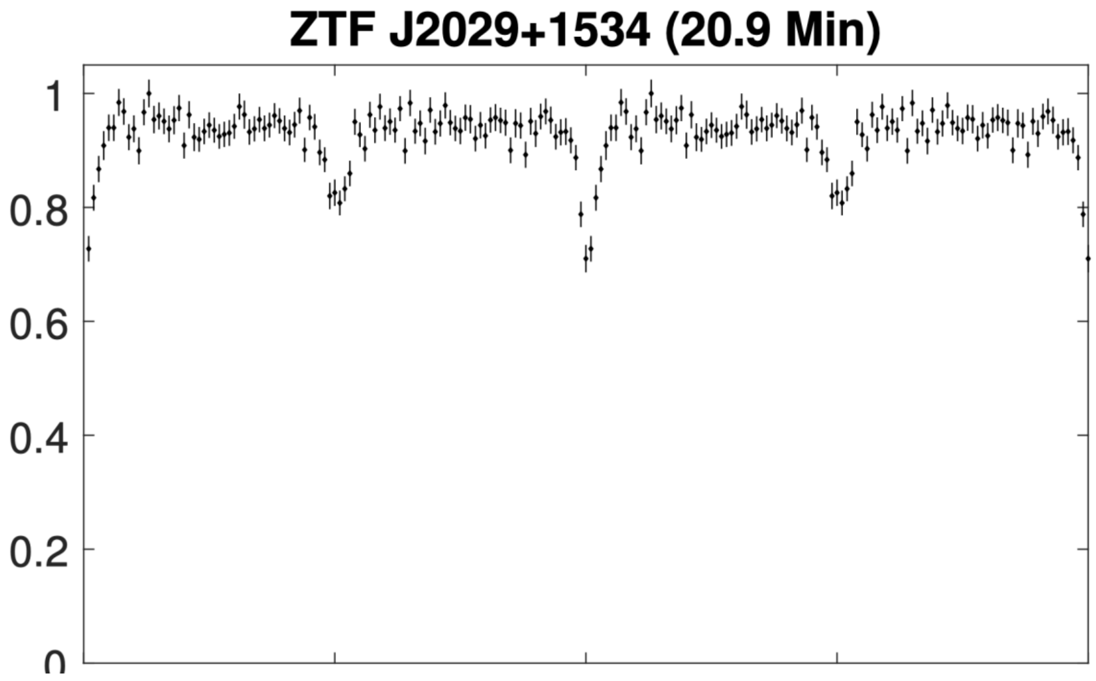
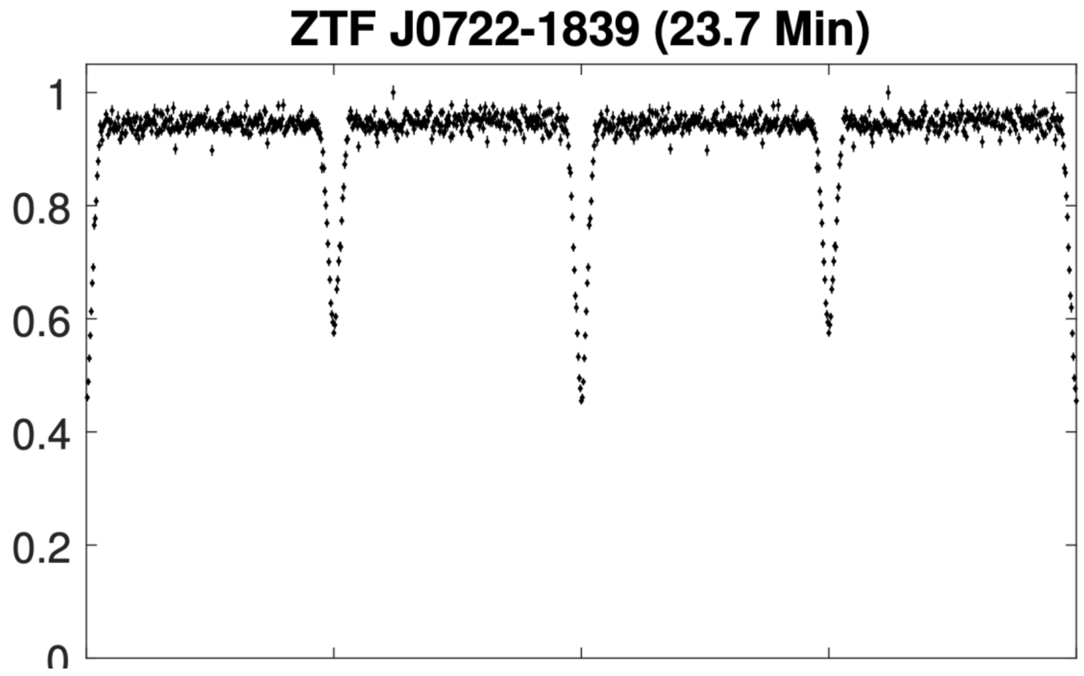
Short-period WD binaries

