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Stefan Jordan, Enrique García-Berro, Santiago Torres & Jordi Isern, Martin Barstow, Matt Burleigh, Tom Marsh, Roberto Silvotti (WGB6 "Endstates of stellar evolution")

GAIA, White Dwarfs & 4MOST

The case for massive ground-based follow-up spectroscopy

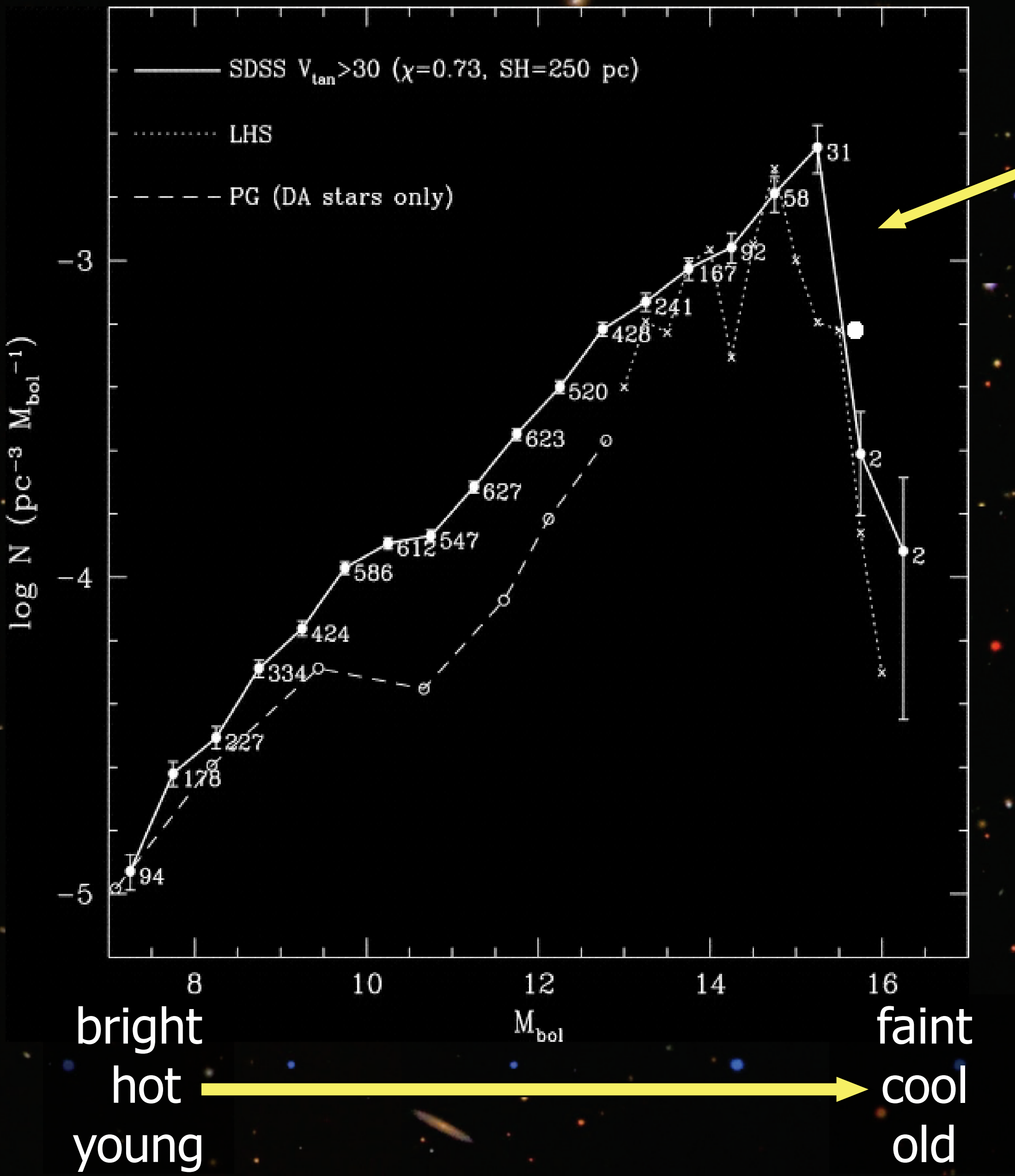
Science with 4MOST, Nov 13-15 2012

Asteroarcheology

- Galactic archeology is one of the key projects of GAIA
- ~95% of all stars end as white dwarfs
- Teff ⇒ cooling age ⇒ (stellar models) ⇒ total age

  ⇒ The 7th dimension - Time
- Key population to probe star formation history

White Dwarf Luminosity Function



Cut-off at faintest, coolest, oldest white dwarfs

Cut-off in the white dwarf luminosity function due to the limited age of the Galaxy

Even the oldest white dwarfs (9-11 Gyrs) are still visible in the solar neighborhood

$\Rightarrow$ Measure the age of the Galaxy (e.g. Oswalt et al. 1996, *Nature* 382, 692)

