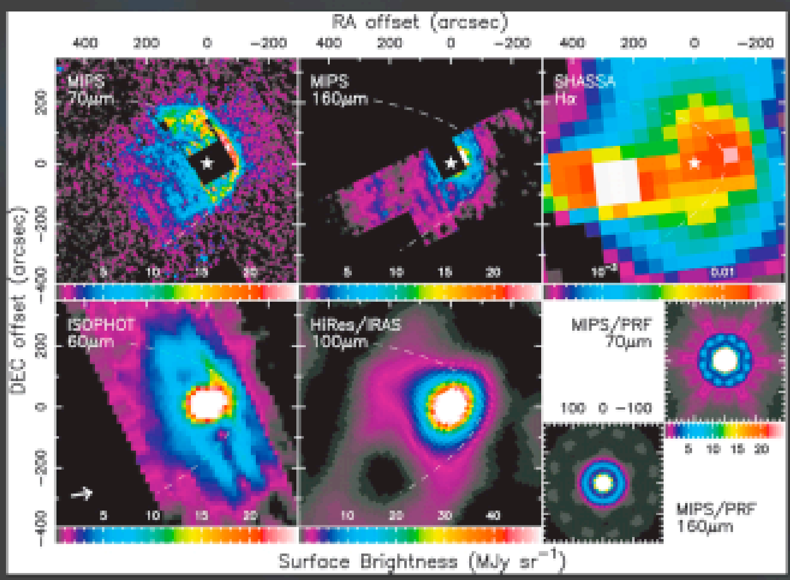
Cosmic Dust - Near & Far: 8 September - 12 September 2008, Heidelberg Convention Center, Heidelberg, Germany

Spitzer's View of the Extended Dust Shells around Evolved Stars

Toshiya Ueta (University of Denver, USA)
+ the MIRIAD and *Spitzer*-MLHES collaborations

1. R Hya: the Discovery

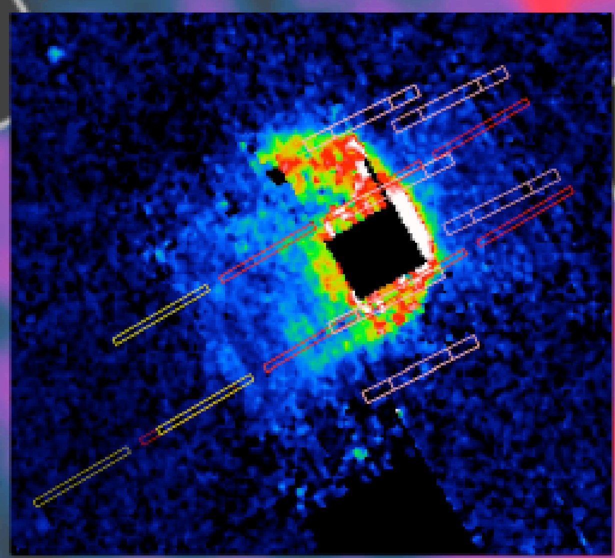


The first discovery of the wind-ISM interaction around an AGB star, revealed by the characteristic bow shock seen in the far-IR (Ueta et al. 2006).

[Top Left] *Spitzer* 70µm, [Top Middle] *Spitzer* 160µm, [Top Right] Hα, [Bottom Left] *ISO* 60µm, [Bottom Middle] *IRAS* 100µm, [Bottom Right] *Spitzer* PSFs/PRFs.

The shape of the bow shock is theoretically well-fixed (e.g. Wilkin 1996). Therefore, the ***spatially-resolved images*** can be used to derive physical parameters of the bow shock and ISM. At 165 pc, R Hya's space velocity is 50 km/s into the direction of the bow head. With the rate of mass loss at 3×10^{-7} M⊙/yr and the wind velocity of 10 km/s, the ambient H density in the ISM local to R Hya is 0.4 cm^{-3} and the total mass of the bow head is 1.3×10^{-4} M⊙, given the ***measured*** dimensions of the bow shock.

Currently, we are analyzing *Spitzer* IRS/MIPS-SED data to diagnose the shock physics in such a low-temperature, low-velocity wind interaction to understand how a dusty molecular wind from AGB stars eventually dispersed into the ISM.