- ELM survey
  - ≈100 DWDs with P_{orb}< 1 day

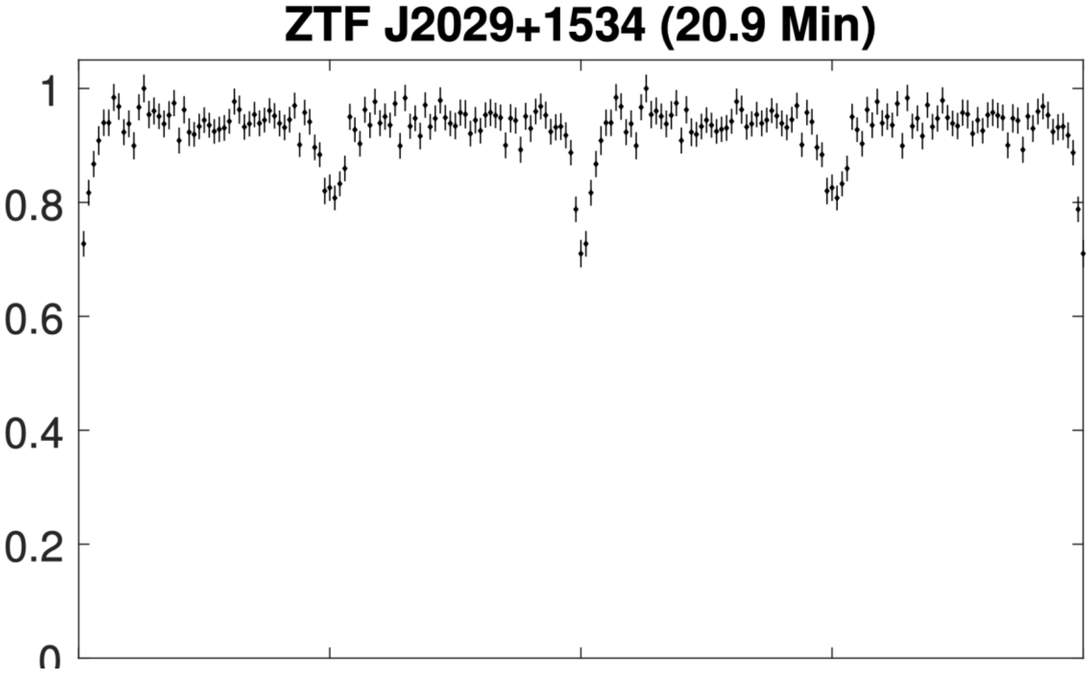
- ZTF: 10 DWDs, P_{orb} < 60 minutes (half eclipsing)

