STUDY OF DUST PROPERTIES AROUND THE WHITE DWARF GD 61 IN IRIS AND AKARI MAPS

A Proposal

Submitted to the Department of Physics,

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By

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(Proforma for Application)

A. PROJECT IDENTIFICATION

1. Title of the proposed Project:

Study of Dust Properties Around the White Dwarf GD 61 in IRIS and AKARI Maps.

2. Duration of the Project in Months:

As per academic schedule which is typically 6 months.

3. Field of Science and Technology Covered by the Proposal:

Stellar Astrophysics

Key words Qualifying the Scope of the Proposal:

White Dwarf, Infrared, Dust color temperature, Dust mass, Spectral emissivity, Jeans mass

4. Project Supervisor/ Co-supervisor (Proposed):

	Supervisor
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B. TECHNICAL INFORMATION

1. Objectives of the Project:

The objectives of the project can be divided as:

General Objective

- To study the properties of dust structures around possible white dwarf candidates and the ongoing astrophysical phenomena.

Specific Objectives

- To evaluate and analyze the IR flux, dust color temperature, visual extinction and dust mass around the possible white dwarf candidates.
- To study three dimensional structure by studying the inclination angle of various internal parts of the dust structure.
- To predict whether the structure around is a probable star forming region or not through the analysis of Jeans criteria.

2. Brief Information About National/ International Scenario in the Proposed Area of Research and Relevance of the Project:

Research on astrophysics leads to the generation of new theory or model of science. The theory of stellar evolution is still unclear. Huge number researchers are involving in stellar and interstellar research.Finding the exact model of stellar evolution is the main challenge to all astrophysicists in this era. There are some national issues regarding astrophysics research in Nepal. Research in astrophysics requires places with low humidity. Nepal is rich in higher Himalayas with large numbers of regions above the 6000 m. This natural structure of our country is beneficial for the astronomer and astrophysicist to study the sky from the higher regions. The sky observation is greatly affected by the atmospheric condition, at higher regions the atmospheric conditions, such as level of humidity, dust and grain content in the atmosphere and so on.

Therefore, this research work can fulfill the national need in the field of astronomy and astrophysics. The development of observatory in these places opens an opportunity to Nepalese students to perform research works in our country. Also, we can collaborate with other prestigious universities to place high resolution telescopes and initiate observatories in higher altitude of Nepal. Such collaborations also help in recognizing our nation in the world and increases the tourism activities as well.

3. Scientific and Technical Description of the Project Including Methodology, Research Plan, etc.

This research attempts to study isolated dust cavities around white dwarfs using Infrared Astronomical Satellite (IRAS) and AKARI surveys in the far IR region (60 μm and 100 μm). The study mainly focuses on the dust color temperature, dust mass, spectral emissivity, Jeans Mass along with their distribution and relations with each other.

3.1 Methodology

3.1.1 Dust Color Temperature Estimation

The dust temperature (T_d) in each pixel of an FIR image can be obtained by considering the dust in a single beam is isothermal and that the observed ratio of 60 to 100 μm emission is the result of blackbody radiation from the dust grains at T_d modified by a power-law emissivity spectral index (beta). The flux density of emission at wavelength λ_i is given by (Schnee et al., 2005),

$$F_i = \left[\frac{2hc}{\lambda_i^3(e^{\frac{hc}{\lambda_i KT}}-1)}\right] N_d \alpha \lambda_i^{-\beta} \Omega_i \tag{1}$$

where N_d represents column density of dust grains, α is a constant that relates the flux to the optical depth of the dust and Ω_i is the solid angle subtended at λ_i by the detector.

The final formula for the calculation of dust color temperature in IRIS map is,

$$T_d = \frac{-96}{ln\{R \times 0.6^{(3+\beta)}\}} \tag{2}$$

where R is given by,

$$R = \frac{F_{60\mu m}}{F_{100\mu m}} \tag{3}$$

For AKARI FIR data at 90 μm and 140 μm, equation 2 becomes,

$$T_d = \frac{-57}{ln\{R \times 0.6^{(3+\beta)}\}} \tag{4}$$

Here R is given by,

$$R = \frac{F_{90\mu m}}{F_{140\mu m}} \tag{5}$$

3.1.2 Spectral Emissivity

According to (Dupac et al., 2003), the inverse relation between the emissivity index β and dust color temperature T_d is,

$$\beta = \frac{1}{\delta + \omega T_d} \tag{6}$$

where parameters δ and ω depend on the dust grain properties like composition, size, compactness and so on.

3.1.3 Visual Extinction and Optical Thickness

Considering the fact that the dust is optically very thin i.e.: $\tau_d << 1$, the dust optical depth at 100 μm can be calculated as given by (Wood et al., 1994),

$$\tau_{100} = \frac{F_\lambda(100\mu m)}{B_\lambda(\lambda, T_d)} \tag{7}$$

where $F_\lambda(100)$ is the observed flux at wavelength of 100 μm and $B_\lambda(\lambda, T_d)$ is the Planck function.

