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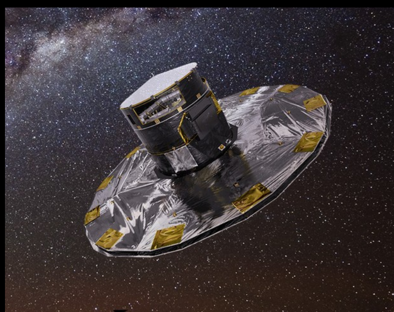
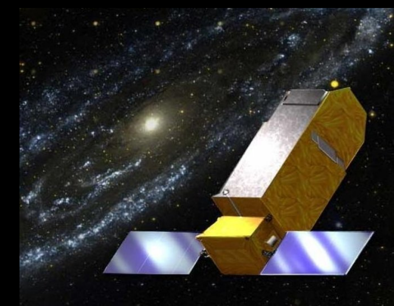
Science & Technology Facilities Council

The white dwarf mass-radius relation with Gaia, Hubble and FUSE





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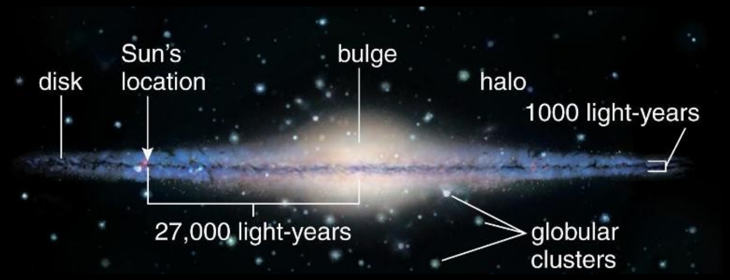
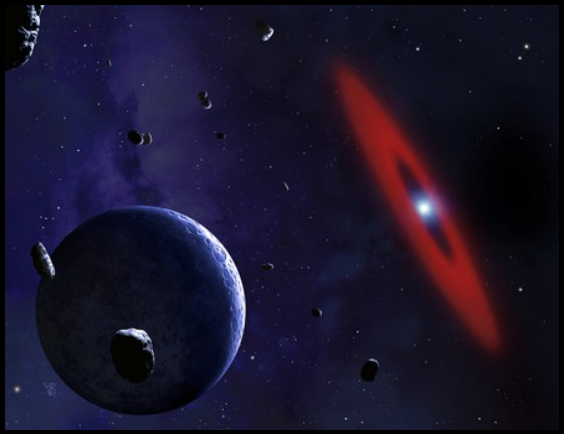
Why are white dwarfs interesting?

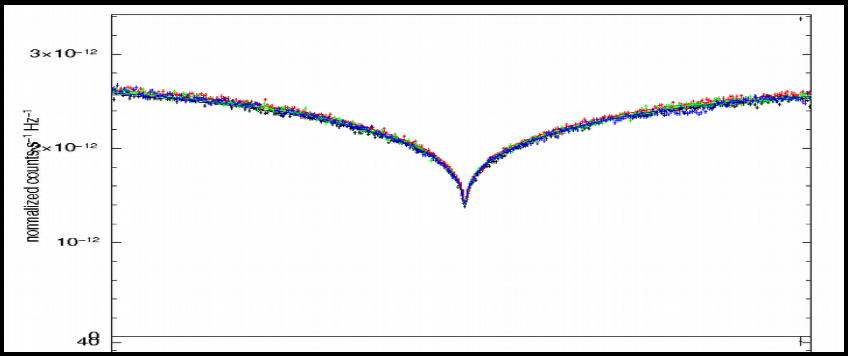
Cosmochronology : Using the temperature of a white dwarf to find its age, and the ages of associated stars.



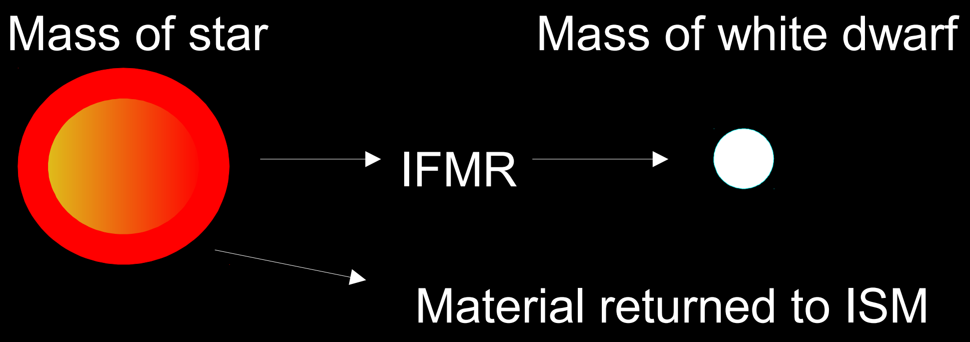
Potential to study the elemental composition of exoplanet systems.



