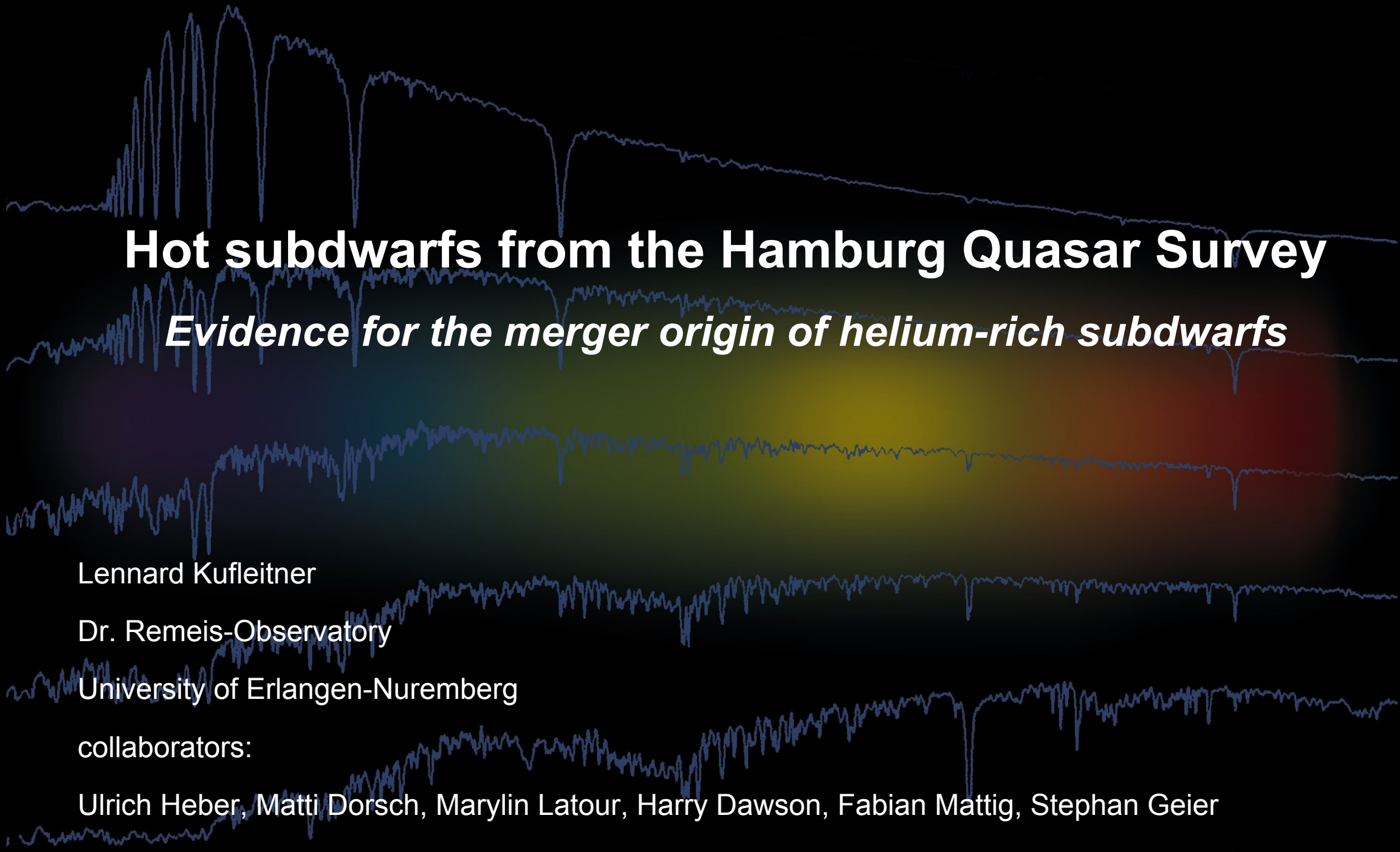


Hot subdwarfs from the Hamburg Quasar Survey

Evidence for the merger origin of helium-rich subdwarfs

Lennard Kufleitner

Dr. Remeis-Observatory

University of Erlangen-Nuremberg

collaborators:

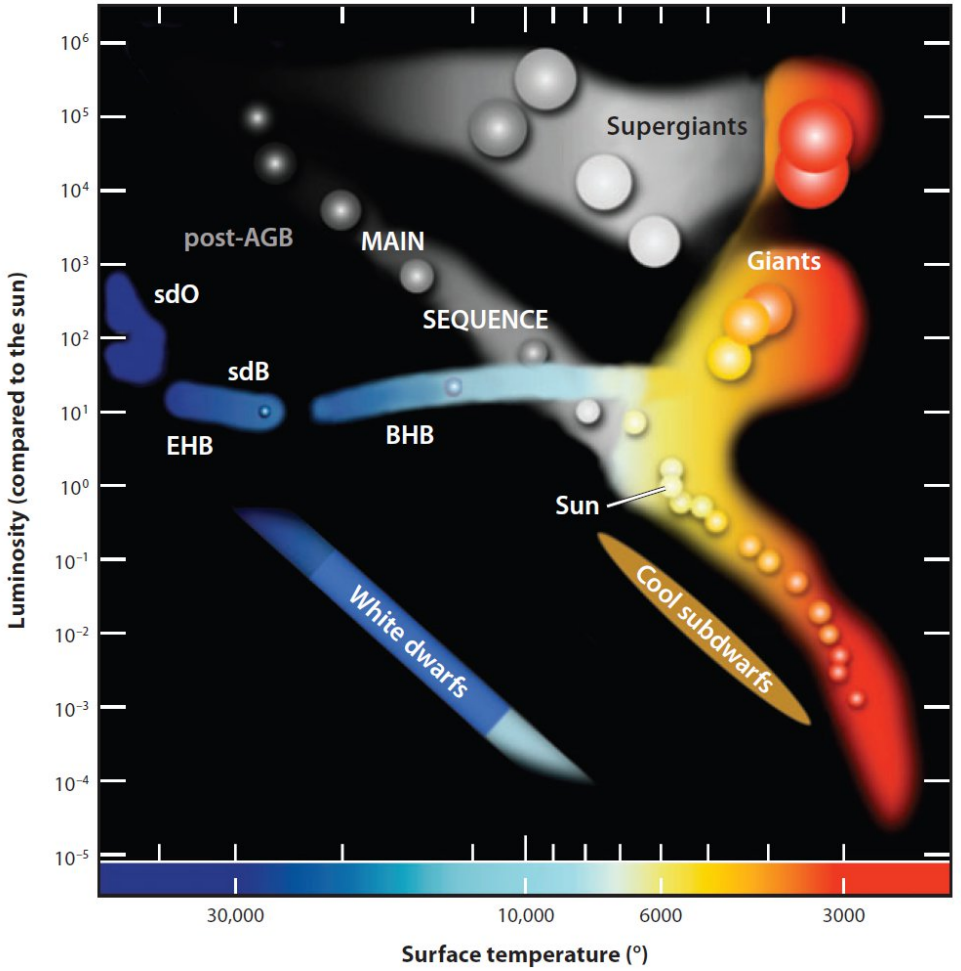
Ulrich Heber, Matti Dorsch, Marylin Latour, Harry Dawson, Fabian Mattig, Stephan Geier

Gray and Corbally 2009

8.9.2026

Hot subdwarfs

- $T_{\mathrm{eff}} \sim 20000\ K - 100000\ K$
- $\log g \sim 4.5 - 6.5$
- $M \sim 0.5\ M_{\odot}$
- $R \sim 0.1\ R_{\odot} - 0.3\ R_{\odot}$
- $L \sim 10\ L_{\odot} - 1000\ L_{\odot}$



Heber, 2009

Hot subdwarfs

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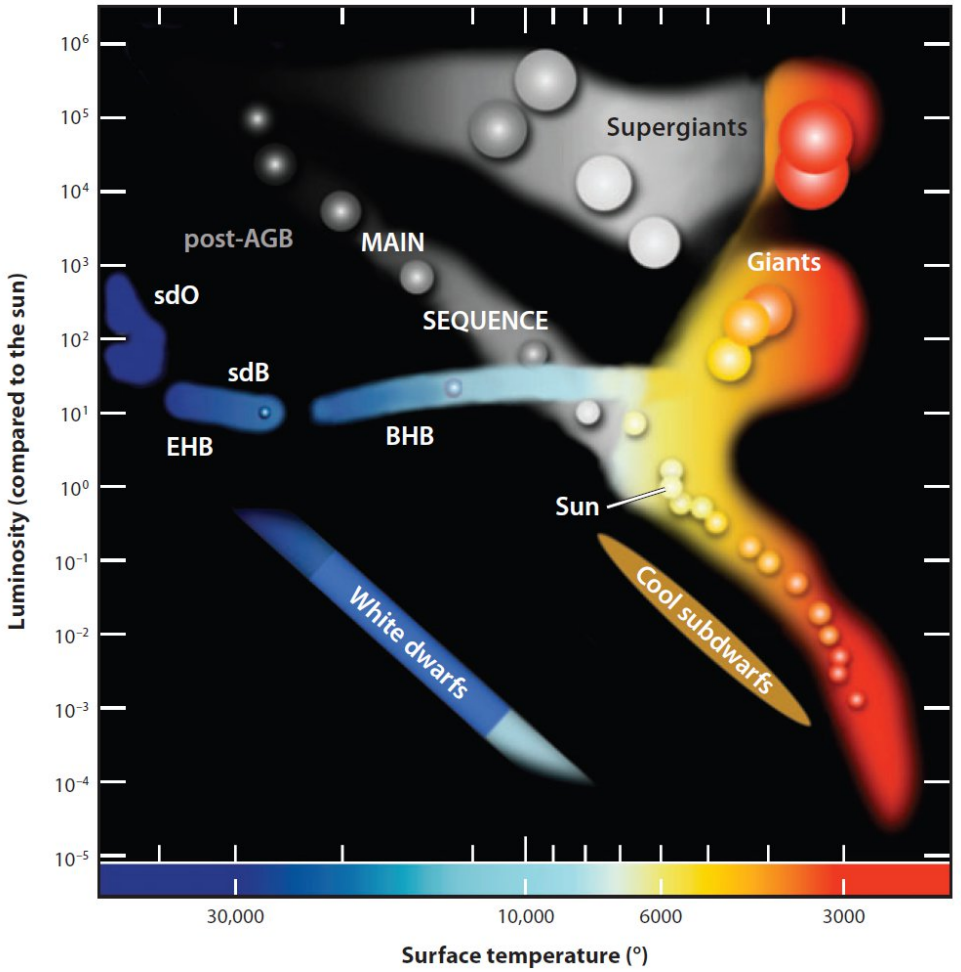
- **Stripped core He-burning stars**
- **Formation**:
  - **Requires binary evolution**
  - **Stable/Unstable mass transfer**

