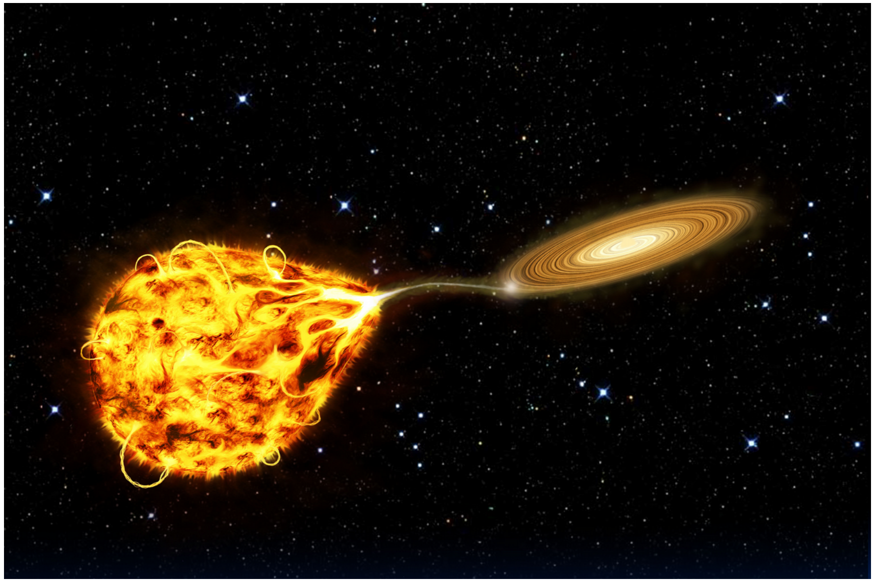
Using wide hot subdwarf binaries to constrain binary interaction mechanisms



Astronomical Institute SAV, Tatranská Lomnica
24-04-2019

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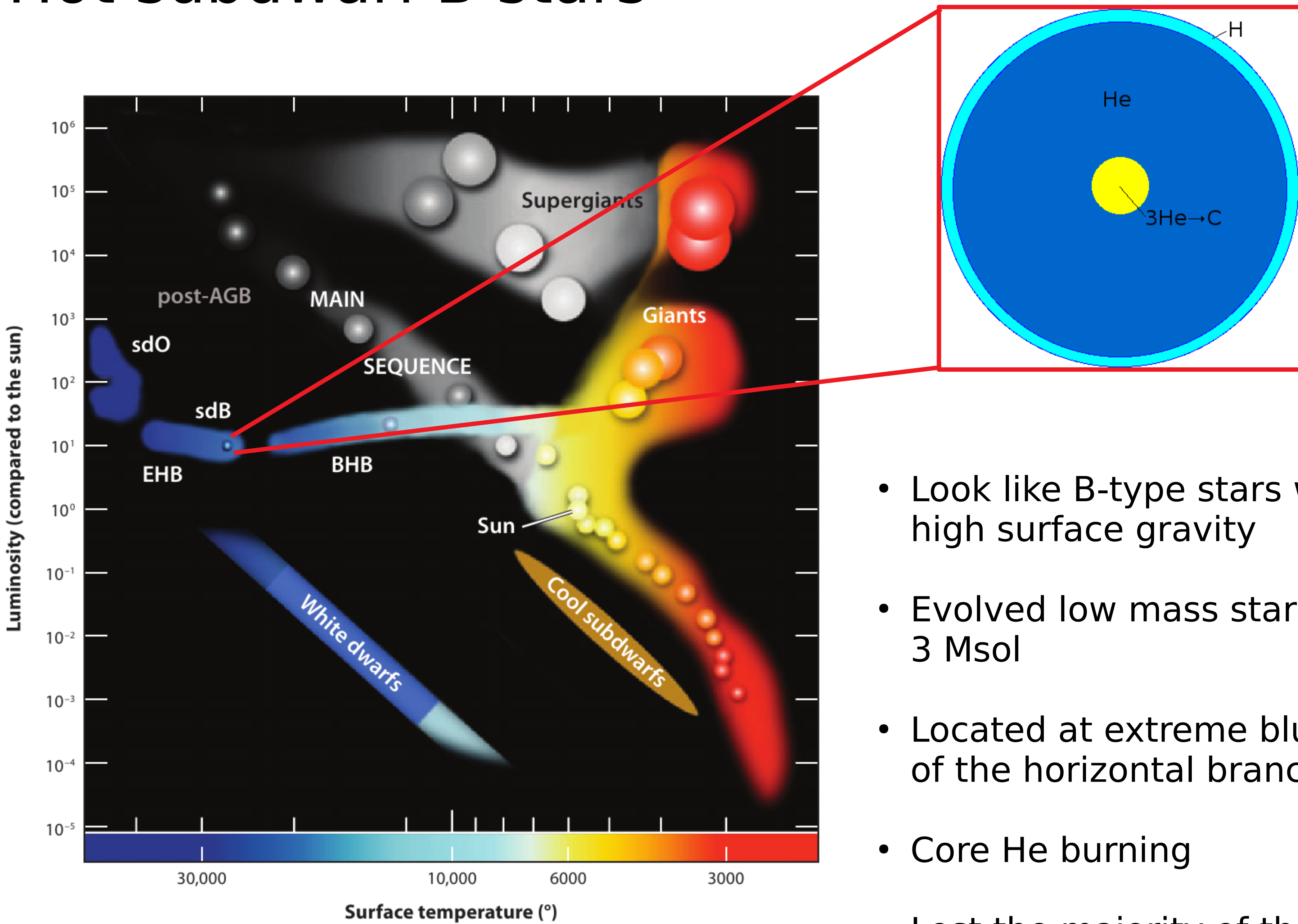
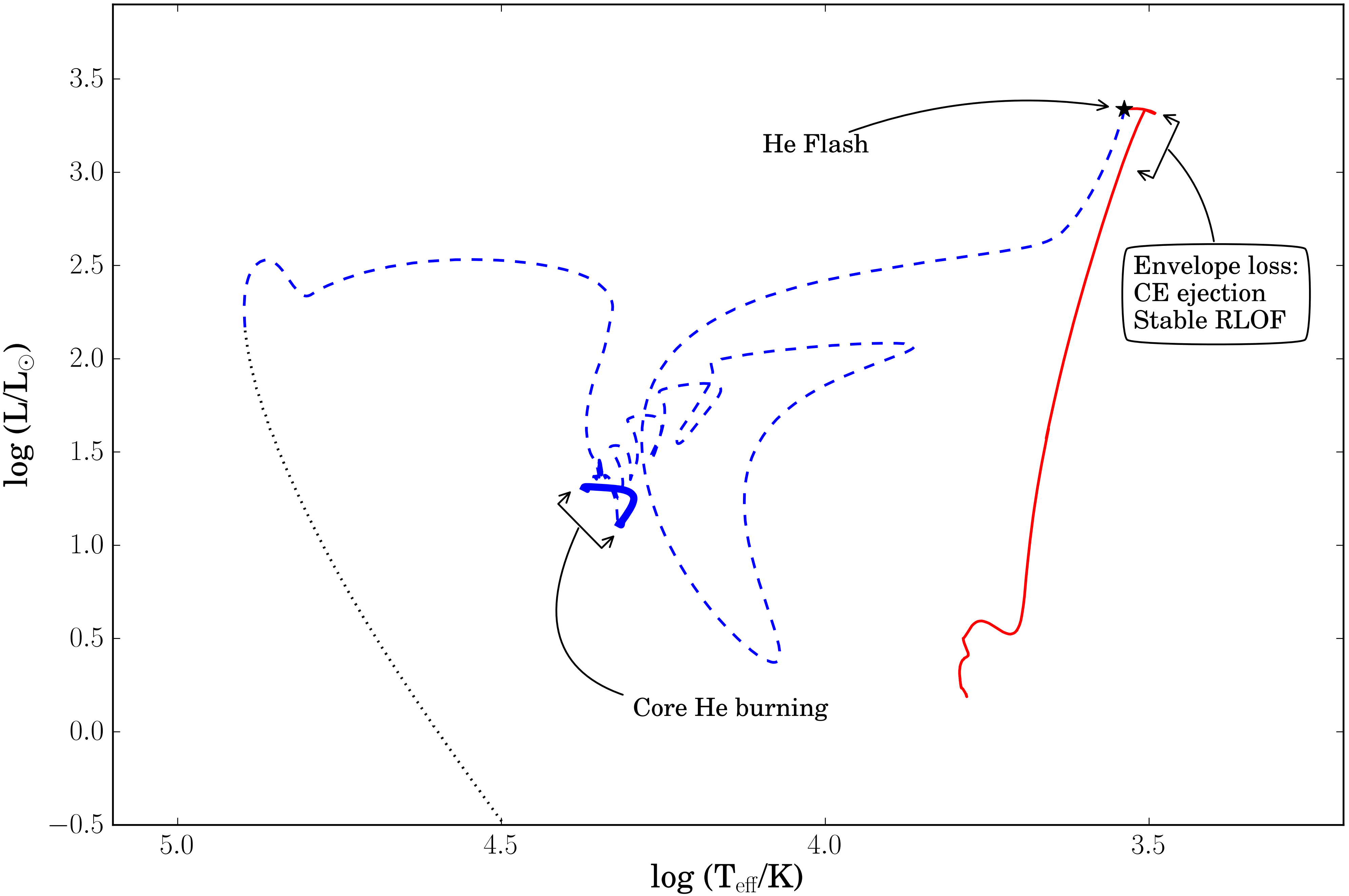
Hot subdwarf-B stars