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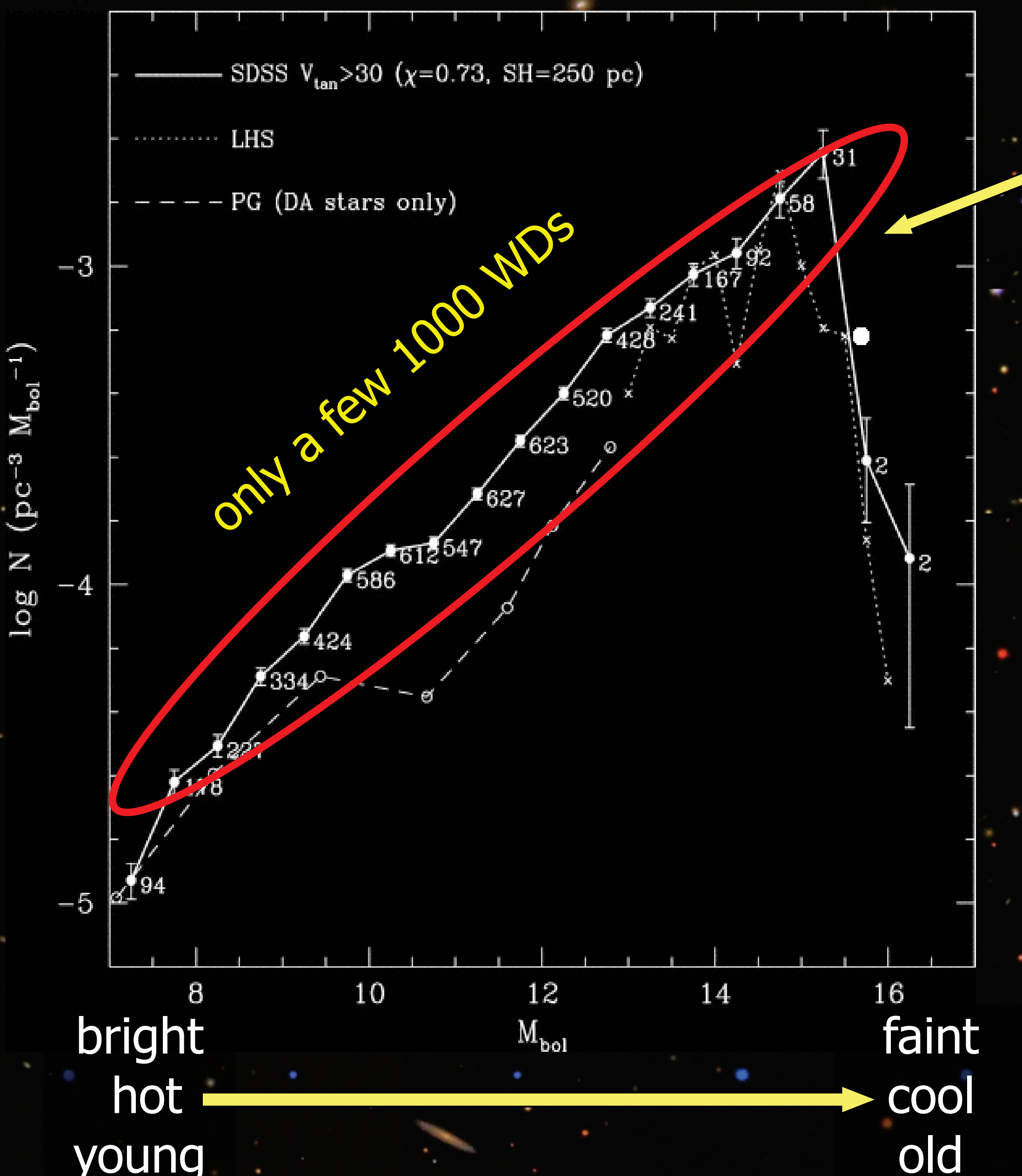

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- ~95% of all stars end as white dwarfs