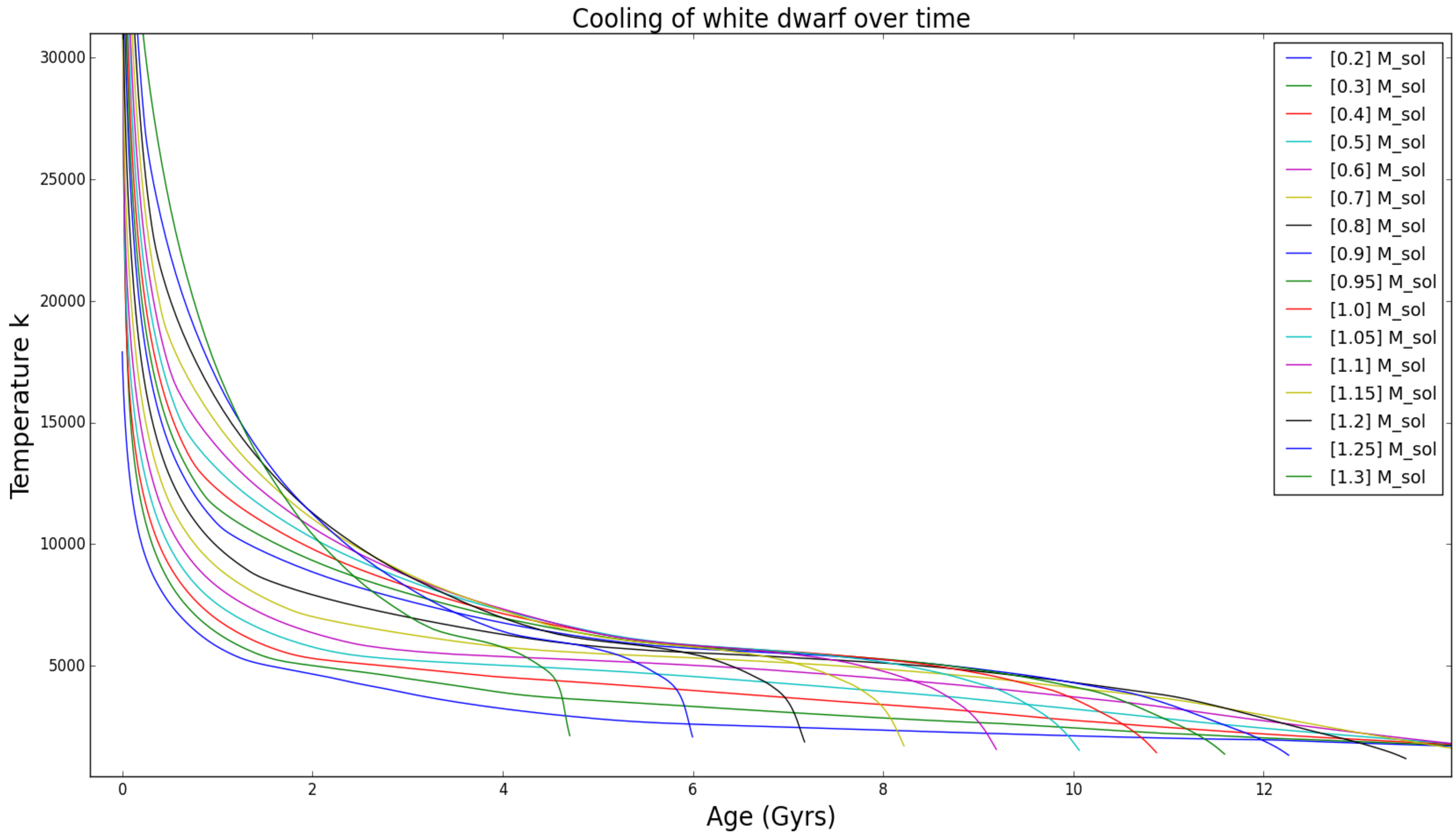
Natural laboratory for physics in a high gravity environment



The initial-final mass relation and chemical evolution of the galaxy.

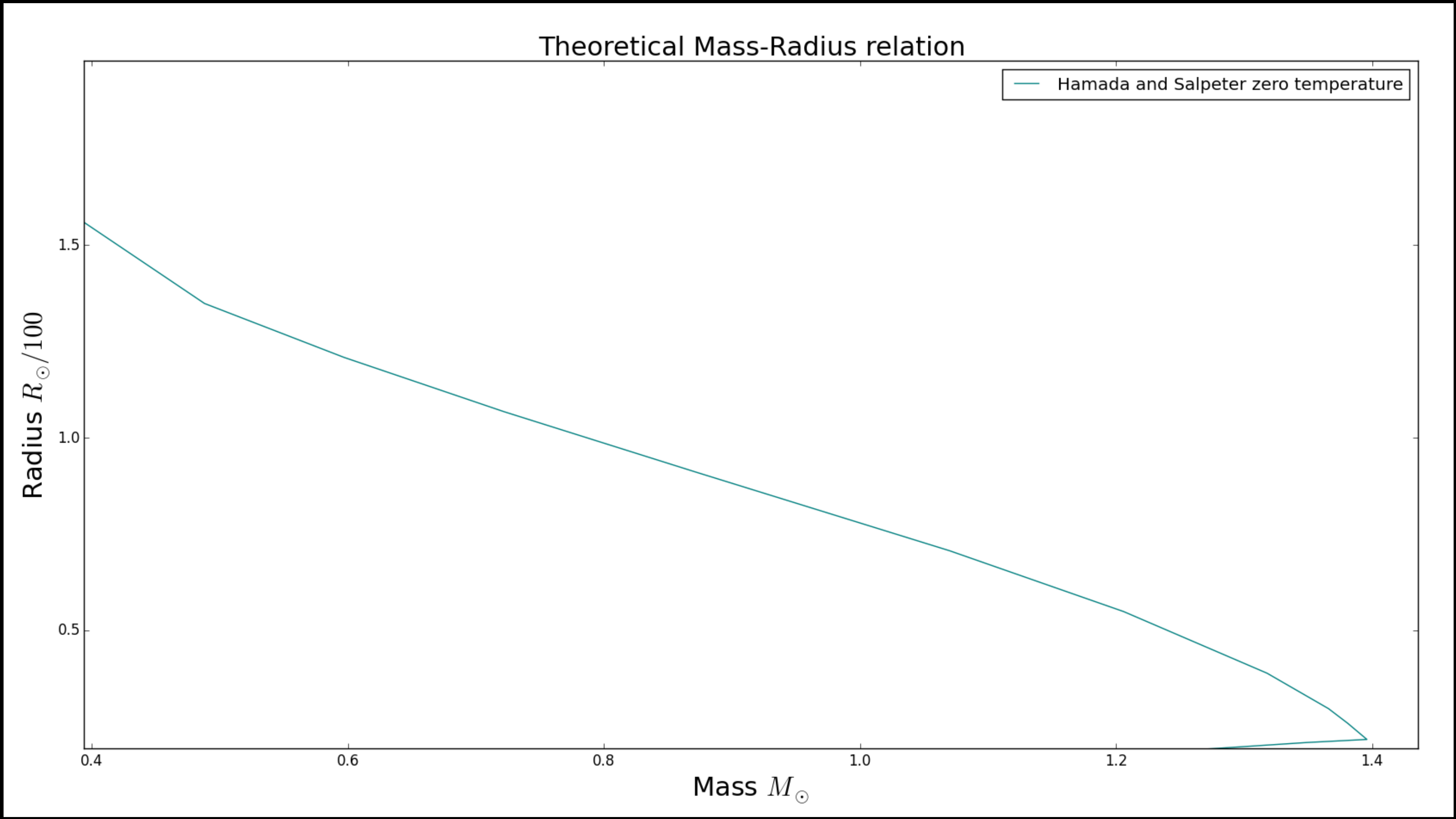


White Dwarf Cosmochronology : Using the temperature of a white dwarf to find its age, and the ages of associated stars.