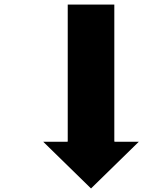


Heber, 2009

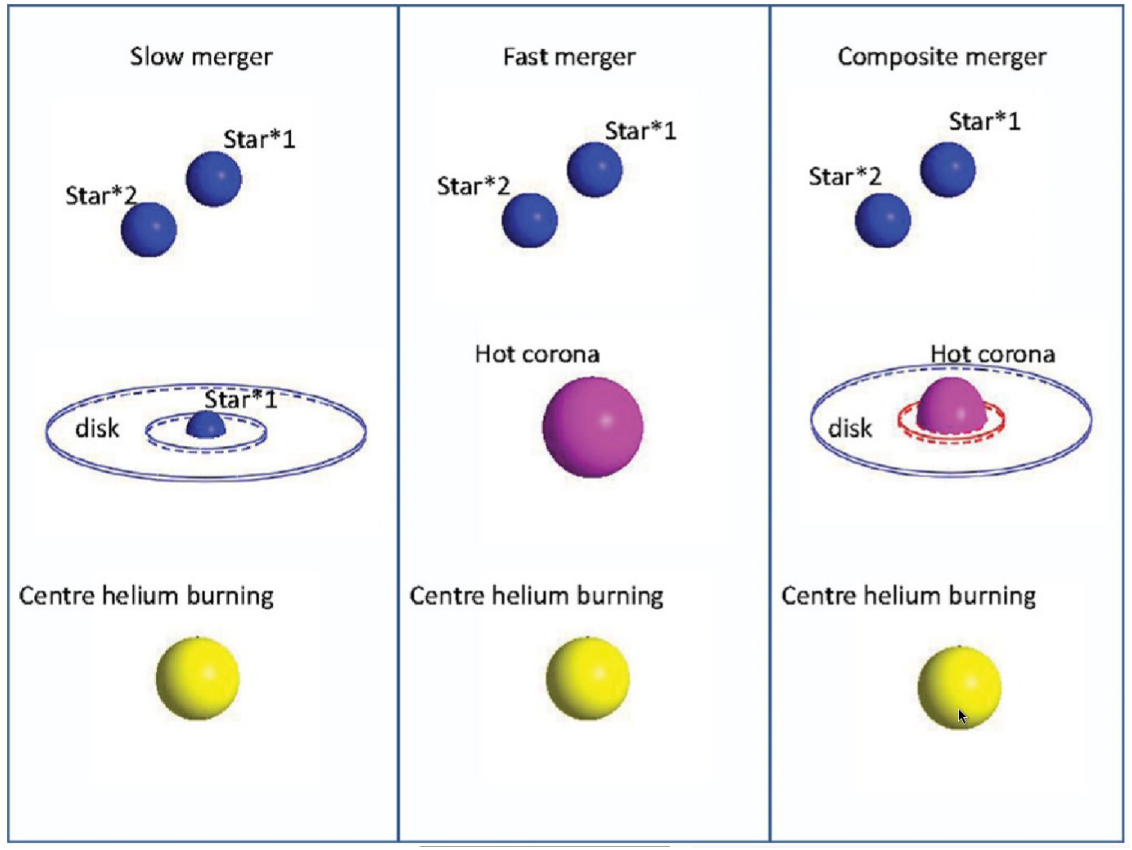
Formation

- White Dwarf Mergers

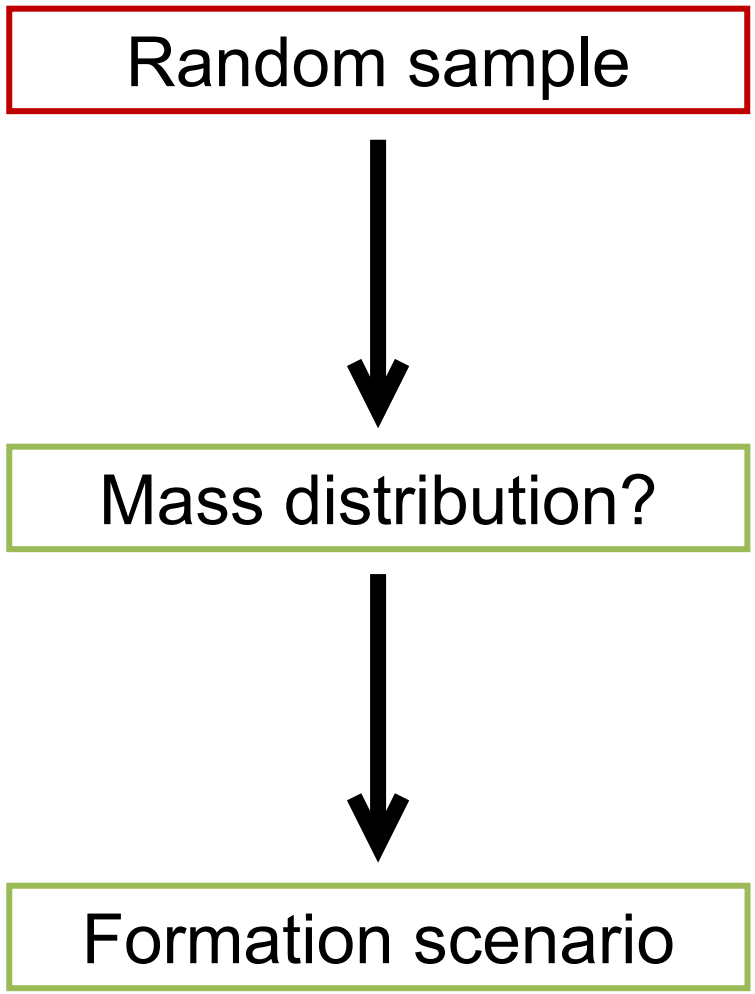
He-white dwarf binary



Hot subdwarf

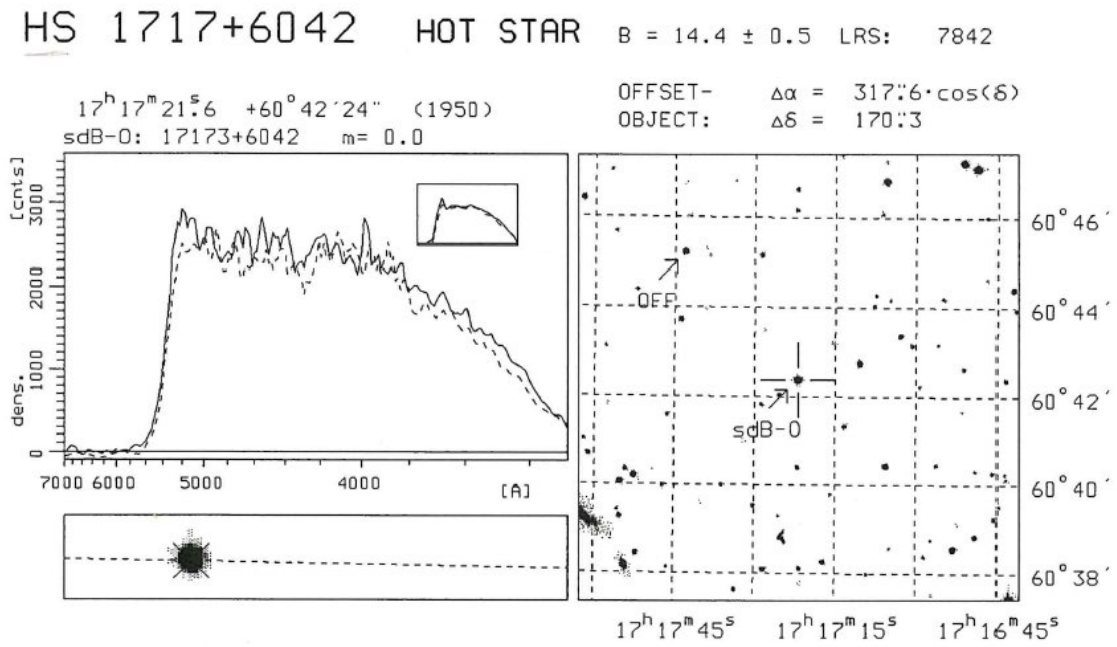


Zhang & Jeffery, 2012


Random sample
Mass distribution?
Formation scenario

The Hamburg Quasar Survey (HQS)

- *Hamburg Quasar Survey*
  - wide-angle objective prism survey in the 1980s/90s
  - Main goal: Quasars

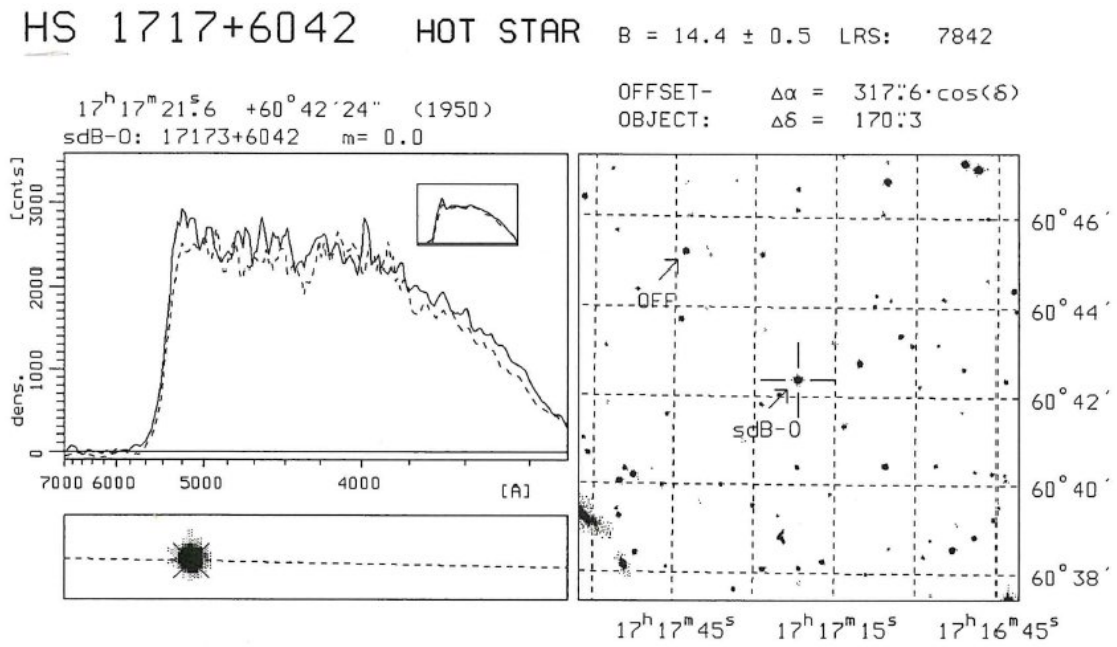


HQS hot star candidate

The Hamburg Quasar Survey (HQS)

