When aspherical cosmic bubbles betray a difficult marriage

A study of binary central stars of Planetary Nebulae

Henri M.J. Boffin (ESO)

Brent Miszalski, D. Frew, A. Moffat, A. Acker, J. Köppen, Q. Parker, R. Corradi, D. Jones, M. Santander-Garcia, P. Rodriguez-Gil, M. Rubio-Diez

Outline

- The zoo of planetary nebulae
- Explaining their shape and common envelope evolution
- The search for binary central stars
- Morphology affected by binarity?
- A barium-rich central star discovered
- Summary

2011年10月27日木曜日

Spherical
Planetary Nebula
Abell 39

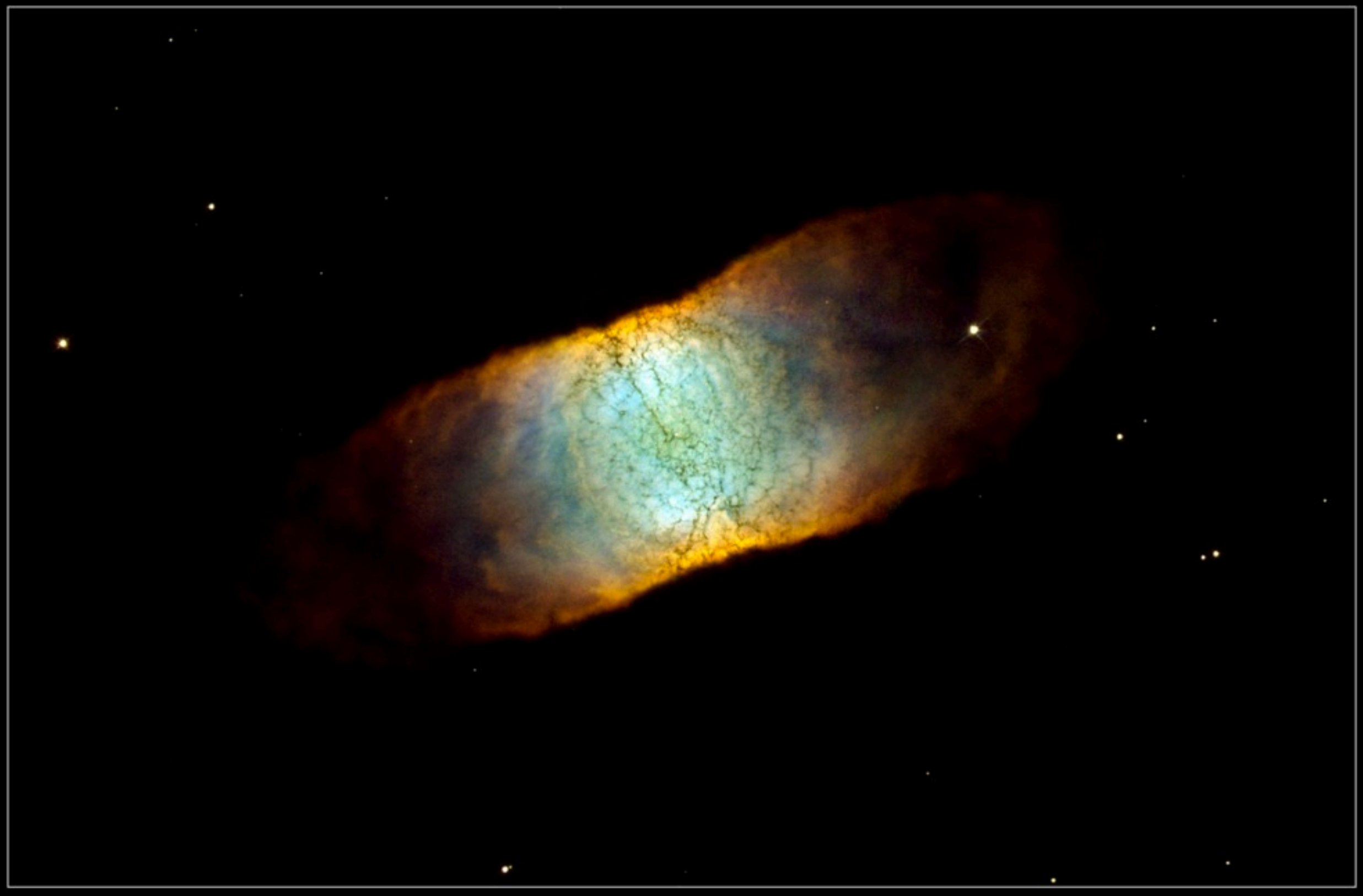
Credit & Copyright:
George Jacoby
(WIYN Obs.) et al.,
WIYN, AURA,
NOAO, NSF

.

