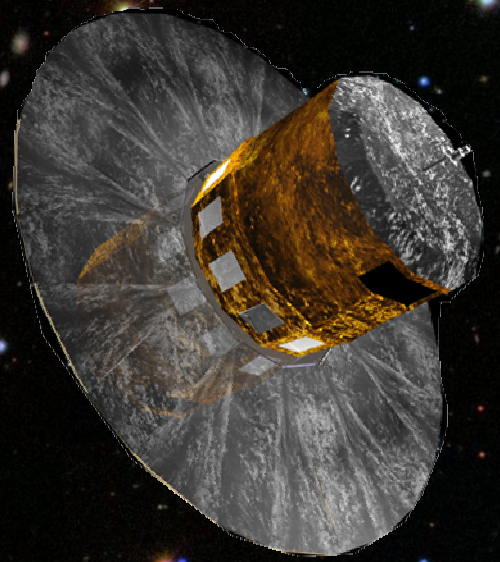
Stefan Jordan
Boris Gänsicke, Enrique García-Berro,
Santiago Torres & Jordi Isern
Martin Barstow, Matt Burleigh, Tom Marsh, Roberto Silvotti



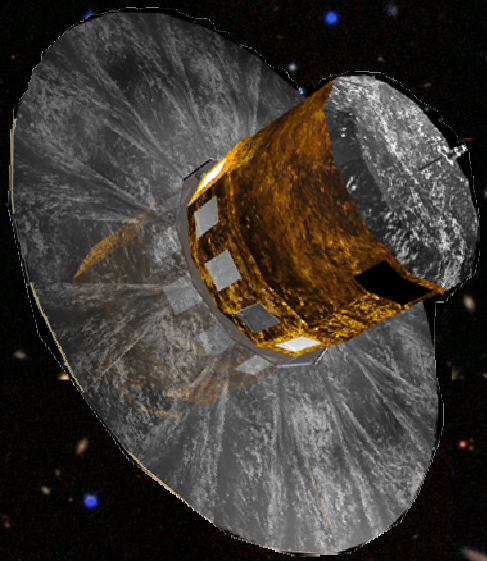
White dwarfs from GAIA: The 7th dimension - Time

Talk outline

1. A bit of background on stellar evolution

2. The white dwarf population seen by GAIA: clues to the star formation history of the Galaxy

3. The need for intensive ground-based follow-up

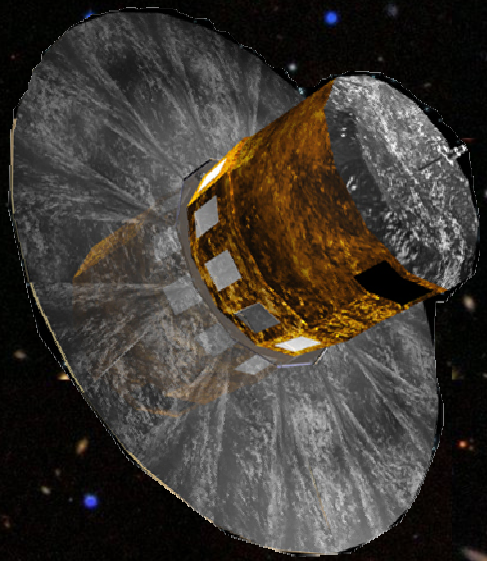


Talk outline

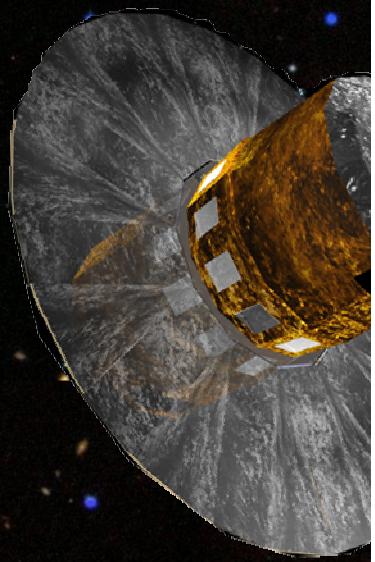
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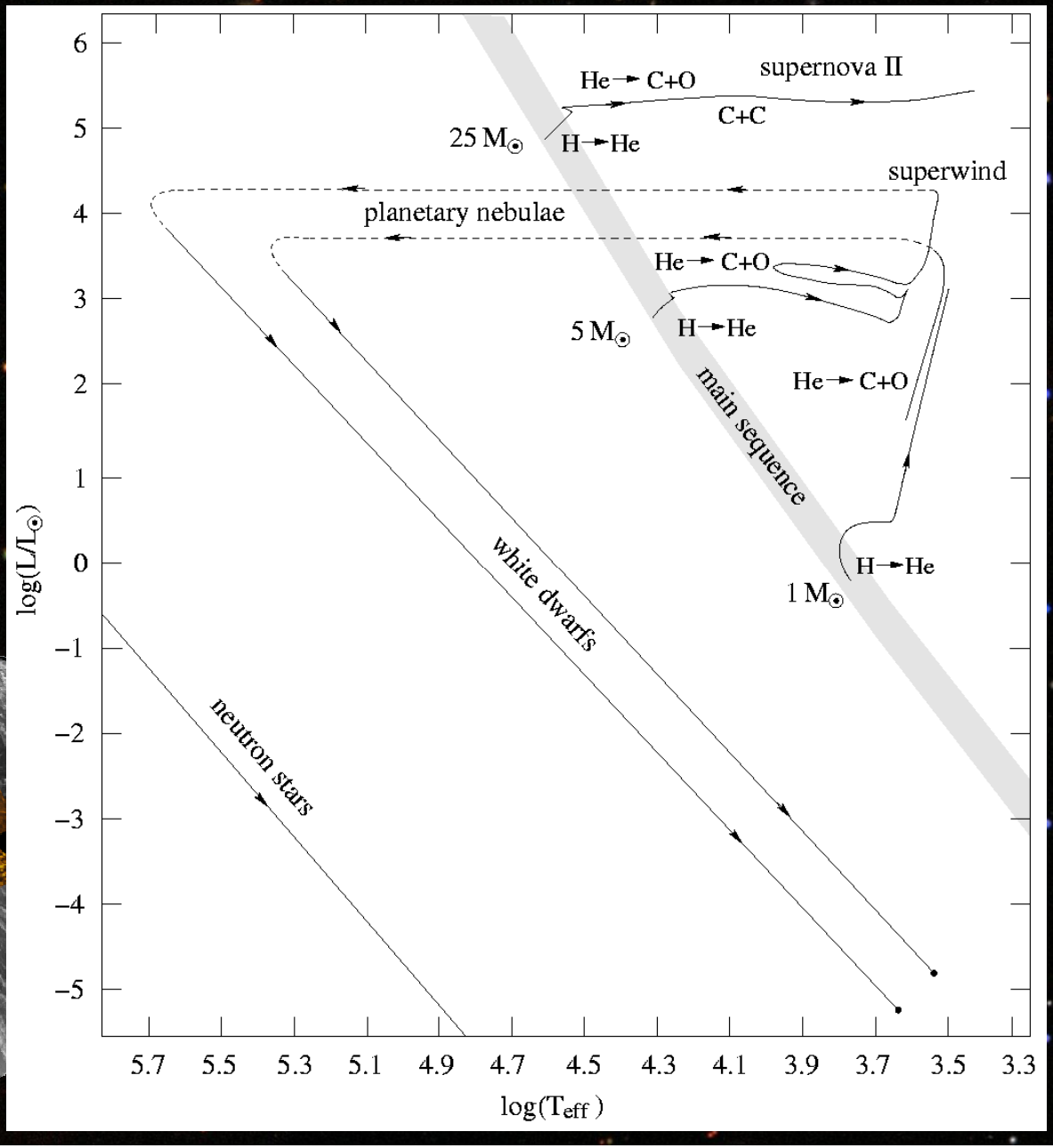
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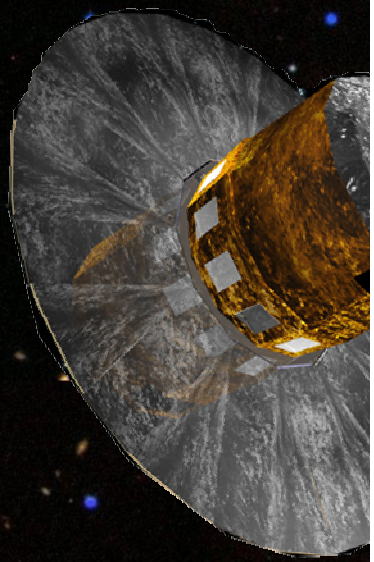