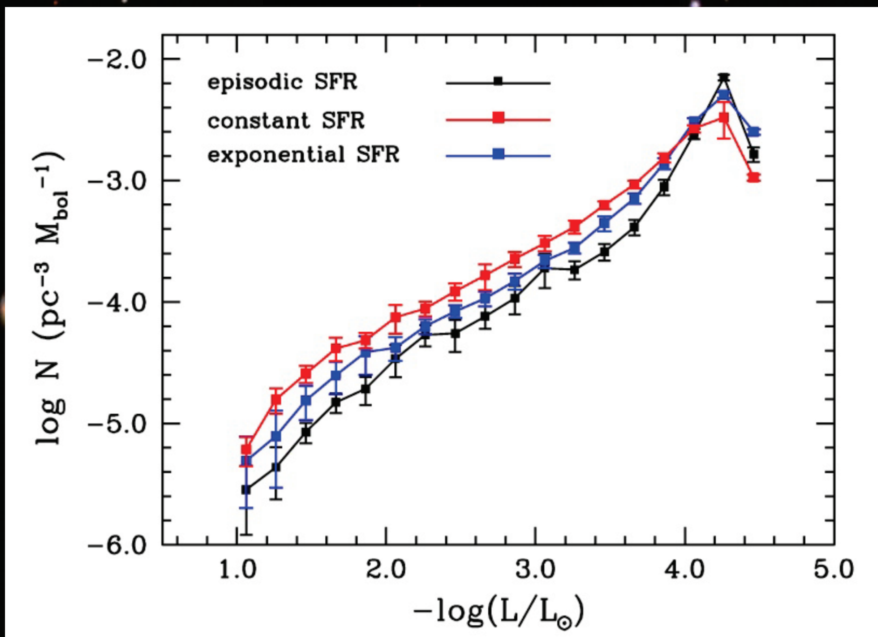
  ⇒ **The 7th dimension - Time**
- Key population to probe star formation history

- GAIA will "see" ~400,000 white dwarfs
- *100% complete within ~100pc*, 50% within ~300pc
- ⇒ ages for thin/thick disc, halo, etc.

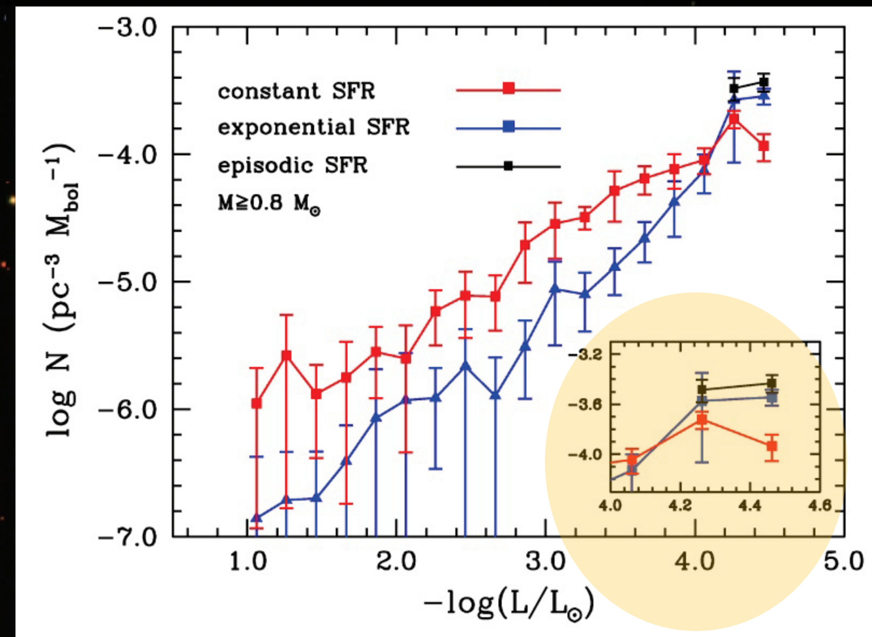
(see e.g. Torres et al. 2005, MNRAS, 360, 1381; Jordan 2007, ASP Conf. Series, 372, 139)

Luminosity functions from non-standard SFR as f(M_{wd})

All white dwarfs



Massive WD (=early-type progenitors)



1 - Exponential SFR: $\Psi \approx \exp(-t/\tau)$ where τ=25Gyr
2 - Episodic SFR: 1 Gyr after the formation of the disk, lasting for 3 Gyr