Fontaine, Brassard, & Bergeron (2001, PASP, 113, 409)

The white dwarf mass-radius relation



Hamada & Salpeter 1961, ApJ, 134,683

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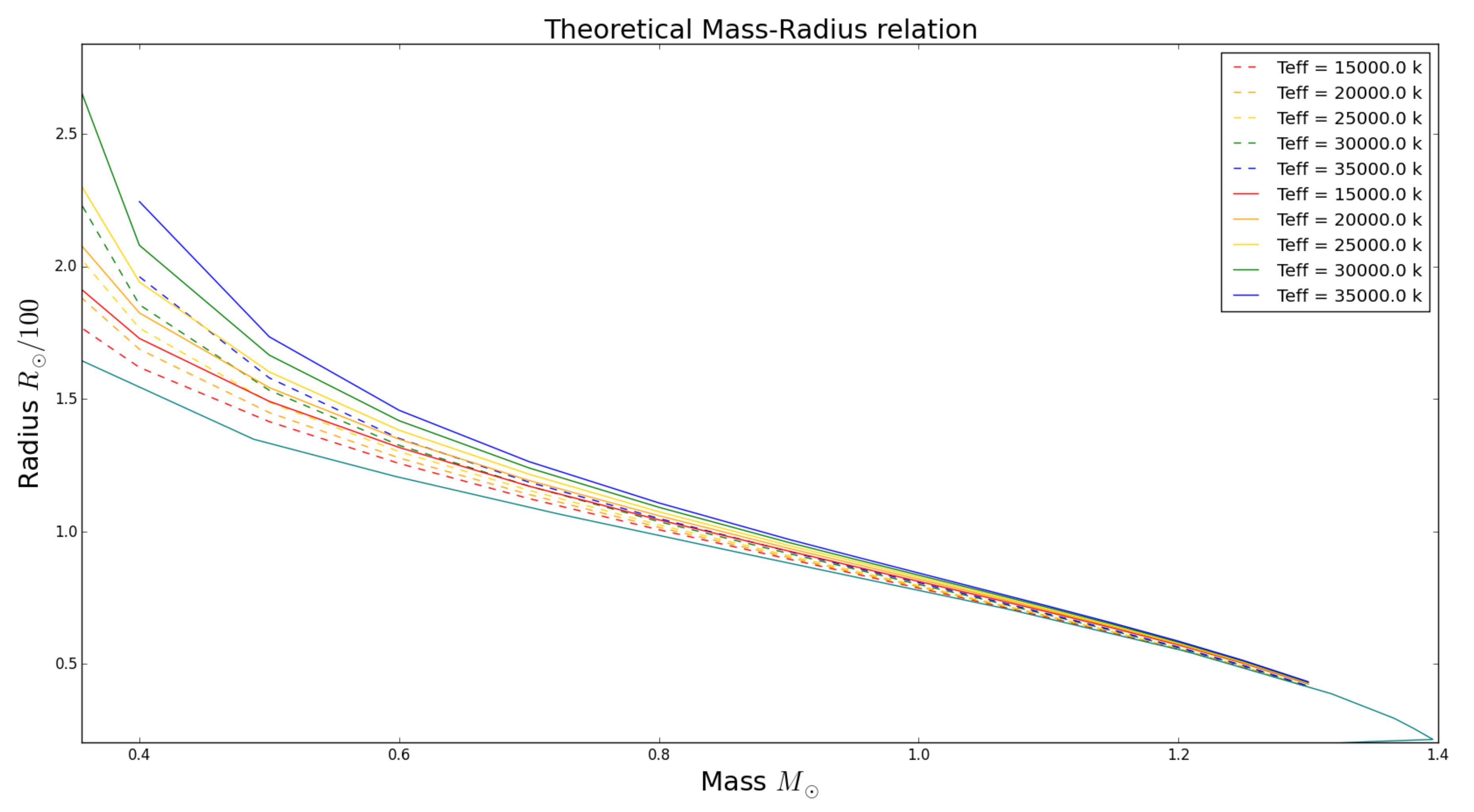
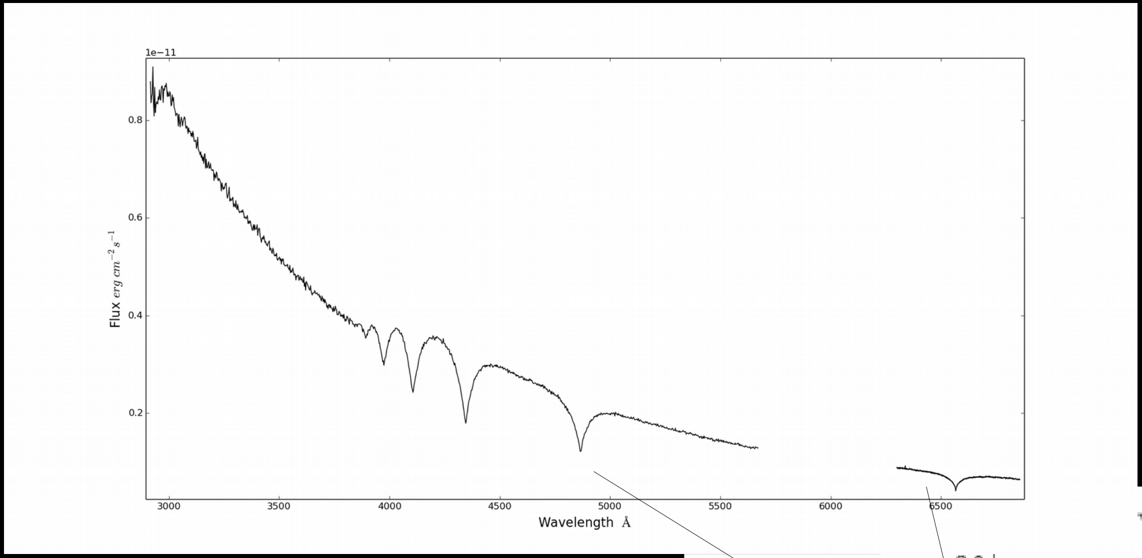
Refinements to the white dwarf mass-radius relation



