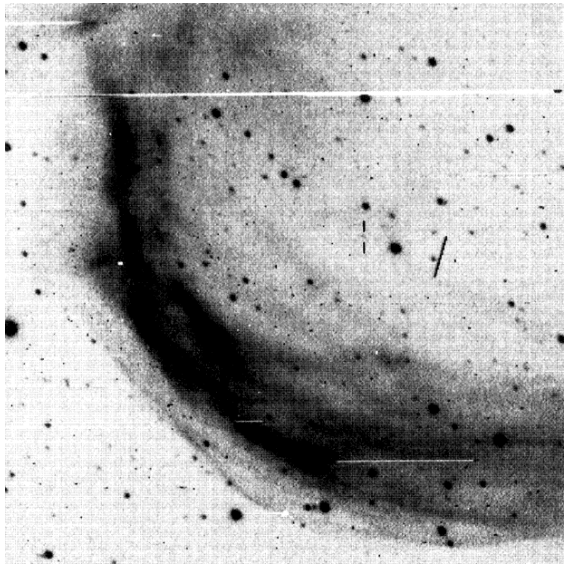
The University of Manchester
Jodrell Bank
Centre for Astrophysics

MANCHESTER 1824

Sh 2-188: an extreme PN-ISM interaction



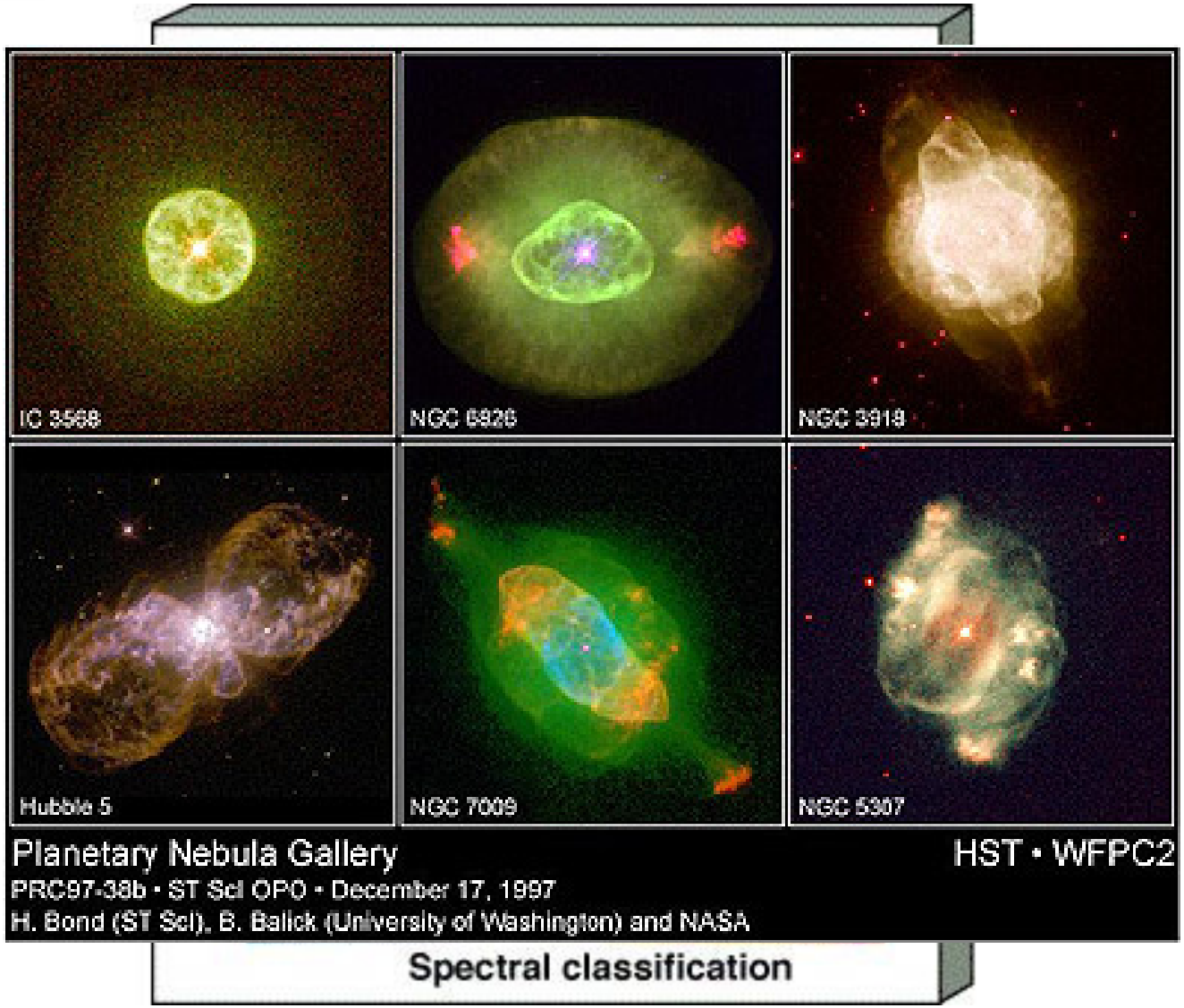
Chris Wareing
Albert Zijlstra
Tim O'Brien *et al!*

