An ESO Workshop on

THE IMPACT OF BINARIES ON STELLAR EVOLUTION

03 – 07 July 2017 I ESO HQ, Garching, Germany

A Newly Discovered Binary Evolutionary Class: **Dusty Post-RGB Stars**

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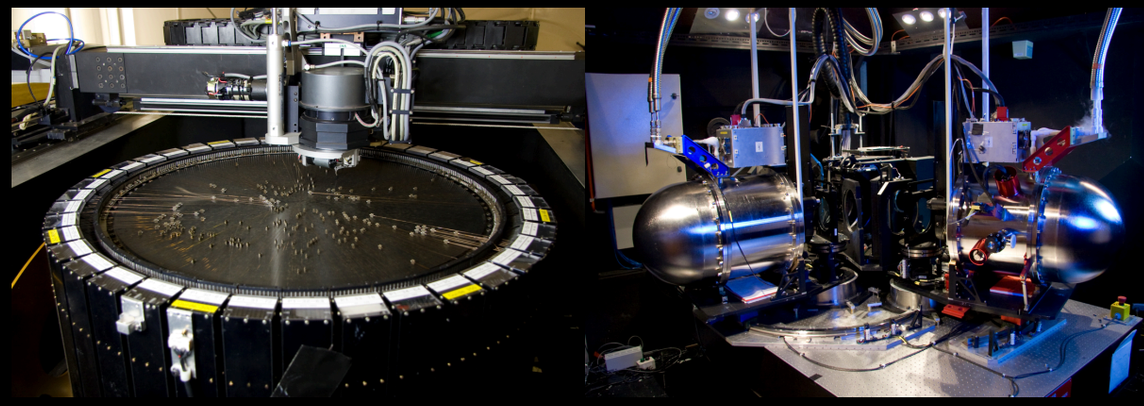
AAO

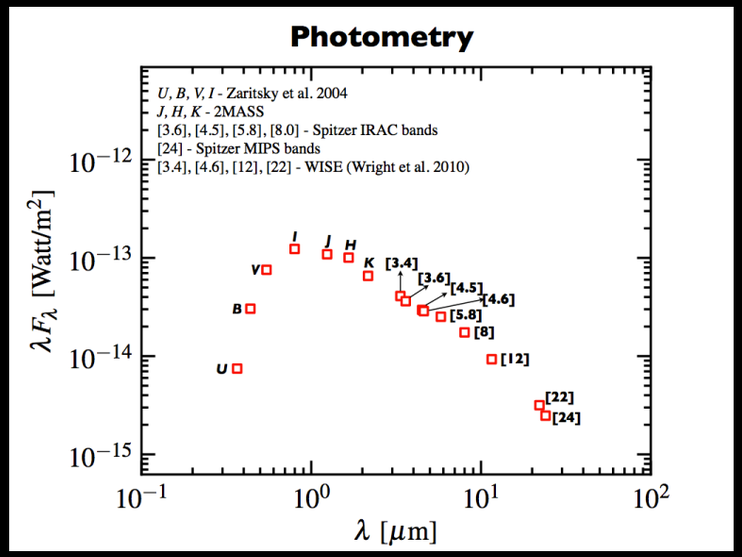
OPTICALLY VISIBLE POST-AGB STARS IN THE LMC AND SMC

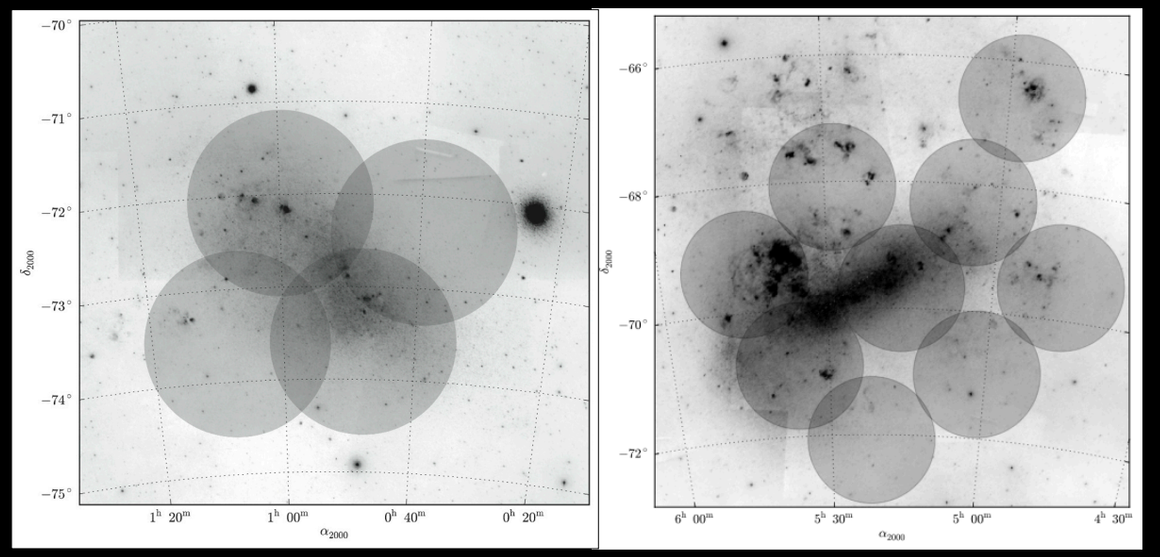
Kamath et al., 2014, 2015

Mid-IR excess selection criteria (SST) UBVIJHK+Near-IR+mid-IR

Low-res optical multi-fibre spectroscopy with AAOMega/AAT

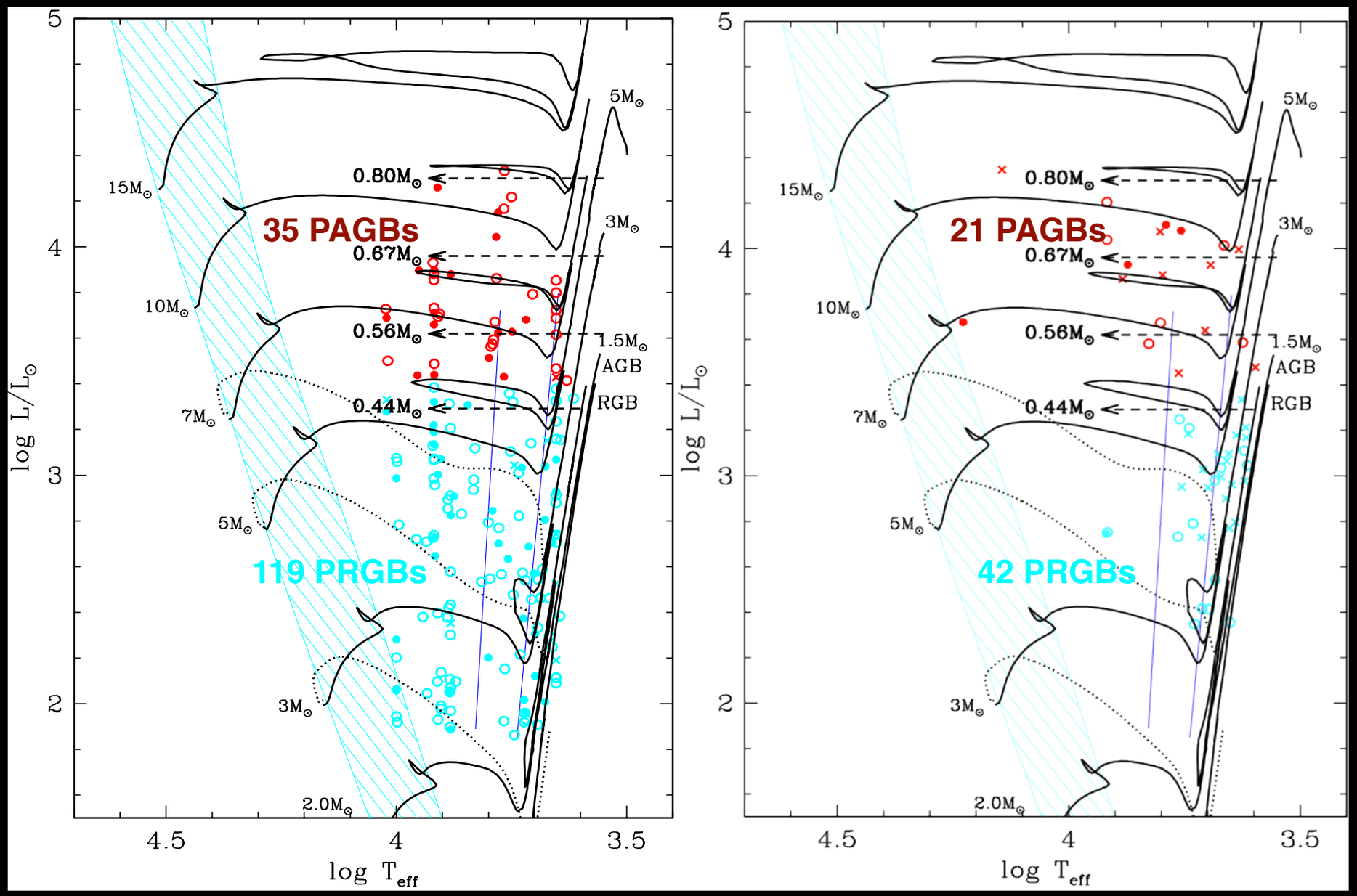






RESULT: Spectroscopically verified Catalogues of optical visible Post-AGBs and other interesting objects…

POST-AGB AND POST-RGB STARS IN THE LMC/SMC



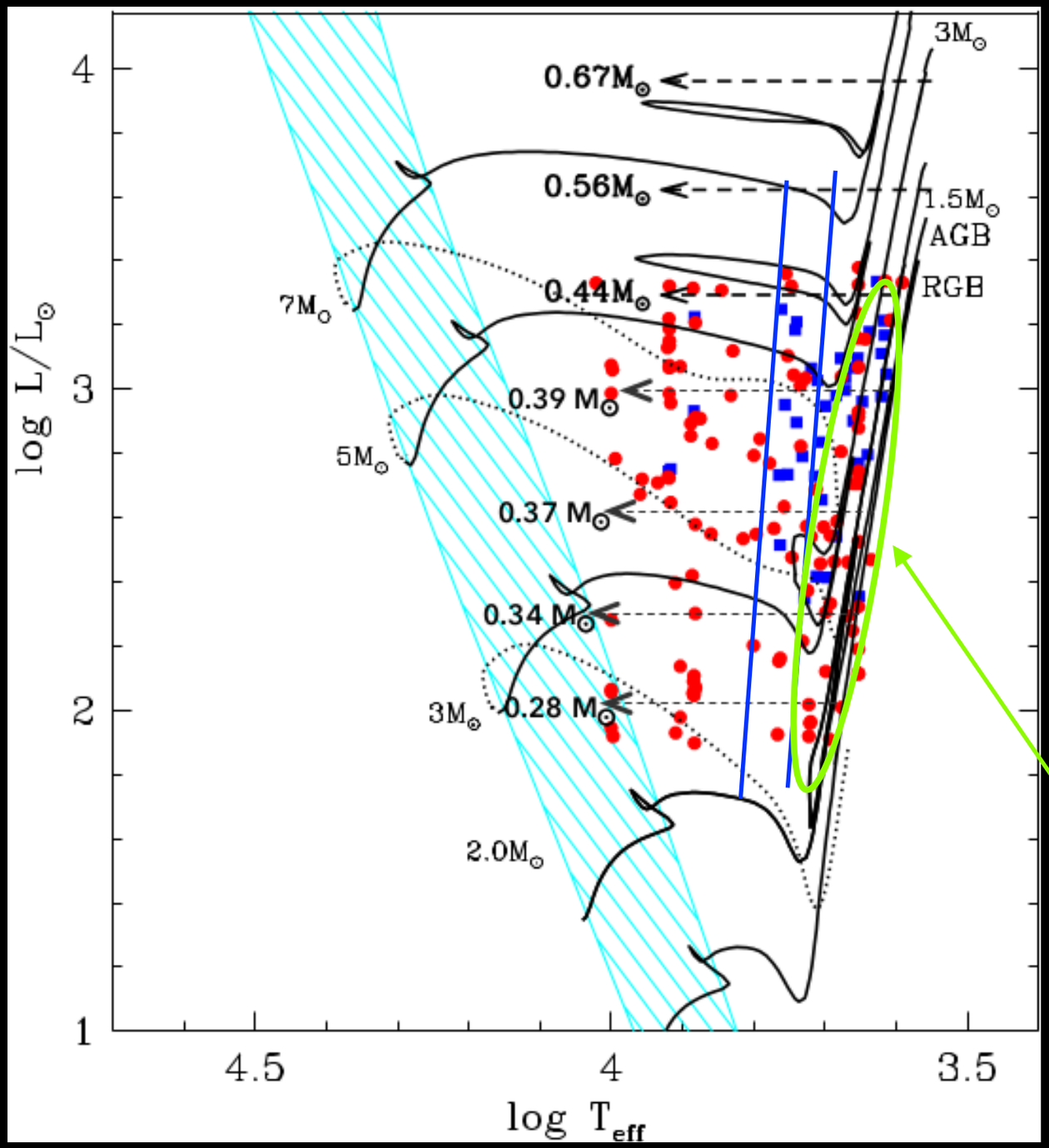
- Mid-IR excess
- A- K spectral types
- Low log g
- low [Fe/H]
- Luminosity > 2500 $L_\odot$

- Same as Post-AGBs
- **Luminosity < 2500 $L_\odot$**

Post-AGB:Post-RGB 1:~2.5

Interactions on the RGB and evolution off the RGB is apparently a common phenomenon!