- *Hamburg Quasar Survey*
  - wide-angle objective prism survey in the 1980s/90s
  - Main goal: Quasars

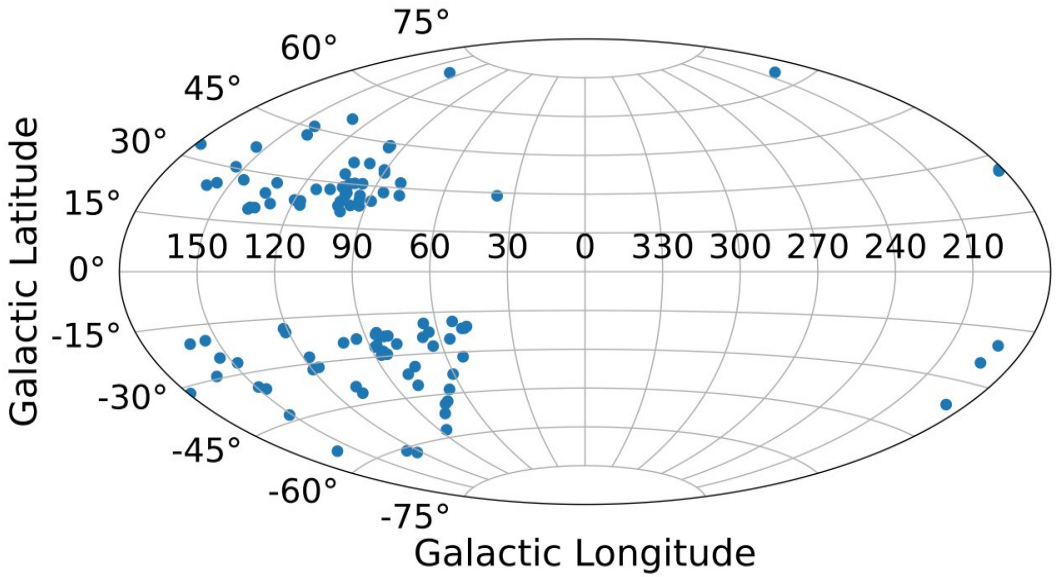
Follow-up spectroscopy required!



HQS hot star candidate

Spectral observations

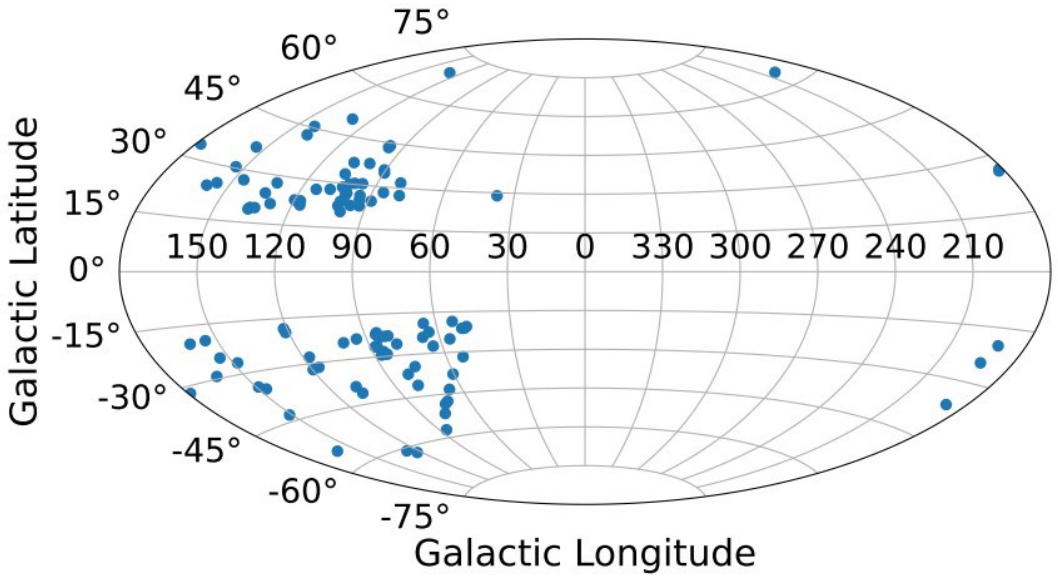
- Spectroscopic follow-up to HQS
  - 1990s: detailed spectra of candidates
  - 3.5m/ 2.2m telescopes in Calar Alto
  - Spectral resolution ~3.5 Å



Spectral observations

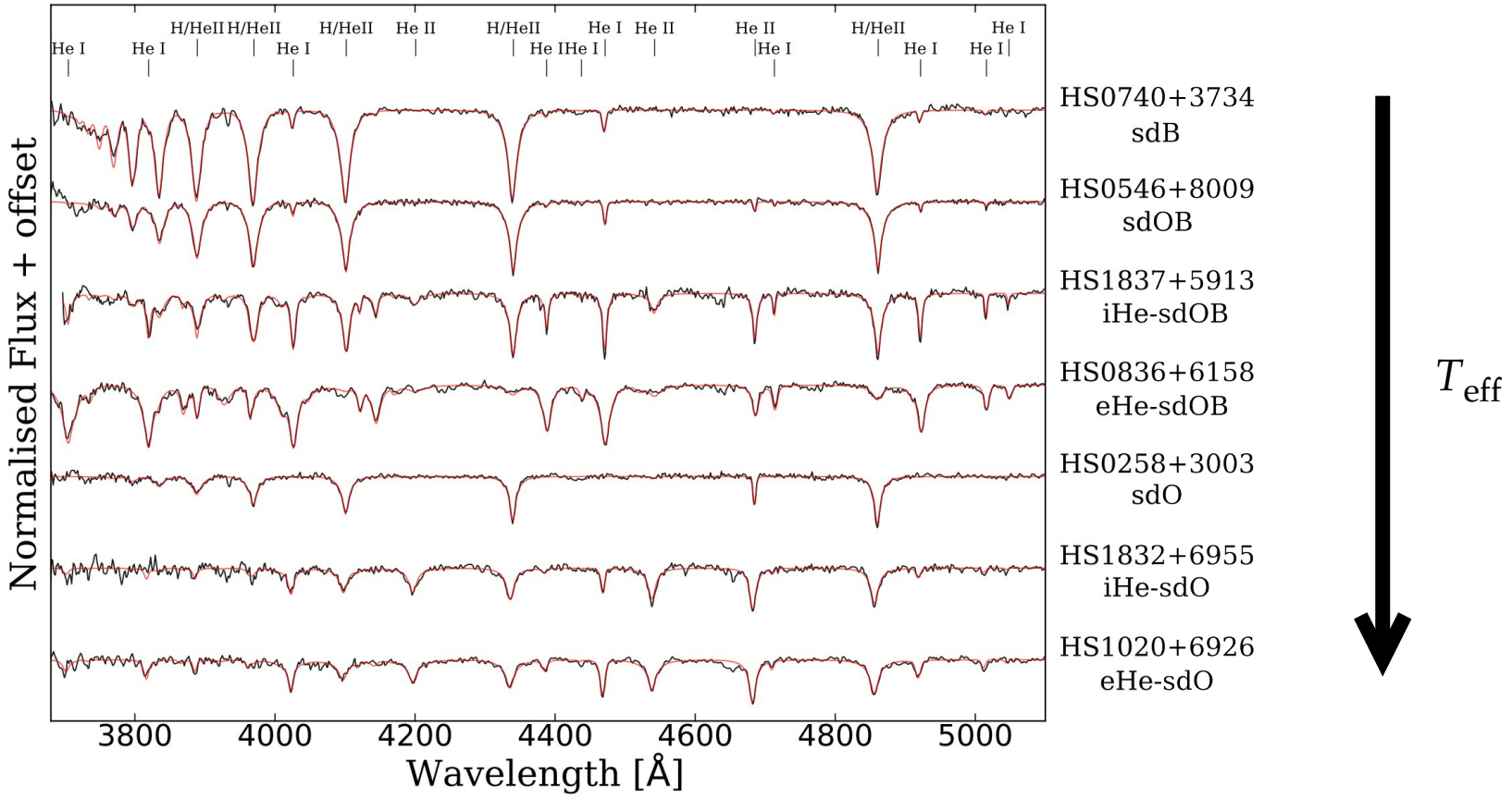
- Spectroscopic follow-up to HQS
  - 1990s: detailed spectra of candidates
  - 3.5m/ 2.2m telescopes in Calar Alto
  - Spectral resolution ~3.5 Å

Total stars selected: 122



Spectroscopic analysis

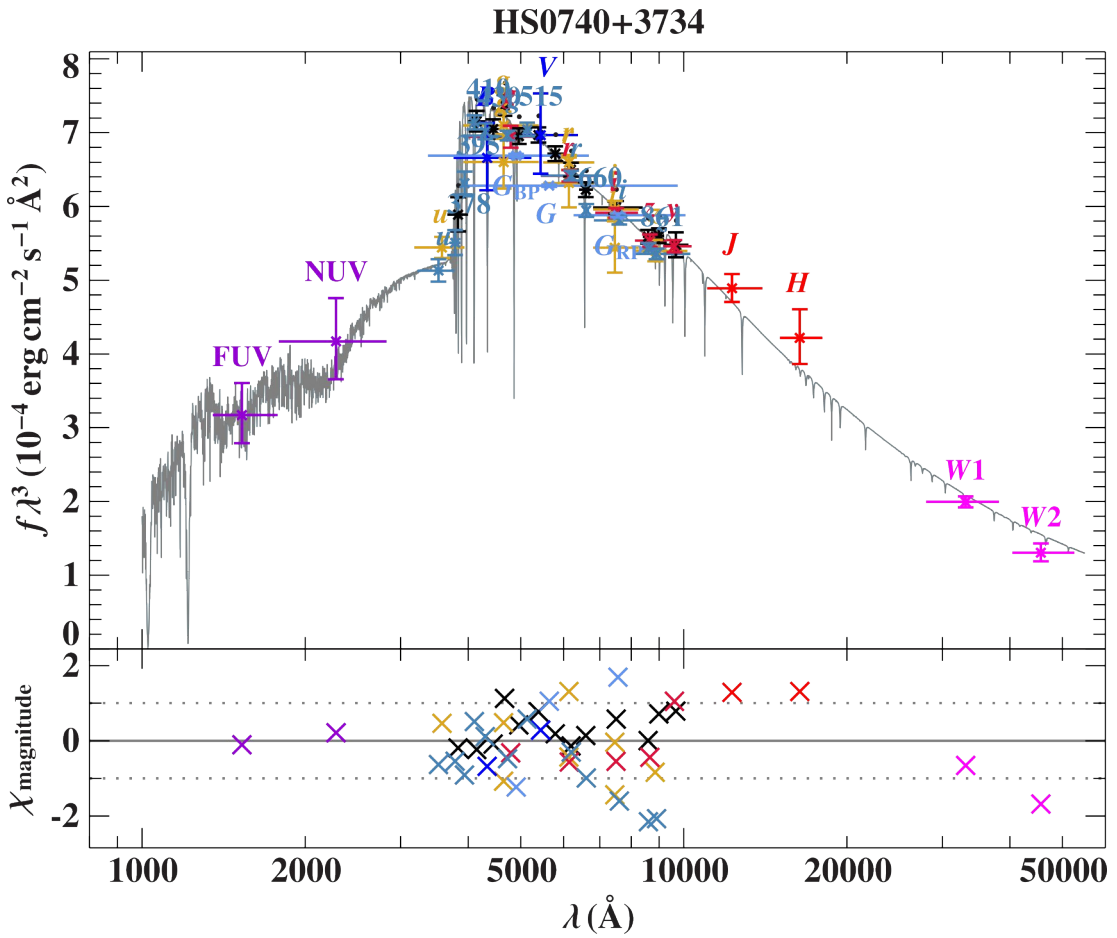
Goal: Atmospheric parameters T_{eff}, $\log g$ and $\log \mathrm{He/H}$ from spectra