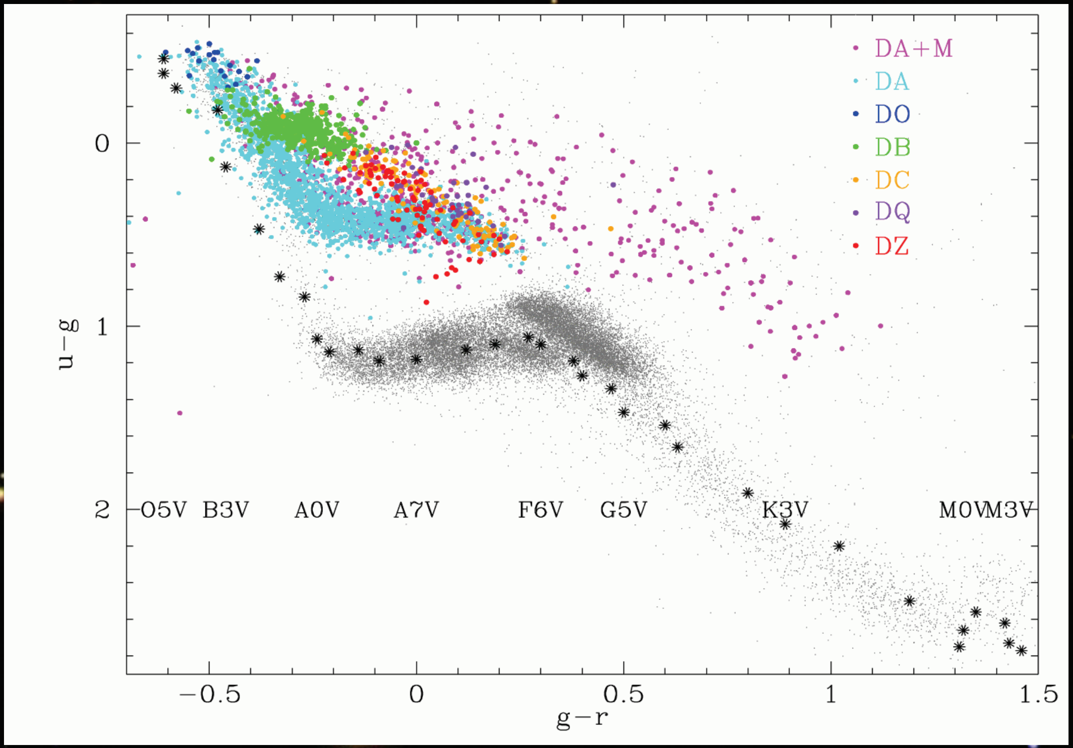
Deviations from a standard star formation history result in *highly significant* differences at the low-luminosity end of the white dwarf luminosity function.

⇒ large number of massive WDs needed

The GAIA white dwarfs

1. How does GAIA find white dwarfs?

Identifying white dwarfs with GAIA



- intrinsically faint (=nearby)
- non-main-sequence colours

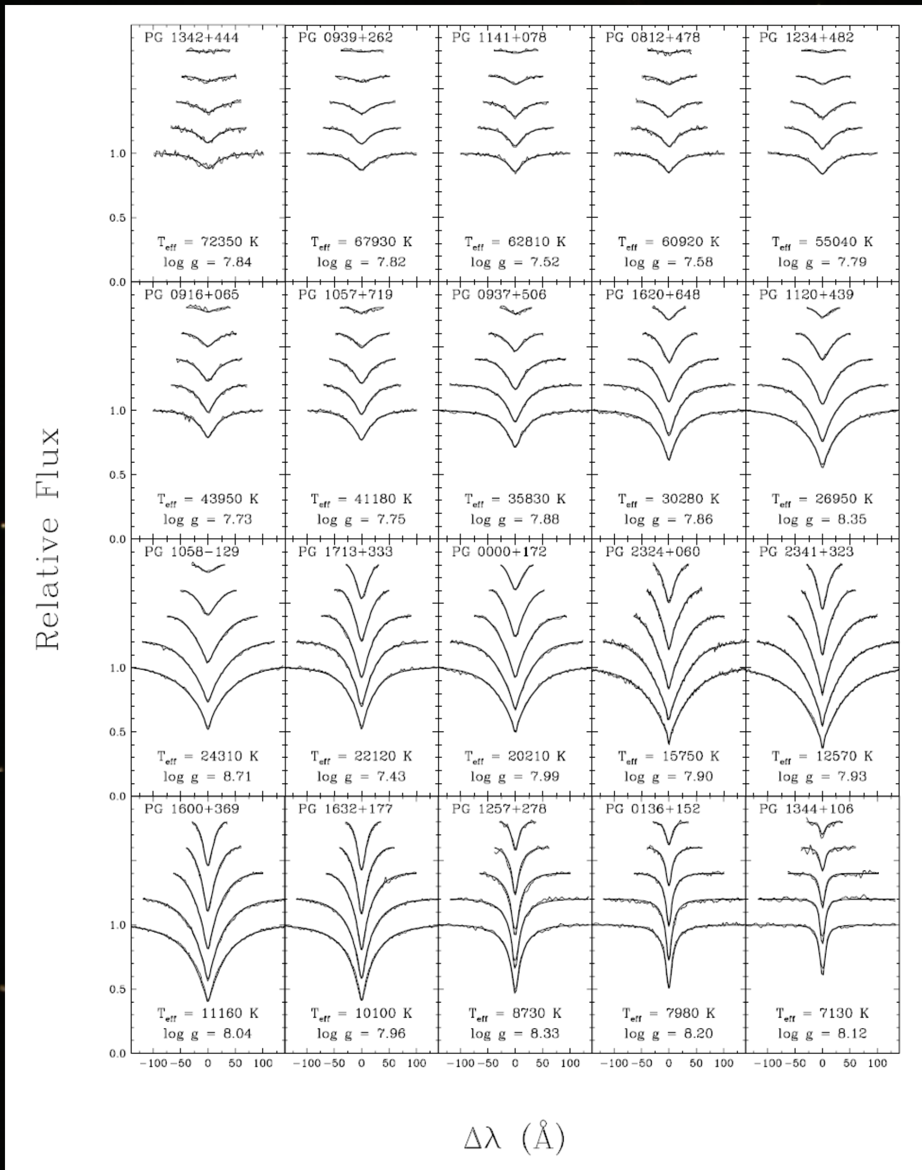
⇒ GAIA should effordlessly find all white dwarfs within its magnitude limit

