



# TYLEND(A) COLLOQUIUM



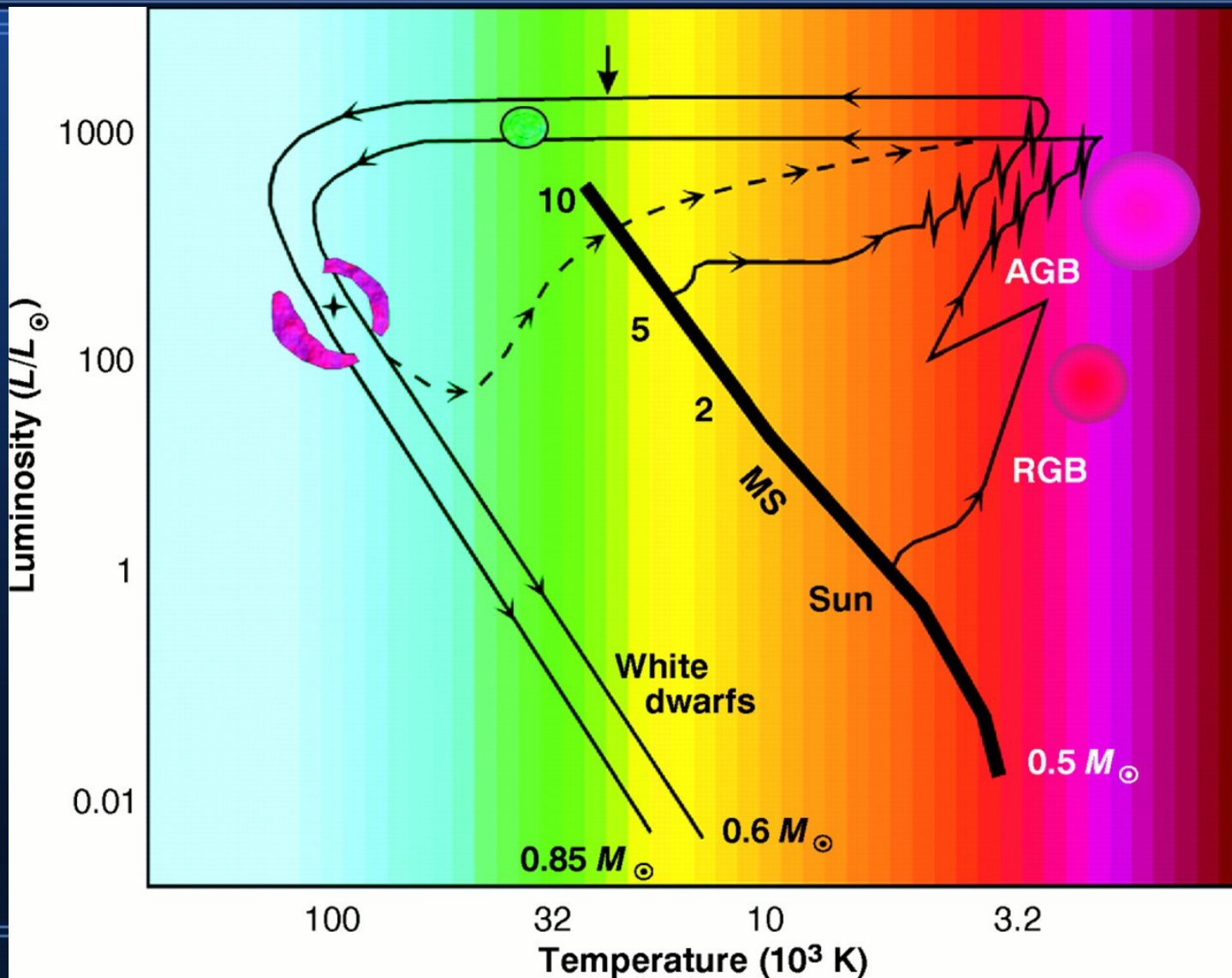
## Dancing giants: binary stars on AGB and beyond

