DEVELOPMENT OF A VIRTUAL SCATTERING LABORATORY SOFTWARE PACKAGE TO STUDY THE OPTICAL PROPERTIES OF COSMIC DUST AGGREGATES

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ABSTRACT

The following paper reports the development of a virtual scattering laboratory software package to study the optical properties of cosmic dust aggregates. This package consists of a Graphical User Interface (GUI) in the front hand and a database of related data's on the back hand. Both the interactive GUI and database package directly enables an astronomer to model by selfmonitoring respective input parameter (viz. wavelength, complex refractive index, grain size parameter, etc.) to study the related optical properties (viz. Extinction, polarization, etc.), of cosmic dust (interstellar dust, interplanetary dust, circumplanetary dust, intergalactic dust) instantly, i.e. with zero computational time, which directly increases the efficiency of the user. The database of different optical properties of the cosmic dust aggregates is generated in a very wide range using many leading mathematical models available (Superposition T-Matrix code, Discrete Dipole Approximation code) with high computational accuracy. This package also has an option where users can compile and run the scattering code directly for aggregates in GUI environment.

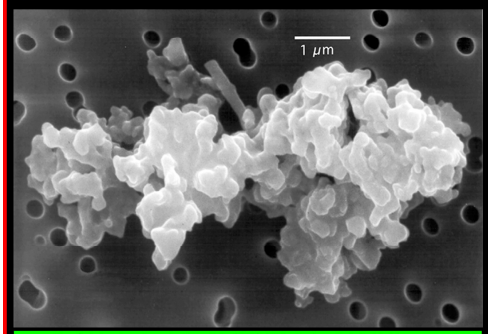


Fig. 1: Interplanetary dust particle (IDP). This dust particle is highly porous (Image courtesy: Jessberger et al. 2001).

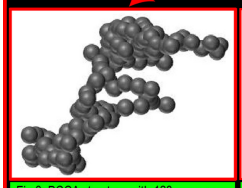


Fig.3: BCCA structure with 128 monomers (P ≈ 0.94, D ≈ 2) (Ref: Das et al. (2008a).

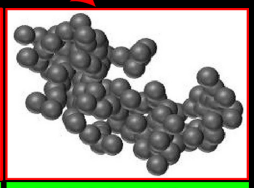
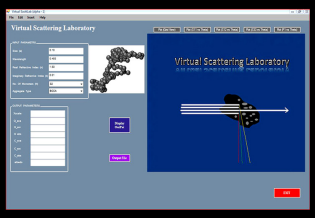
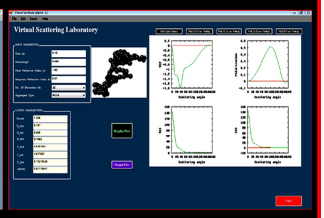


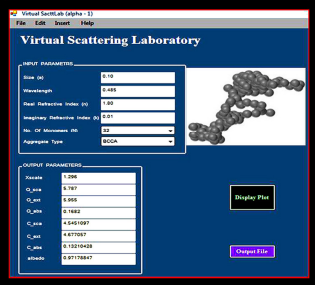
Fig.2: BPCA structure with 128 monomers (P ≈ 0.90, D ≈ 3)

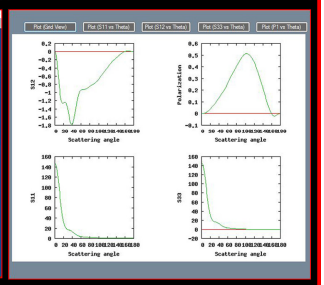
INTRODUCTION

Cosmic dust is a type of dust composed of particles in space which are irregularly shaped with porosity ranging from fluffy to compact. Cosmic dust can be distinguished by its astronomical location as, (a) intergalactic dust, (b) interplanetary dust, (c) interstellar dust and (d) circum planetary dust. In our solar system, interplanetary dust causes the zodiacal light. Sources include comet dust, asteroidal dust, dust from the Kuiper belt and interstellar dust passing through our solar system. It has also been suggested that cosmic dust grains may consist primarily of irregular shapes and fluffy structures, with a mixture of various chemical compositions and vacuum (Wurm & Blum 1998; Krause & Blum 2004 etc.). It is now well accepted from the in situ measurements of comets and Stardust-returned samples of Comet Wild 2 that cometary dust consists of a mixture of compact particles and aggregates (Fomenkova et al. 1999; Horz et al. 2006; Zolensky et al. 2006, Burchell et al. 2008 etc.).