The GAIA white dwarfs

1. How does GAIA find white dwarfs?

2. How do we measure their parameters (Teff, log g, mass, age...)

Most (~80%) WDs have pure hydrogen atmospheres



- Teff and log g from fitting spectral models to the Balmer lines
- Higher Balmer lines essential for accurate log g (Kepler et al. 2006, MNRAS 372, 1799)
- Evolution sequences provide the cooling age, mass, radius

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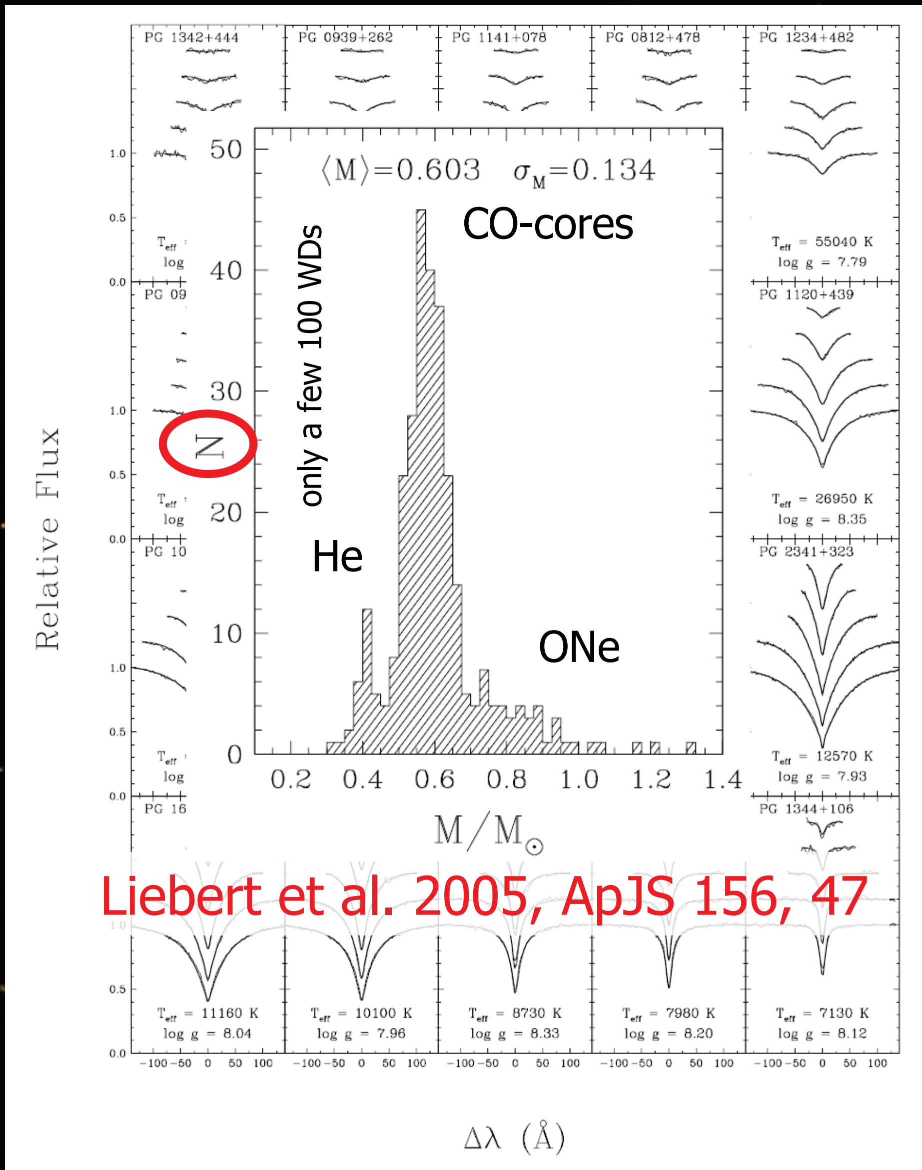
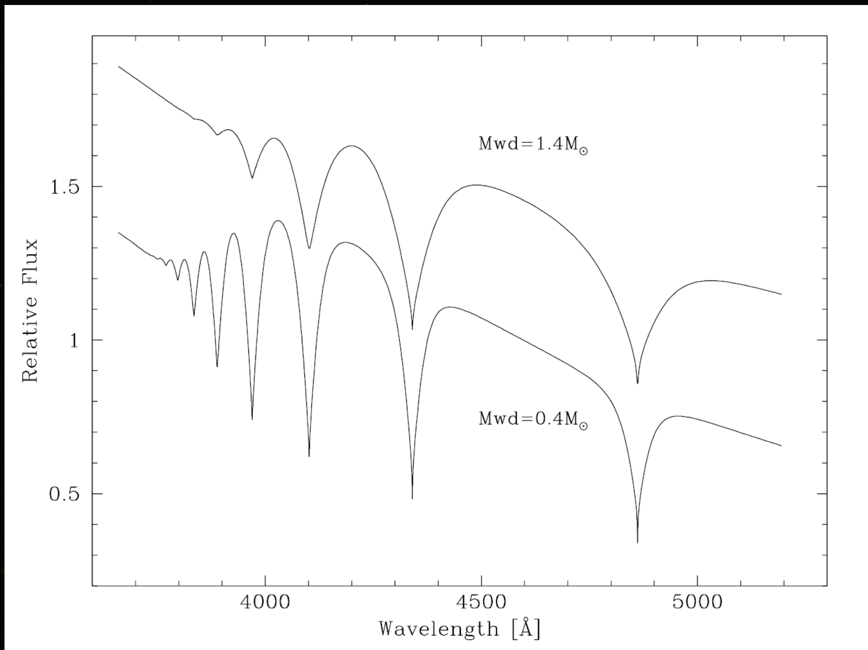