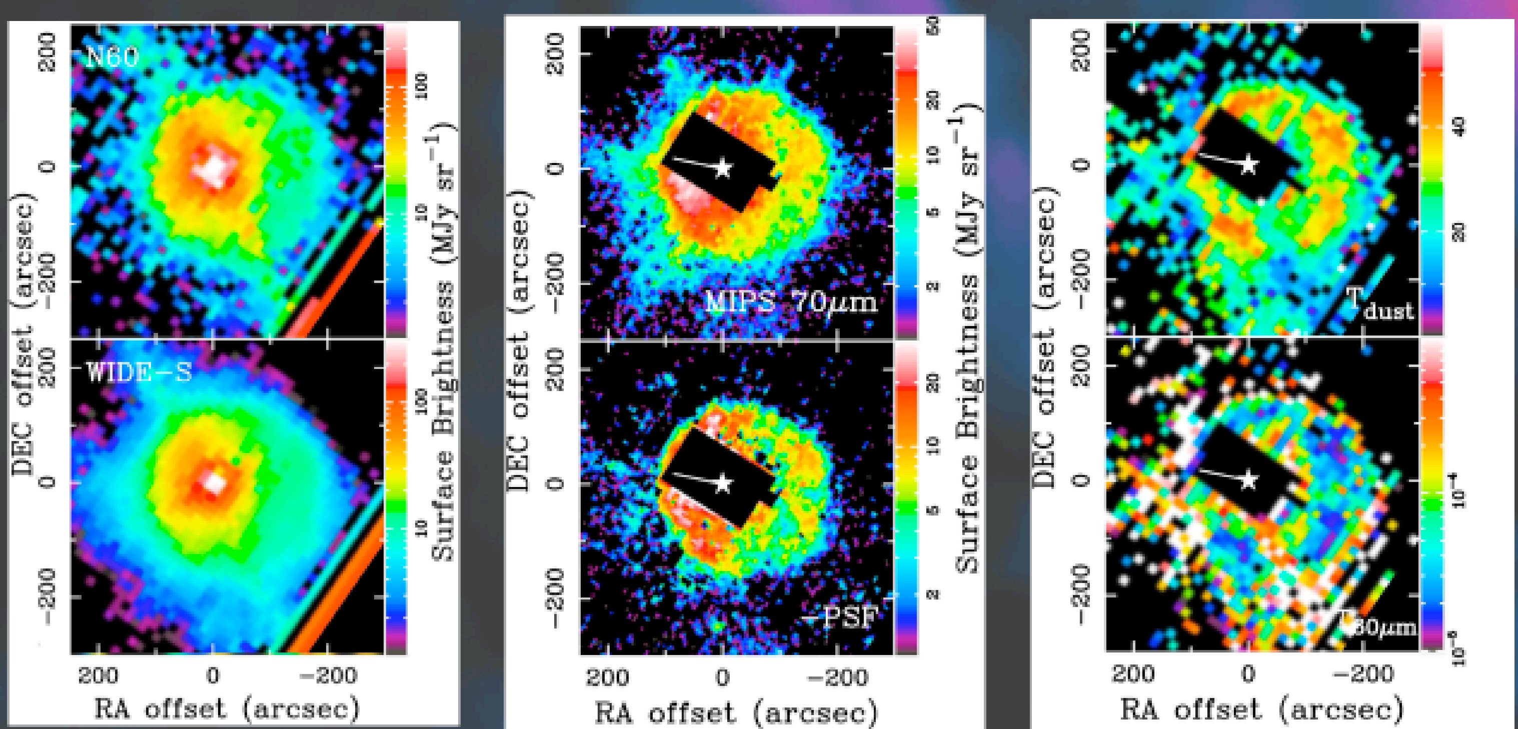


[Right] IRS/MIPS-SED slit placement with respect to the bow (Stencel et al. 2008).

3. R Cas: *Spitzer* meets *AKARI*

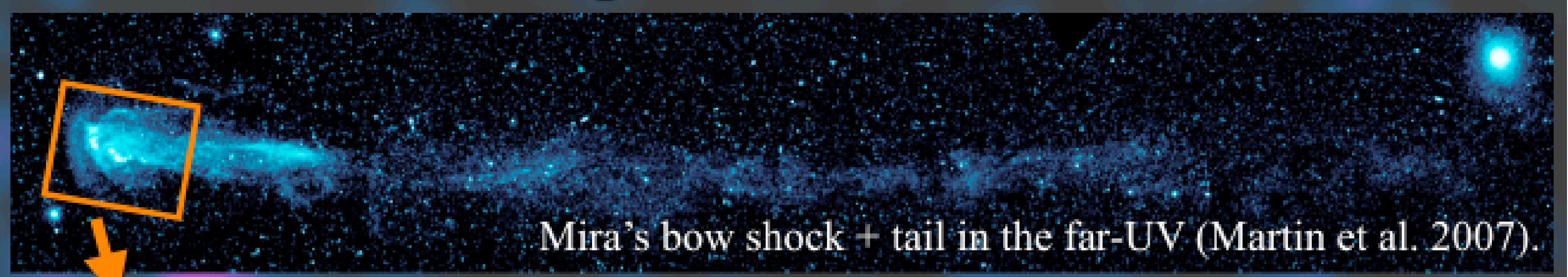
The far-IR capabilities of *Spitzer* are complementary with respect to those of *AKARI* Infrared Astronomy Satellite, especially with the MLHES mission program (Izumiura et al. 2008) in terms of the science scope of our *Spitzer* studies.

