Estimating the binary fraction of central stars of planetary nebulae

D. Douchin[1,2], O. De Marco[1], D.J. Frew[1], G. Jacoby[3], J.-C. Passy[4,5], M. Moe[6], T. Hillwig[7], A. Peyaud[1], G. Jasniewicz[2], Q. Parker[1]

1. Macquarie University, Australia
2. Universite Montpellier 2, France
3. Giant Magellan Telescope,USA
4. University of Victoria, Canada
5. American Museum of Natural History, USA
6. University of Harvard, USA
7. Valparaiso University, USA

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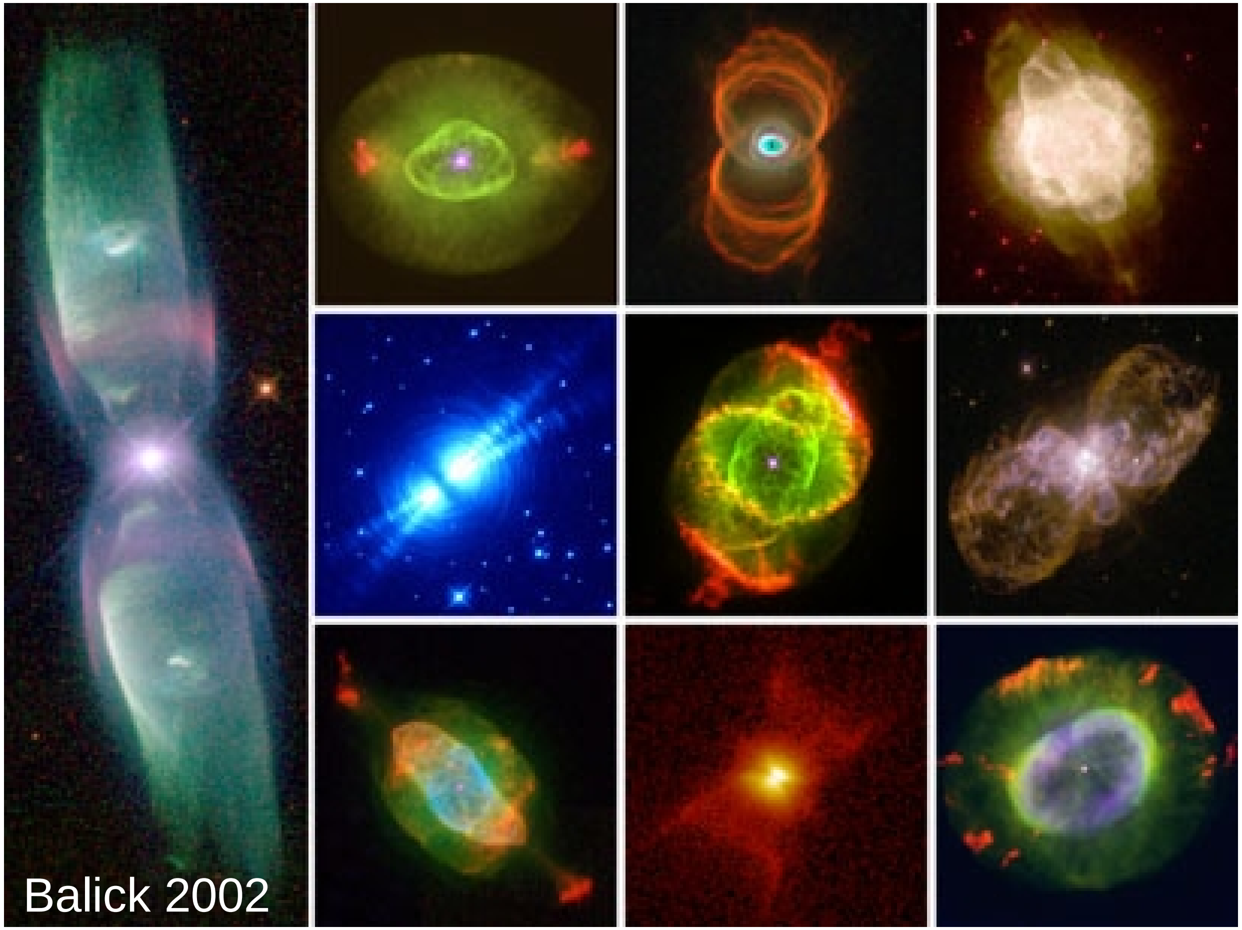
In this talk:

- The Binary hypothesis
- Search for new binary CSPN with the IR excess method
- Implications and future refinements

The Binary Hypothesis

The Binary Hypothesis



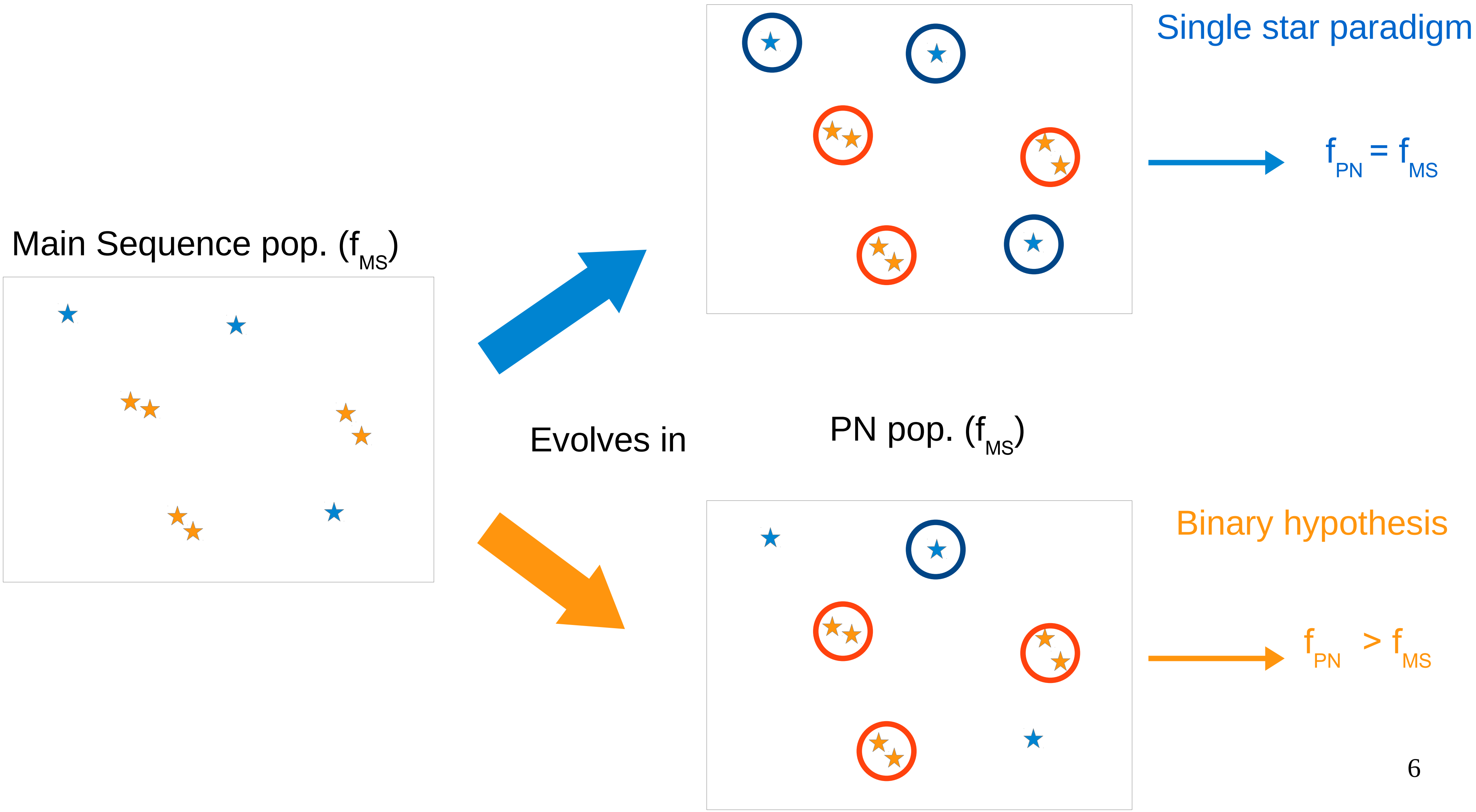
- ~ 80% of PN are non-spherical
- Considered shaping agents are magnetic fields and /or rotation or the presence of a companion