- Teff and log g from fitting spectral models to the Balmer lines
- Higher Balmer lines essential for accurate log g (Kepler et al. 2006, MNRAS 372, 1799)
- Evolution sequences provide the cooling age, mass, radius
- GAIA distances provide strong constraints to enforce (model-) internal consistency
- GAIA BP/RP too low resolution for spectral modelling!

We need: intermediate (R~5000) resolution spectroscopy for a a few 100000 white dwarfs (3700Å – 6800Å)

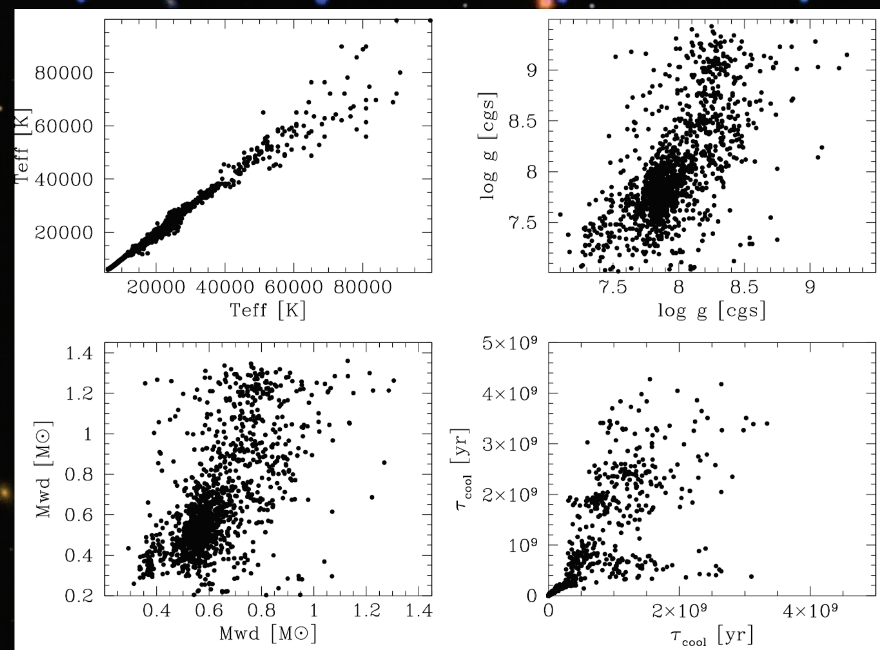
Higher Balmer lines are essential for Mwd & Tcool