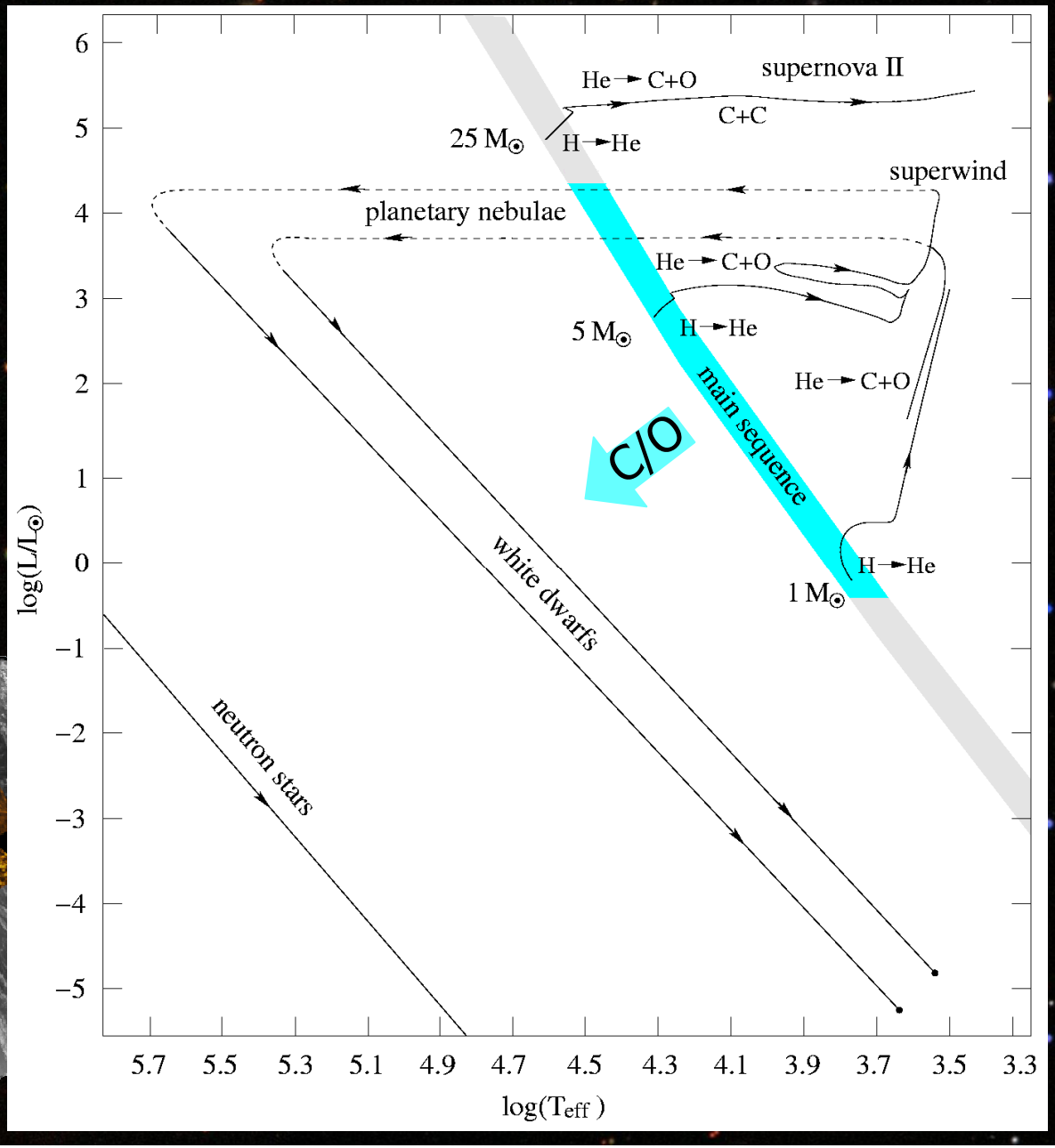
~95% of all stars will become white dwarfs