DUSTY POST-RGB STARS IN THE LMC/SMC



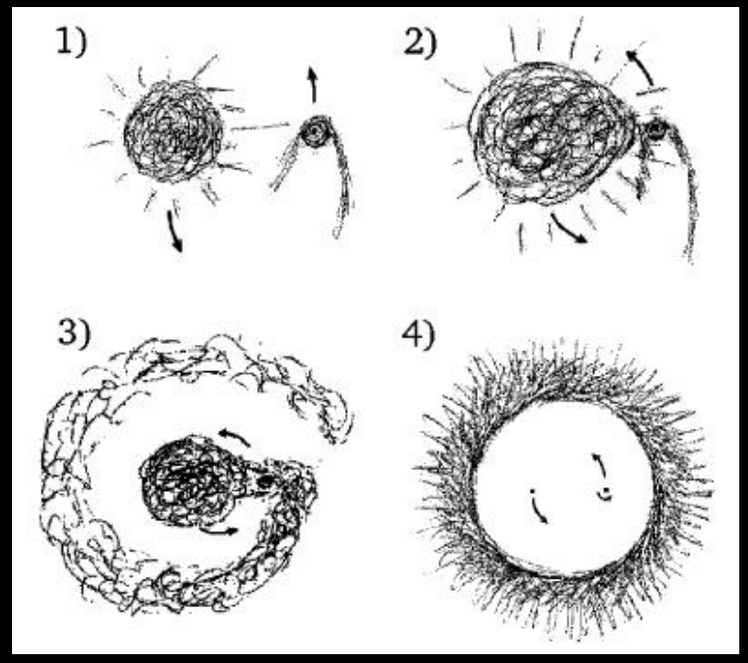
- Pre-mature evolution off the RGB via mass-loss
- Single star mass loss too weak!
- Mass loss induced via binary
- very dusty systems -> circumbinary discs?

Mergers?

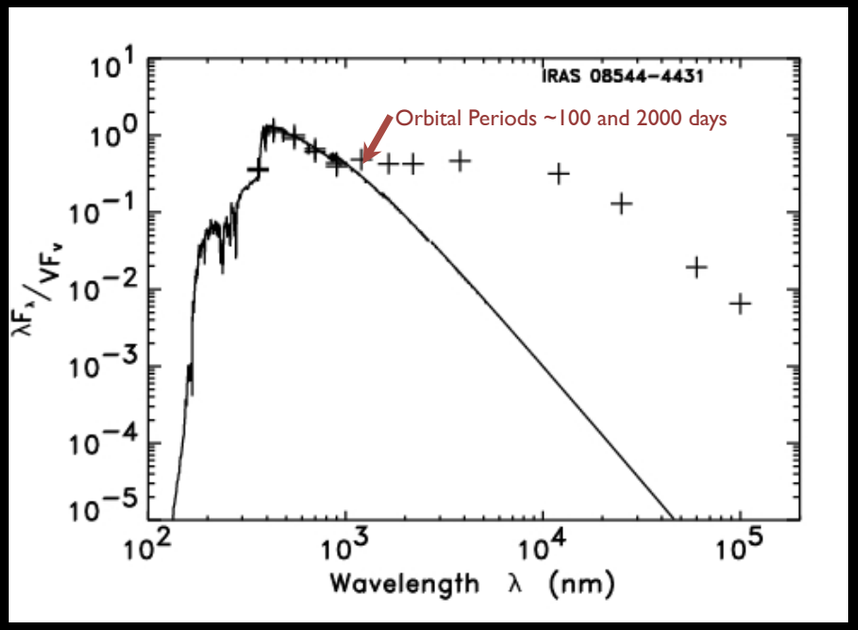
ROCHE LOBE FILLING **ON THE GIANT BRANCHES**

A CE resulting in some sort of **stable mass transfer**

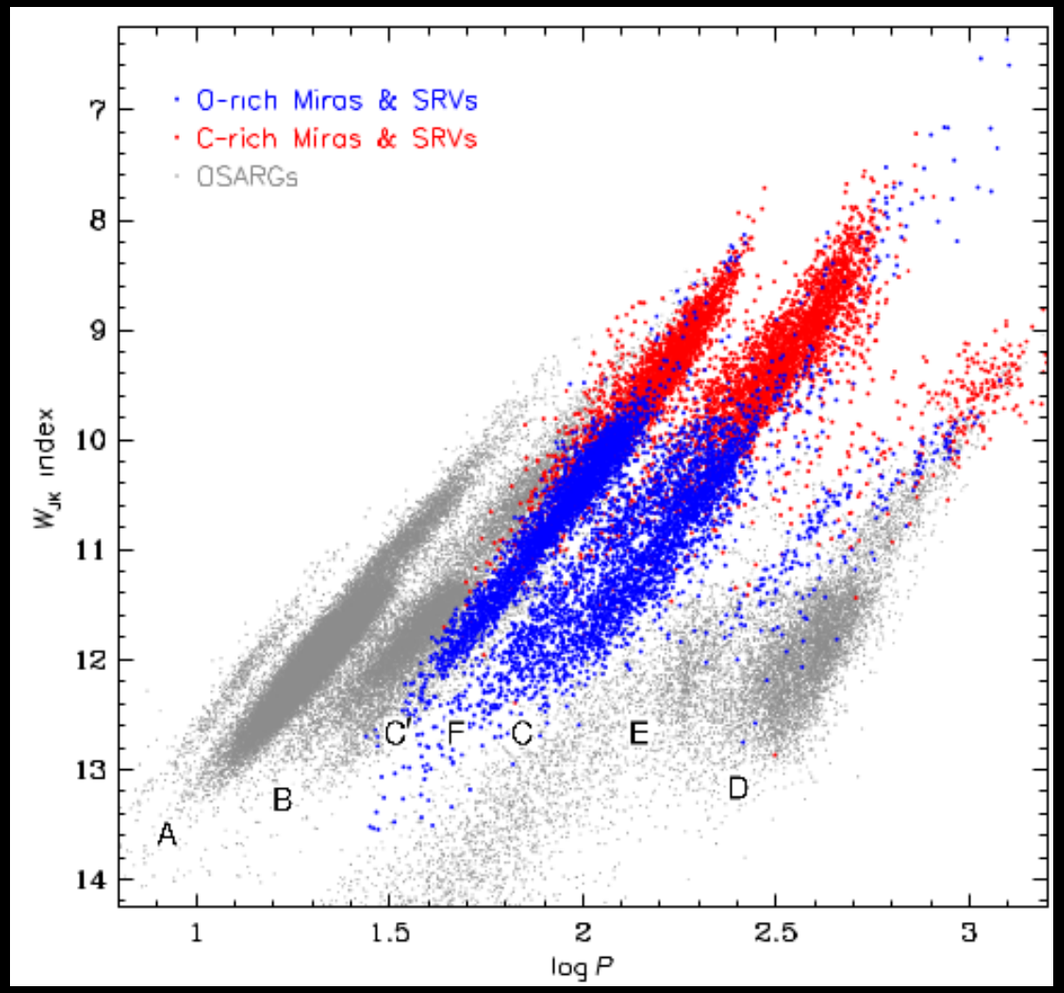
- ON THE AGB:
  - Post-AGB binaries surrounded with DUSTY circumbinary discs with periods of a few 100s of days



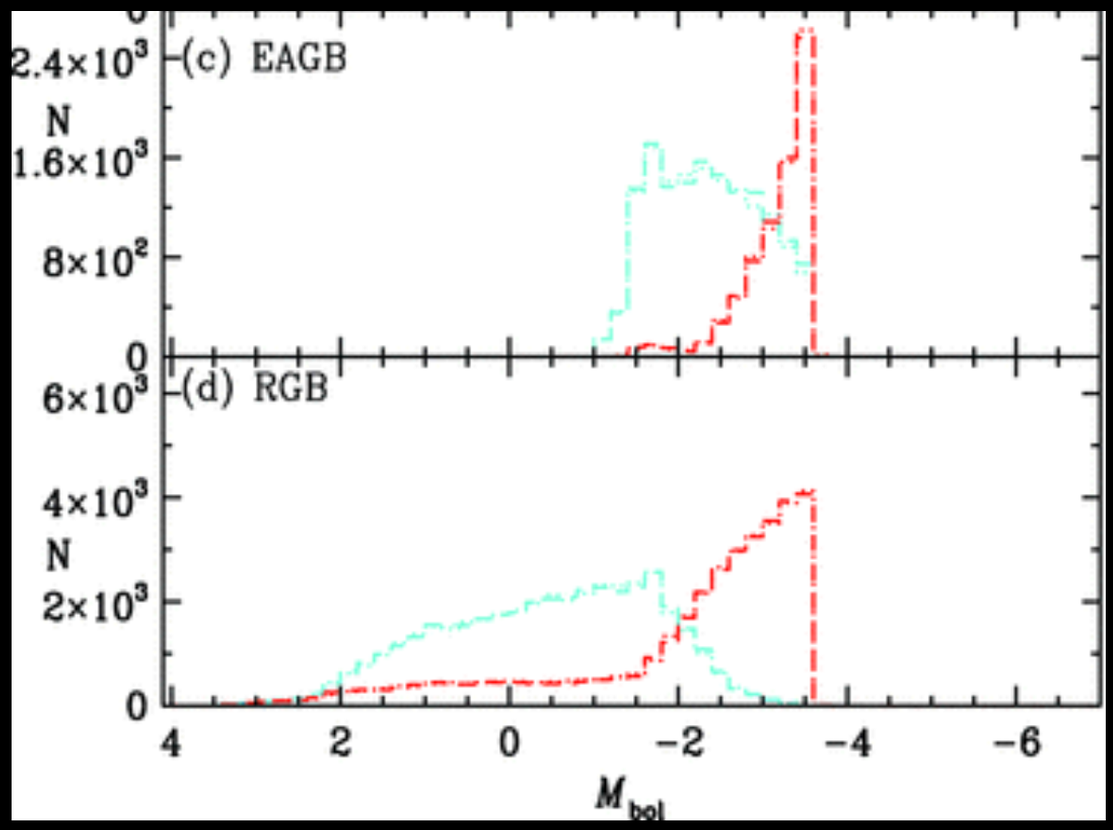
- ON THE RGB:
  - Post-RGB binaries surrounded with DUSTY circumbinary discs!!??



LUMINOSITY DISTRIBUTIONS OF BINARY RED GIANTS



SEQUENCE-E Variables
Close binary red giants that show ellipsoidal light variations

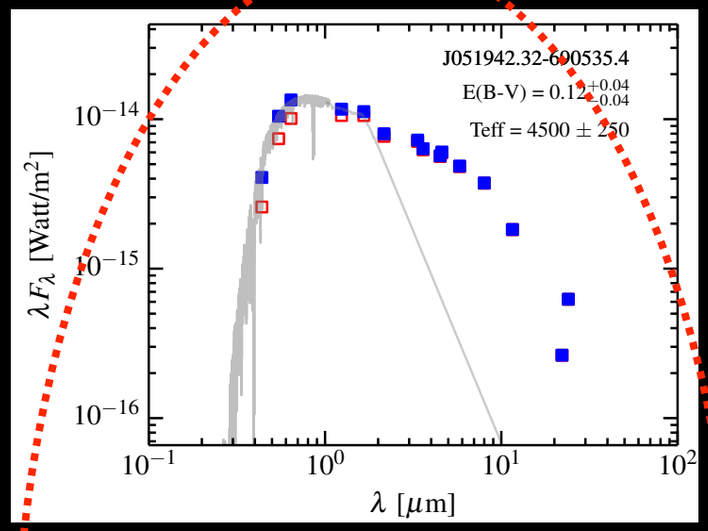


EAGB and RGB binaries undergoing a CE event have luminosities below the TRGB
Nie et al. 2012

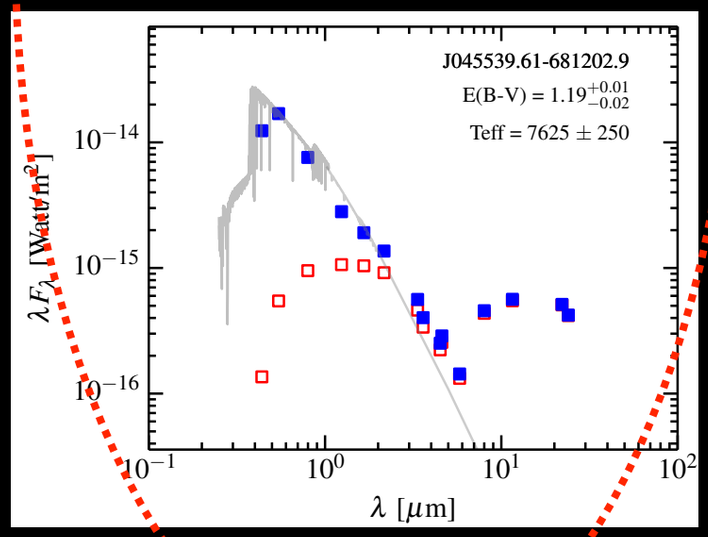
PRECURSORS of dusty post-RGB stars: SEQUENCE-E STARS!
(Kamath et al., 2016)

SPECTRAL ENERGY DISTRIBUTIONS OF THE SAMPLE OF POST-RGB STARS

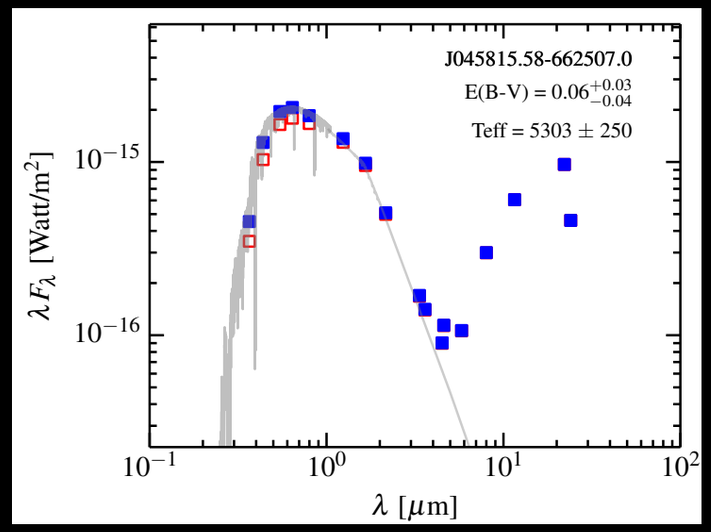
LIMITED UNDERSTANDING OF POST-RGB DISC EVOLUTION!