2011年10月27日木曜日

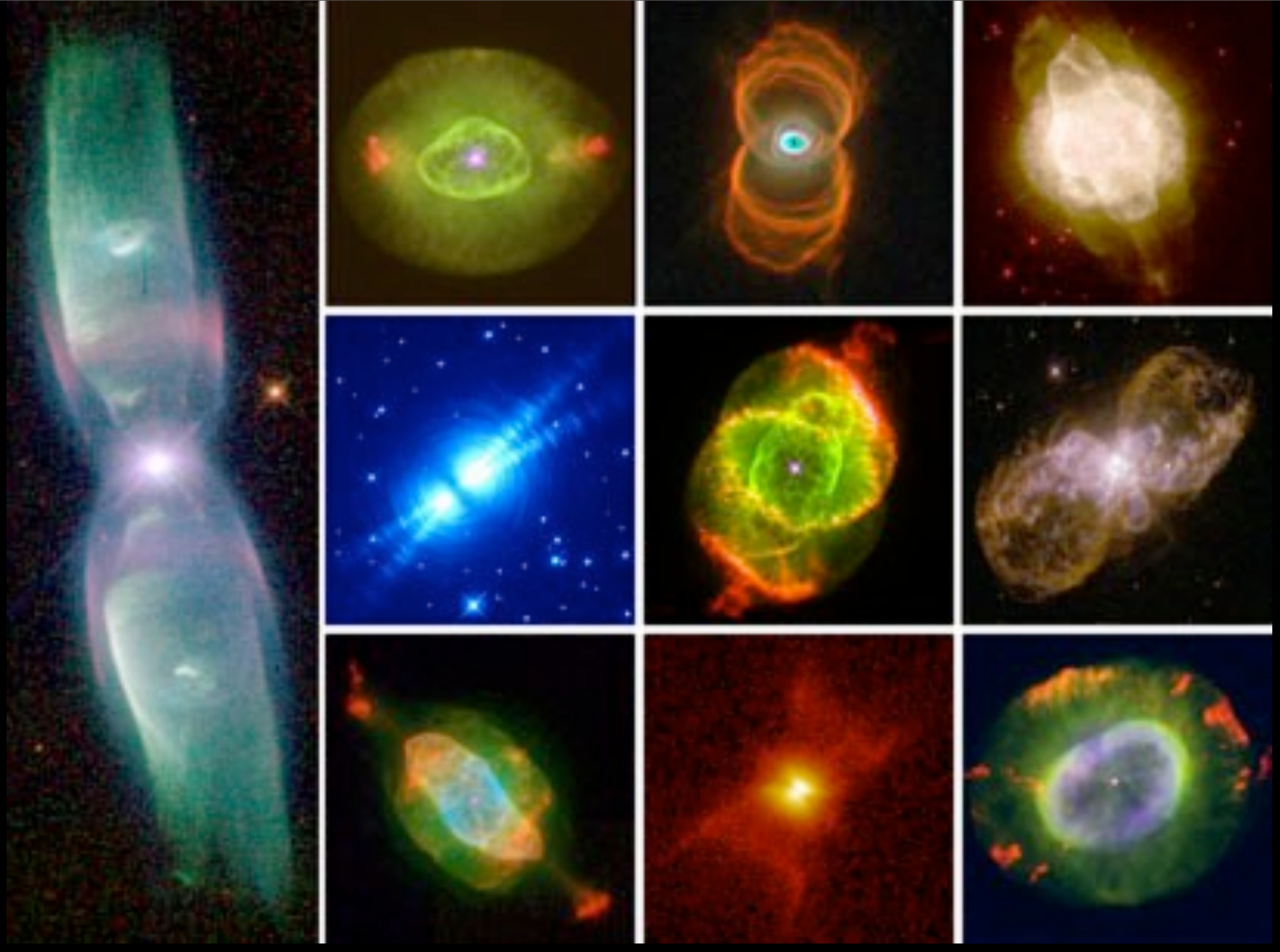
2011年10月27日木曜日

Planetary Nebula IC 4406



Hubble Heritage

2011年10月27日木曜日

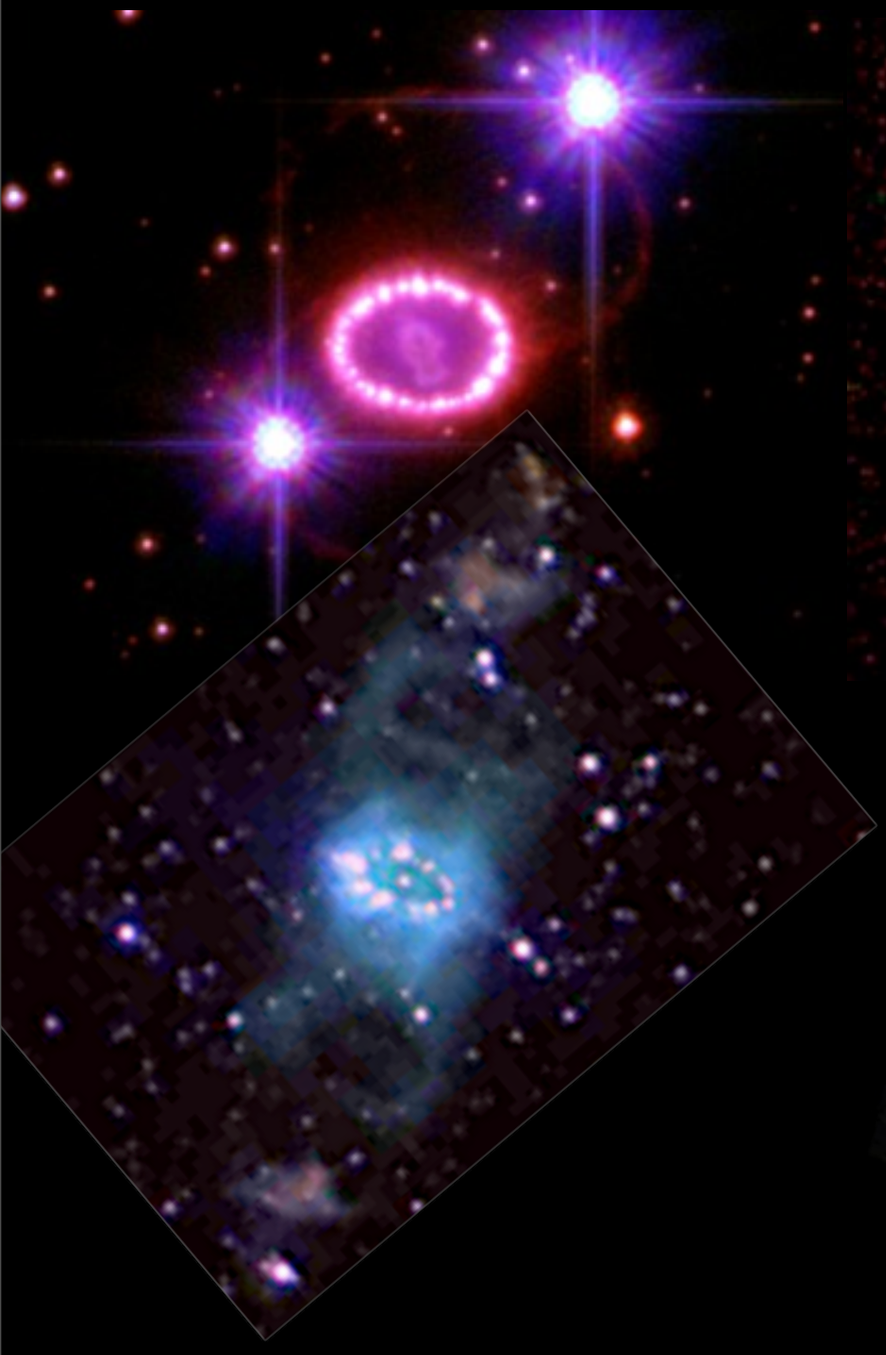


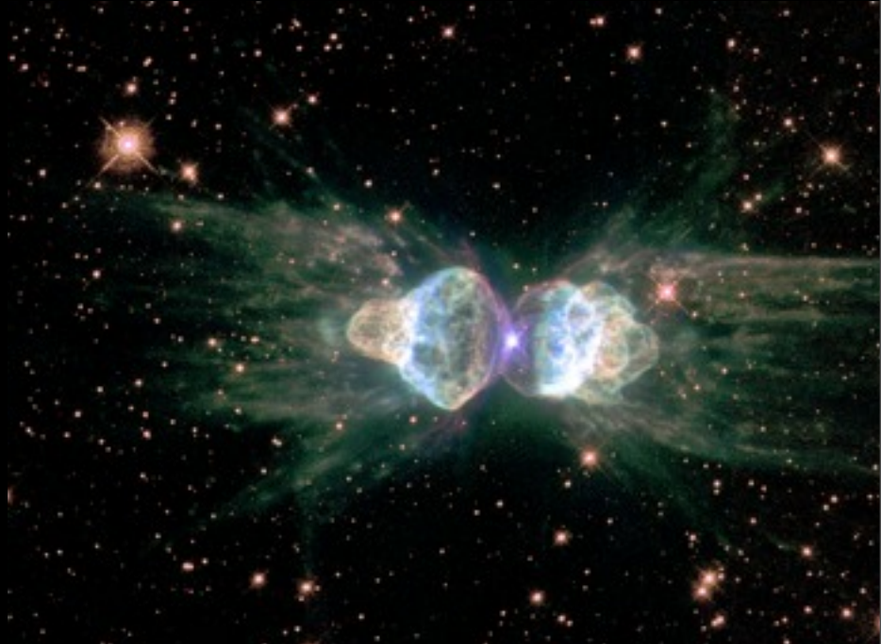
Balick et al./NASA/HST

Planetary Nebulae

SN 1987A

Eta Car

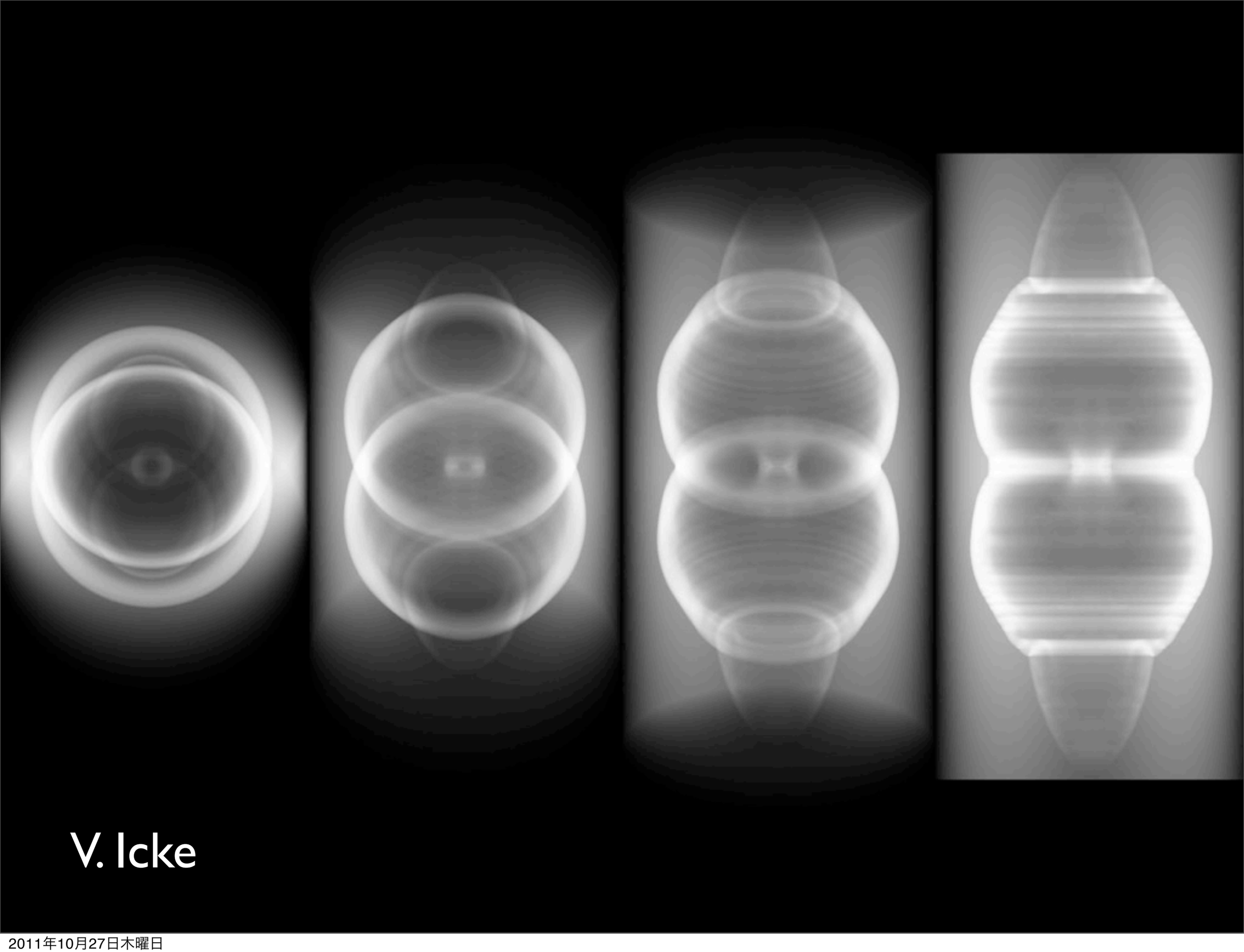




Necklace

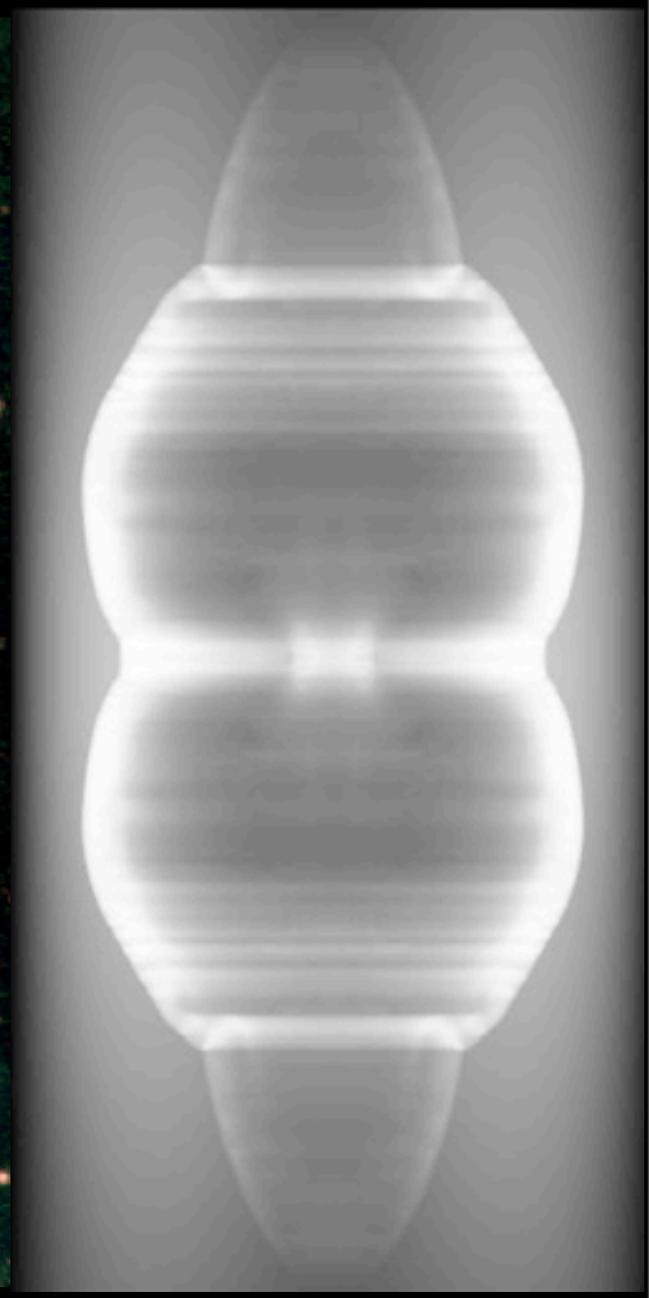
MyCn18

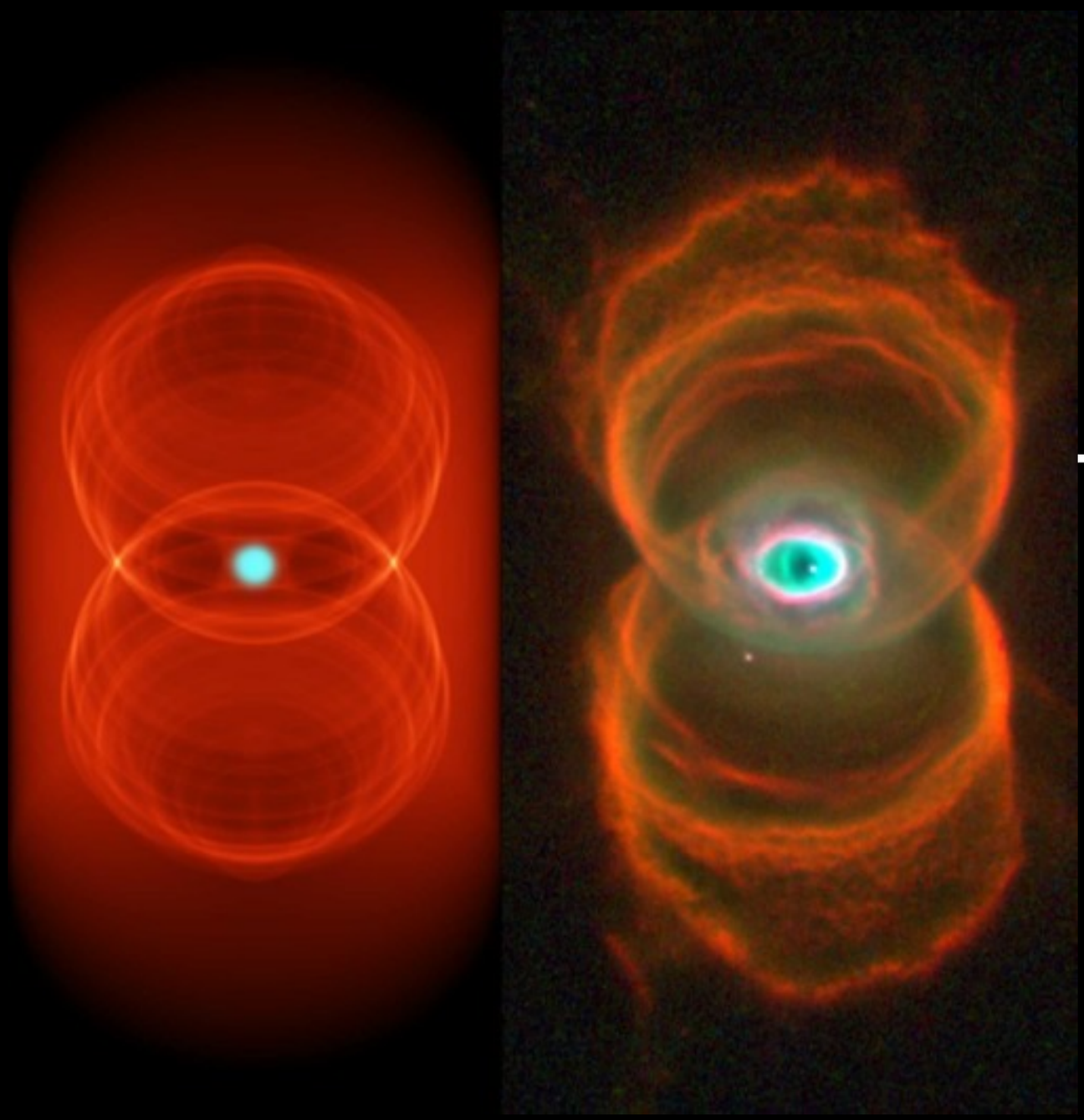
Menzel 3



V. Icke

Cosmic Ant

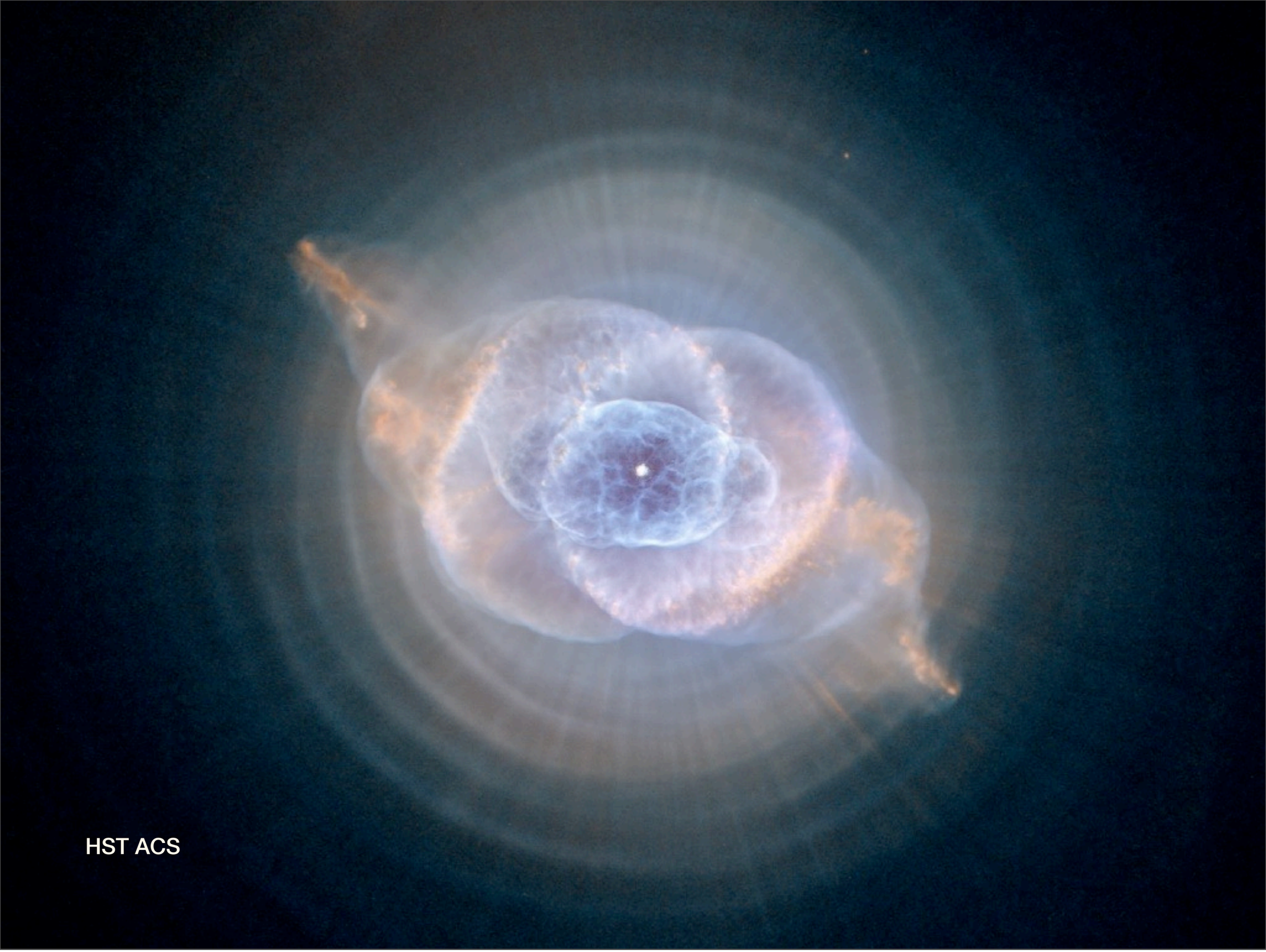




Hourglass Nebula

MyCn18


HST WFPC2


HST ACS

Causes for density contrasts?

- Rapid rotation and/or Magnetic fields?

Causes for density contrasts?

- Rapid rotation and/or Magnetic fields?
  - Models can reproduce some of the features when no feedback on field is introduced
  - But require strong fields (not detected)
  - Need a dynamo to keep the field

(Nordhaus et al. 2007)

Causes for density contrasts?

- Rapid rotation and/or Magnetic fields?

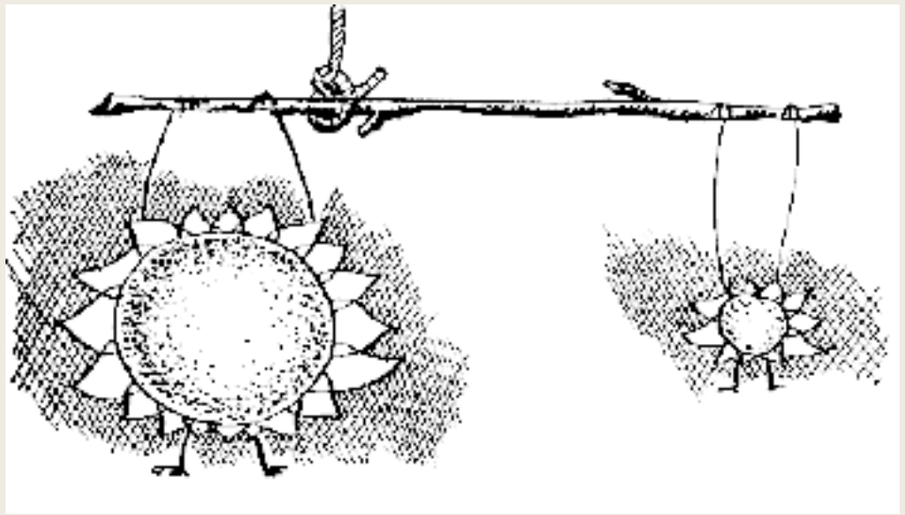
Models can reproduce some of the features

But require strong fields, not detected

Need a dynamo to keep the field

Causes for density contrasts?

- Rapid rotation and/or Magnetic fields?
- Binary star?

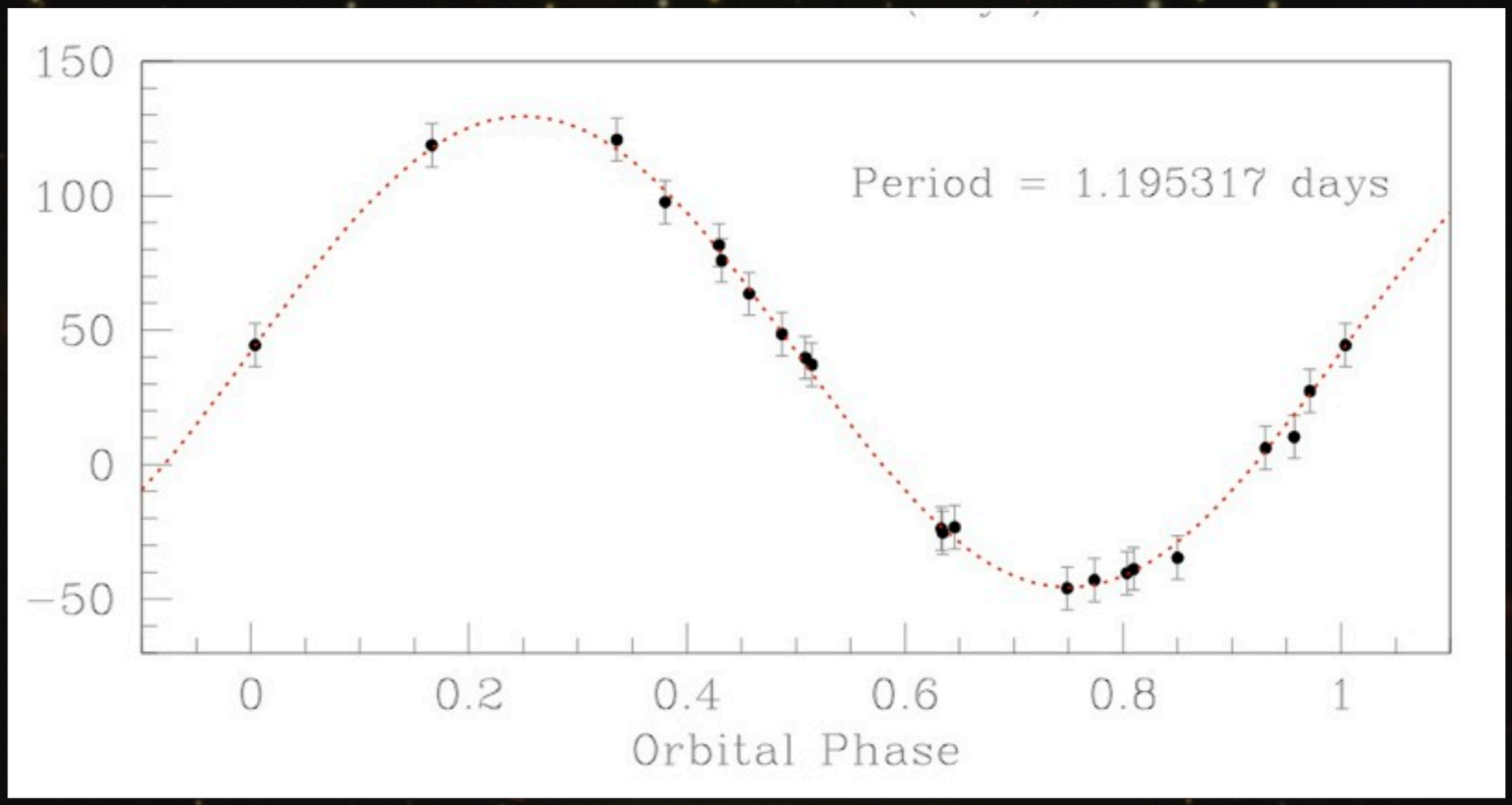


Causes for density contrasts?

- Rapid rotation and/or Magnetic fields?
- Binary star?
  - jets (accretion discs)
  - predicted (common envelope evolution; mass transfer by wind)
  - post-AGB (pre-PNe)

Boffin & Miszalski, 2011

A binary containing 2 WDs!