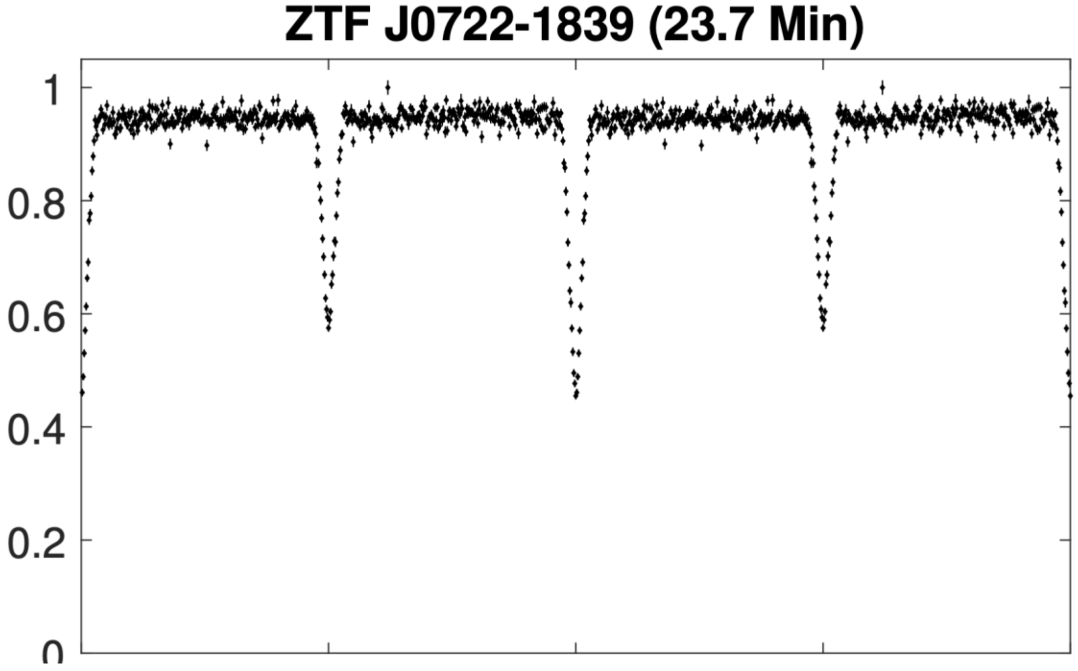




Reverse modeling of WD binaries

- We model:
  - 9 DWDs (7 eclipsing, 4 ZTF)
  - 1 eclipsing WD-BD





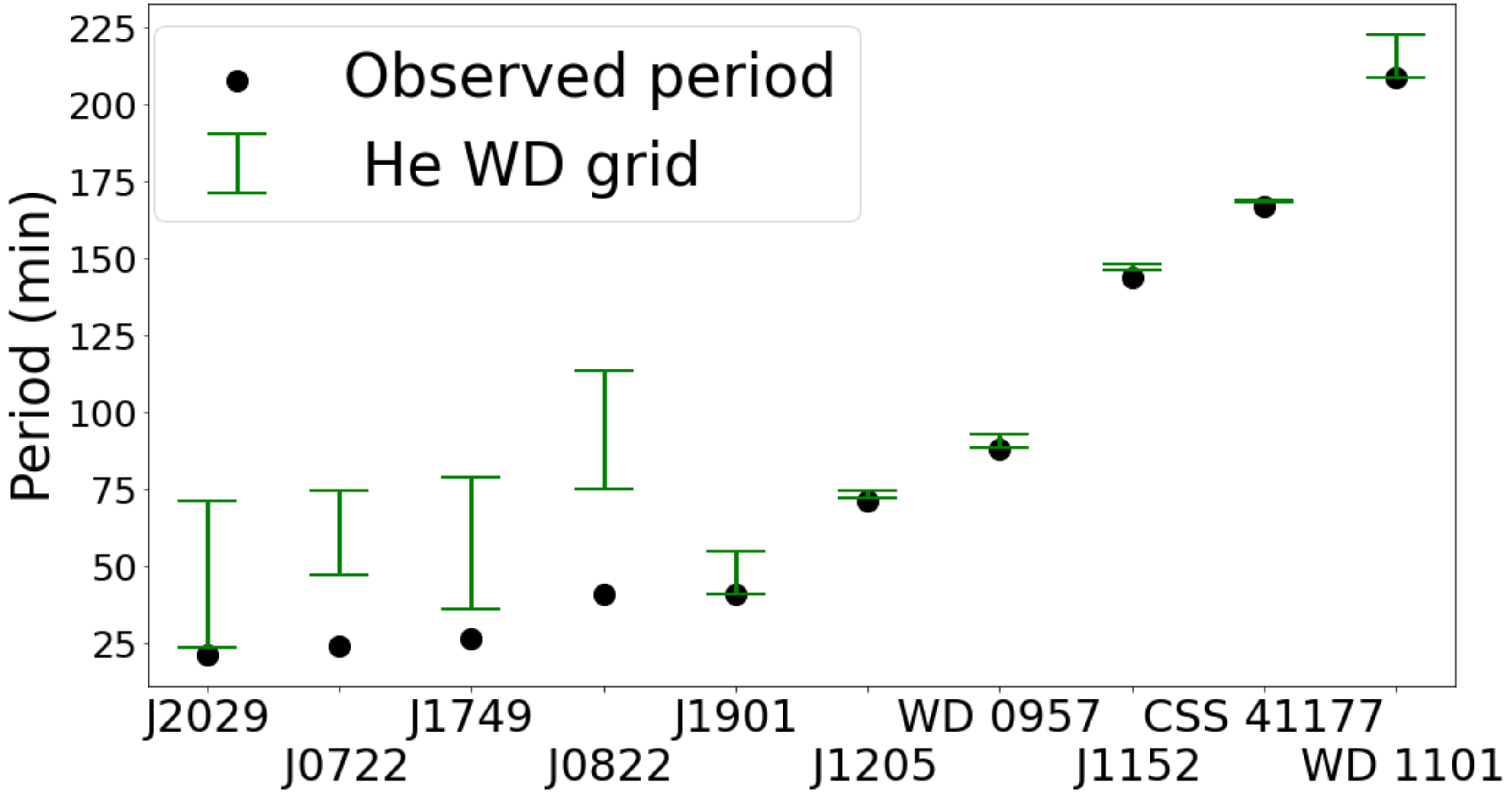
Birth period – when M_1 is formed

- Model cooling of M_1 (hotter + younger WD)
- Observed period + cooling age = orbital evolution