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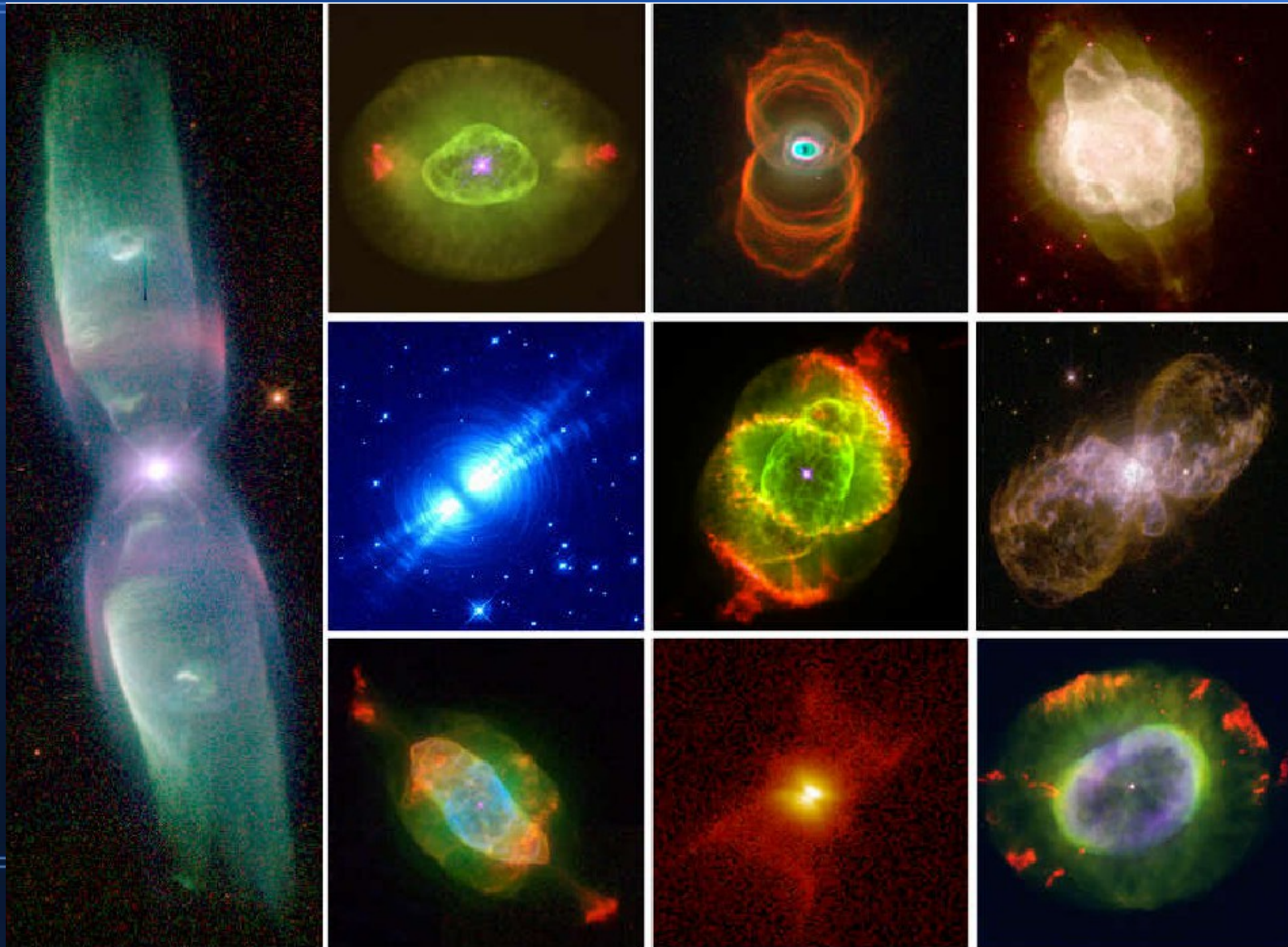
# Stellar paths