Overview

- What is a planetary nebula (PN)?
- Sh 2-188: a PN-ISM interaction?
  - Early observations
  - IPHAS observations
  - Proper motion
  - Simulations
- R Hydrae

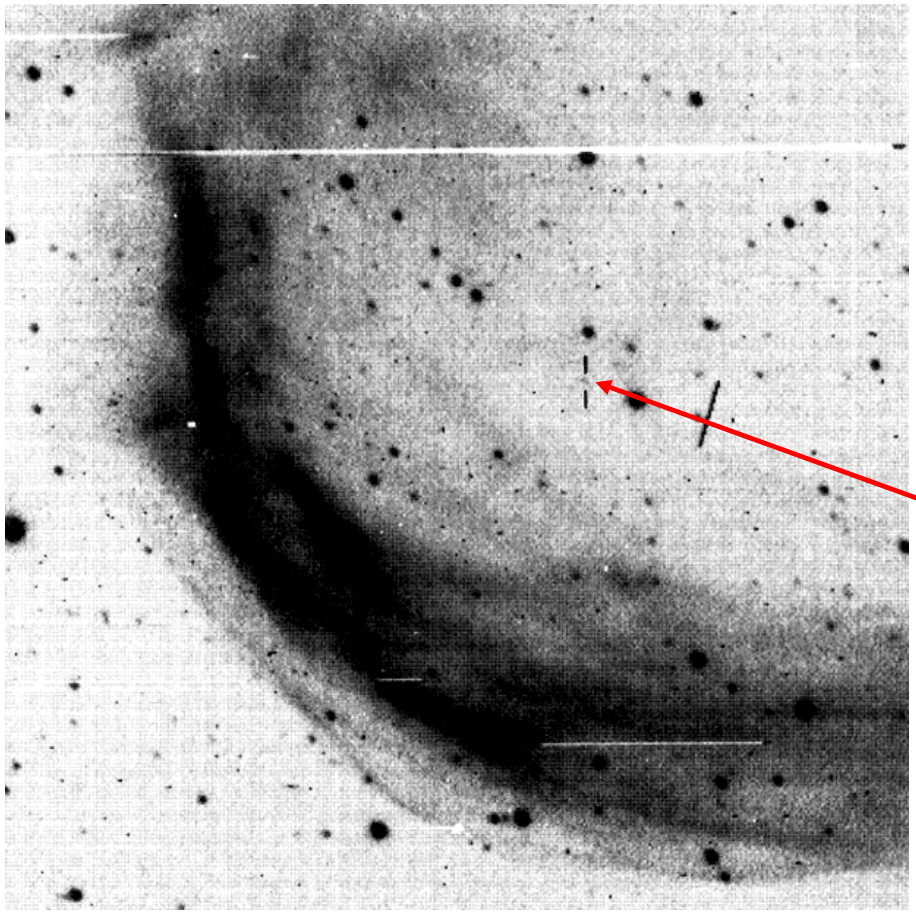
- VGIs and IPHAS Halloween!

Planetary nebulae



Spectral classification

Sh2-188: Optical observation



- Southeast region. 3600s Hα exposure. The image is 5.7′ on a side with North up and East to the left.