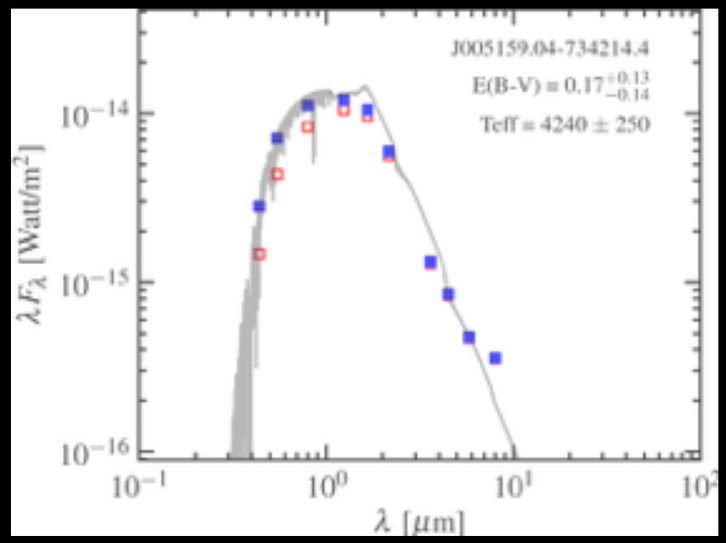
Disc-type SED with hot dust
points to binarity!



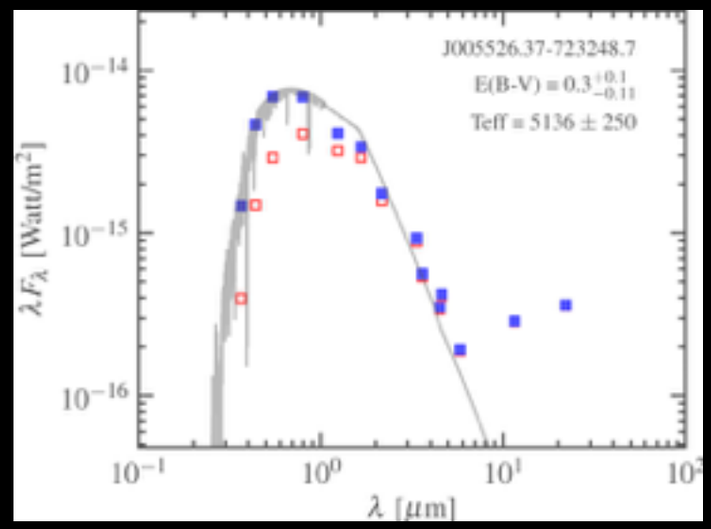
Disc-type SED
(evolved discs)



Shell-type SED?
observationally single!

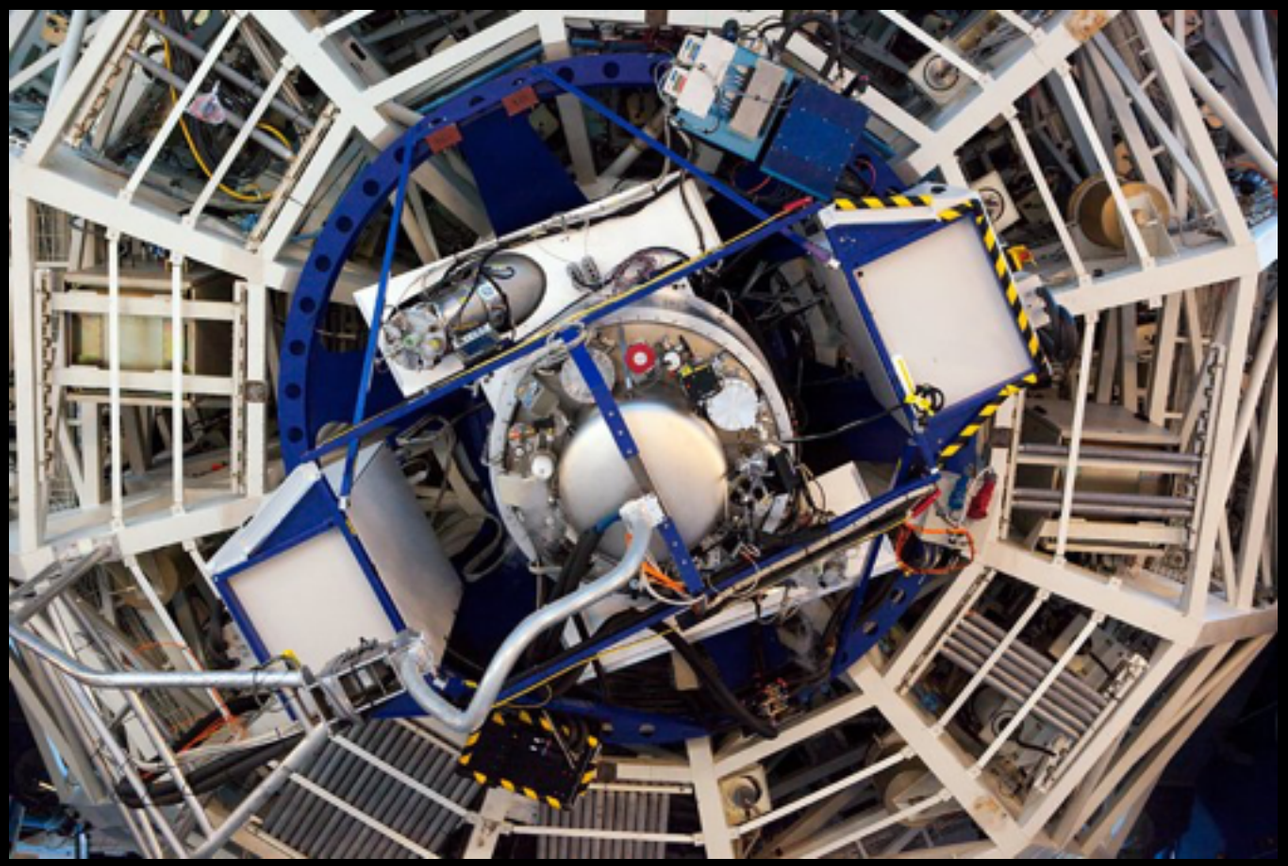


Uncertain SEDs?
???



ESTABLISHING BINARITY IN POST-RGBs

Radial Velocity Monitoring Studies



X-Shooter Spectrograph

UBV - 300 - 559.5nm
VIS - 559.5 - 1024nm
NIR - 1024 - 2480nm

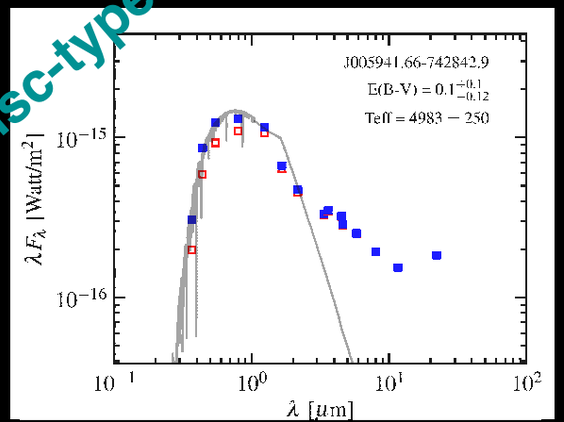
- X-Shooter high-quality spectra
- R=10000 and a S/N per resolution element of ~70 – 80
- 1-2Km/s accuracy

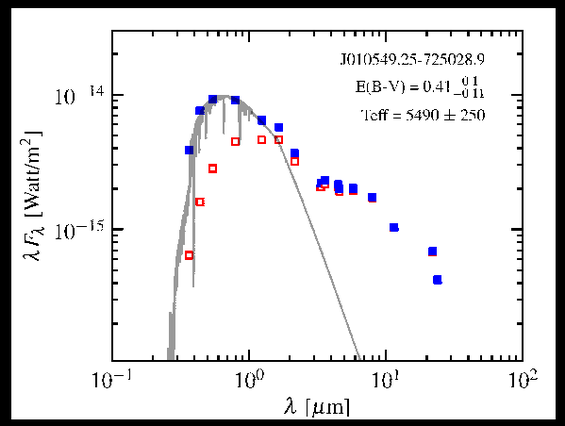
FIRST RADIAL MONITORING STUDY OF POST-RGB STARS (LMC/SMC)

X-SHOOTER/VLT (***P97***, ***P98***, *P99*, *P100*)

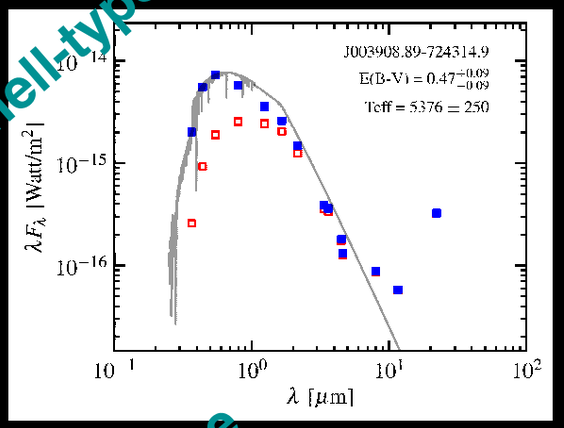
Sample: Spread in luminosity, SEDs & metallicity

