Ultrasound Extinction Properties in The Milky Way

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Abstract
Microbial Model, an ancient idea, posits that microbial life is ubiquitous in the Universe. After several decades of almost irrational rejection, Astronomical data is shown to be consistent with the widespread distribution of complex organic molecules and dust particles that may have a biological provenance. A minuscule (10^{-21}) survival rate of freeze-dried bacteria in space is all that is needed to ensure the continual re-cycling of cosmic microbial life in the galaxy. The aim of this work is to study the nature of interstellar matter throughout Milky Way Galaxy via comparison of stellar spectrum of reddened and un reddened stars of some spectral classes the galactic plane. Observations of six regions in the Milky Way Galaxy were adopted via (IUE) data satellites. These observations are made through wavelength (0.4 - 8.4)\mu m^1. Extinction curve was compared with the microbial model, the results show good agreement with this curve, which explains the interstellar matter as a mixture of organic and inorganic particle of different size.

الخلاصة

النموذج البكتيري هو فكرة قديمة تفترض وجود الحياة الميكروبية في كل مكان في الكون. بعد عدة عقود من الرفض اللافعين أظهرت البيانات الفلكية تأسقا مع التوزيع اللفزي الانتشار للجزيئات العضوية المعقدة وجزيئات الغبار التي لها مصدر بيولوجي. نسبة البقاء للبكتريا المجففة المجمدة هي 10^{-21} وهو ما يحتاج لإعادة دراسة الحياة الميكروبية في المجرة. الهدف من هذه البحث هو دراسة خواص المادة التي يوجد النجوم في كافة أنحاء مجرة درب النبتان من خلال مقارنة الطيف للنجوم المجمدة وغير المجمدة والأرصاد الفلكية لستة مناطق أُخذت أرصادها عن طريق (IUE) حيث امتدت من 8.4 - 0.4 \mu m^{-1} وتم مقارنة منحنى الاعتمام مع النموذج البكتيري وأظهرت النتائج توافقا جيدا بينهما مما يفسر طبيعة المادة ما بين النجوم في مجرة درب النبتان على أنها خليط من المواد العضوية وغير العضوية بأحجام مختلفة.

1. Introduction
On the whole microbiological research of the past 10 years has shown that microorganisms are remarkably space-hardy. Thermophiles are present at temperatures above boiling point of water in oceanic thermal vents, and as we have already pointed out, entire ecologies of psychrophilic and psychrotrophic microorganisms are present in the frozen wastes of Antarctica. A formidable total mass of microbes also exists at great depths in the Earth's crust, some 8 km below the surface, greater than the biomass at the surface [1]. A species of
phototrophic sulfur bacterium has been recently recovered from the Black Sea that can perform photosynthesis at exceedingly low light levels, approaching near total darkness [2]. There are bacteria (e.g., Deinococcus radiodurans) that thrive within the cores of nuclear reactors [3]. Such bacteria perform the amazing feat of using an enzyme system to repair DNA damage, in cases where it is estimated that the DNA experienced as many as a million breaks in its helical structure. Most modern objections to microbiological have been based on arguments relating to cosmic ray survival it being claimed that cosmic ray exposures in space over hundreds of thousands of years would prove fatal for microorganisms. These criticisms are again insecure and, moreover, fail to take account of the fact that the replicative power of bacteria is so great that only a minute (10⁻¹⁰) survival is required at each regeneration site between periods of freeze-dried dormancy in the interstellar medium.

Ionising radiation limits viability by dislodging electrons, causing bond breaks in the DNA, and by forming reactive free radicals. The radiation doses that seriously compromise viability in cultures depend critically on the particular bacterial species, and as mentioned earlier some species such as B. subtilis and D. radiodurans are more resistant than others. In vegetative cultures, under laboratory conditions, doses equivalent to 2 Mrad have been found to limit residual viability of Streptococcus faecium by a factor of 10⁻⁶, whereas similar doses have little, or no effect on cultures of D. radiodurans or Micrococcus radiophilus [4]. The doses of ionising radiation received by a bacterium in interplanetary space within the solar system depends on distance from the sun and the phase of solar activity, being highest at times near the peak of the solar sunspot cycle. In a recent NASA/LDEF (Long Duration Exposure Facility) experiment, direct exposure of spores of B. subtilis to unshielded solar radiation for 2107 days was found to lead to significant rates of survival [5]. The survival of common species of bacteria near the Earth's orbit for about a decade therefore seems well-attested.

