Estimating the binary fraction of central stars of planetary nebulae

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Dimitri Douchin | APN VI Conference
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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

Balick 2002
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

- Main Sequence pop. ($f_{MS}$)
- PN pop. ($f_{PN}$)

Evolves in

- Single star paradigm: $f_{PN} = f_{MS}$
- Binary hypothesis: $f_{PN} > f_{MS}$
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
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.

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

Work of T. Hillwig

Talk tomorrow!
9:15am

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

Lightcurve of NGC 6337, Hillwig et al. 2013

Poster 13!
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 ($A_\lambda$) (CCM law Rv=3.1)
- Observed V–I => de-reddened V – I and IR excess
- If excess, interpolates the companion Mv and spectral type
De Marco et al. 2012 published the analysis of a sample of 27 objects

Douchin et al. (in prep.) adds another 11 objects
Out of 11 newly observed objects:

<table>
<thead>
<tr>
<th>Object</th>
<th>Companion spectral type</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGB 9 (mimic)</td>
<td>G4 [G8 - G0]</td>
</tr>
<tr>
<td>IC 972</td>
<td>G8 [K2 - G5]</td>
</tr>
<tr>
<td>LTNF 1</td>
<td>G5 [G7 - G4]</td>
</tr>
<tr>
<td>NGC 6781</td>
<td>M3 [M5 – M1]</td>
</tr>
<tr>
<td>SkAc 1</td>
<td>M4 [M6 - M4]</td>
</tr>
<tr>
<td>We 2-34</td>
<td>M3 [M3 - M3]</td>
</tr>
</tbody>
</table>

Douchin et al. 2013 (in prep.)
IR excess – Results (J-band)

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

<table>
<thead>
<tr>
<th>Object</th>
<th>Companion spectral type (J-band)</th>
<th>Companion spectral type (I-band)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SkAc 1</td>
<td>M5 [M4 - M6]</td>
<td>M4 [M6 - M4]</td>
</tr>
</tbody>
</table>

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 preliminary selection in nebular brightness 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%
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):

This limit also corresponds to the separation at which the companion is too far to interact to shape the PN.
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.
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)
  \(~ 55\% \pm 20\%\)

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?