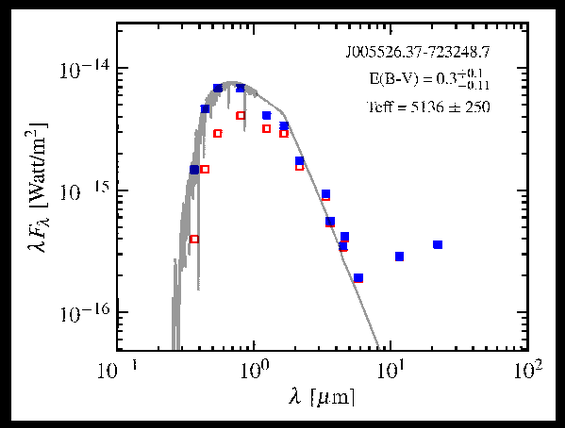
disc-type



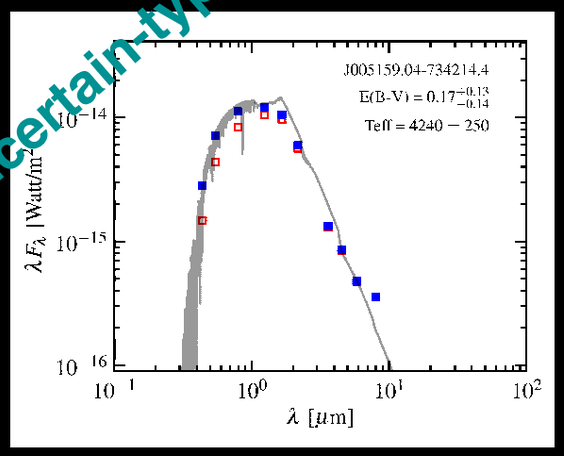


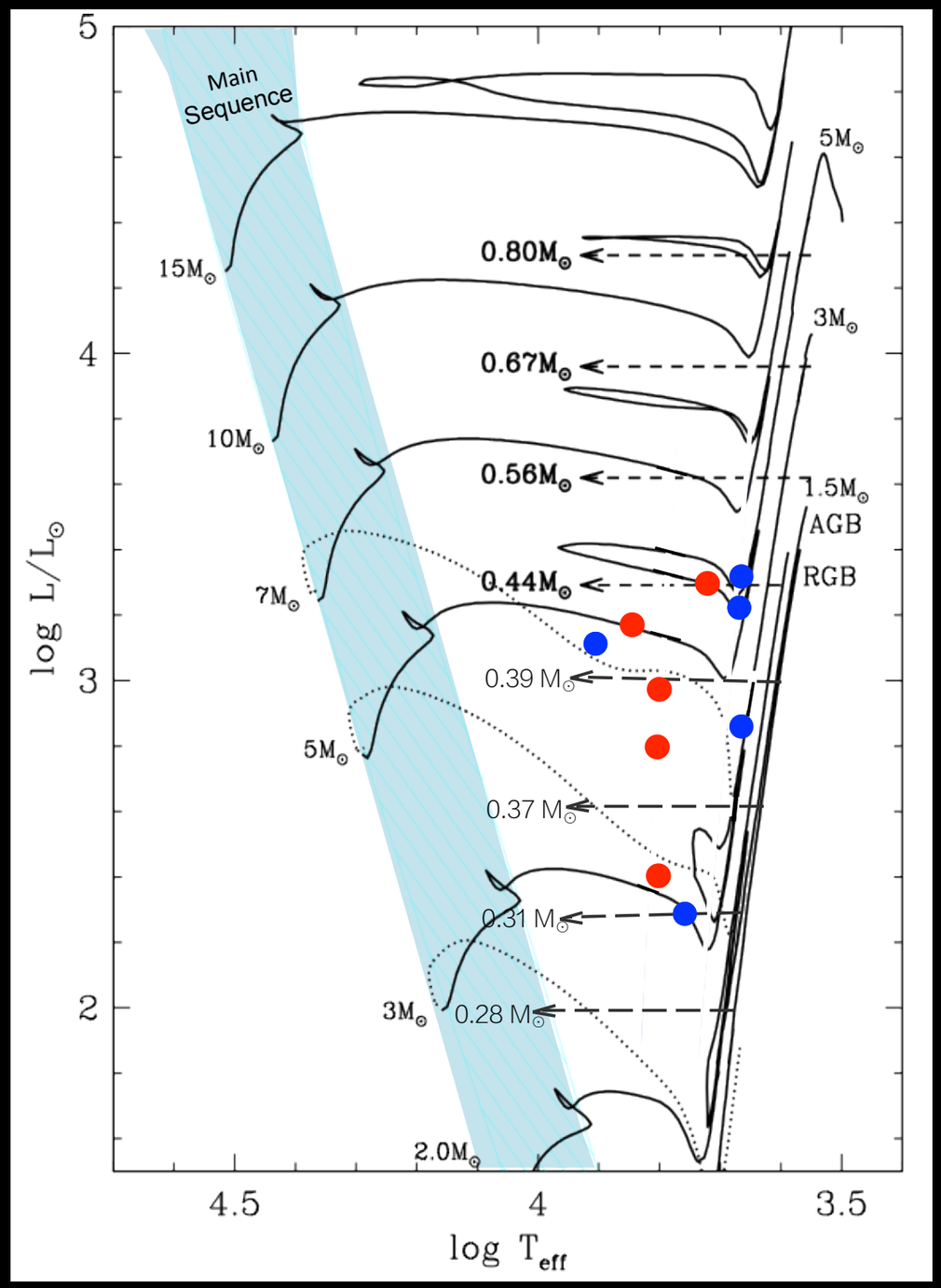
shell-type





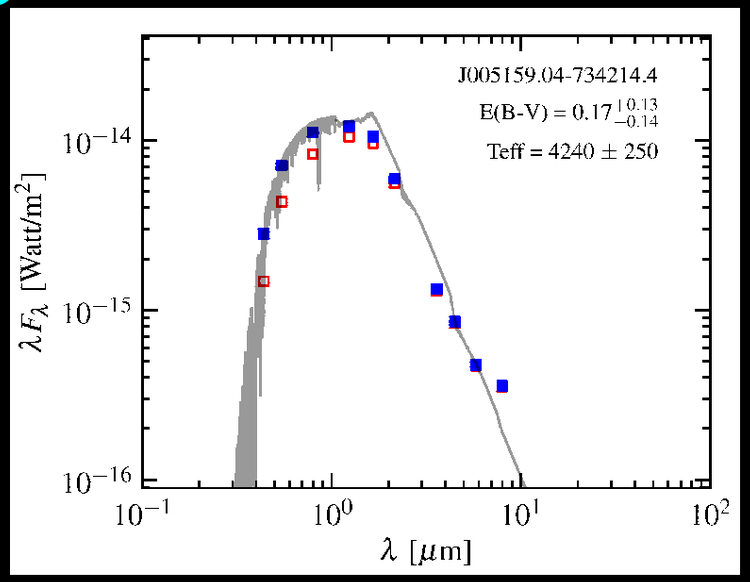
uncertain-type



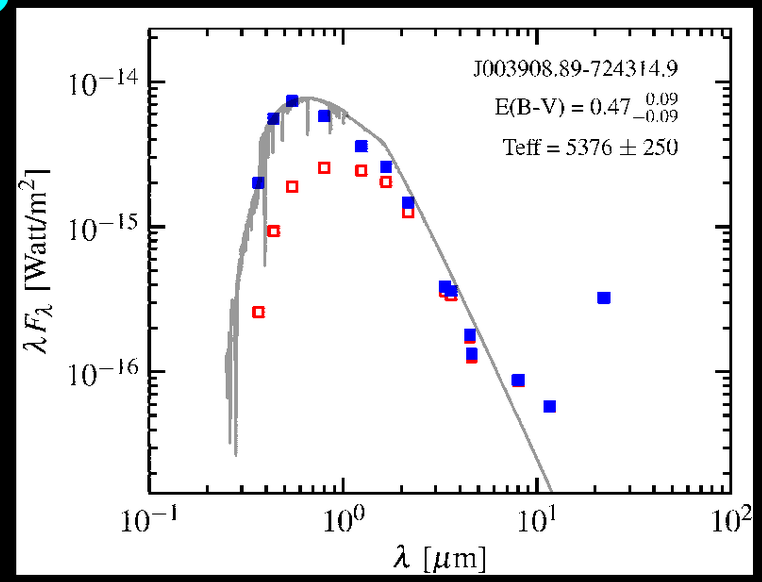


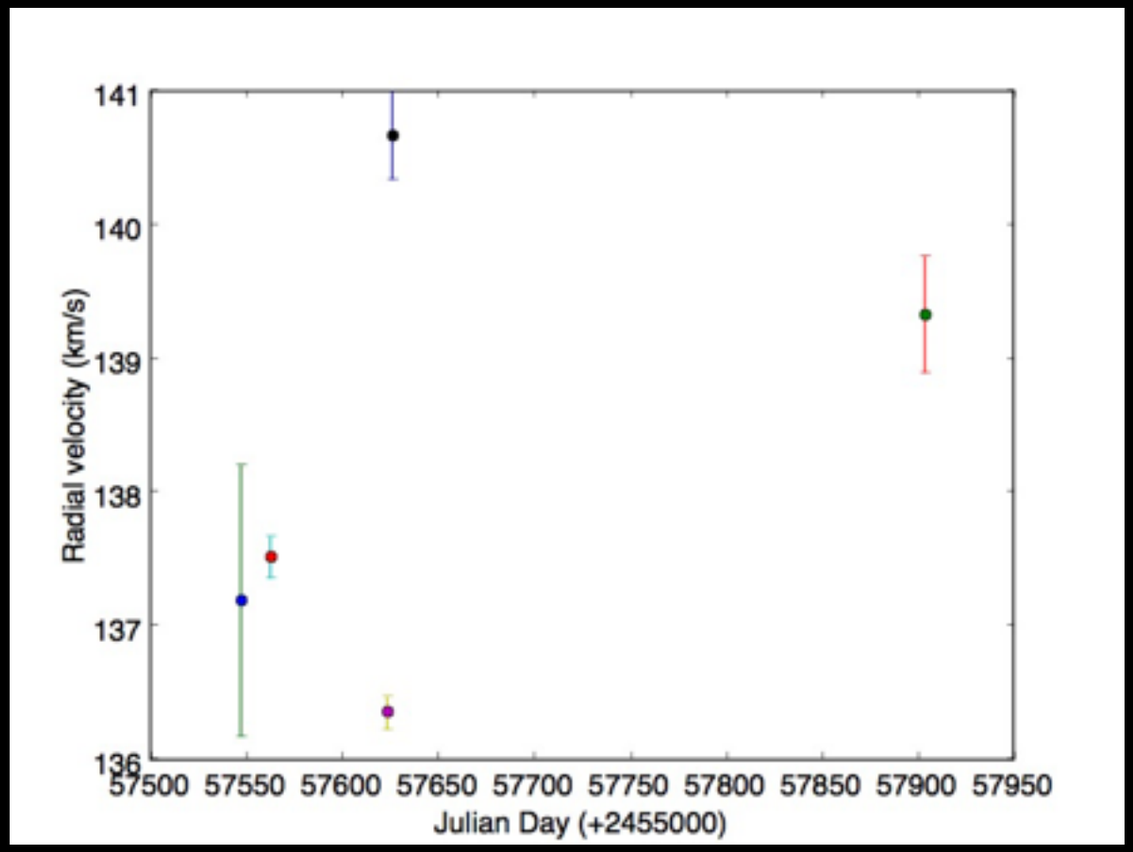
RADIAL VELOCITY MONITORING OF SMC POST-RGBS - FIRST RESULTS!

