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PN-ISM Interaction

Asymmetrical Planetary Nebulae IV

Friday 22nd May, La Palma

Chris Wareing

University of Manchester

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Introduction

- Previous talks have shown how complex structures develop in the inner regions of planetary nebulae (PNe)
- In this talk, I am stepping back to consider how PNe evolve from asymptotic giant branch (AGB) stars
- Going back to basics, I have employed a very simple model to readdress the overall large-scale evolution of PN

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Talk structure

I will discuss…

- Simulations of PN – ISM interaction
- Four stages of PN-ISM interaction?
- Observations

Group: Albert Zijlstra, Tim O'Brien, Myfanwy Bryce

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Our simulation work

- Although the interaction has been considered before in 2D, the importance of the AGB phase has only recently been recognised

- >100 3D hydrodynamical simulations employing a fully tested parallel CFD scheme including the effect of radiative cooling

- 'Triple-wind' model: slow dense AGB wind, fast tenuous post-AGB wind and third wind reflecting the ISM motion

- Variable parameters:
  - mass-loss rate on the AGB: 10^{-7}, 5×10^{-7}, 10^{-6}, 5×10^{-6} $M_\odot$ yr^{-1}
  - local ISM density: n_H = 2, 0.1, 0.01 cm^{-3}
  - relative velocities: 0 to 200 km s^{-1} in 25 km s^{-1} steps

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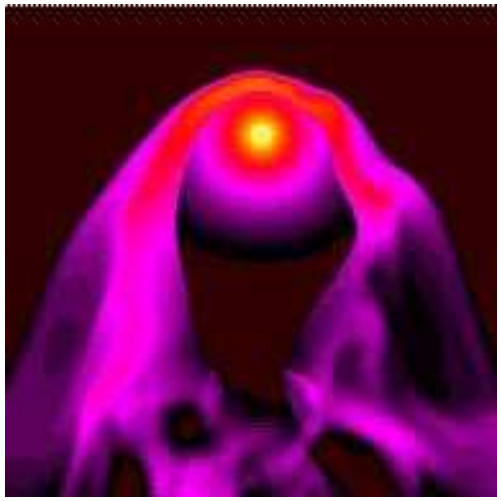
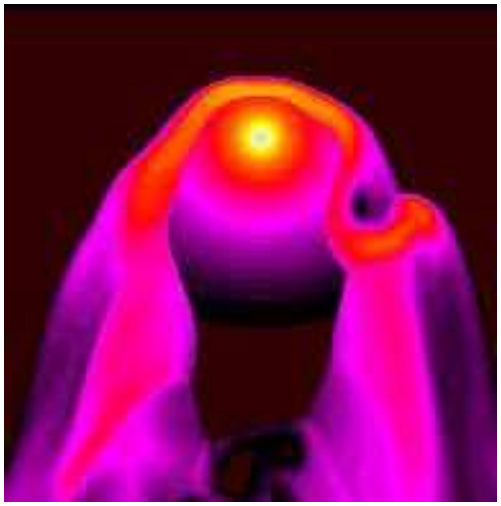
AGB simulations