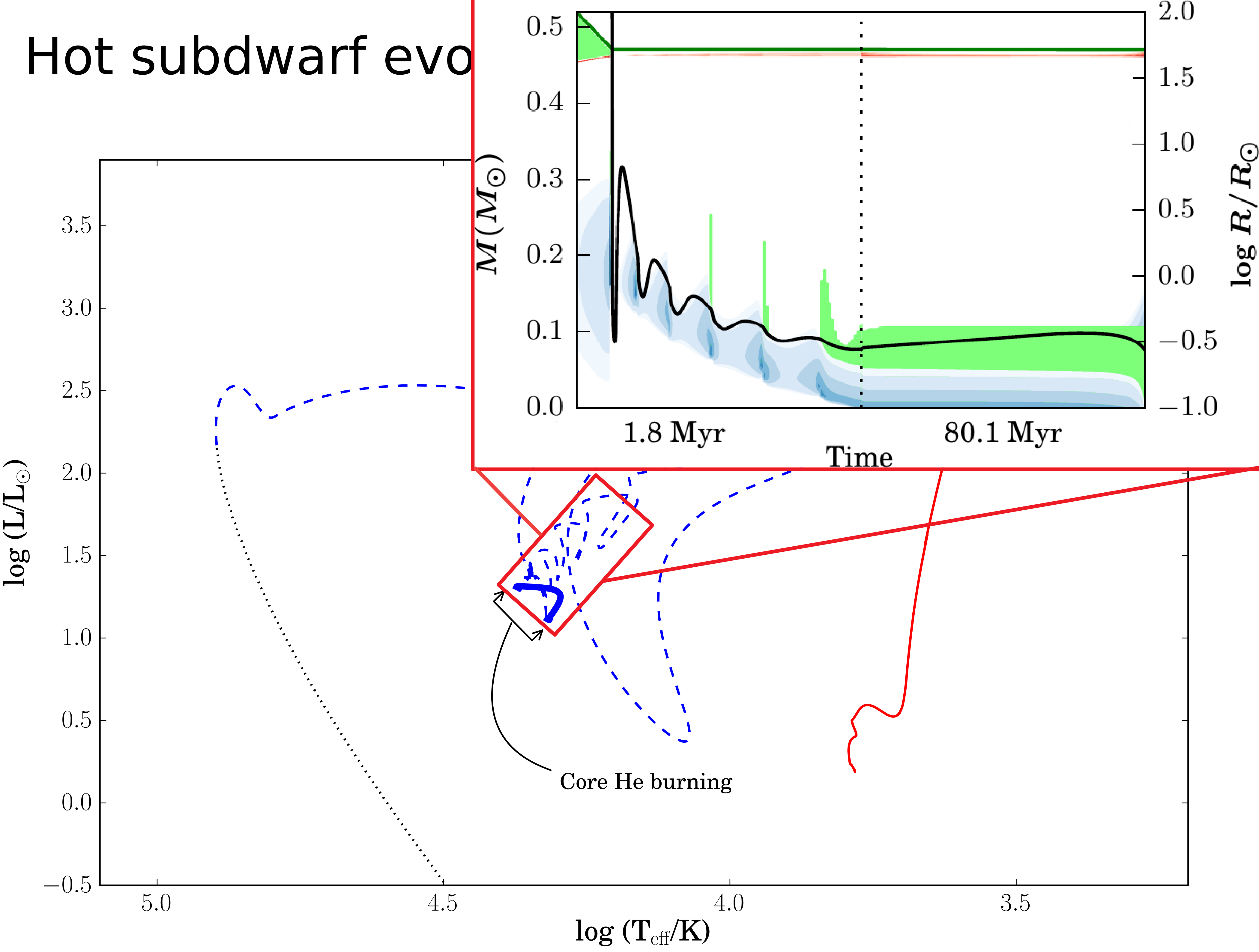


- Look like B-type stars with high surface gravity
- Evolved low mass stars, 1 – 3 Msol
- Located at extreme blue end of the horizontal branch
- Core He burning
- Lost the majority of their H envelope on the RGB

Hot subdwarf evolution

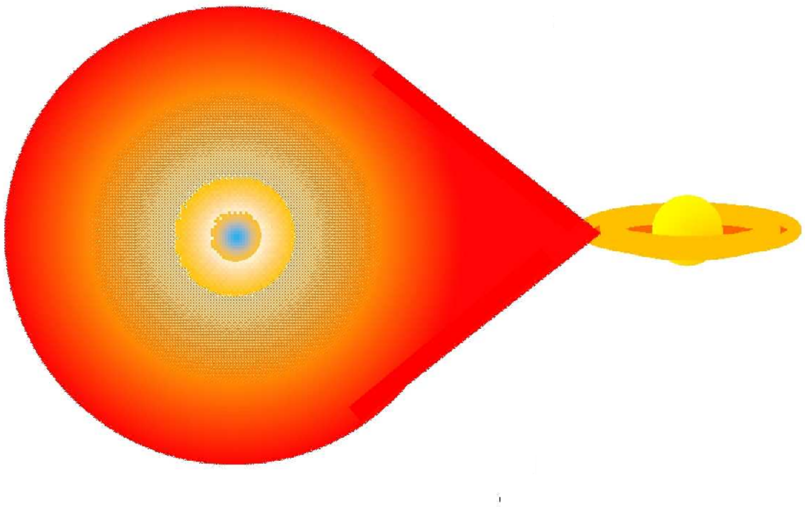


Hot subdwarf evo



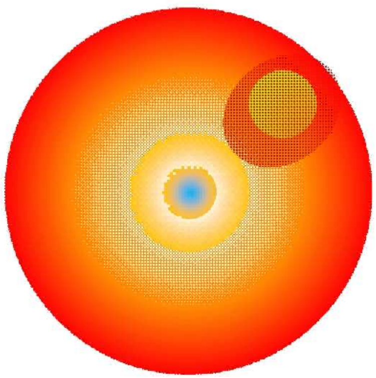
Hot subdwarf formation

stable-RLOF



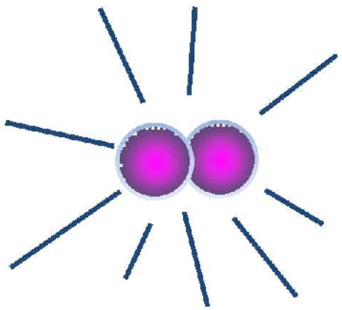
- long periods (> 2 year)
- sdB + MS

CE-ejection



- short periods (< 30 d)
- sdB + MS
- sdB + WD/BD

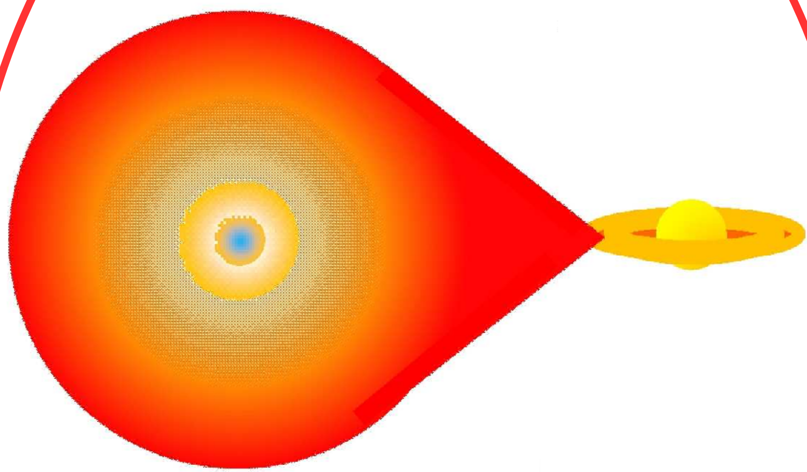
WD merger



- single sdBs

Hot subdwarf formation

stable-RLOF



- long periods (> 2 year)
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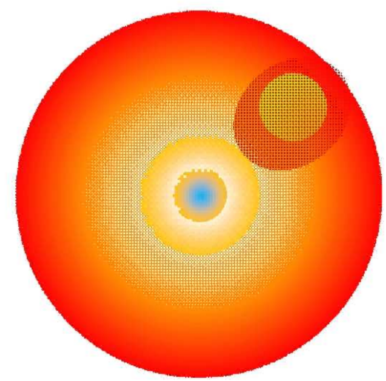
CE-ejection



- short periods (< 30 d)
- sdB + MS
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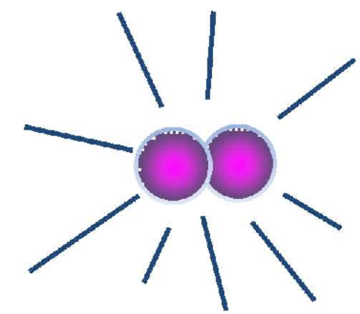
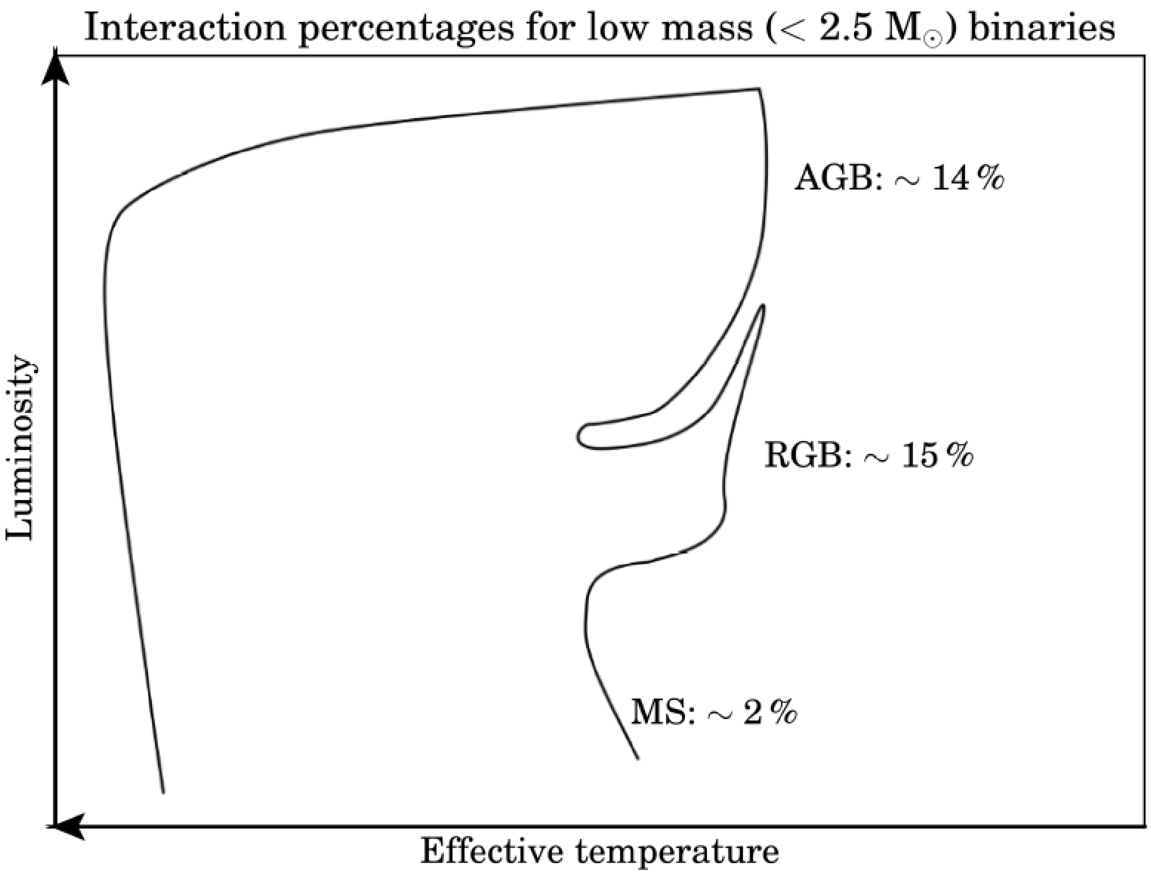
WD merger



- single sdBs

Benefits for theory: double lined, only formed in binaries, from a single population (M=0.45 +- 0.07)

Binary interaction



Roughly 1/3 of low mass binaries will at some point interact:
Supernova Ia, blue stragglers, sdBs, algols, CVs, ...