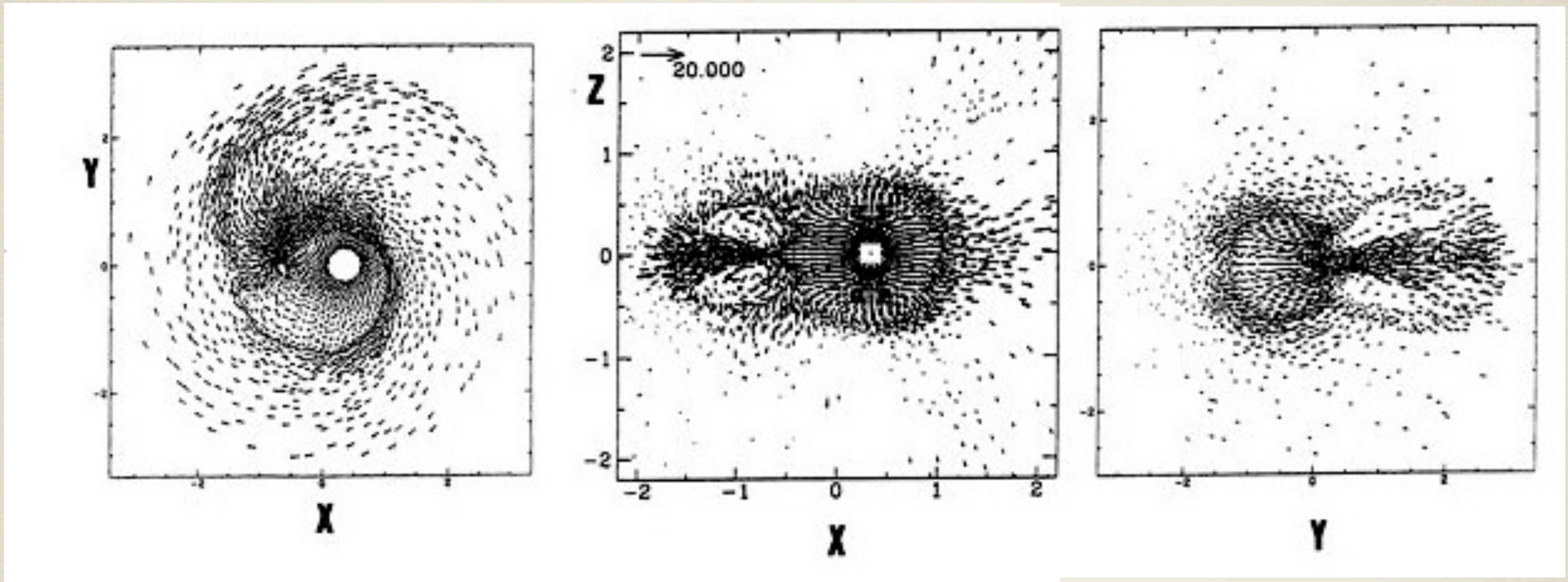


Boffin et al. 2011

Common envelope evolution

Credit: STScI

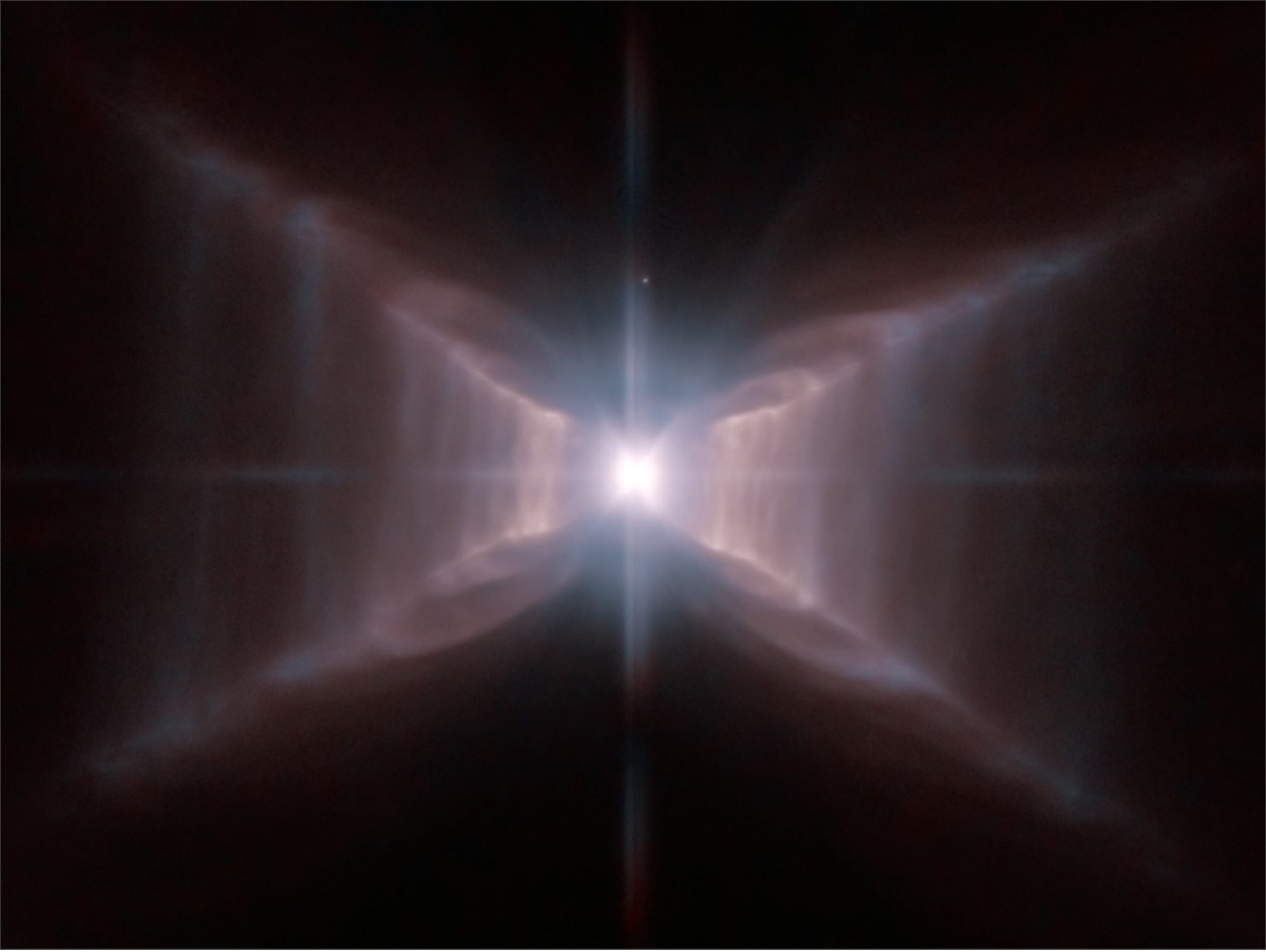

Credit: STScI



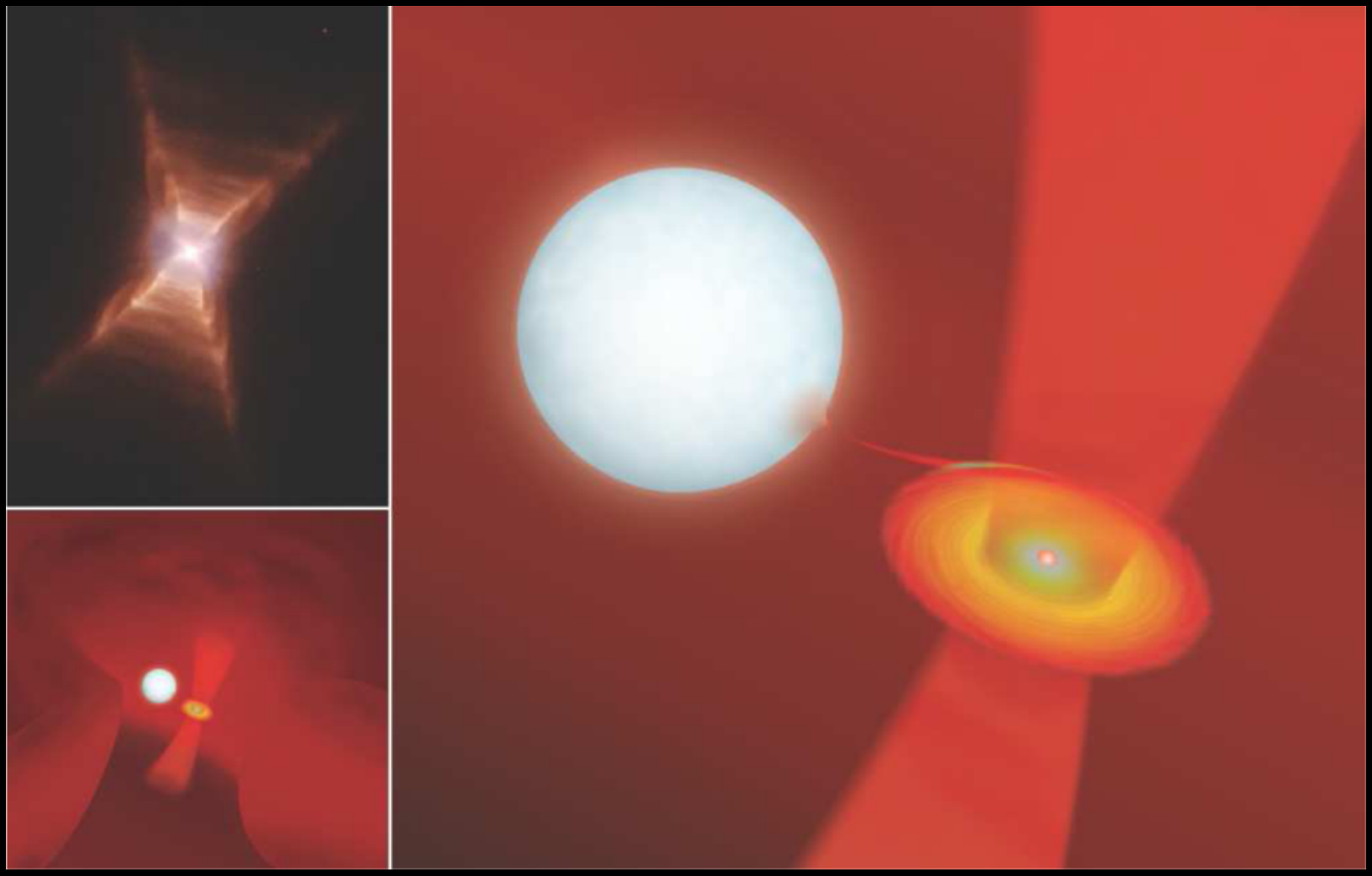
Boffin et al. 1994

Post-AGB stars

- Van Winckel et al. (2009): RV monitoring of 6 post-AGB stars that have a disc and a low pulsational amplitude
- All are binaries with periods in range 120to 1800 days
- This may indicate that binarity is a prerequisite for disc formation
- They found a wide range of orbits and mass functions



2011年10月27日木曜日



A. Witt et al., 2009

Binary star hypothesis

- Planetary Nebulae derive from binary progenitors *more easily* than from single progenitors (De Marco, 2009)

Binary star hypothesis

- Planetary Nebulae derive from binary progenitors *more easily* than from single progenitors (De Marco, 2009)

(also possibly brown dwarf or planetary companion; Soker 1997)

Binary star hypothesis

- Planetary Nebulae derive from binary progenitors *more easily* than from single progenitors (De Marco, 2009)

(also possibly brown dwarf or planetary companion; Soker 1997)

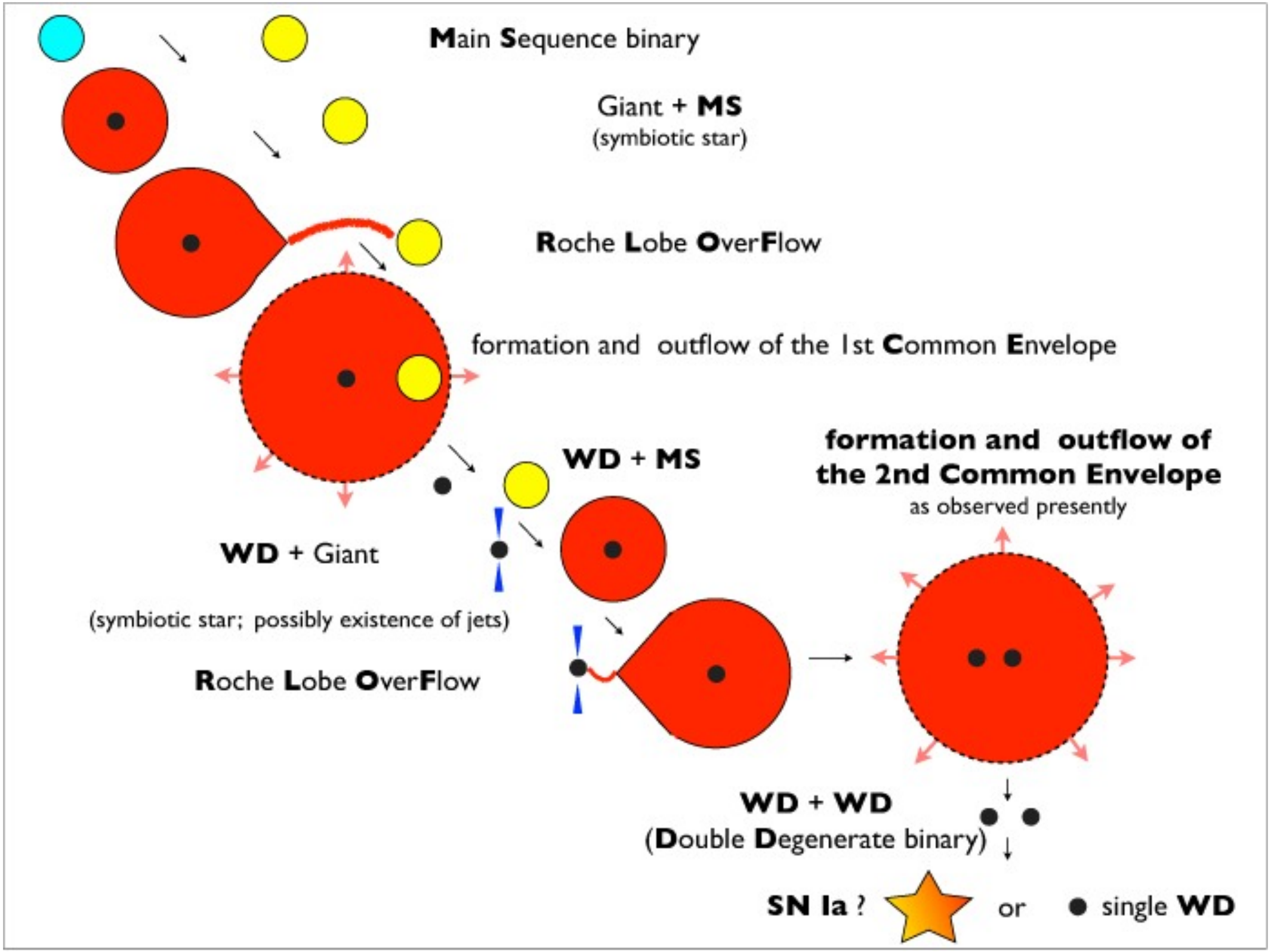
(even when star proves single, it could still have been a binary in the past - merging after CE; e.g. BP Psc: Kastner et al., 2010)

Binary Origin

- 10-25% of CSPN are short period binaries
- Long period systems also existing (e.g. Frew & Parker 2008)
- Could be that indeed all the 80% of aspherical PNe have binary companions
- Binary fraction in G-K stars ~ 30%!
- Does binarity cause the PN? (De Marco 2009)
- (also possibly brown dwarf or planetary companion;

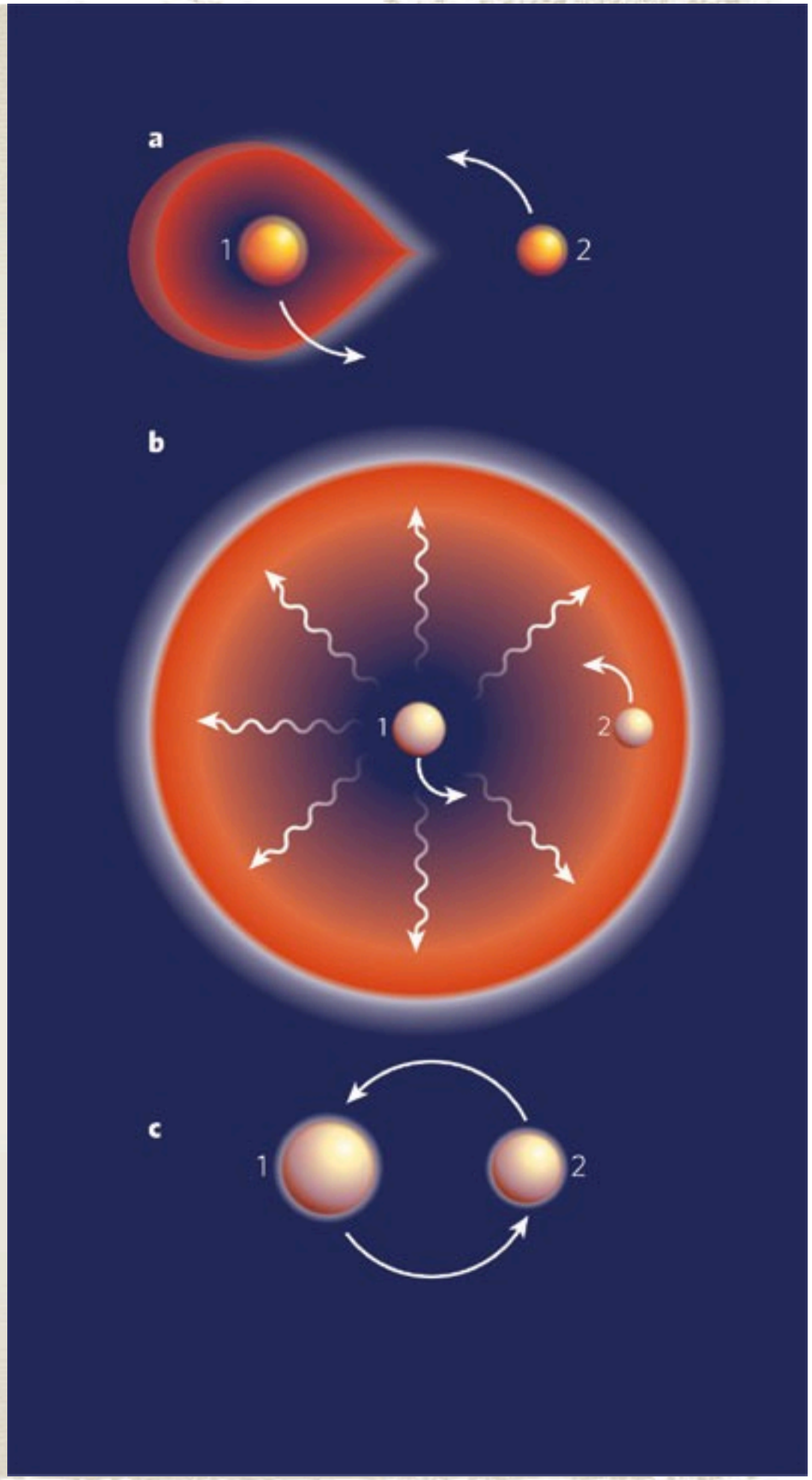
Binary star hypothesis

- Planetary Nebulae derive from binary progenitors *more easily* than from single progenitors (O. De Marco, 2009)
- "It may well be that in another 10 years people will no longer speak of the PN as the *"future of the Sun"* (A. Frank, 2010)


Main Sequence binary
Giant + MS
(symbiotic star)
Roche Lobe OverFlow
formation and outflow of the 1st Common Envelope
WD + MS
WD + Giant
(symbiotic star; possibly existence of jets)
Roche Lobe OverFlow
formation and outflow of the 2nd Common Envelope
as observed presently
WD + WD
(Double Degenerate binary)
SN Ia ?
or
single WD

Post-CE systems

- Cataclysmic variables, novae
- subdwarf B binaries
- low massX-ray binaries
- progenitors of Type Ia SNe?
- Barium stars?

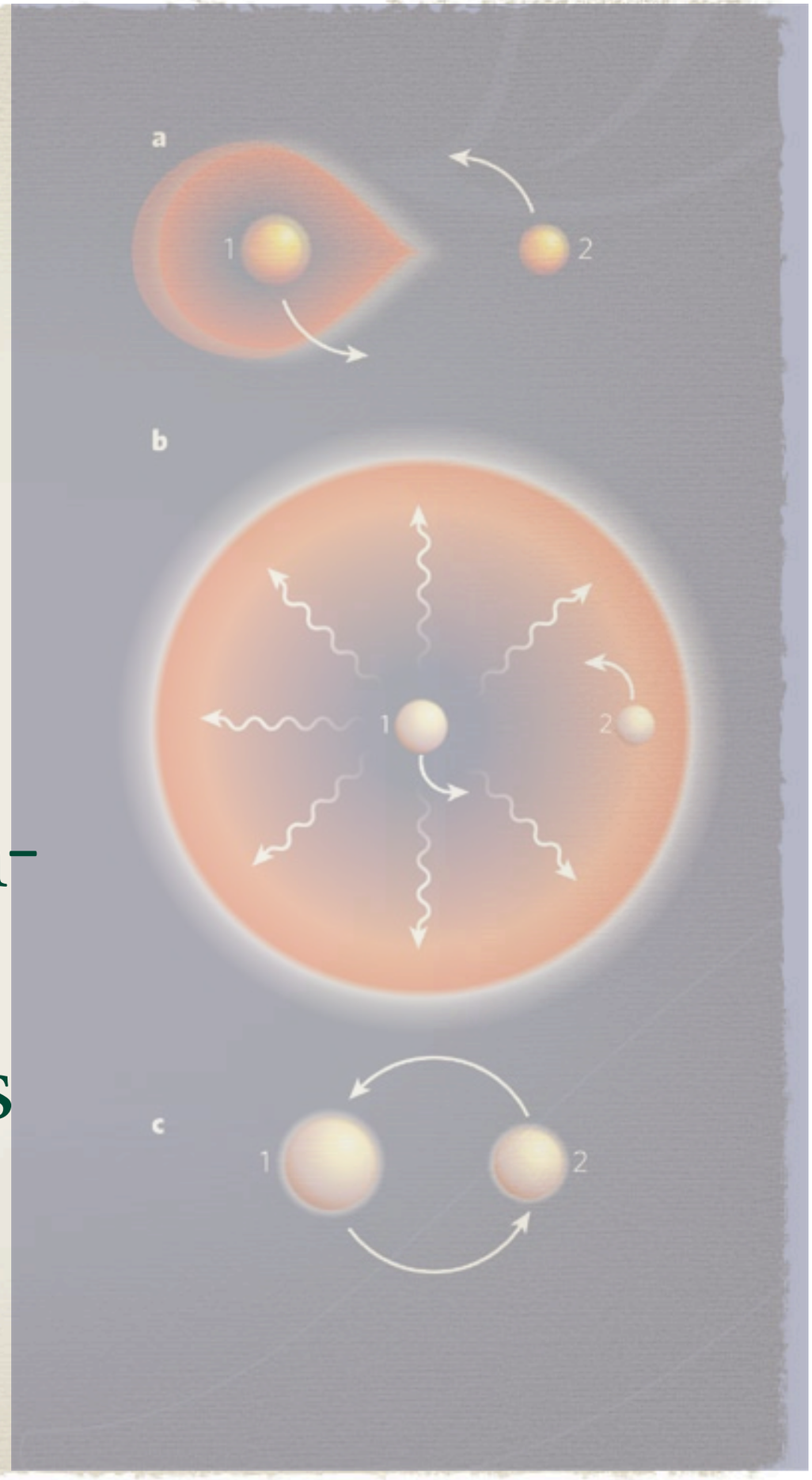


Post-CE systems

Binary CSPN are "fresh out of the oven"!

