	1.673e+00	8.967e-01
3.311e-01	1.681e+00	8.967e-01
3.340e-01	1.690e+00	8.965e-01
3.369e-01	1.698e+00	8.963e-01
3.398e-01	1.707e+00	8.960e-01
3.428e-01	1.715e+00	8.956e-01
3.458e-01	1.723e+00	8.952e-01
3.488e-01	1.732e+00	8.946e-01
3.519e-01	1.740e+00	8.940e-01
3.549e-01	1.748e+00	8.934e-01
3.580e-01	1.756e+00	8.926e-01
3.612e-01	1.764e+00	8.918e-01
3.643e-01	1.772e+00	8.909e-01
3.675e-01	1.780e+00	8.900e-01
3.707e-01	1.787e+00	8.890e-01
3.739e-01	1.795e+00	8.879e-01
3.772e-01	1.803e+00	8.867e-01
3.805e-01	1.810e+00	8.855e-01
3.838e-01	1.818e+00	8.842e-01
3.872e-01	1.825e+00	8.829e-01
3.905e-01	1.833e+00	8.815e-01
3.939e-01	1.840e+00	8.801e-01
3.974e-01	1.847e+00	8.785e-01
4.008e-01	1.855e+00	8.770e-01
4.043e-01	1.862e+00	8.753e-01
4.079e-01	1.869e+00	8.737e-01
4.114e-01	1.876e+00	8.719e-01
4.150e-01	1.883e+00	8.702e-01
4.186e-01	1.889e+00	8.683e-01
4.223e-01	1.896e+00	8.665e-01
4.260e-01	1.903e+00	8.646e-01
4.297e-01	1.909e+00	8.627e-01
4.335e-01	1.916e+00	8.607e-01
4.372e-01	1.922e+00	8.587e-01
4.411e-01	1.929e+00	8.567e-01
4.449e-01	1.935e+00	8.546e-01
4.488e-01	1.941e+00	8.525e-01
4.527e-01	1.947e+00	8.504e-01
4.567e-01	1.953e+00	8.483e-01
4.606e-01	1.959e+00	8.462e-01
4.647e-01	1.965e+00	8.441e-01
4.687e-01	1.971e+00	8.419e-01
4.728e-01	1.977e+00	8.398e-01
4.769e-01	1.982e+00	8.377e-01
4.811e-01	1.988e+00	8.355e-01
4.853e-01	1.993e+00	8.334e-01
4.895e-01	1.999e+00	8.312e-01
4.938e-01	2.004e+00	8.291e-01
4.981e-01	2.009e+00	8.270e-01
5.025e-01	2.014e+00	8.249e-01
5.068e-01	2.020e+00	8.228e-01
5.113e-01	2.025e+00	8.208e-01

5.157e-01	2.030e+00	8.187e-01
5.202e-01	2.035e+00	8.167e-01
5.248e-01	2.040e+00	8.147e-01
5.294e-01	2.044e+00	8.127e-01
5.340e-01	2.049e+00	8.107e-01
5.386e-01	2.054e+00	8.088e-01
5.433e-01	2.059e+00	8.068e-01
5.481e-01	2.063e+00	8.049e-01
5.529e-01	2.068e+00	8.030e-01
5.577e-01	2.073e+00	8.012e-01
5.626e-01	2.077e+00	7.993e-01
5.675e-01	2.082e+00	7.975e-01
5.724e-01	2.086e+00	7.957e-01
5.774e-01	2.091e+00	7.939e-01
5.825e-01	2.095e+00	7.922e-01
5.875e-01	2.099e+00	7.904e-01
5.927e-01	2.104e+00	7.887e-01
5.978e-01	2.108e+00	7.871e-01
6.031e-01	2.112e+00	7.854e-01
6.083e-01	2.117e+00	7.838e-01
6.136e-01	2.121e+00	7.822e-01
6.190e-01	2.125e+00	7.806e-01
6.244e-01	2.129e+00	7.790e-01
6.298e-01	2.133e+00	7.775e-01
6.353e-01	2.138e+00	7.759e-01
6.409e-01	2.142e+00	7.744e-01
6.465e-01	2.146e+00	7.729e-01
6.521e-01	2.150e+00	7.713e-01
6.578e-01	2.154e+00	7.698e-01
6.635e-01	2.158e+00	7.683e-01
6.693e-01	2.162e+00	7.668e-01
6.752e-01	2.166e+00	7.653e-01
6.811e-01	2.170e+00	7.637e-01
6.870e-01	2.174e+00	7.622e-01
6.930e-01	2.178e+00	7.607e-01
6.991e-01	2.182e+00	7.591e-01
7.052e-01	2.186e+00	7.575e-01
7.113e-01	2.190e+00	7.559e-01
7.175e-01	2.194e+00	7.543e-01
7.238e-01	2.197e+00	7.527e-01
7.301e-01	2.201e+00	7.512e-01
7.365e-01	2.205e+00	7.496e-01
7.429e-01	2.208e+00	7.481e-01
7.494e-01	2.211e+00	7.467e-01
7.559e-01	2.215e+00	7.453e-01
7.625e-01	2.218e+00	7.440e-01
7.692e-01	2.221e+00	7.428e-01
7.759e-01	2.224e+00	7.417e-01
7.827e-01	2.227e+00	7.407e-01
7.895e-01	2.230e+00	7.398e-01
7.964e-01	2.233e+00	7.391e-01
8.033e-01	2.236e+00	7.385e-01
8.103e-01	2.239e+00	7.381e-01
8.174e-01	2.242e+00	7.377e-01
8.245e-01	2.246e+00	7.375e-01
8.317e-01	2.249e+00	7.374e-01
8.390e-01	2.252e+00	7.374e-01
8.463e-01	2.256e+00	7.373e-01
8.537e-01	2.260e+00	7.373e-01
8.612e-01	2.264e+00	7.373e-01
8.687e-01	2.268e+00	7.372e-01
8.763e-01	2.272e+00	7.371e-01
8.839e-01	2.276e+00	7.369e-01
8.916e-01	2.281e+00	7.365e-01
8.994e-01	2.285e+00	7.360e-01
9.073e-01	2.290e+00	7.354e-01
9.152e-01	2.294e+00	7.346e-01
9.232e-01	2.299e+00	7.336e-01
9.312e-01	2.303e+00	7.325e-01
9.393e-01	2.307e+00	7.313e-01
9.475e-01	2.311e+00	7.300e-01
9.558e-01	2.316e+00	7.286e-01
9.642e-01	2.319e+00	7.272e-01
9.726e-01	2.323e+00	7.258e-01
9.811e-01	2.327e+00	7.243e-01
9.896e-01	2.331e+00	7.229e-01
9.983e-01	2.334e+00	7.215e-01

1.007e+00	2.337e+00	7.201e-01
1.016e+00	2.341e+00	7.188e-01
1.025e+00	2.344e+00	7.176e-01
1.034e+00	2.347e+00	7.165e-01
1.043e+00	2.350e+00	7.154e-01
1.052e+00	2.353e+00	7.144e-01
1.061e+00	2.356e+00	7.135e-01
1.070e+00	2.358e+00	7.127e-01
1.079e+00	2.361e+00	7.120e-01
1.089e+00	2.364e+00	7.114e-01
1.098e+00	2.367e+00	7.109e-01
1.108e+00	2.370e+00	7.105e-01
1.118e+00	2.373e+00	7.102e-01
1.127e+00	2.376e+00	7.100e-01
1.137e+00	2.379e+00	7.099e-01
1.147e+00	2.382e+00	7.098e-01
1.157e+00	2.385e+00	7.097e-01
1.167e+00	2.389e+00	7.096e-01
1.177e+00	2.392e+00	7.094e-01
1.188e+00	2.395e+00	7.092e-01
1.198e+00	2.399e+00	7.089e-01
1.209e+00	2.402e+00	7.085e-01
1.219e+00	2.406e+00	7.079e-01
1.230e+00	2.409e+00	7.073e-01
1.240e+00	2.413e+00	7.067e-01
1.251e+00	2.416e+00	7.061e-01
1.262e+00	2.419e+00	7.055e-01
1.273e+00	2.422e+00	7.051e-01
1.284e+00	2.424e+00	7.047e-01
1.296e+00	2.427e+00	7.046e-01
1.307e+00	2.430e+00	7.046e-01
1.318e+00	2.432e+00	7.049e-01
1.330e+00	2.435e+00	7.053e-01
1.341e+00	2.439e+00	7.059e-01
1.353e+00	2.442e+00	7.064e-01
1.365e+00	2.445e+00	7.069e-01
1.377e+00	2.449e+00	7.074e-01
1.389e+00	2.453e+00	7.076e-01
1.401e+00	2.457e+00	7.077e-01
1.413e+00	2.461e+00	7.074e-01
1.426e+00	2.465e+00	7.069e-01
1.438e+00	2.469e+00	7.063e-01
1.451e+00	2.472e+00	7.056e-01
1.463e+00	2.475e+00	7.049e-01
1.476e+00	2.478e+00	7.043e-01
1.489e+00	2.481e+00	7.038e-01
1.502e+00	2.484e+00	7.036e-01
1.515e+00	2.486e+00	7.037e-01
1.528e+00	2.489e+00	7.040e-01
1.541e+00	2.492e+00	7.045e-01
1.555e+00	2.495e+00	7.052e-01
1.569e+00	2.498e+00	7.058e-01
1.582e+00	2.501e+00	7.065e-01
1.596e+00	2.505e+00	7.071e-01
1.610e+00	2.508e+00	7.075e-01
1.624e+00	2.512e+00	7.078e-01
1.638e+00	2.516e+00	7.079e-01
1.652e+00	2.519e+00	7.079e-01
1.667e+00	2.522e+00	7.080e-01
1.681e+00	2.526e+00	7.080e-01
1.696e+00	2.529e+00	7.082e-01
1.711e+00	2.532e+00	7.085e-01
1.726e+00	2.535e+00	7.090e-01
1.741e+00	2.538e+00	7.096e-01
1.756e+00	2.542e+00	7.102e-01
1.771e+00	2.545e+00	7.109e-01
1.787e+00	2.549e+00	7.115e-01
1.802e+00	2.553e+00	7.120e-01
1.818e+00	2.556e+00	7.123e-01
1.834e+00	2.560e+00	7.126e-01
1.850e+00	2.564e+00	7.129e-01
1.866e+00	2.567e+00	7.132e-01
1.883e+00	2.570e+00	7.136e-01
1.899e+00	2.574e+00	7.142e-01
1.916e+00	2.577e+00	7.151e-01
1.932e+00	2.581e+00	7.161e-01
1.949e+00	2.585e+00	7.171e-01

1.966e+00	2.590e+00	7.179e-01
1.983e+00	2.594e+00	7.184e-01
2.001e+00	2.599e+00	7.184e-01
2.018e+00	2.604e+00	7.177e-01
2.036e+00	2.608e+00	7.166e-01
2.053e+00	2.612e+00	7.154e-01
2.071e+00	2.614e+00	7.143e-01
2.089e+00	2.617e+00	7.138e-01
2.108e+00	2.619e+00	7.141e-01
2.126e+00	2.621e+00	7.153e-01
2.145e+00	2.625e+00	7.170e-01
2.163e+00	2.629e+00	7.186e-01
2.182e+00	2.634e+00	7.198e-01
2.201e+00	2.639e+00	7.200e-01
2.220e+00	2.645e+00	7.188e-01
2.240e+00	2.649e+00	7.167e-01
2.259e+00	2.652e+00	7.143e-01
2.279e+00	2.654e+00	7.124e-01
2.299e+00	2.655e+00	7.115e-01
2.319e+00	2.655e+00	7.124e-01
2.339e+00	2.657e+00	7.146e-01
2.360e+00	2.659e+00	7.175e-01
2.380e+00	2.663e+00	7.202e-01
2.401e+00	2.668e+00	7.220e-01