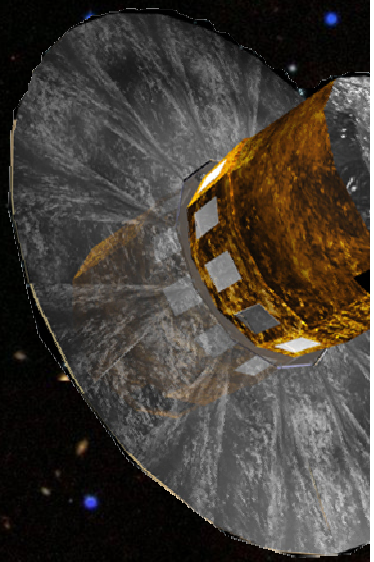


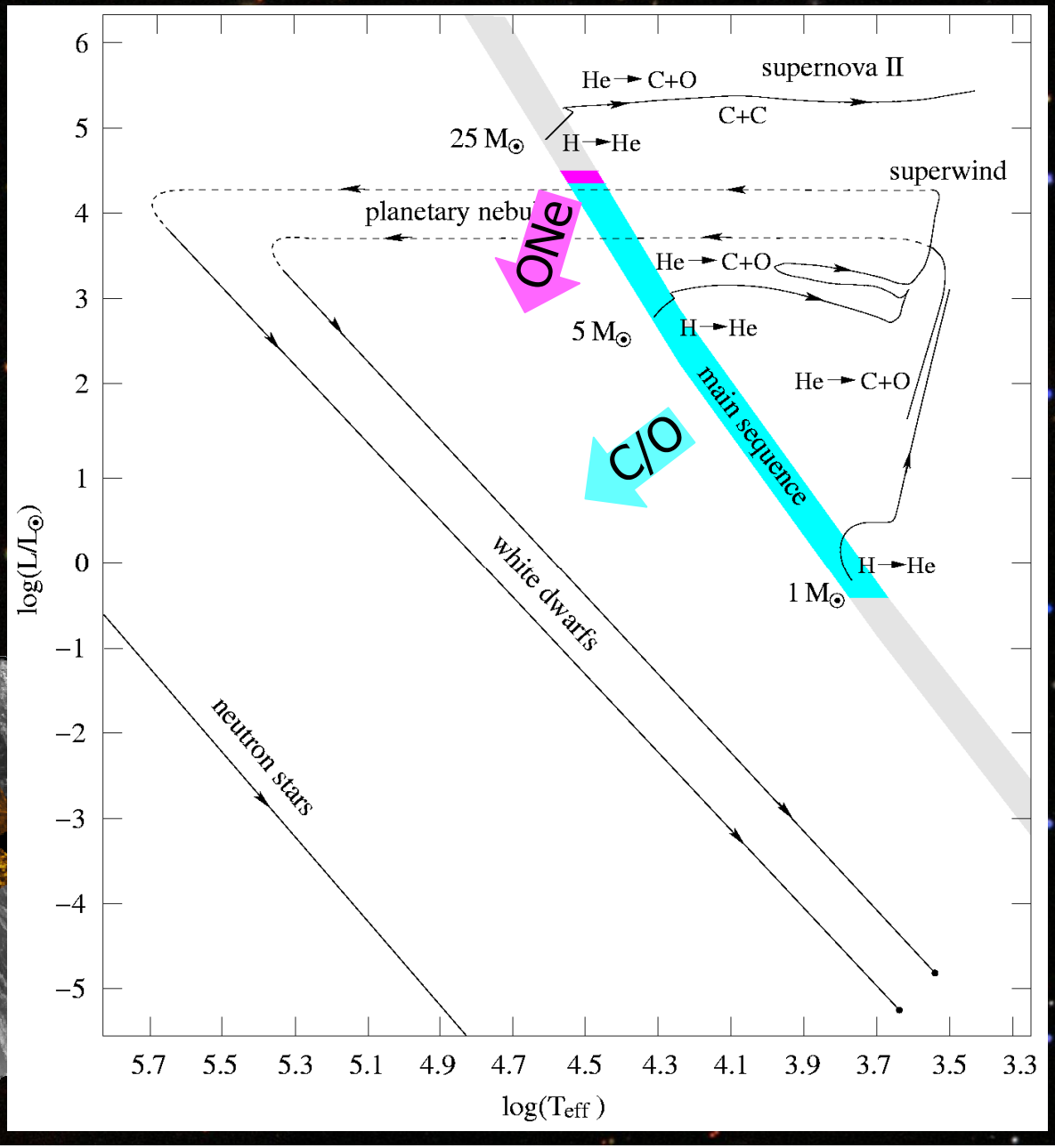
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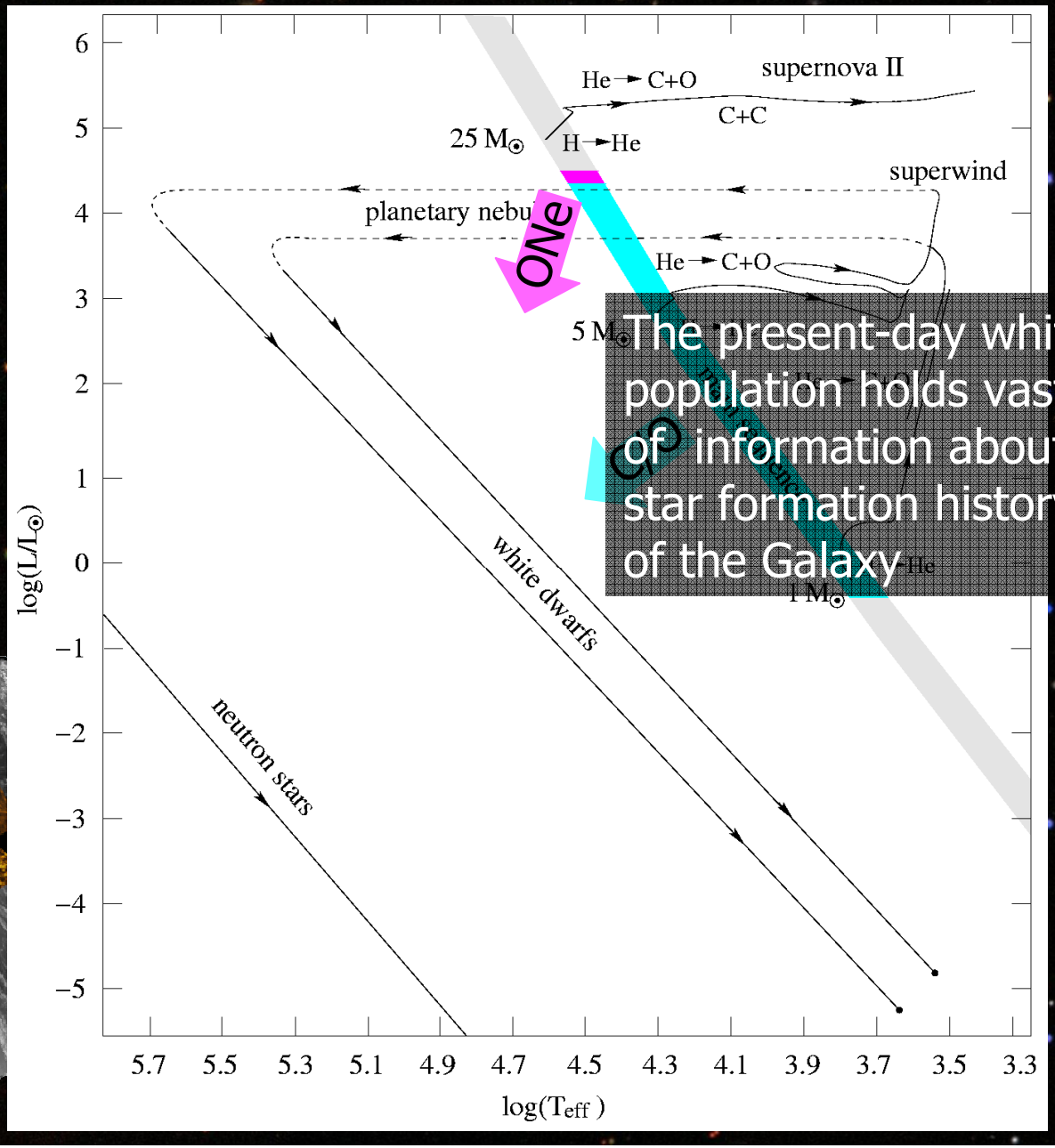