- Type Ia SNe?
- Barium stars?

Ideal for study of Common-Envelope Evolution and formation of close binaries



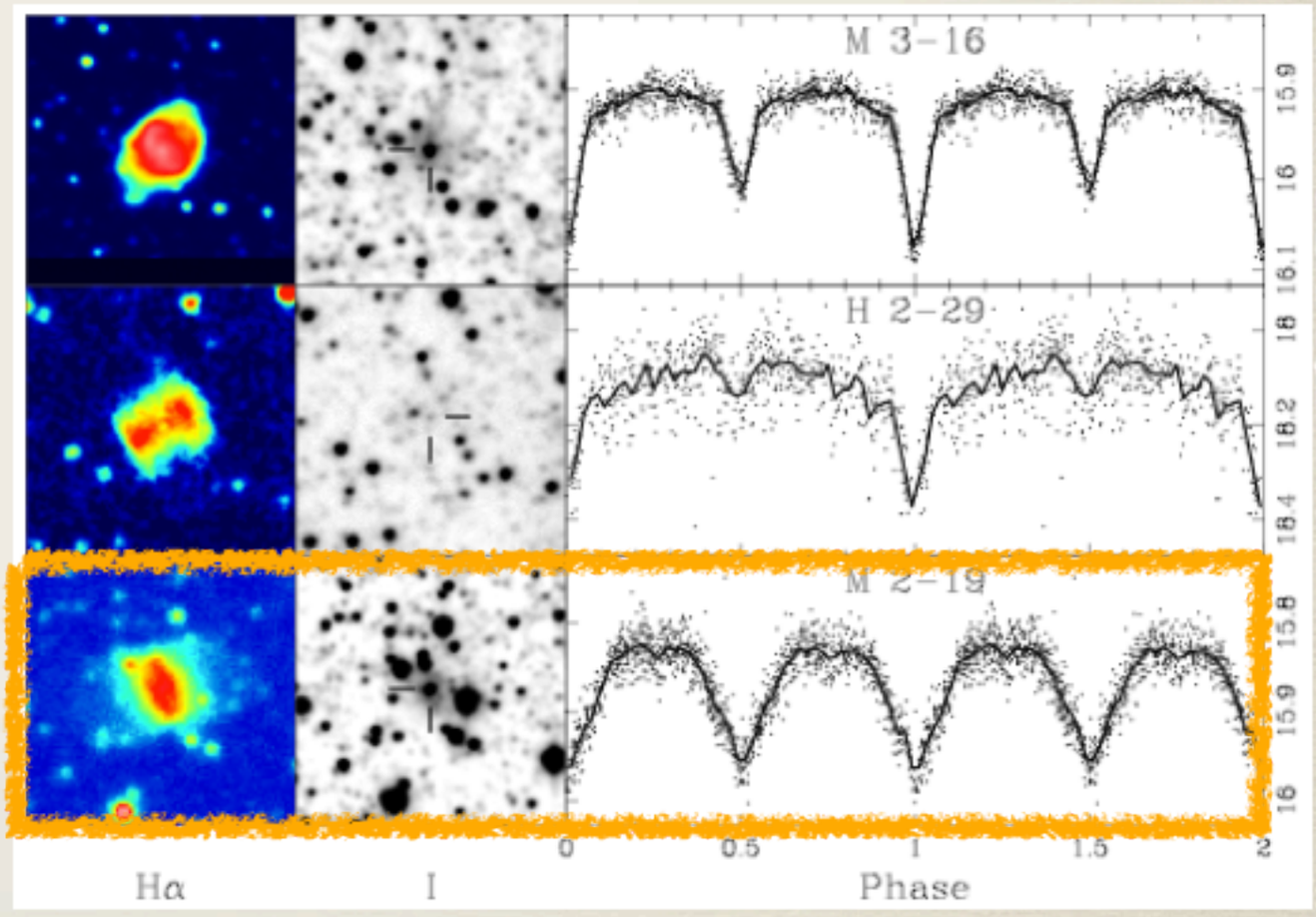
15 close binaries known up to 2008

PN G	Name	Period (days)	Eclipsing	Reference
053.8−03.0	A 63	0.46	Y	Bond, Liller & Mannery (1978)
215.6+03.6	NGC 2346	15.99	(dust)	Mendez & Niemela (1981)
009.6+10.5	A 41	0.23	N	Grauer & Bond (1983)
055.4+16.0	A 46	0.47	Y	Bond (1985)
283.9+09.7	DS 1	0.36	N	Drilling (1985)
136.3+05.5	HFG 1	0.58	N	Grauer et al. (1987)
253.5+10.7	K 1-2	0.68	N	Bond & Grauer (1987)
005.1−08.9	Hf 2-2	0.40	N	Lutz et al. (1998)
017.3−21.9	A 65	1.00	N	Bond & Livio (1990)
329.0+01.9	Sp 1	2.91	N	Bond & Livio (1990)
335.2−03.6	HaTr 4	1.74	N	Bond & Livio (1990)
144.8+65.8	BE UMa	2.29	Y	Liebert et al. (1995)
135.9+55.9	SBS 1150+599A	0.16	N	Tovmassian et al. (2004)
341.6+13.7	NGC 6026	0.53	N	Hillwig (2004)
349.3−01.1	NGC 6337	0.17	N	Hillwig (2004)

The turn of the tide

- Microlensing surveys allow variability studies on a massive scale
- Cadence often high enough to detect short periods
- Fainter MASH-I/II PNe more suitable

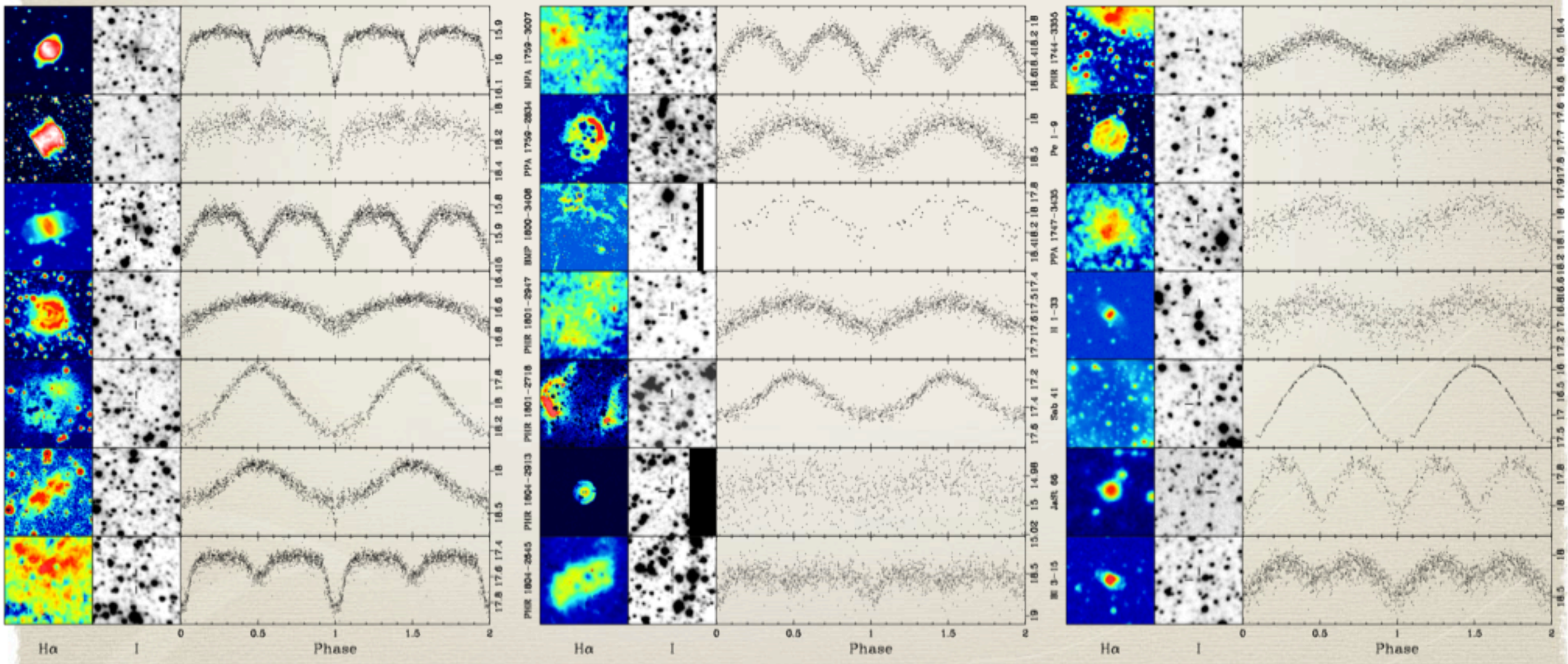
M2-19 - first canonical bipolar with period < 1 day



Miszalski et al. 2008

The OGLE Sample

Miszalski et al. 2009

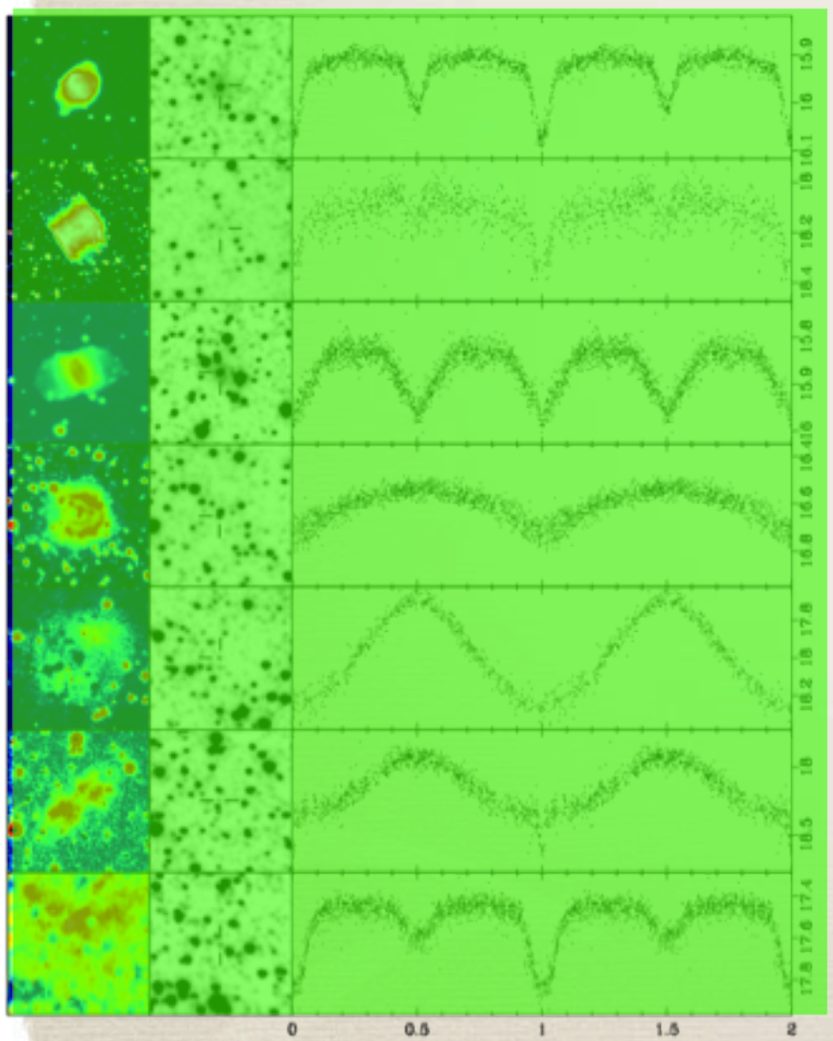


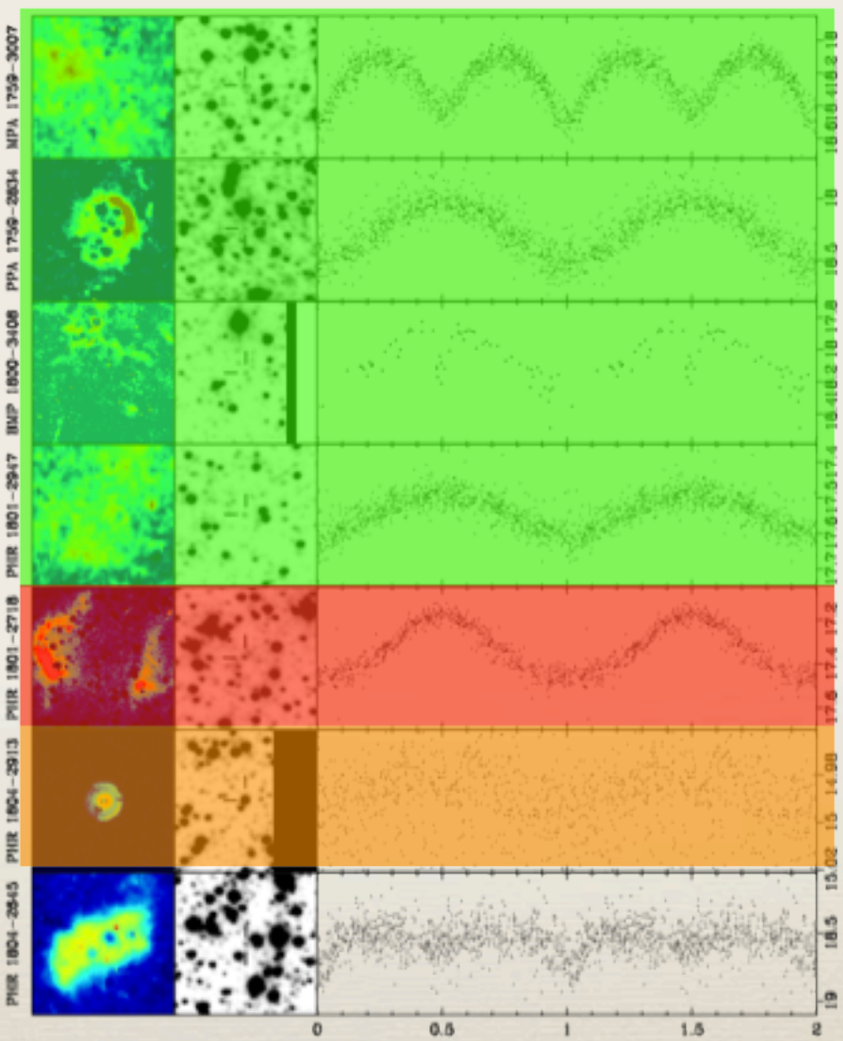
The OGLE Sample

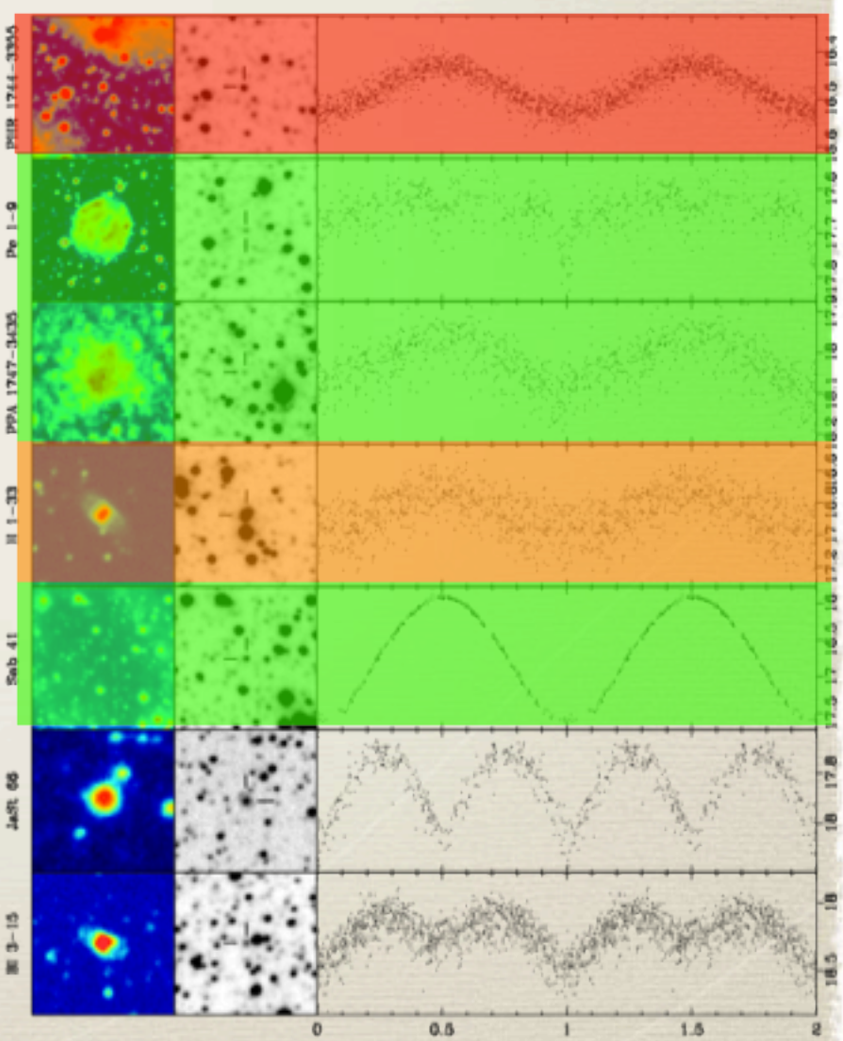
Close binary fraction: up to 26%!