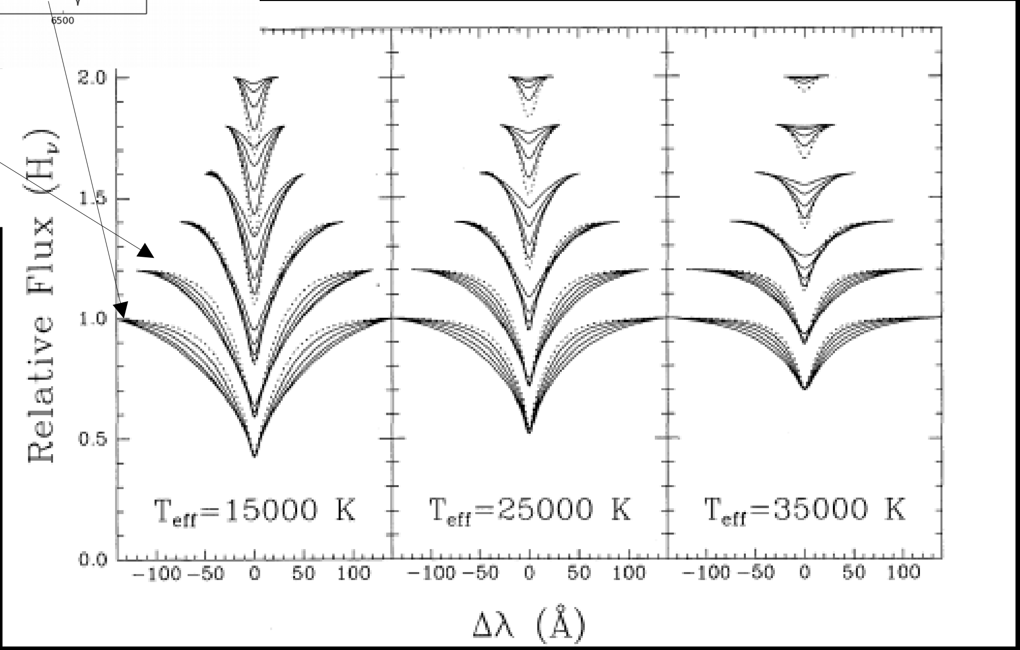
Solid line = thick hydrogen layer,   dashed line = thin hydrogen layer

Fontaine, Brassard, Bergeron, 2001, PASP, 113, 409

How to measure the mass of a white dwarf
The spectroscopic method



Hubble spectrum of Balmer lines of Sirius B



Strong gravitational field causes broadening of the hydrogen lines.
The value of log g is found by fitting a spectral model to the data.

Figure from Bergeron et al 1992 ApJ, 394, 228

Why is the distance measurement so important?