~95% of all stars will become white dwarfs



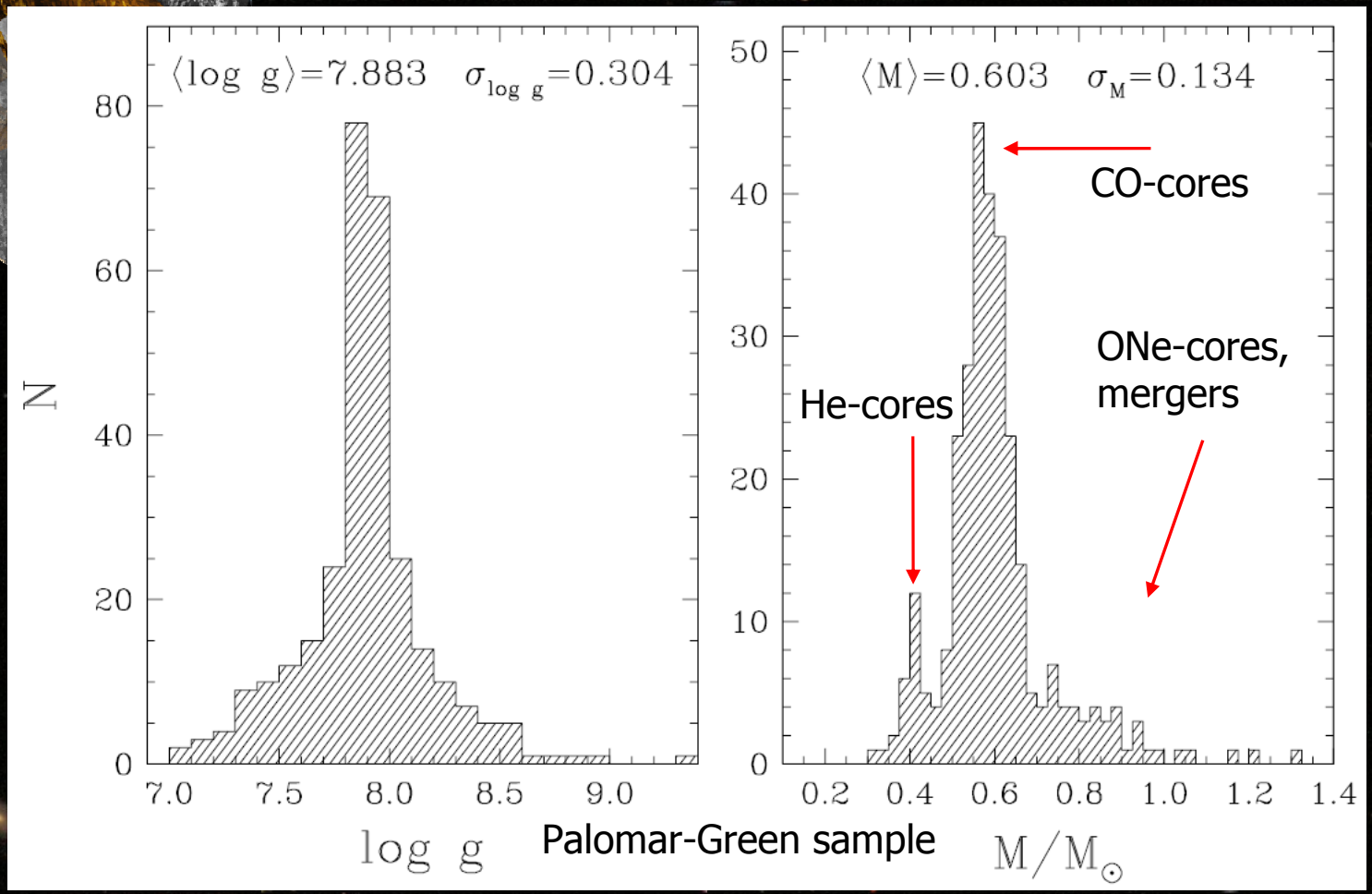


~95% of all stars will become white dwarfs

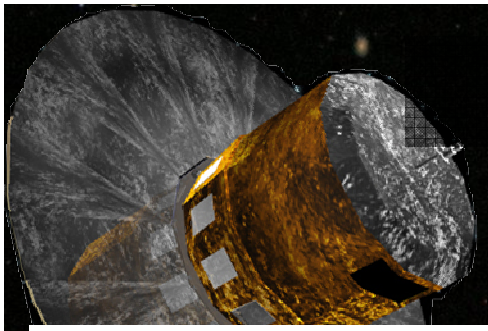


The present-day white dwarf population holds vast amounts of information about the star formation history of the Galaxy