SPN status: confirmed, likely, non-confirmed

Miszalski et al. 2009
Miszalski, Boffin et al. 2011

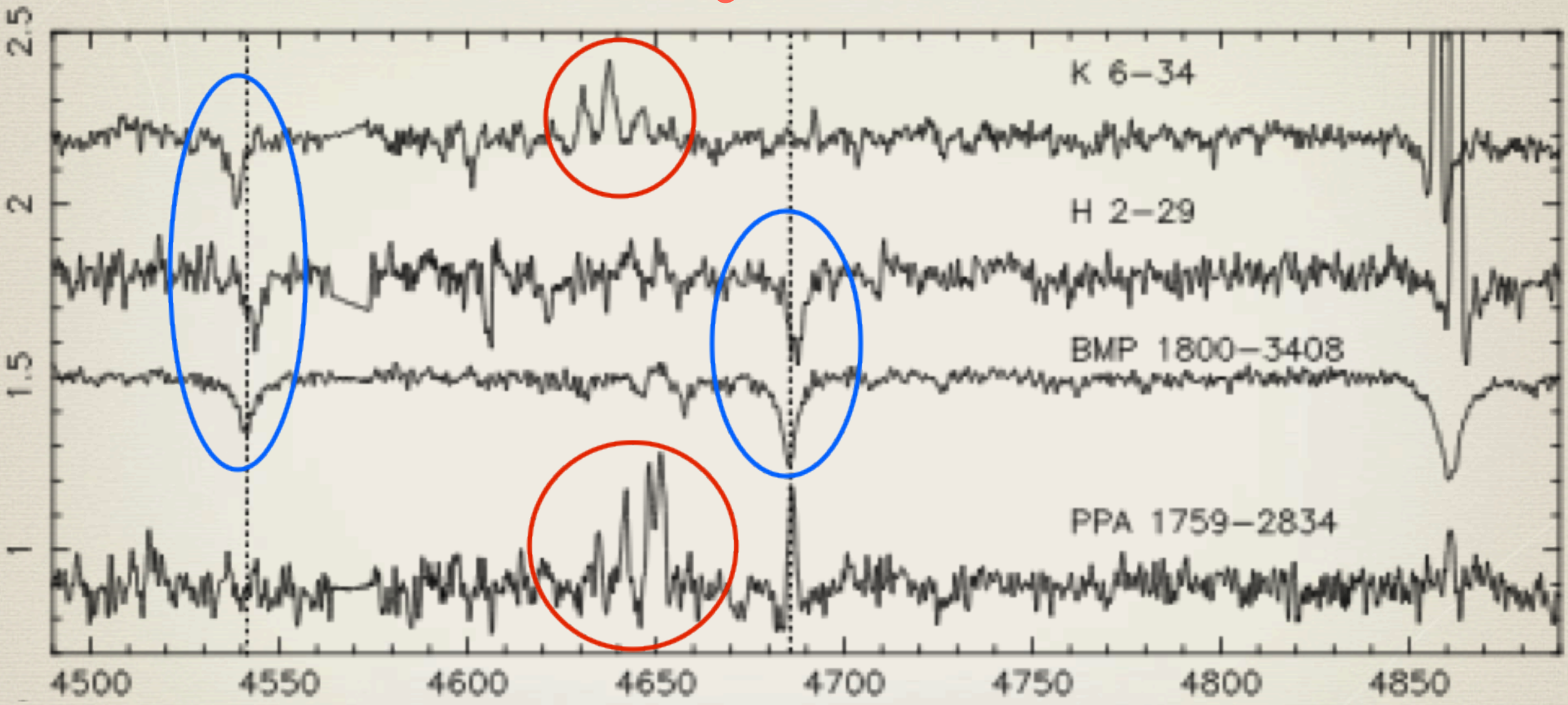




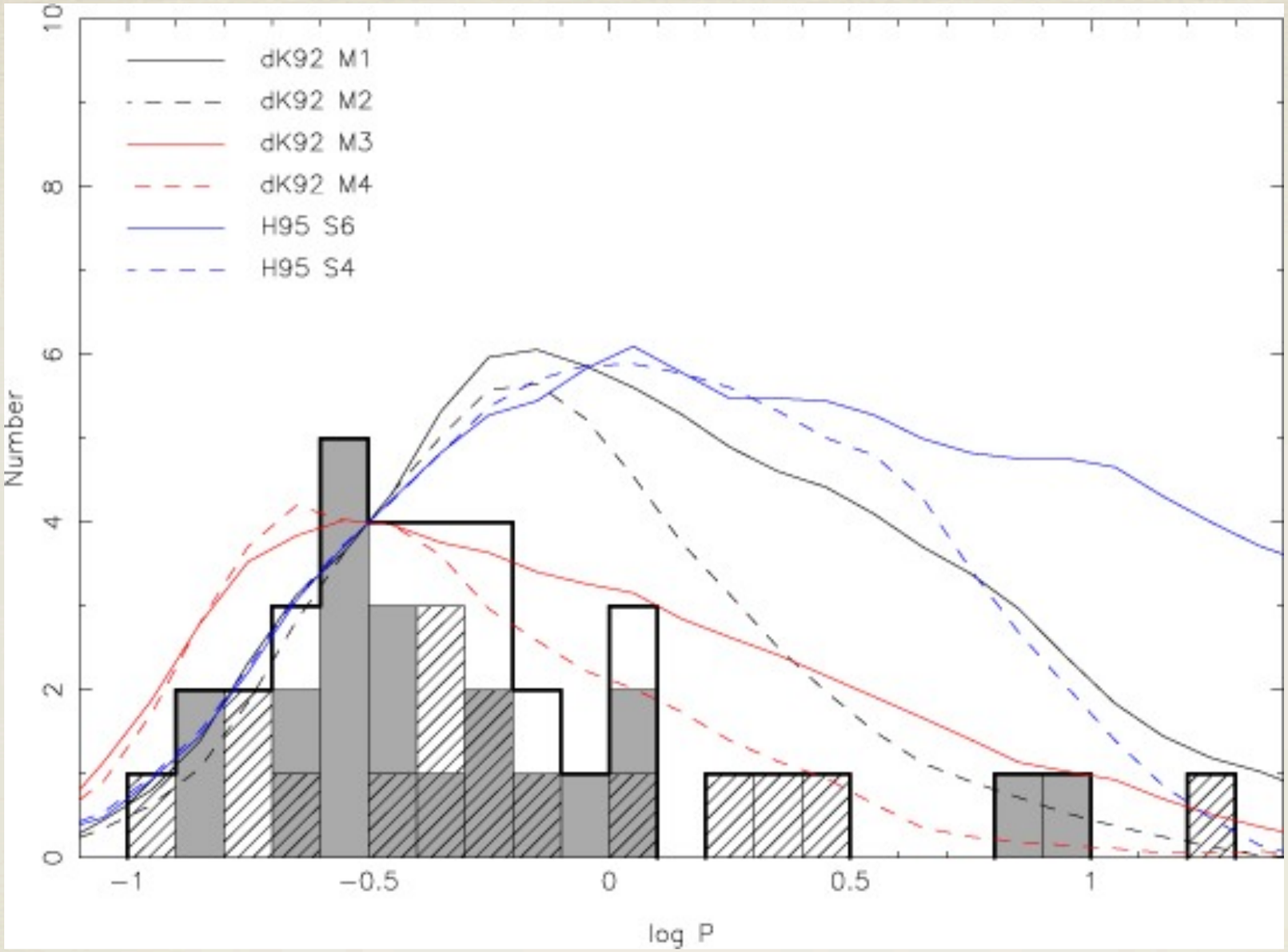


CIII/NIII from irradiated secondary

HeII from primary



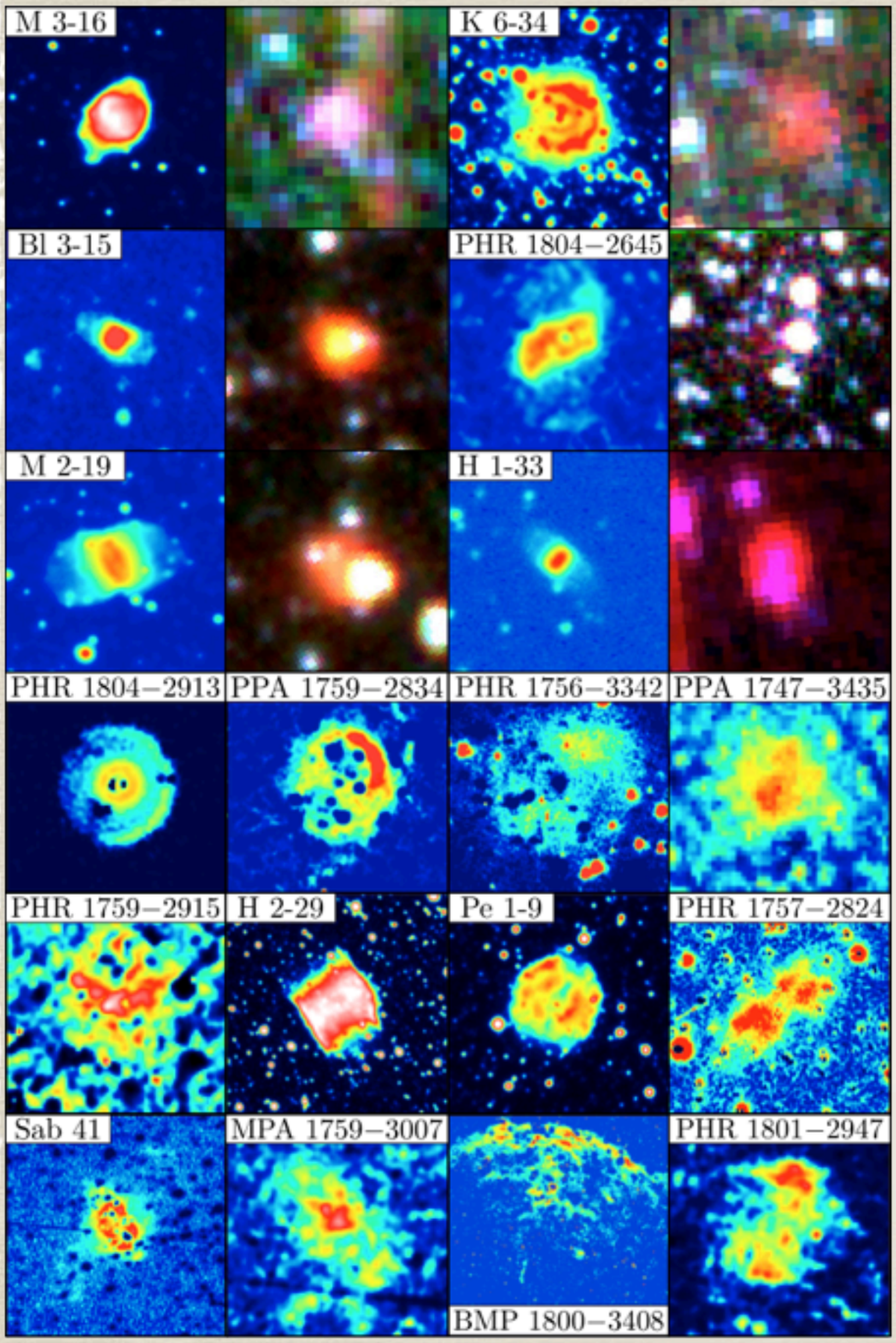
Number of systems



Log Orbital Period (d)

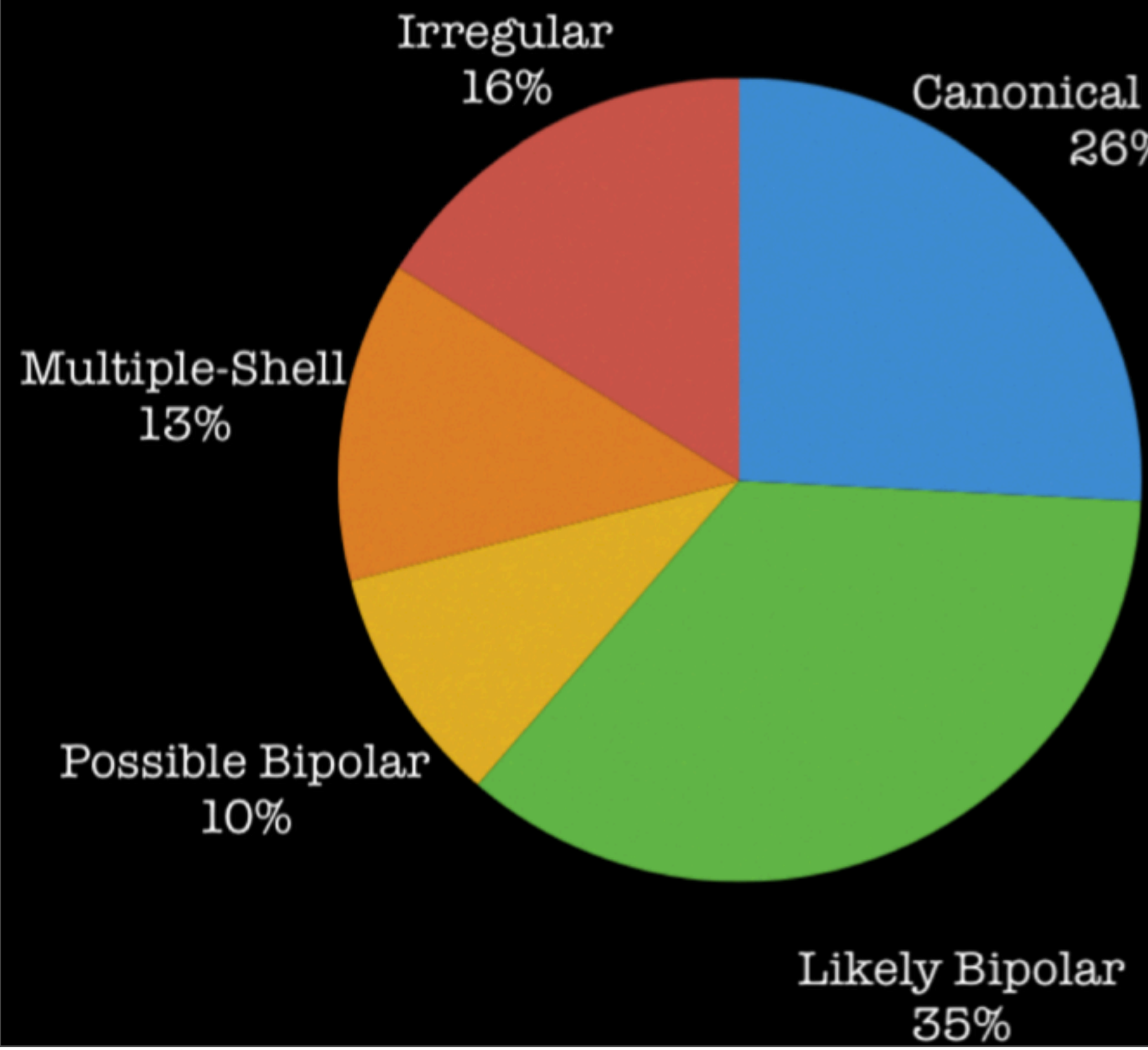
Miszalski et al. 2009

Morphologies



Miszalski et al. 2009

General shapes of 30 Post-CE PNe

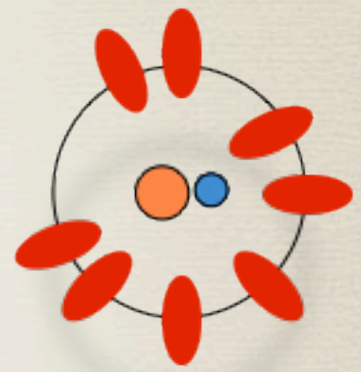


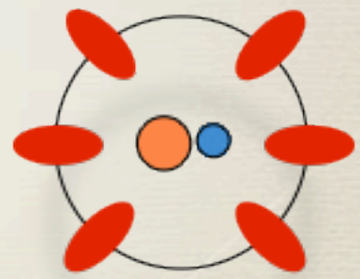
~60% bipolar fraction is plausible

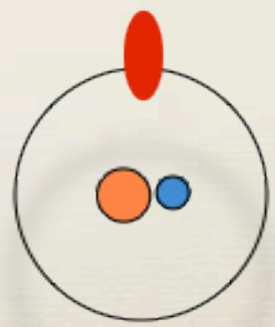
Miszalski et al. 2009

How to spot a close binary

- Bipolars (26% of 30; >60% plausible)
- Low-ionisation knots or filaments in a ring (NGC 6337, Sab 41), point symmetric (K 1-2), on their own (DS 1)
- Low ionisation polar outflows or ‘jets’ (A 63)