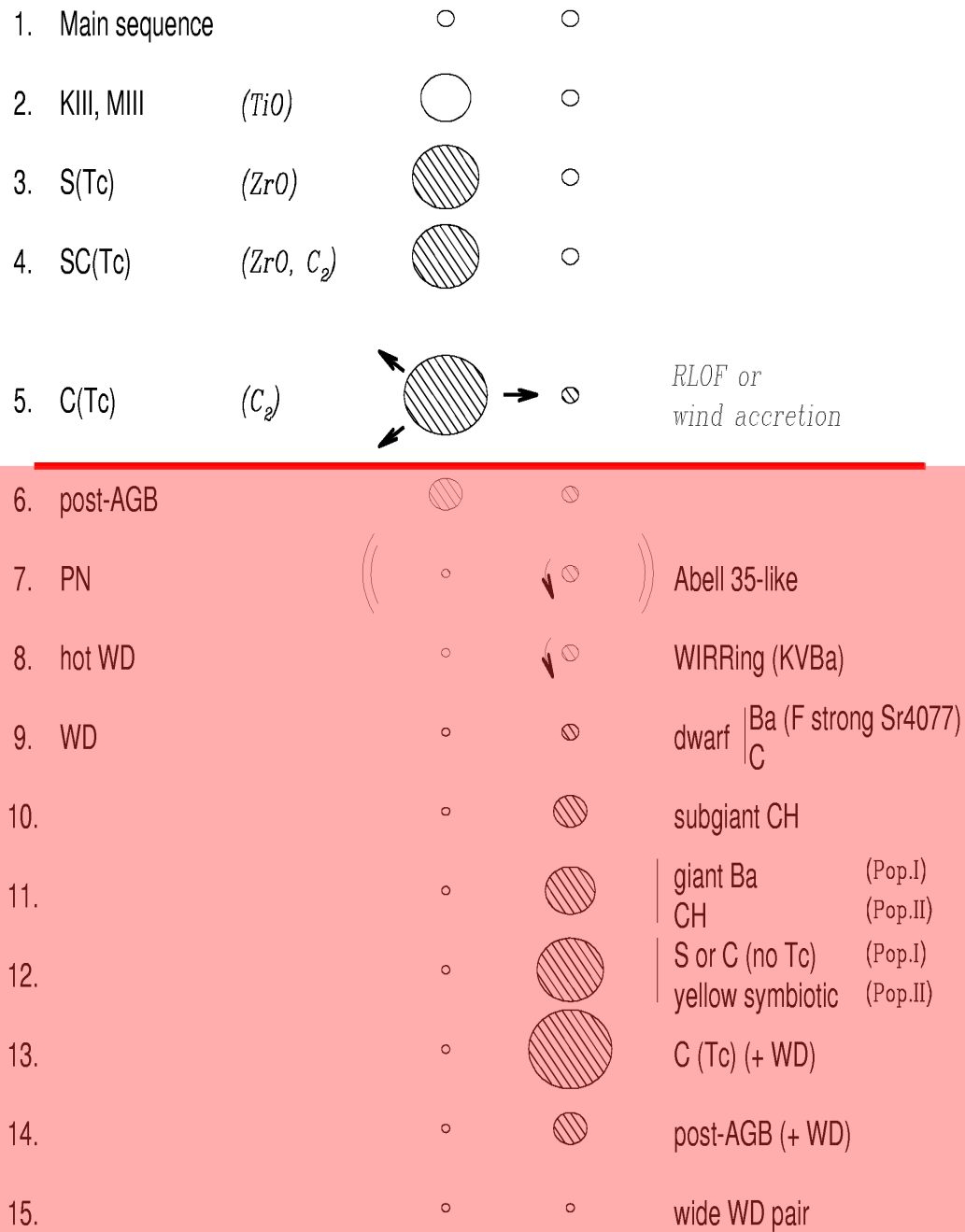
# Stellar paths

- Asymptotic Giant Branch (AGB) stars: luminous & cool, strong winds, thermal pulses, complex nucleosynthesis, dredge-up
- Enrichment of ISM in heavy elements:  
C, F, s-process
- Mira (o Ceti)
- Progenitors of Planetary Nebulae (PNe)
- With binarity: symbiotics, Ba stars, SN Ia (?)

