National Aeronautics and Space Administration

Planet forming disks around dying stars?

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Project Objective

Post-AGB stars in binary systems are found to be surrounded by stable disks which act as a strong background for dust processing.

These objects present a unique opportunity to:

- Gain insight into dust processing leading to planet formation.
- Provide key answers to the shapes and shaping of PNe.

Recent Results

Using state-of-the-art interferometric instruments in the infrared (VLTI, AMBER & MIDI), we were able to determine the spatial structure of the reservoir in which the hot dust around binary post-AGB stars resides.

The material around these objects is locked in a stable circumbinary disk which has a similar structure as the disks around young stellar objects.

We find this disk reservoir to act as a strong dust processing factory, both in grain growth as well as in degree of crystallinity.

In at least one target, the disk structure even shows a gap, which could indicate that planet formation is active even in disks around dying stars.

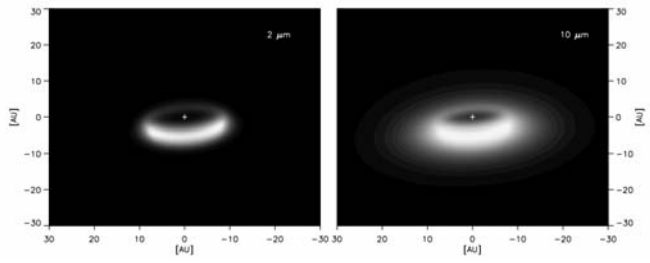
Project Description

Post-AGB stars are found with either a hot disk but no strong outflow or an extended torus and a collimated outlfow. The former objects are:

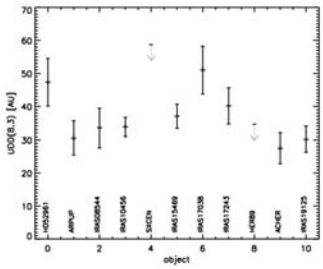
- binaries (separation ~ 1 AU)
- common (60 detected so far out of ~ 300 known post-AGBs)
- displaying a strong IR excess starting already in the K-band

The structure of the disk is probed at an unprecedented angular resolution using state-of-the-art infrared interferometry

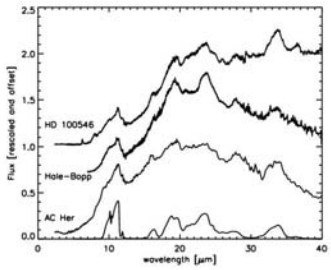
- resolved 9 out of 11 objects
- disks are extremely compact (Ø ~ 40 AU)
- strong asymmetry on milli-arcsecond scale for several cases



IRAS 08544: Image reconstructed from our self-consistent disk model constrained by the SED, the K-band visibilities (with closure phases) and the N-band visibilities. The unresolved stellar contribution has been replaced by a cross.



The diameter of the emission at 8.3 μm for binary post-AGB stars. The different targets are surrounded by very compact disks with comparable sizes (Ø ~ 40 AU).



The infrared spectrum of AC Her is similar to the solar system comet Hale-Bopp and the YSO HD100546 in which a gap is proposed. Modeling of the spectrum of AC Her shows two spatially separated dust components.

Confrontation between 2D radiative transfer models shows that:

- disks are passive and scale-height follows the hydrostatic equilibrium equation (similar as in YSO's)
- the dust disk starts at the sublimation radius where the disk is strongly puffed up

The disks serve as a background for dust processing:

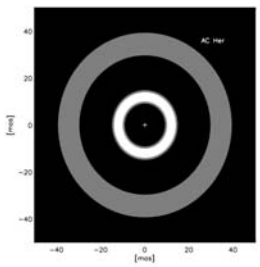
- high degrees of crystallinity (~ 50 %)
- substantial mass (~ 10^{-4} $M_{\odot}$) in large (≥ mm sized) grains
- evidence for a gap (~ 10 - 30 AU) in the disk of AC Her, which could result from the formation of macro-structures

Benefits to NASA and JPL

This study can help improve our understanding of the earliest stages of the planet-forming process, namely the coagulation, growth and evolution of dust grains in disks from submicron to millimeter and larger sizes.

These disks appear to have similar density and temperature conditions, and to have undergone similar processes of grain coagulation and gas depletion as in planet-forming disks of pre-main sequence stars.

Our studies of disks in dying stars have thus opened up an exciting new avenue to study the very early stages of grain processing, i.e. on time-scales (~1000 years), very different from those which are observable in typical planet-forming disks (few million years).



Simplified model of AC Her's dust disk with a gap. This model based on the interferometry is consistent with the two-temperature dust model derived from the spectrum.

Publications

Deroo, P., 2008, PhD thesis

Deroo, P. Acke, B. et al., A&A 2007, 475L, 45

Deroo, P., Van Winckel H. et al., A&A 2006, 450, 181

De Ruyter, 2006, PhD thesis

Gielen, C., Van Winckel H. et al, A&A 2007, 475, 629

Sahai, R., Young, K. et al., ApJ 2006, 653, 241