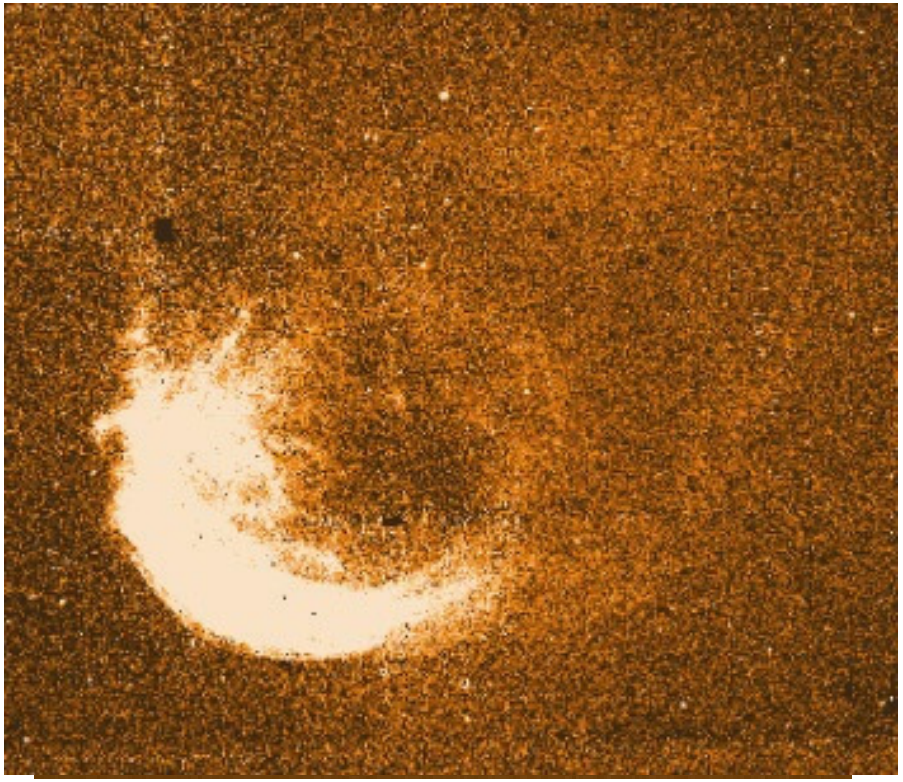
- Central star candidate

- Kwitter, Jacoby and Lydon, AJ, (1988), 96, 997.

Sh 2-188: vital statistics

- Flat (thermal) radio spectrum precludes SNR origin.
- Galactic Plane PN.
- Interaction with ISM suggests highly evolved object.
- One-sided appearance has been attributed to an highly inhomogeneous ISM.
- Filamentary structure is particularly unusual.
- Distance unclear:
  - D = 600pc, d = 1.75pc, t = 12,100yr
  - D = 965pc, d = 2.8pc, t = 22,000yr

Sh 2-188: IPHAS observation



- Hα - r′ mosaic image from IPHAS.
  - Drew et al. MNRAS 362 753
- Note
  - filamentary structure
  - closed ring
  - long tail.

Sh 2-188: IPHAS observation

rtificial colour
mage from
PHAS data.
credit N.Wright)

Form of Sh2-188

- Large-scale nebula suggests this is an old PN
- Brightening in the South-East suggests this PN is in fact moving through the ISM
- Fragmentation of the bow-shock causing filamentary appearance
  - Due to Rayleigh-Taylor instabilities.
  - Galactic magnetic fields may be playing an important part.
- Theoretically, fragmentation occurs with a relative ISM velocity of 100 km/s

Dgani and Soker, ApJ, 434, 262 (1994); Dgani and Soker, ApJL, 499, L83. (1998)

Sh 2-188: proper motion

- Candidate central star has a v_{radial} = -26 km/s.
- Our work has prompted a proper motion investigation between 2003 IPHAS observations and 1976.9 USNO-B1 catalog
- 2003 IPHAS observation showed star offset of 0.8”+-0.3” compared to USNO-B1 catalog (field stars agree to RMS ~0.04”)