R Cas is an AGB star with a far-IR elliptical shell, in which the star is shifted slightly off-center towards the direction of its space motion (Ueta et al. 2008). This is probably the case of an infant state of the wind-ISM interaction, in which the wind-ISM interface is still intact at the downstream side.

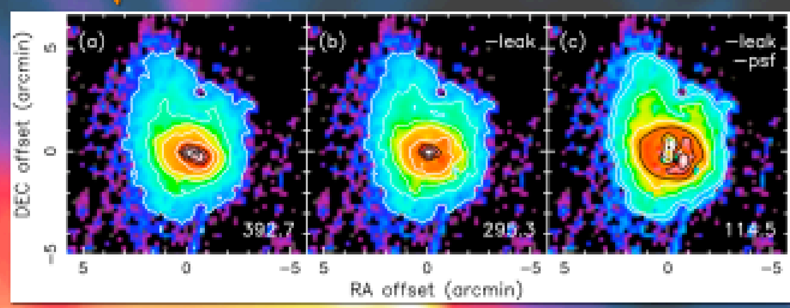


[Left] *AKARI* maps at 60µm (N60) and 90µm (WIDE-S), [Middle] *Spitzer* map at 70µm (cleaned and PRF-subtracted), [Bottom] the dust temperature and optical depth maps derived from the combination of *Spitzer* and *AKARI* maps (Ueta et al. 2008). The dust temperature and optical depth maps indicate that the shell is rather hollow and the wind material is concentrated near the periphery of the shell.

2. Mira: the "Astrosphere" Revealed



Mira's bow shock + tail in the far-UV (Martin et al. 2007).



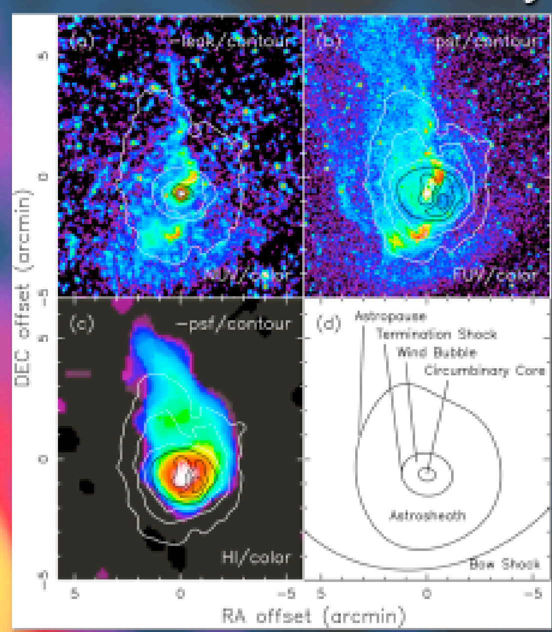
Spitzer observed the bow-shock head of Mira's wind-ISM interaction in the 160µm band (Ueta 2008).

[Left] saturation-corrected, [Middle] leak-corrected and [Right] PRF-subtracted maps.

The *Spitzer* map reveals the wind part of the shock structure (the astropause, a stellar analog of the heliosphere), including the termination shock (the ring structure in the PRF-subtracted map) and astropause (delineated by the faint halo emission) as well as the central circumbinary core (the emission peak).

Spatial correlation with collisionally excited H_2 in UV (by electrons from the shock; Martin et al. 2007) and dissociated atomic H in 21cm line (Matthews et al. 2008) reveals how Mira's dusty molecular wind interacts with the ISM and flows to the downstream.