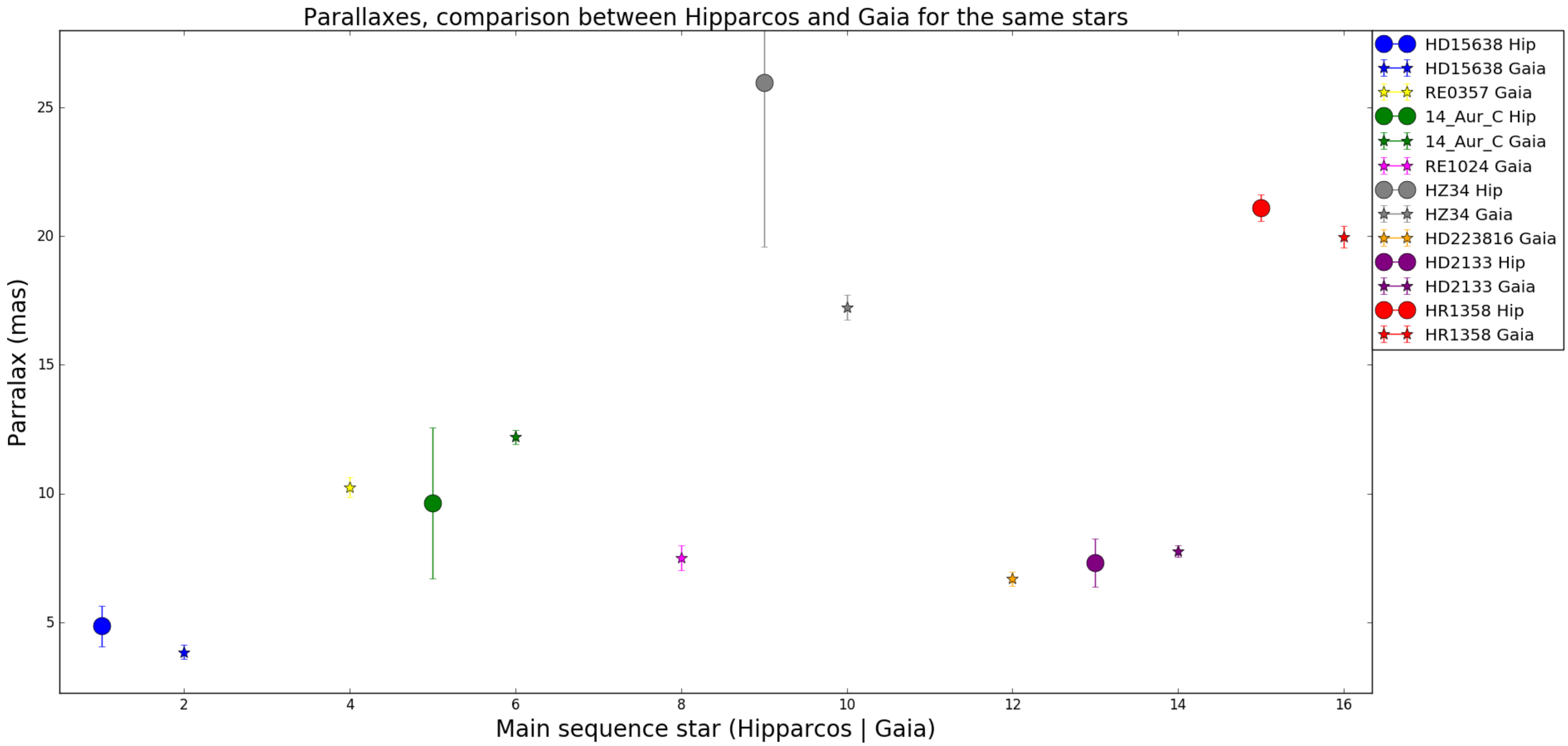
Gaia parallax - distance

$$R = \sqrt{\left(\frac{D^2 \times norm}{1e\text{-}20}\right)} \div R_{sol}$$

$$M = \frac{gR^2}{G}$$

From spectral model fitting:
Normalisation
Log g

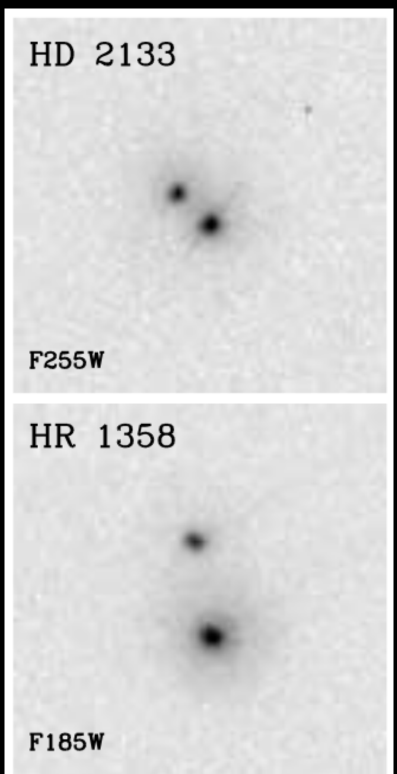
How good are the pre-Gaia distance measurements?

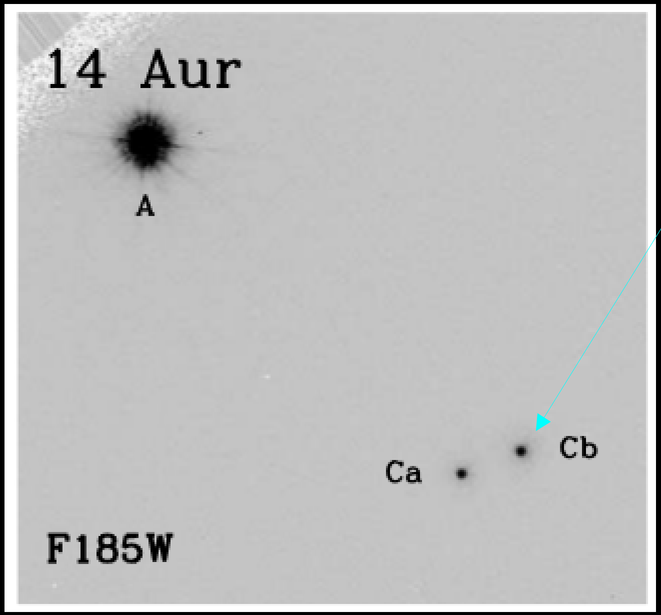


The advantages of Sirius-like binaries

How can Sirius-like binaries help?
: The initial Gaia data release (DR1) only contains parallaxes for a few WD's.

: For Sirius-like binaries we can take the distance of the main sequence companion star to be the same as the distance for the WD. Many more of these MS stars are included in DR1.





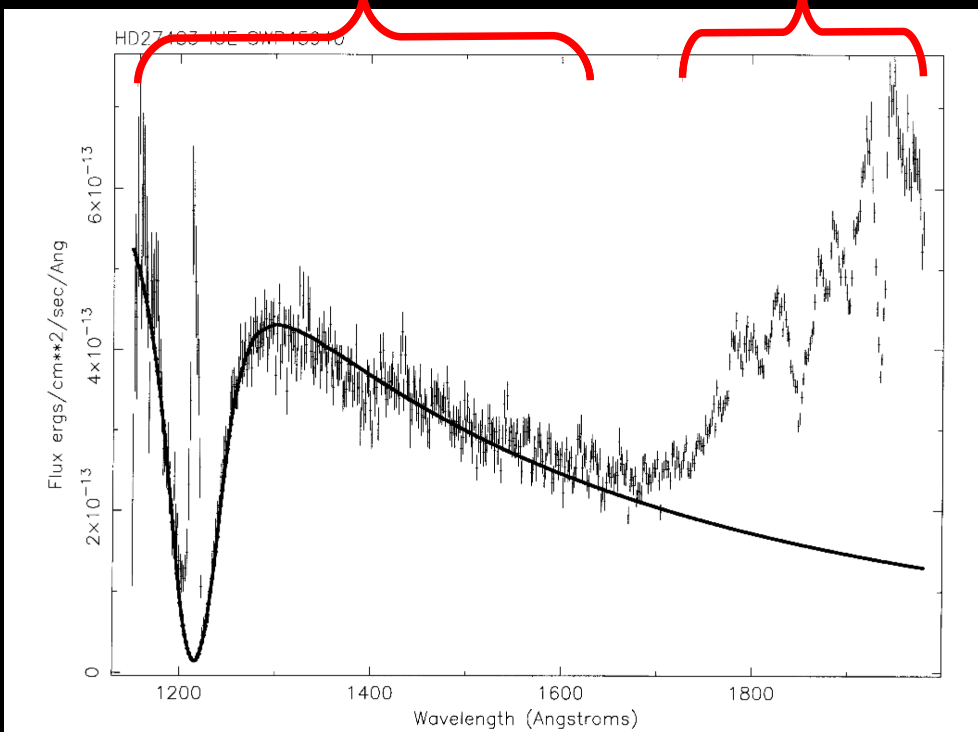
WD in a multiple system resolved with HST

Barstow et al 2001, MNRAS, 322, 891

The benefits of Lyman lines

UV excess caused by the white dwarf.