Proper motion = 30 +- 10 milliarcseconds per year

Position angle = 120 +- 20 degrees East through North

towards the bright arc

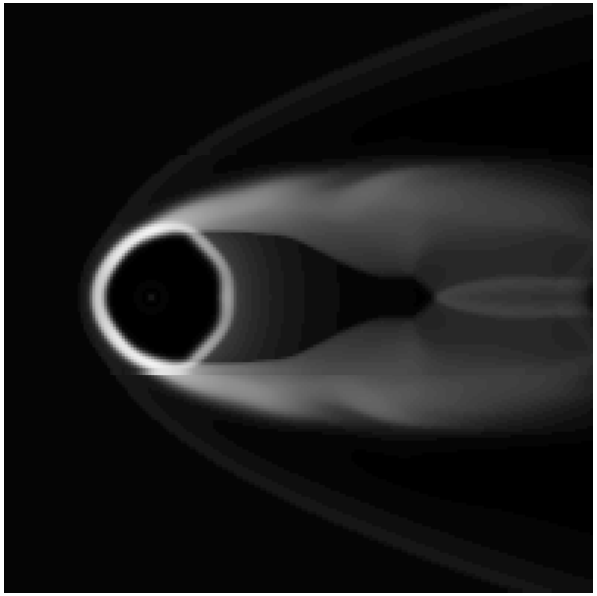
The accuracy of the IPHAS point source catalog is sufficient for proper motion studies

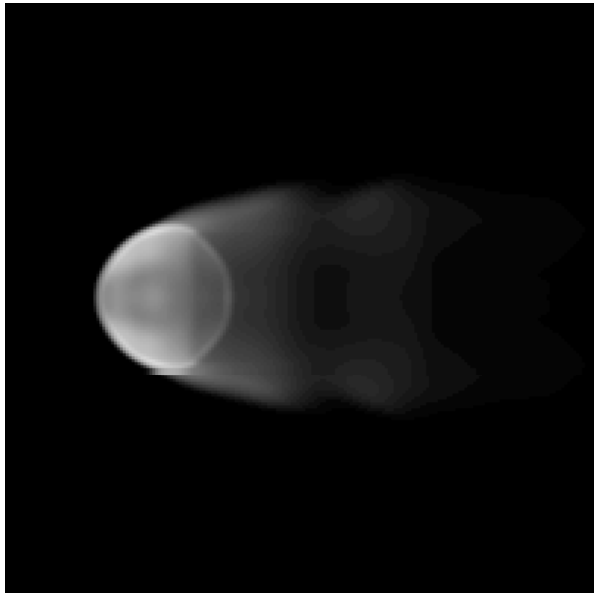
Simulations

- $\log_{10}$ density slice of a cubic grid 10pc on each side, 200^3 resolution
- slow AGB wind (5×10^5 yrs)
  - $dM/dt = 1\times10^{-6}\ M_\odot$ /yr
  - v = 15 km/s
  - T = 10,000 K
- fast post-AGB wind (3×10^4 yrs)
  - $dM/dt = 5\times10^{-8}\ M_\odot$ /yr
  - v = 1000 km/s
  - T = 50,000 K
- ISM
  - T = 2500K
  - $n_H = 0.01\ cm^{-3}$
  - v_{ISM} = 125 km/s

