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

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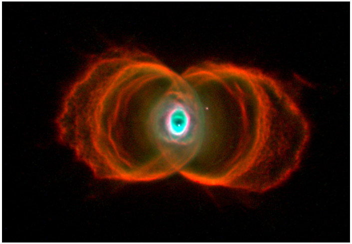
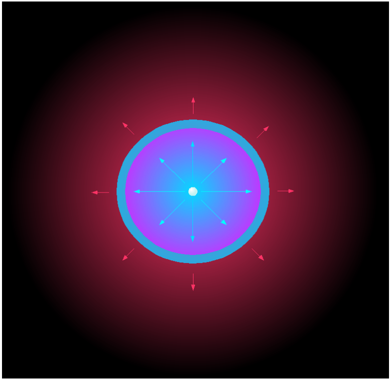
Physics of Evolved Stars 2015

Aspherical planetary nebulae

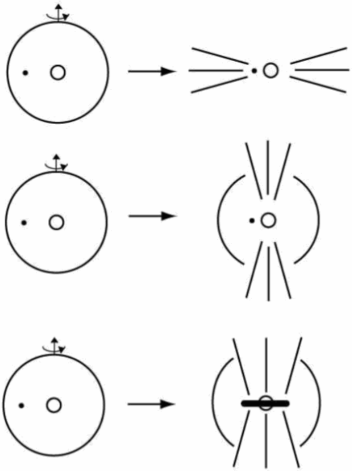
- Rapidly rotating stars?
- Magnetic fields?
- BINARIES!





Common envelope ejection

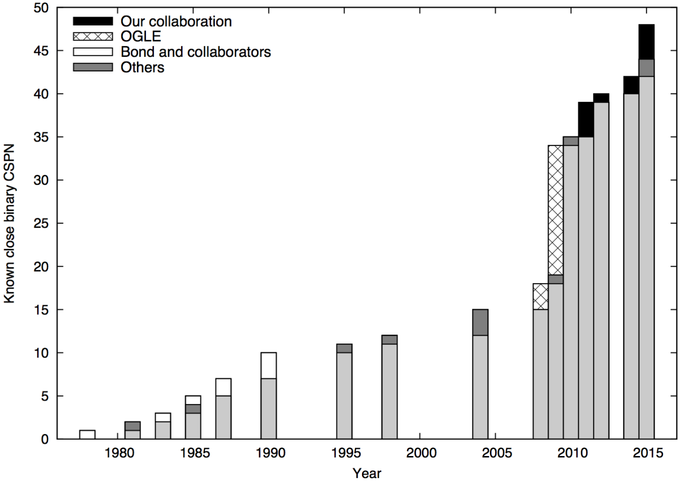
The source of the density contrast



Nordhaus & Blackman (2006)

Slow-going (until now)

drdjones.net/bCSPN for a full list



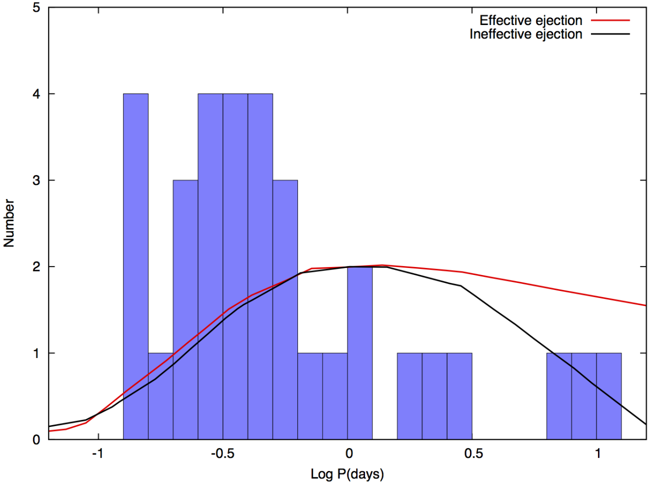
Why should you care?

Hen 2-428 (Santander-García et al. 2015)

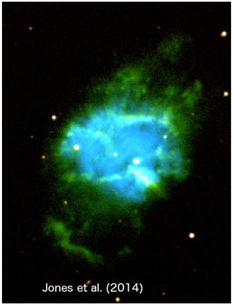
- Only confirmed super-M_C mass DD that will merge in $< t_{Hubble}$
- Higher density of DD than expected
- "Fresh out of the CE oven"
- Key in understanding formation of
  - CVs
  - Novae
  - Supernovae Ia
  - LMXBs
  - ...