Photometric analysis

- Spectral Energy Distribution (SED)
- Input $T_{\rm eff}$, $\log g$ and $\log {\rm He/H}$ from spectra

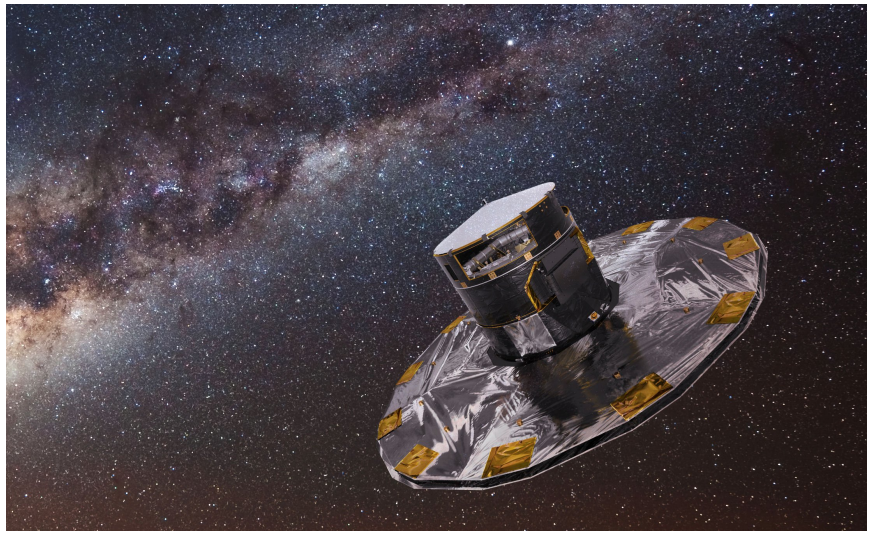
- Fit for:
  - Angular diameter θ
  - Colour excess $E(B-V)$