AGGREGATE DUST MODEL

In the present work, aggregates have been built using ballistic aggregation procedure (Meakin 1983, 1984). Two different models of cluster growth are adopted: first via single-particle aggregation and then through cluster–cluster aggregation. These aggregates are built by random hitting and sticking particles together. When the procedure allows only single particles to join the cluster of particles, the aggregation is called Ballistic Particle-Cluster Aggregate (BPCA), and if the procedure allows clusters of particles to stick together, the aggregate is called Ballistic Cluster–Cluster Aggregate (BCCA). In Figs 2 and 3, BPCA and BCCA structures with 128 monomers are shown, respectively. Usually, the BPCA clusters are more compact than BCCA clusters (Mukai et al. 1992). The porosity of BPCA and BCCA particles of 128 monomers has the values 0.90 and 0.94, respectively, and the fractal dimension of BPCA and BCCA is D ≈ 3 and 2, respectively.

The studies of interplanetary and cometary dust indicate that cosmic grains are likely to be porous, fluffy and composites of many small grains coalesced together, due to grain-grain collisions, dust-gas interactions and various other processes. Porous, composite aggregates are often modeled as cluster of small spheres ("monomers"), assembled under various aggregation rules with typical sizes 0.1-10μm.

LIGHT SCATTERING PROPERTIES OF AGGREGATE PARTICLES

Interplanetary and interstellar dust particles are commonly believed to include aggregated structures of complex morphology. Optical properties of aggregated particles have been extensively investigated through the use of various numerical techniques. The Discrete-Dipole Approximation (DDA) code (Draine & Flatau 1994, 2012) and Superposition T-matrix codes (Mackowski & Mishchenko 1996) are widely used by astronomers and astrophysicists to study the light scattering properties of cosmic dust aggregates. We presently use Superposition Tmatrix code in our software package.

Aggregate dust model has been extensively used by several investigators to study the light scattering properties of cometary dust (Kimura et al. 2006, Das et al. 2008a, 2008b; Paul et al. 2010 etc). Assuming an individual cometary grain to be an aggregate of several monomers, Das et al. (2008a) analyzed the observed polarization data of Comet C/1990 K1 Levy and successfully reproduced the polarization curve through simulations. Again, Das et al. (2008b) successfully explained the polarization characteristics of Comet C/1995 O1 Hale- Bopp at λ = 0. 485 and 0.684μm using aggregate dust model.

Aggregate dust model can be also used to study the extinction properties of porous dust grains. Using aggregate dust model, Iati et al. (2004) have studied optical properties of cosmic dust. Considering cosmic dust as aggregates of amorphous carbon and astronomical silicates, they calculated extinction, scattering, and radiation pressure cross sections using Superposition Transition Matrix approach.

ASSAM UNIVERSITY VIRTUAL SCATTERING LABORATORY SOFTWARE PACKAGE (AUVScatLab)

AUVScatLab has been developed by us in the Department of Physics, Assam University, Silchar (INDIA) to build a user friendly graphical user interface (GUI) environment to study the optical properties of cosmic dust aggregates using Microsoft Visual Studio 2010. Microsoft Visual Studio (http://www.microsoft.com/visualstudio/en-in/products) is an integrated development environment (IDE) from Microsoft which is used to develop console and graphical user interface applications along with Windows Forms applications, web sites, web applications, and web services in both native code together with managed code for all platforms supported by Microsoft Windows, Windows Mobile, Windows CE, .NET Framework, .NET Compact Framework and Microsoft Silverlight. This package consists of a Graphical User Interface (GUI) in the front hand and a database of related data's on the back hand. Both the interactive GUI and database package directly enables an astronomer to model by self-monitoring respective input parameter (viz. wavelength, complex refractive index, grain size parameter, etc.) to study the related optical properties (viz. Extinction, polarization, etc.) of cosmic dust instantly, i.e. with zero computational time, which directly increases the efficiency of the user. We select Superposition T-matrix code from many leading scattering codes available online. The database of different optical properties of the cosmic dust aggregates is generated in a very wide range using Superposition T-Matrix code with high computational accuracy. The suitable GUI makes the comparative analysis of both theoretical and observational/experimental data much easier. This package also has an option where users can compile and run the scattering code directly for aggregates in GUI environment. We use g95 FORTRAN compiler to run the code and GNUPLOT software package to plot the output files in addition to Visual Studio 2010.

CONCLUSION

We develop a light scattering software package Assam University Virtual Scattering **Laboratory Software Package** (AUVScatLab) which uses Superposition T-matrix code. It has been developed by us in the Department of Physics, Assam University, Silchar (INDIA) to build a user friendly graphical user interface (GUI) environment to study the optical properties of cosmic dust aggregates using Microsoft Visual Studio 2010. It is to be noted that **AUVScatLab** is now developed only for WINDOWS environment. It is also planned to develop the package in other environments.

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