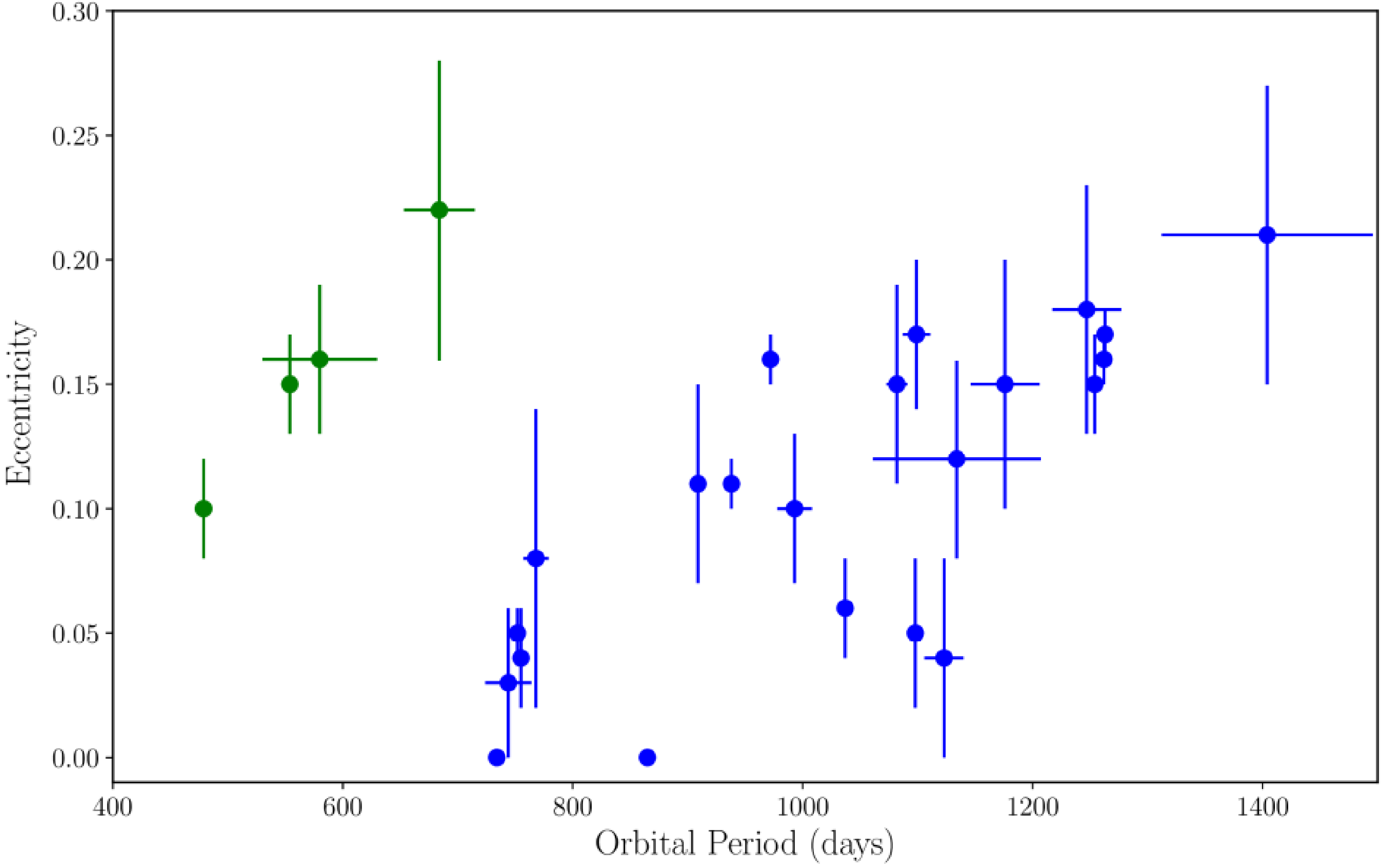
Issues:

- Postulated increase in mass-loss before contact
- Precise description of common envelope
- Accretion efficiency onto the companion
- Mass-loss fractions during RLOF
- Formation/existence of circumbinary disk
- Interaction between disk and binary
- ...