N.B. – there are 5 times more frames per unit time during the post-AGB phase

Sh 2-188: post-AGB evolution



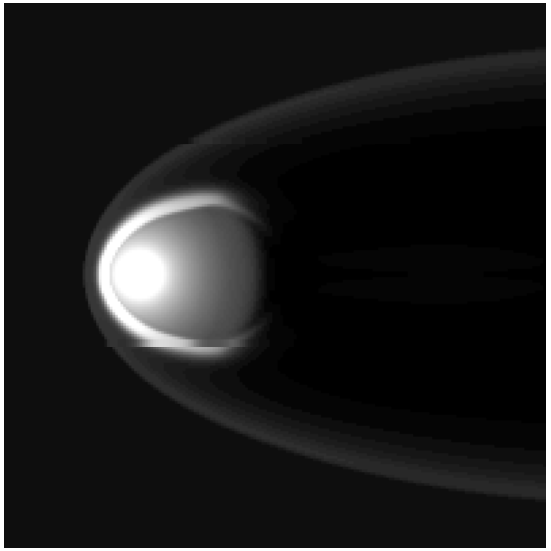


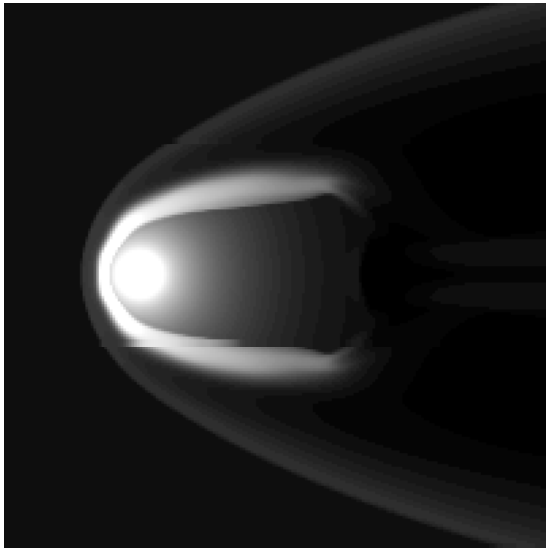
20,000 years into the post-AGB phase.

Left: density slice.
Right: naïve simulated emission.

Sh 2-188: AGB evolution

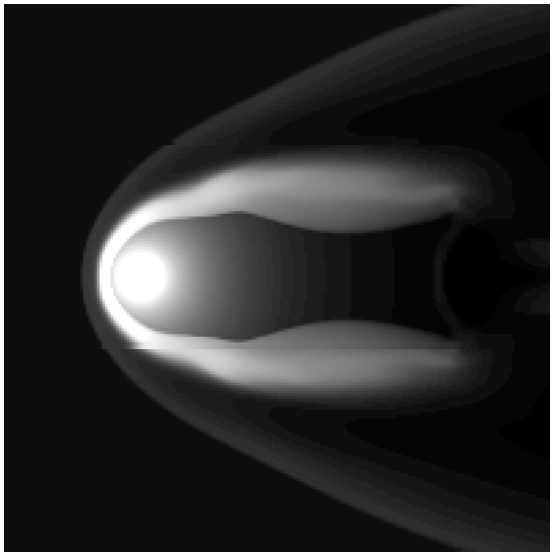
125,000 years

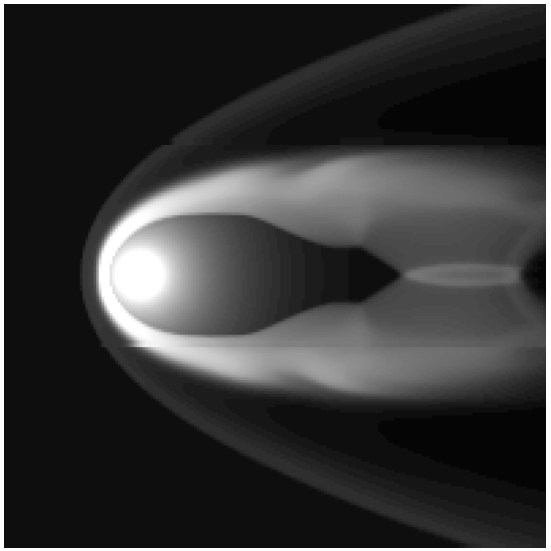




250,000 years

375,000 years





500,000 years

Sh 2-188: dimensions

- Assuming a space velocity of 125 km/s:

D = 850 +- 500 pc

d = 2.5 pc

t = 22.5 +– 2,500 years

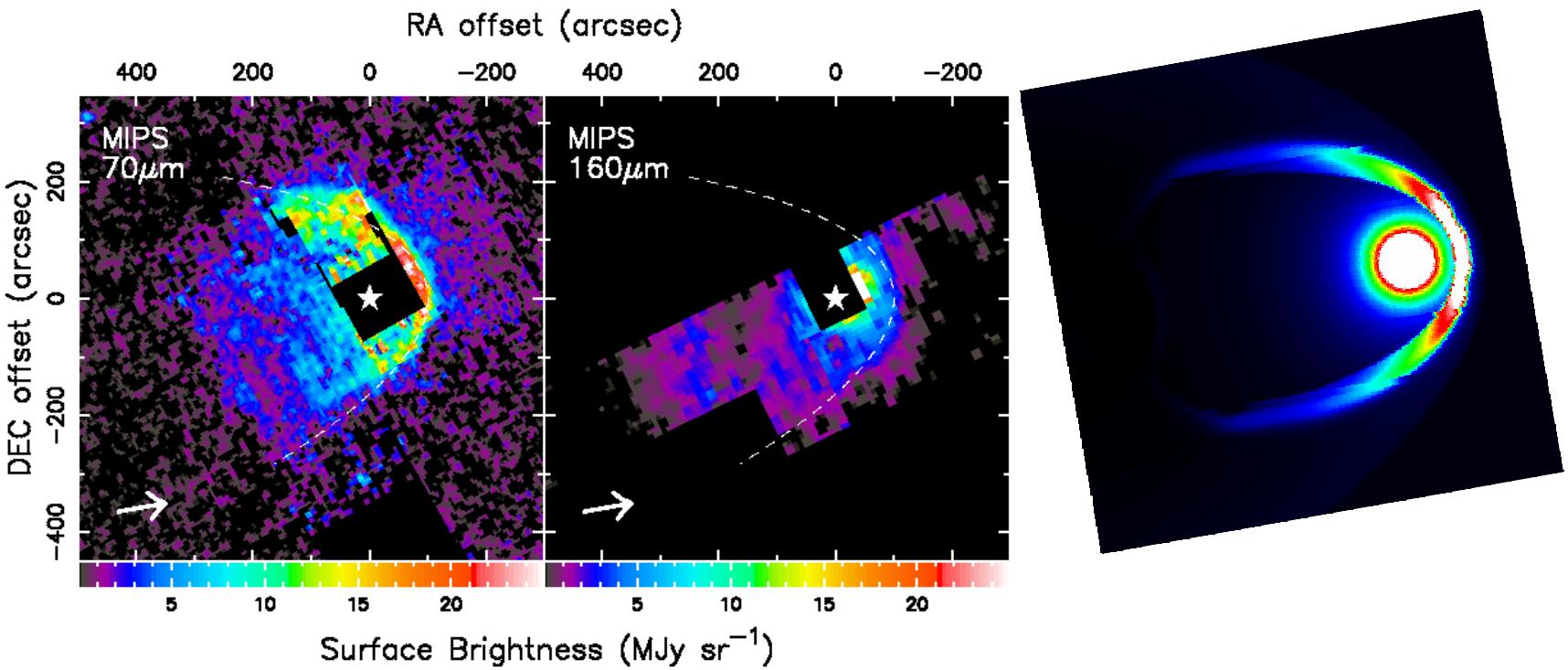
- In agreement with current estimates via non-LTE modelling

IPHAS has revealed the importance of this new field of AGB- and PN-ISM interaction.

From what we see, this is the dominant shaping effect for the haloes of PNe

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).

Instant confirmation of this result! MNRAS letter accepted.

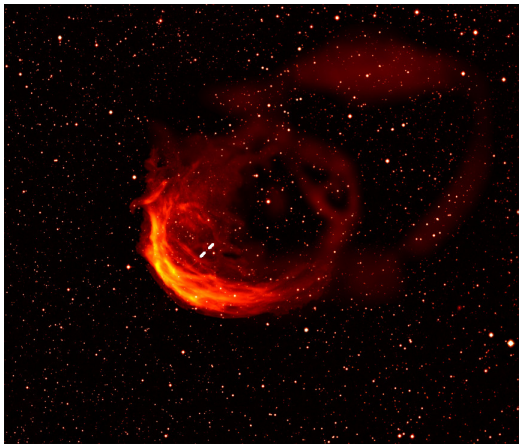
Conclusions I

Essentially a 2 minute observation of an extended nebula shows that the study of such objects at high angular resolution is still in its infancy.

Thus, almost everything that IPHAS sees at the large angular scale will be new structures!

VGIs

Vortex generating instabilities at the head of the bow shock - ApJ Letter to be submitted this week.



- enhanced mixing of stellar material
- turbulence in the ISM

IPHAS halloween!

AGB simulations





IPHAS halloween!

post-AGB simulations





The End!

cwareing@jb.man.ac.uk

Sh 2-188 work published - MNRAS **366** 387 (2006)
R Hya work – MNRAS Letters accepted. A-ph/0607500
Vortices – ApJ L to be submitted this week