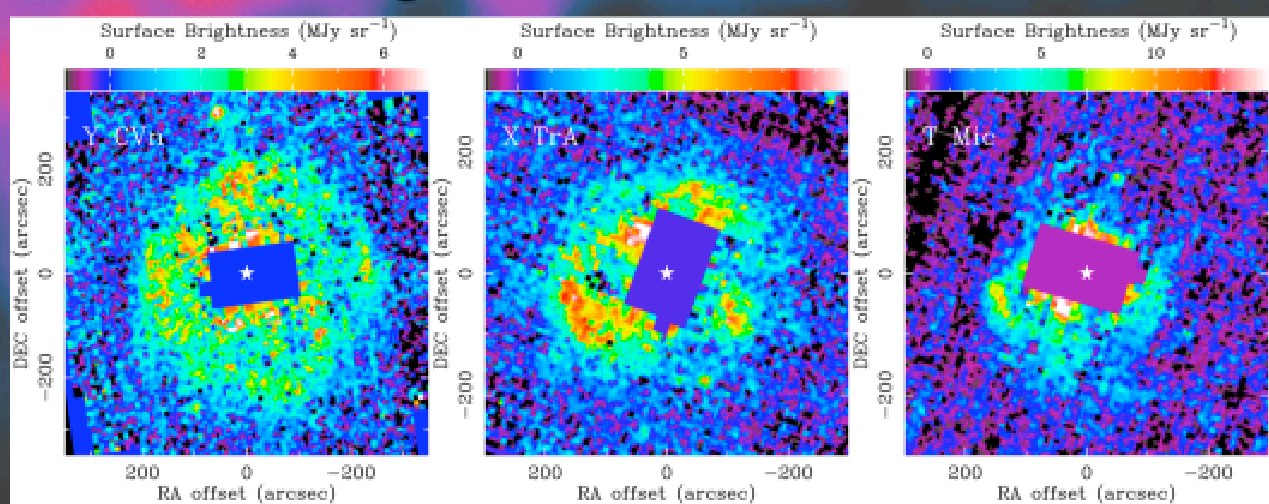
Shock conditions suggest that Mira's wind at 4 km/s colliding with the ISM flow of 150 km/s generates the termination shock of 2 km/s, which needed ~40,000 yr to form the shock ring structure seen in the Spitzer map. This time scale is consistent with the shock re-establishment time since Mira entered the Local Bubble (Wareing et al. 2007).



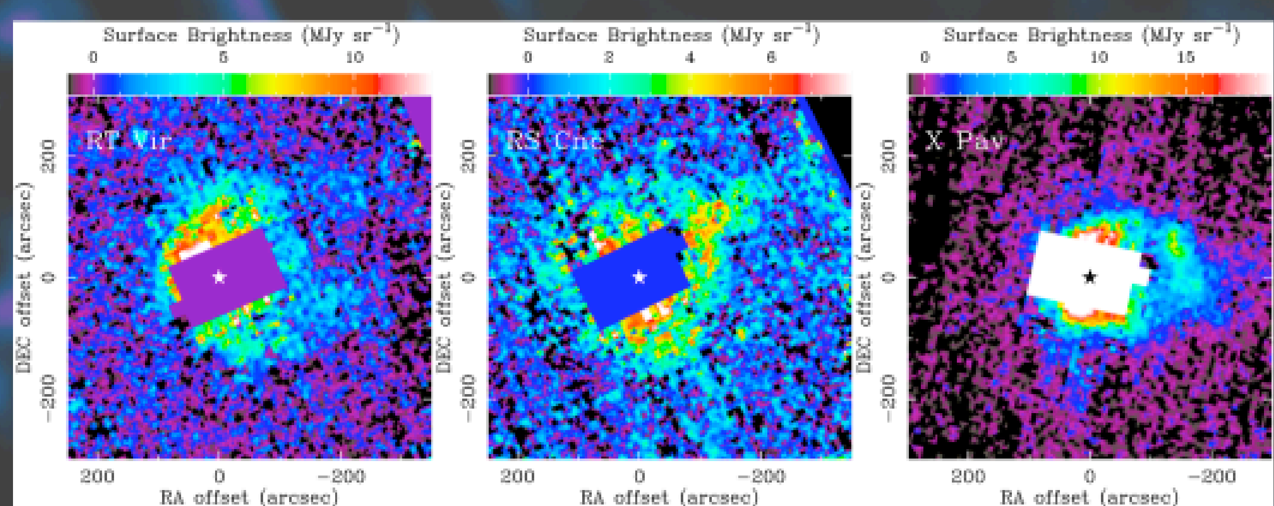
Spatial correlation of the 160µm map with [Top] UV and [Bottom Left] 21cm, with [Bottom Right] a schematic representation of the astrosphere.

4. *Spitzer*-MLHES Survey

The *Spitzer*-MLHES program obtained 70µm maps of the circumstellar dust shells from 26 evolved stars. (Other programs, including MIRIAD, looked at some 20 evolved stars.) Here are some examples of this rich survey data set, from which we will procure more insights how dusty winds from these evolved stars form the circumstellar dust shells and how the winds interact with the surrounding ISM.



[Left] These shells exhibit evidence for episodic mass loss. From left, Y CVn, X TrA and T Mic.



[Right] These shells show signs of the wind-ISM interaction as Mira. From left, RT Vir, RS Cnc and X Pav.

This work is based in part on observations made with the *Spitzer Space Telescope*, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided in part by NASA through an award issued by JPL/Caltech.

Reference

Martin et al. 2007, Nature, 448, 780
Matthews et al. 2008, AJ, 133, 2291
Stencel et al. 2008, in prep.
Ueta at al. 2006, ApJL, 648, 39
Ueta, 2008, ApJL, submitted
Ueta et al. 2008, in prep.
Wareing et al. 2007, ApJL, 670, 125