Parallax

- *Gaia*
  - DR3 (Jun. 13, 2022) parallax for 1.5 billion sources

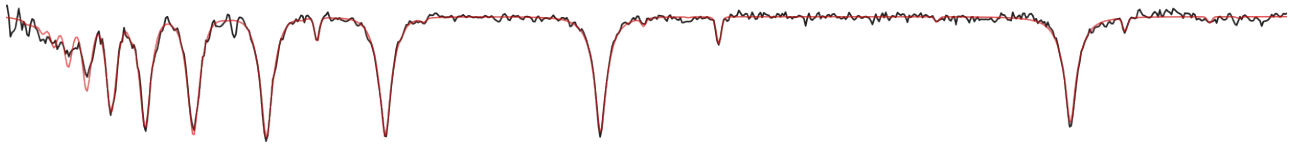
parallax → distance



ESA, 2013

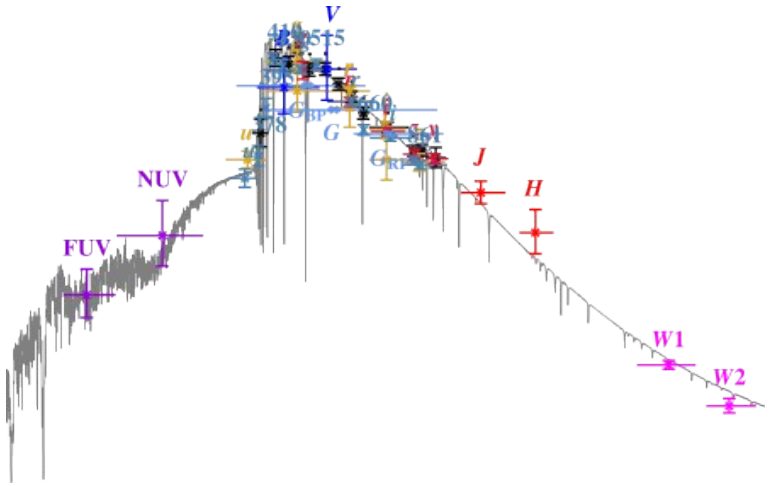
Stellar parameters

atmospheric parameters T_{eff}, $\log g$



+

angular diameter θ



+

parallax ϖ

ESA Gaia

=

Stellar parameters

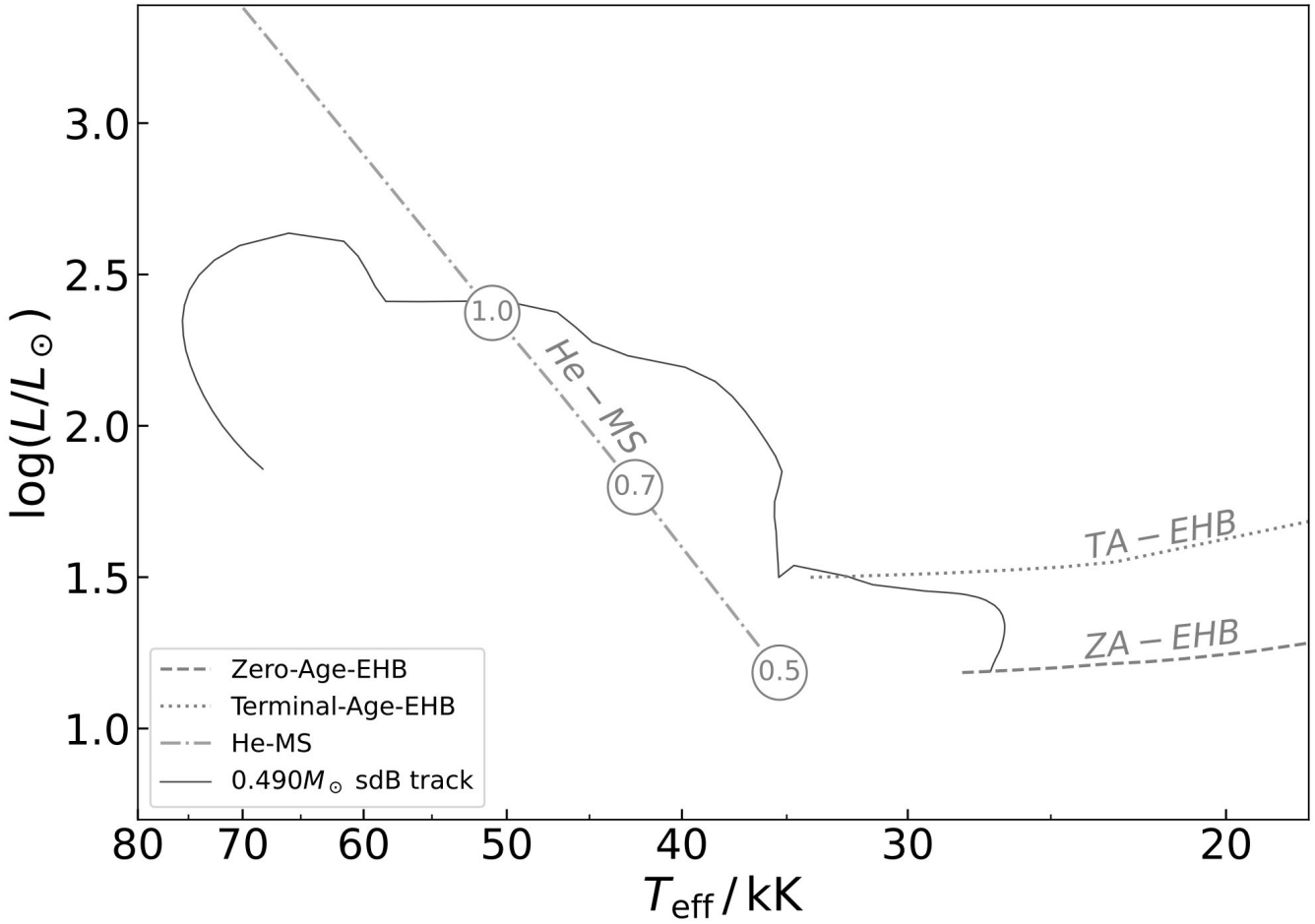
$$R = \frac{\theta}{2\varpi}$$

$$L = 4\pi\sigma R^2 T_{\mathrm{eff}}{}^4$$

$$M = g\,\frac{R^2}{G}$$

Luminosity *L*

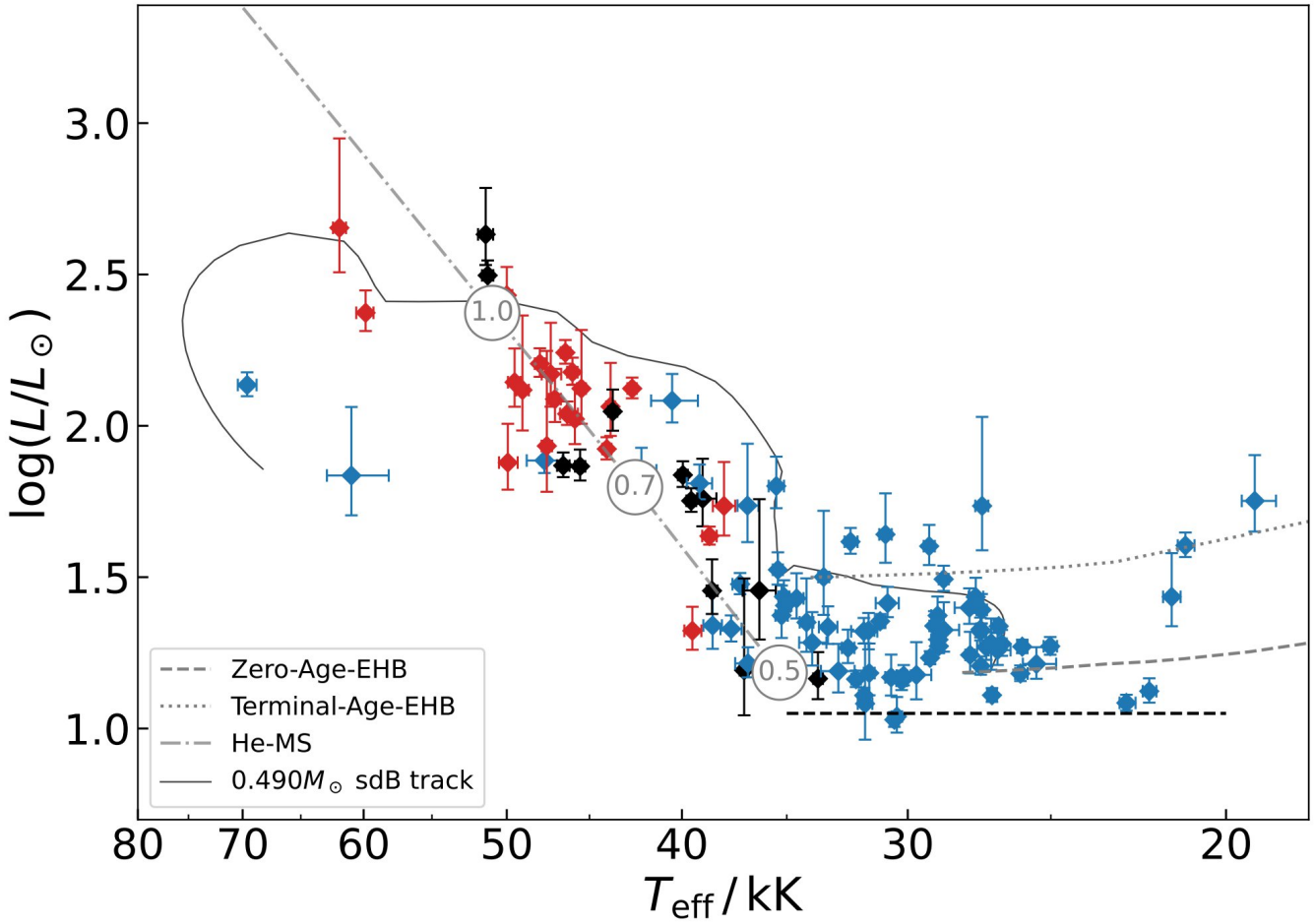
Hertzsprung-Russell diagram



Tracks: Dorman et al., 1993, Paczyński, 1971

Luminosity *L*

Hertzsprung-Russell diagram



helium-poor

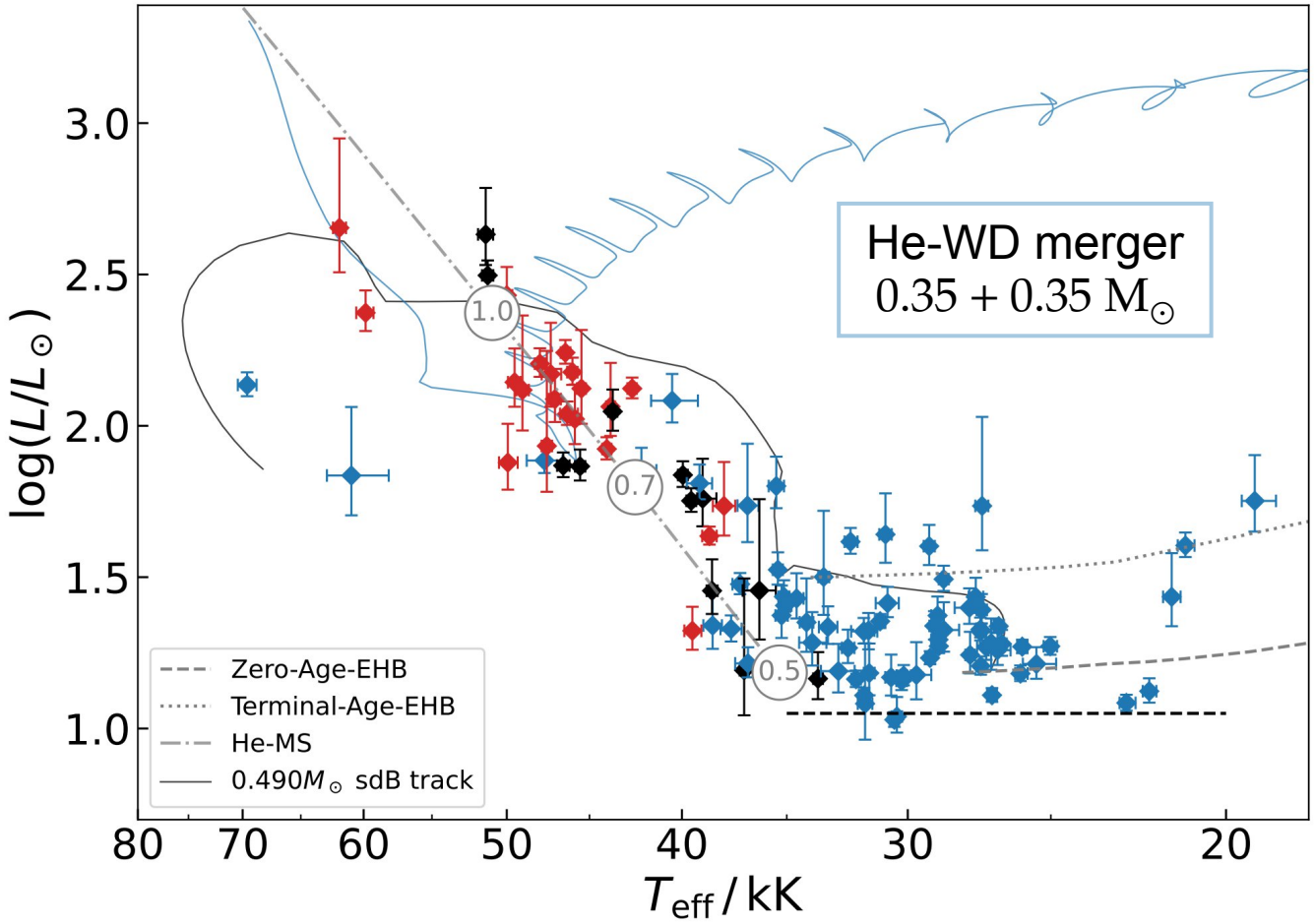