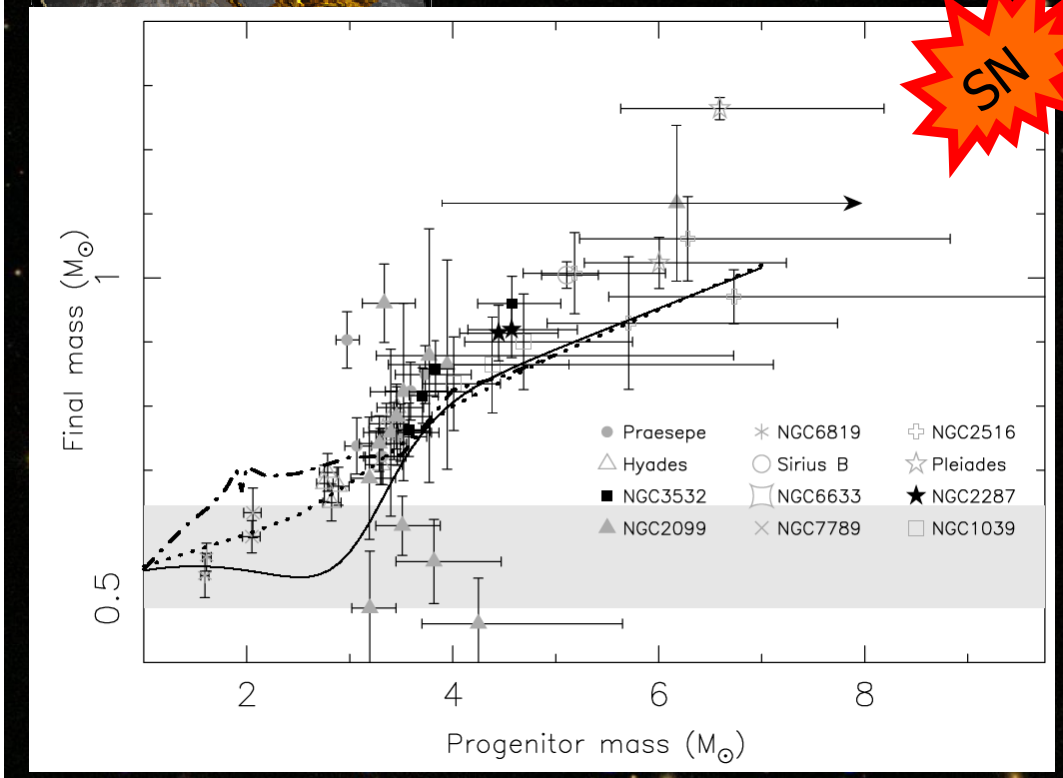
White dwarf mass distribution

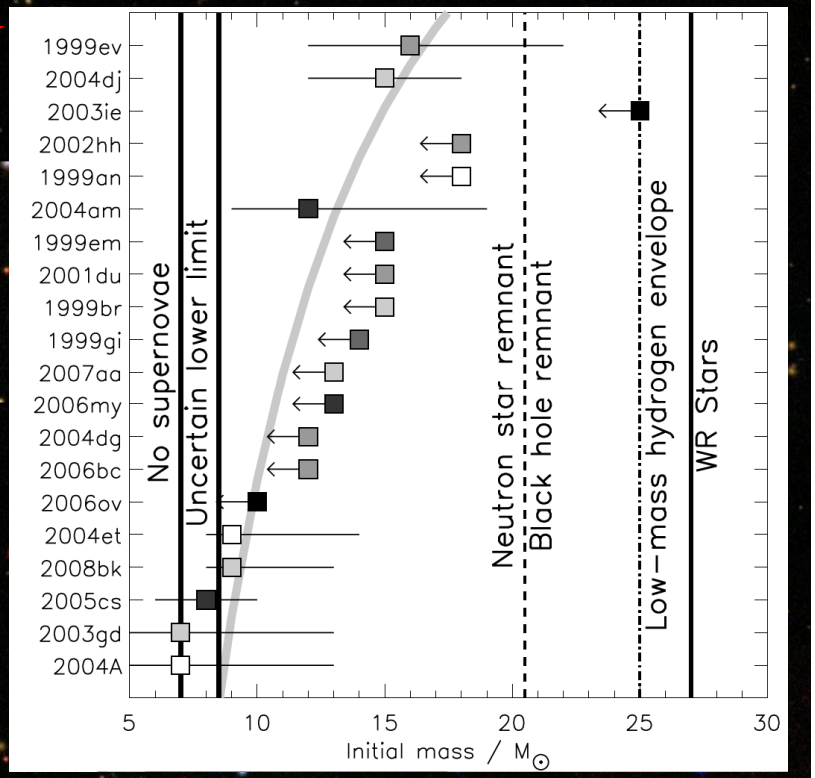


Liebert et al. 2005, ApJS 156, 47



The initial-mass final-mass relation





e.g. Dobbie et al. 2009, MNRAS 395, 2248

SN for $M_{MS}>8.5_{(+1-1.5)}\ M_\odot$

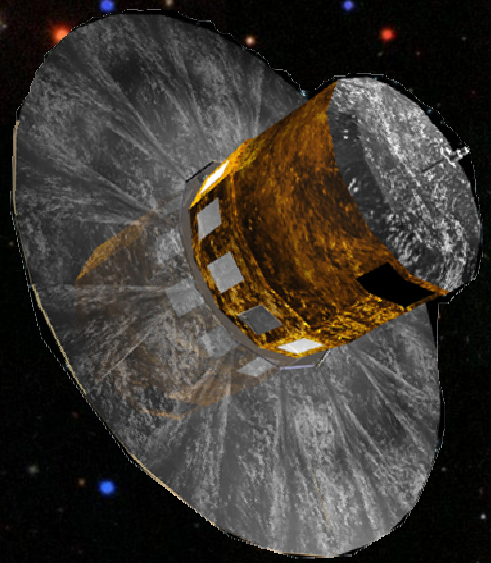
Smartt et al. 2009, MNRAS 395, 1409

Talk outline

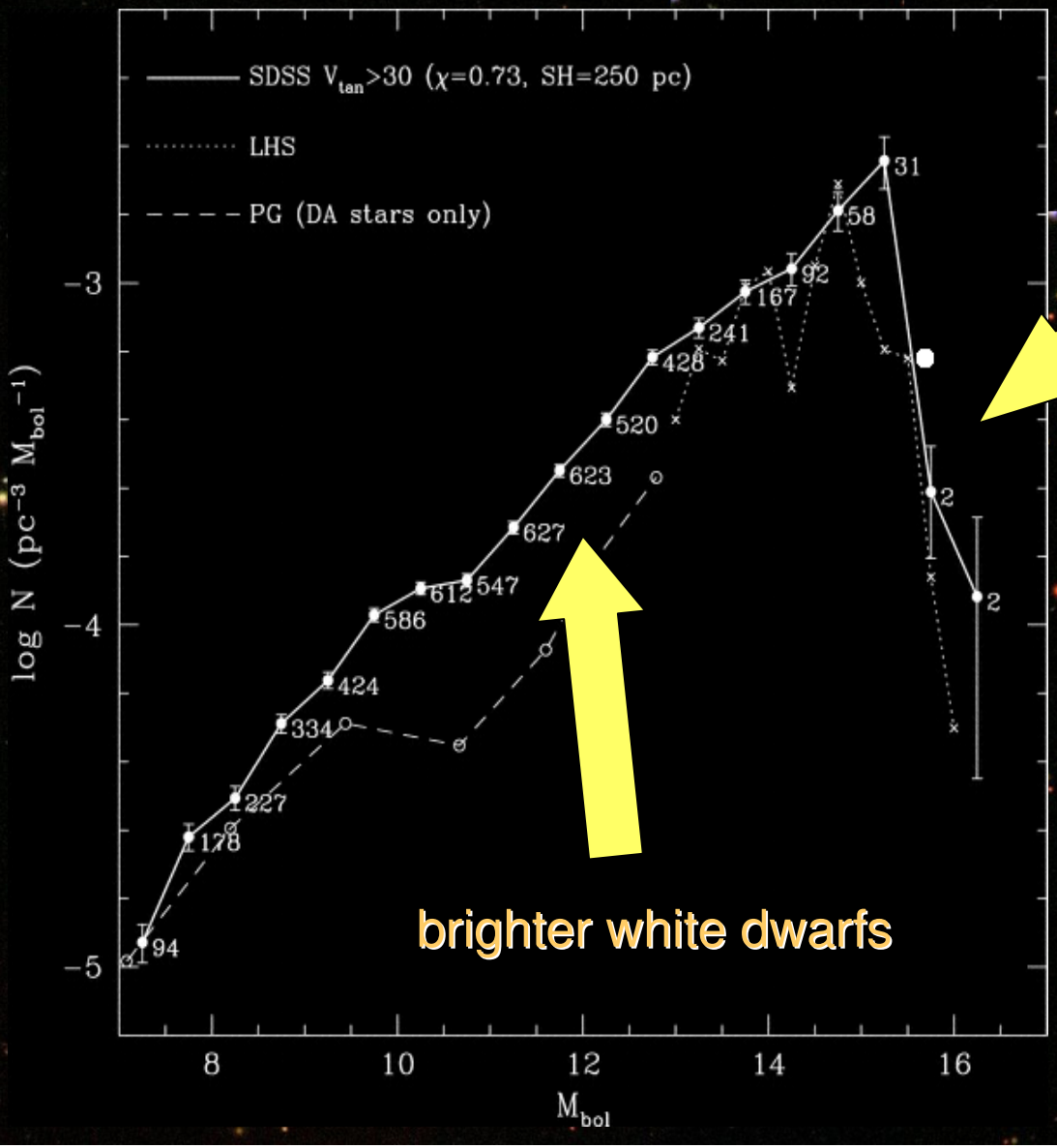
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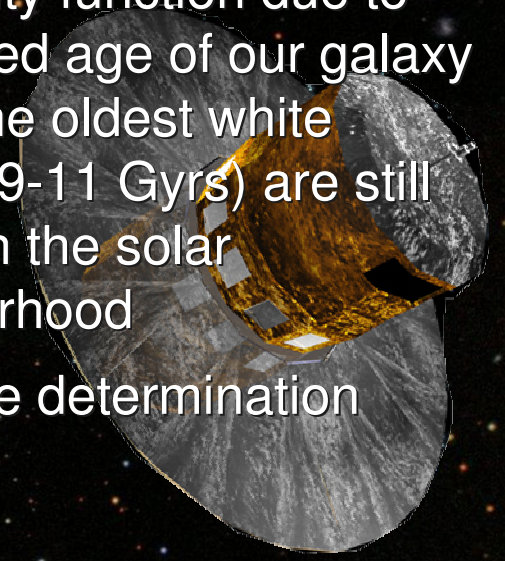
White Dwarf Luminosity Function