$$\frac{da}{dt} = \frac{-64G^3M_1M_2M}{5a^3c^5}$$

$$a_f^4 - a_i^4 = \frac{-256G^3M_1M_2M}{5c^5}\Delta t$$

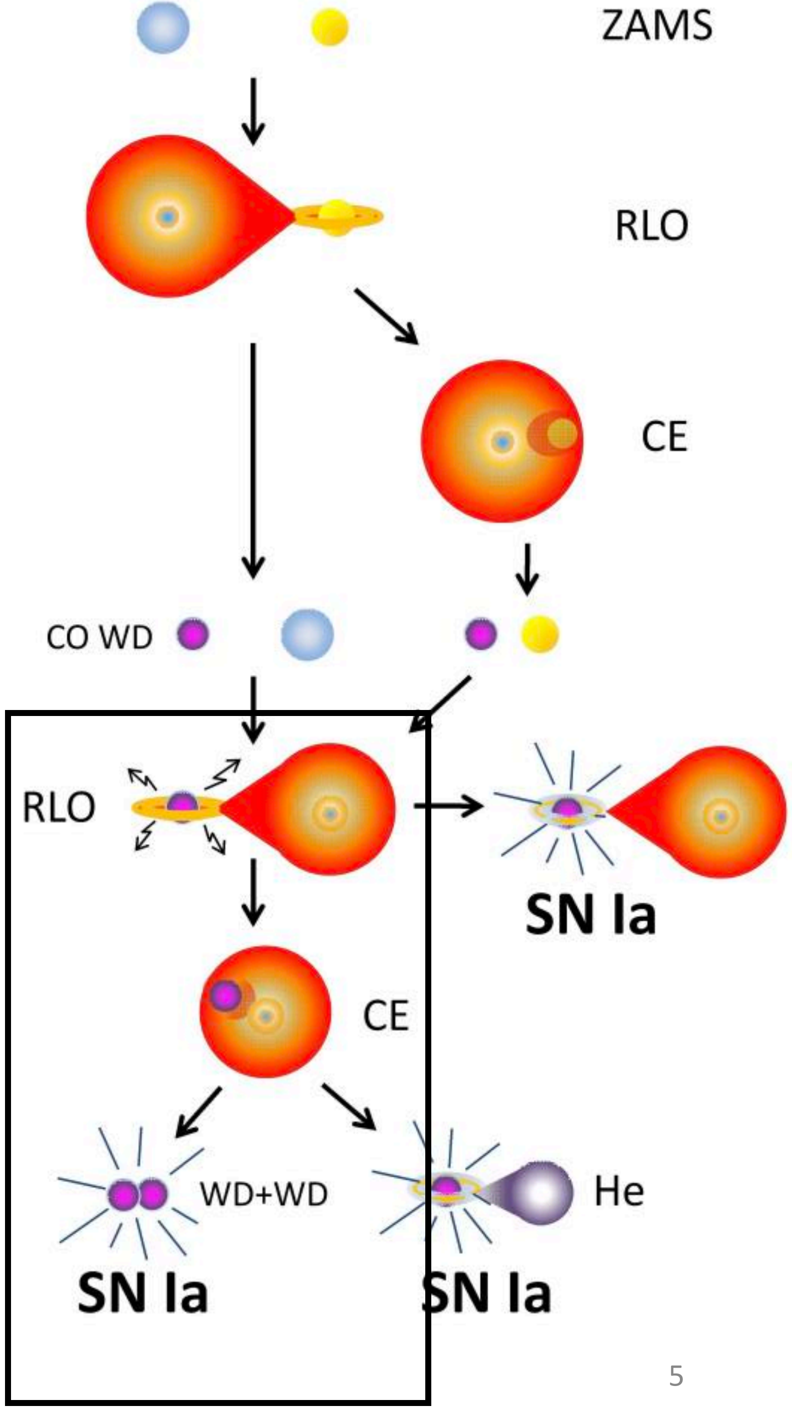
Birth orbit



The Common Envelope Event

- CE event necessary for inspiral
- M_1 formed more recently
    - Birth period = post-CE period!
- Pre-CE: M_{progen} and M_2