intermediate-helium

helium-rich

Tracks: Dorman et al., 1993, Paczyński, 1971

Luminosity *L*

Hertzsprung-Russell diagram



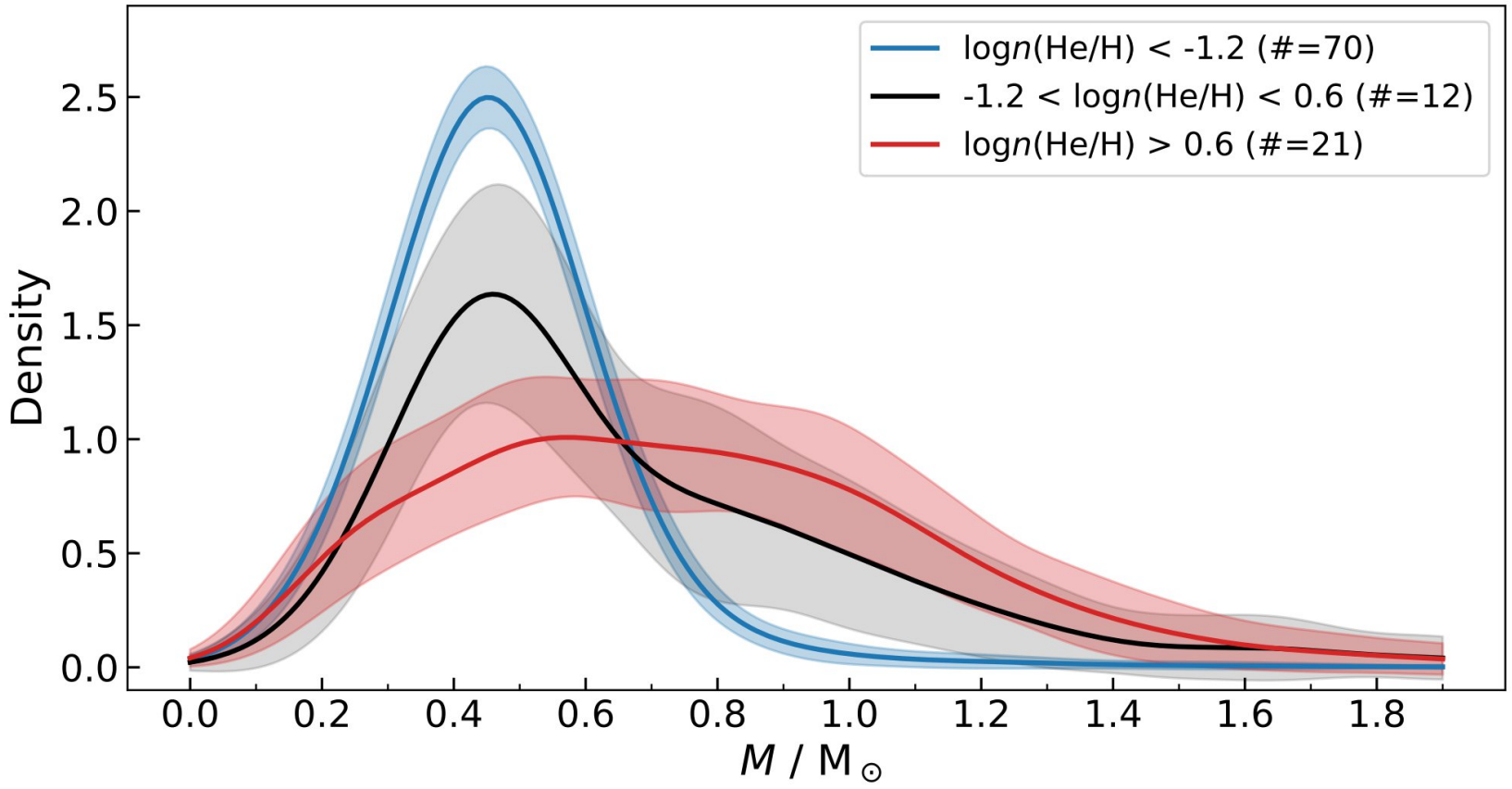
helium-poor

intermediate-helium

helium-rich

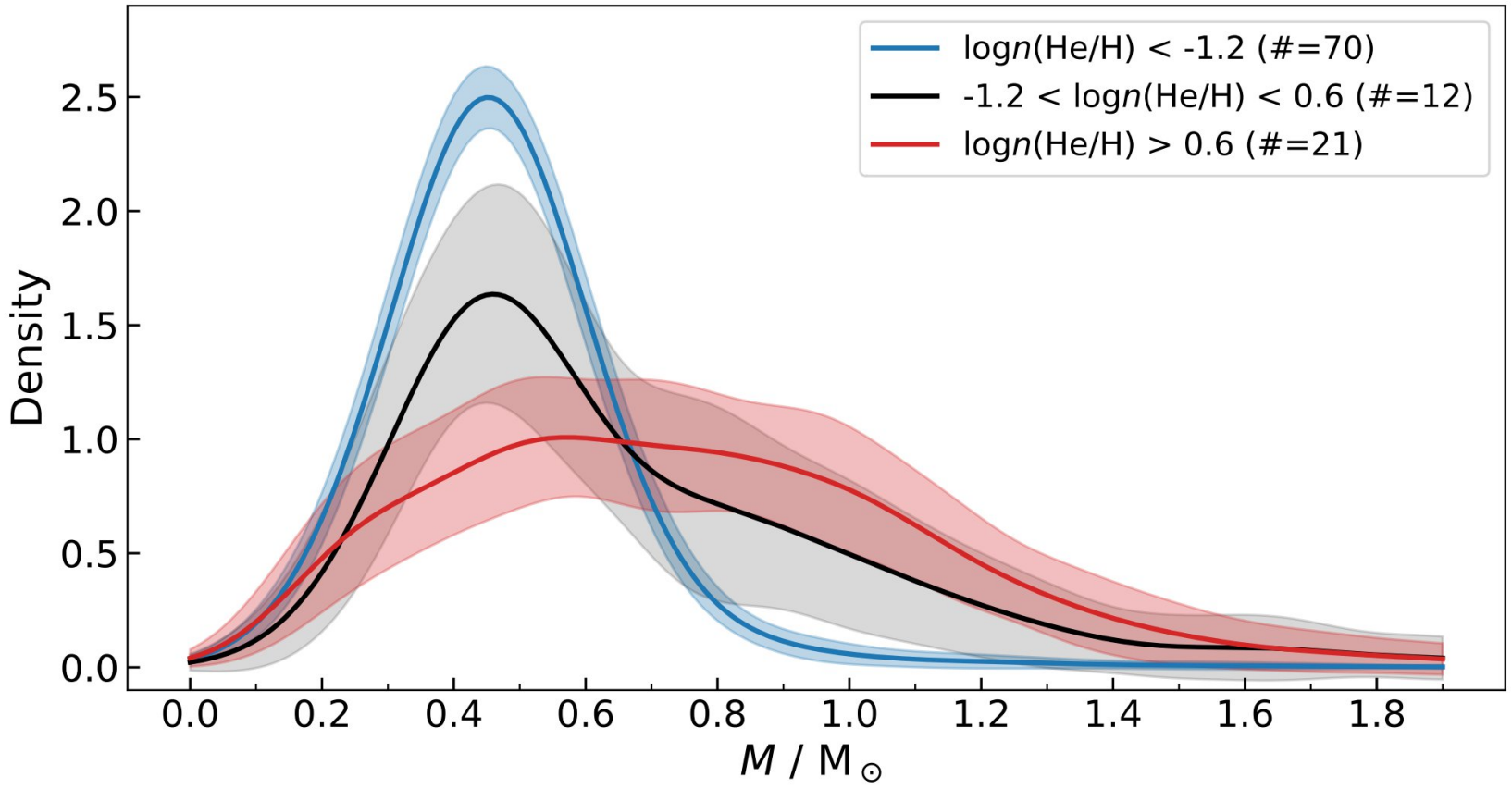
Tracks: Dorman et al., 1993, Paczyński, 1971, Yu et al., 2021

Mass distribution



helium-rich
0.70 $M_\odot$

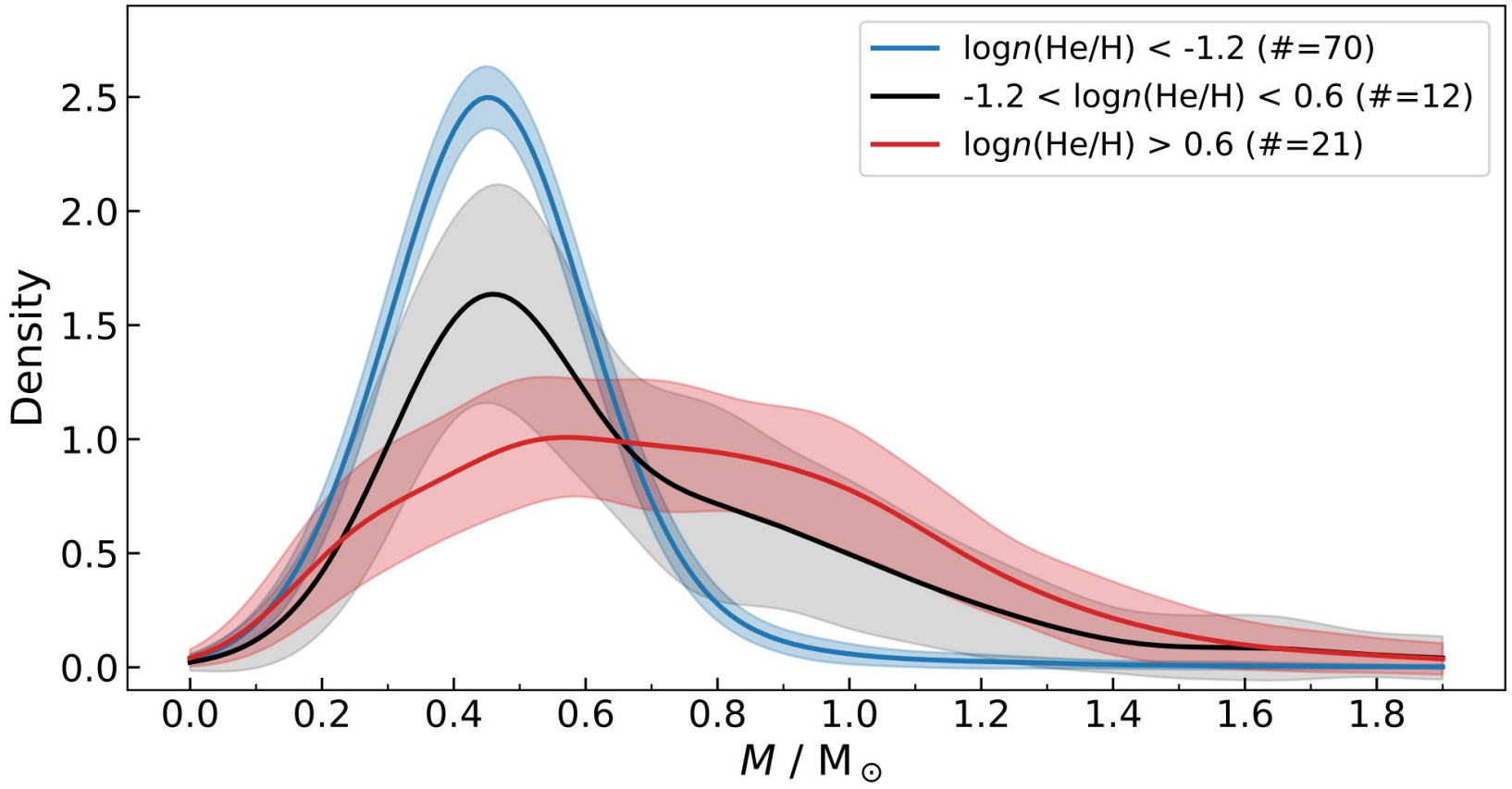
Mass distribution



helium-rich
$0.70\ \mathrm{M}_\odot$

Typical He-WD: $0.2 - 0.45\ \mathrm{M}_\odot$

Mass distribution

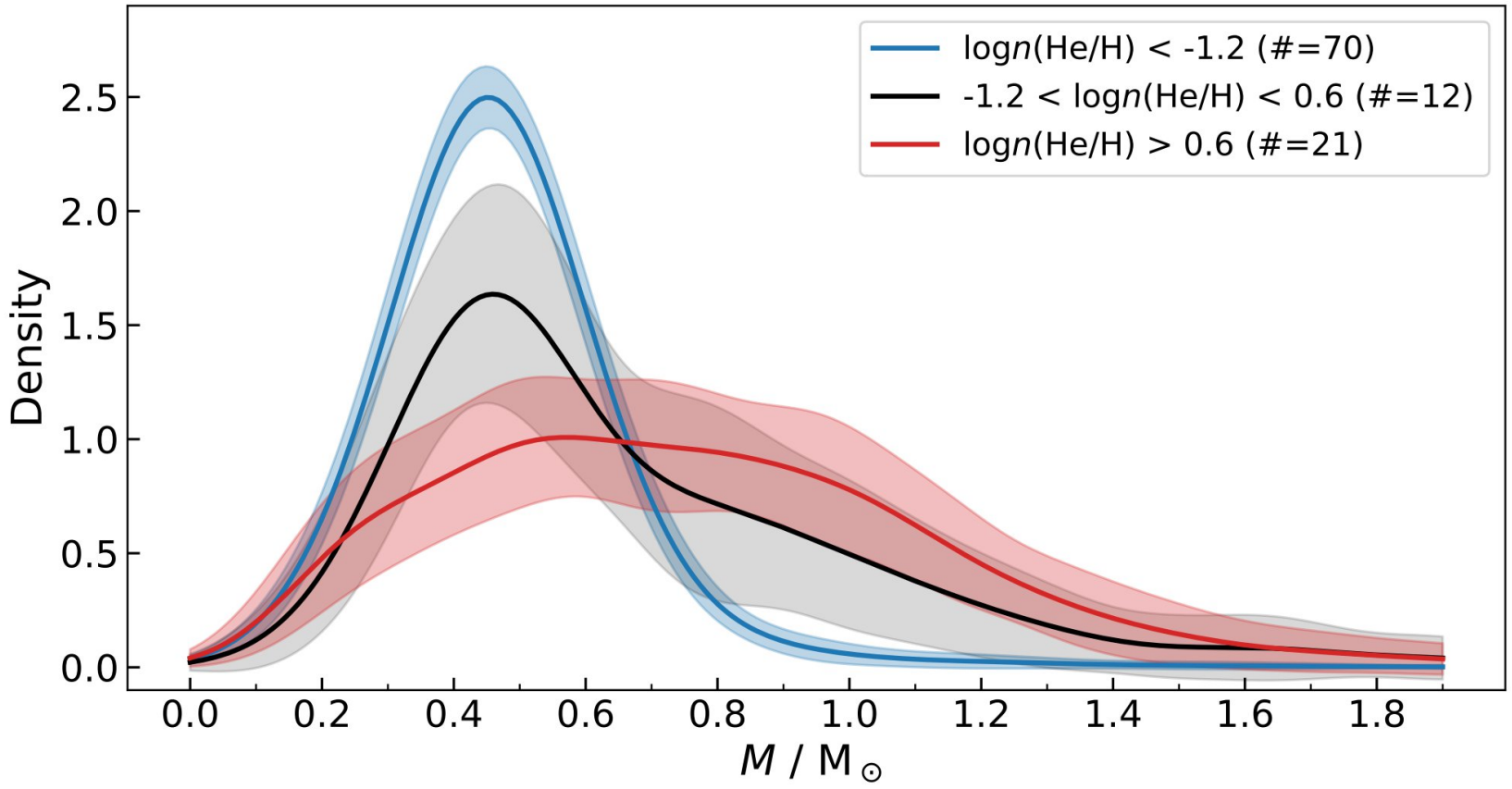


helium-rich
$0.70\ \mathrm{M}_\odot$

Typical He-WD: $0.2 - 0.45\ \mathrm{M}_\odot$

→ He-WD mergers?