23.4 pc

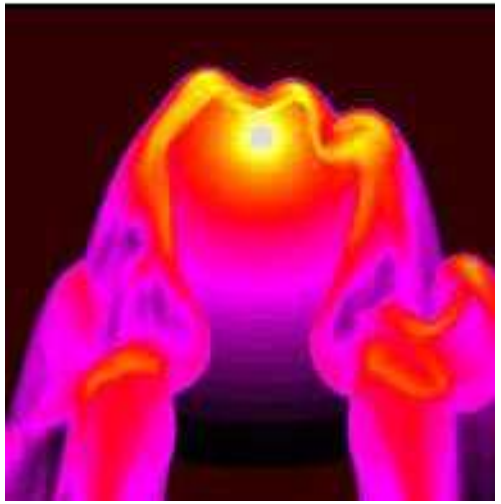


2.6 pc



1.75 pc

1 pc



1 pc

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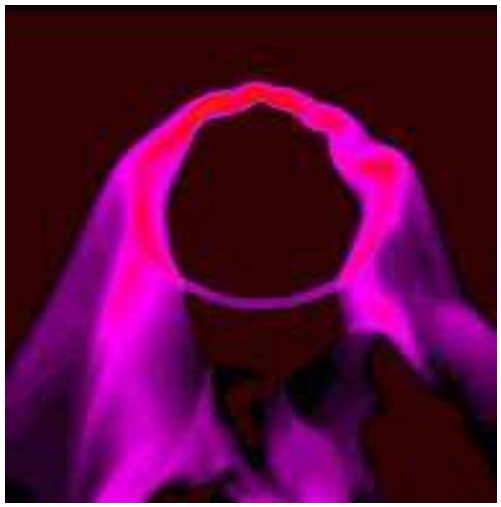
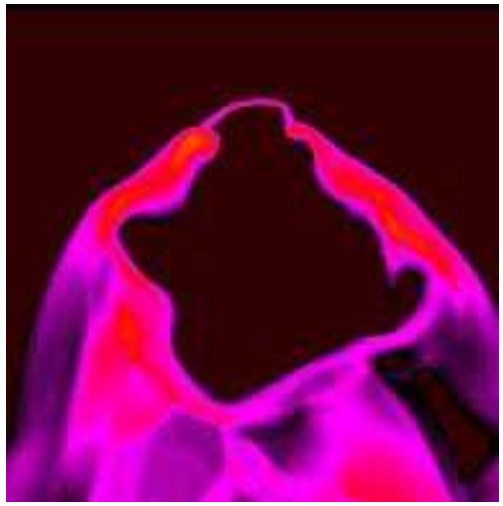
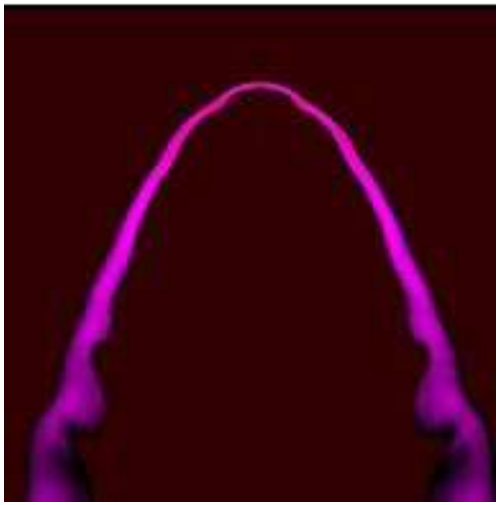
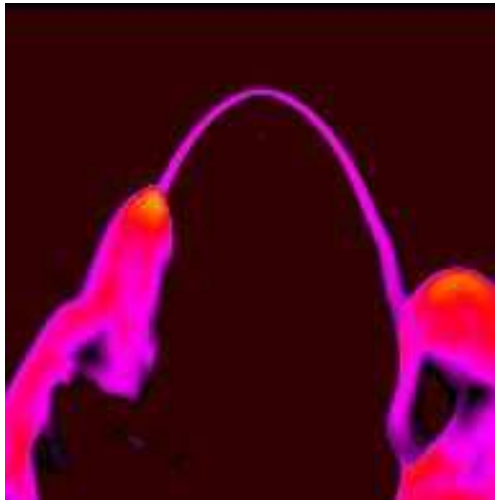
post-AGB / PN Simulations