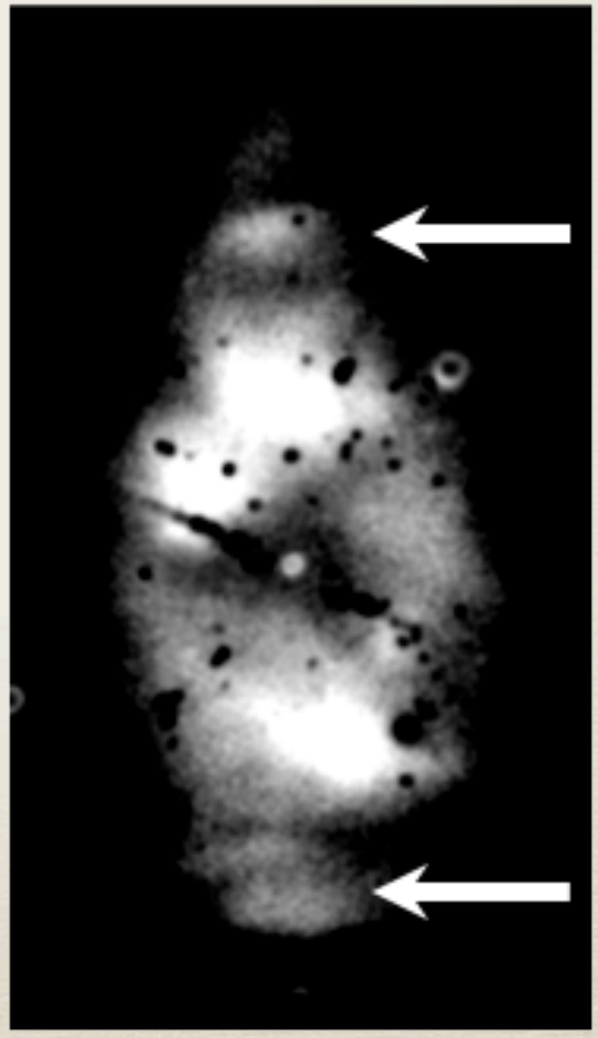




Binarity influences the morphology of PNe

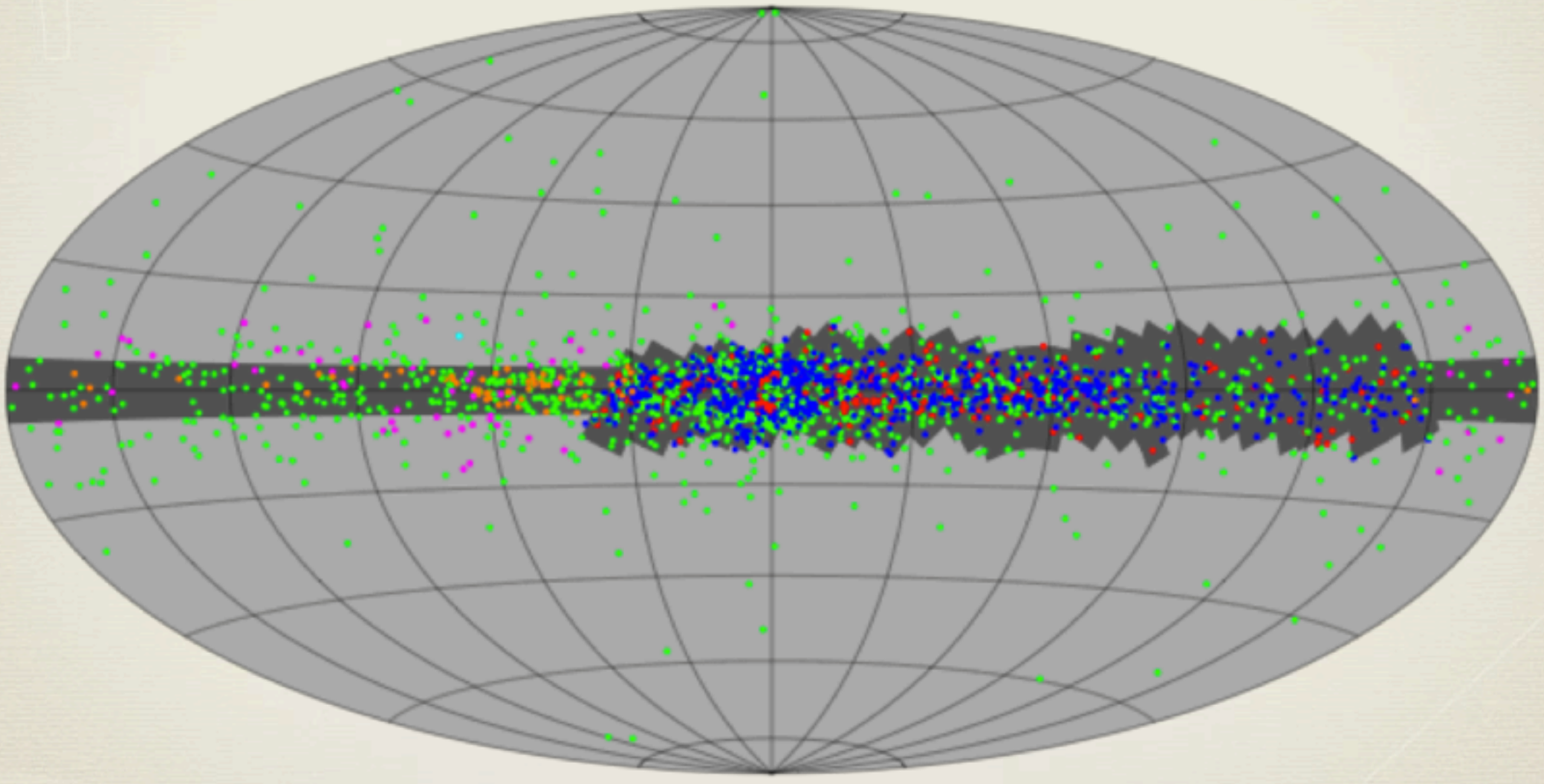
Low Ionisation Structures

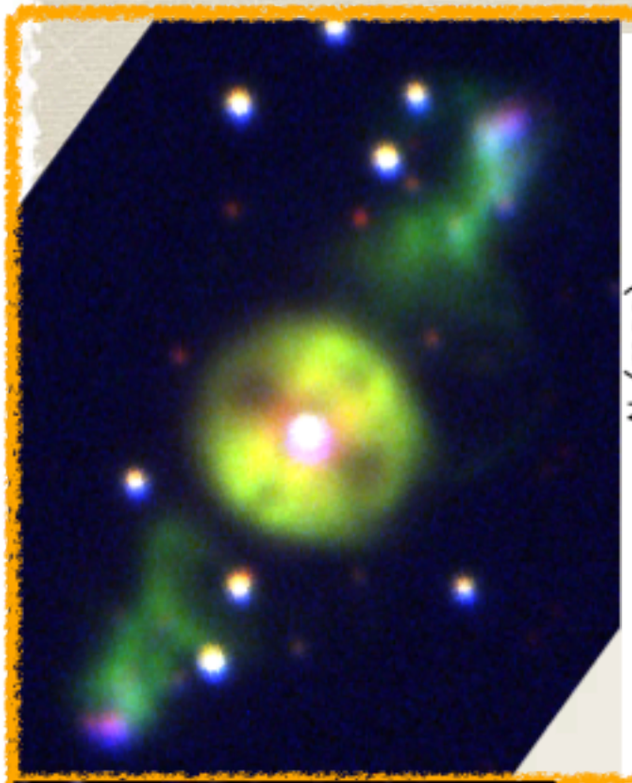
Polar outflows

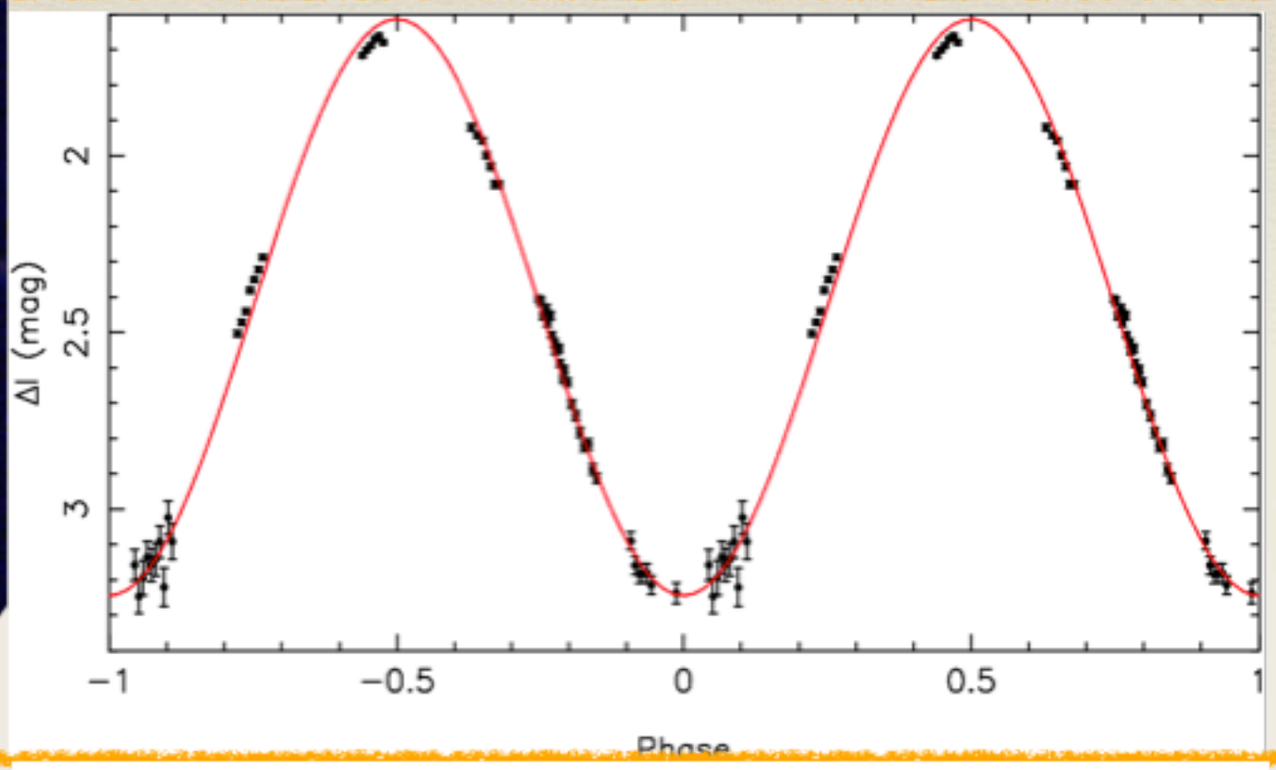


Find the binaries!

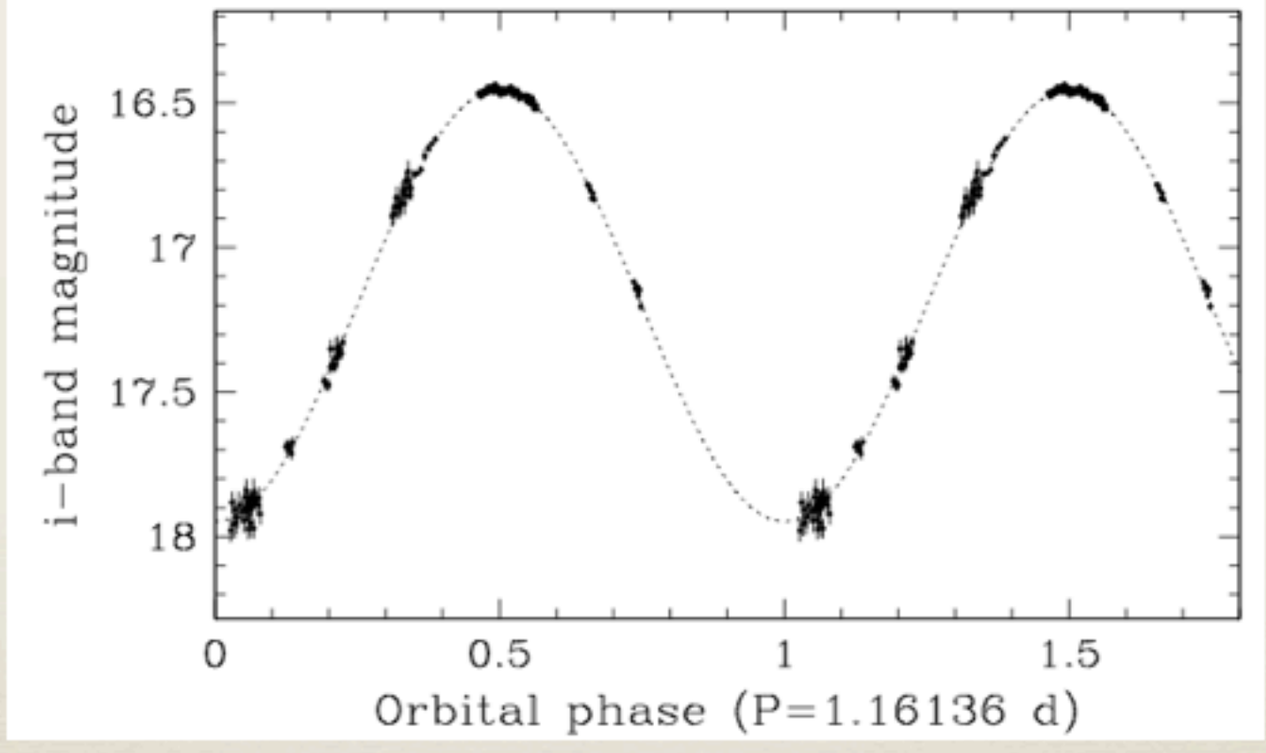
~2800 PNe



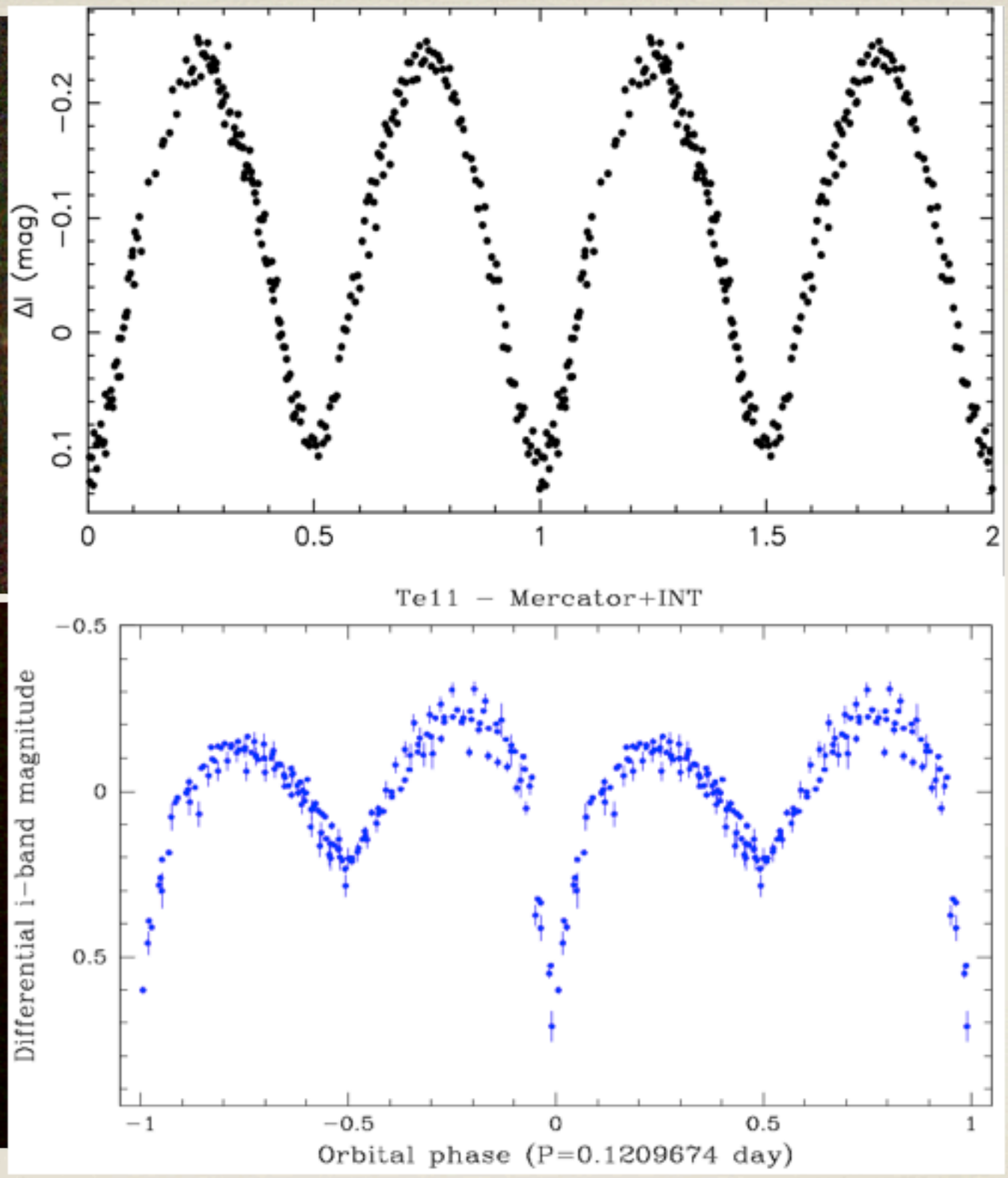




ETHOS1
P=0.535 d
A=0.81 mag
Miszalski, Corradi, Boffin, et al. 2010

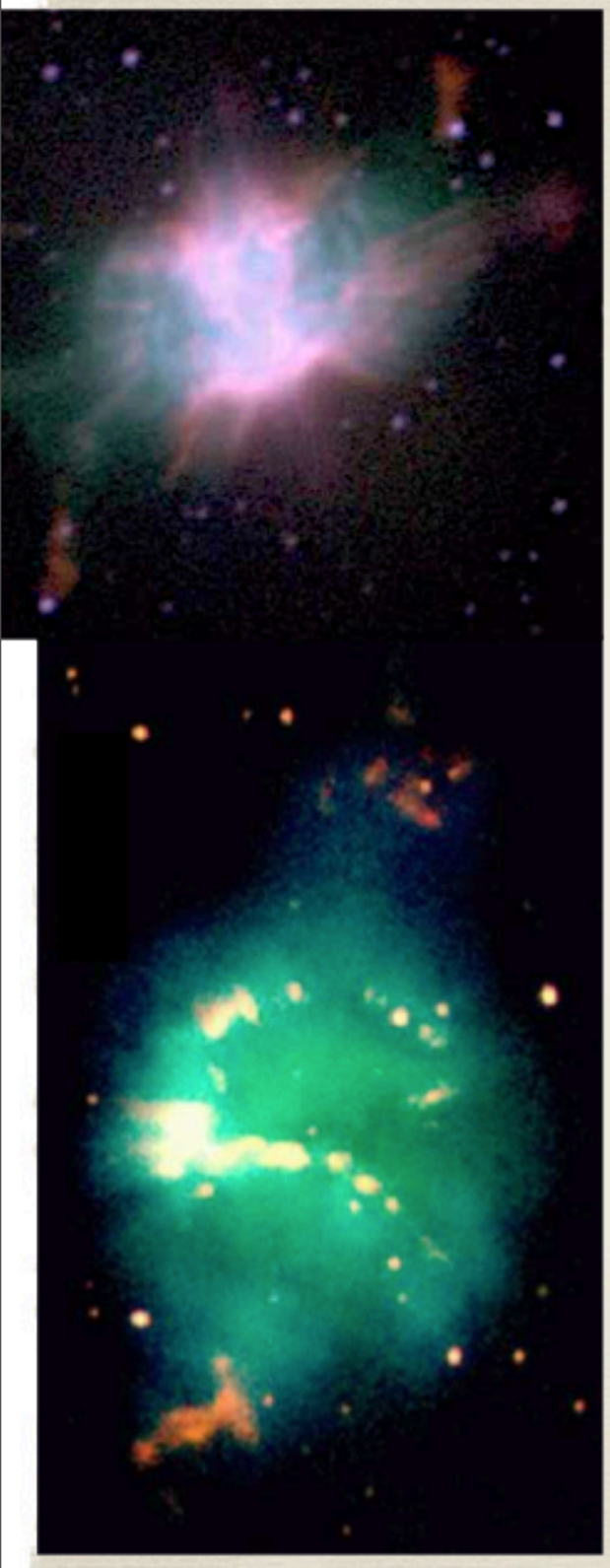


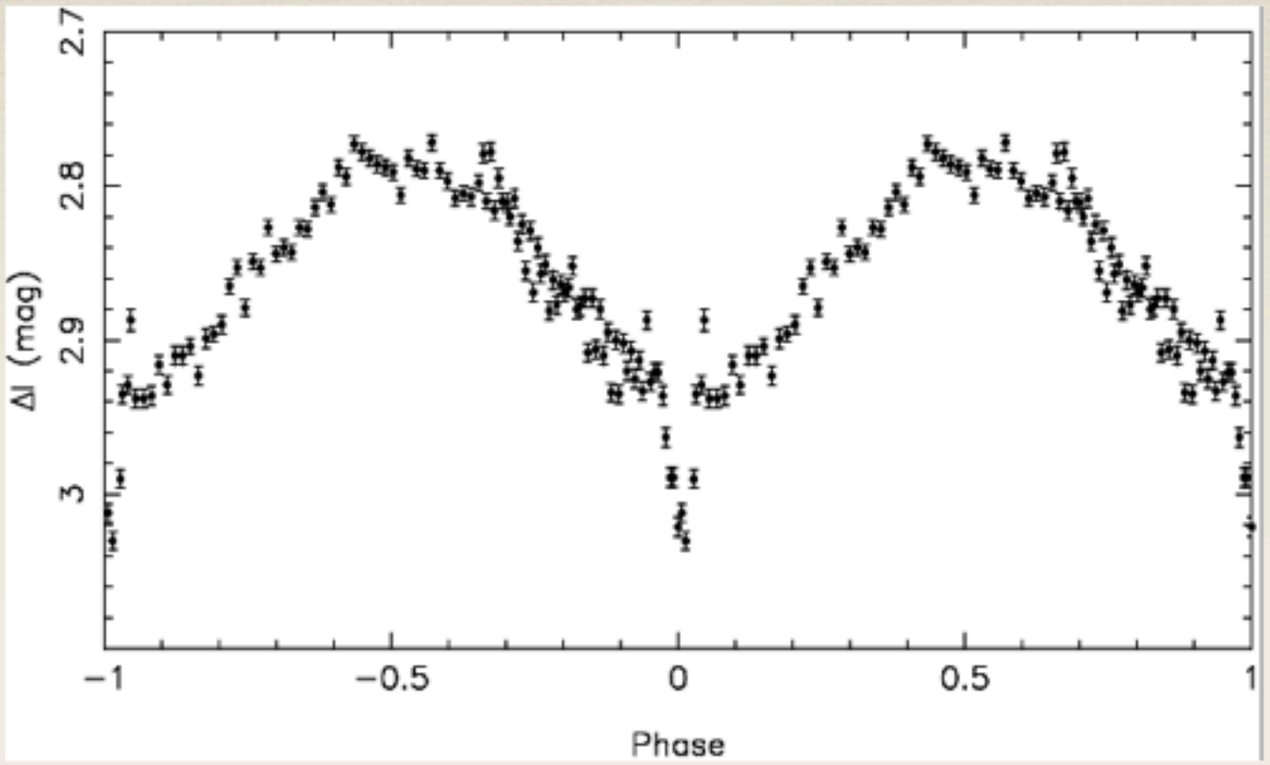
Necklace
P=1.161 d
A=0.75 mag
Corradi et al. 2010