Interstellar extinction is the dimming of distant objects due to the presence of dust in the ISM along the line of sight (LOS). The visual extinction can be defined as the difference between the magnitude with and without the interstellar extinction and is expressed as,

$$A(\lambda) = m_{attenuated} - m_0 = 2.5log_{10}\left[\frac{F_\lambda^0}{F_\lambda^a}\right] \tag{8}$$

Where, F_λ^a is the dust attenuated observed flux and $m_{attenuated}$ is corresponding apparent magnitude of the object, and F_λ^O is the flux that would have been observed if there would have been no attenuation from dust and m_O is corresponding apparent magnitude of the object. Let the optical thickness be $\tau(\lambda)$, then

$$F_\lambda^a = F_\lambda^0 e^{-\tau(\lambda)} \tag{9}$$

Combining equations 3.11 and 3.12 we obtain,

$$A(\lambda) = (2.5log_{10}e)\tau(\lambda) \tag{10}$$

The relation between extinction and optical thickness is linear with slope $(2.5log_{10}e)$ as given by (Schnee et al., 2005). This equation gives very high value of optical thickness for 100 μm and 140 μm wavelength which doesn't comply with our assumption that the dust are optically thin for 100 μm and 140 μm wavelength. Assuming optically thin emission, the value of V - band extinction is as modified by (Wood et al., 1994) for 100 μm flux is given by,

$$A(\lambda) = 15.078(1 - e^{\frac{-\tau_{100}}{641.3}}) \tag{11}$$

3.1.4 Mass Estimation

First the value of flux density, F_λ, at 100 μm is determined then the dust mass can be calculated as given by (Hildebrand, 1983),

$$M_d = \frac{4a\rho}{3Q_\lambda}\left[\frac{F_\lambda D^2}{B_\lambda(\lambda, T)}\right] \tag{12}$$

where a = weighted grain size (0.1 μm)

ρ = grain density (3000 kg m^3)

Q_λ = grain emissivity at wavelength λ (0.001 for 100 μm)

$B_\lambda(\lambda, T)$ = Planck's function

Substituting the values we get the reduced equation as suggested by (Young et al., 1993),

$$M_d = 0.4\left[\frac{F_\lambda D^2}{B_\lambda(\lambda, T)}\right] \tag{13}$$

FIR emission is measured from the 100 μm IRAS images for the derivation of the dust mass because the longer wavelength measurements give us more precise dust masses due to the characteristics of the Planck function.

3.1.5 Jeans Criteria

According to the Virial theorem, the kinetic energy $< T >$ of a stable system must be equal to the negative half of it's gravitational potential energy $< U >$.i.e.:

$$< 2T >= -\frac{1}{2} < U > \tag{14}$$

It implies that there must exist a critical mass of a molecular cloud to be stable or to collapse. The process of collapsing of a molecular cloud due its own gravity is known as gravitational collapse. For the cloud to be stable, it must be in hydrostatic equilibrium. If the internal pressure of the gas is greater than the gravitational force then the mass will collapse and instability occurs which is known as Jeans instability. Jeans mass, named after British physicist James Jeans, is the critical mass required for the Jeans stability. It depends on two thermodynamic parameters; pressure (P) and density (ρ) (Carroll and Ostlie, 2014). The relation can be expressed as,

$$M \propto P^a \rho^b G^c \tag{15}$$

where G = universal gravitational constant and a, b, c are constants to be determined. On determining the values of a, b, c using dimensional method we get Jeans mass as,

$$M_J = \frac{KP^{\frac{3}{2}}}{\rho^2 G^{\frac{3}{2}}} \tag{16}$$

where K is proportionality constant which depends on the nature of perturbation. The perturbation depends on the speed of acoustic waves and adiabatic index.

For slow varying perturbation,

$$K = \frac{4}{3}\pi^{\frac{5}{2}} \tag{17}$$

From equation 3.20 Jeans length λ_J can also be calculated as,

$$\lambda_J = \left[\frac{\pi k_B T}{\mu m_H G \rho}\right]^{\frac{1}{2}} \tag{18}$$

where k_B = Boltzmann's constant

T = temperature of the molecular cloud

μ = mass per particle in the cloud

m_H = mass of proton (in kg)

Jeans length gives the critical size of the cloud at a given temperature for Jeans stability (Karttunen et al., 2007).

3.1.6 Inclination Angle

The inclination angle (i) is the angle between the LOS and the normal vector of the plane of the structure. This can be estimated by using (Holmberg, 1946) formula,

$$cos^2 i = \frac{(\frac{b}{a})^2 - q*^2}{1 - q*^2} \tag{19}$$

where, (b/a) is the ratio of minor to major diameter and $q*$ is the intrinsic flatness of the structure.