2.422e+00	2.674e+00	7.224e-01
2.443e+00	2.679e+00	7.217e-01
2.465e+00	2.683e+00	7.205e-01
2.486e+00	2.685e+00	7.194e-01
2.508e+00	2.687e+00	7.192e-01
2.530e+00	2.690e+00	7.201e-01
2.552e+00	2.692e+00	7.217e-01
2.574e+00	2.696e+00	7.235e-01
2.596e+00	2.700e+00	7.251e-01
2.619e+00	2.704e+00	7.259e-01
2.642e+00	2.709e+00	7.259e-01
2.665e+00	2.713e+00	7.256e-01
2.688e+00	2.717e+00	7.250e-01
2.712e+00	2.720e+00	7.246e-01
2.735e+00	2.722e+00	7.246e-01
2.759e+00	2.725e+00	7.249e-01
2.783e+00	2.727e+00	7.257e-01
2.808e+00	2.730e+00	7.269e-01
2.832e+00	2.733e+00	7.286e-01
2.857e+00	2.737e+00	7.303e-01
2.882e+00	2.741e+00	7.318e-01
2.907e+00	2.746e+00	7.326e-01
2.932e+00	2.751e+00	7.326e-01
2.958e+00	2.755e+00	7.320e-01
2.984e+00	2.758e+00	7.313e-01
3.010e+00	2.761e+00	7.309e-01
3.036e+00	2.764e+00	7.310e-01
3.063e+00	2.766e+00	7.316e-01
3.089e+00	2.769e+00	7.325e-01
3.116e+00	2.772e+00	7.337e-01
3.143e+00	2.775e+00	7.350e-01
3.171e+00	2.778e+00	7.361e-01
3.199e+00	2.782e+00	7.367e-01
3.226e+00	2.785e+00	7.367e-01
3.255e+00	2.788e+00	7.366e-01
3.283e+00	2.789e+00	7.373e-01
3.312e+00	2.790e+00	7.398e-01
3.341e+00	2.792e+00	7.440e-01
3.370e+00	2.796e+00	7.488e-01
3.399e+00	2.802e+00	7.530e-01
3.429e+00	2.810e+00	7.553e-01
3.459e+00	2.817e+00	7.558e-01
3.489e+00	2.823e+00	7.551e-01
3.519e+00	2.829e+00	7.537e-01
3.550e+00	2.833e+00	7.520e-01
3.581e+00	2.837e+00	7.505e-01
3.612e+00	2.840e+00	7.495e-01
3.644e+00	2.842e+00	7.492e-01
3.676e+00	2.845e+00	7.496e-01
3.708e+00	2.847e+00	7.503e-01
3.740e+00	2.850e+00	7.514e-01
3.773e+00	2.854e+00	7.525e-01
3.806e+00	2.857e+00	7.533e-01

3.839e+00	2.861e+00	7.539e-01
3.872e+00	2.864e+00	7.545e-01
3.906e+00	2.866e+00	7.555e-01
3.940e+00	2.870e+00	7.573e-01
3.975e+00	2.873e+00	7.593e-01
4.009e+00	2.878e+00	7.609e-01
4.044e+00	2.883e+00	7.616e-01
4.080e+00	2.888e+00	7.615e-01
4.115e+00	2.892e+00	7.608e-01
4.151e+00	2.895e+00	7.599e-01
4.187e+00	2.897e+00	7.597e-01
4.224e+00	2.898e+00	7.611e-01
4.261e+00	2.901e+00	7.638e-01
4.298e+00	2.905e+00	7.665e-01
4.335e+00	2.910e+00	7.680e-01
4.373e+00	2.915e+00	7.685e-01
4.411e+00	2.919e+00	7.689e-01
4.450e+00	2.923e+00	7.693e-01
4.489e+00	2.927e+00	7.697e-01
4.528e+00	2.931e+00	7.697e-01
4.568e+00	2.934e+00	7.696e-01
4.607e+00	2.937e+00	7.699e-01
4.648e+00	2.939e+00	7.711e-01
4.688e+00	2.942e+00	7.729e-01
4.729e+00	2.946e+00	7.750e-01
4.770e+00	2.951e+00	7.767e-01
4.812e+00	2.957e+00	7.774e-01
4.854e+00	2.962e+00	7.768e-01
4.896e+00	2.966e+00	7.756e-01
4.939e+00	2.970e+00	7.744e-01
4.982e+00	2.974e+00	7.731e-01
5.026e+00	2.977e+00	7.713e-01
5.070e+00	2.979e+00	7.693e-01
5.114e+00	2.980e+00	7.676e-01
5.158e+00	2.980e+00	7.669e-01
5.203e+00	2.980e+00	7.677e-01
5.249e+00	2.981e+00	7.699e-01
5.295e+00	2.983e+00	7.721e-01
5.341e+00	2.987e+00	7.728e-01
5.387e+00	2.989e+00	7.719e-01
5.434e+00	2.990e+00	7.699e-01
5.482e+00	2.988e+00	7.686e-01
5.530e+00	2.986e+00	7.705e-01
5.578e+00	2.984e+00	7.750e-01
5.627e+00	2.984e+00	7.791e-01
5.676e+00	2.984e+00	7.828e-01
5.725e+00	2.984e+00	7.889e-01
5.775e+00	2.986e+00	7.970e-01
5.826e+00	2.992e+00	8.022e-01
5.877e+00	2.998e+00	8.035e-01
5.928e+00	3.001e+00	8.037e-01
5.980e+00	3.002e+00	8.047e-01
6.032e+00	3.001e+00	8.071e-01
6.084e+00	3.001e+00	8.112e-01
6.138e+00	3.000e+00	8.173e-01
6.191e+00	3.001e+00	8.252e-01
6.245e+00	3.004e+00	8.337e-01
6.300e+00	3.010e+00	8.413e-01
6.355e+00	3.016e+00	8.466e-01
6.410e+00	3.022e+00	8.508e-01
6.466e+00	3.027e+00	8.554e-01
6.522e+00	3.032e+00	8.599e-01
6.579e+00	3.037e+00	8.644e-01
6.637e+00	3.043e+00	8.696e-01
6.695e+00	3.050e+00	8.741e-01
6.753e+00	3.058e+00	8.757e-01
6.812e+00	3.064e+00	8.752e-01
6.872e+00	3.067e+00	8.747e-01
6.931e+00	3.068e+00	8.756e-01
6.992e+00	3.067e+00	8.797e-01
7.053e+00	3.069e+00	8.880e-01
7.115e+00	3.074e+00	8.955e-01
7.177e+00	3.079e+00	8.989e-01
7.239e+00	3.082e+00	9.058e-01
7.302e+00	3.088e+00	9.150e-01
7.366e+00	3.097e+00	9.200e-01
7.431e+00	3.104e+00	9.235e-01

7.495e+00	3.111e+00	9.278e-01
7.561e+00	3.117e+00	9.322e-01
7.627e+00	3.123e+00	9.354e-01
7.693e+00	3.128e+00	9.392e-01
7.760e+00	3.133e+00	9.481e-01
7.828e+00	3.143e+00	9.572e-01
7.897e+00	3.156e+00	9.609e-01
7.965e+00	3.166e+00	9.590e-01
8.035e+00	3.172e+00	9.591e-01
8.105e+00	3.177e+00	9.634e-01
8.176e+00	3.185e+00	9.670e-01
8.247e+00	3.192e+00	9.704e-01
8.319e+00	3.200e+00	9.739e-01
8.392e+00	3.207e+00	9.773e-01
8.465e+00	3.216e+00	9.806e-01
8.539e+00	3.224e+00	9.839e-01
8.613e+00	3.233e+00	9.870e-01
8.689e+00	3.242e+00	9.901e-01
8.764e+00	3.253e+00	9.947e-01
8.841e+00	3.265e+00	9.933e-01
8.918e+00	3.273e+00	9.894e-01
8.996e+00	3.278e+00	9.922e-01
9.074e+00	3.287e+00	9.945e-01
9.154e+00	3.297e+00	9.982e-01
9.233e+00	3.310e+00	9.972e-01
9.314e+00	3.319e+00	9.911e-01
9.395e+00	3.325e+00	9.905e-01
9.477e+00	3.333e+00	9.907e-01
9.560e+00	3.341e+00	9.883e-01
9.644e+00	3.348e+00	9.856e-01
9.728e+00	3.354e+00	9.842e-01
9.813e+00	3.361e+00	9.832e-01
9.898e+00	3.369e+00	9.819e-01
9.985e+00	3.376e+00	9.775e-01
1.007e+01	3.381e+00	9.746e-01
1.016e+01	3.385e+00	9.689e-01
1.025e+01	3.386e+00	9.672e-01
1.034e+01	3.390e+00	9.695e-01
1.043e+01	3.396e+00	9.667e-01
1.052e+01	3.397e+00	9.628e-01
1.061e+01	3.398e+00	9.650e-01
1.070e+01	3.403e+00	9.686e-01
1.080e+01	3.408e+00	9.669e-01
1.089e+01	3.412e+00	9.671e-01
1.099e+01	3.415e+00	9.645e-01
1.108e+01	3.416e+00	9.666e-01
1.118e+01	3.419e+00	9.702e-01
1.128e+01	3.425e+00	9.718e-01
1.137e+01	3.429e+00	9.709e-01
1.147e+01	3.432e+00	9.732e-01
1.157e+01	3.436e+00	9.741e-01
1.168e+01	3.439e+00	9.759e-01
1.178e+01	3.444e+00	9.792e-01
1.188e+01	3.450e+00	9.786e-01
1.198e+01	3.452e+00	9.775e-01
1.209e+01	3.454e+00	9.794e-01
1.219e+01	3.454e+00	9.808e-01
1.230e+01	3.457e+00	9.898e-01
1.241e+01	3.464e+00	9.922e-01
1.252e+01	3.469e+00	9.942e-01
1.262e+01	3.472e+00	9.967e-01
1.274e+01	3.478e+00	1.004e+00
1.285e+01	3.486e+00	1.006e+00
1.296e+01	3.491e+00	1.005e+00
1.307e+01	3.494e+00	1.009e+00
1.319e+01	3.500e+00	1.015e+00
1.330e+01	3.508e+00	1.018e+00
1.342e+01	3.514e+00	1.019e+00
1.353e+01	3.520e+00	1.023e+00
1.365e+01	3.527e+00	1.026e+00
1.377e+01	3.535e+00	1.030e+00
1.389e+01	3.544e+00	1.031e+00
1.401e+01	3.551e+00	1.032e+00
1.413e+01	3.560e+00	1.033e+00
1.426e+01	3.568e+00	1.030e+00
1.438e+01	3.572e+00	1.027e+00
1.451e+01	3.578e+00	1.032e+00

1.463e+01	3.584e+00	1.026e+00
1.476e+01	3.586e+00	1.029e+00
1.489e+01	3.591e+00	1.030e+00
1.502e+01	3.597e+00	1.033e+00
1.515e+01	3.604e+00	1.031e+00
1.528e+01	3.607e+00	1.029e+00
1.542e+01	3.611e+00	1.034e+00
1.555e+01	3.618e+00	1.035e+00
1.569e+01	3.623e+00	1.032e+00
1.583e+01	3.627e+00	1.036e+00
1.596e+01	3.632e+00	1.033e+00
1.610e+01	3.633e+00	1.034e+00
1.624e+01	3.638e+00	1.038e+00
1.638e+01	3.642e+00	1.036e+00
1.653e+01	3.644e+00	1.039e+00
1.667e+01	3.648e+00	1.042e+00
1.682e+01	3.651e+00	1.044e+00
1.696e+01	3.655e+00	1.049e+00
1.711e+01	3.659e+00	1.051e+00
1.726e+01	3.666e+00	1.058e+00
1.741e+01	3.675e+00	1.057e+00
1.756e+01	3.679e+00	1.056e+00
1.772e+01	3.681e+00	1.057e+00
1.787e+01	3.685e+00	1.062e+00