The Binary Hypothesis

The Binary Hypothesis states that

a companion is needed to account for the shapes of non-spherical PN,
i.e. the majority of them.

How to test the Binary Hypothesis



How to estimate the binary fraction of CSPNe

We need:

- a sample representative of the galactic population
- efficient methods to detect binarity
- to control the biases

The sample – from Frew 2008

We want a sample that is statistically large and that is as unbiased as possible with respect to binarity.

- Frew 2008:
  - ~ 300-400 closest PN from us within ~ 3-4kp
  - Objects with an apparent V magnitude < 21
  - The sample is volume-limited, not magnitude limited. It is probably complete within 2kpc.

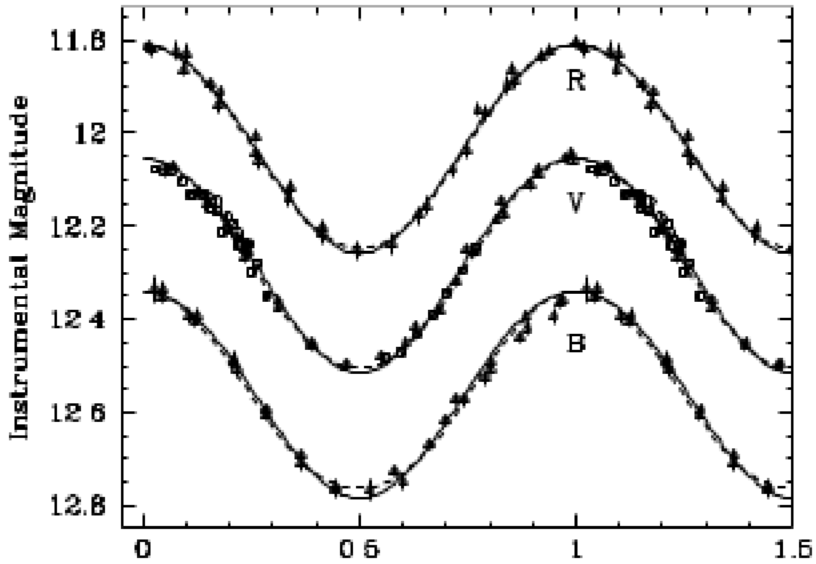
Poster 21!

- Our sub-sample:
  - From Frew 2008
  - Select CSPNe surrounded by extended, low-surface brightness Pne
  - Select CSPNe with Mv > 5 to avoid wind-induced variability
  - Contains 36 objects at the moment
  - We aim at having studied ~100 by June