Mass distribution



helium-rich
$0.70\ \mathrm{M}_\odot$

Typical He-WD: $0.2 - 0.45\ \mathrm{M}_\odot$

→ He-WD mergers?

C/N abundance?

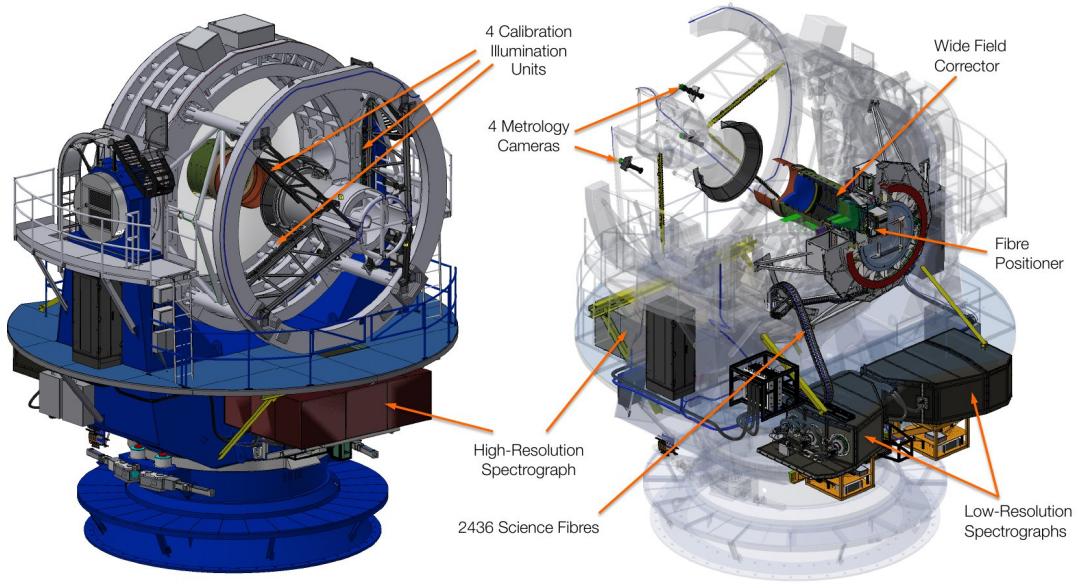
Summary

- Gaia parallaxes, spectroscopy and photometry
  - Mass distribution → extreme He-rich subdwarfs from He-WD mergers

- The future
  - Gaia DR4 ~ Dec. 2026
  - Spectroscopic survey 4MOST

    → Large samples

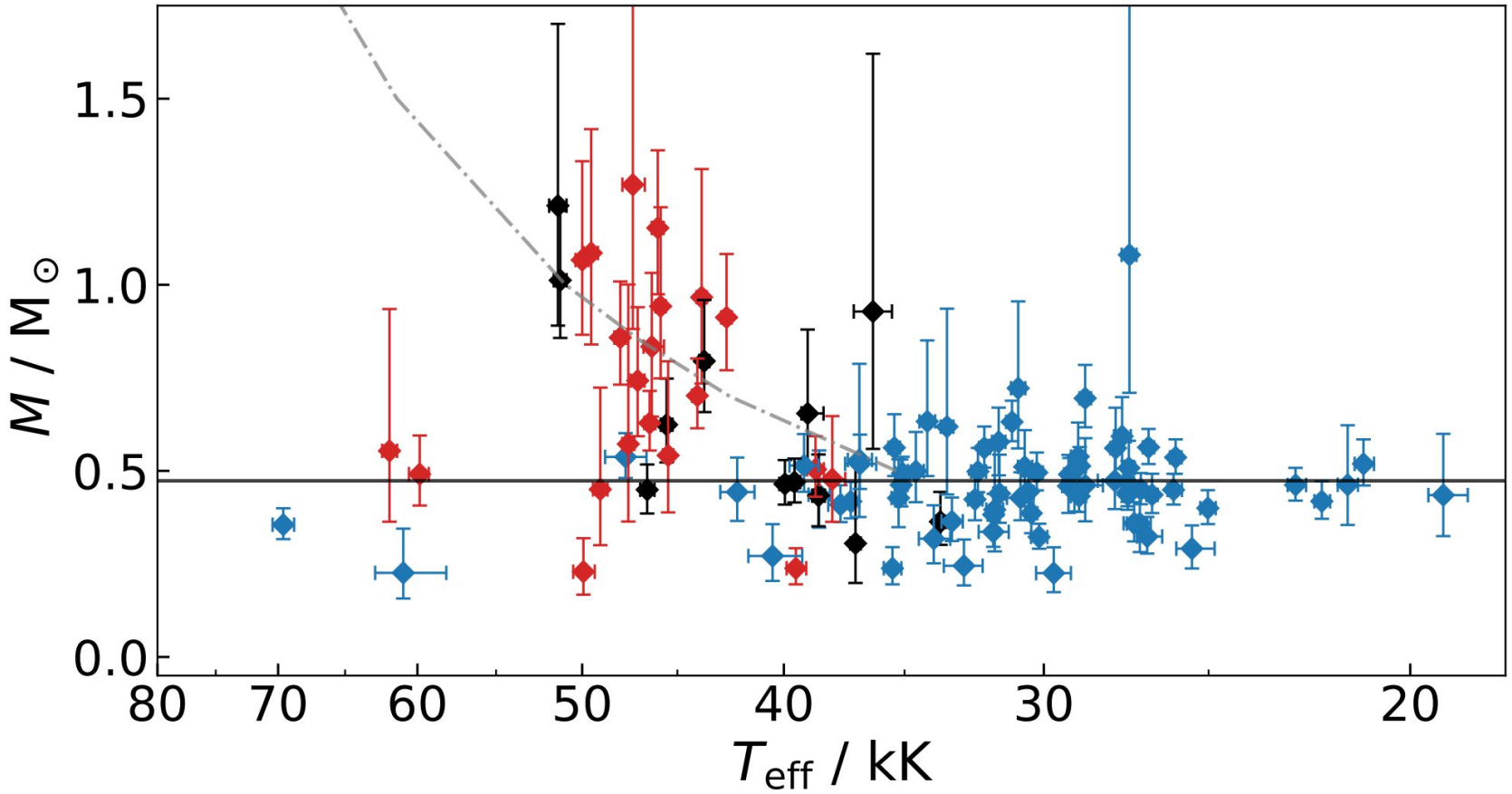
  Splinter Wed. & Thu.



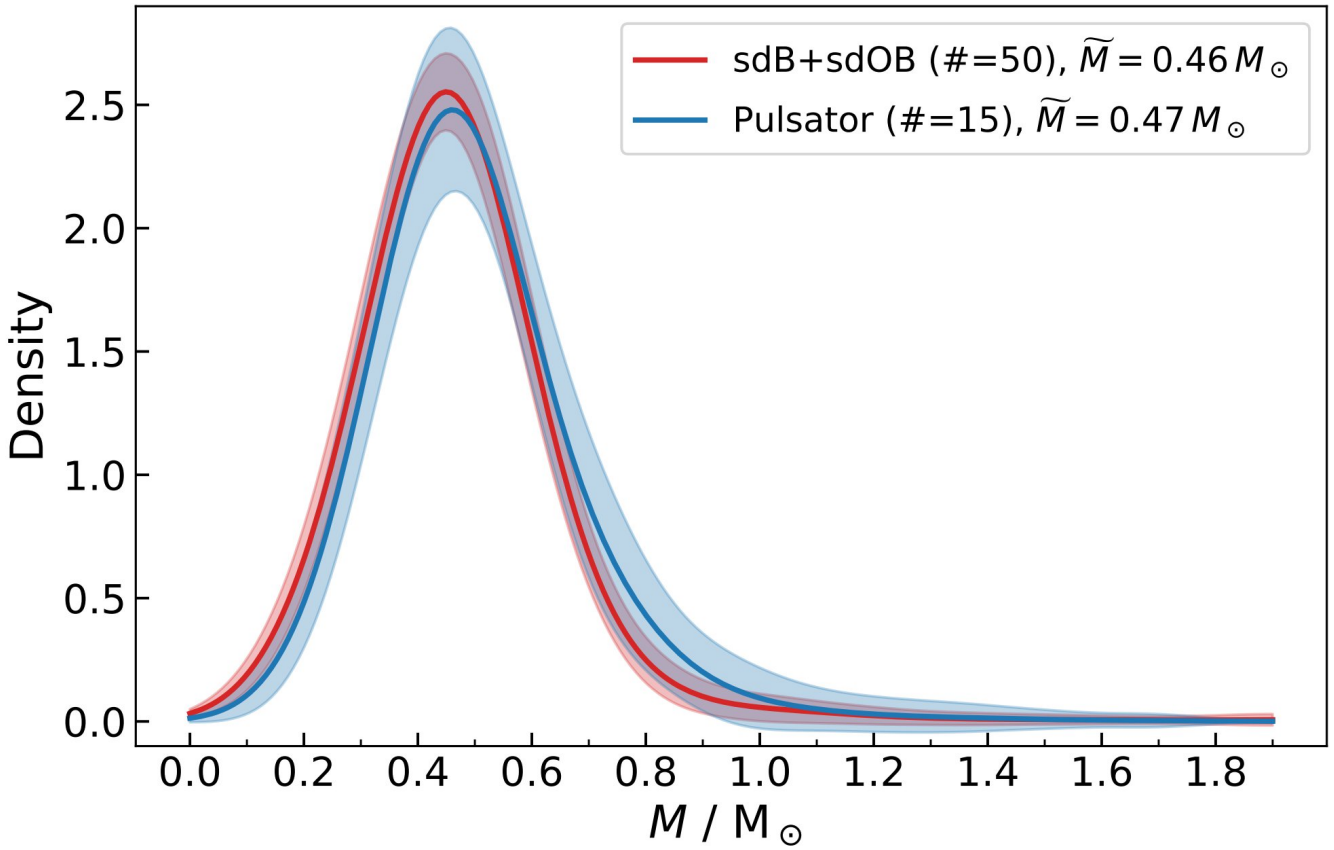
Thank you for your attention!