$$E_{\rm bind} = \alpha_{\rm CE}\left(E_{\rm orb,f} - E_{\rm orb,i}\right)$$

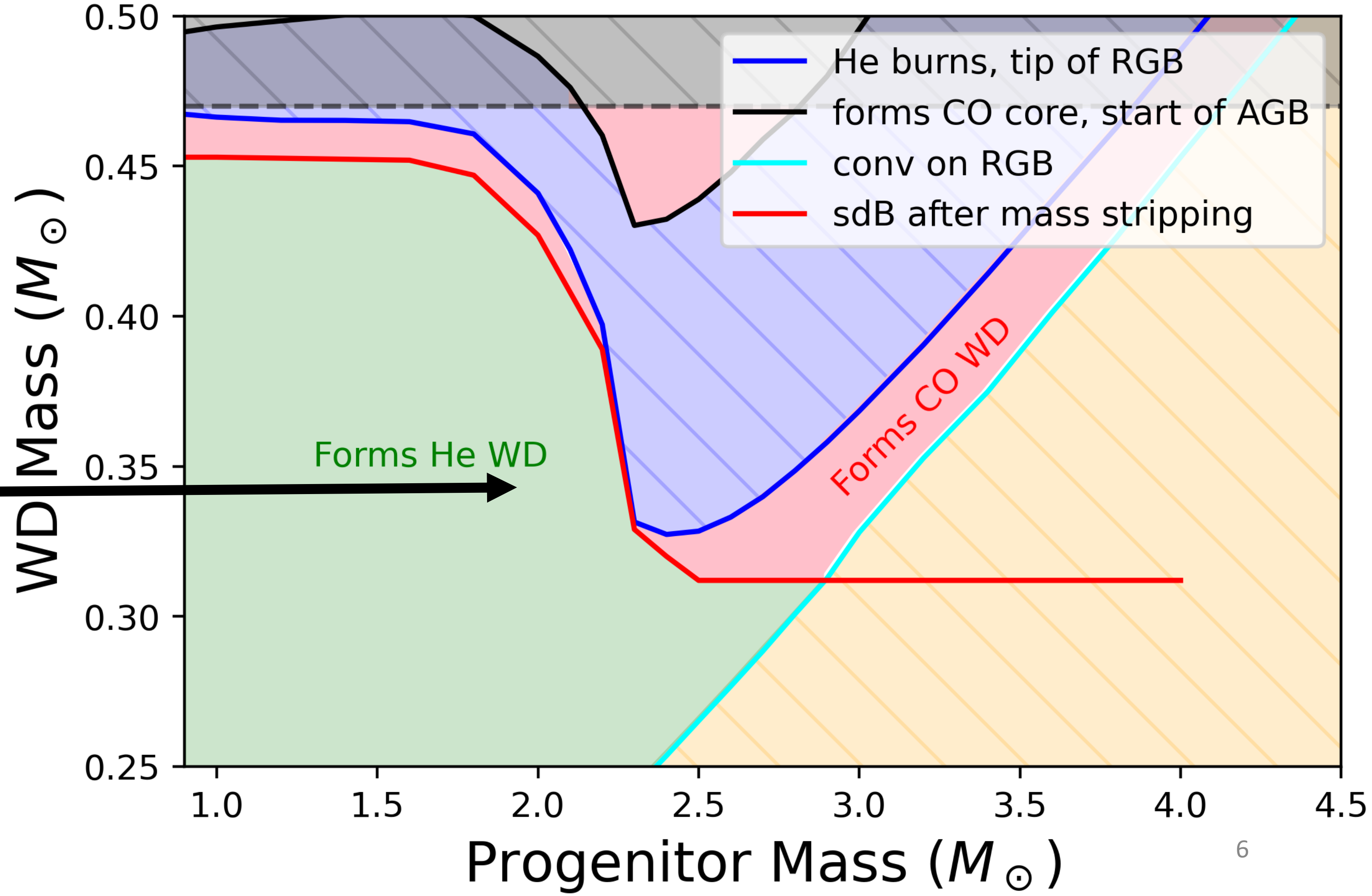


Map between RGB models and M_1

- Giant M_{progen} initiates mass transfer when $M_{core} = M_1$
- $\approx 0.9 - 2.3\ M_\odot$ progenitors for He WD