J005159

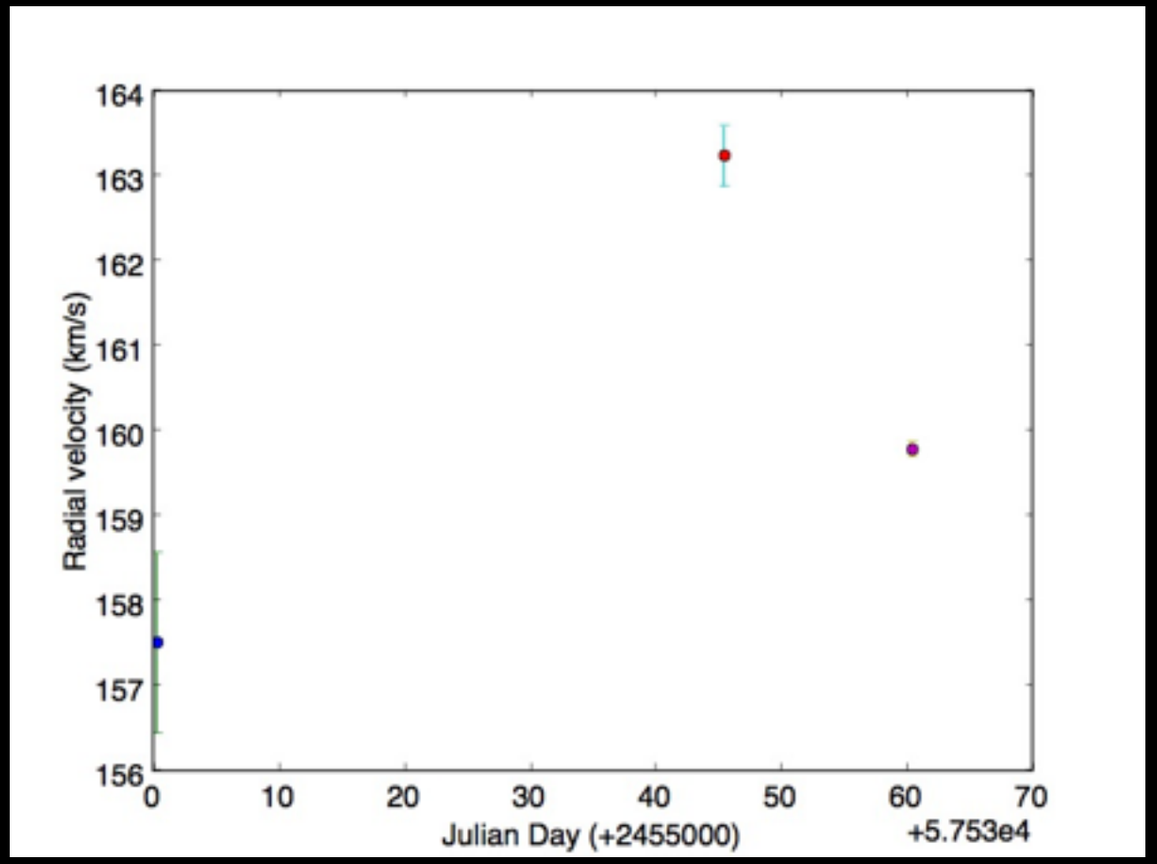


J003908





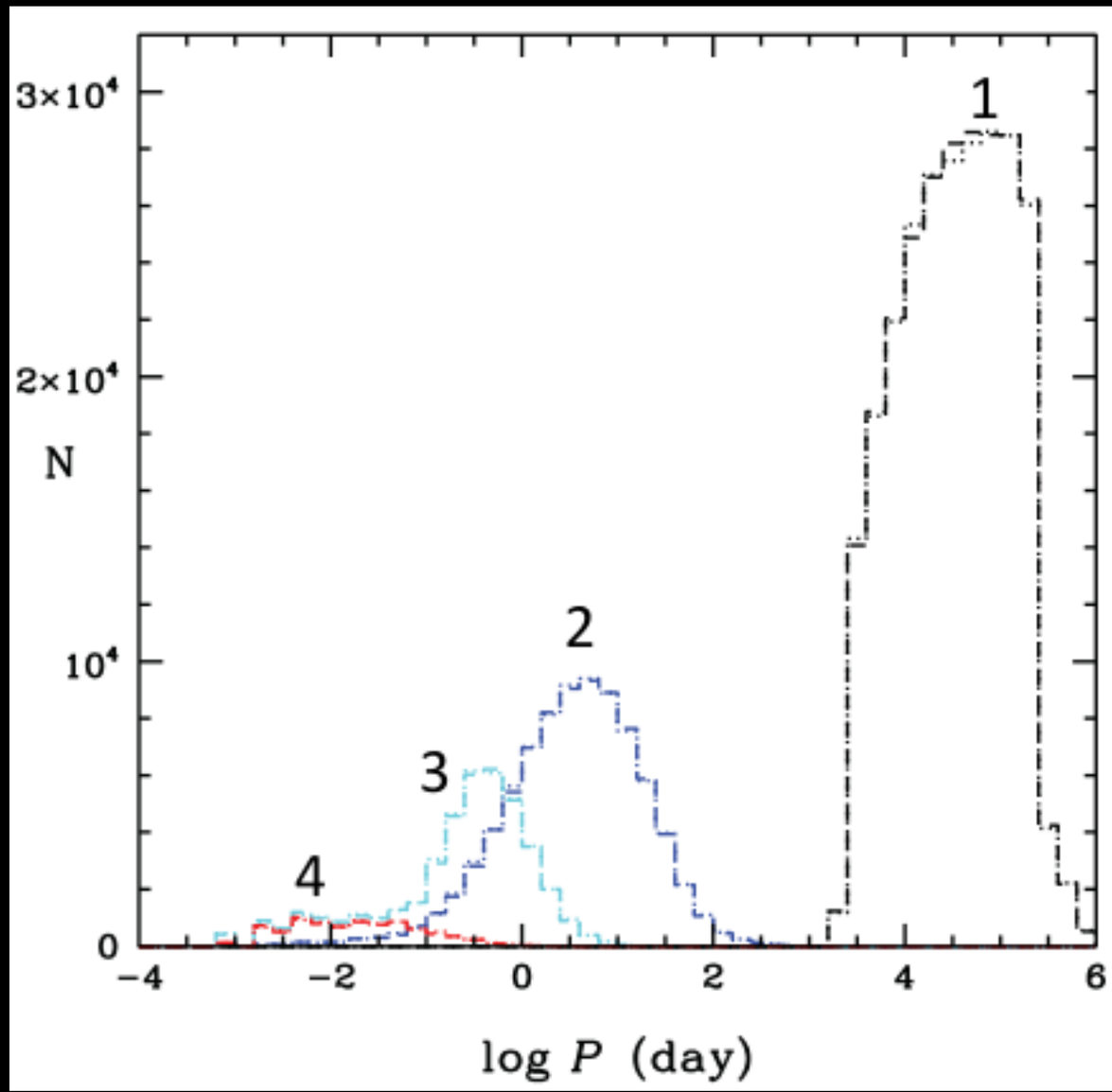
3 epochs in P97+2 epochs in P99
Spread in data = 365 days
Amplitude shift in RV ~ 5km/s

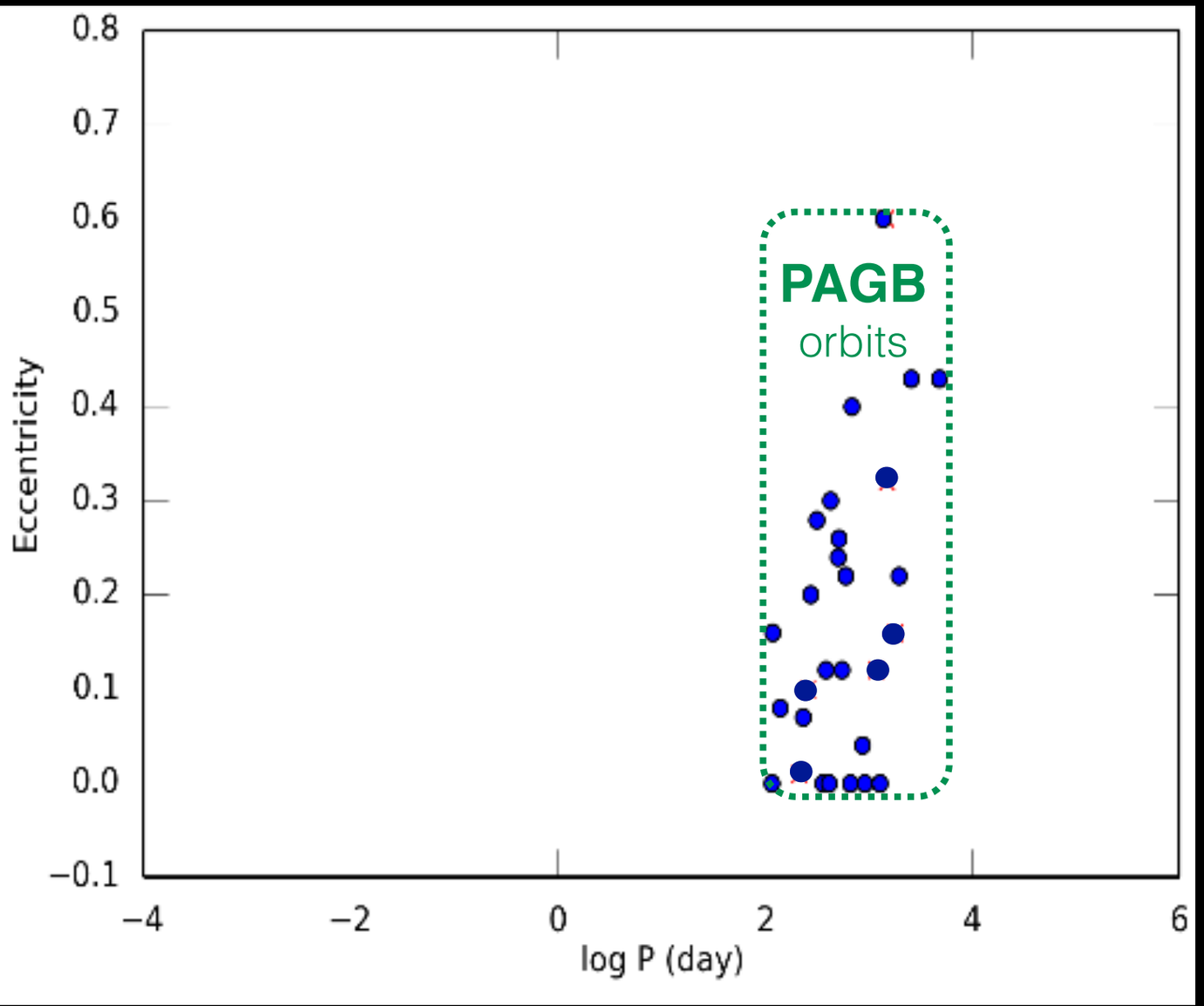


3 epochs in P97
Spread in data = 61 days
Amplitude shift in RV ~ 6km/s

PERIOD DISTRIBUTION OF BINARY RED GIANTS

Predictions Vs Observations



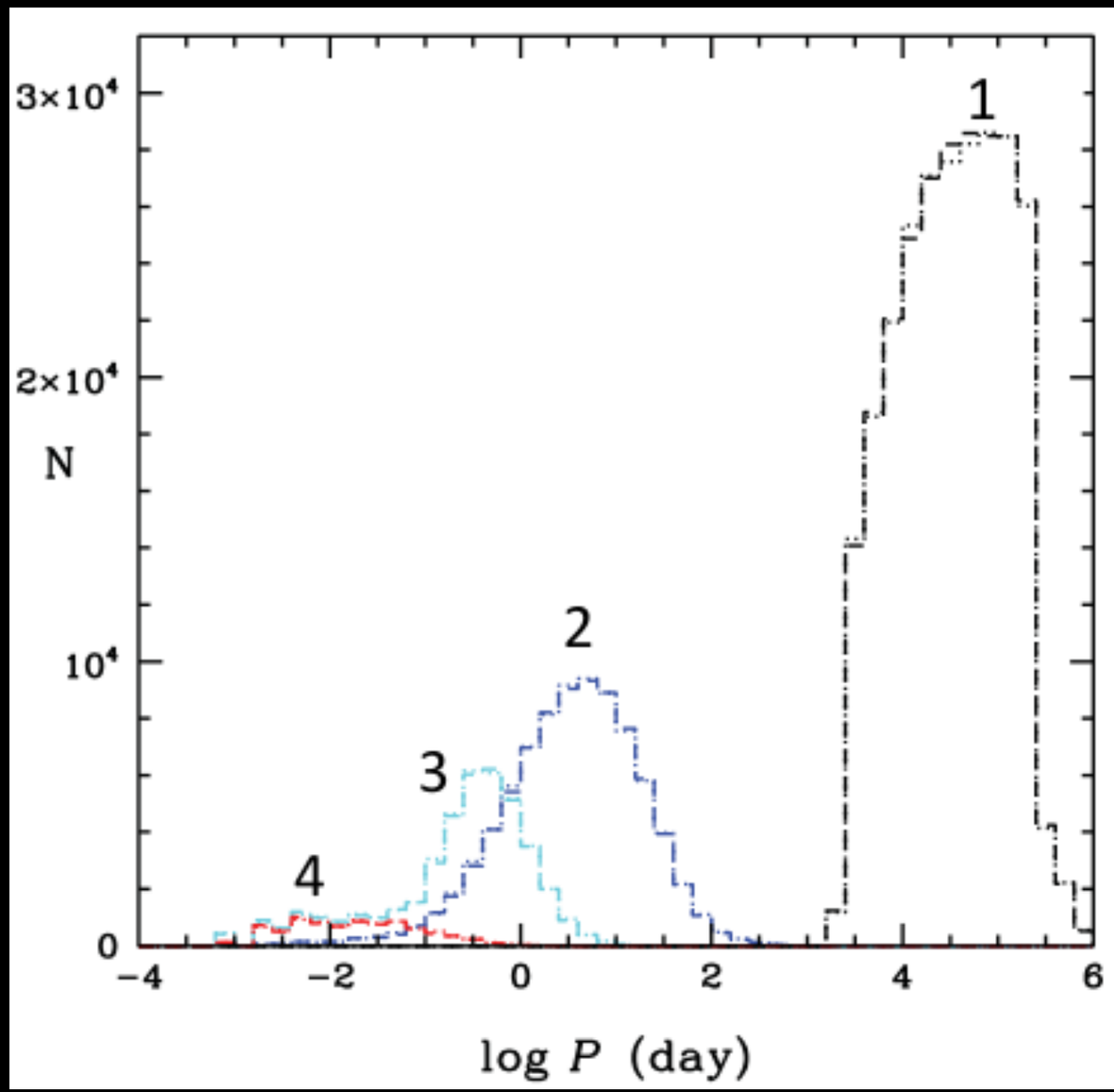


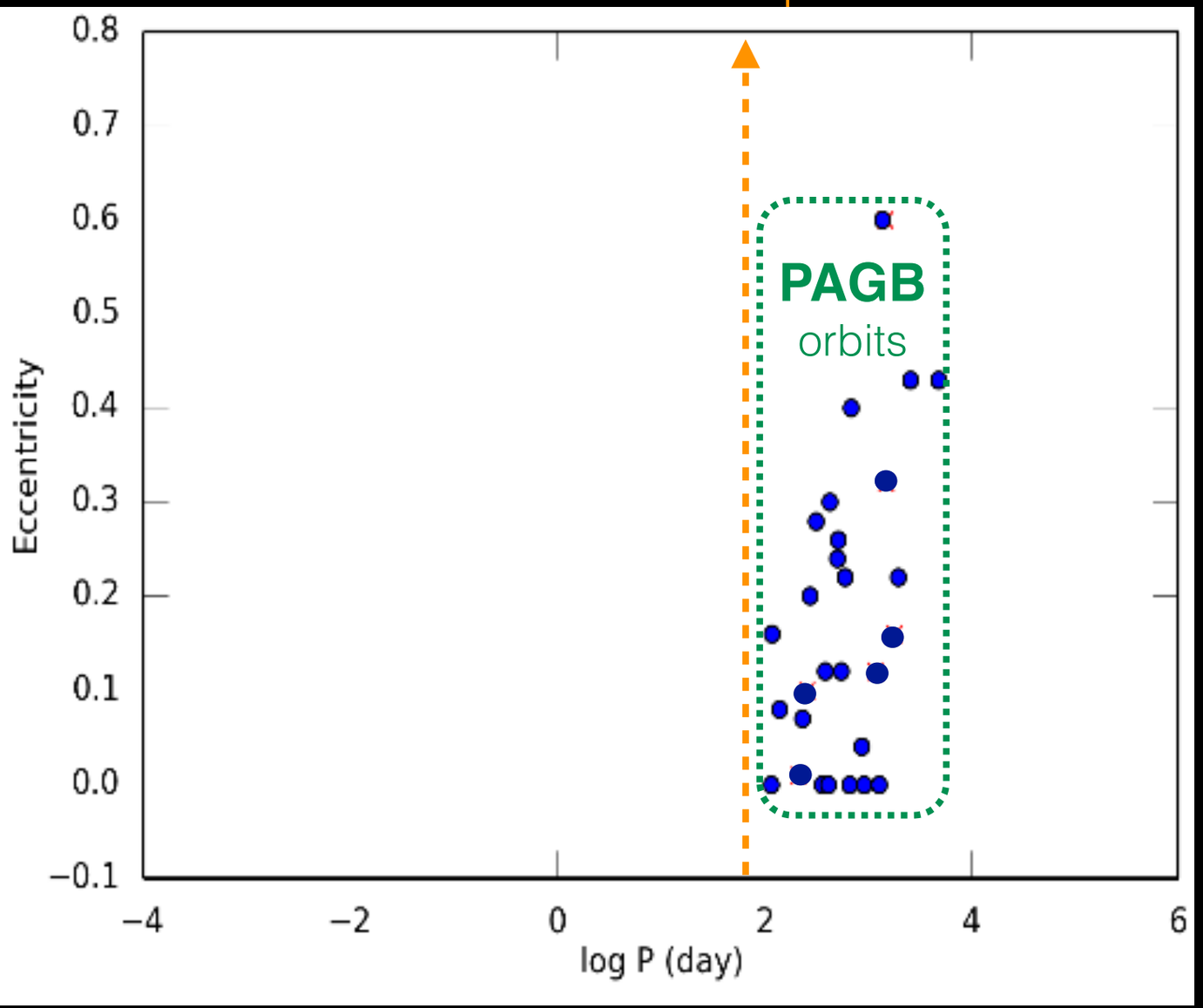
1. The distribution of intermediate period binary post-AGB
2. The close binary post-AGB
3. The post-RGB and post-EAGB binaries in cyan/grey
4. The double degenerate secondaries