The dose of cosmic rays received by a naked bacterium in a typical location in interstellar space, over a timescale of a million years, can at present be only very poorly estimated. It is possibly in the range (10 – 45) Mrad per million years. Doses of this order are of course higher than the doses that have been delivered to laboratory cultures where survival is well-attested. Yet the exposure conditions in space, where two successive cosmic ray ionizing events are separated by about 100 years, would be dramatically different from those pertaining to the laboratory experiments. Most of the data on irradiation of bacteria have been obtained in the context of
food sterilization. It is found that the oxidising effects of free radicals, particularly OH, causes over 90% of DNA damage, and so reducing H2O content would drastically reduce the lethal effects of ionising radiation. Ionizing radiation delivered under anaerobic conditions with low O2 pressures is also found to diminish DNA damage. Low temperatures also go in the same direction by immobilising and preventing the diffusion of free radicals. Much more work is urgently needed to be done by cryobiologists to resolve these important issues.

2. The Extinction Basics

While the ultimate interpretation of results from extinction studies may be very complex, the measurements themselves for Galactic (and many extra-Galactic) sightlines are, in principle, straightforward. The most commonly used technique for deriving the $\lambda$-dependence of extinction, the “pair method,” is illustrated in idealized forming Figure 1. Measuring the extinction produced by an interstellar cloud requires photometric or spectrophotometric observations of the spectral energy distribution (SED) of some astronomical object — usually a star — located behind the cloud and identical measurements of an identical object located at an identical distance, but unaffected by interstellar dust. The total extinction in magnitudes at each wavelength $\lambda_\lambda$ (which is essentially a measure of the optical depth $\tau_\lambda$) is then simply computed from the ratios of the SEDs as shown in Figure 1. Note that the assumption implicit in this discussion is that the star is located far from the interstellar cloud (as indicated in Figure 1) and that no photons are scattered into the line of sight. Such an assumption is not necessarily valid in the case of extinction produced by circumstellar material.

Figure 1. A schematic illustration of the “Pair Method,” the principal technique used to study Milky Way

$$A_\lambda = -2.5 \log \left( \frac{F_\lambda}{F_\lambda^0} \right) = 1.086 \tau_\lambda$$

extinction.
Because reddened/unreddened star pairs are nearly never at the same distance and, in fact, the stellar distances are usually poorly determined, the total extinction \( A_\lambda \) is rarely computed directly. Instead, the stellar SEDs are usually normalized by the flux in a common wavelength region before computing the extinction. The usual choice for this is the optical V band. This normalized extinction \( A_{\lambda-V} \) (computed by substituting \( F_\lambda / F_V \) and \( F_\lambda^0 / F_V^0 \) into the equation in Figure 1) is also known as the color excess \( E(\lambda-V) \) and is related to the total extinction by \( E(\lambda-V) = A_\lambda - A_V \).

To effectively compare the \( \lambda \)-dependence of extinction among sightlines with very different quantities of interstellar dust, the color excess \( E(\lambda-V) \) itself must be normalized by some factor related to the amount of dust sampled. The optical color excess \( E(B-V) \) is usually employed for this purpose. This second normalization yields the most commonly found form for observed “extinction curves”, namely \( E(\lambda-V) / E(B-V) \). This normalized extinction is related to the total extinction \( A_\lambda \) through the relation \( E(\lambda-V) / E(B-V) = A_\lambda / E(B-V) - A_V / E(B-V) \). The quantity \( A_V / E(B-V) \), i.e., the ratio of total extinction to color excess in the optical region, is usually denoted RV. If its value can be determined for a line of sight, then the easily-measured normalized extinction can be converted into total extinction.

It has been noted often that \( E(B-V) \) is a less-than-ideal normalization factor. Certainly a physically unambiguous quantity, such as the dust mass column density, would be preferred, or even a measure of the total extinction at some particular wavelength, such as \( A_V \). However, the issue is simply measurability. We have no model-independent ways to assess dust mass and total extinction requires either that we have precise stellar distances or can measure the stellar SEDs in the far-IR where extinction is negligible. While IR photometry is now available for many stars through the 2MASS survey, the determination of total extinction from these data still requires assumptions about the \( \lambda \)-dependence of extinction longward of 2\( \mu \)m and can be compromised by emission or scattering by dust grains near the stars. In this paper, all the observed extinction curves will be presented in the standard form of \( E(\lambda-V) / E(B-V) \). Only in the case of model curves, and for illustrative purposes, will alternate normalizations be employed.