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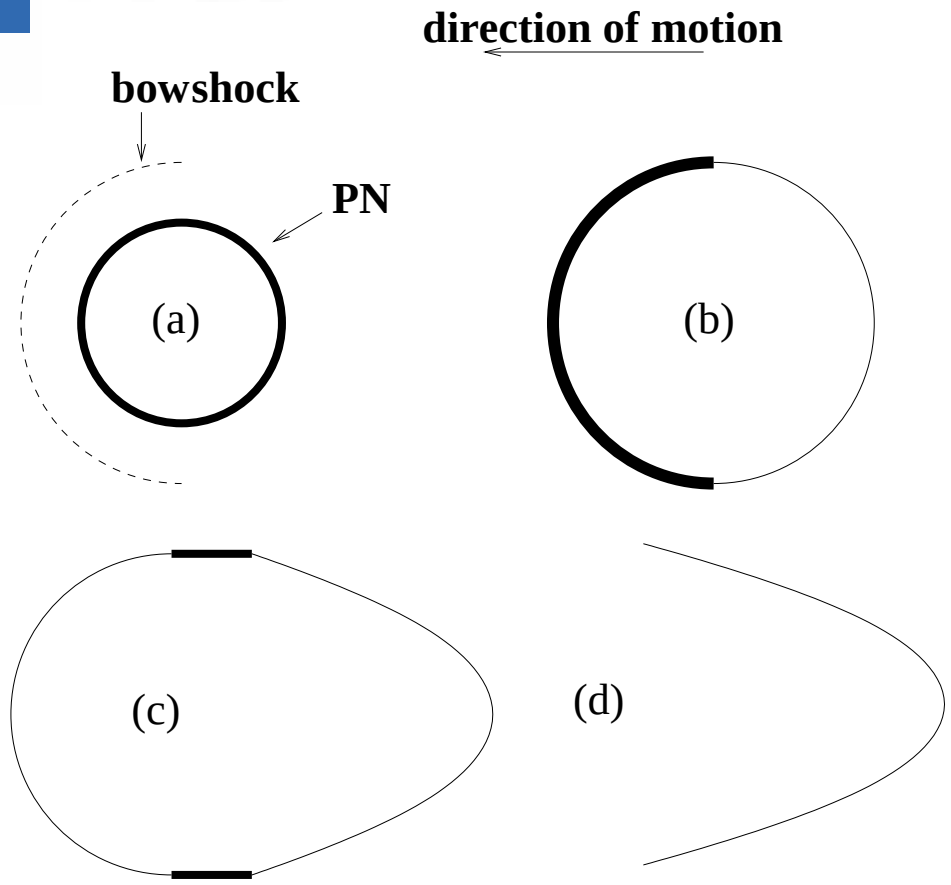
Generalisation of the interaction



Stage 1 – PN as yet unaffected by the interaction, but a faint bow shock may be observable (a)

Stage 2 – PN shell is brightened in the direction of motion (b)

Stage 3 – the geometric centre of the nebula shifts downstream away from the central star (c)

Stage 4 – the PN is completely disrupted; central star can now appear outside its nebula (d)

- **Modelling of the AGB phase of evolution is crucial!**
- **PN-ISM interaction is not limited to ancient PNe**