3 methods to detect binaries

- Radial velocity variability
- Flux variability
- Infrared excess

Flux variability



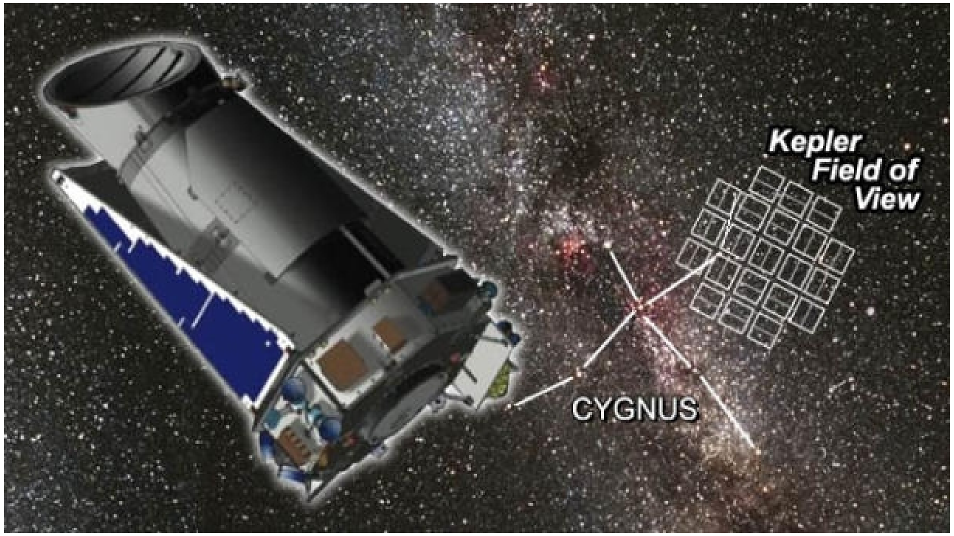
Lightcurve of NGC 6337, Hillwig et al. 2013

- Work of T. Hillwig

Talk tomorrow!
9:15am

Poster 13!

- Work of G.Jacoby et al.
  Poster by Orsola De Marco



3 methods to detect binaries

- Radial velocity variability
- Flux variability
- Infrared excess

The search for infrared excess in CSPN

IR excess detection: how to?

- Calibrated B, V, I (J) photometry on the targets in pristine weather conditions

  => observed B, V, I (J)

- Teff and log g from literature

  => theoretical single star B-V and V-I (V-J) from synthetic spectra
  (TheoSSA and TMAP, Tuebingen code @ the German Virtual Observatory)

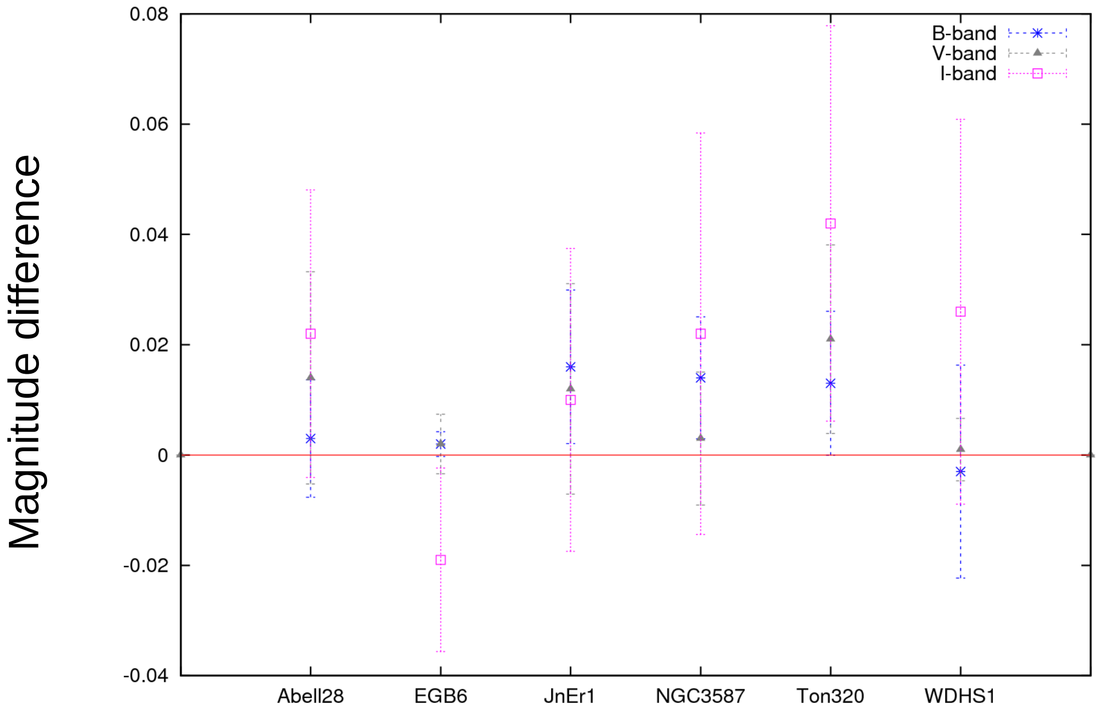
  Observed B-V => E(B-V) and reddening (A_λ) (CCM law Rv=3.1)