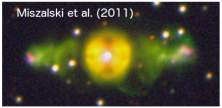
Problem children

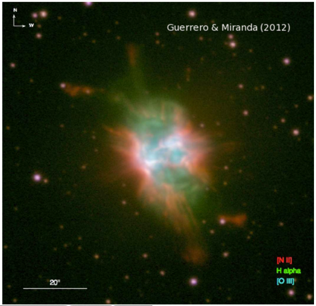
Pop-synth comparison with Han et al. (1995)



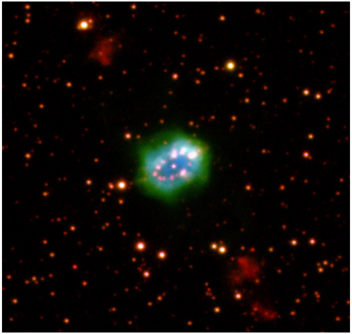
Morphologies

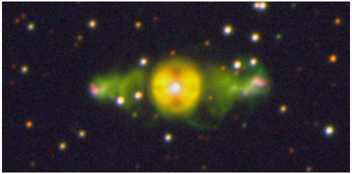


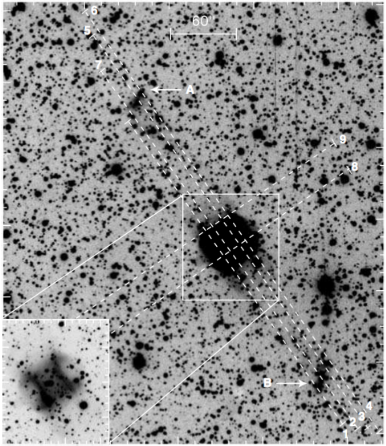




Polar outflows







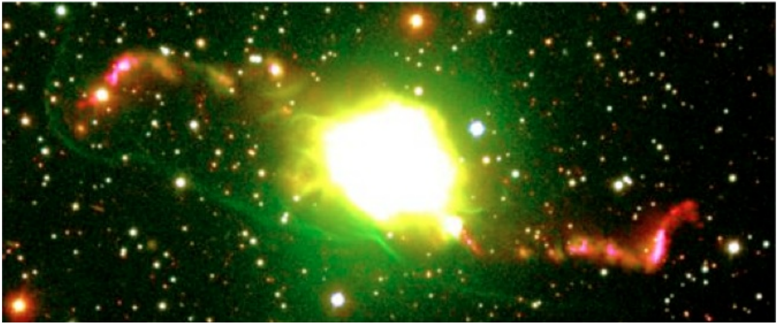
Polar outflows

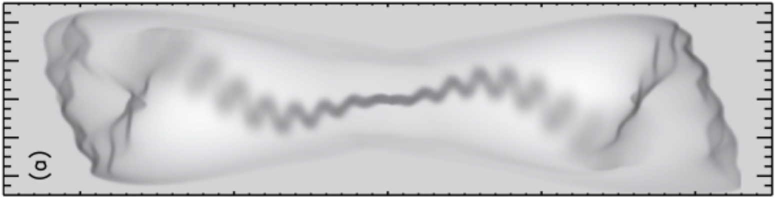
Fg 1

Boffin et al. (2012)

Fg1

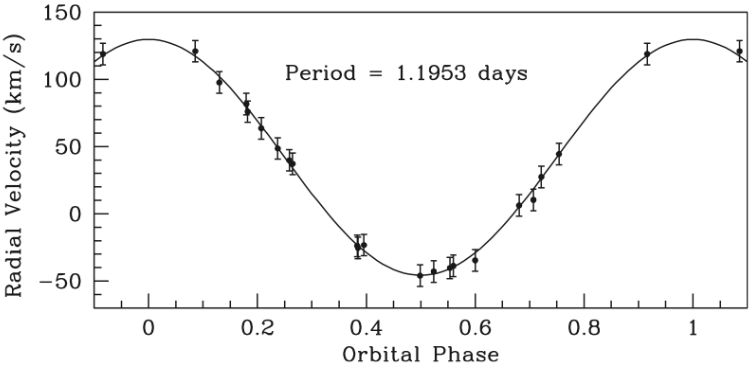
Hydro models from Raga et al. (2009) → P ∼ 100–1000 years!





Fg1

Period is much shorter!

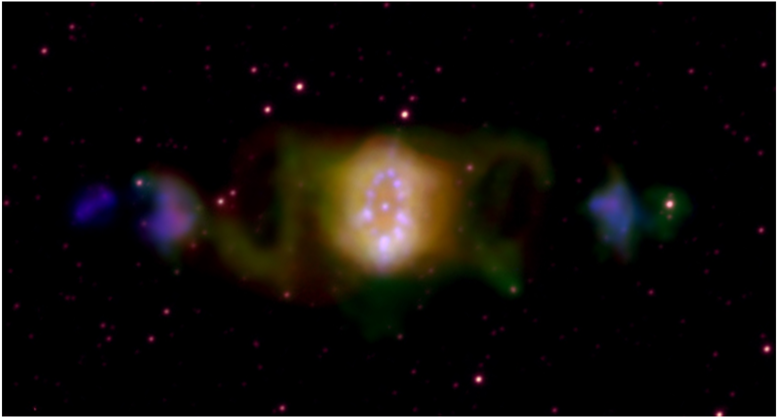


Polar Outflows

Ages

PN	t_{nebula} (yrs/kpc)	t_{jets} (yrs/kpc)
A 63	3500±200	5200±1200
The Necklace	1100±100	2350±450
ETHOS 1	900±100	1750±250
Fg 1	5000	6000-16000