MNRAS submitted

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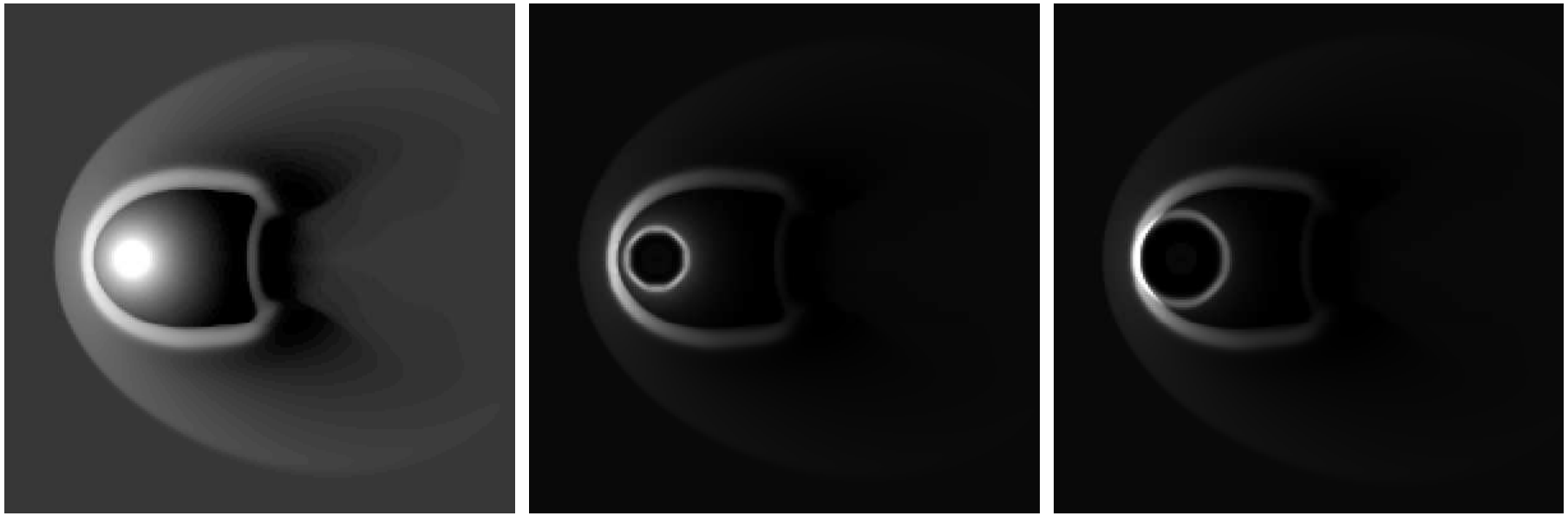
Re-brightening



23.4 pc

T_{AGB} = 500,000 yrs

T_{pAGB} = 0 yrs

T_{pAGB} = 15,000 yrs

Re-brightening via
PN-ISM interaction

T_{pAGB} = 30,000 yrs

Shown are slices through the density datacube at the position of the central star, parallel to the direction of motion

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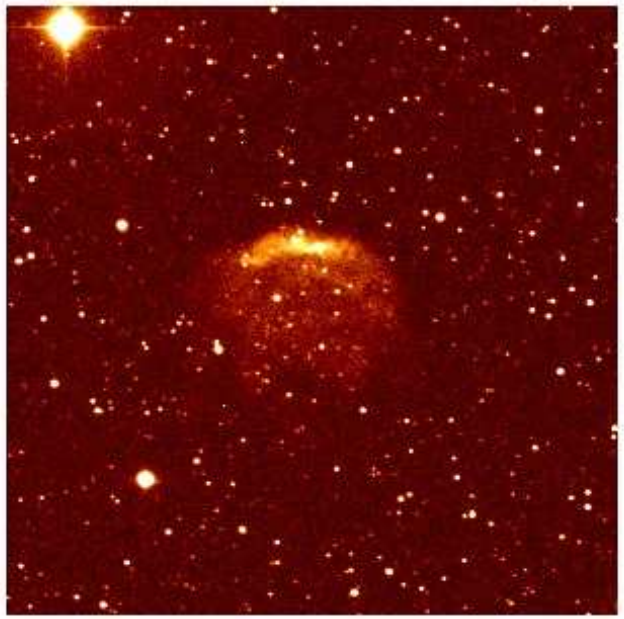
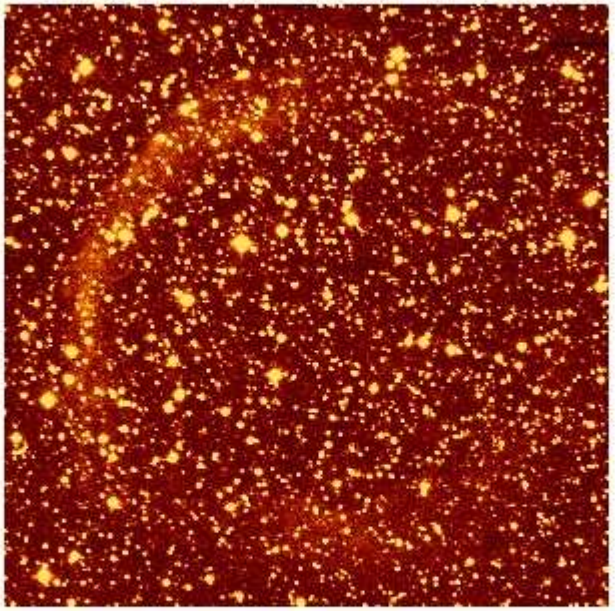
PN-ISM interactions from IPHAS