  Observed V–I => de-reddened V – I and IR excess

- If excess, interpolates the companion Mv and spectral type

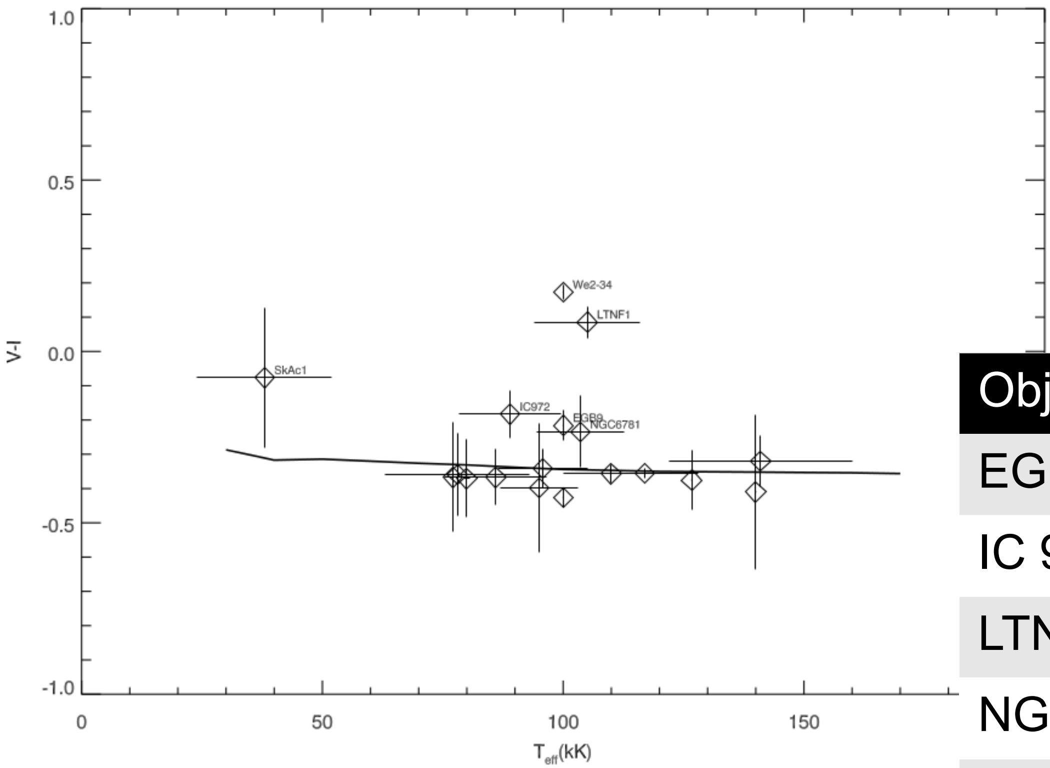
Insuring precision: the overlap sample

- De Marco et al. 2012 published the analysis of a sample of 27 objects
- Douchin et al. (in prep.) adds another 11 objects



IR excess – Results (I-band)