Observing Campaign

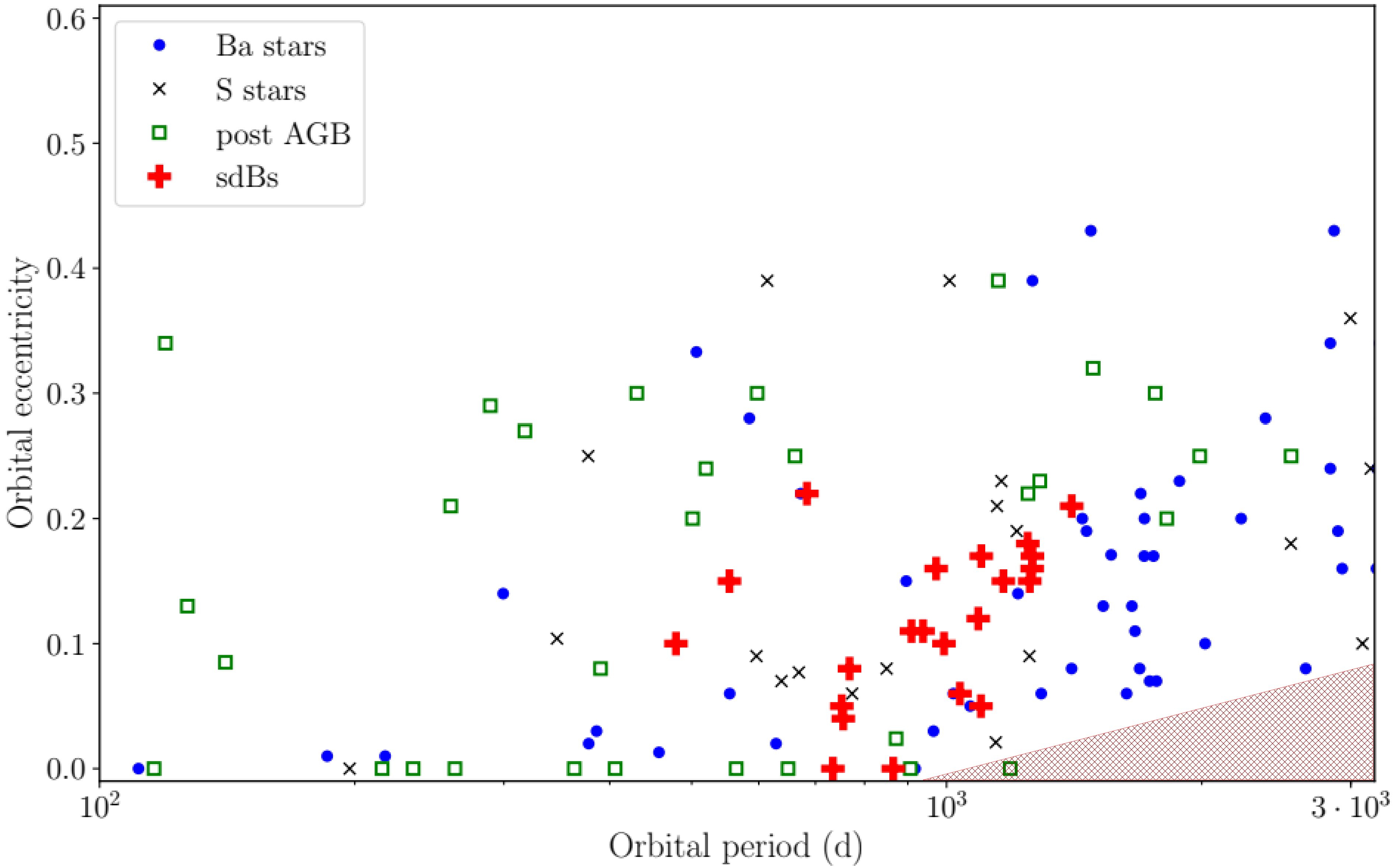
2009 - Now

1) Period – Eccentricity

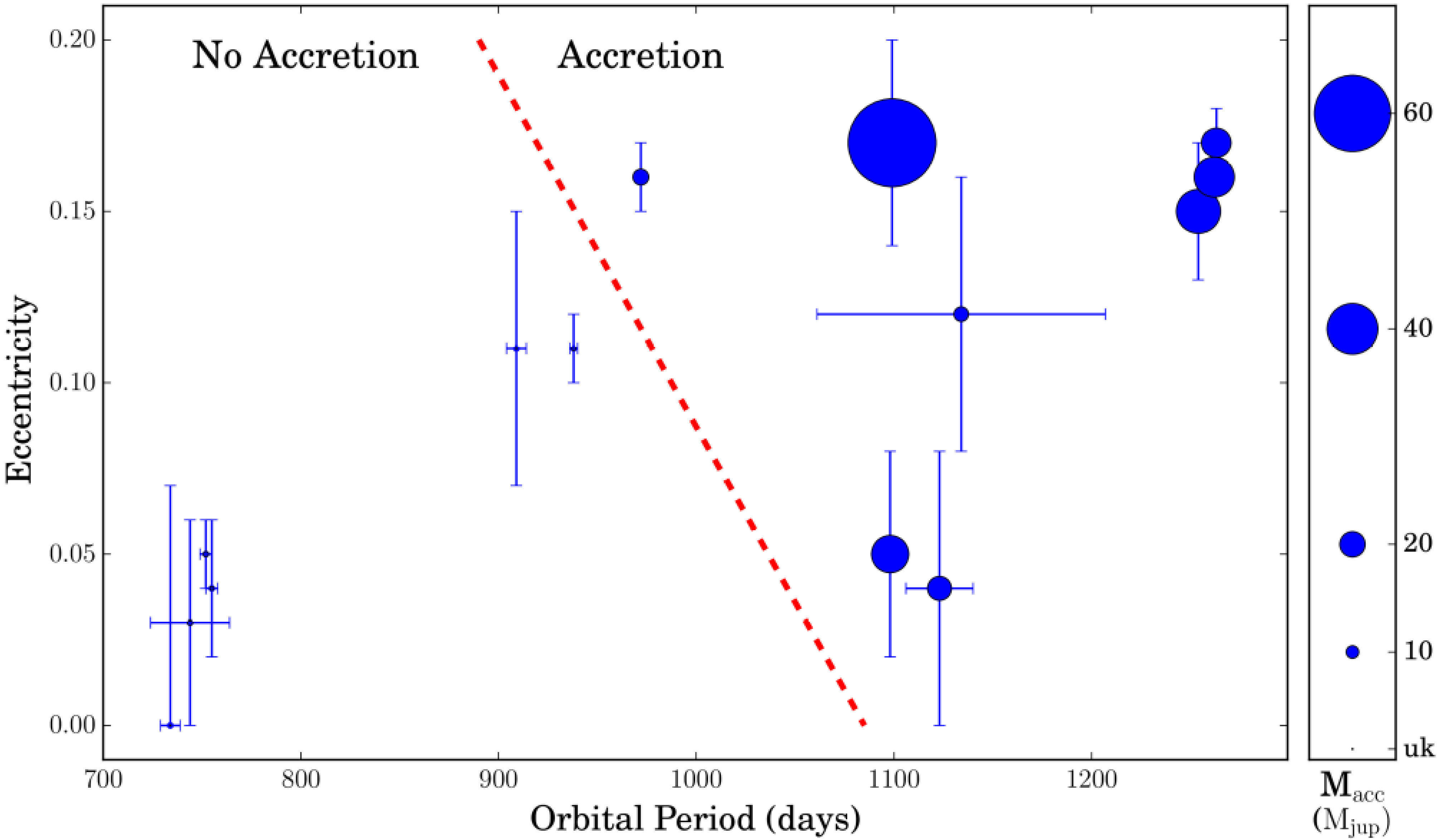


- Could be 2 distinct groups
- Main group with orbital periods around 2 – 4 years
- Theory predicts circular systems
- Almost all systems have significantly eccentric orbits

Period – eccentricity comparison

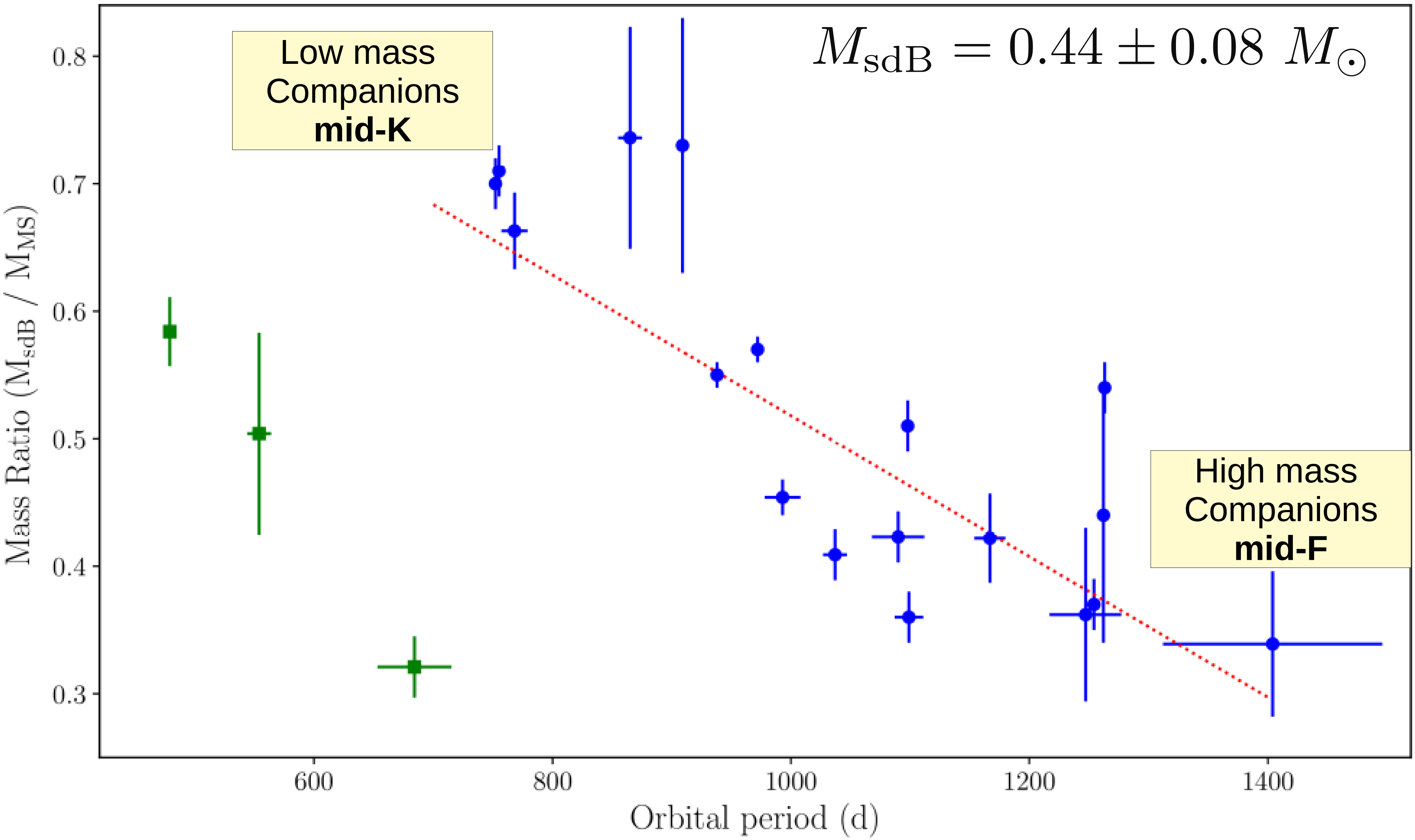


2) Period – Accreted mass



Accreted Mass: 0.001 → 0.05 $M_\odot$ ➡ **~1 $M_\odot$ lost from the system**

3) Period – Mass ratio



Binary interaction models

MESA

VERSION 1

Period - Eccentricity

- Cover observed period range
- Explain observed eccentricity
- Little predictive power