# Planetary Nebula shapes



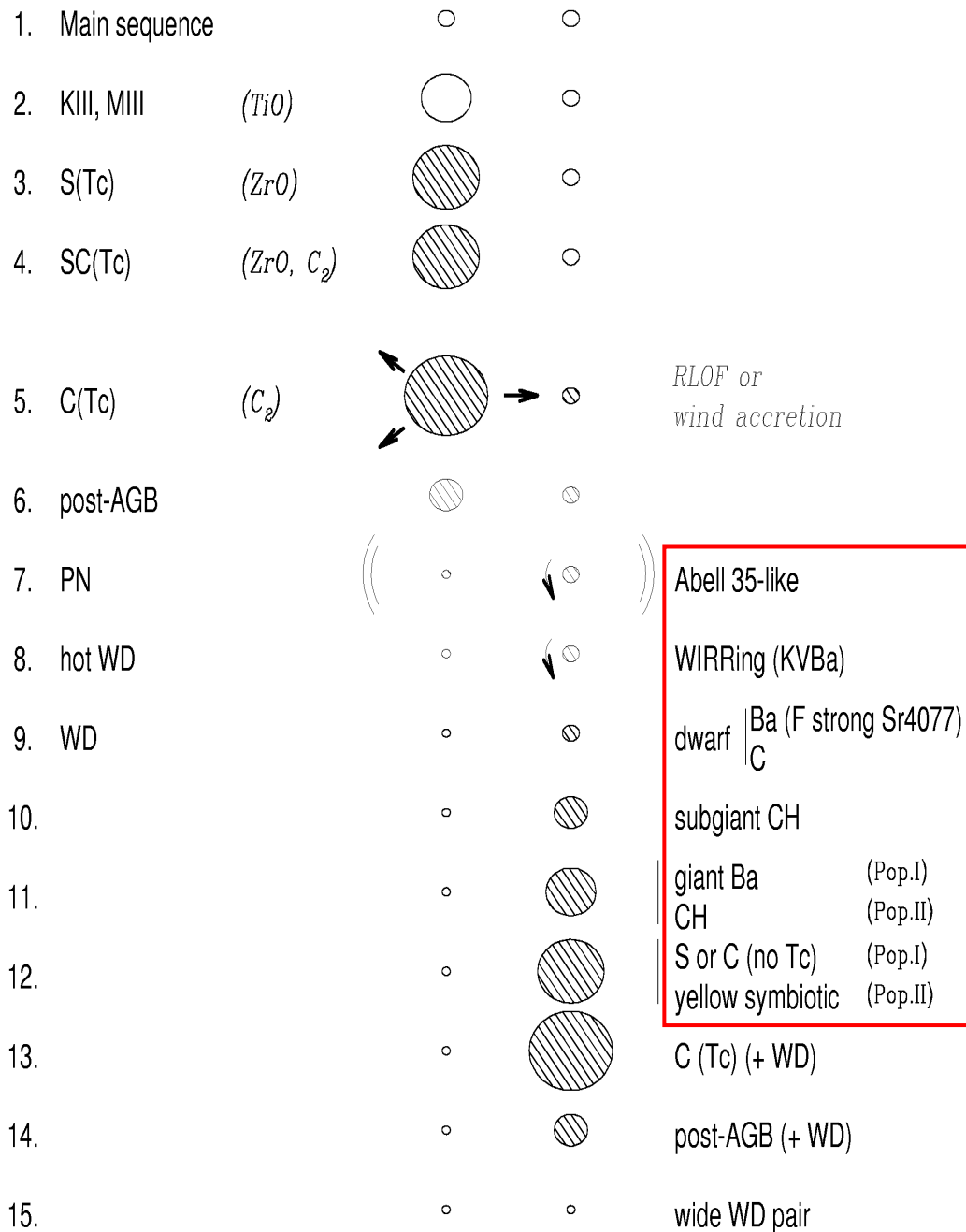
# binary evolution scheme



# Progeny of AGB stars in binaries...

...all binaries in which at least one component has gone through the AGB

# binary evolution scheme



# Progeny of AGB stars in binaries...

...includes several classes of s-process-rich stars resulting from mass transfer from a former AGB companion (now a white dwarf)

# AGB and binarity

Not all descendants of AGB binaries are s-process-rich:

- Post-AGB stars (some s-process-rich, not all)
- Binary CSPNe
- Red symbiotics with massive WD companions ( $M_h > 0.5M_{\text{sun}}$ )

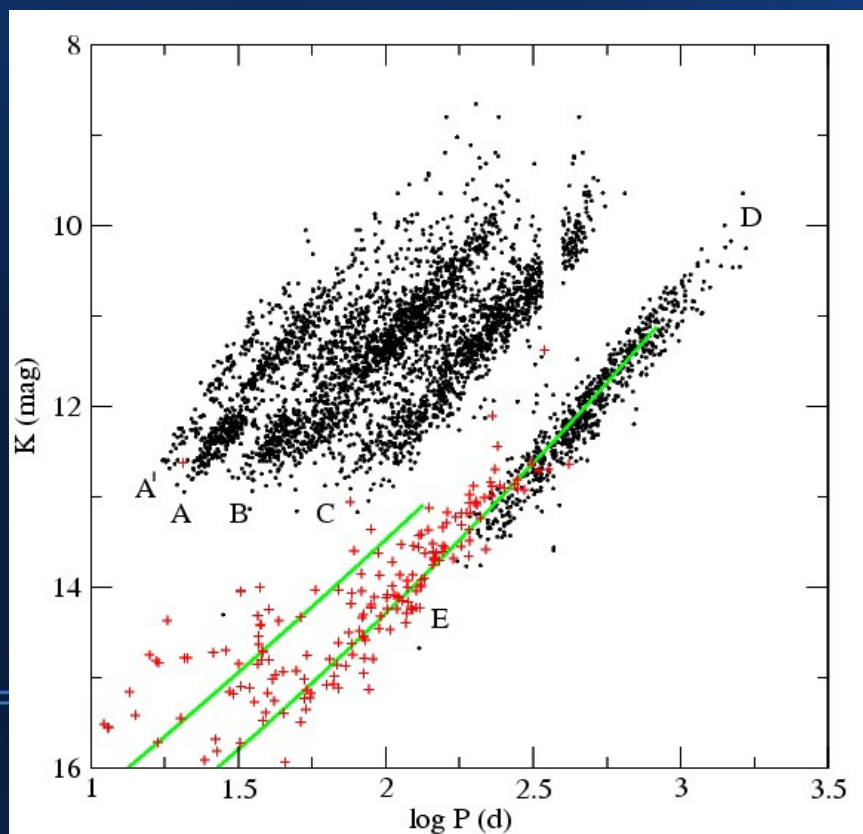
# How often do the giants dance?