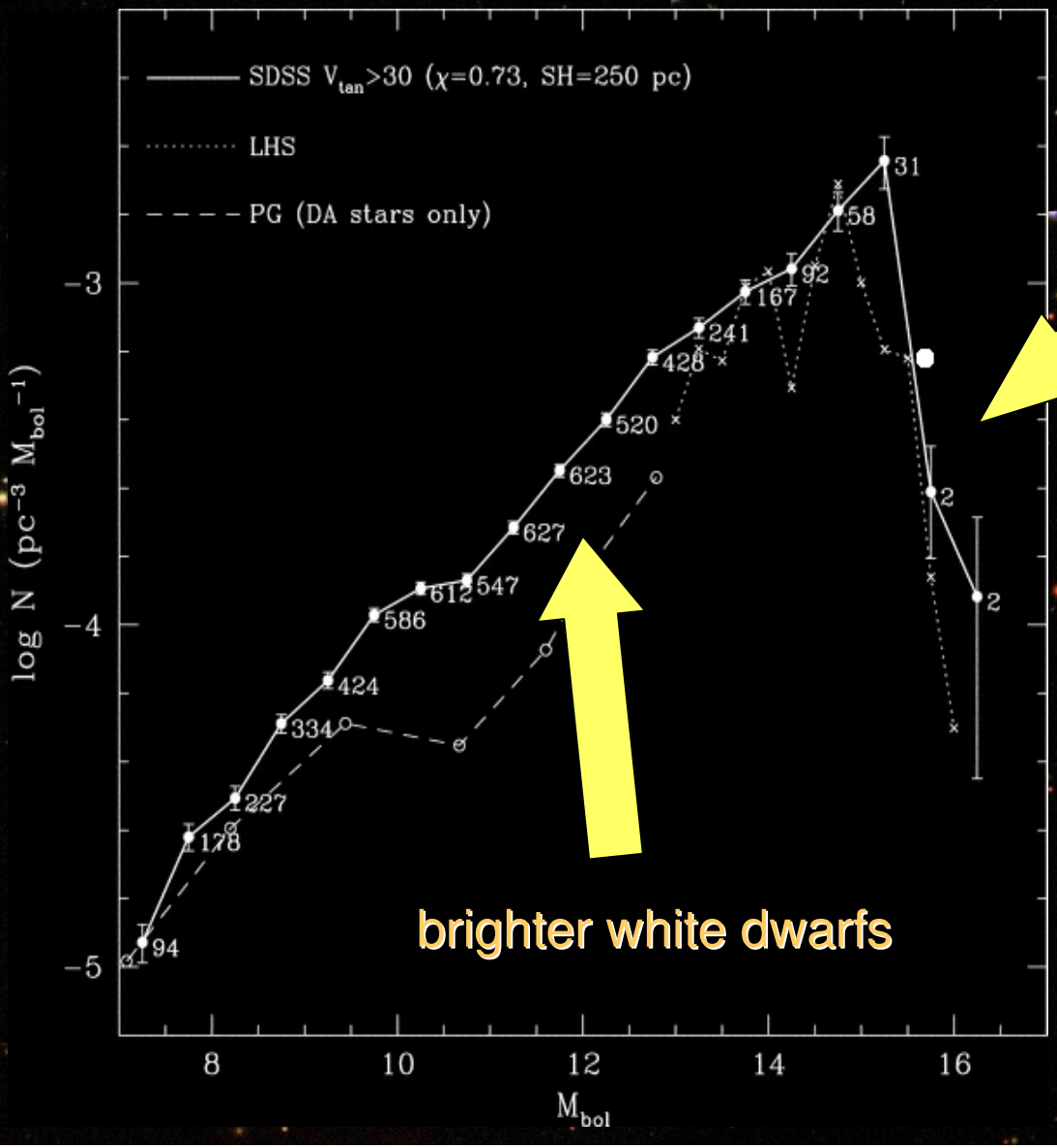
Cut-off at faintest white dwarfs

brighter white dwarfs

- Cut-off in the white dwarf luminosity function due to the limited age of our galaxy
- Even the oldest white dwarfs (9-11 Gyrs) are still visible in the solar neighborhood
- ⇒ Age determination



White Dwarf Luminosity Function



Cut-off at faintest white dwarfs

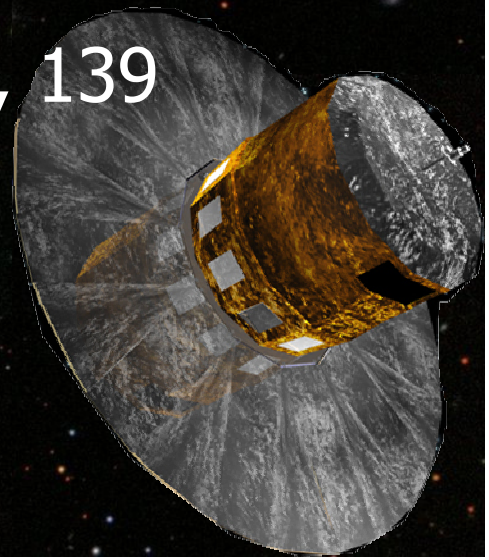
brighter white dwarfs

- Gaia will provide a much better statistic for the age determination of our solar neighborhood (factor of 5 more objects in the faintest bin!)
- Reconstruction of the star formation history of our galaxy (Asteroarcheology)



Asteroarcheology

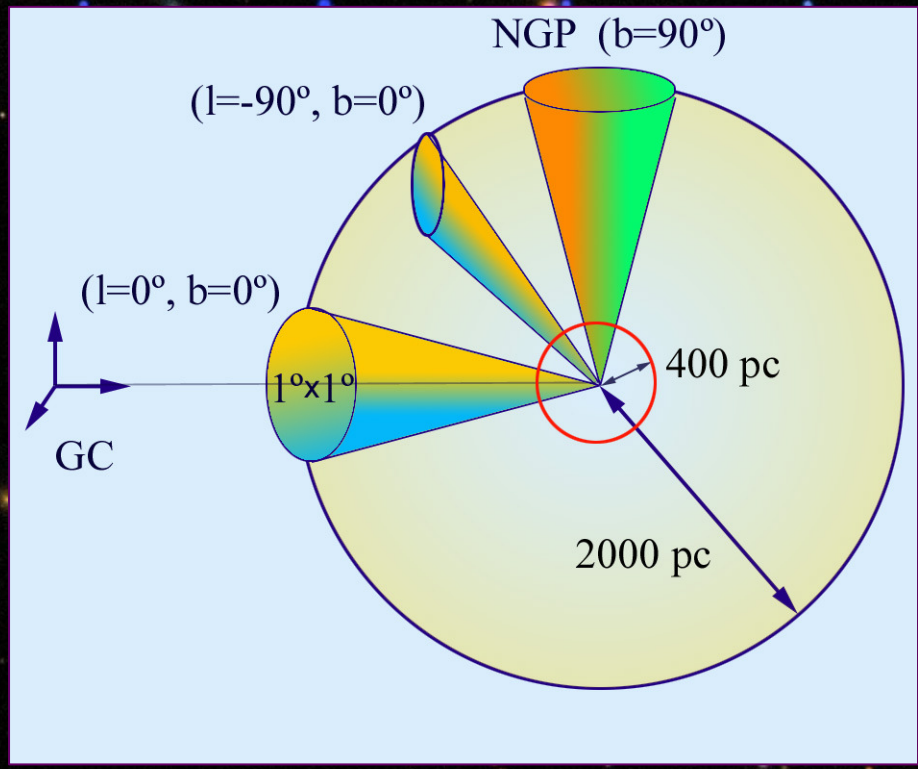
- Asteroarcheology is one of the key projects of GREAT
- White Dwarfs play a very important role in this business
- White Dwarfs and Gaia:
  - Torres et al., 2005, MNRAS, 360, 1381
  - Jordan, 2007, ASP Conf. Series, 372, 139



A Monte Carlo simulation of the GAIA WD population

- Disk and halo WD population in a sphere (400 pc) around the Sun
- Plus 3 perpendicular pencils of 1ºx1º of 2 kpc, each normalized to the local WD density

1. (l=0º, b=0º) in the direction of the Galactic Center
2. (b=90º) in the direction of the North Galactic Pole
3. (l=-90º, b=0º) in the direction of the Galactic antirotation



Input to the MC simulation

Disk:

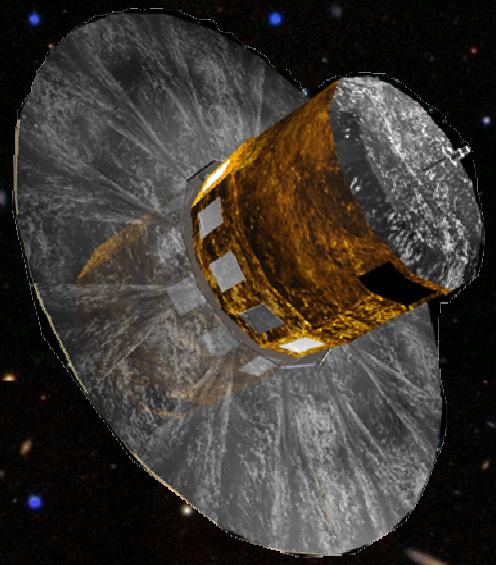
- Disk age of 11 Gyr.
- White dwarfs follow a double-exponential density law with a scale length L=3.5 kpc and a scale height h=500 pc
- A standard IMF was adopted
- Velocities from detailed model of Galactic structure
- Accurate modelling of Galactic absorption
- Fully evolutionary cooling sequences and reliable stellar evolutionary inputs

