Planetary nebulae: What can they tell us about binary evolution?

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Physics of Evolved Stars 2015
Aspherical planetary nebulae

- Rapidly rotating stars?
- Magnetic fields?
- BINARIES!
Common envelope ejection
The source of the density contrast

Nordhaus & Blackman (2006)
PNe with binary central stars

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Slow-going (until now)
drdjones.net/bCSPN for a full list
Only confirmed super-\( M_C \) mass DD that will merge in \(< t_{\text{Hubble}} \)

Higher density of DD than expected

“Fresh out of the CE oven”

Key in understanding formation of

- CVs
- Novae
- Supernovae Ia
- LMXBs
- …
Problem children
Pop-synth comparison with Han et al. (1995)
Morphologies

PNe with binary central stars

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Jones et al. (2014)

Miszalski et al. (2011)

Guerrero & Miranda (2012)

Miszalski et al. (2011)

Santander-Garcia et al. (2015)

Boffin et al. (2012)
Polar outflows
Polar outflows

Boffin et al. (2012)
Fg1
Hydro models from Raga et al. (2009) $\rightarrow P \sim 100$–1000 years!
Fg1
Period is much shorter!
### Ages

<table>
<thead>
<tr>
<th>PN</th>
<th>$t_{\text{nebula}}$ (yrs/kpc)</th>
<th>$t_{\text{jets}}$ (yrs/kpc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 63</td>
<td>$3500 \pm 200$</td>
<td>$5200 \pm 1200$</td>
</tr>
<tr>
<td>The Necklace</td>
<td>$1100 \pm 100$</td>
<td>$2350 \pm 450$</td>
</tr>
<tr>
<td>ETHOS 1</td>
<td>$900 \pm 100$</td>
<td>$1750 \pm 250$</td>
</tr>
<tr>
<td>Fg 1</td>
<td>$5000$</td>
<td>$6000-16000$</td>
</tr>
</tbody>
</table>
The Necklace
IPHASX J194359.5+170901

PNe with binary central stars
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Carbon dwarf secondary
Miszalski, Boffin & Corradi (2013)
Inflated secondaries
Further evidence of mass transfer?

Abell 46 (Afşar & Ibanoglu 2008)
Hen2-155 (Jones et al. 2015a)
Jets older than main nebula

- Masses can be used to measure $B$-fields (Tocknell et al. 2014)

Inflated and/or chemically polluted secondaries
And now for something completely different
Abundances from ORLs and CELs are discrepant, on average by a factor of 2–5.

Some show much higher \( adf \)s, most of those are binaries (or born again).
High $adfs$

- Low nebular masses (Corradi et al. 2015)
  - Not a typical CE phase?
  - Fall-back?
  - Planets?
- Abundances more consistent with novae?
  - An intrinsically binary phenomenon
- Presence of a second, low-temp, high-Z gas phase
  - Enriched material ejected into a pre-existing nebula?
- Not all binaries have high $adfs$
  - High $adf \Rightarrow$ binarity, but binarity $\nRightarrow$ high $adf$
Summary

- Binaries responsible for shaping of some PN
- Pre-CE mass transfer
- Chemisty more consistent with eruptive event?
- PN are good laboratories for studying binaries
- Critical for understanding lots of other phenomena
Thank you!