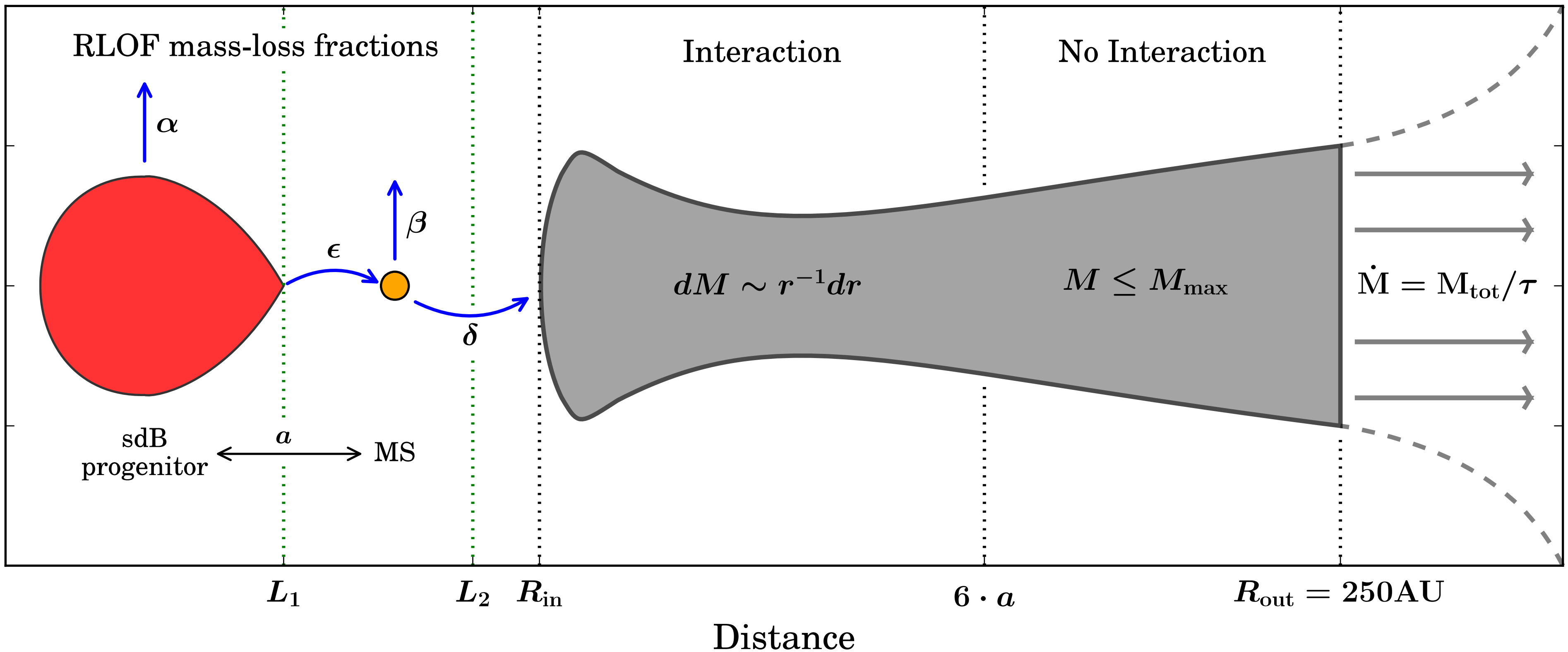
VERSION 2

Period – Mass ratio

- Improved RLOF model
- Stability
- Period-mass ratio relation

Paxton et al. 2011, 2013, 2015, 2019

VERSION 1: mass loss



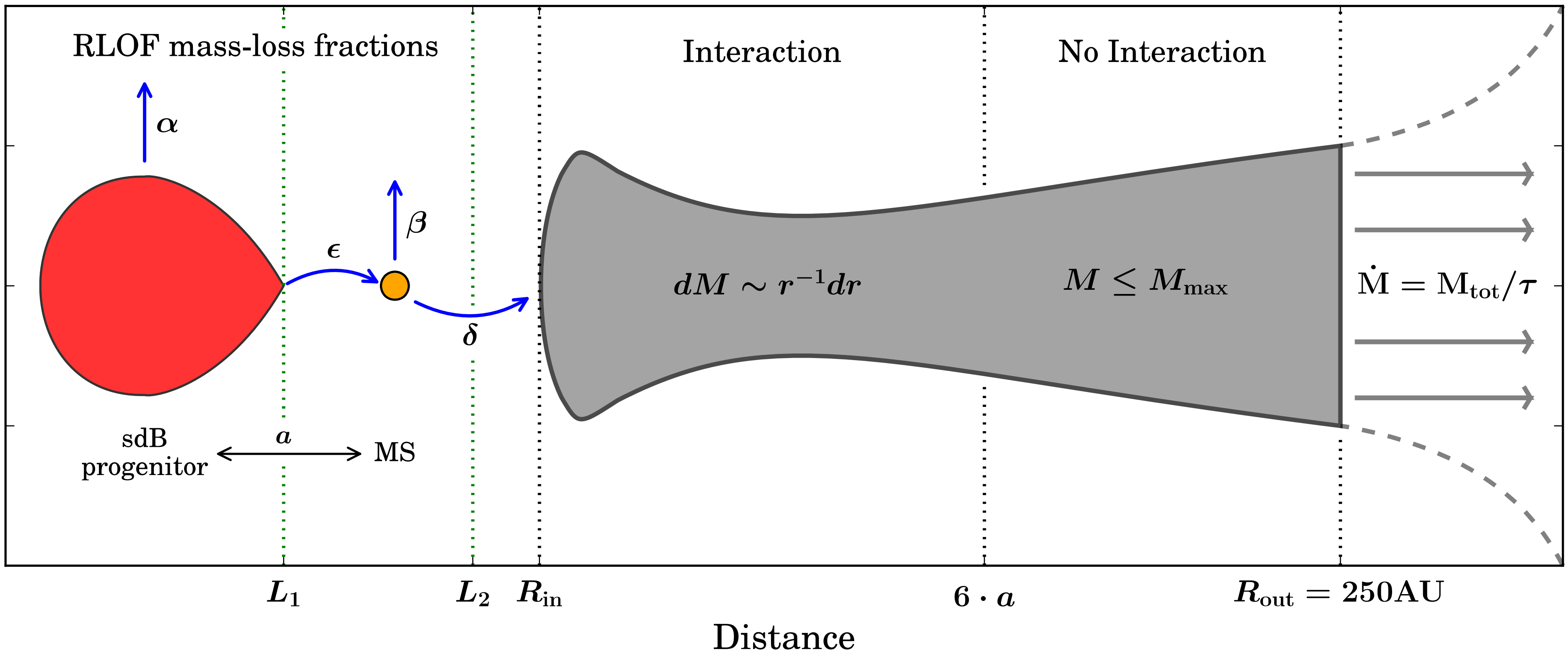
Mass transfer / loss fractions:

- α : Jeans Mode
- β : Isotropic re-emission → **Orbital period**
- δ : Circumbinary toroid

- ε : Accreted mass → **Companion rotation, composition**

Phase dependent mass-loss → **Eccentricity**

VERSION 1: Circumbinary disks



Circumbinary disk

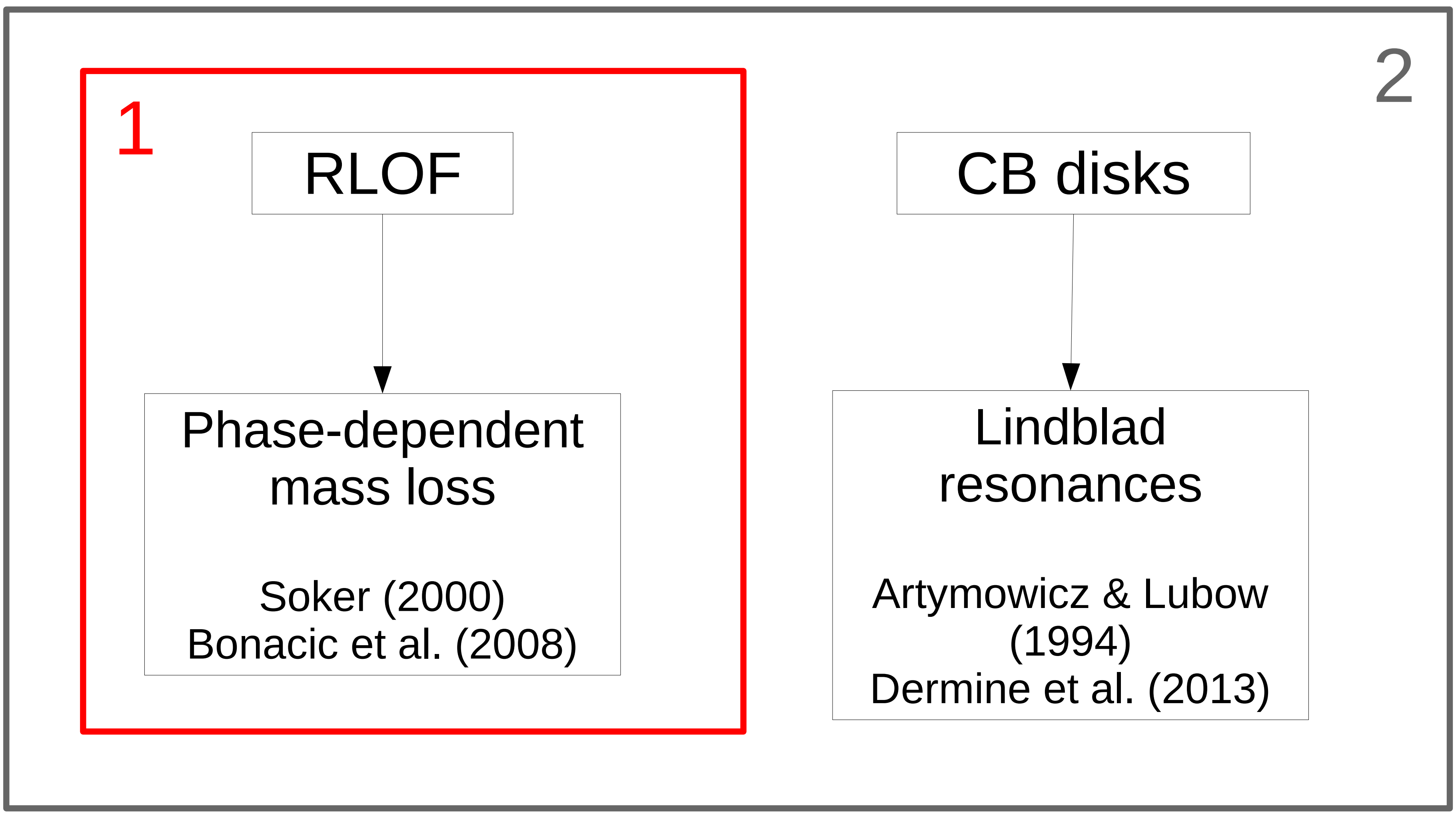
- Total Mass
- Life time
- Mass distribution