Emission from the F6V main sequence stars.



At the wavelength range of the Lyman lines there is minimal contamination from the main sequence companion.

Balmer lines can only be used if the WD can be resolved and an uncontaminated spectrum obtained.

Burleigh, Barstow and Holberg 1998, MNRAS, 300, 511

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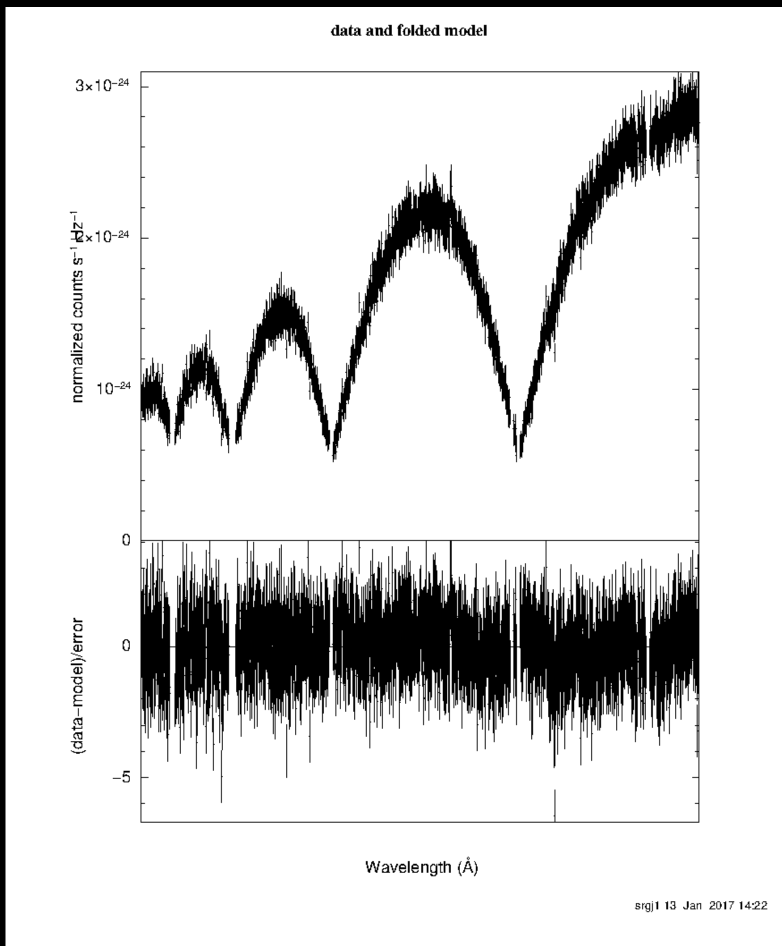
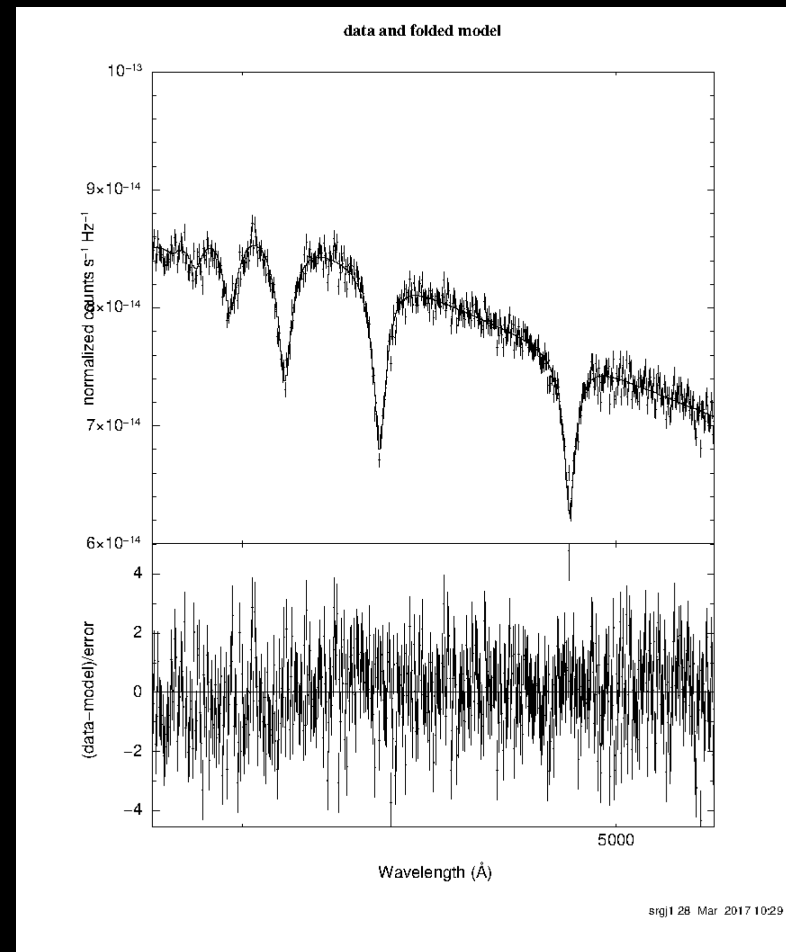
Example of Lyman and Balmer spectra for HZ43