High & low mass WD @ T=20000K

1600 white dwarfs from SDSS

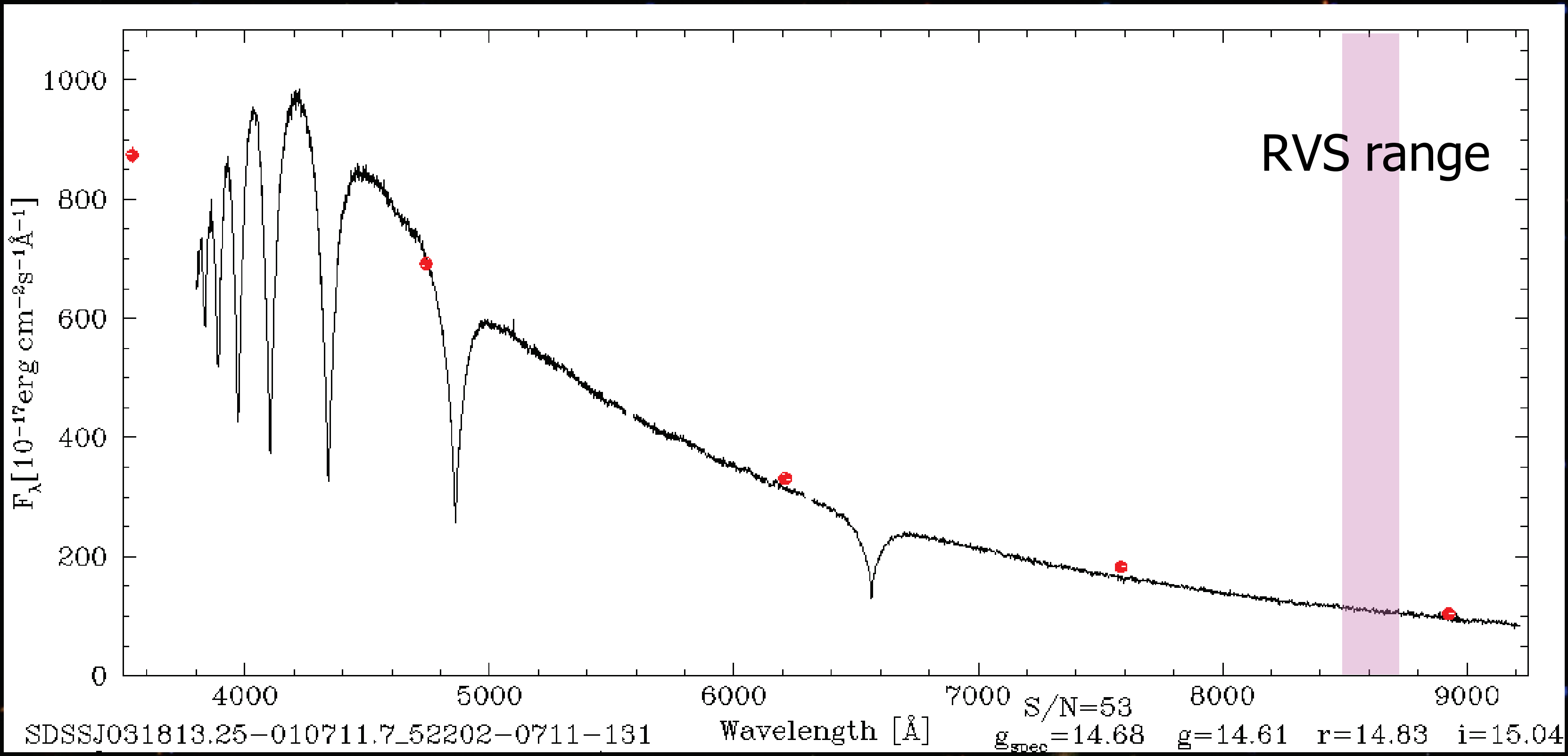
Hα-Hε (3800-6800Å)



Hα & Hβ (4500-6800Å)

GAIA RVS data provide *no* radial velocities for WDs!

... necessary for full 3D velocity / galactic orbit reconstruction ....



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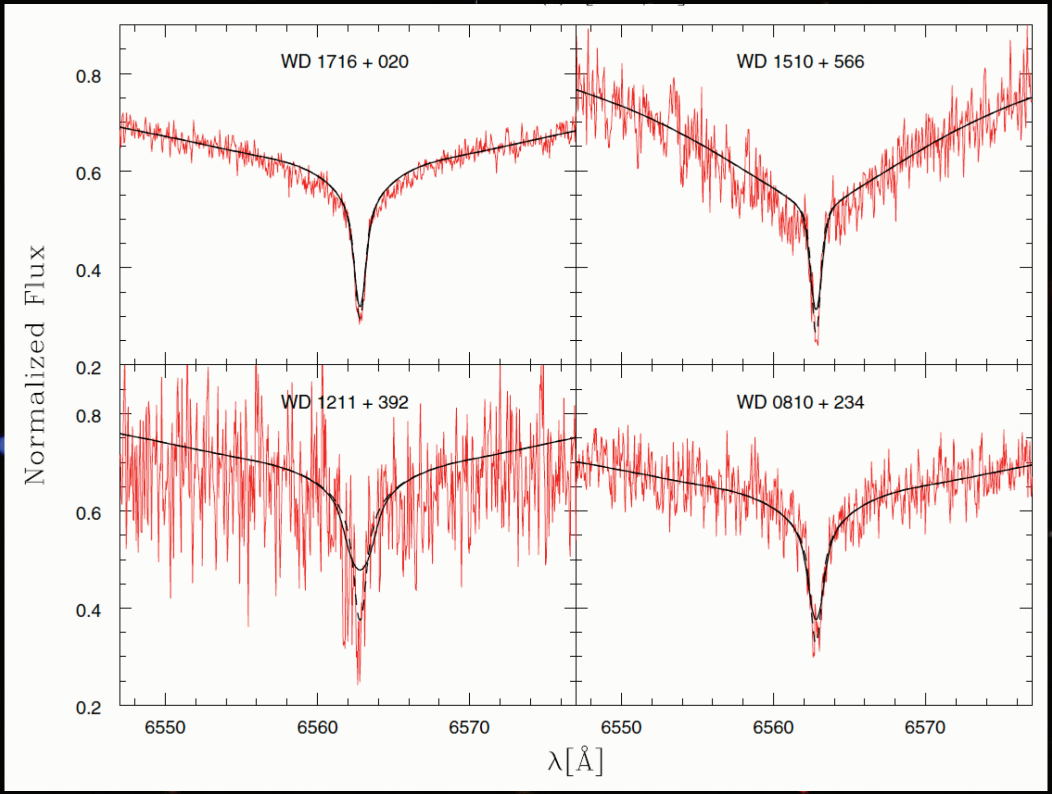