→ **orbital eccentricity / period**

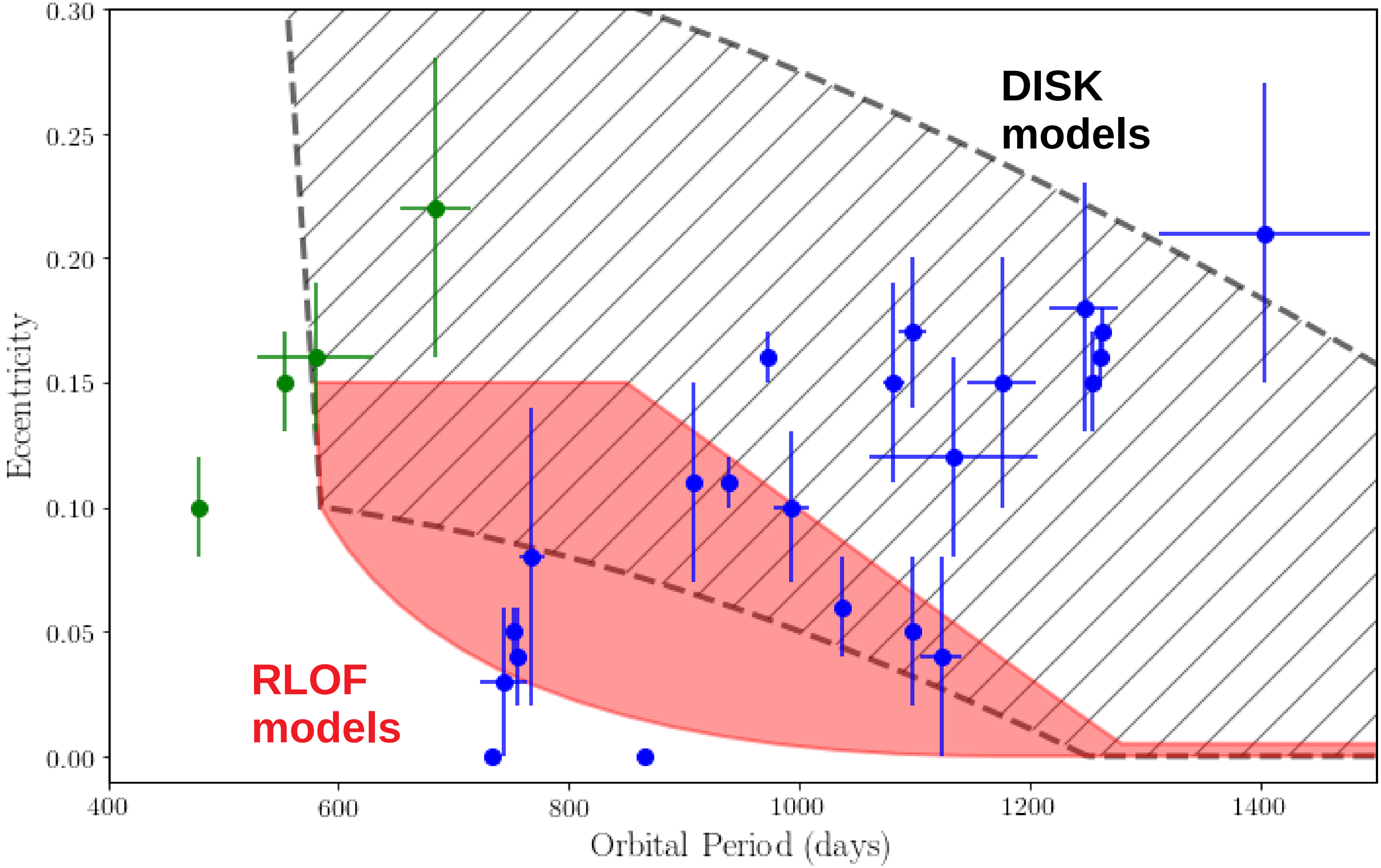
MESA : Eccentricity pumping

1) Only models with phase dependent RLOF

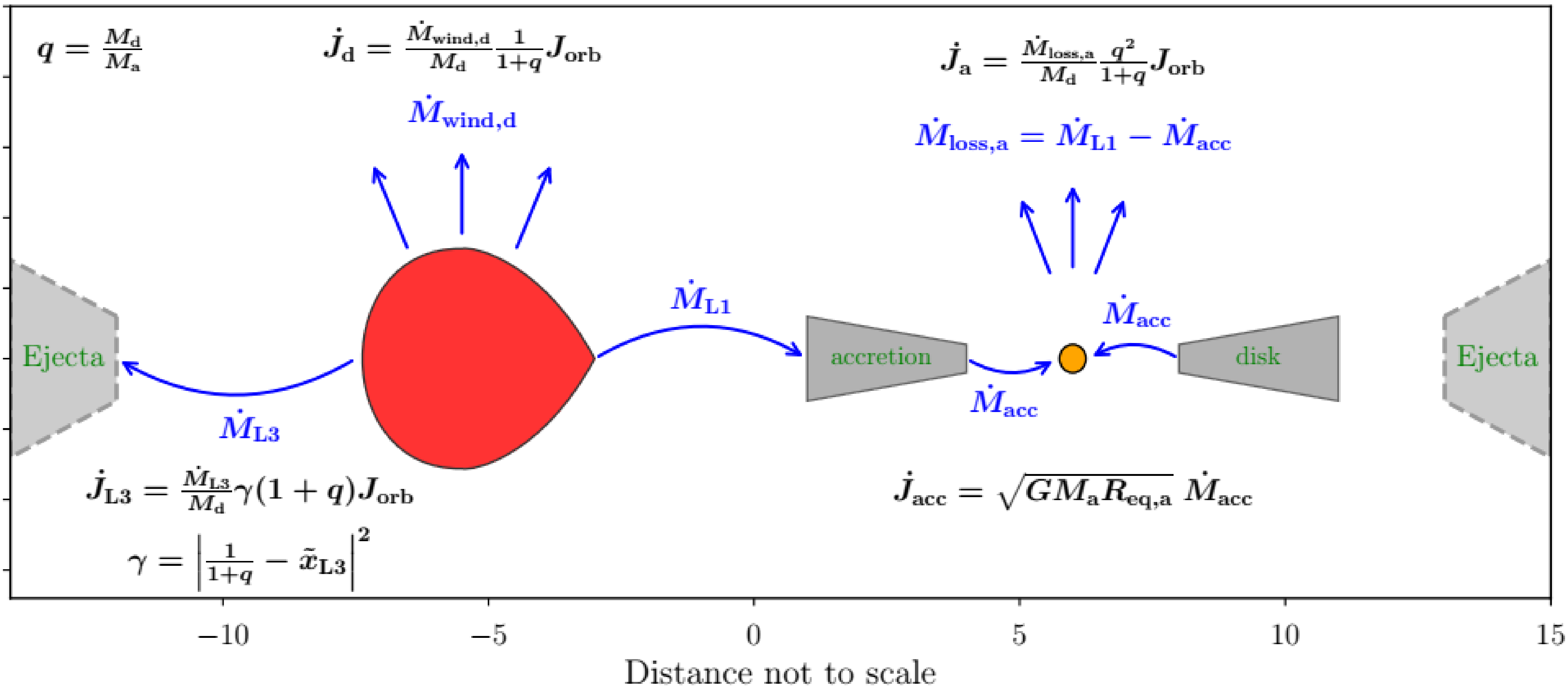
2) Models with phase dependent RLOF and a CB disk



Period – Eccentricity: Models



VERSION 2: Improved RLOF



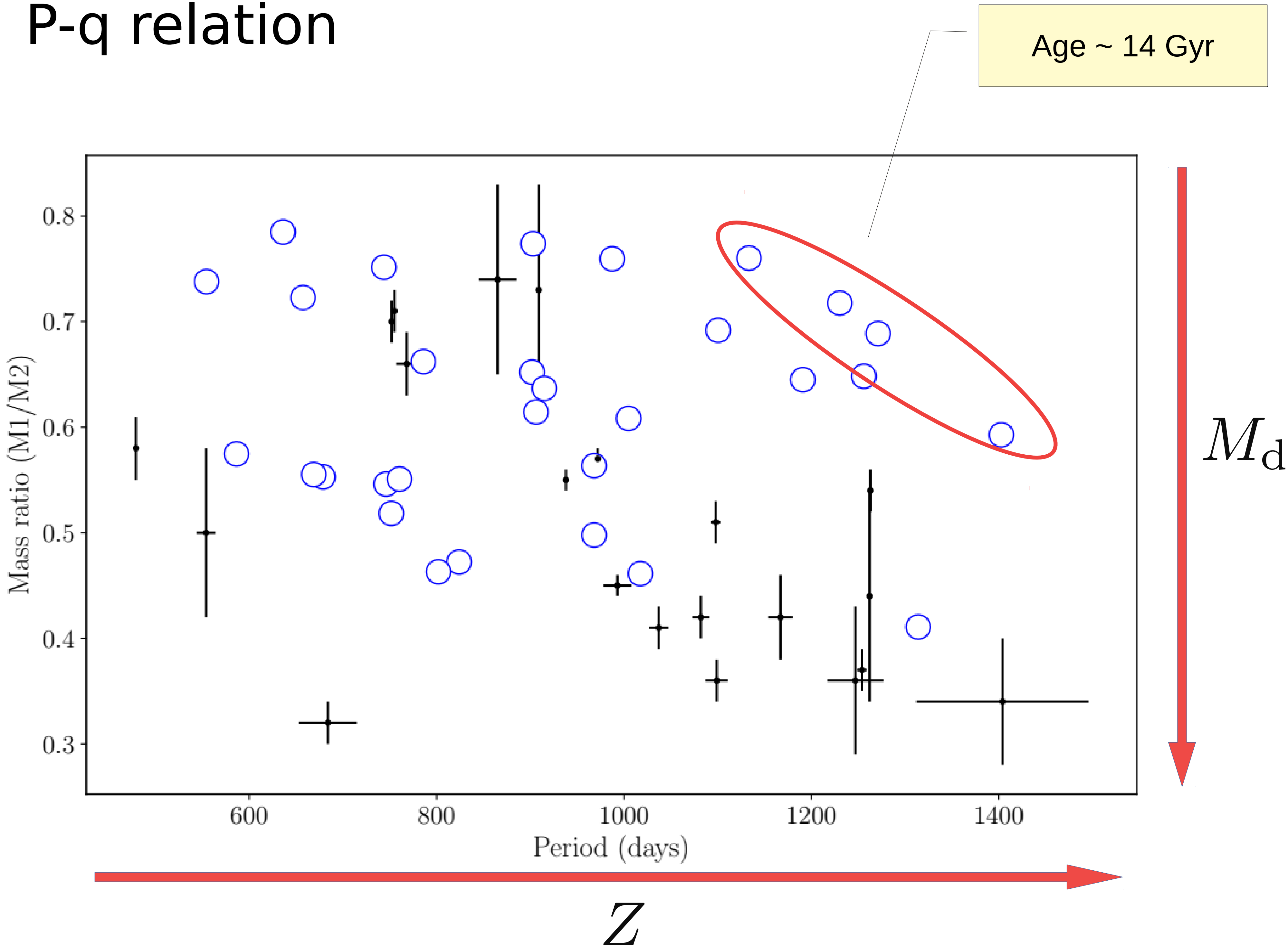
Mass loss fractions

- Analytical treatment of mass loss through L1 and L3 (less free variables)
- Mass accretion onto companion until breakup velocity is reached

→ Initial setup determines final parameters (P, q)