- Observational bias against direct discovery while on the AGB: pulsations, turbulence, shocks, long orbital periods, large brightness contrast
- Indirect hints of binarity – bipolar outflows ( $\nu$  Hya), expanding tori ( $\pi$  Gru), fast rotation (yellow d' symbiotics)
- Binary fraction in the solar neighborhood from RV and astrometry: K giants: 15-30%, M giants: 14-20%



# How often do the giants dance?

- Photometric observations of LMC variables:  
Period-Luminosity sequences: Long Secondary  
Periods



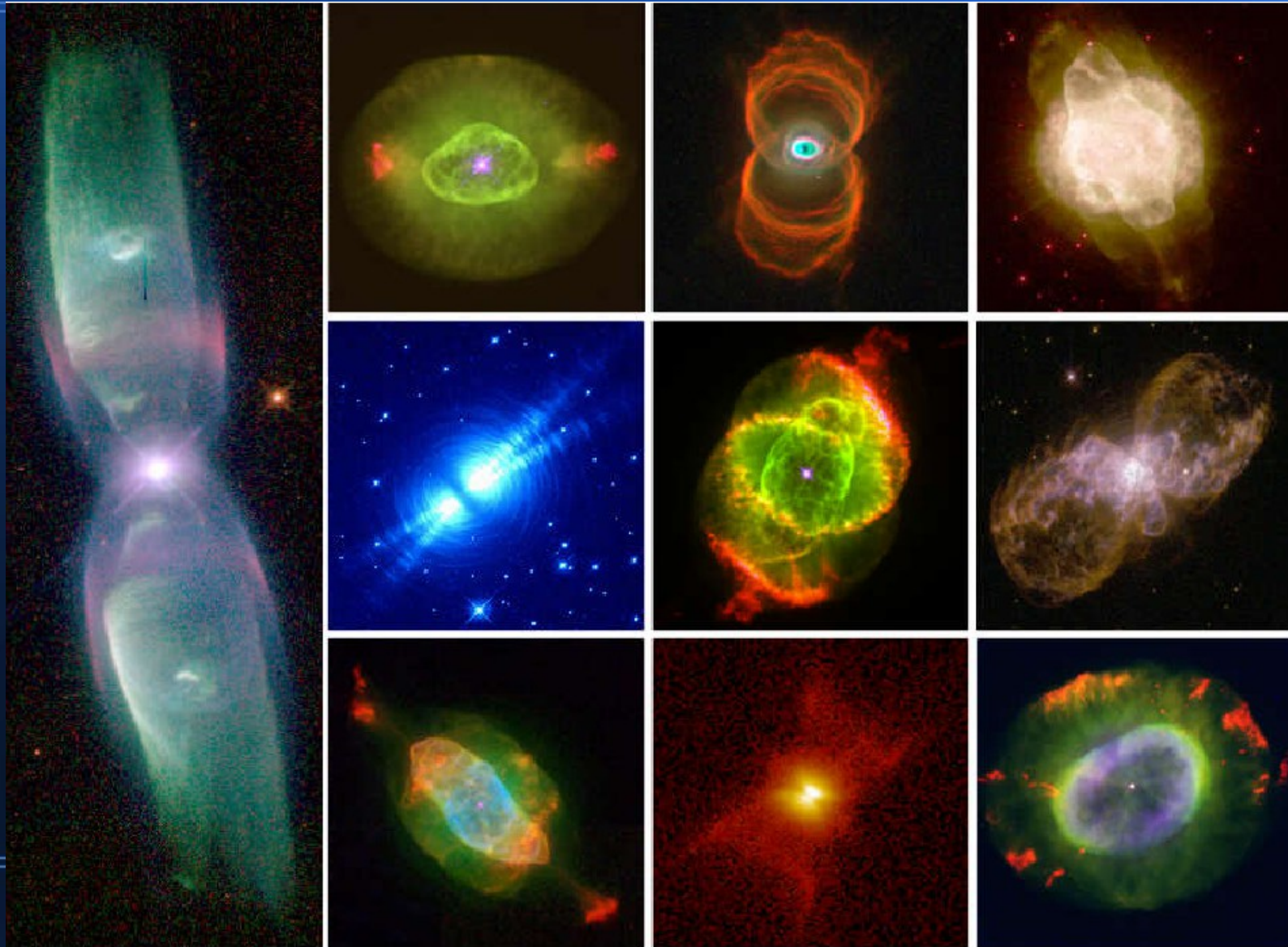
Sequence D:  
Pulsations?  
Rotation and spots?  
Ellipsoidal variables?  
Eclipsing variables?

Doubles binarity fraction  
of AGB stars!? Companions  
rather sub-stellar...