PERIOD DISTRIBUTION OF BINARY RED GIANTS

Predictions Vs Observations

SMC/LMC PRGBs:
Orbital period minimum



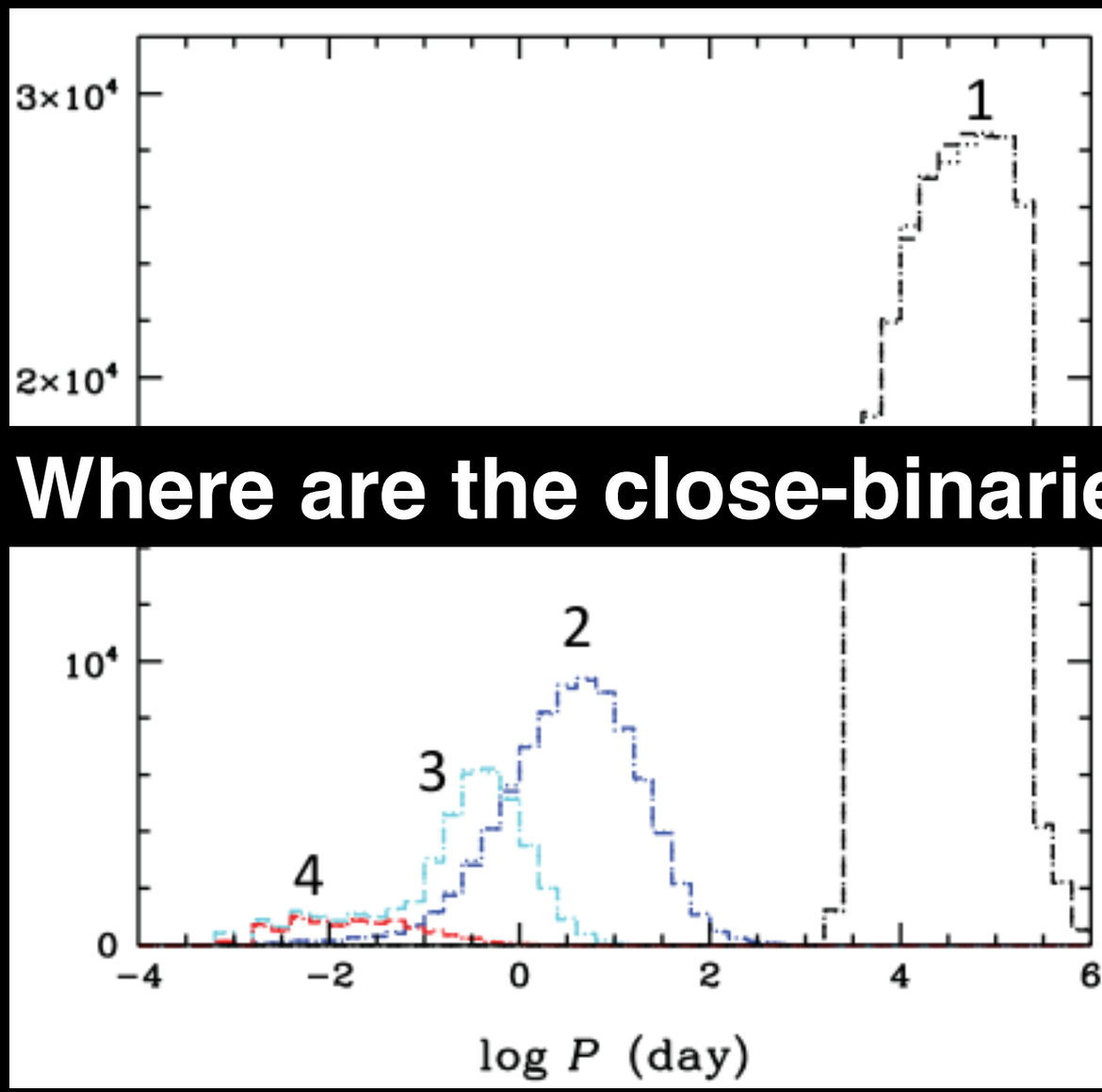


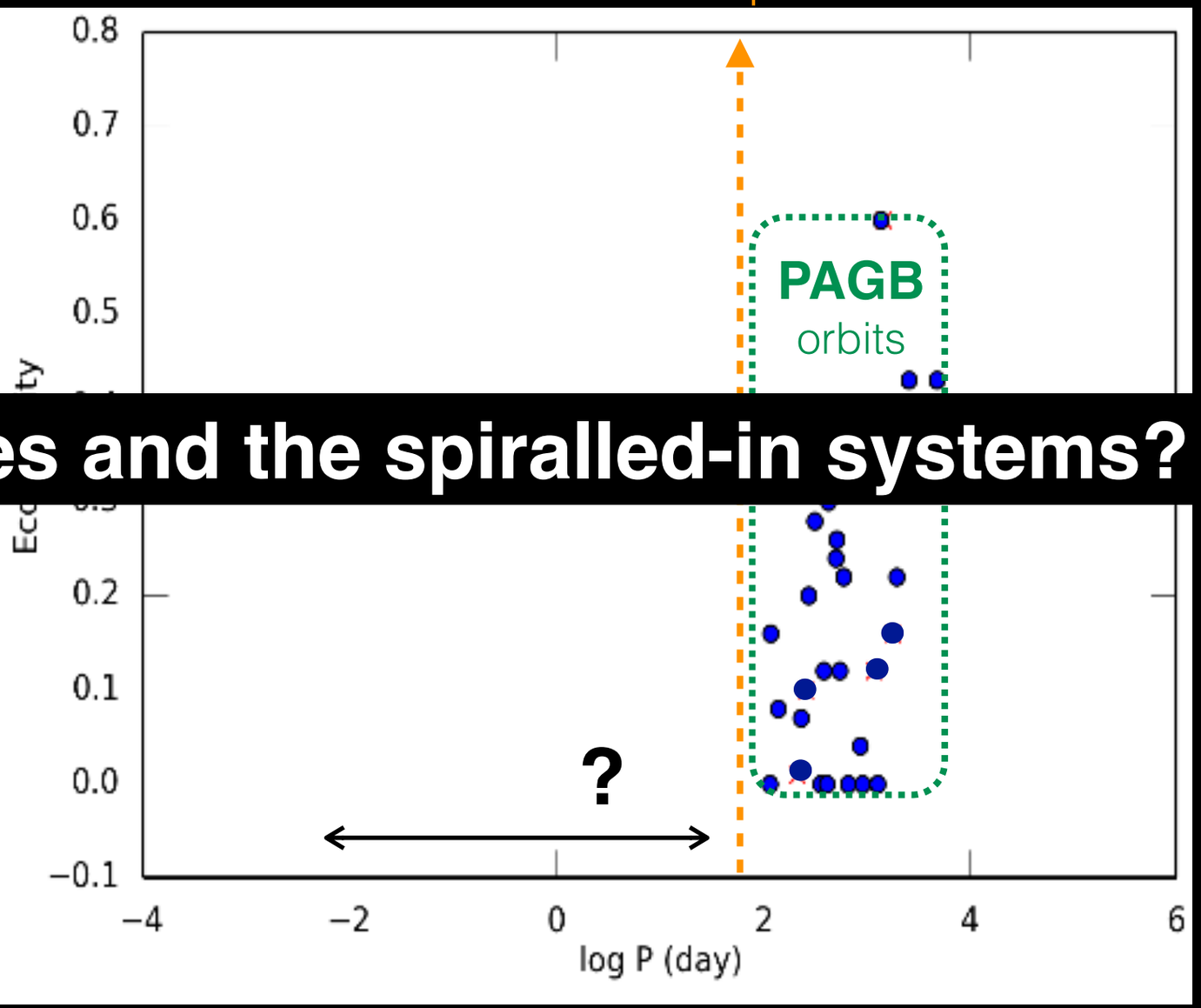
1. The distribution of intermediate period binary post-AGB
2. The close binary post-AGB
3. The post-RGB and post-EAGB binaries in cyan/grey
4. The double degenerate secondaries

PERIOD DISTRIBUTION OF BINARY RED GIANTS

Predictions Vs Observations

Sample of SMC/LMC PRGBs:
Orbital period minimum





Where are the close-binaries and the spiralled-in systems?

1. The distribution of intermediate period binary post-AGB
2. The close binary post-AGB
3. The post-RGB and post-EAGB binaries in cyan/grey
4. The double degenerate secondaries

Possible Progeny

Low luminosity pre-planetary nebulae, where the companion has merged into the primary component.