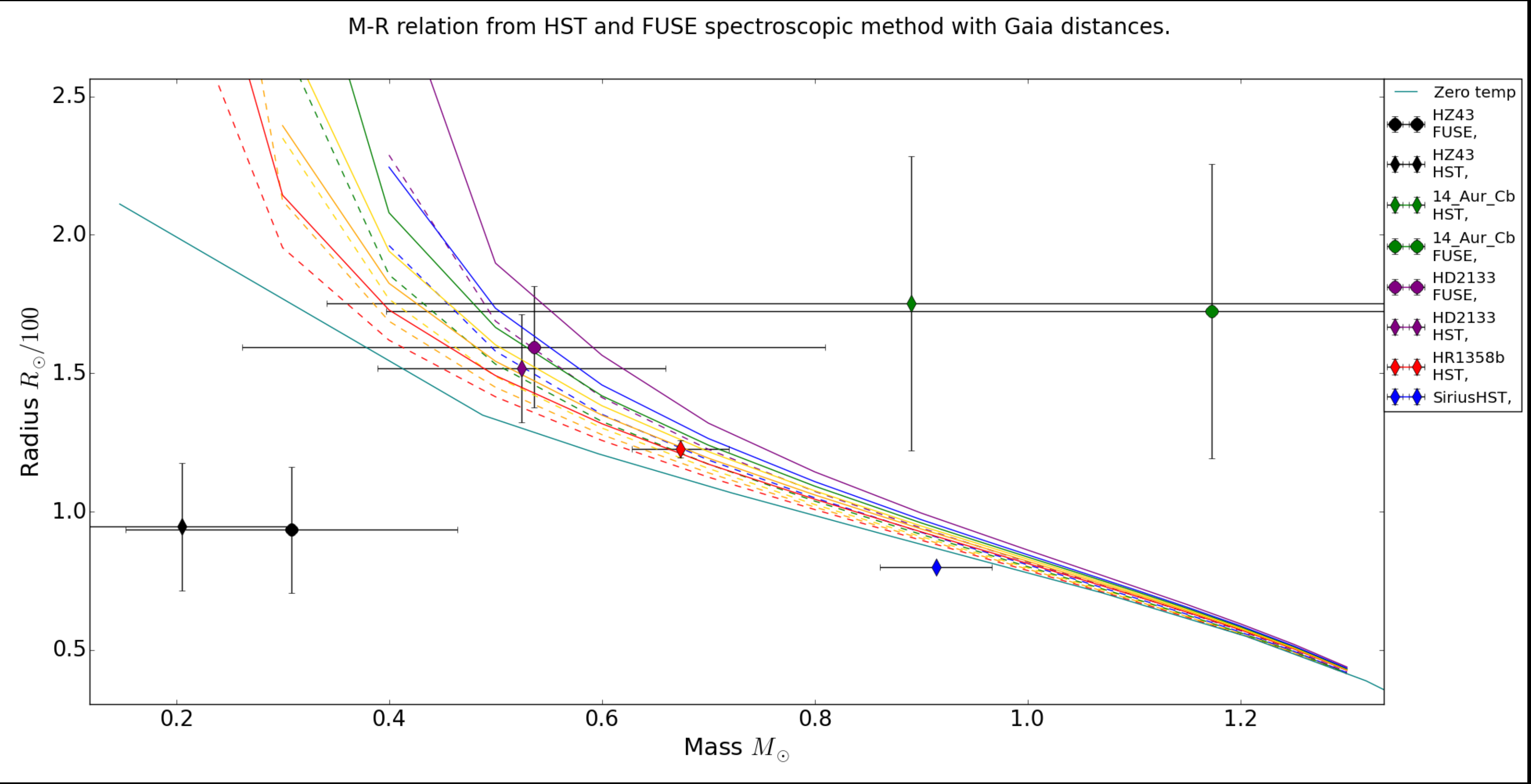


FUSE Lyman line spectrum

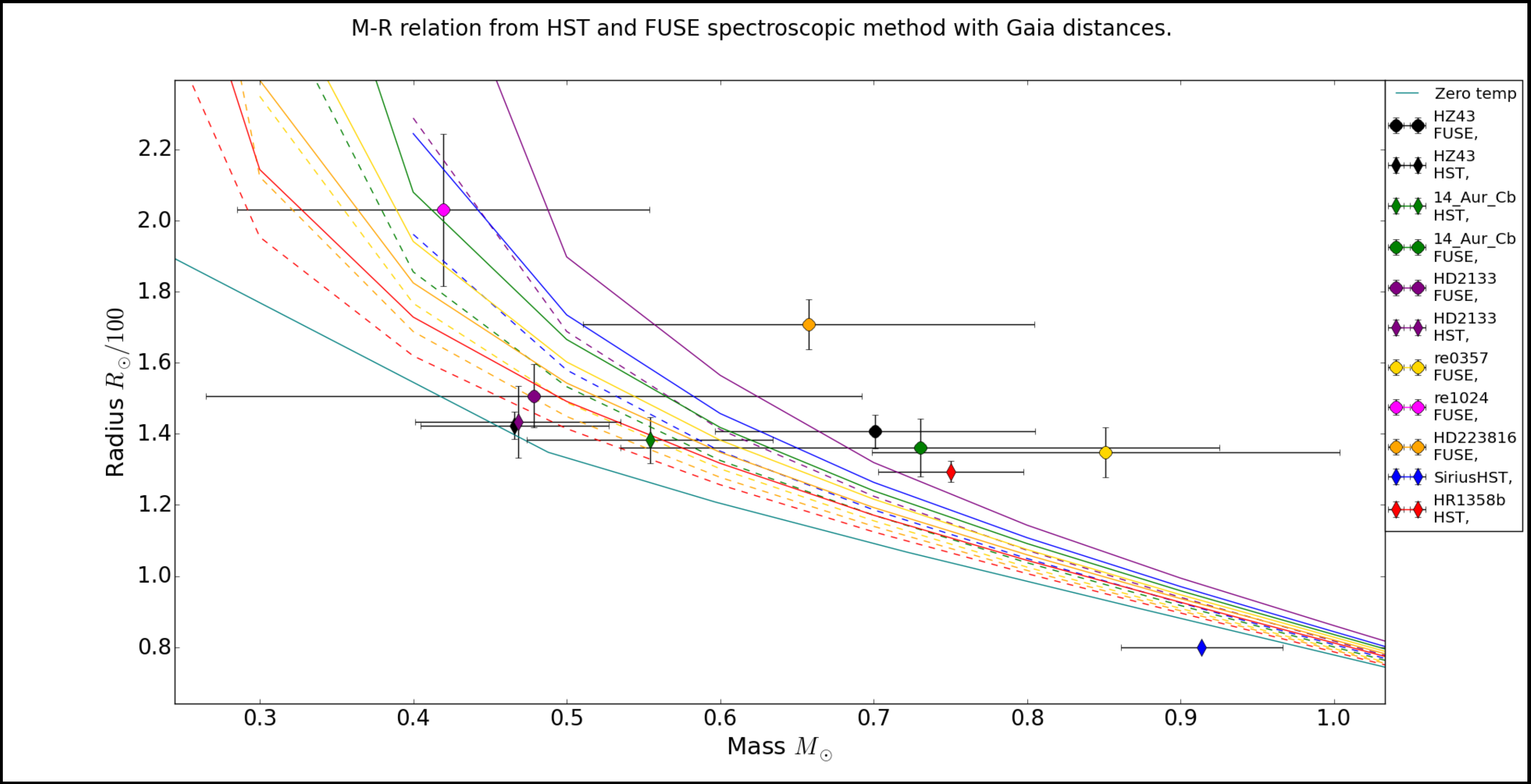


HST Balmer line spectrum

The Mass-Radius relation using Hipparcos parallaxes



The Mass-Radius relation using Gaia parallaxes



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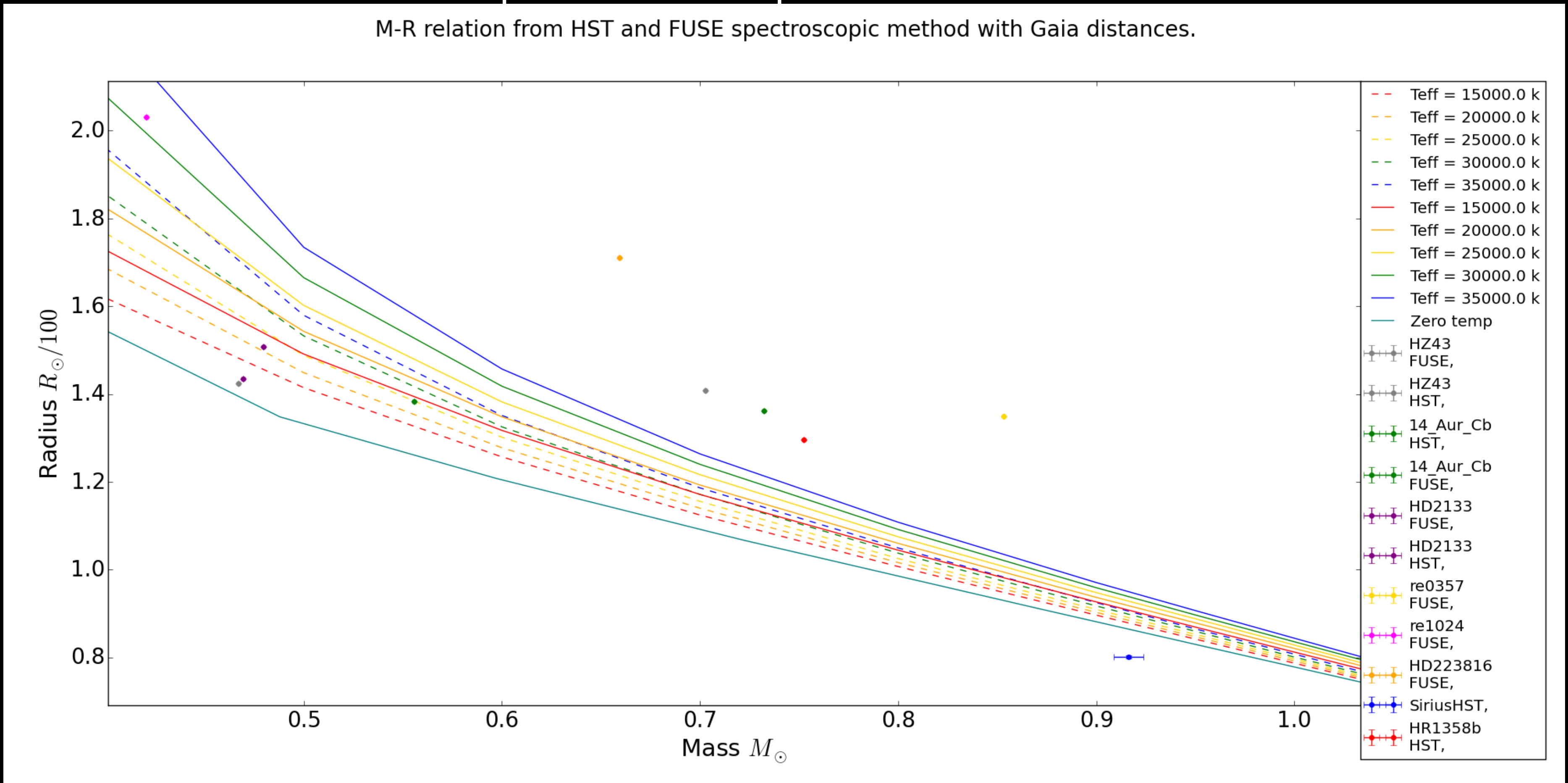
How accurately can we expect to measure distances in the future?

For this sample, the average parallax error in DR1 is 0.39 mili arc sec.

The final data release is expected to have parallax error of ~6.7 micro arc sec.



Conclusions and future plans

- The distances from Gaia have removed much of the scatter in the observed mass-radius data and show that the overall form of the MRR is correct.
- The improved accuracy of the white dwarf distances in later data releases will allows us to begin to truly test the theoretical mass-radius relation at an accuracy level where temperature and H layer thickness in the models can be distinguished.
- The limiting factors contributing to uncertainty in the M-R mesurements are the reliability of the spectral fitting and log g determination.
- A comparison of results from Lyman and Balmer lines shows that there may be an unexplained systematic offset.
- It will be important to quantify the remaining sources of error and develop the gravitaional redshift method to the required level of accuracy to take full advantage of the Gaia data.