The quality of a pair method extinction curve clearly depends on how well a reddened object can be matched with an unreddened comparison object. Massa et al.[6] discuss the effects and magnitude of “mismatch errors” on extinction curves. In general, mismatch effects become less important as the amount of extinction increases, and strongly limit our ability to probe the \( \lambda \)-
dependence of extinction in lightly reddened sightlines, such as through the nearby interstellar medium and the galactic halo.

Several decades of work utilizing pair method extinction curves spanning the near-IR through UV spectral domain have provided a good estimate of the “average” λ-dependence of extinction in the Milky Way galaxy. Figure 2 shows the familiar shape of this “Average Galactic Extinction Curve”, plotted as E(λ−V)/E(B−V) vs. inverse wavelength. This type of presentation was clearly invented by UV astronomers to emphasize that spectral region, but also has the advantage of being essentially a plot of normalized extinction cross section vs. photon energy. The Average Curve itself is shown by the thick solid and dashed curve, with a number of specific features labeled.

The most prominent feature in the curve is the “bump” at 2175 Å. This has been shown to be a pure absorption feature with a Lorentzian-like cross section, and likely arises from a specific physical process occurring on a specific although currently unidentified type of dust grain. The mean profile of the bump is shown by the dash-dot curve at the bottom of the figure. If the profile of the bump is removed from the extinction curve, the underlying extinction in its vicinity is seen to be linear and its slope can be used to characterize the steepness of UV extinction (“UV slope” in Figure 2). At wavelengths shortward of ≈1500 Å the extinction departs from the linear extrapolation, rising more rapidly and generally with pronounced curvature (“FUV rise” in Figure 2).

Figure 2. The average Milky Way extinction curve, corresponding to the case RV = 3.1, as computed by Fitzpatrick 1999.[7]
Probably the most outstanding observational characteristic of interstellar extinction is its spatial variability. Its shown the graphically in Figure 3 where analytic fits to 96 Galactic extinction curves are overplotted, in the form E(\(\lambda - V\))/E(B -V). Only the highly constrained IR, optical, and UV spectral regions are shown. Here they simply serve to demonstrate the degree of variability found along Milky Way sightlines. This variability is a two-edged sword. It can provide endless misery to those who seek to correct astronomical observations for the effects of extinction, but also a wealth of data for those who model the interstellar dust grain populations. The extinction variations presumably reflect general differences in the grain populations from sight-line to sightline. Understanding how the various spectral regions of the curves relate to each other and how they respond to changes in the interstellar environments can provide information critical for characterizing interstellar grains. [8]

![Figure 3. These illustrate the wide range of extinction properties observed in the Milky Way.][8]

**3. The microbial Mode**

In late 1970s, Prof. Sir Fred Hoyle and Prof. Chandra Wickramasinghe and Jabir,[9] have argued that interstellar grains have a biogenic origin, being generally similar in character to terrestrial microorganisms. They first argued that interstellar extinction data over the visual waveband could be explained with remarkable precision by terrestrially determined size distribution of space forming bacteria, provided account is
taken of the evacuation of free water under interstellar condition. Later proposed that interstellar grains are distributed between three main classes of particles.

1- Bacterial grains in the form of long hollow needles with cavities due to evacuation of water. The average refractive index (m) has been taken to be m=n-ik, where n is equal to 1.149, 1.16 and 1.167 and k is varied in the range 0.0 To 0.25 with mean radius=1/3 μm.

2- Graphite spherical particles of mean radius 0.02 μm and complex refractive index is wavelength dependent.

3- Small dielectric spheres, of radius 0.04 μm, and complex refractive index varied with wavelength.

In the three-component model the smaller dielectric component was identified with mycoplasmas and the graphite spheres were taken to be degraded bacterial cells.

Jabir, [10] have used this model and the Mie formulae to compute the extinction properties of the spherical grain species of component 2 and 3 and the corresponding formulae for infinite cylinders to compute the properties of cylindrical bacterial grains species of component 1. The combined extinction behavior of the three component model were calculated according to the expression:

$$ Q(\lambda) = \frac{Q_{ext}^{(1)}(\lambda)}{Q_{ext}^{(1)}(\lambda_0)} + w_g \frac{Q_{ext}^{(2)}(\lambda)}{Q_{ext}^{(2)}(\lambda_0)} + w_d \frac{Q_{ext}^{(3)}(\lambda)}{Q_{ext}^{(3)}(\lambda_0)} \quad \text{..................................(1)} $$

Where $Q_{ext}$ the efficiency factor for extinction and $\lambda=1.8 \mu m^{-1}$ and $w_g$ and $w_d$ are the weighting parameters specified such that the contribution from individual species to the extinction at $\lambda^{-1}=1.8 \mu m^{-1}$ are in the ratio:

Hollow needle(1):graphite(2):dielectric spheres(3)

1.0 : $w_g : w_d \quad \text{..................................(2)}$

The total extinction coefficient calculated from equation (1) and then normalized to obtain(22):

$$ \frac{E(\lambda - \nu)}{E(B - \nu)} = A + BQ(u) \quad \text{..................................(3)} $$

Where $E(\lambda - \nu)$ refers to the extinction in magnitude between a wavelength $\lambda$ and the $\nu$ band of the photometric UBV system. $E(B - \nu)$ is the $(B - \nu)$ colour excess in magnitude, and $A$ and $B$ are two normalization factors chosen so as to give two specified values of normalized extinction two specific wavelengths.[11]

4. Results and Discussion

Figures (4) to (9) shows plots of observed normalized extinction data for eleven region fitted with microbial model of interstellar dust grains that
obtained by using Mie formula to compute the extinction properties of the spherical grain species of both graphite and dielectric spheres and corresponding formulae for infinite cylinders to compute the properties of cylindrical bacterial grains species.

It was found here that the best fit between HD294264 observational data and microbial model was for \( m_1 = 1.16 - 0.015i \) of long hollow needle shape bacteria with mean radius 0.33 \( \mu \)m, as shown in fig.(4).

From studying Graphite spheres of mean refractive index \( m_2 = n - ik \), radius 0.02 \( \mu \)m and dielectric particle grains of mean refractive index \( m_3 = 1.5 - 0.0i \), mean radius 0.04 \( \mu \)m, the refractive indices of the spherical graphite grains were varied with wavelength. The relative proportion of three component bacterial model i.e. hollow needle: graphite: dielectric spheres are defined as \( \text{wb : wg : wd} \) and the contributions of each component are in the ratio 1.0 : 0.55 : 0.00005 respectively, normalization is to
\[
\Delta m = -25 \quad \text{at} \quad \lambda^{-1} = 0.4 \ \mu \text{m}^{-1}
\]
\[
\Delta m = -18 \quad \text{at} \quad \lambda^{-1} = 7 \ \mu \text{m}^{-1}
\]

And for BRUN885 It was found here that the best fit between observational data and microbial model was for \( m_1 = 1.16 - 0.015i \) of long hollow needle shape bacteria with mean radius 0.33 \( \mu \)m, as shown in fig.(5). From studying Graphite spheres of mean refractive index \( m_2 = n - ik \), radius 0.02 \( \mu \)m and dielectric particle grains of mean refractive index \( m_3 = 1.5 - 0.0i \), mean radius 0.04 \( \mu \)m, the refractive indices of the spherical graphite grains were varied with wavelength. The relative proportion of three component bacterial model i.e. hollow needle: graphite: dielectric spheres are defined as \( \text{wb : wg : wd} \) and the contributions of each component are in the ratio 1.0 : 0.2 : 0.00005 respectively, normalization is to
\[
\Delta m = -16 \quad \text{at} \quad \lambda^{-1} = 3.2 \ \mu \text{m}^{-1}
\]
\[
\Delta m = -14 \quad \text{at} \quad \lambda^{-1} = 5 \ \mu \text{m}^{-1}
\]

And for HD37061 It was found here that the best fit between observational data and microbial model was for \( m_1 = 1.16 - 0.015i \) of long hollow needle shape bacteria with mean radius 0.33 \( \mu \)m, as shown in fig.(6). From studying Graphite spheres of mean refractive index \( m_2 = n - ik \), radius 0.02 \( \mu \)m and dielectric particle grains of mean refractive index \( m_3 = 1.5 - 0.0i \), mean radius 0.04 \( \mu \)m, the refractive indices of the spherical graphite grains were varied with wavelength. The relative proportion of three component bacterial model i.e. hollow needle: graphite: dielectric spheres are defined as \( \text{wb : wg : wd} \) and the contributions of each component are in the ratio 1.0 : 0.01 : 0.0005 respectively, normalization is to
\[
\Delta m = -16 \quad \text{at} \quad \lambda^{-1} = 1.8 \ \mu \text{m}^{-1}
\]
Δm= -12 at $\lambda^{-1} = 4.8 \mu m^{-1}$

And for HD147888 It was found here that the best fit between observational data and microbial model was for $m_1 = 1.16 - 0.015i$ of long hollow needle shape bacteria with mean radius $0.33 \mu m$, as shown in fig.(7). From studying Graphite spheres of mean refractive index $m_2 = n - ik$, radius $0.02 \mu m$ and dielectric particle grains of mean refractive index $m_3 = 1.5 - 0.0i$, mean radius $0.04 \mu m$, the refractive indices of the spherical graphite grains were varied with wavelength. The relative proportion of three component bacterial model i.e. hollow needle: graphite: dielectric spheres are defined as $wb : wg : wd$ : and the contributions of each component are in the ratio $1.0 : 0.02 : 0.0005$ respectively, normalization is to