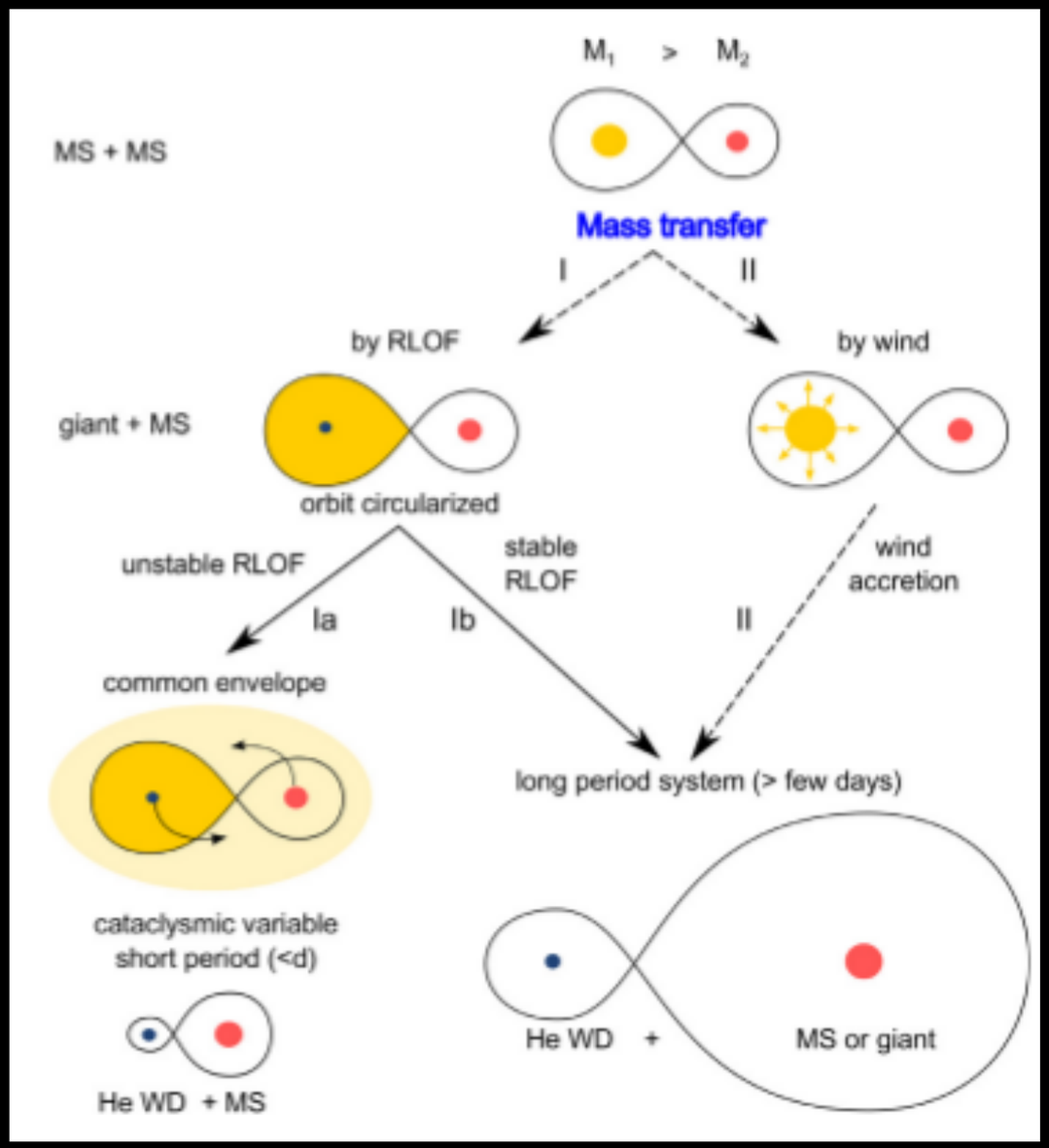
Boomerang Nebula
Sahai et al., 2017

<u>CONCERNS with PNe:</u>

- Disk evolution
- Disk lifetimes
- Accretion rates

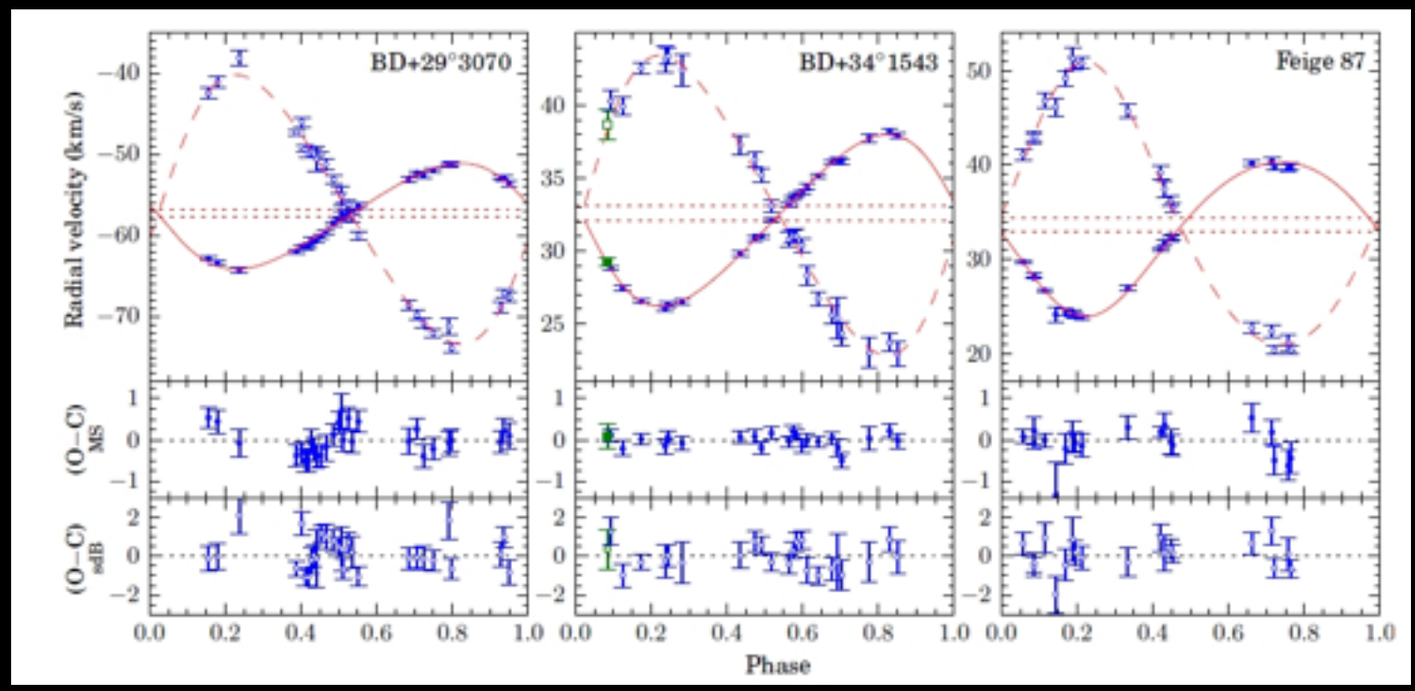
Possible Progeny

Binary He WDs/ Cataclysmic Variables



Merle. T et al., 2014

Sub-dwarf B stars



Vos et al., 2012, 2013, 2014

GALACTIC POST-RGBs

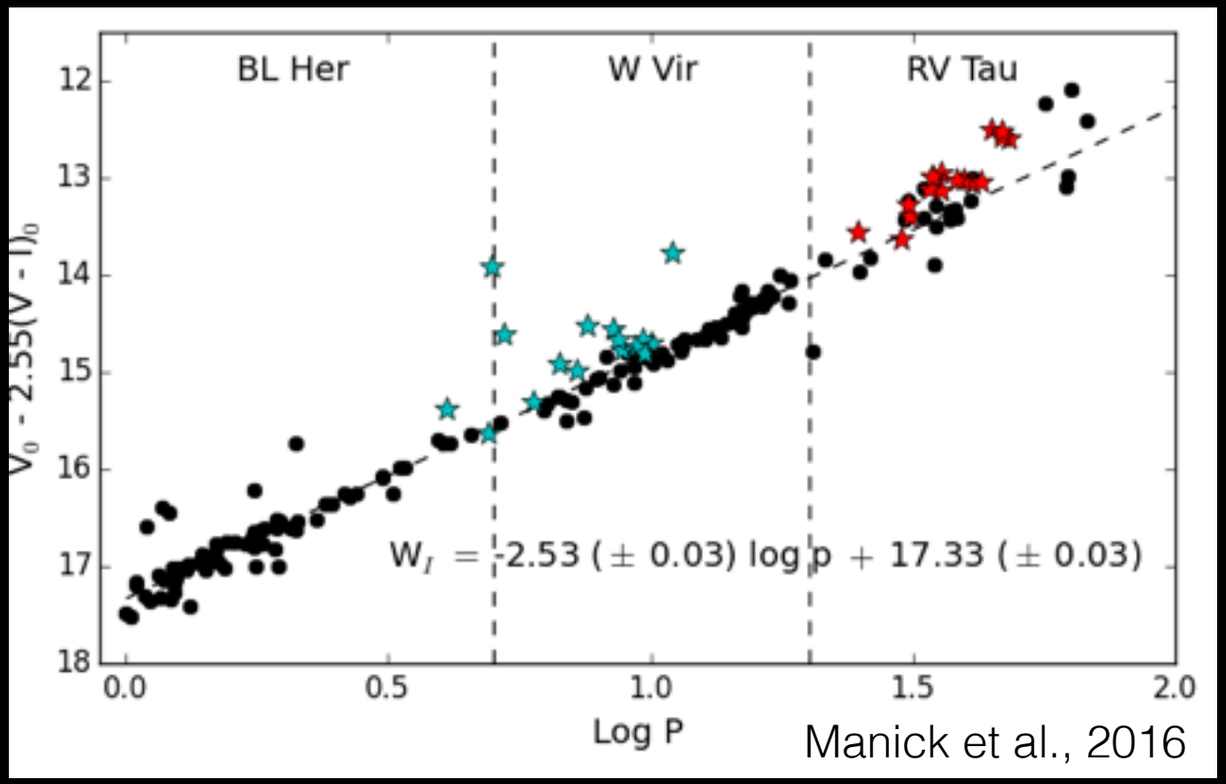
1. Post-RGBs amongst Post-AGBs

Luminosities from GAIA!

Distance determination for these Galactic post-RGB objects will be difficult because of proper motion caused by binary motion will affect accurate parallax determinations.

2. Dusty Population II Cepheids

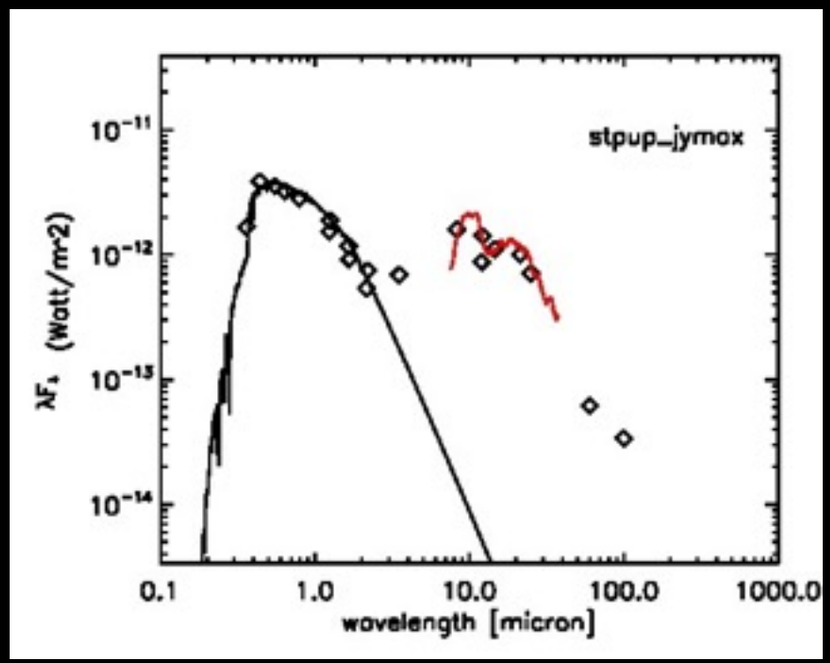
Period-Luminosity-Colour relations in the LMC re-calibrated to the Galaxy.