- Out of 11 newly observed objects

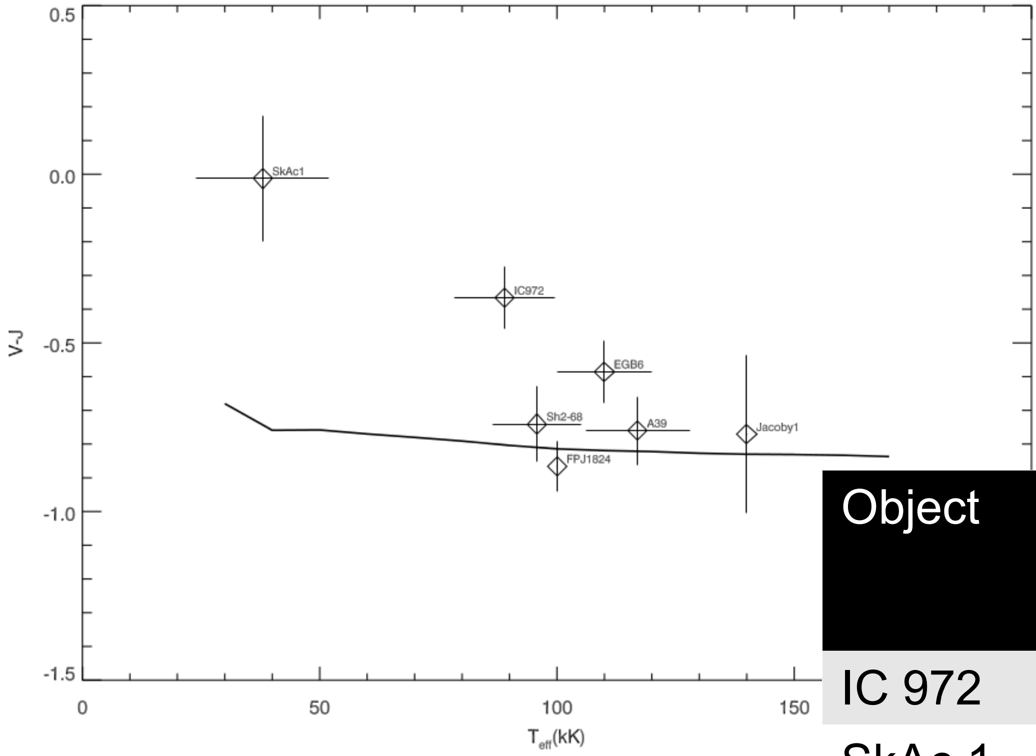


Douchin et al. 2013 (in prep.)

Object	Companion spectral type
EGB 9 (mimic)	G4 [G8 - G0]
IC 972	G8 [K2 - G5]
LTNF 1	G5 [G7 - G4]
NGC 6781	M3 [M5 – M1] :
SkAc 1	M4 [M6 - M4]
We 2-34	M3 [M3 - M3]

IR excess – Results (J-band)

- Crossmatch between our observed sample and 2MASS /UKIDSS (6 objects)