# How often do the giants dance?

- Only 5-10% of PNe are round, most are elliptical

# Planetary Nebula shapes



# How often do the giants dance?

- Only 5-10% of PNe are round, most are elliptical
- Any shaping mechanism requires angular momentum – an argument for a companion
- Ongoing search for companions to CSPNs (10%-20% are close binaries)

# Symbiotic vs. Ba stars

Why some descendants of binary AGBs show s-process enhancement while others do not?

Almost solved (mostly due to initial abundances),  
with the notable exception of:

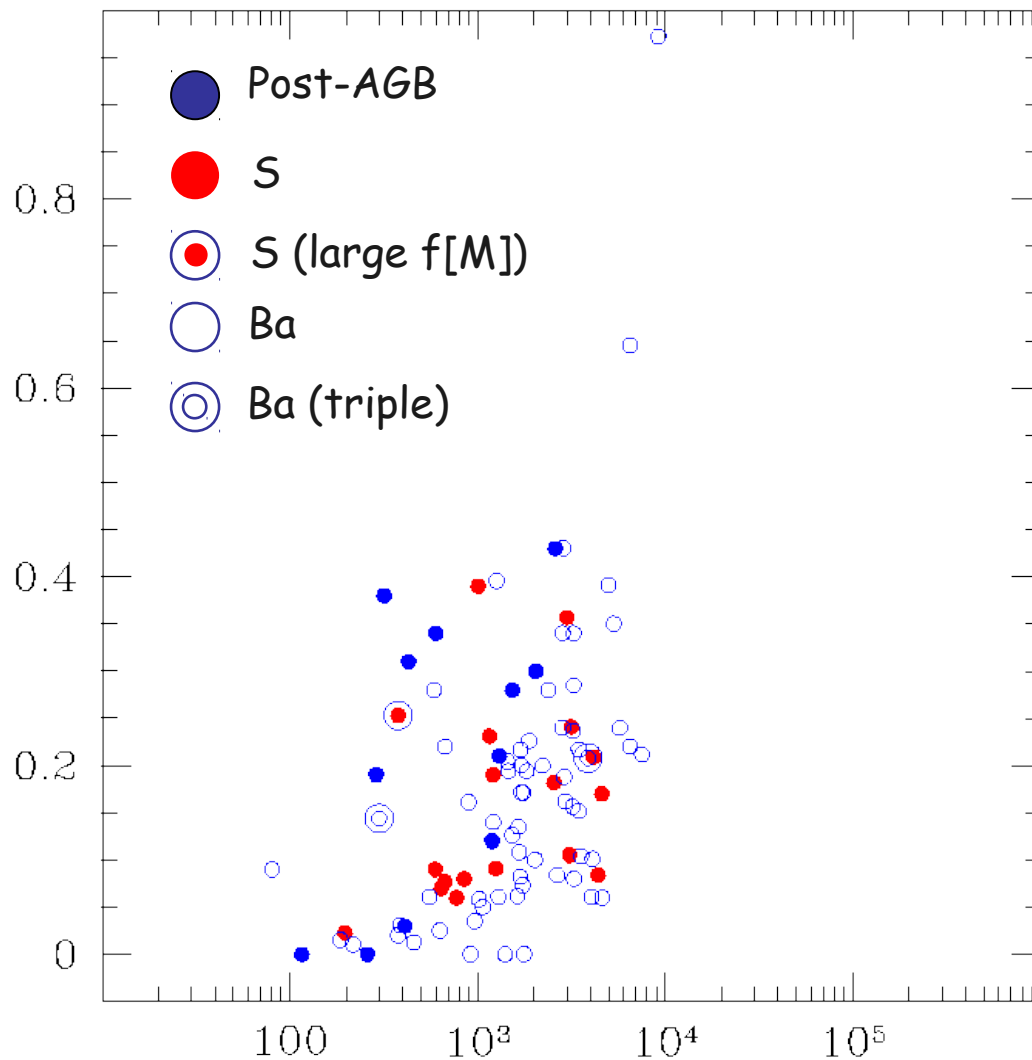
why red symbiotics are not S stars?

# Symbiotic vs. Ba stars

How to reconcile orbital periods and eccentricities of systems that went through AGB?

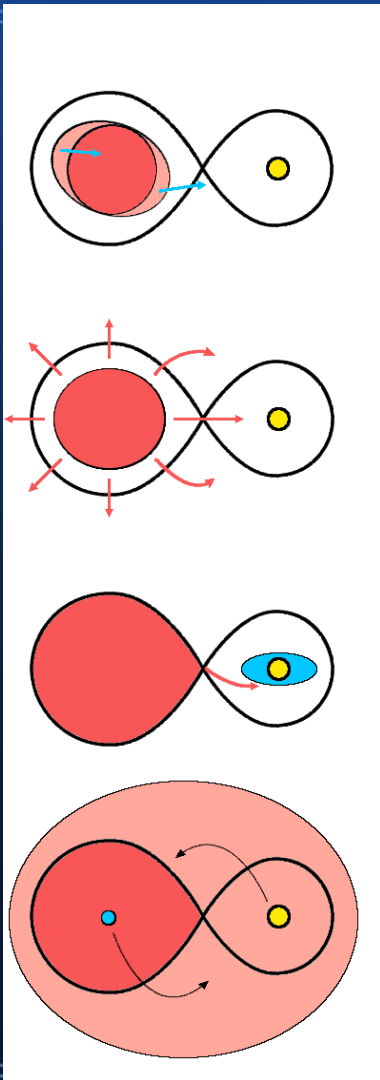
- post-AGB binaries
- Ba and S stars
- Symbiotic stars