1.803e+01	3.692e+00	1.067e+00
1.819e+01	3.698e+00	1.063e+00
1.834e+01	3.700e+00	1.065e+00
1.850e+01	3.702e+00	1.067e+00
1.867e+01	3.705e+00	1.073e+00
1.883e+01	3.710e+00	1.074e+00
1.899e+01	3.714e+00	1.080e+00
1.916e+01	3.718e+00	1.081e+00
1.933e+01	3.722e+00	1.087e+00
1.950e+01	3.726e+00	1.089e+00
1.967e+01	3.730e+00	1.095e+00
1.984e+01	3.731e+00	1.095e+00
2.001e+01	3.731e+00	1.108e+00
2.018e+01	3.739e+00	1.123e+00
2.036e+01	3.754e+00	1.132e+00
2.054e+01	3.769e+00	1.135e+00
2.072e+01	3.781e+00	1.134e+00
2.090e+01	3.790e+00	1.132e+00
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2.126e+01	3.801e+00	1.132e+00
2.145e+01	3.806e+00	1.134e+00
2.164e+01	3.812e+00	1.138e+00
2.183e+01	3.820e+00	1.142e+00
2.202e+01	3.828e+00	1.145e+00
2.221e+01	3.836e+00	1.147e+00
2.240e+01	3.844e+00	1.148e+00
2.260e+01	3.852e+00	1.149e+00
2.280e+01	3.859e+00	1.149e+00
2.299e+01	3.865e+00	1.150e+00
2.320e+01	3.871e+00	1.150e+00
2.340e+01	3.877e+00	1.151e+00
2.360e+01	3.882e+00	1.153e+00
2.381e+01	3.887e+00	1.155e+00
2.402e+01	3.892e+00	1.157e+00
2.423e+01	3.897e+00	1.160e+00
2.444e+01	3.902e+00	1.163e+00
2.465e+01	3.907e+00	1.166e+00
2.487e+01	3.913e+00	1.169e+00
2.508e+01	3.919e+00	1.173e+00
2.530e+01	3.926e+00	1.177e+00
2.552e+01	3.933e+00	1.180e+00
2.574e+01	3.940e+00	1.184e+00
2.597e+01	3.947e+00	1.187e+00
2.620e+01	3.955e+00	1.189e+00
2.642e+01	3.962e+00	1.191e+00
2.666e+01	3.968e+00	1.193e+00
2.689e+01	3.974e+00	1.195e+00
2.712e+01	3.980e+00	1.198e+00
2.736e+01	3.985e+00	1.201e+00
2.760e+01	3.991e+00	1.205e+00
2.784e+01	3.998e+00	1.209e+00
2.808e+01	4.005e+00	1.213e+00
2.833e+01	4.012e+00	1.218e+00

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2.882e+01	4.026e+00	1.226e+00
2.908e+01	4.034e+00	1.231e+00
2.933e+01	4.042e+00	1.236e+00
2.959e+01	4.051e+00	1.241e+00
2.984e+01	4.061e+00	1.246e+00
3.010e+01	4.072e+00	1.250e+00
3.037e+01	4.082e+00	1.253e+00
3.063e+01	4.093e+00	1.256e+00
3.090e+01	4.103e+00	1.258e+00
3.117e+01	4.113e+00	1.262e+00
3.144e+01	4.125e+00	1.265e+00
3.171e+01	4.138e+00	1.268e+00
3.199e+01	4.152e+00	1.269e+00
3.227e+01	4.165e+00	1.266e+00
3.255e+01	4.178e+00	1.262e+00
3.284e+01	4.187e+00	1.257e+00
3.312e+01	4.195e+00	1.253e+00
3.341e+01	4.201e+00	1.250e+00
3.370e+01	4.207e+00	1.248e+00
3.400e+01	4.213e+00	1.247e+00
3.429e+01	4.219e+00	1.246e+00
3.459e+01	4.226e+00	1.246e+00
3.490e+01	4.232e+00	1.245e+00
3.520e+01	4.239e+00	1.244e+00
3.551e+01	4.245e+00	1.242e+00
3.582e+01	4.250e+00	1.240e+00
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3.708e+01	4.269e+00	1.241e+00
3.741e+01	4.273e+00	1.241e+00
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4.188e+01	4.339e+00	1.282e+00
4.225e+01	4.351e+00	1.287e+00
4.262e+01	4.362e+00	1.290e+00
4.299e+01	4.372e+00	1.292e+00
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4.374e+01	4.393e+00	1.298e+00
4.412e+01	4.405e+00	1.299e+00
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4.490e+01	4.425e+00	1.294e+00
4.529e+01	4.433e+00	1.293e+00
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4.813e+01	4.476e+00	1.293e+00
4.855e+01	4.483e+00	1.292e+00
4.897e+01	4.489e+00	1.292e+00
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5.342e+01	4.549e+00	1.309e+00
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5.483e+01	4.571e+00	1.319e+00
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5.579e+01	4.588e+00	1.318e+00
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5.677e+01	4.598e+00	1.321e+00
5.727e+01	4.605e+00	1.323e+00
5.776e+01	4.612e+00	1.325e+00
5.827e+01	4.619e+00	1.326e+00
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5.929e+01	4.629e+00	1.330e+00
5.981e+01	4.636e+00	1.336e+00
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6.086e+01	4.655e+00	1.339e+00
6.139e+01	4.663e+00	1.339e+00
6.192e+01	4.670e+00	1.340e+00
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6.301e+01	4.681e+00	1.339e+00
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6.411e+01	4.692e+00	1.347e+00
6.467e+01	4.701e+00	1.351e+00
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6.638e+01	4.723e+00	1.352e+00
6.696e+01	4.731e+00	1.356e+00
6.755e+01	4.740e+00	1.354e+00
6.813e+01	4.745e+00	1.352e+00
6.873e+01	4.748e+00	1.354e+00
6.933e+01	4.754e+00	1.357e+00
6.993e+01	4.760e+00	1.359e+00
7.054e+01	4.766e+00	1.360e+00
7.116e+01	4.772e+00	1.362e+00
7.178e+01	4.778e+00	1.364e+00
7.241e+01	4.783e+00	1.364e+00
7.304e+01	4.785e+00	1.366e+00
7.368e+01	4.790e+00	1.373e+00
7.432e+01	4.798e+00	1.377e+00
7.497e+01	4.803e+00	1.377e+00
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7.628e+01	4.817e+00	1.388e+00
7.695e+01	4.823e+00	1.387e+00
7.762e+01	4.828e+00	1.394e+00
7.830e+01	4.836e+00	1.397e+00
7.898e+01	4.841e+00	1.396e+00
7.967e+01	4.844e+00	1.401e+00
8.037e+01	4.849e+00	1.408e+00
8.107e+01	4.855e+00	1.414e+00
8.177e+01	4.862e+00	1.420e+00
8.249e+01	4.870e+00	1.426e+00
8.321e+01	4.877e+00	1.431e+00
8.393e+01	4.886e+00	1.437e+00
8.467e+01	4.894e+00	1.443e+00
8.541e+01	4.903e+00	1.448e+00
8.615e+01	4.913e+00	1.455e+00
8.690e+01	4.926e+00	1.461e+00
8.766e+01	4.934e+00	1.457e+00
8.843e+01	4.936e+00	1.462e+00
8.920e+01	4.946e+00	1.477e+00
8.998e+01	4.960e+00	1.481e+00
9.076e+01	4.971e+00	1.486e+00
9.155e+01	4.985e+00	1.493e+00
9.235e+01	5.001e+00	1.493e+00
9.316e+01	5.011e+00	1.488e+00
9.397e+01	5.018e+00	1.493e+00
9.479e+01	5.031e+00	1.499e+00
9.562e+01	5.044e+00	1.495e+00
9.646e+01	5.048e+00	1.491e+00
9.730e+01	5.050e+00	1.500e+00
9.815e+01	5.063e+00	1.514e+00
9.900e+01	5.080e+00	1.517e+00
9.987e+01	5.098e+00	1.522e+00
1.007e+02	5.114e+00	1.514e+00
1.016e+02	5.125e+00	1.515e+00
1.025e+02	5.138e+00	1.511e+00
1.034e+02	5.145e+00	1.504e+00
1.043e+02	5.153e+00	1.509e+00
1.052e+02	5.167e+00	1.508e+00
1.061e+02	5.175e+00	1.497e+00
1.071e+02	5.178e+00	1.499e+00
1.080e+02	5.185e+00	1.500e+00

1.089e+02	5.193e+00	1.500e+00
1.099e+02	5.200e+00	1.501e+00
1.108e+02	5.208e+00	1.501e+00
1.118e+02	5.216e+00	1.501e+00
1.128e+02	5.224e+00	1.501e+00
1.138e+02	5.232e+00	1.500e+00
1.148e+02	5.238e+00	1.499e+00
1.158e+02	5.245e+00	1.499e+00
1.168e+02	5.246e+00	1.495e+00
1.178e+02	5.249e+00	1.508e+00
1.188e+02	5.259e+00	1.508e+00
1.199e+02	5.267e+00	1.513e+00
1.209e+02	5.277e+00	1.515e+00
1.220e+02	5.287e+00	1.517e+00
1.230e+02	5.295e+00	1.514e+00
1.241e+02	5.299e+00	1.515e+00
1.252e+02	5.304e+00	1.520e+00
1.263e+02	5.312e+00	1.525e+00
1.274e+02	5.323e+00	1.529e+00
1.285e+02	5.335e+00	1.531e+00
1.296e+02	5.345e+00	1.529e+00
1.307e+02	5.351e+00	1.526e+00
1.319e+02	5.355e+00	1.529e+00
1.330e+02	5.362e+00	1.533e+00
1.342e+02	5.371e+00	1.537e+00
1.354e+02	5.380e+00	1.538e+00
1.365e+02	5.388e+00	1.539e+00
1.377e+02	5.396e+00	1.540e+00
1.389e+02	5.403e+00	1.540e+00
1.402e+02	5.409e+00	1.543e+00
1.414e+02	5.417e+00	1.546e+00
1.426e+02	5.425e+00	1.547e+00
1.439e+02	5.433e+00	1.548e+00
1.451e+02	5.440e+00	1.548e+00
1.464e+02	5.446e+00	1.548e+00
1.477e+02	5.450e+00	1.549e+00
1.489e+02	5.454e+00	1.551e+00
1.502e+02	5.457e+00	1.555e+00