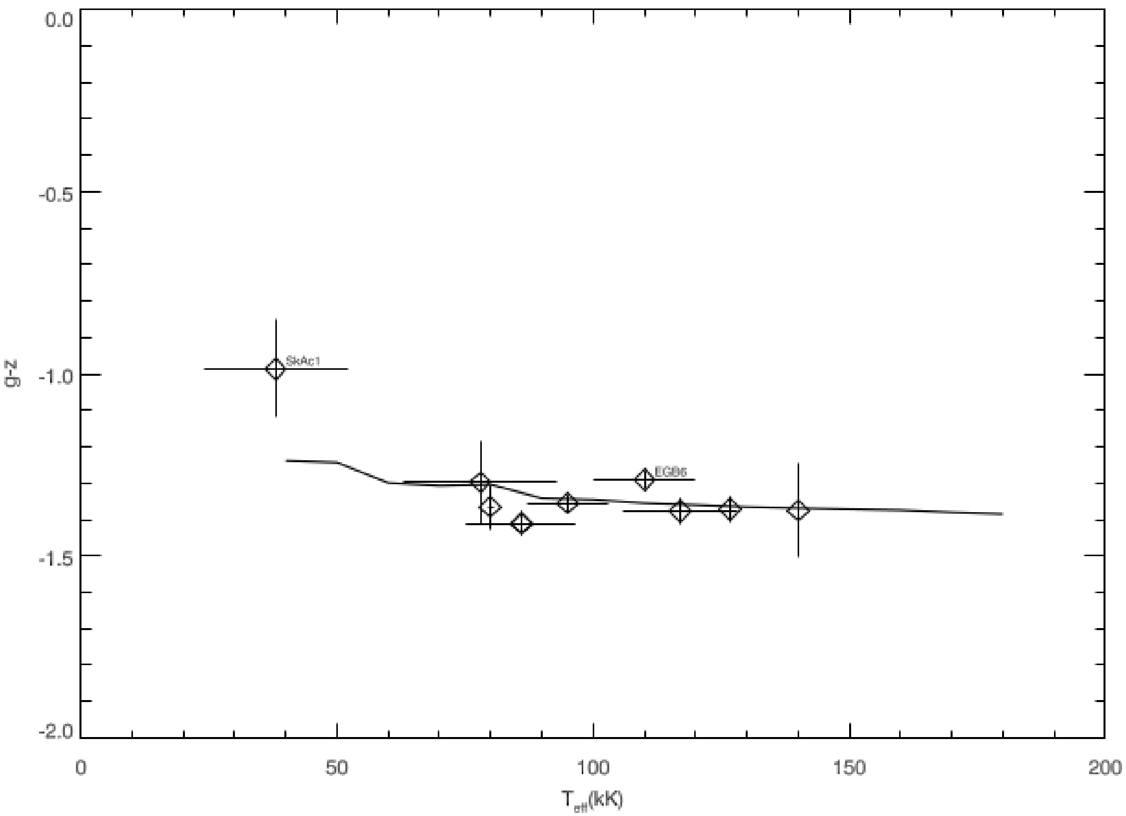


Object	Companion spectral type (J-band)	Companion spectral type (I-band)
IC 972	G6 [K0 - G4]	G8 [K2 - G5]
SkAc 1	M5 [M4 - M6]	M4 [M6 - M4]

Douchin et al. 2013 (in prep.)

Extending the search to SDSS

- Looking for g-z excess
- Using the 9 overlapping objects to check color-calibration
- G-r color for reddening is consistent
- ~50 objects crossmatch with the sample of Frew 2008
- Confirms that a prelminary selection in nebular brighness is necessary