$\Delta m = -14$ at $\lambda^{-1} = 1.8 \mu m^{-1}$

$\Delta m = -11$ at $\lambda^{-1} = 5.8 \mu m^{-1}$

And for HD147701 It was found here that the best fit between observational data and microbial model was for $m_1 = 1.16 - 0.015i$ of long hollow needle shape bacteria with mean radius $0.33 \mu m$, as shown in fig.(8). From studying Graphite spheres of mean refractive index $m_2 = n - ik$, radius $0.02 \mu m$ and dielectric particle grains of mean refractive index $m_3 = 1.5 - 0.0i$, mean radius $0.04 \mu m$, the refractive indices of the spherical graphite grains were varied with wavelength. The relative proportion of three component bacterial model i.e. hollow needle: graphite: dielectric spheres are defined as $wb : wg : wd$ : and the contributions of each component are in the ratio $1.0 : 0.02 : 0.0005$ respectively, normalization is to

$\Delta m = -12$ at $\lambda^{-1} = 1.8 \mu m^{-1}$

$\Delta m = -6$ at $\lambda^{-1} = 8.2 \mu m^{-1}$

And for HD203068 It was found here that the best fit between observational data and microbial model was for $m_1 = 1.16 - 0.015i$ of long hollow needle shape bacteria with mean radius $0.33 \mu m$, as shown in fig.(9). From studying Graphite spheres of mean refractive index $m_2 = n - ik$, radius $0.02 \mu m$ and dielectric particle grains of mean refractive index $m_3 = 1.5 - 0.0i$, mean radius $0.04 \mu m$, the refractive indices of the spherical graphite grains were varied with wavelength. The relative proportion of three component bacterial model i.e. hollow needle: graphite: dielectric spheres are defined as $wb : wg : wd$ : and the contributions of each component are in the ratio $1.0 : 0.02 : 0.0005$ respectively, normalization is to

$\Delta m = -10$ at $\lambda^{-1} = 1.8 \mu m^{-1}$

$\Delta m = -5$ at $\lambda^{-1} = 6.6 \mu m^{-1}$

From figures, (4) to (9) it is obvious that there is a very close agreement between the observed extinction and microbial model, With some simple
differences because of disuniform distribution of grains and the differences in the density and volume of grains.

When the $2175\,\text{Å}$ bump was first detected, Hoyle and Wickramasinghe(12) immediately suggested that the feature was produced by interstellar graphite grains, which were taken to be degraded bacterial cell. Since that time graphite has become the most widely accepted explanation for the bump. It has been shown also by Fitzpatrik and Massa(13) that in addition to the bump, graphite model is also produce the upturn seen in the Milky way extinction curve and about half the selective extinction in the visual region. They found a good agreement with observational data of extinction in the infrared waveband.

5. Conclusions

The consideration which was put forward by Hoyle and Wickramasinghe concerning the responsibility of micro-organisms for producing the behavior of interstellar extinction was found more likely, there result and ours, reinforced this consideration. The absorbing materials which responsible for excess extinction over a band centered at $2175\,\text{Å}$ are required to be concentrated in irregularly distributed chromophores. The interior structures of micro-organisms are indeed highly irregular (organic matter comprising irregularities). These are small spheres and distributed randomly within the shell of an evacuated hollow bacterium, and provide several scales within them selves.

Computation of the detailed optical properties of eleven regions over the waveband $0.4\,\mu\text{m}^{-1} \leq \lambda^{-1} \leq 8.4\,\mu\text{m}^{-1}$ for three biologically derived components of this model is shown to be in close agreement with the observational data of interstellar dust extinction in Milky Way Galaxy.

![Figure (4): The Normalized Extinction Curve for HD294264 region Fitted with Microbial Model.](image-url)
Figure (5): The Normalized Extinction Curve for BRUN885 region Fitted with Microbial Model.

Figure (6): The Normalized Extinction Curve for HD37061 region Fitted with Microbial Model.
Figure (7): The Normalized Extinction Curve for HD147888 region Fitted with Microbial Model.

Figure (8): The Normalized Extinction Curve for HD147701 region Fitted with Microbial Model.
Figure (9): The Normalized Extinction Curve for HD303068 region Fitted with Microbial Model.

References