IPHASX J194359.5+170901
Corradi et al. (2011)



The Necklace
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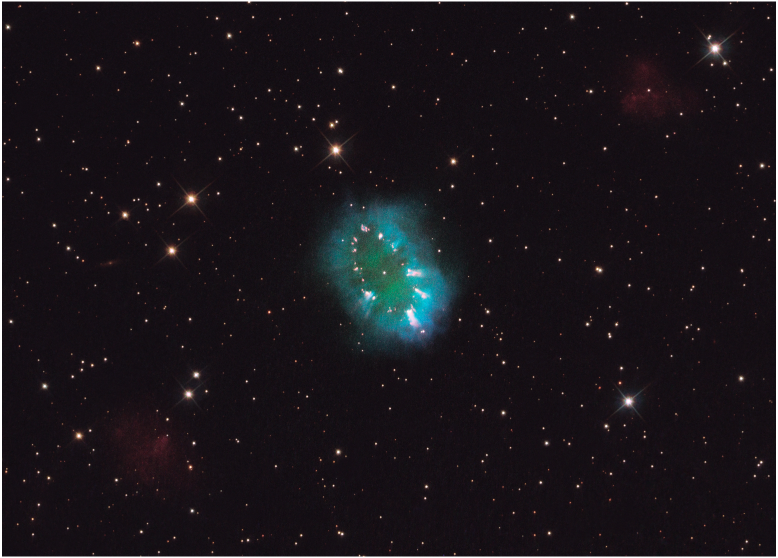
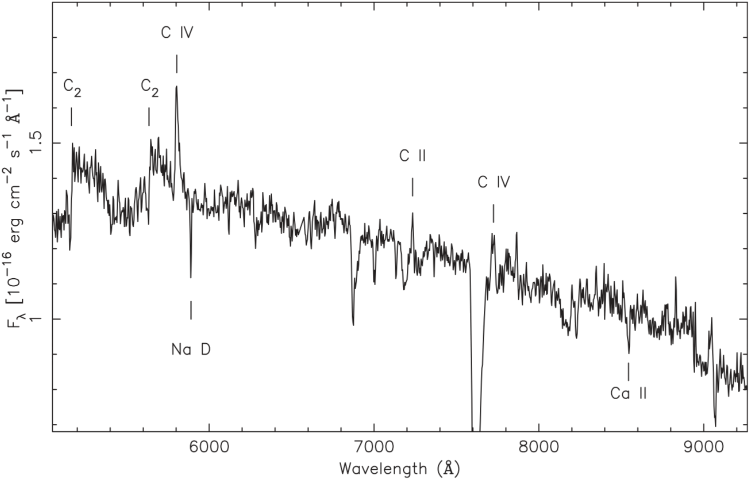


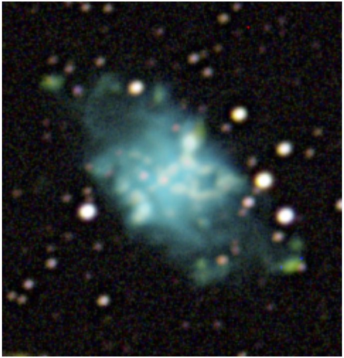
Carbon dwarf secondary
Miszalski, Boffin & Corradi (2013)



Inflated secondaries

Further evidence of mass transfer?

Abell 46 (Afşar & Ibanoğlu 2008)



Hen2-155 (Jones et al. 2015a)

Pre-CE mass transfer episode

- 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

Jones et al. (2015b), Corradi et al. (2015)

Abundances from ORLs and CELs are discrepant, on average by a factor of 2–5.

Some show much higher *adfs*, most of those are binaries (or born again).

PN	*adf*	Period(days)
A 30	$\gg$100	?
A 46	120	0.47
A 58	89	?
Hf 2-2	70	0.40
Ou 5	56	0.36
NGC 1501	32	N/A
M 1-42	20	N/A
NGC 6778	18	0.15
NGC 40	17	N/A
NGC 2022	16	N/A
Hen 2-161	11	$\sim$1
A 63	8	0.46
Hen 2-155	6	0.15
NGC 5189	2	4.04

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!

Christophe Morisset (2013)