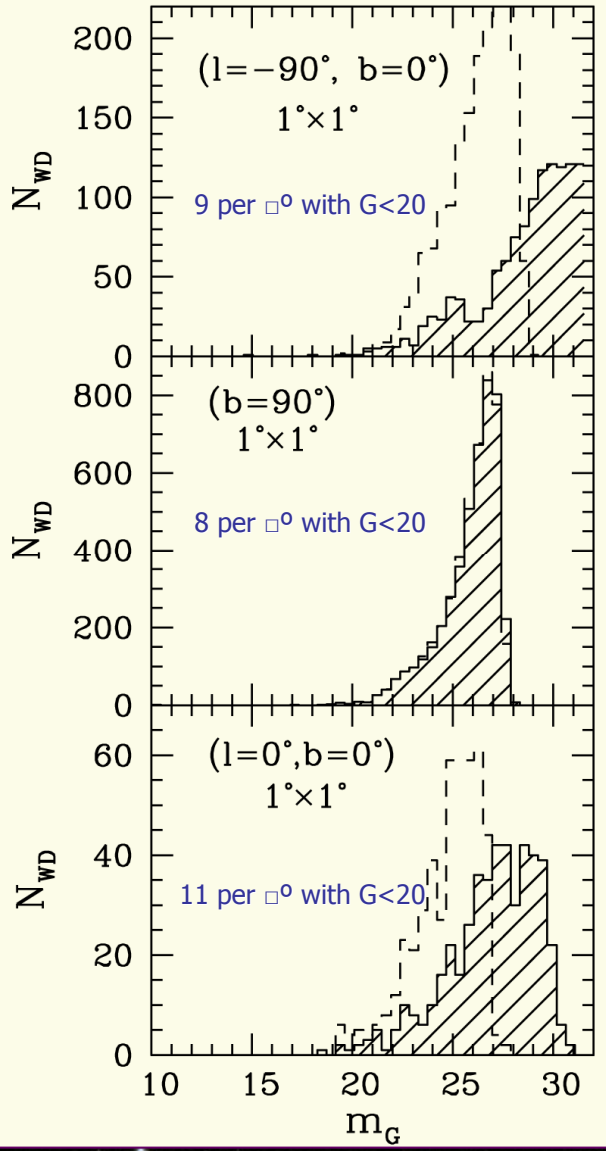
Halo:

- Halo formed 14 Gyr ago in an intense star burst lasting 1 Gyr
- White dwarfs follow an isothermal spherically symmetric halo distribution
- A standard IMF was adopted
- Velocities randomly drawn according normal distributions and adopting a rotation velocity of 250 km/s.

Results: GAIA white dwarfs within the 3 pencil beams

The dashed histograms show the effects of Galactic extinction.





Completeness with Gaia

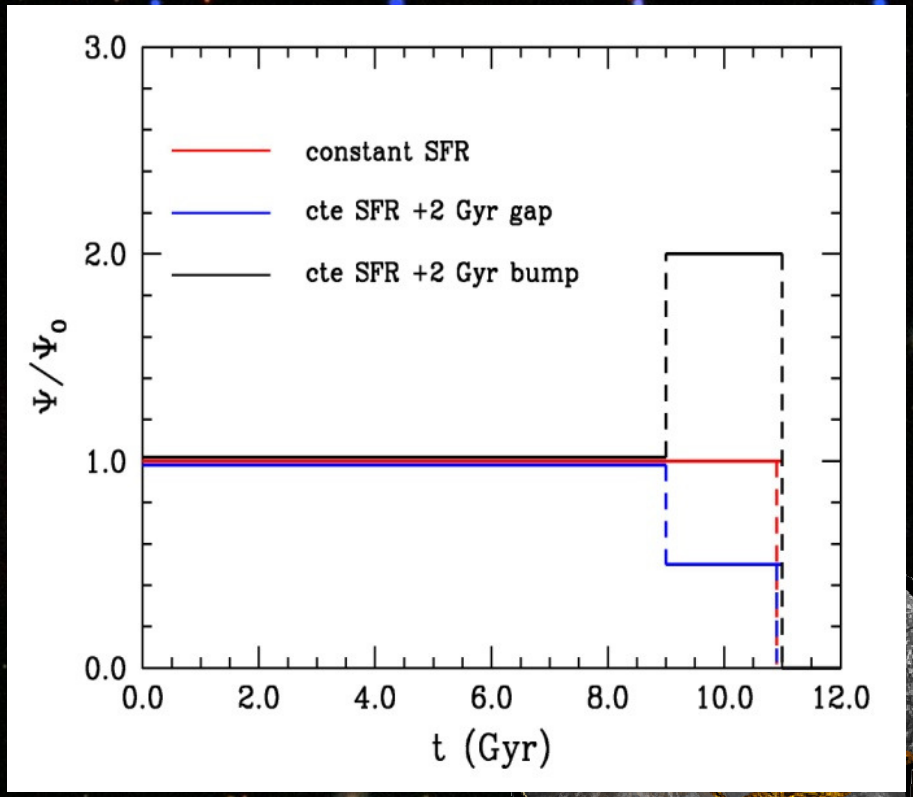
- White dwarfs:
  - complete up to 100 pc,
  - half at 300 pc,
  - one third at 400 pc.
  - Disk: 400,000
  - Halo: several hundred (only 10 known)
- Disk white dwarfs at the cut-off of the luminosity function ($M_{bol} \approx 15.3$, $M_V \approx 16$):
  - up to distances of 100 pc.
- Luminosity function:
  - Considerably improving the age determination of the solar neighborhood to about ±0.3Gyr.

Variations from standard SFR - I

We have studied the influence of variations of the SFR during the last 2 Gyr:

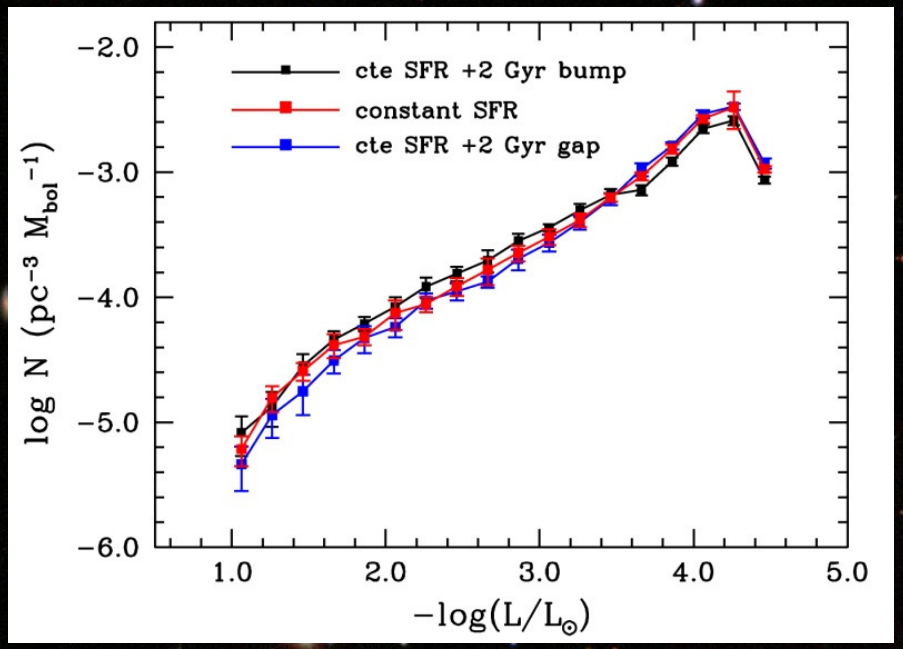
1 - We adopt a constant SFR from 0 to 11 Gyr