1.516e+02	5.461e+00	1.562e+00
1.529e+02	5.466e+00	1.569e+00
1.542e+02	5.473e+00	1.578e+00
1.556e+02	5.482e+00	1.587e+00
1.569e+02	5.493e+00	1.595e+00
1.583e+02	5.506e+00	1.603e+00
1.597e+02	5.521e+00	1.608e+00
1.611e+02	5.536e+00	1.610e+00
1.625e+02	5.550e+00	1.610e+00
1.639e+02	5.562e+00	1.609e+00
1.653e+02	5.573e+00	1.606e+00
1.668e+02	5.581e+00	1.603e+00
1.682e+02	5.588e+00	1.601e+00
1.697e+02	5.593e+00	1.600e+00
1.712e+02	5.596e+00	1.600e+00
1.727e+02	5.600e+00	1.603e+00
1.742e+02	5.604e+00	1.607e+00
1.757e+02	5.608e+00	1.612e+00
1.772e+02	5.614e+00	1.619e+00
1.788e+02	5.620e+00	1.626e+00
1.803e+02	5.628e+00	1.633e+00
1.819e+02	5.636e+00	1.640e+00
1.835e+02	5.646e+00	1.648e+00
1.851e+02	5.656e+00	1.655e+00
1.867e+02	5.667e+00	1.661e+00
1.883e+02	5.679e+00	1.668e+00
1.900e+02	5.691e+00	1.673e+00
1.916e+02	5.703e+00	1.678e+00
1.933e+02	5.716e+00	1.682e+00
1.950e+02	5.729e+00	1.686e+00
1.967e+02	5.741e+00	1.689e+00
1.984e+02	5.754e+00	1.692e+00
2.001e+02	5.766e+00	1.694e+00
2.019e+02	5.778e+00	1.695e+00
2.036e+02	5.790e+00	1.697e+00
2.054e+02	5.801e+00	1.698e+00
2.072e+02	5.812e+00	1.699e+00
2.090e+02	5.822e+00	1.700e+00
2.109e+02	5.832e+00	1.700e+00

2.127e+02	5.841e+00	1.702e+00
2.145e+02	5.849e+00	1.703e+00
2.164e+02	5.857e+00	1.705e+00
2.183e+02	5.865e+00	1.708e+00
2.202e+02	5.873e+00	1.713e+00
2.221e+02	5.881e+00	1.718e+00
2.241e+02	5.891e+00	1.725e+00
2.260e+02	5.902e+00	1.731e+00
2.280e+02	5.914e+00	1.737e+00
2.300e+02	5.928e+00	1.743e+00
2.320e+02	5.943e+00	1.747e+00
2.340e+02	5.957e+00	1.750e+00
2.361e+02	5.971e+00	1.751e+00
2.381e+02	5.985e+00	1.753e+00
2.402e+02	5.998e+00	1.753e+00
2.423e+02	6.011e+00	1.754e+00
2.444e+02	6.024e+00	1.754e+00
2.466e+02	6.036e+00	1.754e+00
2.487e+02	6.048e+00	1.754e+00
2.509e+02	6.059e+00	1.753e+00
2.531e+02	6.070e+00	1.753e+00
2.553e+02	6.081e+00	1.752e+00
2.575e+02	6.091e+00	1.752e+00
2.597e+02	6.100e+00	1.751e+00
2.620e+02	6.109e+00	1.751e+00
2.643e+02	6.117e+00	1.751e+00
2.666e+02	6.124e+00	1.752e+00
2.689e+02	6.131e+00	1.754e+00
2.713e+02	6.138e+00	1.759e+00
2.736e+02	6.147e+00	1.764e+00
2.760e+02	6.157e+00	1.770e+00
2.784e+02	6.169e+00	1.776e+00
2.809e+02	6.183e+00	1.781e+00
2.833e+02	6.197e+00	1.784e+00
2.858e+02	6.211e+00	1.786e+00
2.883e+02	6.224e+00	1.787e+00
2.908e+02	6.236e+00	1.788e+00
2.934e+02	6.249e+00	1.790e+00
2.959e+02	6.261e+00	1.791e+00
2.985e+02	6.274e+00	1.792e+00
3.011e+02	6.287e+00	1.793e+00
3.037e+02	6.299e+00	1.793e+00
3.064e+02	6.310e+00	1.792e+00
3.091e+02	6.322e+00	1.792e+00
3.117e+02	6.332e+00	1.793e+00
3.145e+02	6.343e+00	1.794e+00
3.172e+02	6.354e+00	1.795e+00
3.200e+02	6.365e+00	1.797e+00
3.228e+02	6.376e+00	1.799e+00
3.256e+02	6.389e+00	1.801e+00
3.284e+02	6.402e+00	1.802e+00
3.313e+02	6.415e+00	1.802e+00
3.342e+02	6.428e+00	1.802e+00
3.371e+02	6.440e+00	1.801e+00
3.401e+02	6.452e+00	1.800e+00
3.430e+02	6.463e+00	1.800e+00
3.460e+02	6.475e+00	1.800e+00
3.490e+02	6.488e+00	1.799e+00
3.521e+02	6.500e+00	1.796e+00
3.552e+02	6.511e+00	1.793e+00
3.583e+02	6.519e+00	1.789e+00
3.614e+02	6.526e+00	1.789e+00
3.645e+02	6.533e+00	1.790e+00
3.677e+02	6.542e+00	1.793e+00
3.709e+02	6.554e+00	1.796e+00
3.742e+02	6.566e+00	1.797e+00
3.774e+02	6.578e+00	1.796e+00
3.807e+02	6.589e+00	1.794e+00
3.840e+02	6.597e+00	1.791e+00
3.874e+02	6.603e+00	1.789e+00
3.908e+02	6.607e+00	1.791e+00
3.942e+02	6.613e+00	1.798e+00
3.976e+02	6.624e+00	1.807e+00
4.011e+02	6.639e+00	1.812e+00
4.046e+02	6.654e+00	1.814e+00
4.081e+02	6.667e+00	1.813e+00
4.117e+02	6.678e+00	1.814e+00

4.153e+02	6.690e+00	1.817e+00
4.189e+02	6.704e+00	1.819e+00
4.226e+02	6.718e+00	1.820e+00
4.263e+02	6.732e+00	1.819e+00
4.300e+02	6.744e+00	1.818e+00
4.337e+02	6.756e+00	1.819e+00
4.375e+02	6.769e+00	1.820e+00
4.413e+02	6.783e+00	1.820e+00
4.452e+02	6.798e+00	1.818e+00
4.491e+02	6.811e+00	1.815e+00
4.530e+02	6.824e+00	1.812e+00
4.569e+02	6.836e+00	1.809e+00
4.609e+02	6.847e+00	1.806e+00
4.649e+02	6.858e+00	1.803e+00
4.690e+02	6.868e+00	1.800e+00
4.731e+02	6.878e+00	1.797e+00
4.772e+02	6.888e+00	1.794e+00
4.814e+02	6.897e+00	1.791e+00
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4.941e+02	6.924e+00	1.785e+00
4.984e+02	6.932e+00	1.783e+00
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5.072e+02	6.948e+00	1.780e+00
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5.160e+02	6.964e+00	1.778e+00
5.206e+02	6.971e+00	1.778e+00
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5.297e+02	6.986e+00	1.777e+00
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5.390e+02	7.001e+00	1.779e+00
5.437e+02	7.009e+00	1.780e+00
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5.532e+02	7.024e+00	1.783e+00
5.580e+02	7.032e+00	1.786e+00
5.629e+02	7.040e+00	1.788e+00
5.678e+02	7.049e+00	1.791e+00
5.728e+02	7.058e+00	1.794e+00
5.778e+02	7.067e+00	1.797e+00
5.828e+02	7.077e+00	1.800e+00
5.879e+02	7.087e+00	1.804e+00
5.930e+02	7.097e+00	1.807e+00
5.982e+02	7.108e+00	1.810e+00
6.034e+02	7.119e+00	1.814e+00
6.087e+02	7.131e+00	1.817e+00
6.140e+02	7.143e+00	1.820e+00
6.194e+02	7.155e+00	1.823e+00
6.248e+02	7.168e+00	1.825e+00
6.302e+02	7.181e+00	1.827e+00
6.357e+02	7.194e+00	1.829e+00
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6.525e+02	7.235e+00	1.832e+00
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6.639e+02	7.262e+00	1.832e+00
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6.756e+02	7.289e+00	1.831e+00
6.815e+02	7.303e+00	1.829e+00
6.874e+02	7.316e+00	1.828e+00
6.934e+02	7.328e+00	1.826e+00
6.995e+02	7.341e+00	1.824e+00
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7.117e+02	7.365e+00	1.820e+00
7.180e+02	7.377e+00	1.817e+00
7.242e+02	7.388e+00	1.815e+00
7.305e+02	7.400e+00	1.812e+00
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7.434e+02	7.421e+00	1.807e+00
7.498e+02	7.432e+00	1.805e+00
7.564e+02	7.442e+00	1.802e+00
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7.696e+02	7.463e+00	1.798e+00
7.764e+02	7.473e+00	1.795e+00
7.831e+02	7.483e+00	1.793e+00
7.900e+02	7.492e+00	1.791e+00
7.969e+02	7.502e+00	1.789e+00
8.038e+02	7.512e+00	1.787e+00

8.108e+02	7.521e+00	1.785e+00
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8.251e+02	7.540e+00	1.780e+00
8.323e+02	7.550e+00	1.778e+00
8.395e+02	7.559e+00	1.776e+00
8.468e+02	7.568e+00	1.774e+00
8.542e+02	7.577e+00	1.772e+00
8.617e+02	7.585e+00	1.770e+00
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8.768e+02	7.602e+00	1.765e+00
8.845e+02	7.610e+00	1.763e+00
8.922e+02	7.618e+00	1.761e+00
9.000e+02	7.625e+00	1.760e+00
9.078e+02	7.633e+00	1.758e+00
9.157e+02	7.640e+00	1.757e+00
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9.318e+02	7.654e+00	1.754e+00
9.399e+02	7.660e+00	1.754e+00
9.481e+02	7.667e+00	1.754e+00
9.564e+02	7.673e+00	1.754e+00
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9.732e+02	7.687e+00	1.755e+00
9.817e+02	7.693e+00	1.756e+00
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1.016e+03	7.722e+00	1.762e+00
1.025e+03	7.729e+00	1.764e+00