(Karl et al. 2005, A&A 434, 637; Berger et al. 2005, A&A 444, 565)

We need: intermediate resolution (R~5000) spectroscopy of the sharp NLTE core in Hα

The GAIA white dwarfs

1. How does GAIA find white dwarfs?

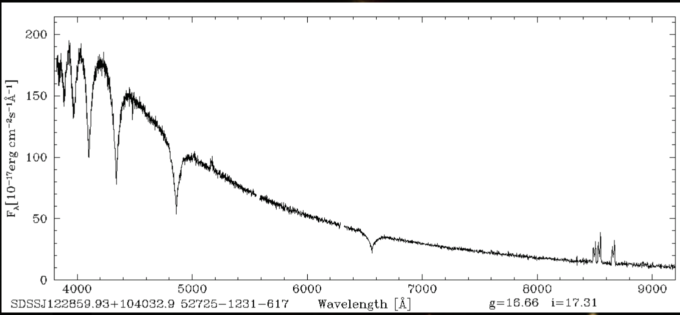
2. How do we measure their parameters (Teff, log g, mass, age...)

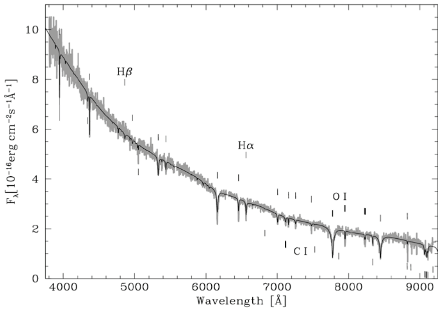
3. ~1% of WDs are freaks...

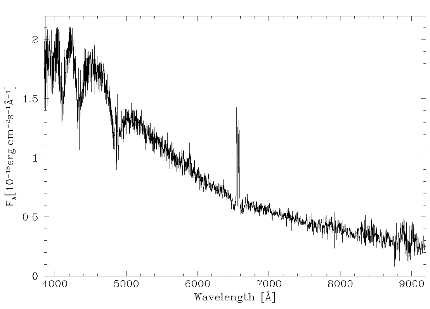
... *but one freak teaches you more than a 100 normal stars* ...

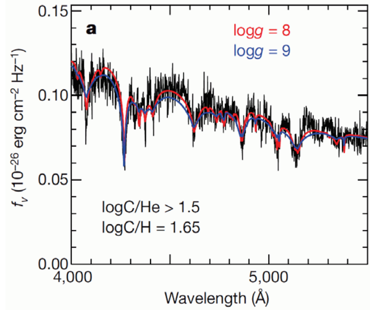
e.g. ONe cores, remnants of planetary systems, SNIa progenitors

(because they trace extremes in the parameter space,
or short-lived phases in the evolution)









Gänsicke et al. 2006, *Science* 314, 1908
Gänsicke et al. 2010, *Science* 327, 188

Littlefair et al. 2006, *Science* 314, 1578
Dufour et al. 2007, *Nature* 450, 522

Conclusions

GAIA will identify a few 100000 white dwarfs, an enormous potential for advancing our understanding of stellar and galactic evolution. However, to fully exploit this potential, we need ground-based follow-up spectroscopy.

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GAIA follow-up requirements:

- ≈10 white dwarfs per square degree
- Blue coverage up to ≈ 3700Å is essential to measure accurate Teff / logg (=higher Balmer), and to detect metal lines
- Broad wavlength coverage (up to ~9000Å) is important to identify unusual compositions and magnetic white dwarfs
- Resolution of $\lambda/\Delta\lambda \approx 5000$ to measure radial velocities from Hα and to resolve narrow metal lines

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4MOST:

- 1500 fibers per π deg^2 $\Rightarrow$ 3% of all available fibres will be sufficient to observe *all* GAIA white dwarfs
- Adequate resolution, broad wavelength coverage
- S/N: SDSS achieves ~20-30 at V≈18.5. Scaling for the aperture of the VISTA, 4MOST can get similar quality data down to GAIA's magnitude limit
- *But 4MOST* ***has*** *to be optimised to extend down to ≈ 3700Å!*