Galactic archeology is one of the key projects of GAIA

~95% of all stars end as white dwarfs

Teff $\Rightarrow$ cooling age $\Rightarrow$ (stellar models) $\Rightarrow$ total age

$\Rightarrow$ The 7th dimension - Time

Key population to probe star formation history
Whites 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

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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.

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

1 - Exponential SFR: $\Psi \approx \exp(-t/\tau)$ where $\tau = 25\text{Gyr}$
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.  

$\Rightarrow$ 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 effortlessly 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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- 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 $M_{wd}$ & $T_{cool}$

- High & low mass WD @ $T=20000K$

1600 white dwarfs from SDSS

Ha-Hε (3800-6800Å)

Ha & Hβ (4500-6800Å)
GAIA RVS data provide *no* radial velocities for WDs!

... necessary for full 3D velocity / galactic orbit reconstruction ....
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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 100,000 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 wavelength coverage (up to ~9000Å) is important to identify unusual compositions and magnetic white dwarfs
- Resolution of $\lambda/\Delta\lambda\approx5000$ to measure radial velocities from Hα and to resolve narrow metal lines
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**4MOST:**

- 1500 fibers per $\pi$ deg$^2$ ⇒ 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!