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1.043e+03	7.744e+00	1.769e+00
1.052e+03	7.752e+00	1.771e+00
1.062e+03	7.760e+00	1.774e+00
1.071e+03	7.769e+00	1.776e+00
1.080e+03	7.777e+00	1.779e+00
1.090e+03	7.785e+00	1.782e+00
1.099e+03	7.794e+00	1.784e+00
1.109e+03	7.802e+00	1.787e+00
1.118e+03	7.811e+00	1.790e+00
1.128e+03	7.820e+00	1.794e+00
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1.148e+03	7.838e+00	1.800e+00
1.158e+03	7.848e+00	1.804e+00
1.168e+03	7.857e+00	1.808e+00
1.178e+03	7.867e+00	1.811e+00
1.188e+03	7.877e+00	1.815e+00
1.199e+03	7.887e+00	1.819e+00
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1.231e+03	7.918e+00	1.832e+00
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1.252e+03	7.941e+00	1.842e+00
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1.274e+03	7.965e+00	1.851e+00
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1.308e+03	8.006e+00	1.865e+00
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1.354e+03	8.066e+00	1.880e+00
1.366e+03	8.082e+00	1.883e+00
1.378e+03	8.098e+00	1.885e+00
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1.402e+03	8.130e+00	1.888e+00
1.414e+03	8.147e+00	1.889e+00
1.426e+03	8.163e+00	1.890e+00
1.439e+03	8.180e+00	1.891e+00
1.451e+03	8.196e+00	1.891e+00
1.464e+03	8.214e+00	1.891e+00
1.477e+03	8.231e+00	1.891e+00
1.490e+03	8.250e+00	1.891e+00
1.503e+03	8.268e+00	1.889e+00
1.516e+03	8.288e+00	1.887e+00
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1.542e+03	8.327e+00	1.878e+00
1.556e+03	8.346e+00	1.871e+00
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1.583e+03	8.383e+00	1.854e+00
1.597e+03	8.399e+00	1.844e+00
1.611e+03	8.414e+00	1.832e+00
1.625e+03	8.428e+00	1.821e+00
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1.668e+03	8.460e+00	1.784e+00
1.682e+03	8.468e+00	1.773e+00
1.697e+03	8.475e+00	1.761e+00
1.712e+03	8.481e+00	1.751e+00
1.727e+03	8.486e+00	1.741e+00
1.742e+03	8.490e+00	1.732e+00
1.757e+03	8.493e+00	1.724e+00
1.773e+03	8.496e+00	1.716e+00
1.788e+03	8.499e+00	1.710e+00
1.804e+03	8.501e+00	1.703e+00
1.819e+03	8.502e+00	1.698e+00
1.835e+03	8.504e+00	1.693e+00
1.851e+03	8.504e+00	1.688e+00
1.867e+03	8.505e+00	1.685e+00
1.884e+03	8.505e+00	1.681e+00
1.900e+03	8.504e+00	1.679e+00
1.917e+03	8.502e+00	1.676e+00
1.933e+03	8.498e+00	1.674e+00
1.950e+03	8.492e+00	1.672e+00
1.967e+03	8.479e+00	1.671e+00
1.984e+03	8.435e+00	1.670e+00

A.3 Amorphous carbon, BE sample

```
# wavelength in micron, 'n' and 'k'
# of amorphous carbon
#
# BE sample
#
# Reference:
# Zubko V.G., Mennella V., Colangeli L., Bussoletti E., 1996
# MNRAS, 282, 1321

  w(micron)  n          k
  5.024e-02  9.410e-01  7.788e-02
  5.067e-02  9.345e-01  8.309e-02
  5.112e-02  9.305e-01  8.826e-02
  5.156e-02  9.274e-01  9.335e-02
  5.201e-02  9.250e-01  9.835e-02
  5.247e-02  9.231e-01  1.033e-01
  5.292e-02  9.216e-01  1.081e-01
  5.339e-02  9.204e-01  1.128e-01
  5.385e-02  9.194e-01  1.174e-01
  5.432e-02  9.188e-01  1.220e-01
  5.480e-02  9.183e-01  1.264e-01
  5.527e-02  9.180e-01  1.308e-01
  5.576e-02  9.180e-01  1.350e-01
  5.624e-02  9.180e-01  1.392e-01
  5.673e-02  9.182e-01  1.432e-01
  5.723e-02  9.185e-01  1.472e-01
  5.773e-02  9.190e-01  1.510e-01
  5.823e-02  9.195e-01  1.548e-01
  5.874e-02  9.201e-01  1.584e-01
  5.925e-02  9.208e-01  1.619e-01
  5.977e-02  9.216e-01  1.654e-01
  6.029e-02  9.224e-01  1.687e-01
  6.082e-02  9.232e-01  1.719e-01
  6.135e-02  9.241e-01  1.750e-01
  6.189e-02  9.249e-01  1.781e-01
  6.243e-02  9.258e-01  1.811e-01
  6.297e-02  9.266e-01  1.840e-01
  6.352e-02  9.275e-01  1.868e-01
  6.407e-02  9.283e-01  1.896e-01
  6.463e-02  9.291e-01  1.924e-01
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  6.577e-02  9.305e-01  1.978e-01
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1.541e+00	2.758e+00	1.113e+00
1.555e+00	2.764e+00	1.112e+00
1.569e+00	2.770e+00	1.111e+00
1.582e+00	2.775e+00	1.111e+00
1.596e+00	2.781e+00	1.110e+00
1.610e+00	2.787e+00	1.109e+00
1.624e+00	2.793e+00	1.107e+00
1.638e+00	2.799e+00	1.106e+00
1.652e+00	2.804e+00	1.105e+00
1.667e+00	2.810e+00	1.104e+00
1.681e+00	2.815e+00	1.103e+00
1.696e+00	2.821e+00	1.101e+00
1.711e+00	2.826e+00	1.100e+00
1.726e+00	2.832e+00	1.099e+00
1.741e+00	2.837e+00	1.097e+00
1.756e+00	2.842e+00	1.096e+00
1.771e+00	2.846e+00	1.095e+00
1.787e+00	2.851e+00	1.094e+00
1.802e+00	2.856e+00	1.094e+00
1.818e+00	2.860e+00	1.093e+00
1.834e+00	2.865e+00	1.093e+00
1.850e+00	2.870e+00	1.093e+00
1.866e+00	2.875e+00	1.093e+00
1.883e+00	2.881e+00	1.093e+00
1.899e+00	2.886e+00	1.093e+00
1.916e+00	2.892e+00	1.092e+00
1.932e+00	2.898e+00	1.092e+00
1.949e+00	2.904e+00	1.091e+00
1.966e+00	2.909e+00	1.090e+00
1.983e+00	2.915e+00	1.089e+00
2.001e+00	2.920e+00	1.088e+00
2.018e+00	2.926e+00	1.087e+00
2.036e+00	2.931e+00	1.086e+00
2.053e+00	2.936e+00	1.085e+00
2.071e+00	2.941e+00	1.084e+00
2.089e+00	2.946e+00	1.083e+00
2.108e+00	2.951e+00	1.082e+00
2.126e+00	2.956e+00	1.082e+00
2.145e+00	2.960e+00	1.081e+00
2.163e+00	2.965e+00	1.080e+00
2.182e+00	2.970e+00	1.079e+00
2.201e+00	2.975e+00	1.079e+00
2.220e+00	2.979e+00	1.078e+00
2.240e+00	2.984e+00	1.078e+00
2.259e+00	2.989e+00	1.077e+00
2.279e+00	2.993e+00	1.077e+00
2.299e+00	2.997e+00	1.076e+00
2.319e+00	3.002e+00	1.076e+00
2.339e+00	3.006e+00	1.076e+00
2.360e+00	3.011e+00	1.076e+00
2.380e+00	3.016e+00	1.076e+00
2.401e+00	3.021e+00	1.076e+00
2.422e+00	3.026e+00	1.076e+00
2.443e+00	3.031e+00	1.076e+00

2.465e+00	3.036e+00	1.075e+00
2.486e+00	3.041e+00	1.075e+00
2.508e+00	3.046e+00	1.074e+00
2.530e+00	3.050e+00	1.072e+00
2.552e+00	3.054e+00	1.071e+00
2.574e+00	3.057e+00	1.070e+00
2.596e+00	3.060e+00	1.069e+00
2.619e+00	3.063e+00	1.069e+00
2.642e+00	3.066e+00	1.070e+00
2.665e+00	3.069e+00	1.072e+00
2.688e+00	3.072e+00	1.073e+00
2.712e+00	3.076e+00	1.075e+00
2.735e+00	3.081e+00	1.077e+00
2.759e+00	3.086e+00	1.079e+00
2.783e+00	3.091e+00	1.080e+00
2.808e+00	3.097e+00	1.081e+00
2.832e+00	3.102e+00	1.081e+00
2.857e+00	3.107e+00	1.081e+00
2.882e+00	3.112e+00	1.081e+00
2.907e+00	3.116e+00	1.081e+00
2.932e+00	3.120e+00	1.081e+00
2.958e+00	3.123e+00	1.082e+00
2.984e+00	3.127e+00	1.083e+00
3.010e+00	3.131e+00	1.084e+00
3.036e+00	3.134e+00	1.085e+00
3.063e+00	3.138e+00	1.087e+00
3.089e+00	3.143e+00	1.089e+00
3.116e+00	3.147e+00	1.092e+00
3.143e+00	3.152e+00	1.094e+00
3.171e+00	3.157e+00	1.096e+00
3.199e+00	3.163e+00	1.099e+00
3.226e+00	3.169e+00	1.101e+00
3.255e+00	3.176e+00	1.103e+00
3.283e+00	3.184e+00	1.104e+00
3.312e+00	3.191e+00	1.103e+00
3.341e+00	3.197e+00	1.100e+00
3.370e+00	3.201e+00	1.098e+00
3.399e+00	3.203e+00	1.096e+00
3.429e+00	3.205e+00	1.097e+00
3.459e+00	3.207e+00	1.100e+00
3.489e+00	3.211e+00	1.104e+00
3.519e+00	3.217e+00	1.106e+00
3.550e+00	3.223e+00	1.108e+00
3.581e+00	3.228e+00	1.109e+00
3.612e+00	3.232e+00	1.110e+00
3.644e+00	3.236e+00	1.112e+00
3.676e+00	3.241e+00	1.114e+00
3.708e+00	3.247e+00	1.116e+00
3.740e+00	3.252e+00	1.118e+00
3.773e+00	3.258e+00	1.119e+00