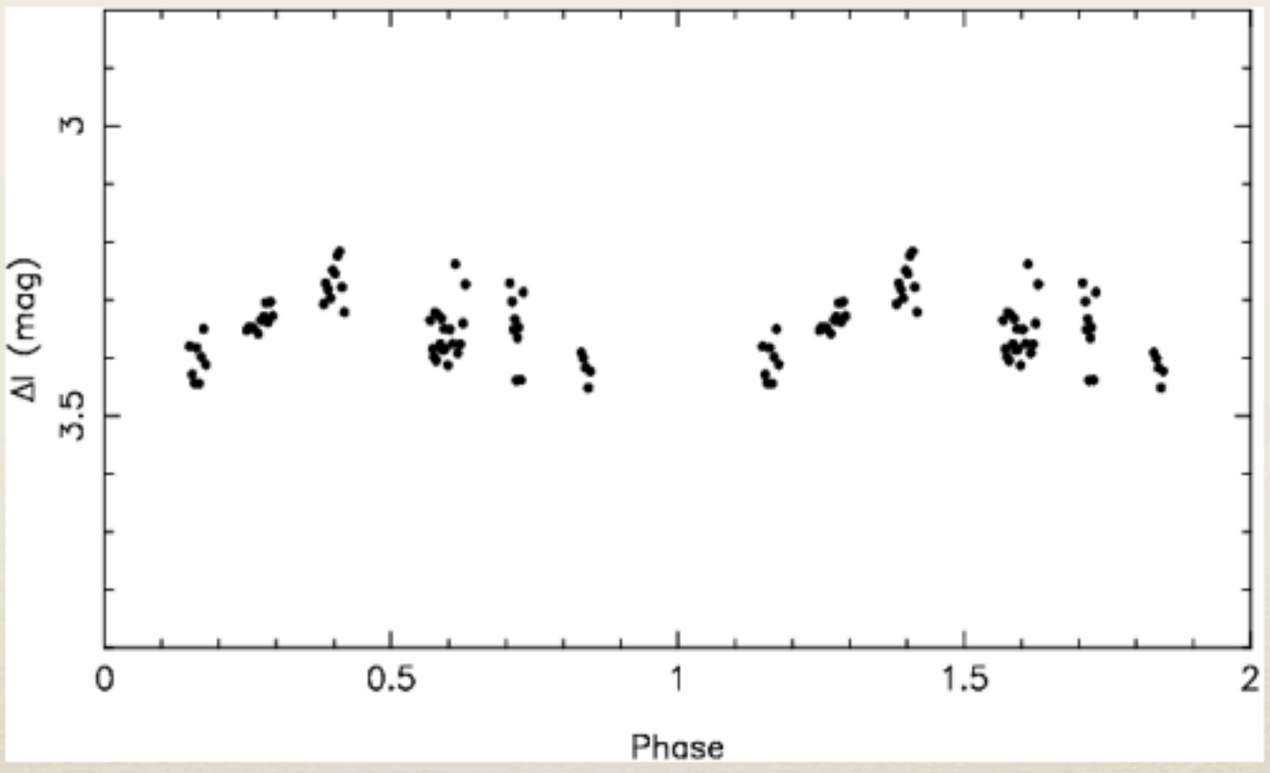
He2-428
P=0.176 d
A=0.2 mag
Santander-Garcia et al. 2010

Te11
P=0.121 d
A=0.3 mag
Jacoby et al. 2010





NGC6778
P=0.153 d
A=0.1 mag
Miranda et al.
2010



PM1-333
P=0.15 d (?)
A=0.1 mag
Miranda et al. 2010

Name	LIS	'Jets'	Bipolar	Variable?
Necklace	Y	Y	Y	binary
ETHOS1	N	Y	Y?	binary
PM1-333	Y	Y	?	variable
He2-428	N	N	Y	binary
Asturias	N	Y	Y	no
Tell	N	N	?	binary
A70	Y	Y?	Y?	variable?
A57	Y	Y	Y?	no
K3-36	N	N	Y	variable?

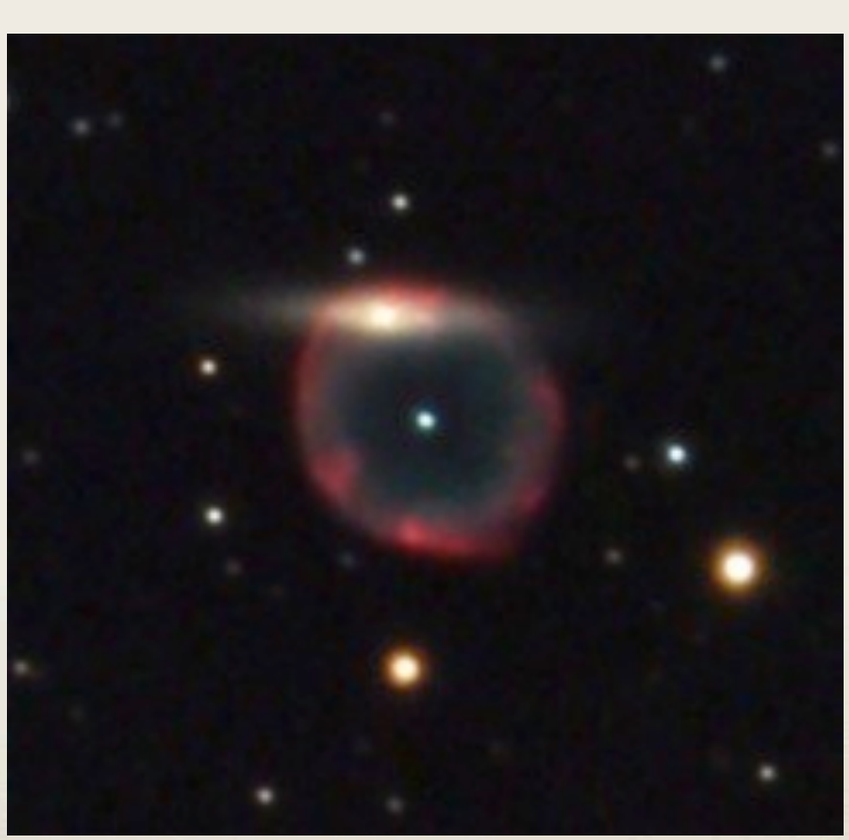
Name	LIS	'Jets'	Bipolar	Variable?
Necklace	Y	Y	Y	binary
ETHOS1				binary
PM1-333				variable
He2-428				binary
Asturias				no
Tell				binary
A70				variable?
A57	Y	Y	Y?	no
K3-36	N	N	Y	variable?

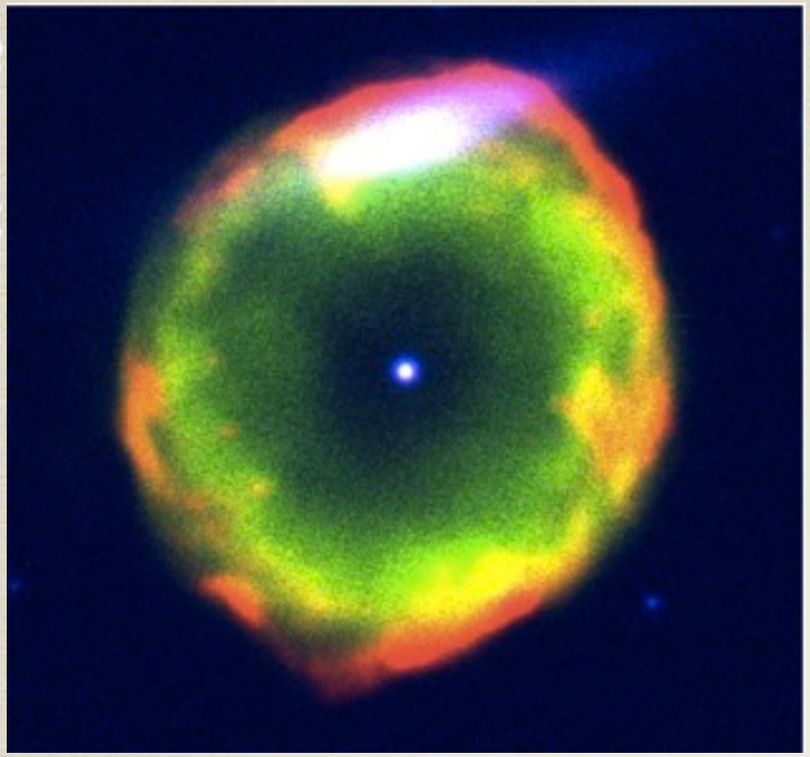
4/14 are binaries (28%)
11/14 are variable (78%)
3/14 non-variable (21%)

extremely encouraging
pending full analysis

- Photometric searches are limited to close-by objects (< 3 days for most; perhaps up to 2 weeks at most) due to the effect it mimics
- But must have systems with much larger periods (cf post-AGB systems), i.e. orbital period in range 100 - 1500 days
- Important to probe the full range of periods

- Look for evolved, cool star as CSPN, as they need the space
- Abell 70 is one!

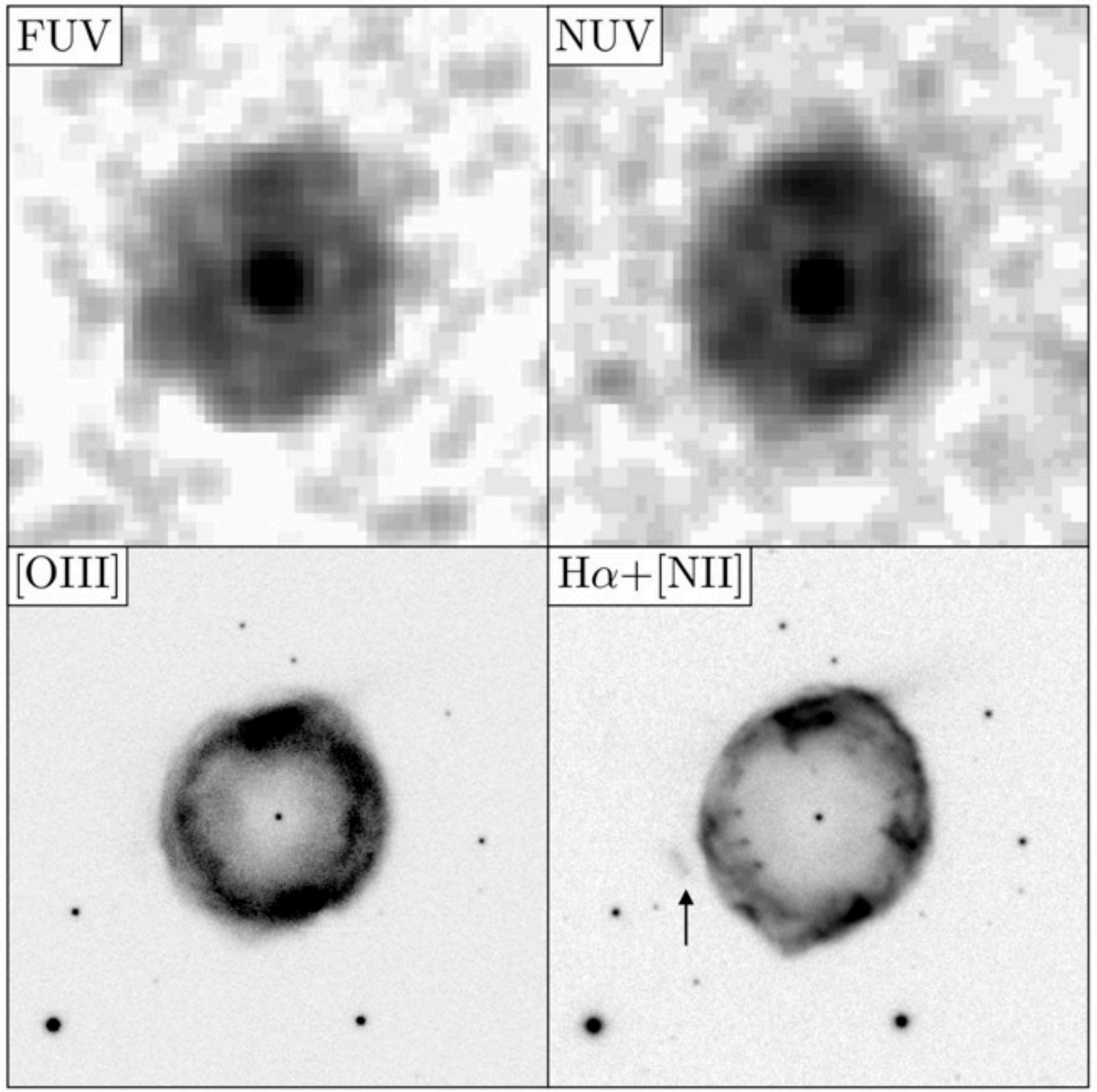


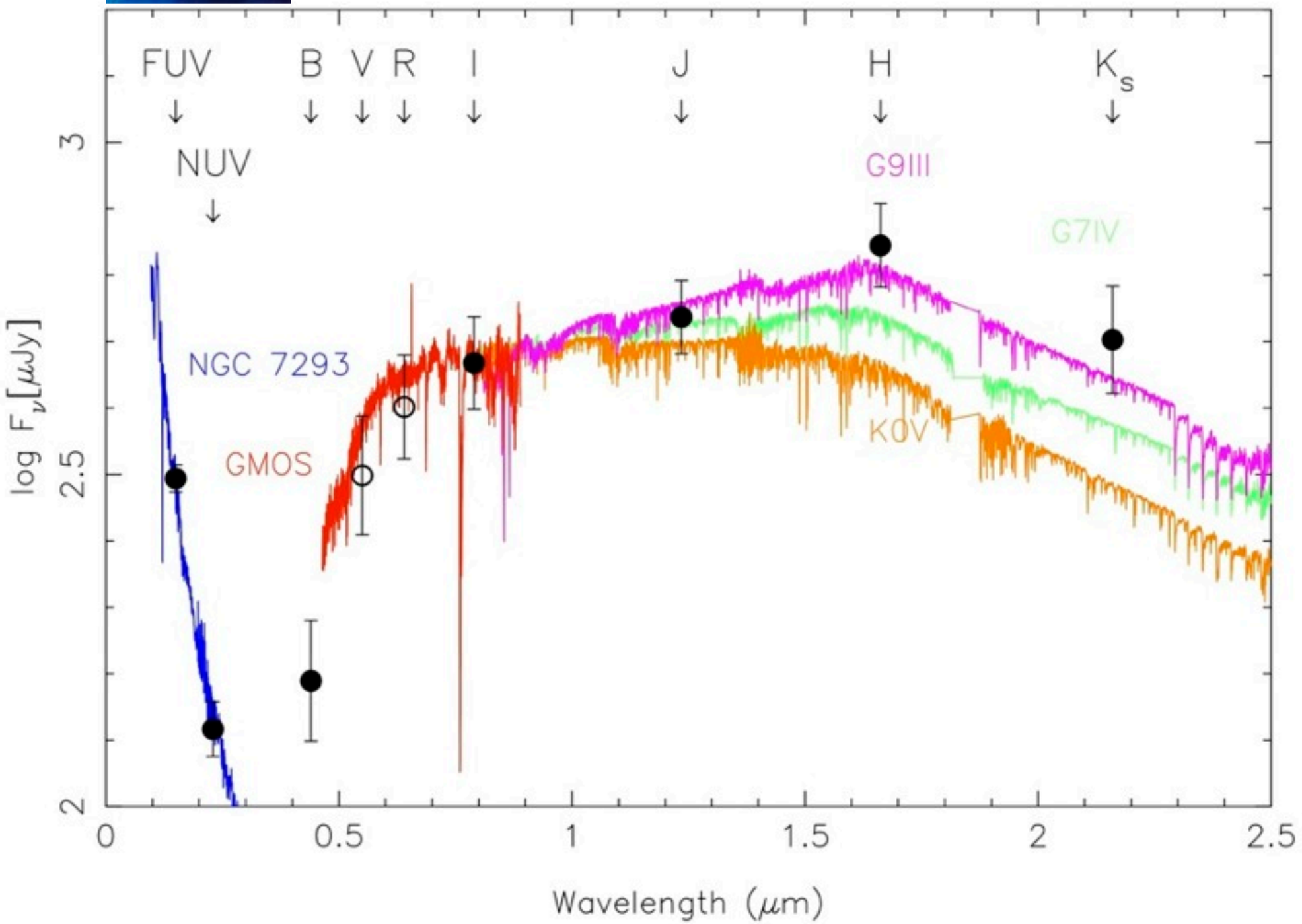


- ✳CSPN is G5-G8 subgiant
- ✳RV compatible with nebula line
- ✳UV observations reveal presence of a hot companion (the true CSPN)