# e-log P diagrams



- The observational e-log P diagram of descendants from AGB systems
- What about theory?

# e – log P diagrams

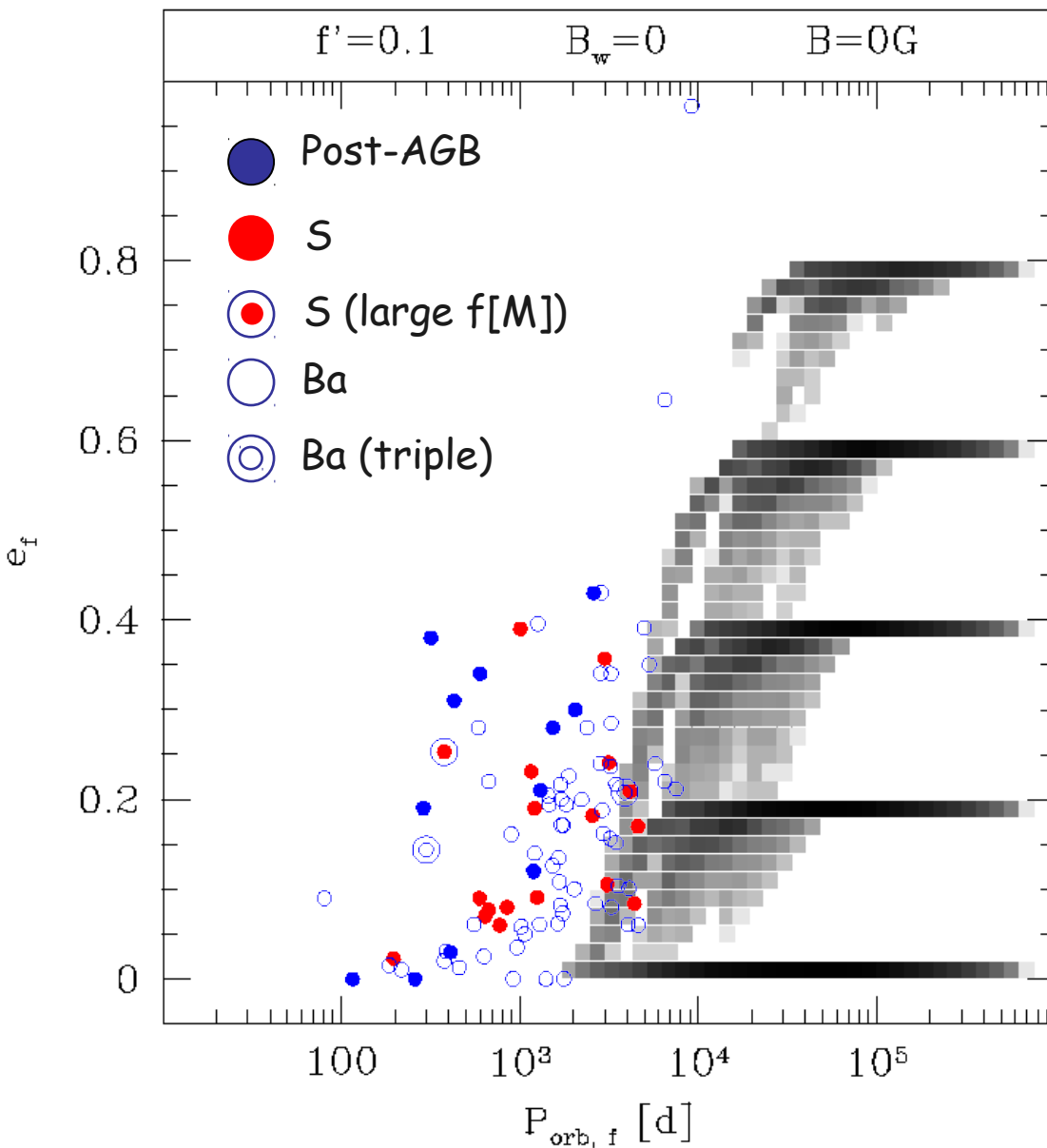


Binary evolution channels/processes

- Tidal interactions
- Wind accretion, wind tidal enhancement
- Roche-lobe overflow
- Common envelope event



# e-log P diagrams



- Binaries after the AGB – theory vs. observations...