3.806e+00	3.263e+00	1.121e+00
3.839e+00	3.269e+00	1.123e+00
3.872e+00	3.276e+00	1.125e+00
3.906e+00	3.283e+00	1.124e+00
3.940e+00	3.289e+00	1.122e+00
3.975e+00	3.292e+00	1.120e+00
4.009e+00	3.293e+00	1.122e+00
4.044e+00	3.296e+00	1.128e+00
4.080e+00	3.305e+00	1.134e+00
4.115e+00	3.317e+00	1.134e+00
4.151e+00	3.325e+00	1.127e+00
4.187e+00	3.325e+00	1.120e+00
4.224e+00	3.322e+00	1.122e+00
4.261e+00	3.323e+00	1.131e+00
4.298e+00	3.331e+00	1.139e+00
4.335e+00	3.343e+00	1.139e+00
4.373e+00	3.350e+00	1.134e+00
4.411e+00	3.351e+00	1.131e+00
4.450e+00	3.352e+00	1.133e+00
4.489e+00	3.355e+00	1.137e+00
4.528e+00	3.361e+00	1.141e+00
4.568e+00	3.368e+00	1.142e+00
4.607e+00	3.373e+00	1.142e+00
4.648e+00	3.378e+00	1.142e+00
4.688e+00	3.381e+00	1.143e+00
4.729e+00	3.385e+00	1.145e+00
4.770e+00	3.390e+00	1.148e+00

4.812e+00	3.397e+00	1.149e+00
4.854e+00	3.403e+00	1.150e+00
4.896e+00	3.409e+00	1.149e+00
4.939e+00	3.414e+00	1.148e+00
4.982e+00	3.419e+00	1.148e+00
5.026e+00	3.423e+00	1.146e+00
5.070e+00	3.427e+00	1.144e+00
5.114e+00	3.429e+00	1.143e+00
5.158e+00	3.431e+00	1.144e+00
5.203e+00	3.433e+00	1.144e+00
5.249e+00	3.436e+00	1.145e+00
5.295e+00	3.439e+00	1.144e+00
5.341e+00	3.441e+00	1.143e+00
5.387e+00	3.441e+00	1.143e+00
5.434e+00	3.441e+00	1.144e+00
5.482e+00	3.443e+00	1.146e+00
5.530e+00	3.446e+00	1.146e+00
5.578e+00	3.446e+00	1.144e+00
5.627e+00	3.444e+00	1.143e+00
5.676e+00	3.441e+00	1.144e+00
5.725e+00	3.437e+00	1.145e+00
5.775e+00	3.430e+00	1.147e+00
5.826e+00	3.422e+00	1.157e+00
5.877e+00	3.421e+00	1.172e+00
5.928e+00	3.427e+00	1.179e+00
5.980e+00	3.427e+00	1.177e+00
6.032e+00	3.418e+00	1.182e+00
6.084e+00	3.410e+00	1.197e+00
6.138e+00	3.408e+00	1.215e+00
6.191e+00	3.409e+00	1.234e+00
6.245e+00	3.416e+00	1.256e+00
6.300e+00	3.432e+00	1.276e+00
6.355e+00	3.452e+00	1.282e+00
6.410e+00	3.466e+00	1.280e+00
6.466e+00	3.470e+00	1.278e+00
6.522e+00	3.470e+00	1.285e+00
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6.695e+00	3.497e+00	1.304e+00
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6.812e+00	3.500e+00	1.310e+00
6.872e+00	3.502e+00	1.318e+00
6.931e+00	3.505e+00	1.325e+00
6.992e+00	3.506e+00	1.333e+00
7.053e+00	3.507e+00	1.344e+00
7.115e+00	3.511e+00	1.358e+00
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7.239e+00	3.524e+00	1.386e+00
7.302e+00	3.535e+00	1.400e+00
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7.431e+00	3.557e+00	1.418e+00
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7.561e+00	3.578e+00	1.437e+00
7.627e+00	3.589e+00	1.447e+00
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7.760e+00	3.616e+00	1.460e+00
7.828e+00	3.624e+00	1.463e+00
7.897e+00	3.629e+00	1.473e+00
7.965e+00	3.640e+00	1.490e+00
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8.105e+00	3.672e+00	1.502e+00
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8.247e+00	3.701e+00	1.518e+00
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8.392e+00	3.726e+00	1.520e+00
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8.539e+00	3.747e+00	1.537e+00
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8.689e+00	3.783e+00	1.546e+00
8.764e+00	3.797e+00	1.547e+00
8.841e+00	3.810e+00	1.546e+00
8.918e+00	3.820e+00	1.547e+00
8.996e+00	3.832e+00	1.556e+00
9.074e+00	3.850e+00	1.557e+00
9.154e+00	3.863e+00	1.554e+00
9.233e+00	3.874e+00	1.558e+00
9.314e+00	3.892e+00	1.564e+00

9.395e+00	3.910e+00	1.552e+00
9.477e+00	3.915e+00	1.545e+00
9.560e+00	3.924e+00	1.553e+00
9.644e+00	3.941e+00	1.548e+00
9.728e+00	3.948e+00	1.538e+00
9.813e+00	3.954e+00	1.545e+00
9.898e+00	3.967e+00	1.539e+00
9.985e+00	3.972e+00	1.532e+00
1.007e+01	3.978e+00	1.536e+00
1.016e+01	3.989e+00	1.534e+00
1.025e+01	3.996e+00	1.524e+00
1.034e+01	3.997e+00	1.522e+00
1.043e+01	4.001e+00	1.523e+00
1.052e+01	4.002e+00	1.513e+00
1.061e+01	3.995e+00	1.517e+00
1.070e+01	3.996e+00	1.531e+00
1.080e+01	4.004e+00	1.534e+00
1.089e+01	4.009e+00	1.536e+00
1.099e+01	4.008e+00	1.536e+00
1.108e+01	4.006e+00	1.548e+00
1.118e+01	4.014e+00	1.566e+00
1.128e+01	4.024e+00	1.569e+00
1.137e+01	4.033e+00	1.583e+00
1.147e+01	4.048e+00	1.589e+00
1.157e+01	4.061e+00	1.591e+00
1.168e+01	4.071e+00	1.592e+00
1.178e+01	4.080e+00	1.594e+00
1.188e+01	4.084e+00	1.593e+00
1.198e+01	4.090e+00	1.607e+00
1.209e+01	4.105e+00	1.611e+00
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1.230e+01	4.127e+00	1.611e+00
1.241e+01	4.138e+00	1.610e+00
1.252e+01	4.138e+00	1.594e+00
1.262e+01	4.131e+00	1.607e+00
1.274e+01	4.128e+00	1.605e+00
1.285e+01	4.120e+00	1.629e+00
1.296e+01	4.130e+00	1.655e+00
1.307e+01	4.147e+00	1.671e+00
1.319e+01	4.170e+00	1.692e+00
1.330e+01	4.198e+00	1.694e+00
1.342e+01	4.221e+00	1.694e+00
1.353e+01	4.243e+00	1.687e+00
1.365e+01	4.254e+00	1.670e+00
1.377e+01	4.257e+00	1.668e+00
1.389e+01	4.257e+00	1.661e+00
1.401e+01	4.258e+00	1.675e+00
1.413e+01	4.268e+00	1.677e+00
1.426e+01	4.279e+00	1.689e+00
1.438e+01	4.296e+00	1.687e+00
1.451e+01	4.304e+00	1.680e+00
1.463e+01	4.309e+00	1.683e+00
1.476e+01	4.316e+00	1.681e+00
1.489e+01	4.318e+00	1.681e+00
1.502e+01	4.320e+00	1.689e+00
1.515e+01	4.326e+00	1.696e+00
1.528e+01	4.335e+00	1.707e+00
1.542e+01	4.351e+00	1.712e+00
1.555e+01	4.363e+00	1.707e+00
1.569e+01	4.368e+00	1.706e+00
1.583e+01	4.370e+00	1.703e+00
1.596e+01	4.368e+00	1.708e+00
1.610e+01	4.371e+00	1.724e+00
1.624e+01	4.377e+00	1.729e+00
1.638e+01	4.385e+00	1.748e+00
1.653e+01	4.404e+00	1.758e+00
1.667e+01	4.421e+00	1.758e+00
1.682e+01	4.431e+00	1.753e+00
1.696e+01	4.434e+00	1.754e+00
1.711e+01	4.434e+00	1.757e+00
1.726e+01	4.437e+00	1.777e+00
1.741e+01	4.455e+00	1.791e+00
1.756e+01	4.472e+00	1.793e+00
1.772e+01	4.484e+00	1.795e+00
1.787e+01	4.494e+00	1.801e+00
1.803e+01	4.506e+00	1.804e+00
1.819e+01	4.519e+00	1.813e+00

1.834e+01	4.535e+00	1.813e+00
1.850e+01	4.548e+00	1.814e+00
1.867e+01	4.561e+00	1.814e+00
1.883e+01	4.571e+00	1.807e+00
1.899e+01	4.580e+00	1.811e+00
1.916e+01	4.587e+00	1.801e+00
1.933e+01	4.587e+00	1.804e+00
1.950e+01	4.591e+00	1.807e+00
1.967e+01	4.591e+00	1.806e+00
1.984e+01	4.594e+00	1.823e+00
2.001e+01	4.606e+00	1.826e+00
2.018e+01	4.610e+00	1.824e+00
2.036e+01	4.608e+00	1.832e+00
2.054e+01	4.609e+00	1.845e+00
2.072e+01	4.616e+00	1.862e+00
2.090e+01	4.629e+00	1.879e+00
2.108e+01	4.646e+00	1.891e+00
2.126e+01	4.664e+00	1.898e+00
2.145e+01	4.681e+00	1.900e+00
2.164e+01	4.694e+00	1.900e+00
2.183e+01	4.704e+00	1.900e+00
2.202e+01	4.712e+00	1.902e+00
2.221e+01	4.717e+00	1.906e+00
2.240e+01	4.724e+00	1.913e+00
2.260e+01	4.732e+00	1.922e+00
2.280e+01	4.741e+00	1.931e+00
2.299e+01	4.753e+00	1.940e+00
2.320e+01	4.766e+00	1.948e+00
2.340e+01	4.780e+00	1.954e+00
2.360e+01	4.793e+00	1.960e+00
2.381e+01	4.805e+00	1.964e+00
2.402e+01	4.817e+00	1.968e+00
2.423e+01	4.829e+00	1.972e+00
2.444e+01	4.840e+00	1.977e+00
2.465e+01	4.851e+00	1.981e+00
2.487e+01	4.862e+00	1.985e+00
2.508e+01	4.872e+00	1.990e+00
2.530e+01	4.883e+00	1.995e+00
2.552e+01	4.893e+00	2.000e+00
2.574e+01	4.903e+00	2.005e+00
2.597e+01	4.914e+00	2.011e+00