Pre-CE orbital period: RLOF

$$\frac{R_i}{a_i} = \frac{0.49 q_i^{2/3}}{0.6 q_i^{2/3} + \ln\left(1 + q_i^{1/3}\right)}$$



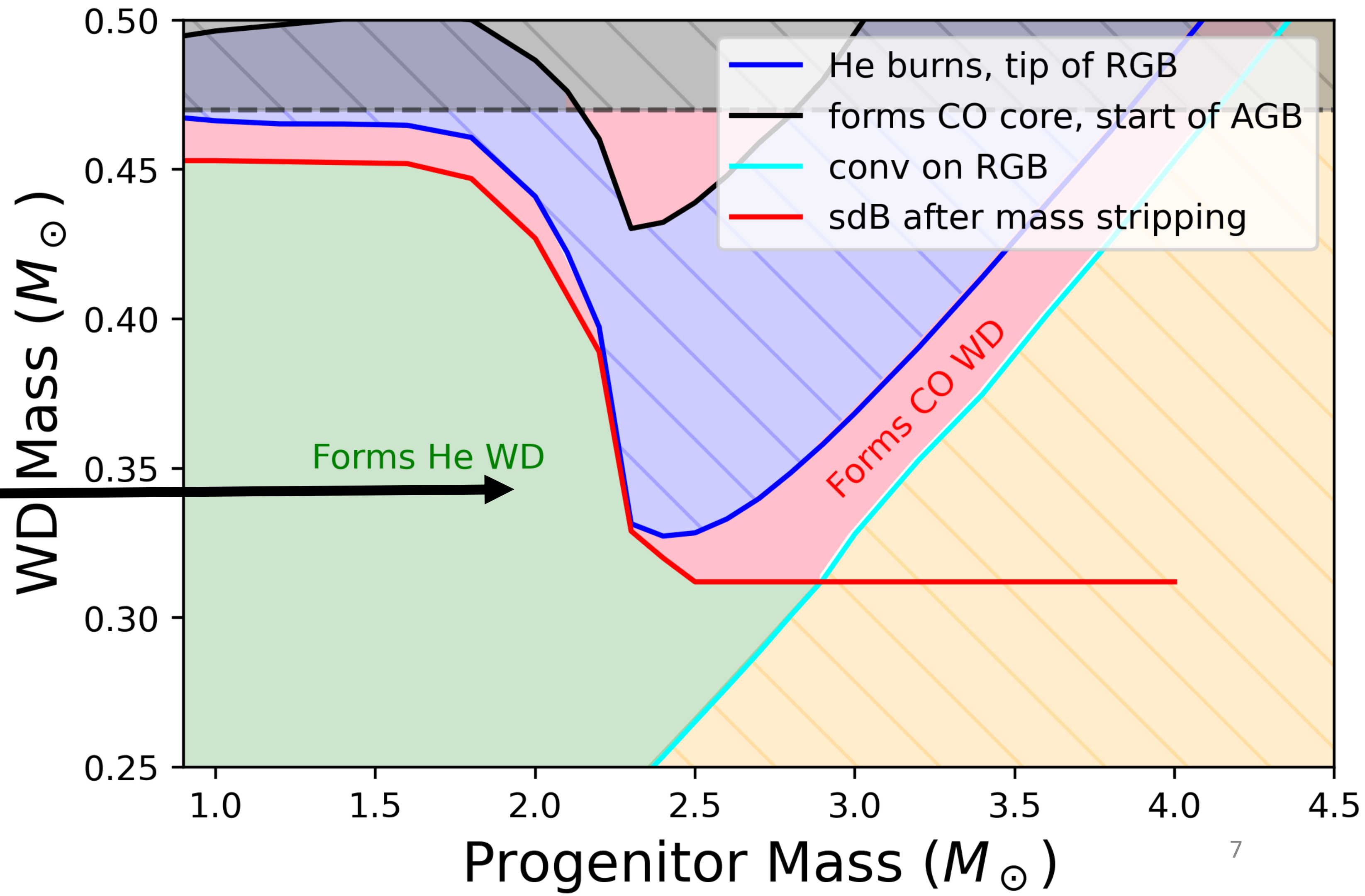
Map between RGB models and M_1

- Giant M_{progen} initiates mass transfer when M_{core} = M_1
- ≈0.9 - 2.3 $M_\odot$ progenitors for He WD