# e – log P diagrams

Solutions proposed – avoid drastic orbital shrinkage during CE:

- CRAP (Companion-Reinforced Attrition Process)
  - inhibits s-process exchange
- Diminished binding energy of the envelope
  - is ionization energy recyclable?
- Inclusion of tidal forces
  - did not help
- Angular momentum balance-based CE (instead of energy based)
  - what physics?

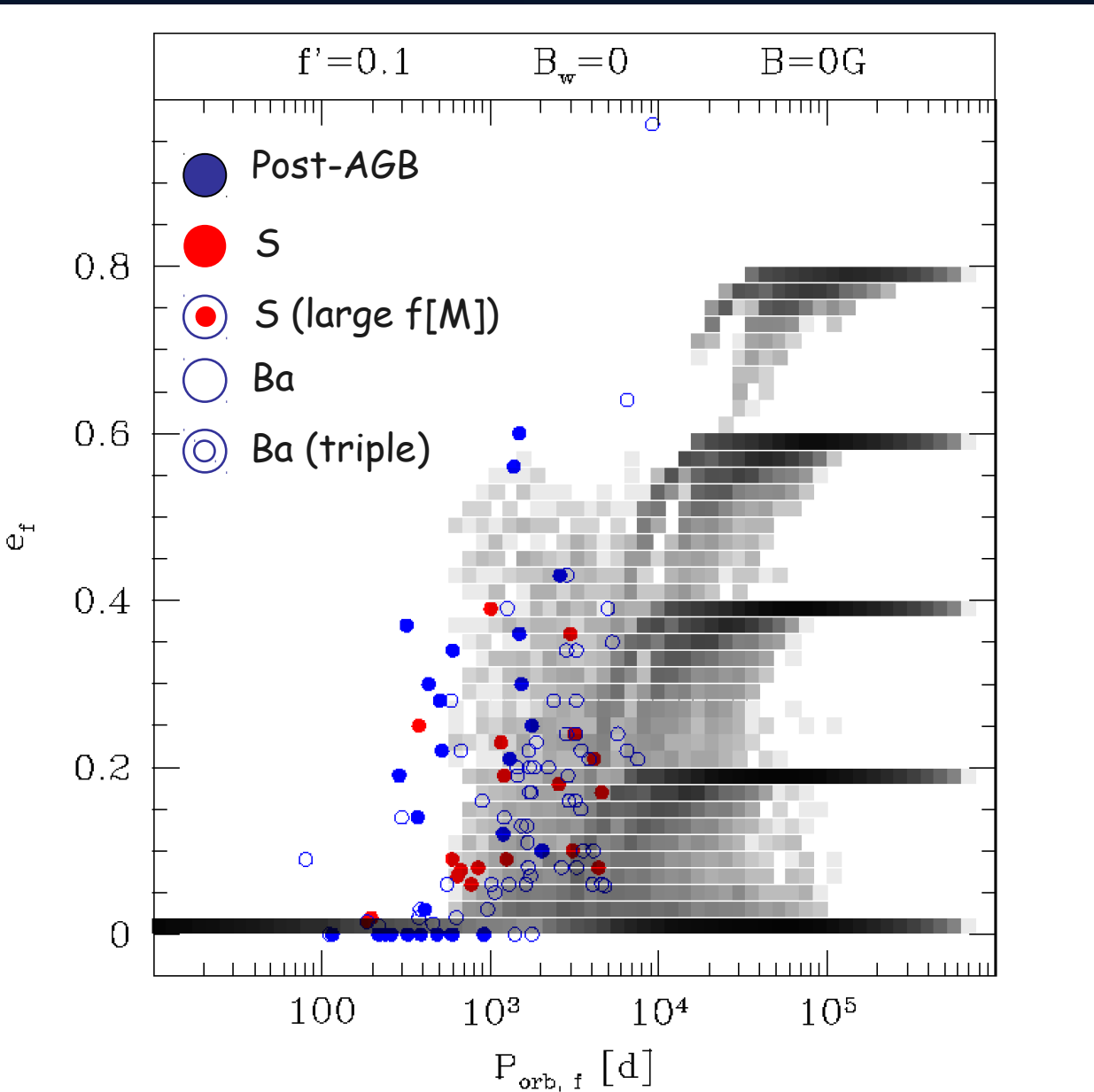
# $e - \log P$ diagrams

Solutions proposed – stay eccentric:

- Periastron mass-loss
- Eccentricity pumping by a circumbinary disk

But: only for detached systems!

# e-log P diagrams



- Perhaps there is hope. Could it be a transient torus effect?

**Thank you, Romek!**