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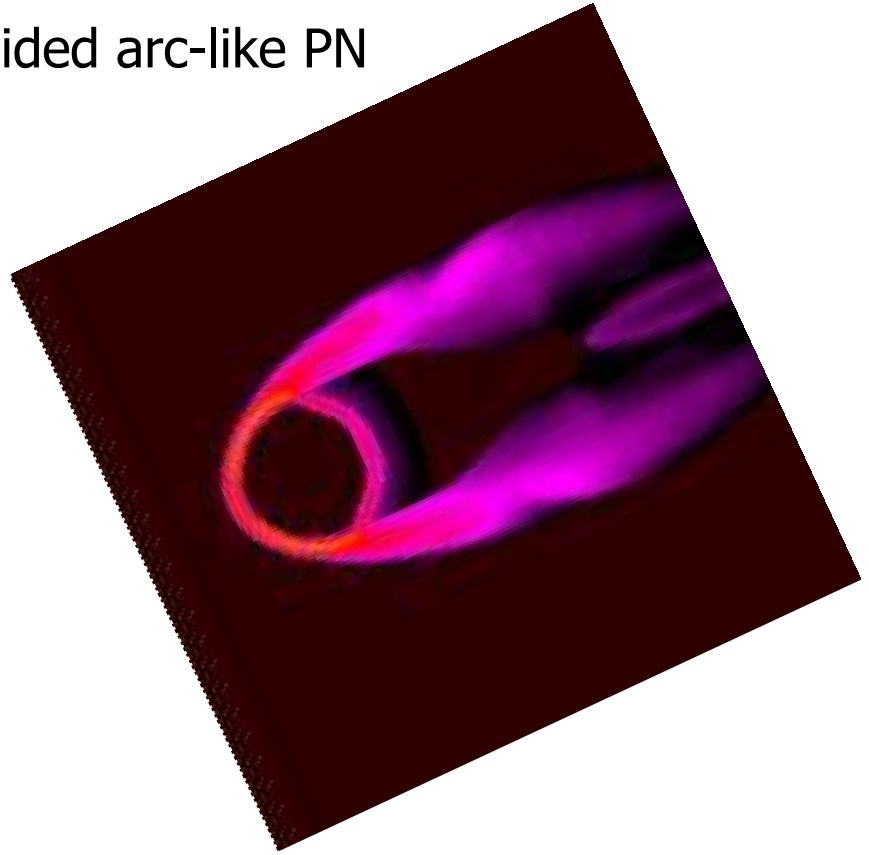
Sh 2-188

Initially thought to be a bright one-sided arc-like PN



IPHAS images revealed faint structure – a circular completion of the arc and a tail

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Sh 2-188

- Proper motion analysis using USNO-B1 and IPHAS catalogues:-

Proper motion = 30 +- 10 milliarcseconds per year
Position angle = 120 +- 20 degrees East through North
towards the bright arc

- Assuming a space velocity of 125 km/s:-

D = 850 +- 500 pc
d = 2.5 pc
T_{pAGB} = 22.5 +– 2,500 years
in agreement with current estimates via non-LTE modelling

Sh 2-188 is a case of strong PN-ISM interaction

IPHAS has revealed the importance of the PN-ISM interaction.