2.620e+01	4.925e+00	2.017e+00
2.642e+01	4.936e+00	2.024e+00
2.666e+01	4.949e+00	2.030e+00
2.689e+01	4.962e+00	2.036e+00
2.712e+01	4.976e+00	2.041e+00
2.736e+01	4.989e+00	2.044e+00
2.760e+01	5.001e+00	2.047e+00
2.784e+01	5.012e+00	2.050e+00
2.808e+01	5.022e+00	2.054e+00
2.833e+01	5.031e+00	2.059e+00
2.857e+01	5.042e+00	2.065e+00
2.882e+01	5.052e+00	2.071e+00
2.908e+01	5.064e+00	2.079e+00
2.933e+01	5.077e+00	2.086e+00
2.959e+01	5.091e+00	2.093e+00
2.984e+01	5.106e+00	2.099e+00
3.010e+01	5.121e+00	2.103e+00
3.037e+01	5.136e+00	2.105e+00
3.063e+01	5.150e+00	2.107e+00
3.090e+01	5.163e+00	2.109e+00
3.117e+01	5.174e+00	2.111e+00
3.144e+01	5.186e+00	2.115e+00
3.171e+01	5.199e+00	2.119e+00
3.199e+01	5.213e+00	2.121e+00
3.227e+01	5.226e+00	2.122e+00
3.255e+01	5.238e+00	2.123e+00
3.284e+01	5.248e+00	2.123e+00
3.312e+01	5.257e+00	2.124e+00
3.341e+01	5.266e+00	2.127e+00
3.370e+01	5.276e+00	2.131e+00
3.400e+01	5.286e+00	2.135e+00
3.429e+01	5.296e+00	2.137e+00
3.459e+01	5.305e+00	2.140e+00
3.490e+01	5.313e+00	2.145e+00
3.520e+01	5.321e+00	2.151e+00
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3.582e+01	5.344e+00	2.167e+00
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3.645e+01	5.373e+00	2.175e+00
3.676e+01	5.385e+00	2.176e+00
3.708e+01	5.395e+00	2.178e+00
3.741e+01	5.405e+00	2.182e+00
3.773e+01	5.415e+00	2.187e+00
3.806e+01	5.427e+00	2.191e+00
3.840e+01	5.438e+00	2.194e+00
3.873e+01	5.449e+00	2.197e+00
3.907e+01	5.459e+00	2.201e+00
3.941e+01	5.470e+00	2.206e+00
3.975e+01	5.481e+00	2.211e+00
4.010e+01	5.494e+00	2.214e+00
4.045e+01	5.505e+00	2.215e+00
4.080e+01	5.513e+00	2.216e+00
4.116e+01	5.520e+00	2.220e+00
4.152e+01	5.527e+00	2.226e+00
4.188e+01	5.536e+00	2.234e+00
4.225e+01	5.547e+00	2.241e+00
4.262e+01	5.559e+00	2.248e+00
4.299e+01	5.572e+00	2.253e+00
4.336e+01	5.584e+00	2.257e+00
4.374e+01	5.595e+00	2.261e+00
4.412e+01	5.605e+00	2.264e+00
4.451e+01	5.614e+00	2.267e+00
4.490e+01	5.621e+00	2.273e+00
4.529e+01	5.630e+00	2.282e+00
4.568e+01	5.641e+00	2.292e+00
4.608e+01	5.655e+00	2.300e+00
4.649e+01	5.671e+00	2.305e+00
4.689e+01	5.685e+00	2.308e+00
4.730e+01	5.696e+00	2.310e+00
4.771e+01	5.705e+00	2.312e+00
4.813e+01	5.713e+00	2.318e+00
4.855e+01	5.724e+00	2.327e+00
4.897e+01	5.738e+00	2.334e+00
4.940e+01	5.752e+00	2.337e+00
4.983e+01	5.762e+00	2.337e+00
5.027e+01	5.770e+00	2.341e+00
5.071e+01	5.778e+00	2.348e+00
5.115e+01	5.788e+00	2.356e+00
5.159e+01	5.799e+00	2.362e+00
5.204e+01	5.810e+00	2.368e+00
5.250e+01	5.822e+00	2.374e+00
5.296e+01	5.833e+00	2.380e+00
5.342e+01	5.844e+00	2.384e+00
5.389e+01	5.853e+00	2.390e+00
5.436e+01	5.862e+00	2.398e+00
5.483e+01	5.874e+00	2.406e+00
5.531e+01	5.886e+00	2.411e+00
5.579e+01	5.896e+00	2.415e+00
5.628e+01	5.903e+00	2.422e+00
5.677e+01	5.912e+00	2.434e+00
5.727e+01	5.926e+00	2.446e+00
5.776e+01	5.943e+00	2.453e+00
5.827e+01	5.957e+00	2.455e+00
5.878e+01	5.967e+00	2.457e+00
5.929e+01	5.974e+00	2.465e+00
5.981e+01	5.986e+00	2.476e+00
6.033e+01	6.001e+00	2.480e+00
6.086e+01	6.008e+00	2.480e+00
6.139e+01	6.011e+00	2.488e+00
6.192e+01	6.017e+00	2.505e+00
6.246e+01	6.030e+00	2.520e+00
6.301e+01	6.046e+00	2.534e+00
6.356e+01	6.065e+00	2.546e+00
6.411e+01	6.086e+00	2.551e+00
6.467e+01	6.100e+00	2.548e+00
6.524e+01	6.105e+00	2.551e+00
6.581e+01	6.111e+00	2.566e+00
6.638e+01	6.126e+00	2.584e+00
6.696e+01	6.149e+00	2.596e+00
6.755e+01	6.170e+00	2.594e+00
6.813e+01	6.180e+00	2.590e+00
6.873e+01	6.184e+00	2.597e+00
6.933e+01	6.192e+00	2.608e+00

6.993e+01	6.202e+00	2.621e+00
7.054e+01	6.217e+00	2.635e+00
7.116e+01	6.234e+00	2.645e+00
7.178e+01	6.248e+00	2.650e+00
7.241e+01	6.261e+00	2.661e+00
7.304e+01	6.277e+00	2.673e+00
7.368e+01	6.293e+00	2.677e+00
7.432e+01	6.305e+00	2.686e+00
7.497e+01	6.321e+00	2.698e+00
7.562e+01	6.337e+00	2.702e+00
7.628e+01	6.348e+00	2.709e+00
7.695e+01	6.360e+00	2.720e+00
7.762e+01	6.370e+00	2.728e+00
7.830e+01	6.382e+00	2.749e+00
7.898e+01	6.413e+00	2.775e+00
7.967e+01	6.446e+00	2.766e+00
8.037e+01	6.455e+00	2.752e+00
8.107e+01	6.452e+00	2.761e+00
8.177e+01	6.463e+00	2.788e+00
8.249e+01	6.487e+00	2.804e+00
8.321e+01	6.511e+00	2.811e+00
8.393e+01	6.534e+00	2.820e+00
8.467e+01	6.564e+00	2.826e+00
8.541e+01	6.584e+00	2.808e+00
8.615e+01	6.580e+00	2.797e+00
8.690e+01	6.582e+00	2.826e+00
8.766e+01	6.604e+00	2.839e+00
8.843e+01	6.621e+00	2.841e+00
8.920e+01	6.633e+00	2.853e+00
8.998e+01	6.656e+00	2.870e+00
9.076e+01	6.679e+00	2.867e+00
9.155e+01	6.692e+00	2.868e+00
9.235e+01	6.705e+00	2.876e+00
9.316e+01	6.720e+00	2.881e+00
9.397e+01	6.735e+00	2.886e+00
9.479e+01	6.745e+00	2.889e+00
9.562e+01	6.756e+00	2.903e+00
9.646e+01	6.775e+00	2.914e+00
9.730e+01	6.791e+00	2.915e+00
9.815e+01	6.800e+00	2.920e+00
9.900e+01	6.810e+00	2.936e+00
9.987e+01	6.830e+00	2.952e+00
1.007e+02	6.849e+00	2.955e+00
1.016e+02	6.861e+00	2.964e+00
1.025e+02	6.879e+00	2.982e+00
1.034e+02	6.902e+00	2.989e+00
1.043e+02	6.920e+00	2.993e+00
1.052e+02	6.941e+00	3.006e+00
1.061e+02	6.963e+00	3.004e+00
1.071e+02	6.974e+00	3.005e+00
1.080e+02	6.990e+00	3.018e+00
1.089e+02	7.004e+00	3.016e+00
1.099e+02	7.014e+00	3.028e+00
1.108e+02	7.029e+00	3.041e+00
1.118e+02	7.051e+00	3.055e+00
1.128e+02	7.070e+00	3.053e+00
1.138e+02	7.081e+00	3.061e+00
1.148e+02	7.095e+00	3.074e+00
1.158e+02	7.113e+00	3.085e+00
1.168e+02	7.132e+00	3.096e+00
1.178e+02	7.157e+00	3.109e+00
1.188e+02	7.177e+00	3.104e+00
1.199e+02	7.188e+00	3.112e+00
1.209e+02	7.204e+00	3.123e+00
1.220e+02	7.222e+00	3.133e+00
1.230e+02	7.243e+00	3.143e+00
1.241e+02	7.268e+00	3.151e+00
1.252e+02	7.284e+00	3.142e+00
1.263e+02	7.293e+00	3.153e+00
1.274e+02	7.308e+00	3.162e+00
1.285e+02	7.319e+00	3.168e+00
1.296e+02	7.333e+00	3.190e+00
1.307e+02	7.359e+00	3.205e+00
1.319e+02	7.385e+00	3.211e+00
1.330e+02	7.413e+00	3.218e+00
1.342e+02	7.429e+00	3.205e+00
1.354e+02	7.434e+00	3.212e+00

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1.377e+02	7.469e+00	3.246e+00
1.389e+02	7.492e+00	3.250e+00
1.402e+02	7.511e+00	3.255e+00
1.414e+02	7.528e+00	3.261e+00
1.426e+02	7.544e+00	3.268e+00
1.439e+02	7.561e+00	3.276e+00
1.451e+02	7.578e+00	3.285e+00
1.464e+02	7.595e+00	3.295e+00
1.477e+02	7.613e+00	3.305e+00
1.489e+02	7.632e+00	3.315e+00
1.502e+02	7.651e+00	3.325e+00
1.516e+02	7.671e+00	3.335e+00
1.529e+02	7.691e+00	3.344e+00
1.542e+02	7.711e+00	3.353e+00
1.556e+02	7.732e+00	3.362e+00
1.569e+02	7.753e+00	3.371e+00
1.583e+02	7.774e+00	3.380e+00
1.597e+02	7.795e+00	3.389e+00
1.611e+02	7.816e+00	3.397e+00
1.625e+02	7.838e+00	3.405e+00
1.639e+02	7.861e+00	3.413e+00
1.653e+02	7.884e+00	3.420e+00
1.668e+02	7.907e+00	3.427e+00
1.682e+02	7.930e+00	3.432e+00
1.697e+02	7.953e+00	3.436e+00
1.712e+02	7.974e+00	3.439e+00
1.727e+02	7.994e+00	3.440e+00
1.742e+02	8.012e+00	3.442e+00
1.757e+02	8.028e+00	3.445e+00
1.772e+02	8.042e+00	3.449e+00
1.788e+02	8.055e+00	3.456e+00
1.803e+02	8.069e+00	3.466e+00
1.819e+02	8.083e+00	3.480e+00
1.835e+02	8.101e+00	3.495e+00
1.851e+02	8.122e+00	3.511e+00
1.867e+02	8.146e+00	3.526e+00
1.883e+02	8.173e+00	3.540e+00
