MID-IR OBSERVATIONS AND MODELING OF ASTROPHYSICAL DUST

AGB CIRCUMSTELLAR ENVELOPES AND ICM DUST

Thesis submitted for the degree of
"Doctor Philosophiæ"

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To Mayli

Acknowledgments

Writing a thesis is just the last, hectic, step of a long journey. For me, that journey started at the end of a bright october day, when I was stunned by the most incredible sunset on the gulf of Trieste, and by the news that I was admitted to graduate school in SISSA. Many years have passed since then. As I look back, I see all the fond memories of the many persons that shared this journey with me. To all of them I am indebted.

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Abstract

Astrophysical dust plays a major role in stellar formation and evolution, and in the chemical enrichment of the Galaxy. However, the processes which lead to its formation in the circumstellar environment of evolved stars, and describe its interactions with the Interstellar Medium, are largely unknown. Mid-IR observations, combined with radiative transfer modeling aimed to derive the dust physical parameters from its thermal emission, are our best tool to investigate the physics of dust in many astrophysical contexts.

In this thesis, I first analyze the current status of mid-IR observations of circumstellar envelopes around Asymptotic Giant Branch (AGB) stars. I then propose a new set of tools, based on the photometric system available in mid-IR imaging cameras, aimed to derive the chemical and evolutionary status of the envelopes from their mid-IR colors. A large sample of sources, observed in the IR and radio, is used to test the effectiveness of the proposed tools, and to derive the correlations between mid-IR colors and mass loss rates in the AGB.

Next, I explore the connections between the pulsational characteristics of Long Period Variables of Mira, Semiregular and Irregular type, with the temporal modulation of their mass loss rates. The mid-IR emission of a large sample of AGB variables is studied, with the aid of spherically symmetric radiative transfer models of circumstellar dust in local thermodynamical equilibrium. This technique allows to analyze the thermal structure of the envelopes, and the timescales of their dust production. A deficiency of hot dust in the majority of Semiregular variables is found, suggesting the frequent occurrence of circumstellar dust shell detachment in these sources, and a different efficiency of the mass loss processes between the Mira and the Semiregular class.

I then study a sample of 46 AGB and post-AGB sources, by analyzing the images I have collected with several mid-IR cameras. The photometry of the envelopes is used to determine their chemical and evolutionary status. The spatial distribution

of the dust and the envelope symmetry is measured from the collected data. These observations show how sub-arcsecond resolution can be obtained with ground-based mid-IR imaging, by using a special technique here described.

MIRAC images of the Young Stellar Object AFGL 2591 at 11.7, 12.5 and 18.0 μm are also presented. I discuss the discovery of a previously unknown dust ejection episode, associated to the molecular outflow of the source. By measuring the photometry of the object, the total mass of the ejection ($\sim$0.1 $M_{\odot}$) is derived.

Finally, I present a new numerical code, able to compute the stochastic temperature distribution of dust surviving in a hot astrophysical plasma. Applications of this code, which has been parallelized to increase the computational efficiency with multi-processor computer clusters, are discussed. A particular emphasis is given on dust in the intracluster medium of cluster of galaxies, and the consequences of its dust emission on the Sunyaev-Zel'dovich effect.

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