Envelope binding energy

$$E_{\rm grav} = \int_{M_{\rm core}}^{M_{\rm tot}} \frac{-Gm(r)dm}{r}$$

$$E_{\rm int} = \int_{M_{\rm core}}^{M_{\rm tot}} U dm$$

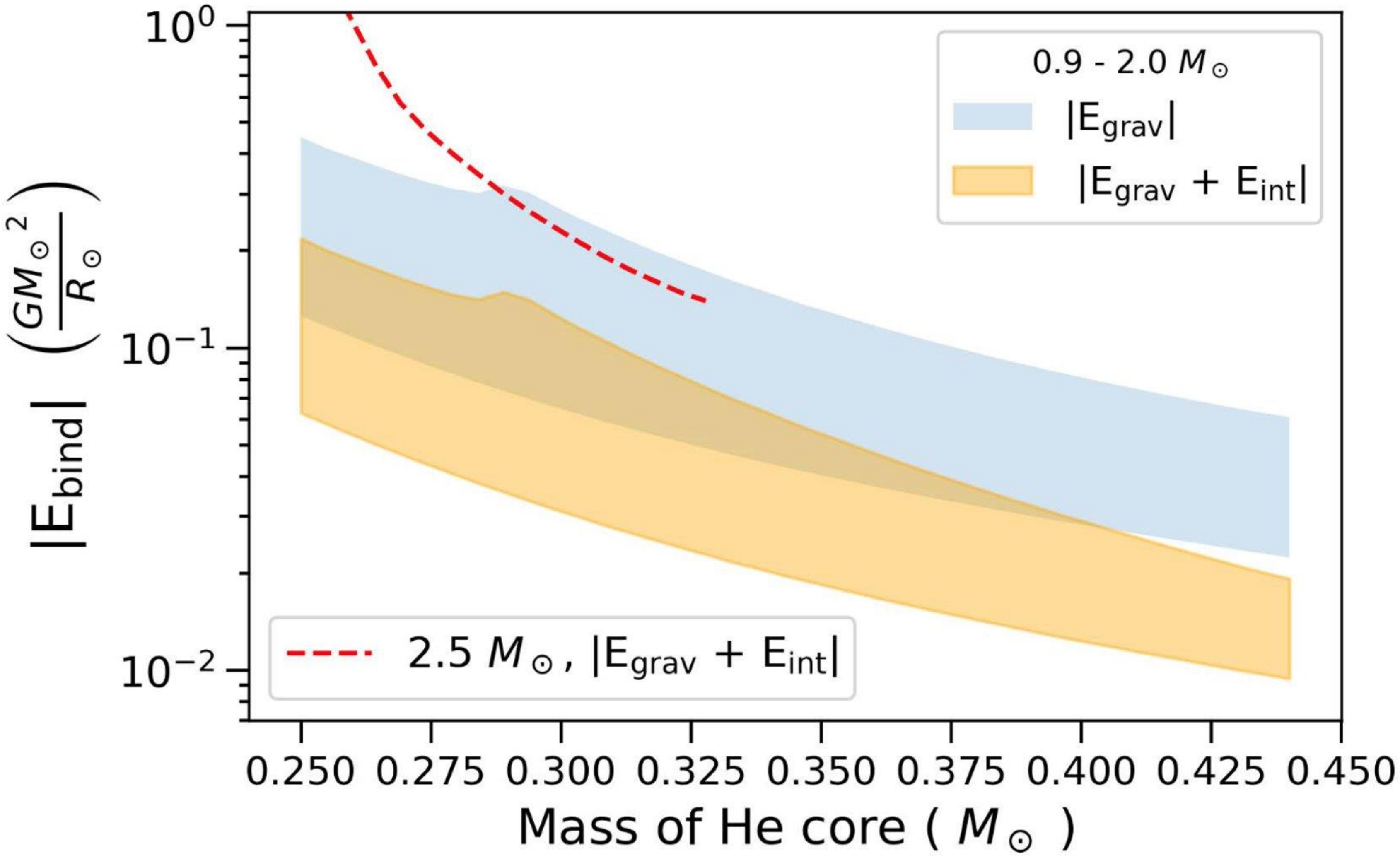


Progenitor envelope binding energy

- E_{bind} increases with:
  - Increasing M_{progen}
  - Decreasing M_{core}

$$E_{\rm grav} = \int_{M_{\rm core}}^{M_{\rm tot}} \frac{-Gm(r)dm}{r}$$

$$E_{\rm int} = \int_{M_{\rm core}}^{M_{\rm tot}} U dm$$



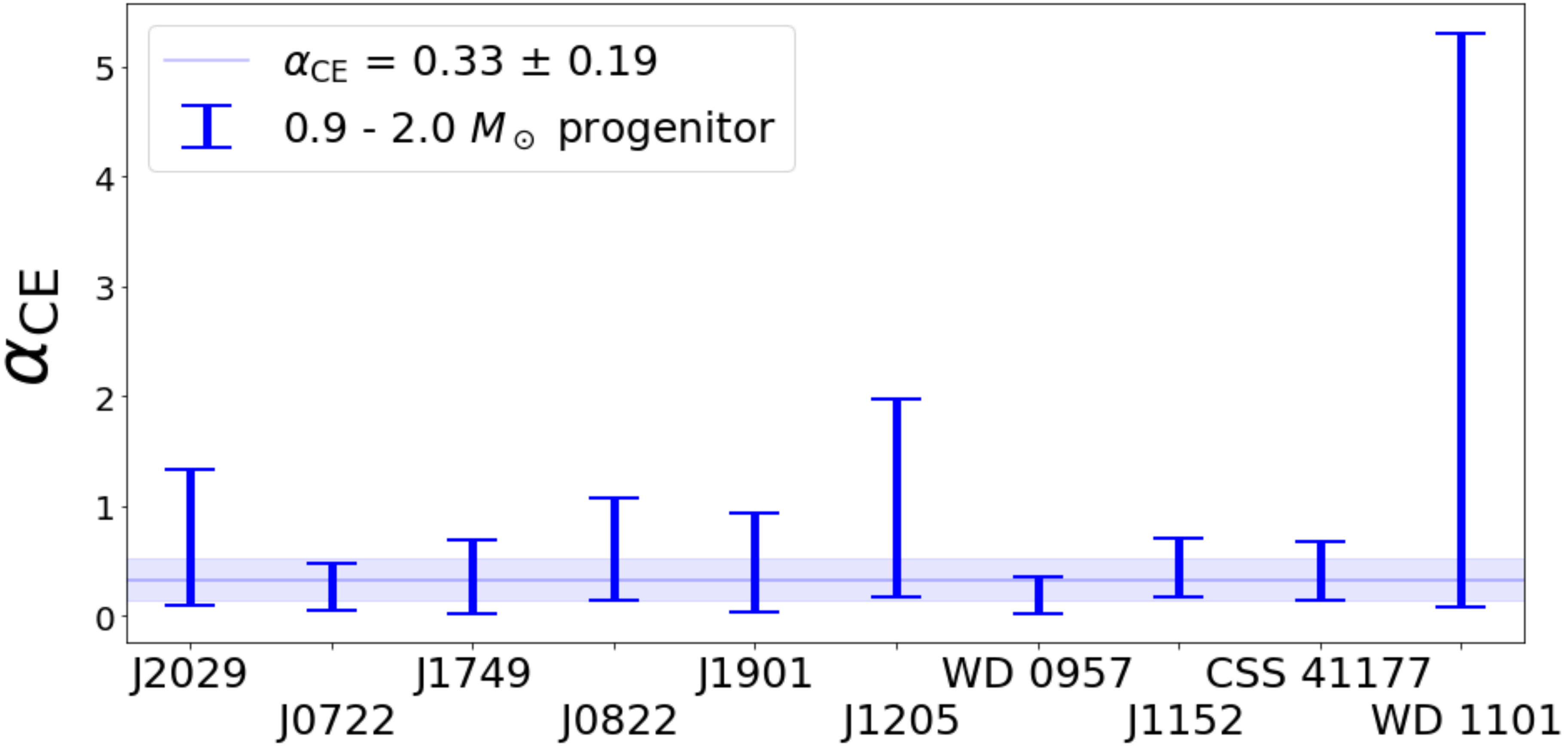
The CE efficiency: α_{CE}

$$E_{\rm bind} = \alpha_{\rm CE}\left(-\frac{GM_1M_2}{2a_{\rm f}} + \frac{GM_{\rm progen}M_2}{2a_{\rm i}}\right)$$

Pre-CE orbital energy (RLOF criteria of M_{progen})

Envelope of M_{progen}

Post-CE orbital energy (birth period of M_1)



Summary

- Cooling of WD primary modeled to find post-CE orbital period
- Unknown progenitor mass leads to large uncertainty in CE energy budget
- α_{CE} of 0.2 - 0.4 consistent with all 10 binaries if:
  - M_1 is He-core WD
  - M_{progen} between 0.9 - 2.0 $M_\odot$