1.900e+02	8.202e+00	3.550e+00
1.916e+02	8.232e+00	3.557e+00
1.933e+02	8.260e+00	3.560e+00
1.950e+02	8.286e+00	3.562e+00
1.967e+02	8.310e+00	3.563e+00
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2.001e+02	8.351e+00	3.567e+00
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2.036e+02	8.391e+00	3.577e+00
2.054e+02	8.412e+00	3.583e+00
2.072e+02	8.434e+00	3.589e+00
2.090e+02	8.457e+00	3.594e+00
2.109e+02	8.479e+00	3.599e+00
2.127e+02	8.502e+00	3.601e+00
2.145e+02	8.523e+00	3.604e+00
2.164e+02	8.542e+00	3.606e+00
2.183e+02	8.561e+00	3.609e+00
2.202e+02	8.578e+00	3.614e+00
2.221e+02	8.596e+00	3.620e+00
2.241e+02	8.615e+00	3.627e+00
2.260e+02	8.636e+00	3.635e+00
2.280e+02	8.657e+00	3.642e+00
2.300e+02	8.680e+00	3.648e+00
2.320e+02	8.701e+00	3.652e+00
2.340e+02	8.721e+00	3.655e+00
2.361e+02	8.740e+00	3.659e+00
2.381e+02	8.757e+00	3.664e+00
2.402e+02	8.775e+00	3.672e+00
2.423e+02	8.793e+00	3.682e+00
2.444e+02	8.815e+00	3.694e+00
2.466e+02	8.839e+00	3.705e+00
2.487e+02	8.867e+00	3.713e+00
2.509e+02	8.895e+00	3.718e+00
2.531e+02	8.921e+00	3.719e+00
2.553e+02	8.944e+00	3.717e+00
2.575e+02	8.964e+00	3.716e+00
2.597e+02	8.981e+00	3.717e+00
2.620e+02	8.997e+00	3.722e+00
2.643e+02	9.015e+00	3.729e+00

2.666e+02	9.034e+00	3.736e+00
2.689e+02	9.055e+00	3.744e+00
2.713e+02	9.077e+00	3.750e+00
2.736e+02	9.098e+00	3.754e+00
2.760e+02	9.118e+00	3.758e+00
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2.809e+02	9.155e+00	3.769e+00
2.833e+02	9.175e+00	3.777e+00
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2.883e+02	9.218e+00	3.794e+00
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2.985e+02	9.304e+00	3.811e+00
3.011e+02	9.322e+00	3.817e+00
3.037e+02	9.340e+00	3.824e+00
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3.091e+02	9.379e+00	3.842e+00
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3.145e+02	9.420e+00	3.861e+00
3.172e+02	9.442e+00	3.871e+00
3.200e+02	9.464e+00	3.882e+00
3.228e+02	9.488e+00	3.894e+00
3.256e+02	9.515e+00	3.906e+00
3.284e+02	9.544e+00	3.916e+00
3.313e+02	9.575e+00	3.923e+00
3.342e+02	9.605e+00	3.927e+00
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3.401e+02	9.658e+00	3.931e+00
3.430e+02	9.683e+00	3.934e+00
3.460e+02	9.708e+00	3.937e+00
3.490e+02	9.733e+00	3.940e+00
3.521e+02	9.759e+00	3.943e+00
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3.583e+02	9.810e+00	3.949e+00
3.614e+02	9.836e+00	3.951e+00
3.645e+02	9.865e+00	3.953e+00
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3.709e+02	9.924e+00	3.946e+00
3.742e+02	9.949e+00	3.934e+00
3.774e+02	9.968e+00	3.922e+00
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3.840e+02	9.988e+00	3.902e+00
3.874e+02	9.992e+00	3.899e+00
3.908e+02	9.995e+00	3.903e+00
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4.263e+02	1.016e+01	4.030e+00
4.300e+02	1.018e+01	4.042e+00
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4.413e+02	1.025e+01	4.077e+00
4.452e+02	1.027e+01	4.090e+00
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4.530e+02	1.033e+01	4.115e+00
4.569e+02	1.035e+01	4.126e+00
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4.731e+02	1.047e+01	4.158e+00
4.772e+02	1.050e+01	4.164e+00
4.814e+02	1.052e+01	4.170e+00
4.856e+02	1.055e+01	4.175e+00
4.898e+02	1.058e+01	4.179e+00
4.941e+02	1.061e+01	4.183e+00
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5.028e+02	1.066e+01	4.189e+00
5.072e+02	1.069e+01	4.192e+00
5.116e+02	1.071e+01	4.194e+00
5.160e+02	1.074e+01	4.197e+00

5.206e+02	1.076e+01	4.199e+00
5.251e+02	1.079e+01	4.201e+00
5.297e+02	1.081e+01	4.203e+00
5.343e+02	1.084e+01	4.205e+00
5.390e+02	1.086e+01	4.208e+00
5.437e+02	1.088e+01	4.210e+00
5.484e+02	1.091e+01	4.213e+00
5.532e+02	1.093e+01	4.215e+00
5.580e+02	1.095e+01	4.218e+00
5.629e+02	1.097e+01	4.221e+00
5.678e+02	1.100e+01	4.225e+00
5.728e+02	1.102e+01	4.228e+00
5.778e+02	1.104e+01	4.232e+00
5.828e+02	1.106e+01	4.236e+00
5.879e+02	1.108e+01	4.241e+00
5.930e+02	1.110e+01	4.245e+00
5.982e+02	1.112e+01	4.250e+00
6.034e+02	1.115e+01	4.255e+00
6.087e+02	1.117e+01	4.261e+00
6.140e+02	1.119e+01	4.267e+00
6.194e+02	1.121e+01	4.272e+00
6.248e+02	1.123e+01	4.279e+00
6.302e+02	1.125e+01	4.285e+00
6.357e+02	1.127e+01	4.292e+00
6.413e+02	1.130e+01	4.299e+00
6.469e+02	1.132e+01	4.306e+00
6.525e+02	1.134e+01	4.314e+00
6.582e+02	1.136e+01	4.322e+00
6.639e+02	1.138e+01	4.330e+00
6.697e+02	1.141e+01	4.339e+00
6.756e+02	1.143e+01	4.347e+00
6.815e+02	1.145e+01	4.356e+00
6.874e+02	1.148e+01	4.365e+00
6.934e+02	1.150e+01	4.374e+00
6.995e+02	1.152e+01	4.383e+00
7.056e+02	1.155e+01	4.392e+00
7.117e+02	1.157e+01	4.401e+00
7.180e+02	1.160e+01	4.410e+00
7.242e+02	1.163e+01	4.419e+00
7.305e+02	1.165e+01	4.428e+00
7.369e+02	1.168e+01	4.436e+00
7.434e+02	1.171e+01	4.445e+00
7.498e+02	1.173e+01	4.454e+00
7.564e+02	1.176e+01	4.462e+00
7.630e+02	1.179e+01	4.470e+00
7.696e+02	1.181e+01	4.479e+00
7.764e+02	1.184e+01	4.486e+00
7.831e+02	1.187e+01	4.494e+00
7.900e+02	1.190e+01	4.501e+00
7.969e+02	1.193e+01	4.509e+00
8.038e+02	1.196e+01	4.515e+00
8.108e+02	1.199e+01	4.522e+00
8.179e+02	1.202e+01	4.528e+00
8.251e+02	1.205e+01	4.534e+00
8.323e+02	1.208e+01	4.539e+00
8.395e+02	1.211e+01	4.544e+00
8.468e+02	1.214e+01	4.549e+00
8.542e+02	1.217e+01	4.553e+00
8.617e+02	1.220e+01	4.557e+00
8.692e+02	1.222e+01	4.560e+00
8.768e+02	1.225e+01	4.564e+00
8.845e+02	1.228e+01	4.567e+00
8.922e+02	1.231e+01	4.569e+00
9.000e+02	1.234e+01	4.572e+00
9.078e+02	1.237e+01	4.574e+00
9.157e+02	1.240e+01	4.576e+00
9.237e+02	1.242e+01	4.579e+00
9.318e+02	1.245e+01	4.581e+00
9.399e+02	1.248e+01	4.583e+00
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9.564e+02	1.253e+01	4.587e+00
9.647e+02	1.256e+01	4.589e+00
9.732e+02	1.259e+01	4.591e+00
9.817e+02	1.261e+01	4.593e+00
9.902e+02	1.264e+01	4.595e+00
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1.008e+03	1.269e+01	4.599e+00

1.016e+03	1.272e+01	4.602e+00
1.025e+03	1.274e+01	4.604e+00
1.034e+03	1.277e+01	4.607e+00
1.043e+03	1.280e+01	4.610e+00
1.052e+03	1.282e+01	4.613e+00
1.062e+03	1.285e+01	4.616e+00
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1.099e+03	1.295e+01	4.630e+00
1.109e+03	1.298e+01	4.633e+00
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1.188e+03	1.319e+01	4.663e+00
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1.220e+03	1.326e+01	4.674e+00
1.231e+03	1.329e+01	4.678e+00
1.241e+03	1.332e+01	4.681e+00
1.252e+03	1.334e+01	4.685e+00
1.263e+03	1.337e+01	4.689e+00
1.274e+03	1.340e+01	4.693e+00
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1.296e+03	1.345e+01	4.700e+00
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1.390e+03	1.367e+01	4.728e+00
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1.867e+03	1.445e+01	4.889e+00
1.884e+03	1.449e+01	4.900e+00
1.900e+03	1.453e+01	4.909e+00
1.917e+03	1.456e+01	4.916e+00
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1.984e+03  1.471e+01  4.935e+00
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