The intrinsic flatness is closely related to nebula morphology. It depends on the amount of molecular hydrogen and the dust. The dust grains obtain energy from the heating due to photoelectric effect and low-energy cosmic rays. Due to this vibrational degree of freedom is greatly enhanced. This makes the cloud to be flat (opening angle gradually increase with the dilution and vibrational excitation of the dust). Thus the range of the intrinsic flatness of the cloud is taken between 0.13 to 0.33 (Giovanelli and Haynes, 1984).

3.2 Research Plan

The following steps are planned to be adopted throughout the project.

- Search the catalogue of White Dwarfs from literature and use it to carry systematic search in SkyView Virtual Observatory along with Simbad Astronomical Database.
- Select the few clearly isolated regions around White Dwarf in infrared wavelength.

- Use the FITS image of selected regions to find the infrared flux using Aladin.
- Extract the IR flux values of each pixel within the region of interest and process the data to study the distribution of flux, dust color temperature, dust mass, gas mass, density, Planck's function using Python.
- Use appropriate statistical methods for the analysis of the results.

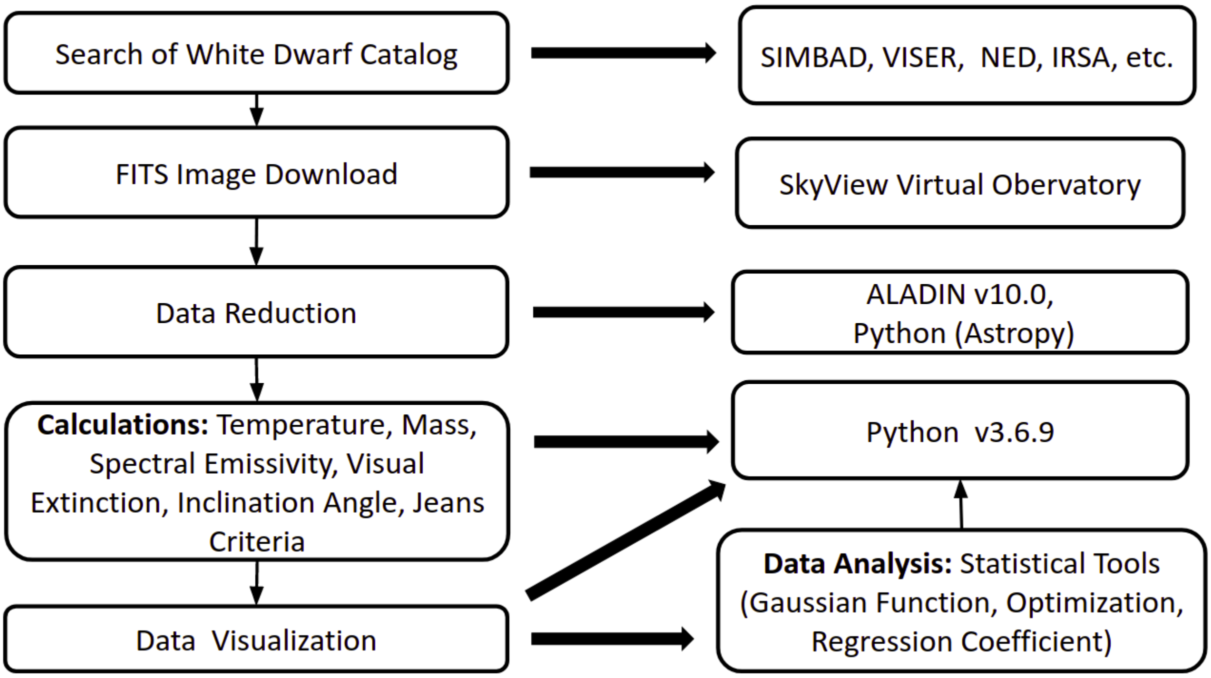

Figure 1: Research Plan

References

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APPENDIX

1. Bio-data of the student:

a. Academic Qualifications:

Level	Board	School/College	Percentage	Symbol Number
SLC	NEB	Ramnagar Academy	92 %	0446928 N
+2	HSEB	Everest English Boarding School	86 %	24909296
BSc. 1st year	TU	Tri-Chandra Multiple Campus	60.6 %	500375003
BSc. 2nd year	TU	Tri-Chandra Multiple Campus	(F)	371638

b. Publications:

Research Paper	Journal	Published Date
Design of Log Periodic Dipole Array Antenna Ranging from 30 to 150 MHz	Journal of Innovations in Engineering Education **(JIEE)**	March 2020
Optimizing Tremaux Algorithm in Micromouse Using Potential Values	International Journal of Advanced Engineering **(IJAE)**	September 2020

I, **Sanjay Rijal**, hereby declare that the proposed research plan is original. I will follow all the regulations of Department of Physics, Tri-Chandra Multiple Campus and IOST, Tribhuvan University regarding.