Backup

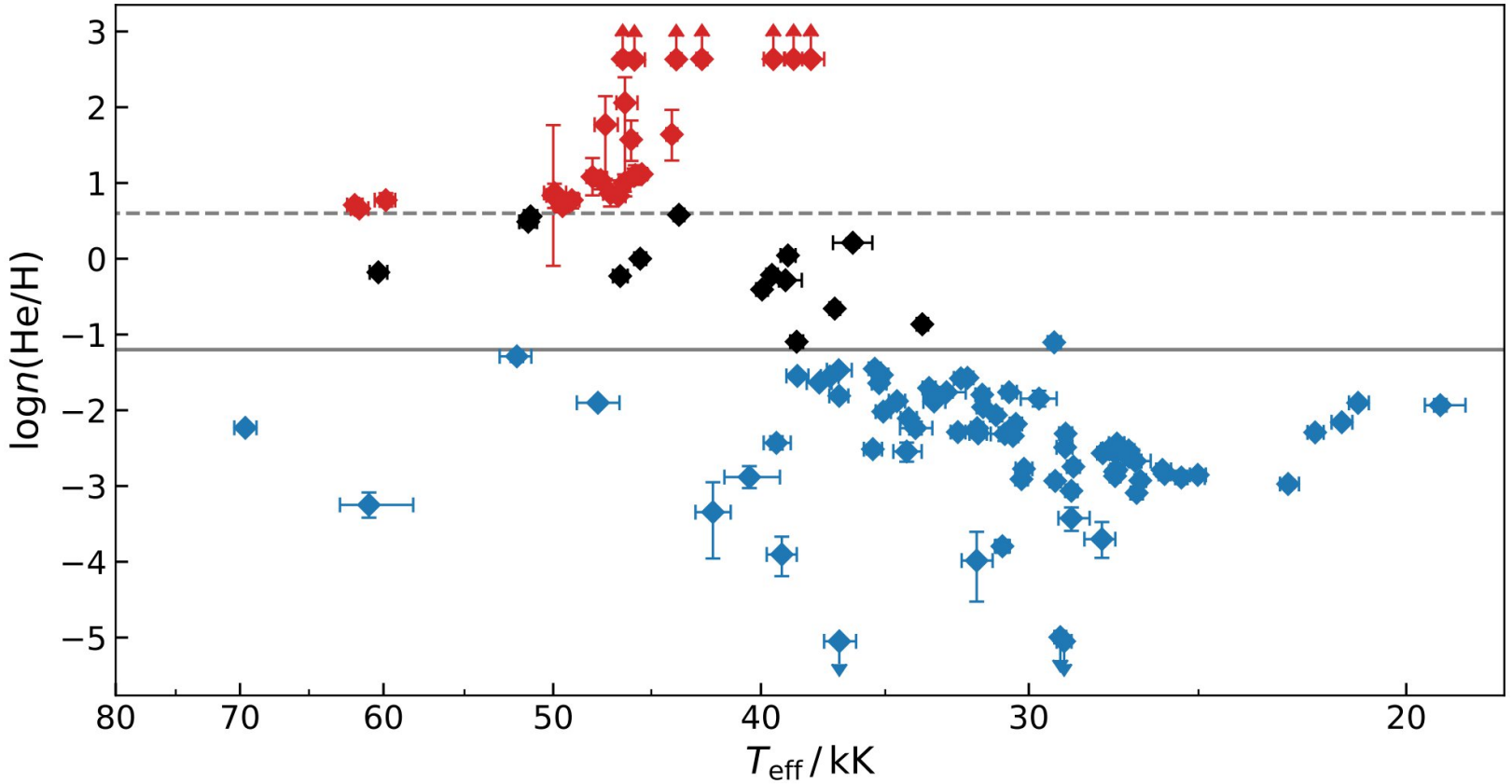
- Canonical mass $0.47\ \mathrm{M}_{\odot}$



Backup

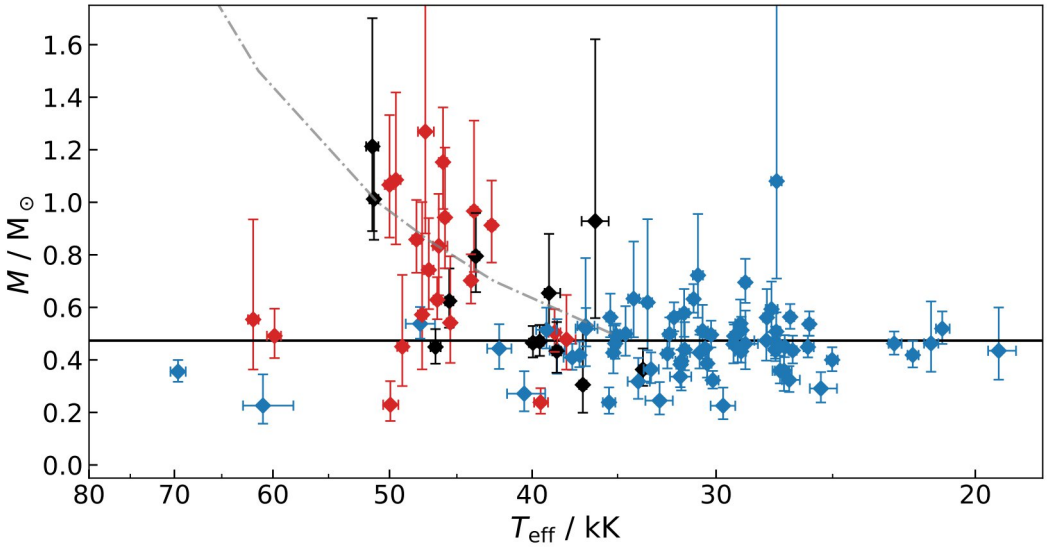

sdB+sdOB (#=50), $\widetilde{M} = 0.46\,M_\odot$
Pulsator (#=15), $\widetilde{M} = 0.47\,M_\odot$
Density
0.0
0.5
1.0
1.5
2.0
2.5
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
M / $M_\odot$

Backup

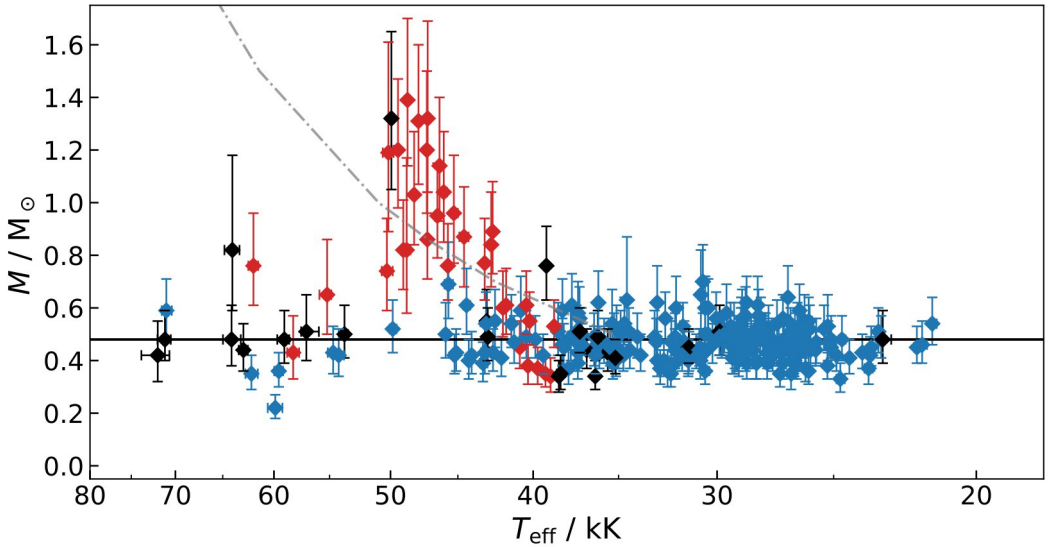


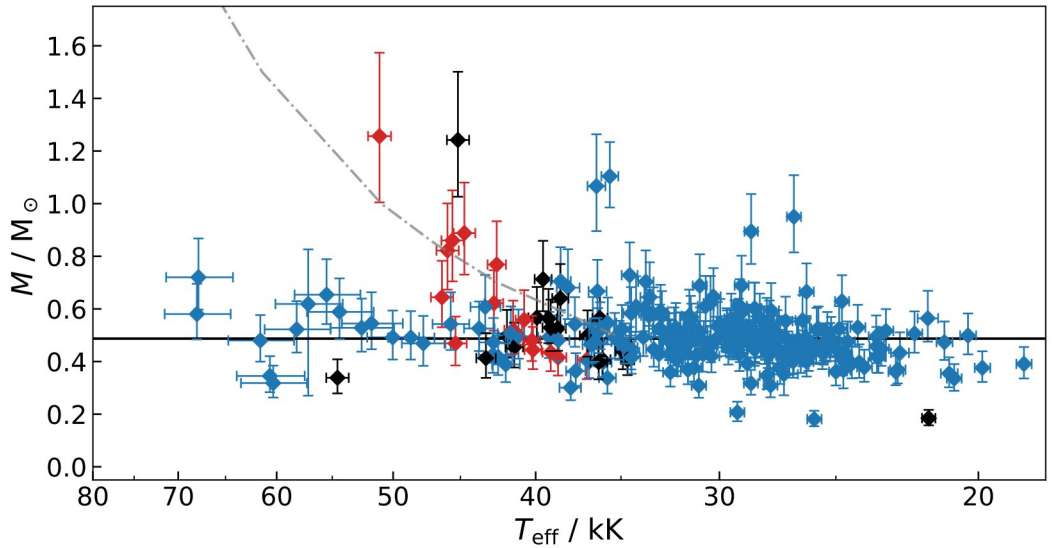
Backup

HQS



Latour, 2026





Dawson, 2026