MNRAS 2006 **366** 387

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Conclusions

- PN-ISM interaction is defined during the AGB phase

- Asymmetry is not limited to inner regions of PNe – very interesting things are going on in the outer regions

- The death of a PN is more complicated than before – in average space velocity cases, it is not a slow fade away, the nebula is re-brightened and eventually literally blown away

- Interaction with the ISM does not necessarily indicate an evolved PN. High velocity cases interact within only a few thousand years

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A few thoughts

- Where do nebulae end?

- 'Roundification'

- Since the bow shock can be self-ionising, can it pre-date the nebula? Will PNe exist around stars that are not hot enough to ionise them?

- Structures are predicted around AGB stars and shaping occurs very early on… what evidence is there for such structures?

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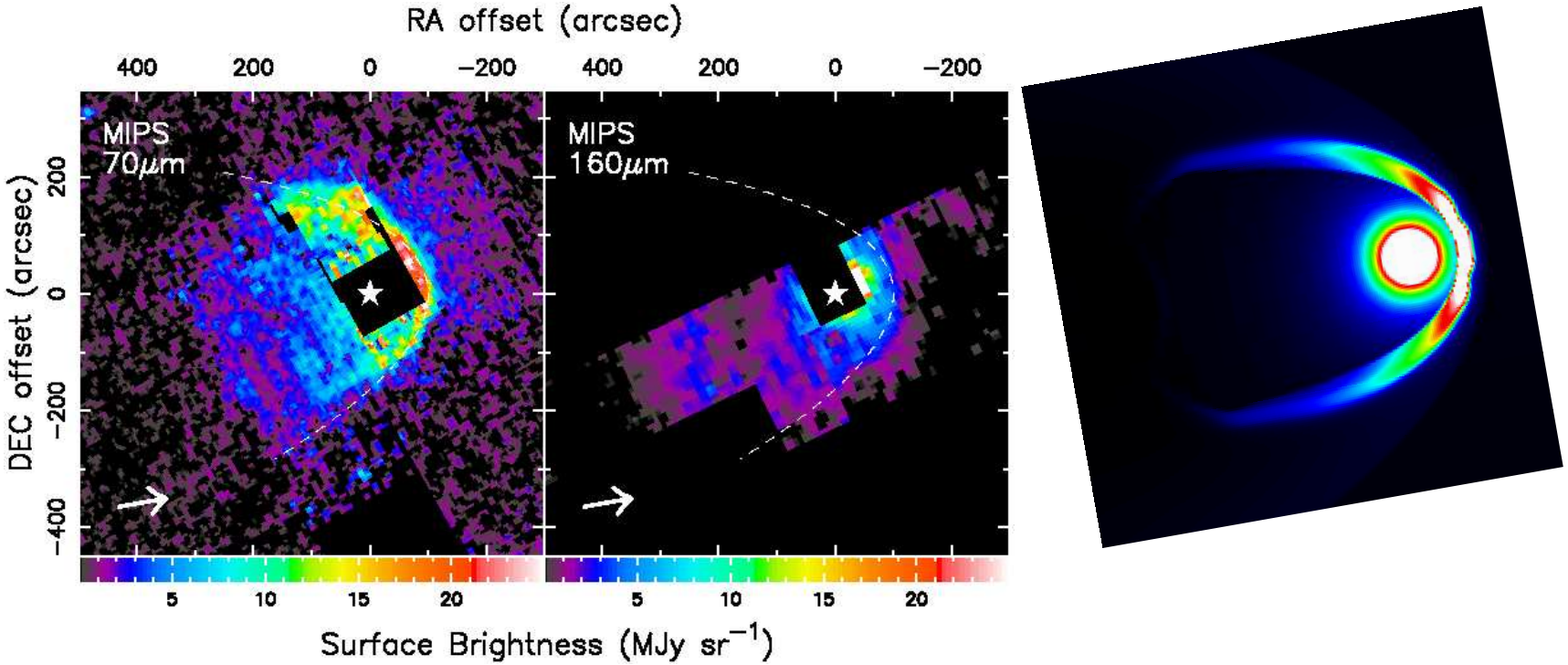
R Hydrae

An alternative explanation of detached shells around AGB stars – shells are in fact AGB-ISM walls.