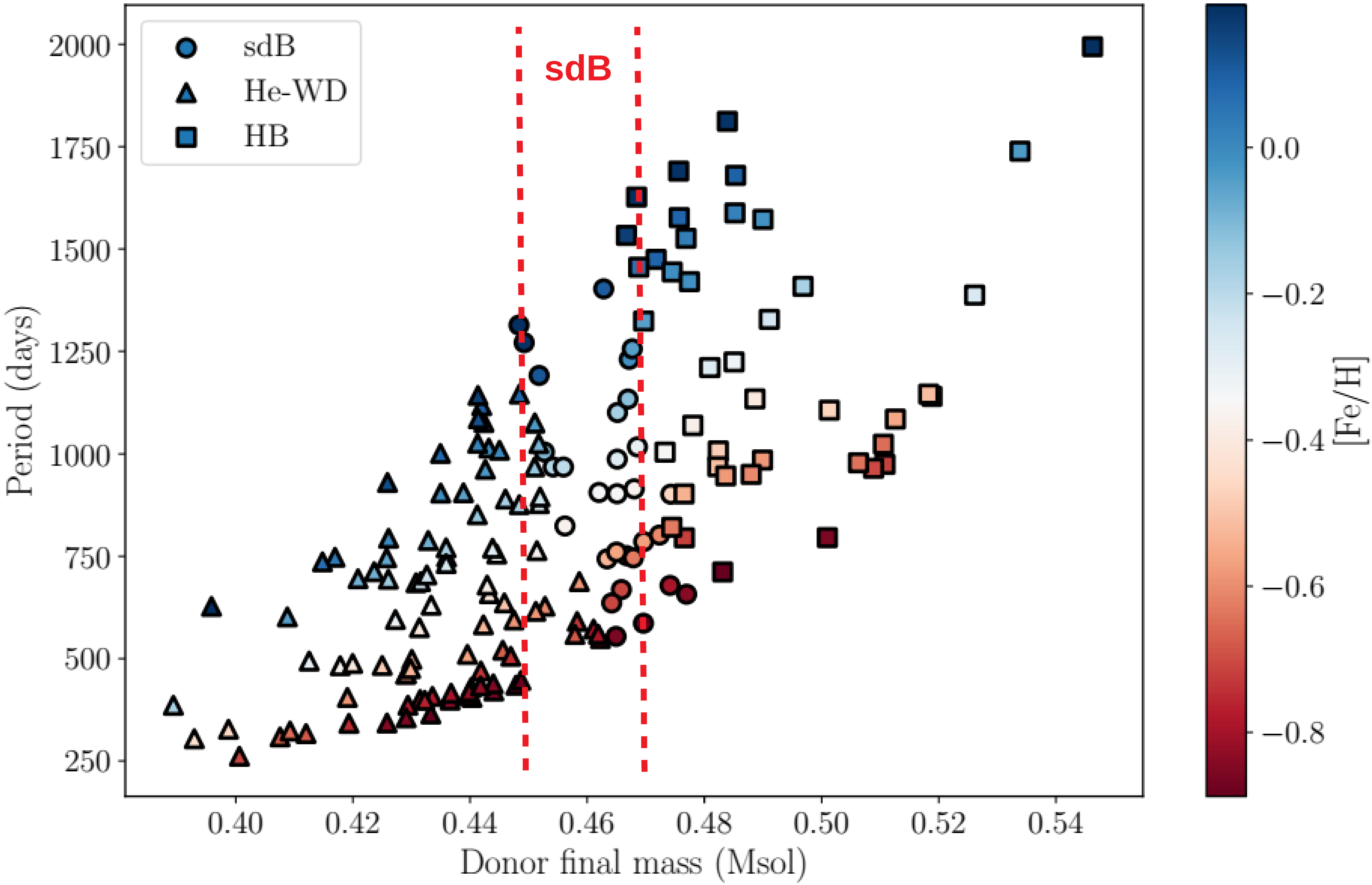
$e = 0$

P-q relation



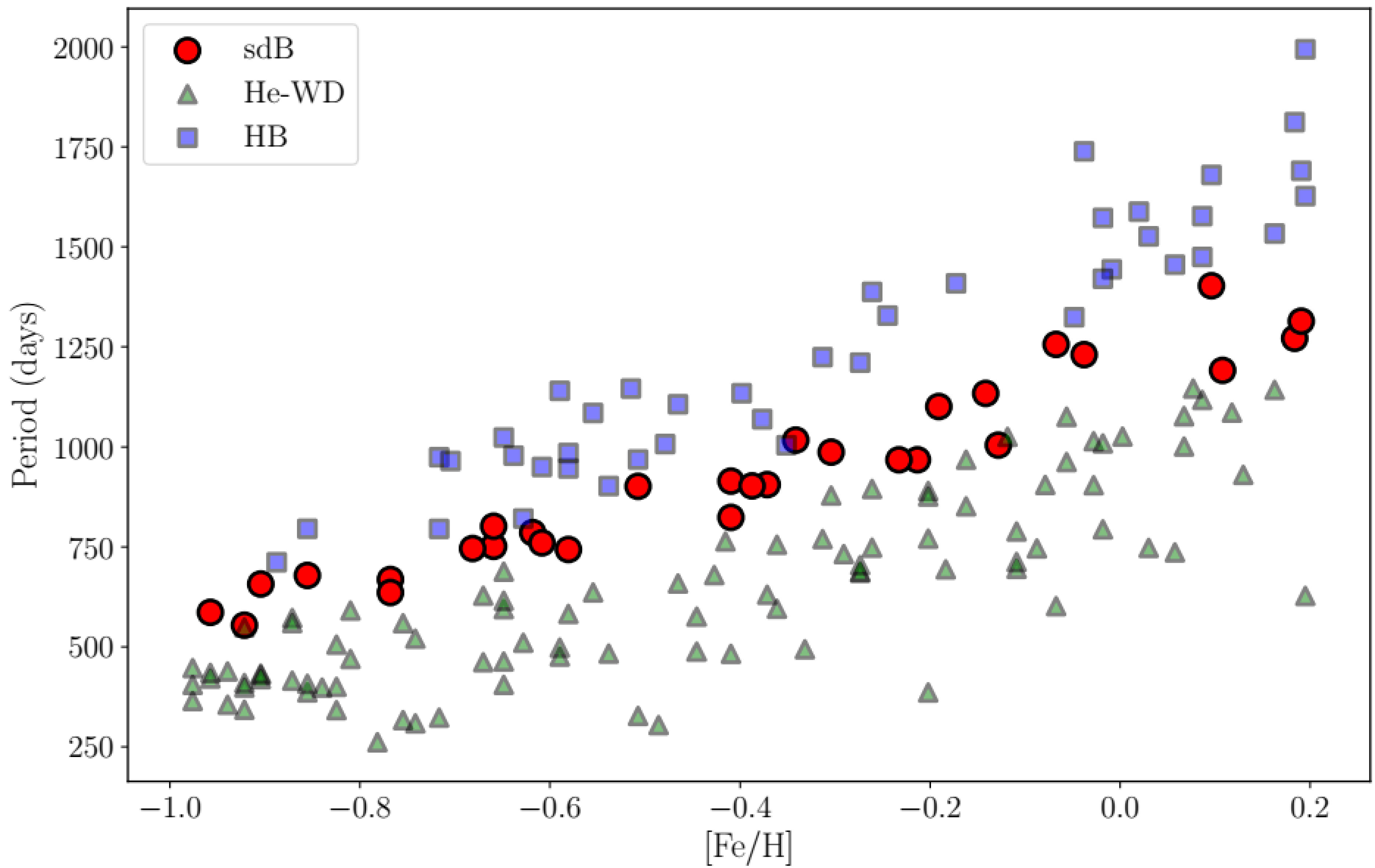
Age ~ 14 Gyr
Mass ratio (M1/M2)
0.8
0.7
0.6
0.5
0.4
0.3
600
800
1000
1200
1400
Period (days)
M_{d}
Z

Period – Final donor mass



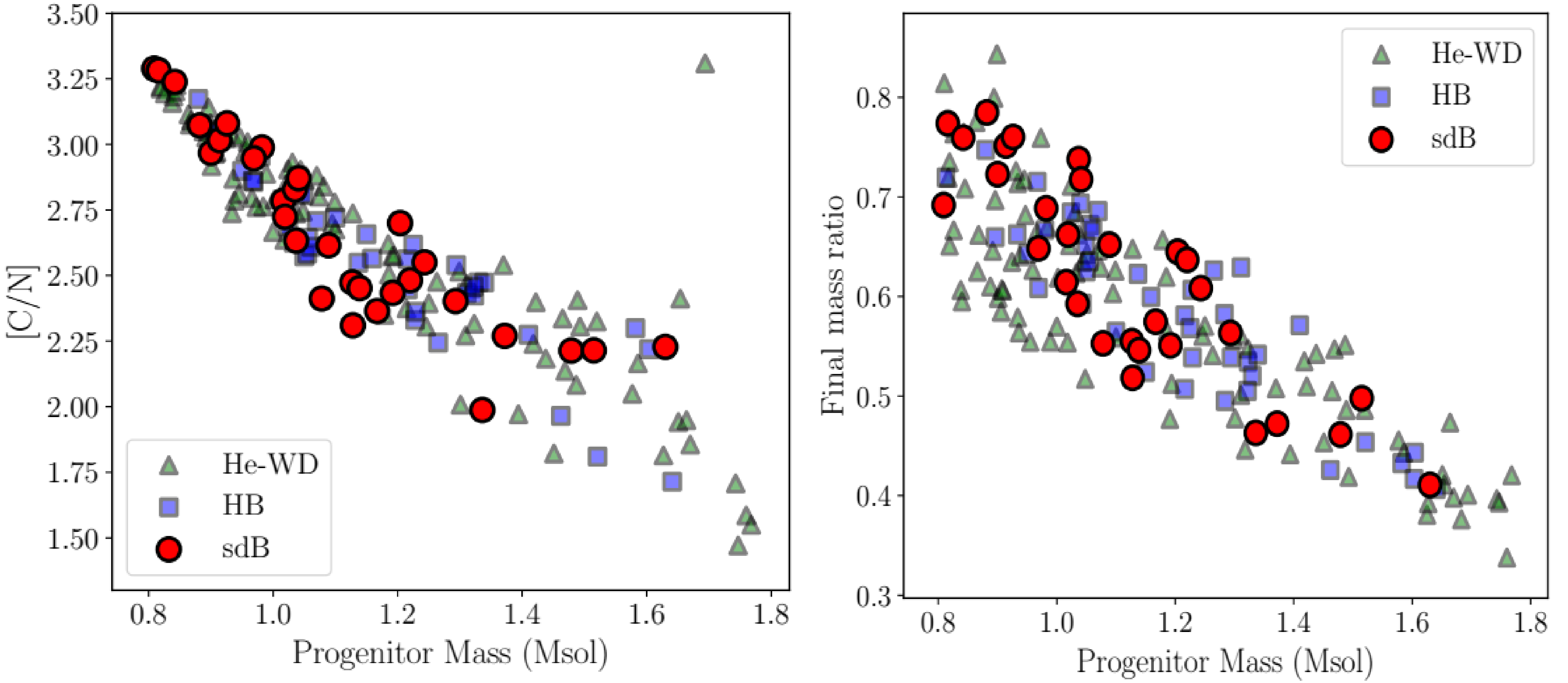
Known for LM WD’s (e.g. Istrate et al. 2016), sdBs (e.g. Chen et al. 2013)

Period – [Fe/H]



Interesting for sdBs because their mass range is very small.