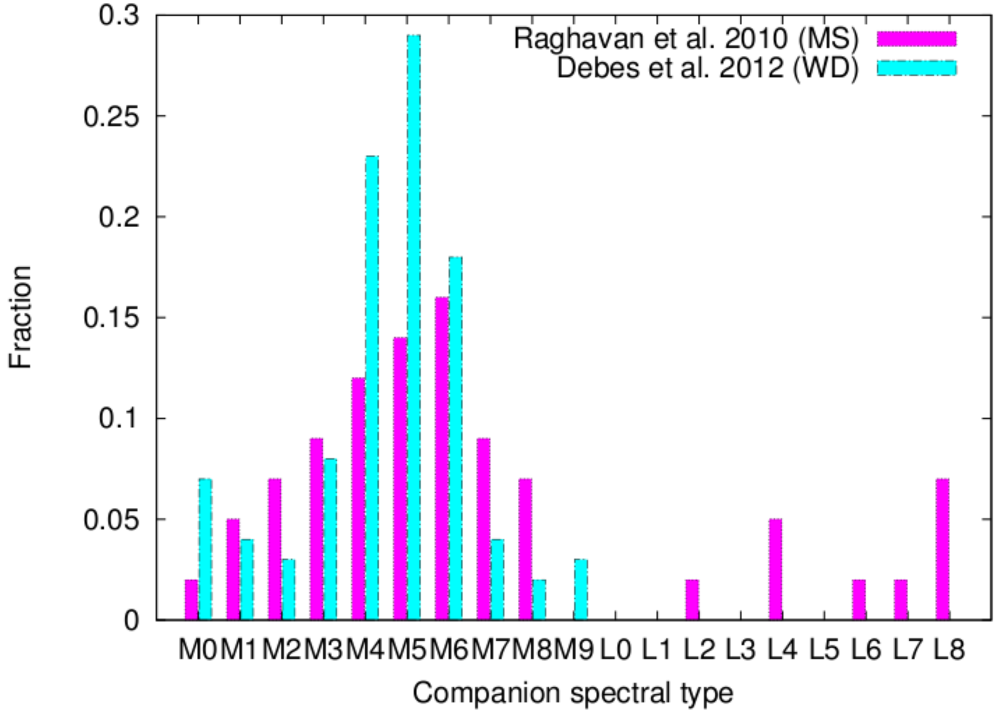
Observed binary fraction

- 12/36 = 33% ± 15% in the I-band
- 8/16 = 50% ± 25% in the J-band
- The sample size is still small => big error bars.
- Missing faint companions. I-band less sensitive than J-band.

Implications on PN shaping and formation from binaries

From the observed to the complete binary fraction

- Accounting for the undetected faint companions:
- Limit in I: M3V ; limit in J: M4V

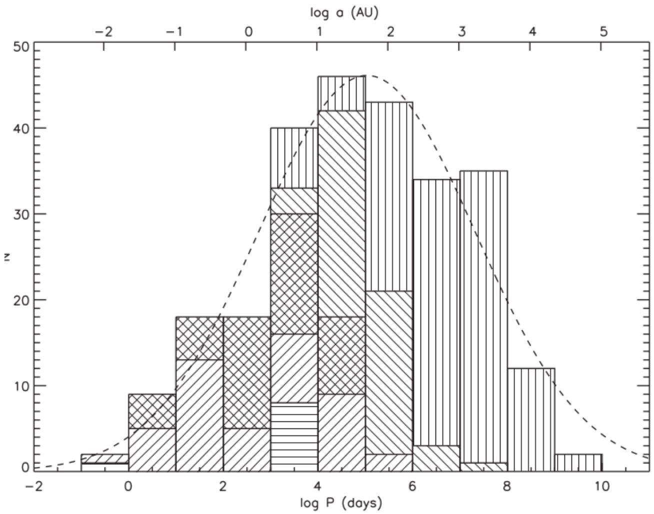


- I-band: 33% → 49%
  J-band: 50% → 59%

From the observed to the complete binary fraction

- Wide binaries that are resolved are not taken into account by our method

- Using the spatial resolution of our observations as the resolution limit (→ de-projected separation a few x100 AU):



Main sequence binary period distribution,
Raghavan et al. 2010

- This limit also corresponds to the separation at which the companion is too far to interact to shape the PN.

Comparing with the non-spherical PN fraction

- The binary fraction is 50% - 60% < 80%
- Some non-spherical PN come from a non-binary channel
- Some might result from planet interaction or a merger
- We can improve the measured binary fraction by getting better statistics from a larger sample.

Comparing with the main sequence

- The total binary/multiple fraction for the MS progenitor population is 50% ± 2% (G2 – F6)
- Excluding MS wide binaries (separation a few x100AU):
- => MS binary fraction is 35%

Conclusions so far

- Binary fraction of central stars of planetary nebulae
(less than a few x100AU)
~ 55% ± 20%

Binary fraction of main sequence stars
(less than a few x100AU)
~ 35%

Our estimate of the binary fraction of CSPN seems to indicate that binaries are indeed a preferred, but not exclusive channel for PN formation.

This is from small number statistics. We have in hand data for ~30 objects. This is going to decrease the error bars significantly.

Thank you for your attention.

Any questions?