A comparison of MIRIAD images (left & middle) and an AGB simulation (right). Large fraction of AGB stars may have these structures.

Instant confirmation of this prediction!

MNRAS 2006 **372** L63

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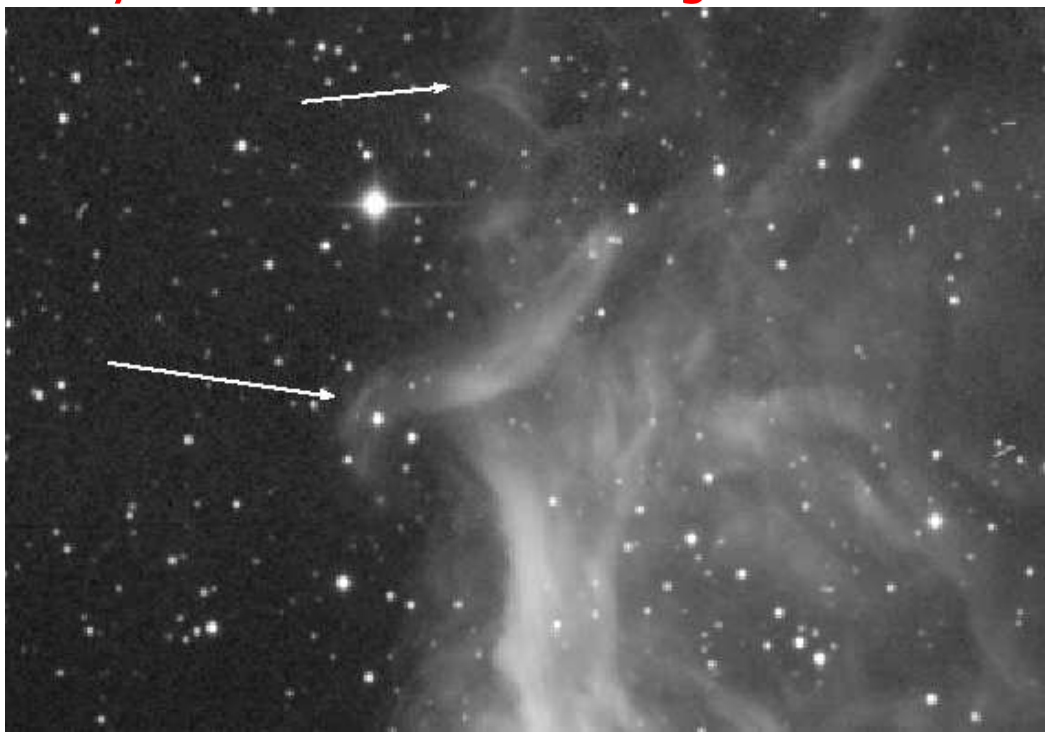
Vortex structures

Vortex generating instabilities at the head of the bow shock

- first discovery of such vortices coming off stars



- enhanced mixing of stellar material
- turbulence in the ISM

ApJ 2007 **660** L129

Detection in the tail behind the Mira AB system?

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Thank you!

E-mail me: c.j.wareing@manchester.ac.uk

Sh 2-188 work -- MNRAS **366** 387 (2006)
R Hya work – MNRAS **372** L63 (2006)
Vortices in the wakes of AGB stars – ApJ **660** L129 (2007)
PN-ISM interaction – MNRAS submitted