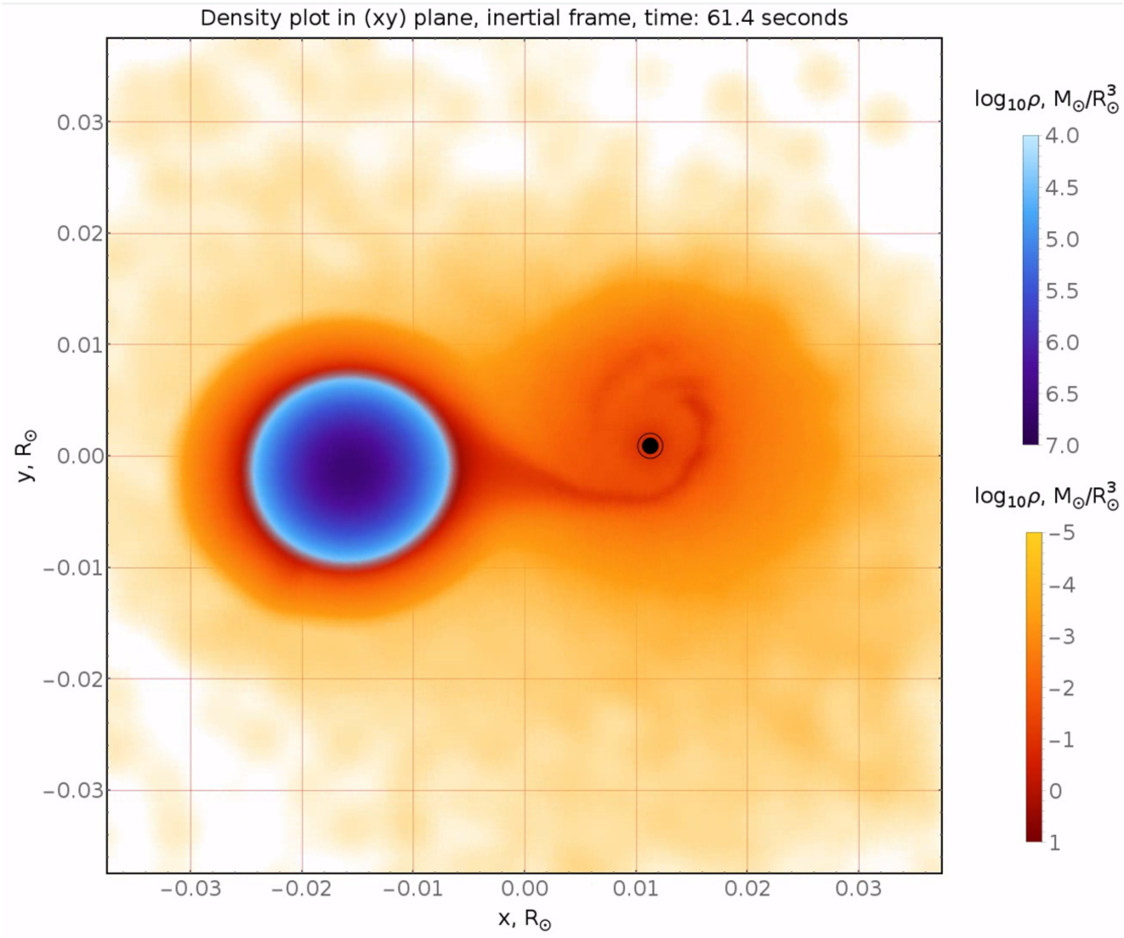
Link to progenitor systems



Valid for all Horizontal branch binaries

What is next?

SPH simulations to check analytical results



Oil on Water code

Davis & Church et al. 2009

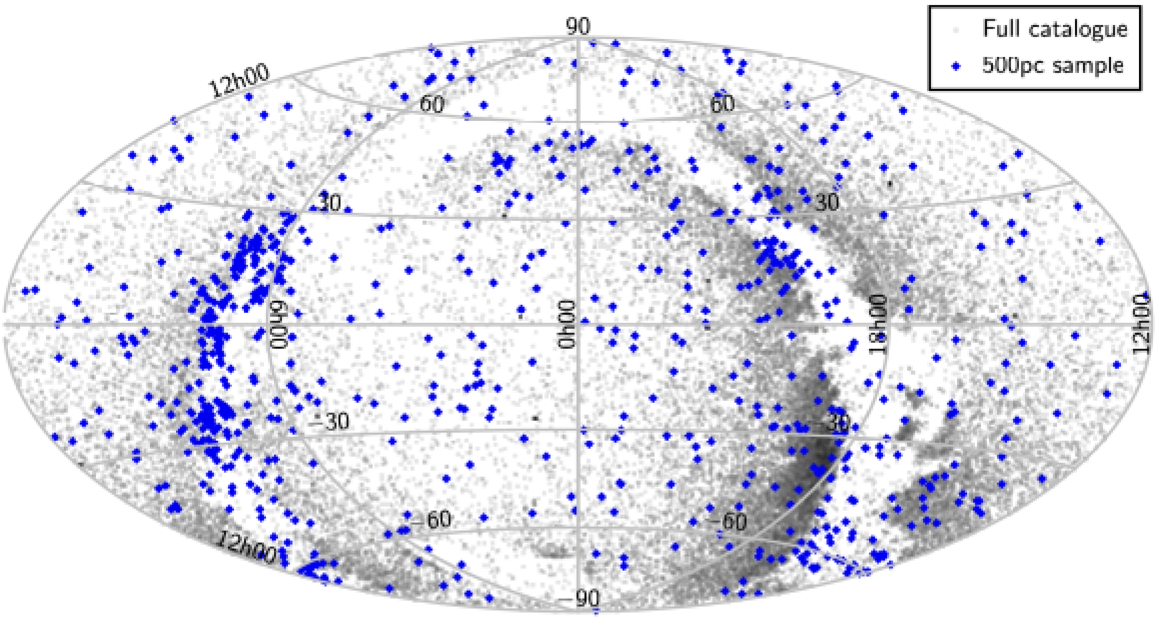
In colaboration with:
Alexey Bobrick

LUNDS UNIVERSITET

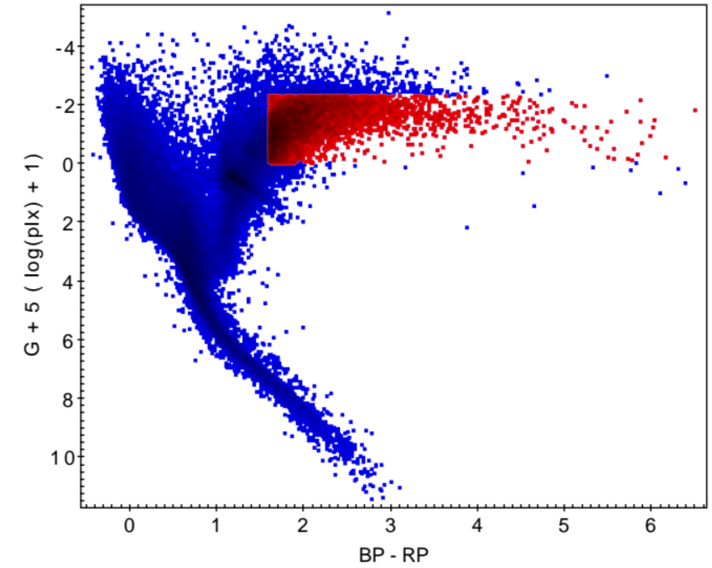
SPH can calculate estimates for the accreted mass and mass loss fractions

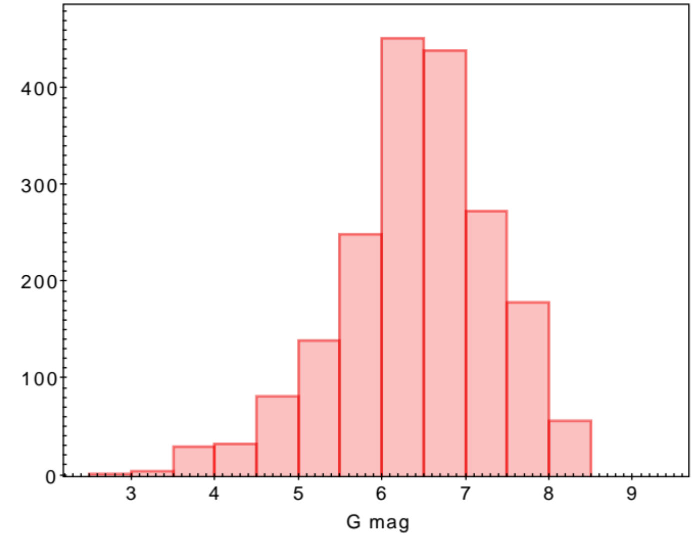
500 Pc samples

500 pc sdB Sample



500 pc RGB sample





- A volume limited sample of hot subdwarfs
- A volume limited sample of RGBs
- Based on the GAIA DR2 catalog
- Ideal to constrain BPS results

500 Pc samples

2m Perek telescope

- All sky, using telescopes in Chile and Europe
- Ideal for student projects

Science goals:

- Stability of RLOF on RGB
- Formation of hot subdwarfs
- Formation of He-Wds and HB objects

- Red giant binaries
- Search for lithium RGs
- Search for red giant binaries with mass transfer history
- Stellar winds on the RGB

- Can be combined with galactic archaeology surveys

Summary

- sdB+MS binaries are ideal systems to study stable RLOF on the RGB
- 25 binaries have now been analyzed
- Orbital periods range from 1 – 4 years
- Almost all systems are eccentric, which can be explained by phase depended mass loss in combination with the formation of a circumbinary disk during the RLOF phase
- The main sequence companions accrete very little mass
- Strong correlation between mass-ratio and orbital period.
- Orbital periods and mass ratios match theoretical predictions
- Model shows relations between Period – [Fe/H] and Progenitor mass with q and [C/N]