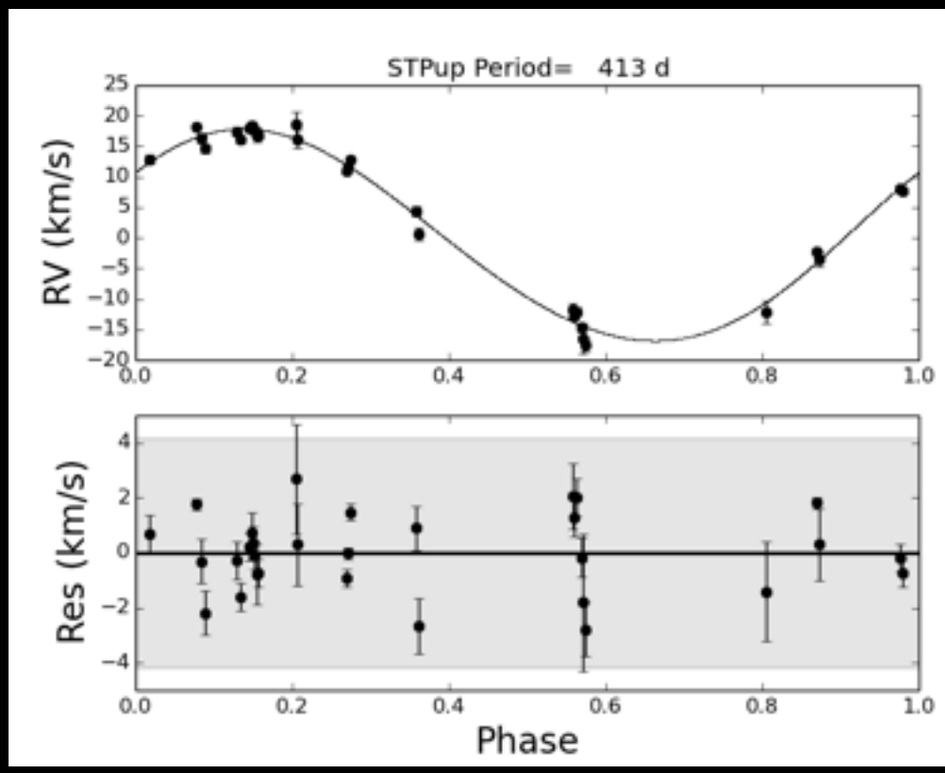


Manick et al., 2016

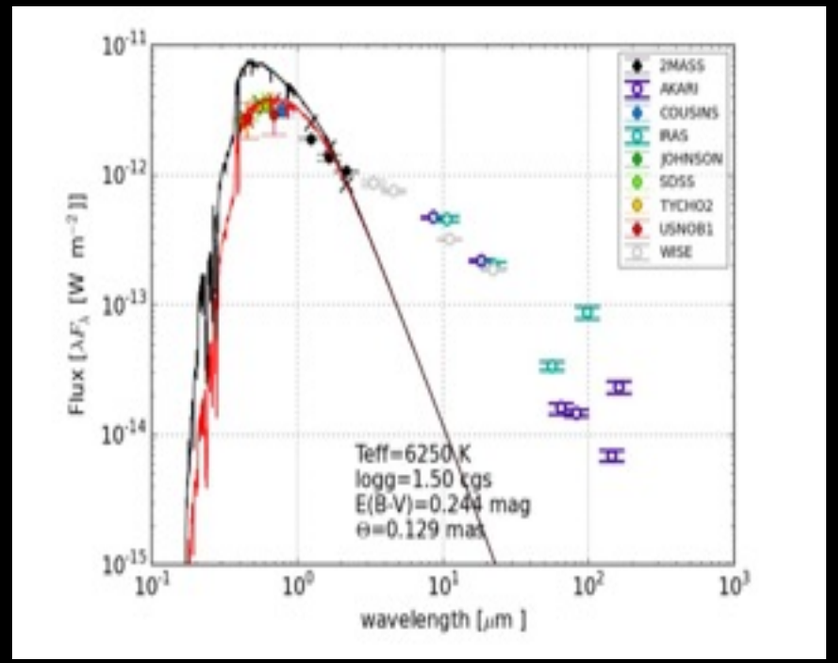
POSSIBLE GALACTIC POST-RGB

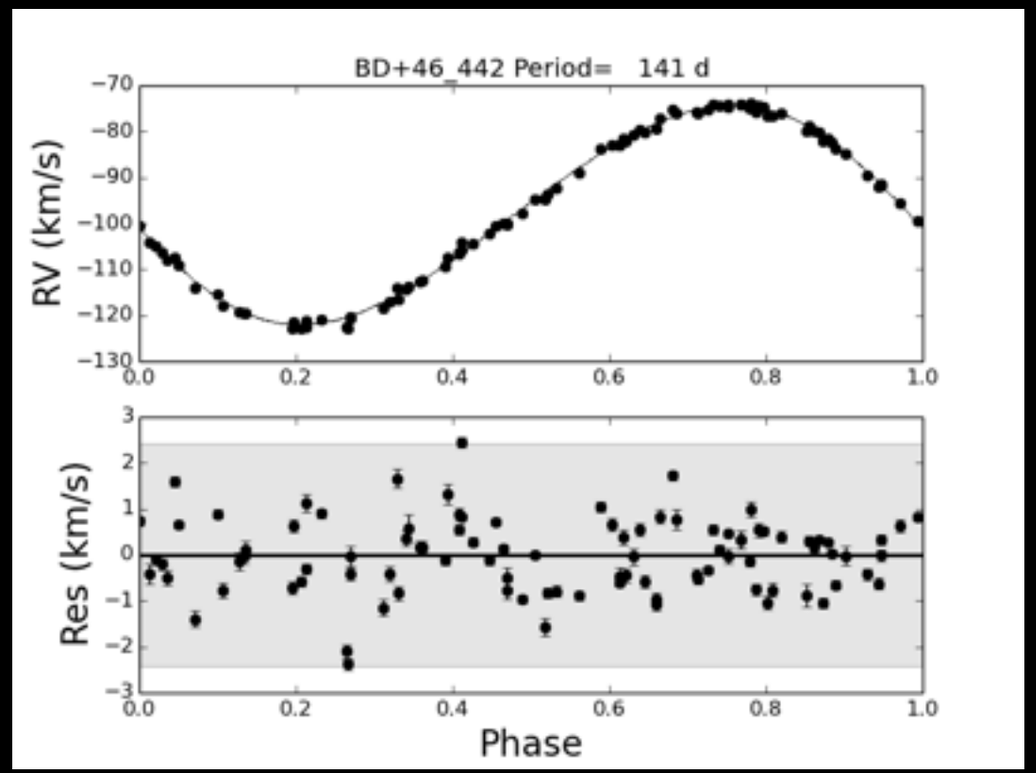
ST Pup





BD +46422





CONCLUDING REMARKS

1. Not all stars evolve through the core-He burning phase!

2. A likely binary interaction on the RGB terminates the RGB evolution for some red giant binaries producing “dusty post-RGB stars”

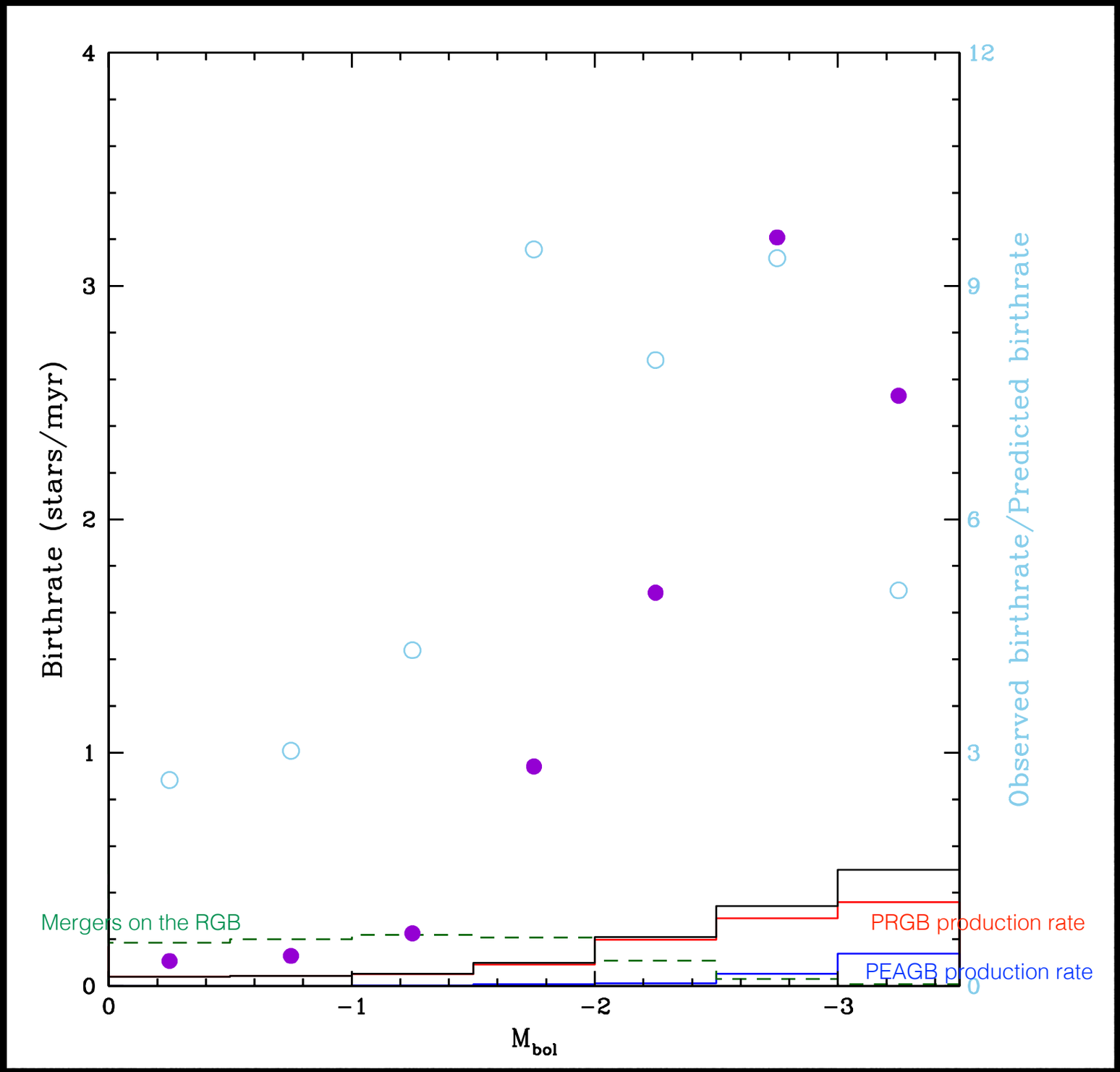
3. Observationally (based on a very small sample) these systems have orbital periods > 100 days

4. The disc is an important ingredient to explain the new dusty post-RGB systems!

5. Can our systems form Planetary Nebulae?

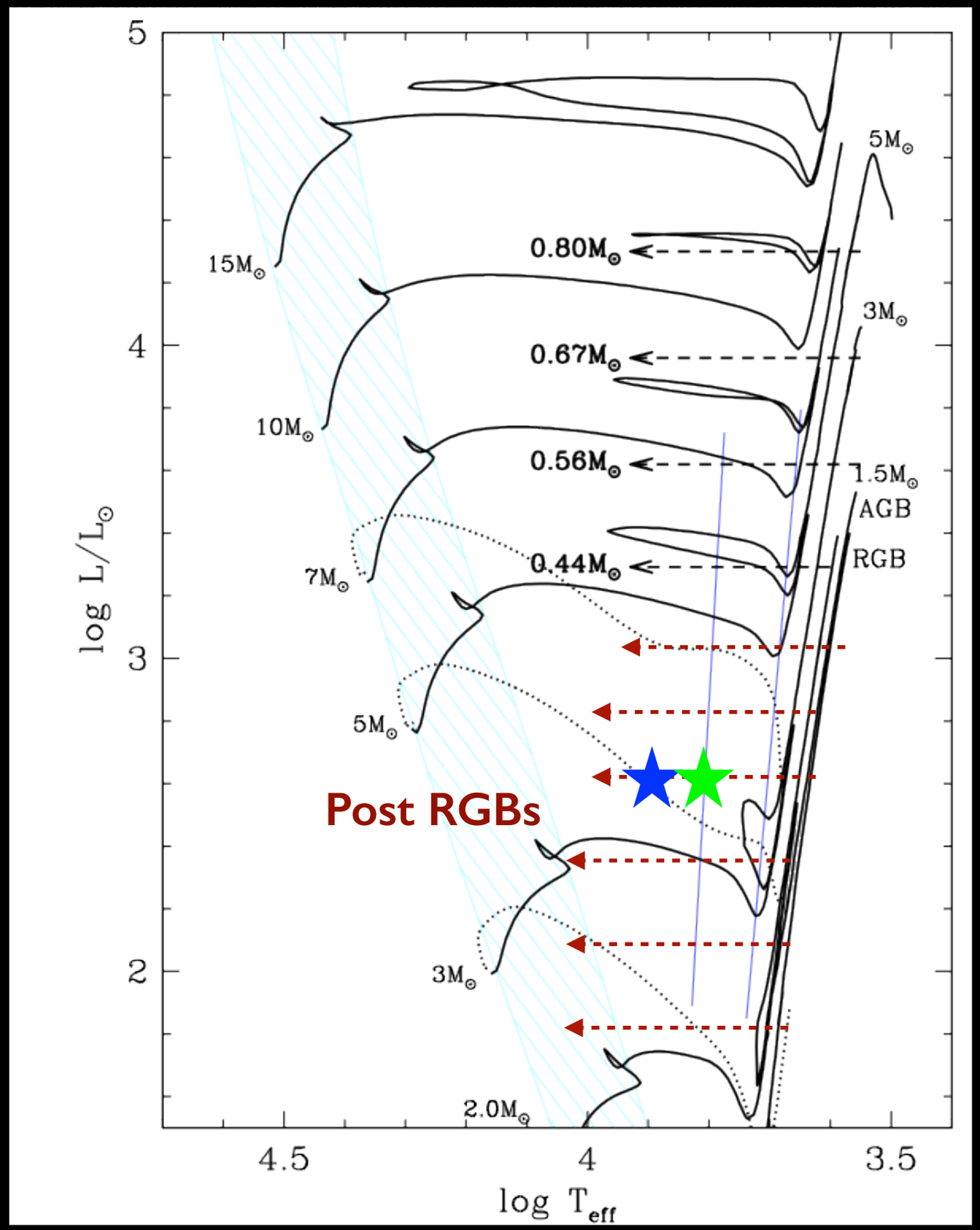
PRECURORS: SEQUENCE-E STARS

Kamath et al., 2016

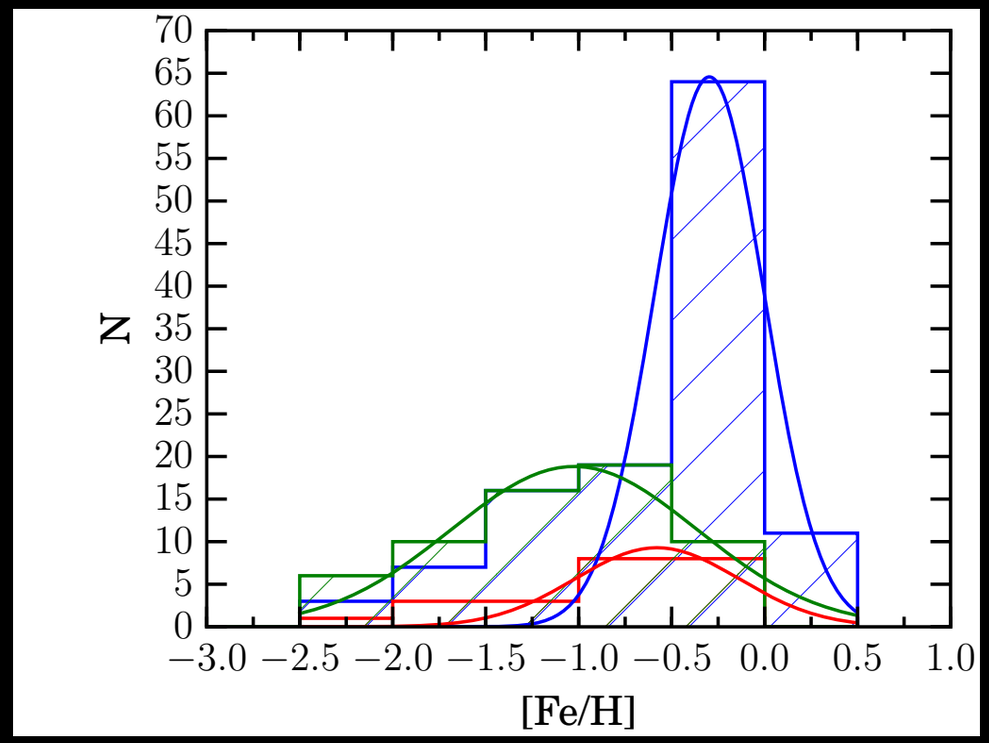


- Sequence E stars - based on birthrate estimates
- Likely to be stars with an initial mass $<1.85\ M_{\odot}$

INTERLOPING OBJECTS IN OTHER EVOLUTIONARY PHASES…



Pre-Main sequence stars
Core-He Burning stars
E-AGB stars



Post-RGB stars (old) have [Fe/H] peaking at about -1.0 dex
Post-AGB stars (old) have [Fe/H] peaking at about -0.7 dex
PMS are a younger population peaking at >-0.5 dex

Photospheric Chemistry of Post-AGB stars

Post-AGB binaries show ‘photospheric depletion’

Photospheric Depletion: Feedback from disc => Loss of nucleosynthetic history