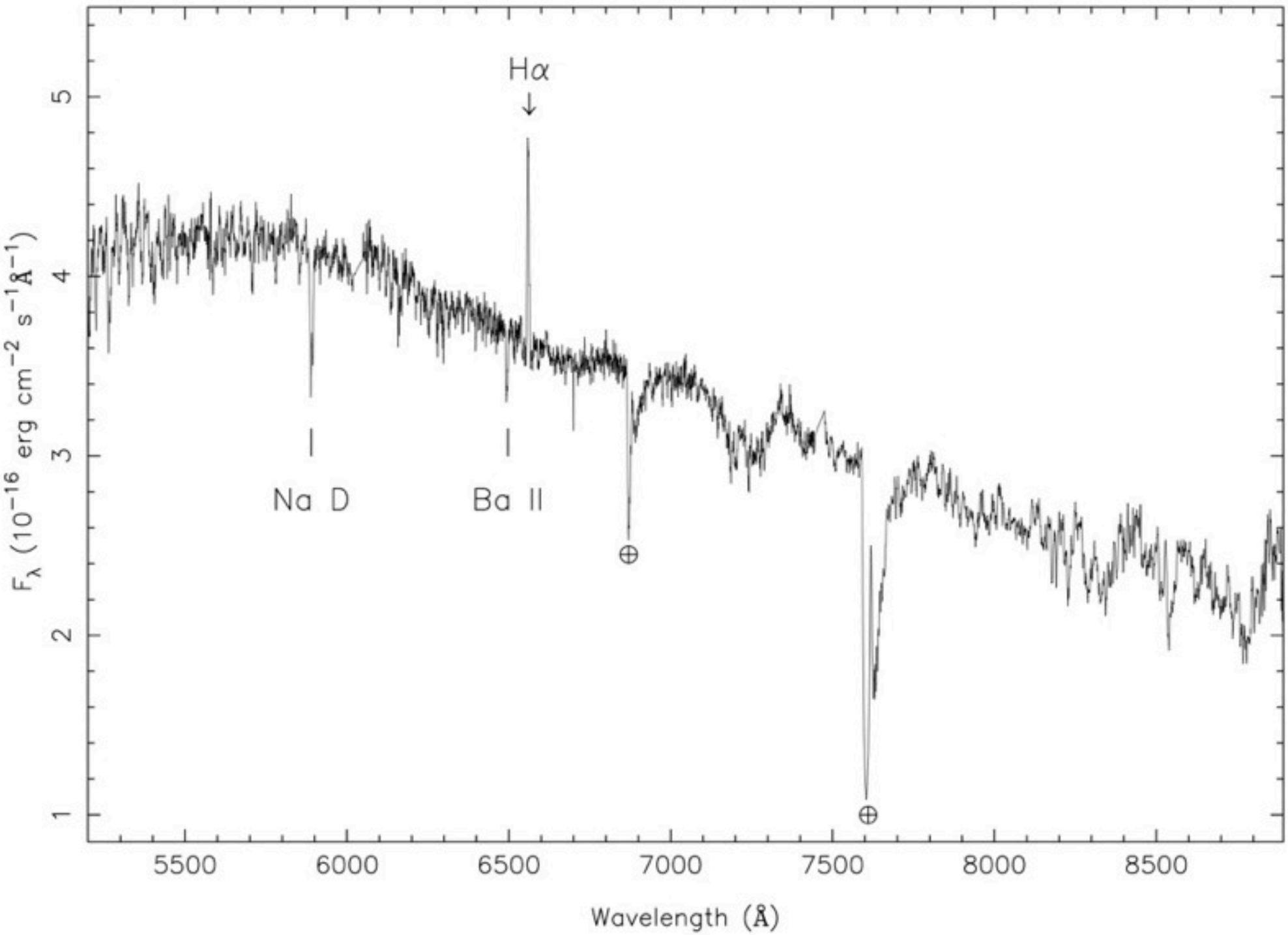
Binary CSPN

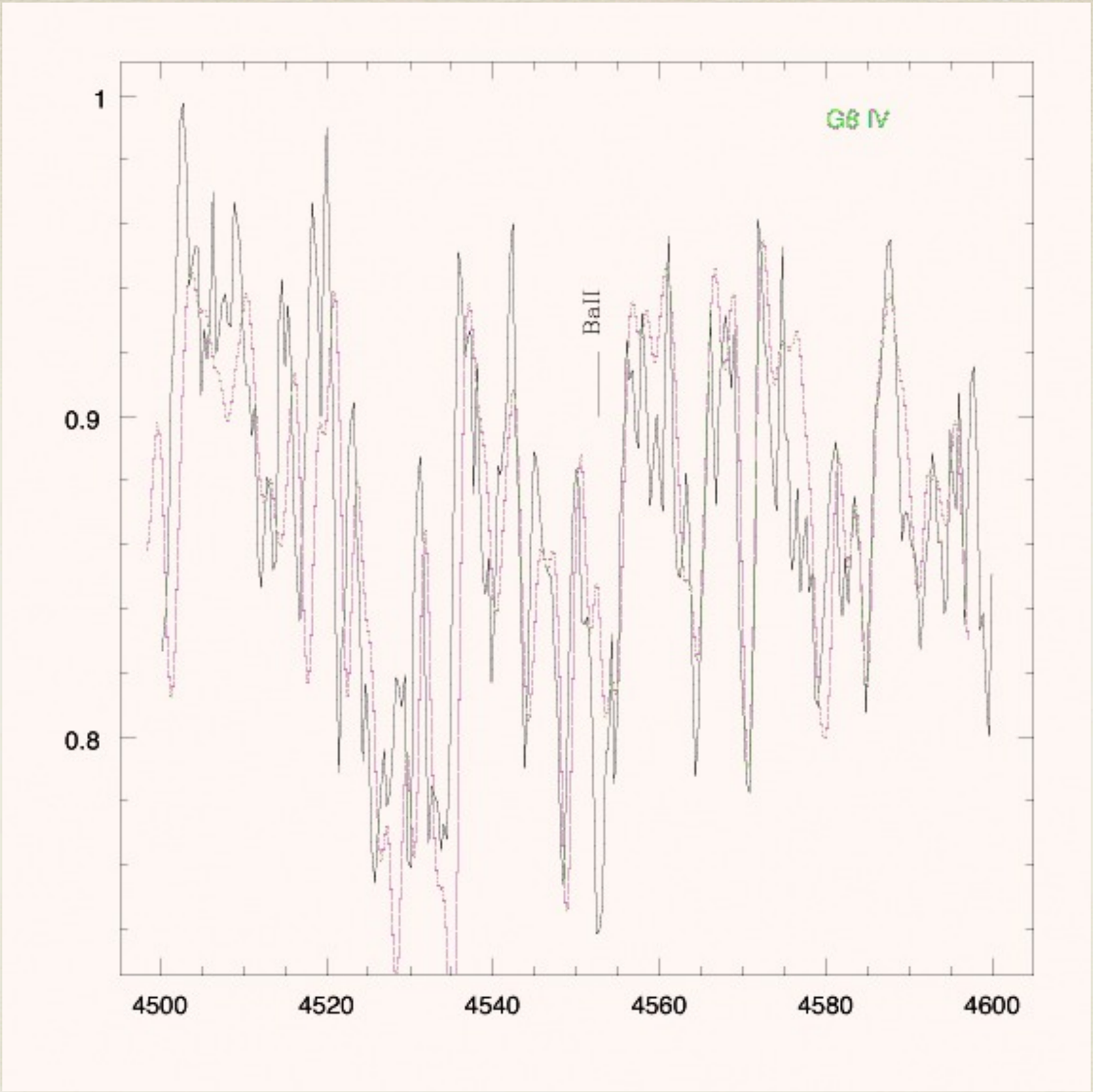
Miszalski, Boffin et al. 2011



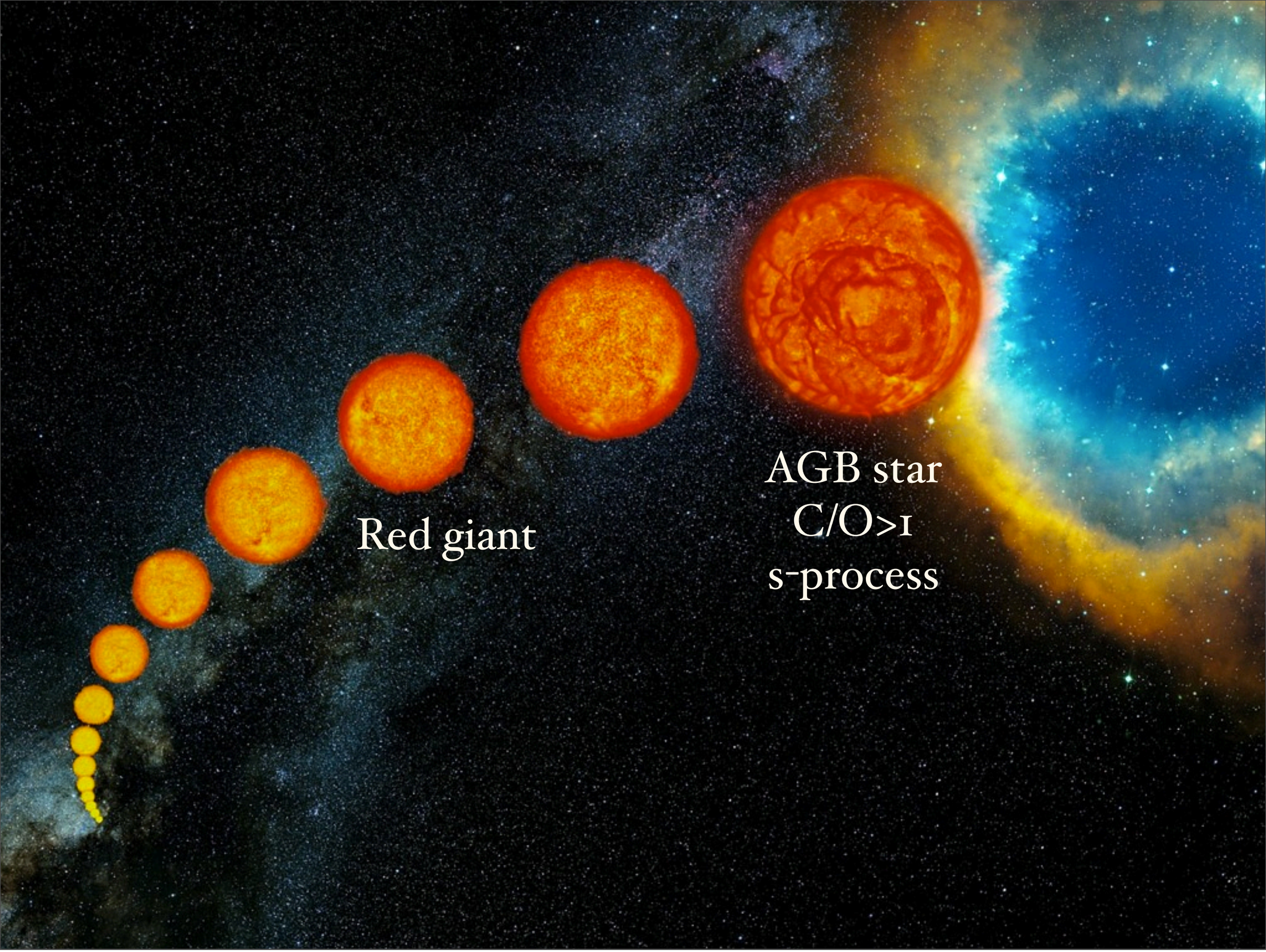

FUV
NUV
B
V
R
I
J
H
K_s
G9III
G7IV
K0V
NGC 7293
GMOS
log F_ν[μJy]
3
2.5
2
0
0.5
1
1.5
2
2.5
Wavelength (μm)

GMOS SPECTRUM





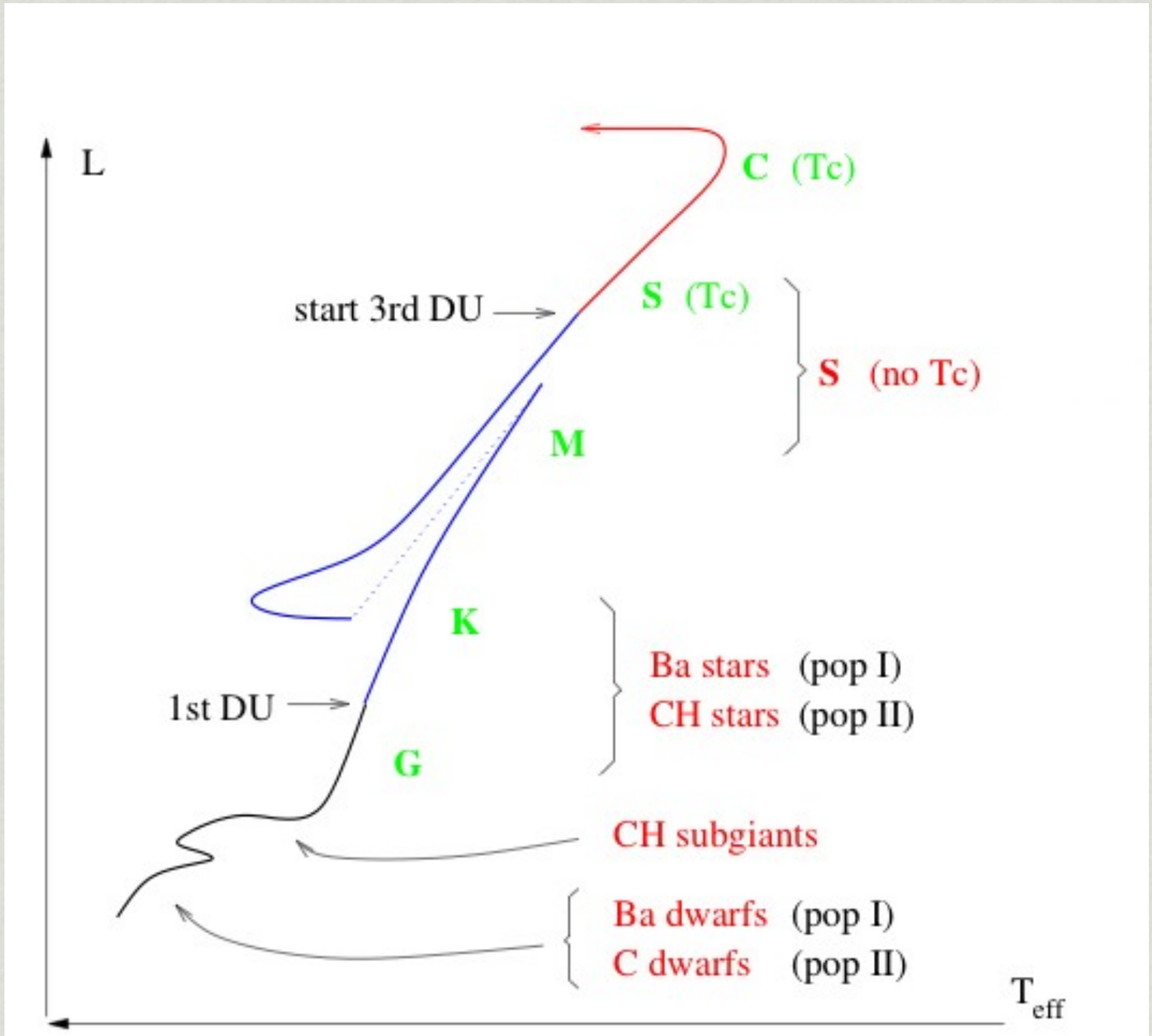
SPECTRUM SYNTHESIS: G5-G8 IV ; [BA/FE] ~ 0.9


AGB star
C/O>1
s-process
Red giant

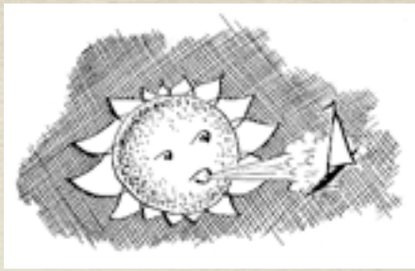
Peculiar Red Giants

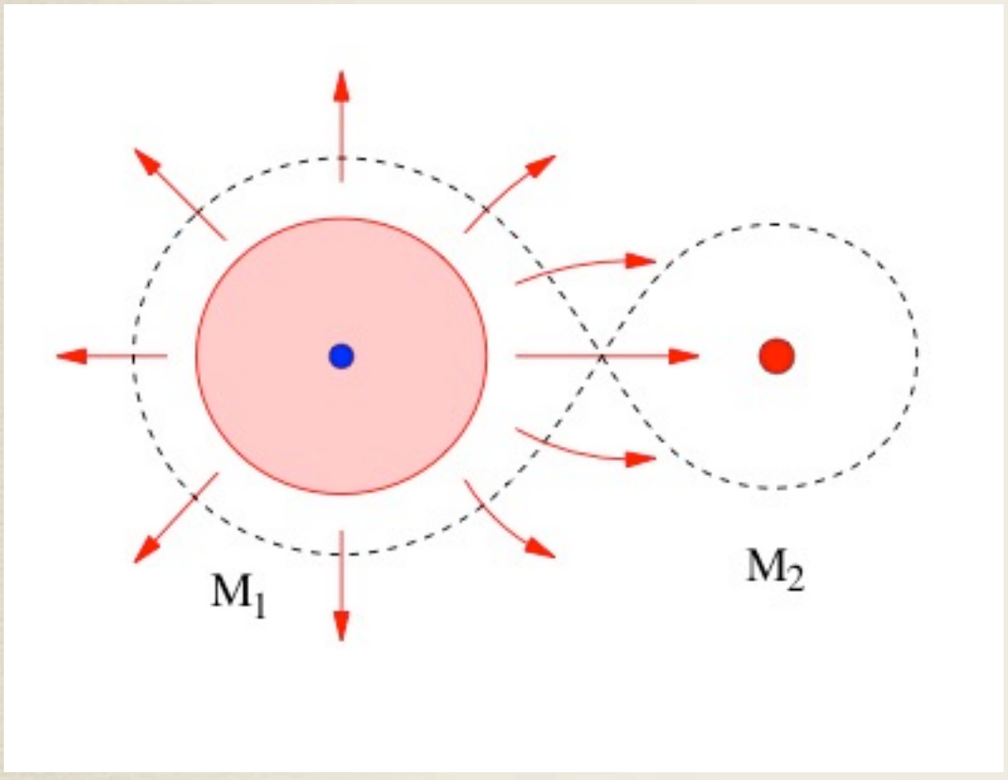
- Barium, CH, S stars:
  - show enhancement in s-process elements but non-AGB stars
  - McClure (1980, 1984) : they are all binaries; P~100 d – several years

    Companions are all WD



Mass transfer by wind





Boffin & Jorissen 1988

- An AGB transfers mass by wind to a normal star
- The normal star becomes polluted
- The AGB star becomes a white dwarf – through a PN
- The normal star evolves to a giant: a Barium star is formed

- A70 is thus a caught in a very transient state, where we still see the PN after the mass transfer

A real Rosetta Stone

- Radial velocity: changes by +/- 10-20 km/s over 1 year

Requested UVES measurements over 6 months

- Combined spectrum: derive abundance of s-process elements, Li, fluorine, and detect Tc!

- Important to understand: s-process in AGB stars, mass transfer by wind and possible CE, mixing process on star

Summary

- 80% of all PNe are aspherical
- Binarity plays a fundamental role in shaping (and perhaps creating) the PNe
- The number of close binaries found has dramatically increased by new, efficient searches
- Allows us to study CE evolution, important for many class of binaries

End of TALK I: Questions?