2 - We add a gap or a bump during the last 2 Gyr

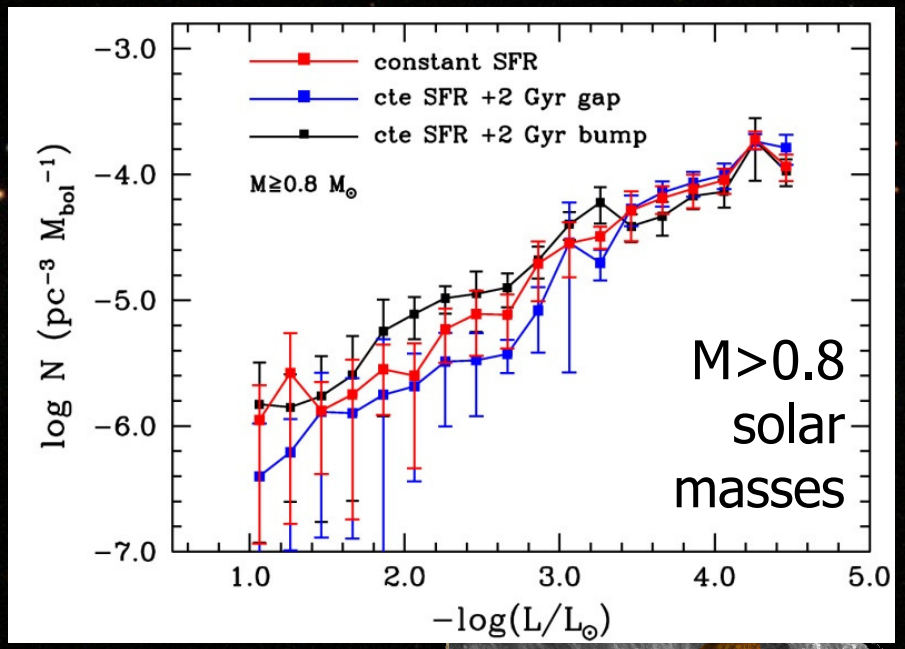


Luminosity functions from non-standard SFR – I

All white dwarfs



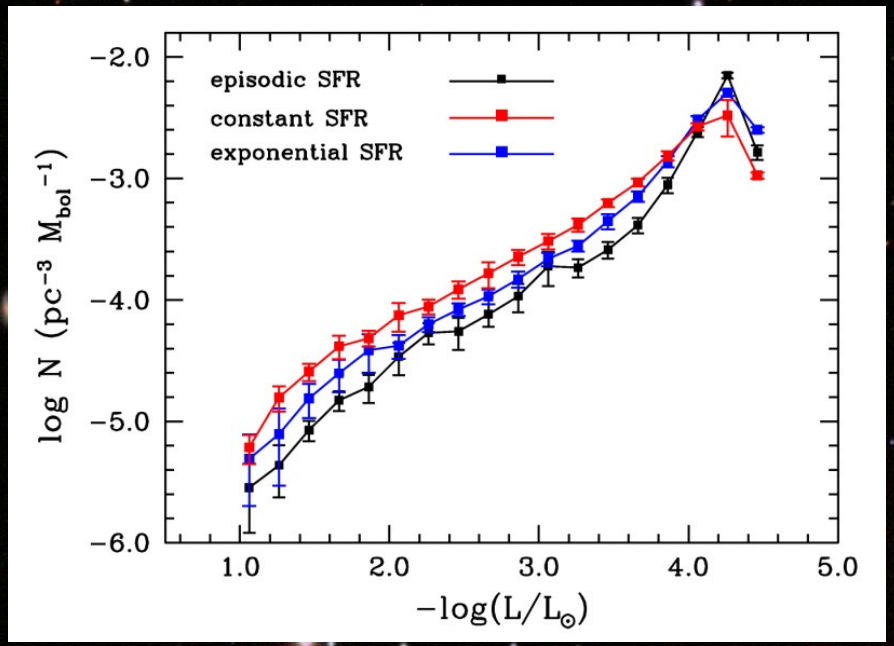
Massive WD (=early-type progenitors)



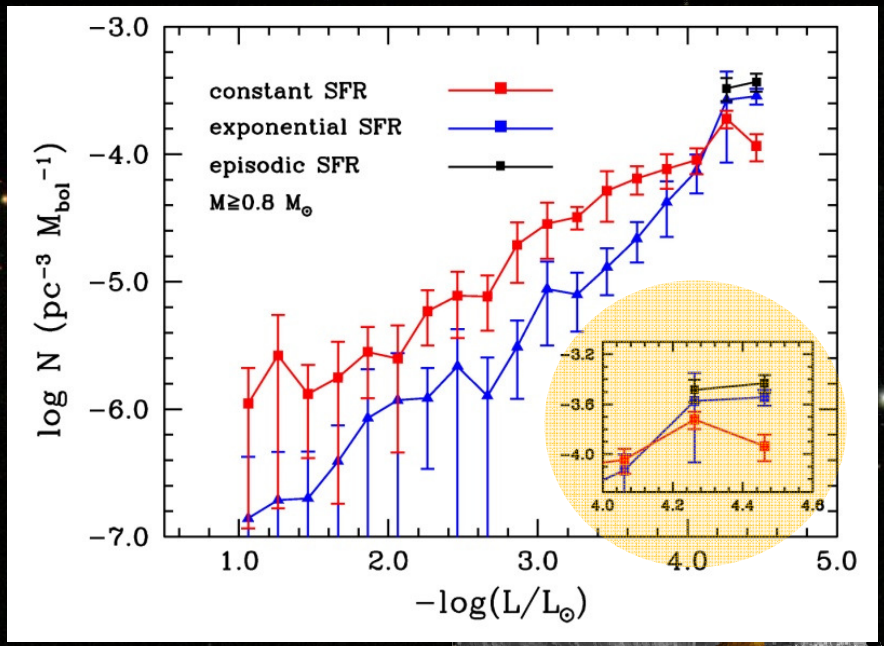
- A maximum likelihood analysis can differentiate between the different luminosity functions, and hence reconstruct the star formation history.
- Massive white dwarfs have a negligible MS+RGC+AGB lifetime

Luminosity functions from non-standard SFR – II

All white dwarfs

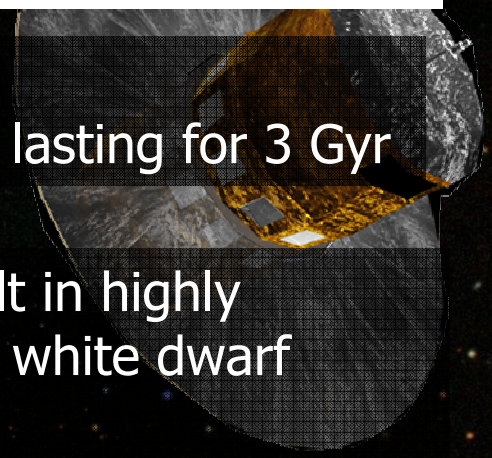


Massive WD (=early-type progenitors)



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



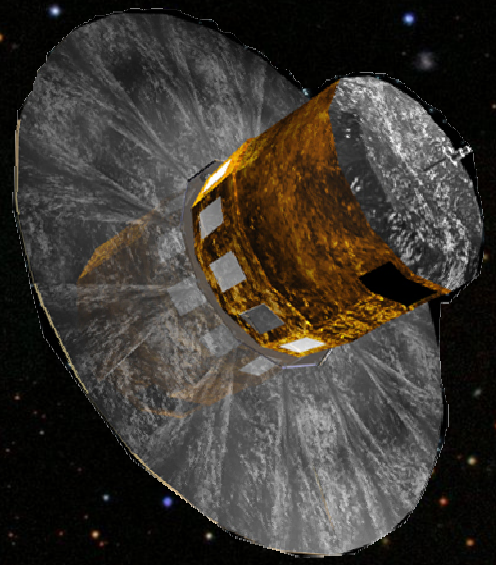
Deviations from a standard star formation history result in highly significant differences at the low-luminosity end of the white dwarf luminosity function.

Talk outline

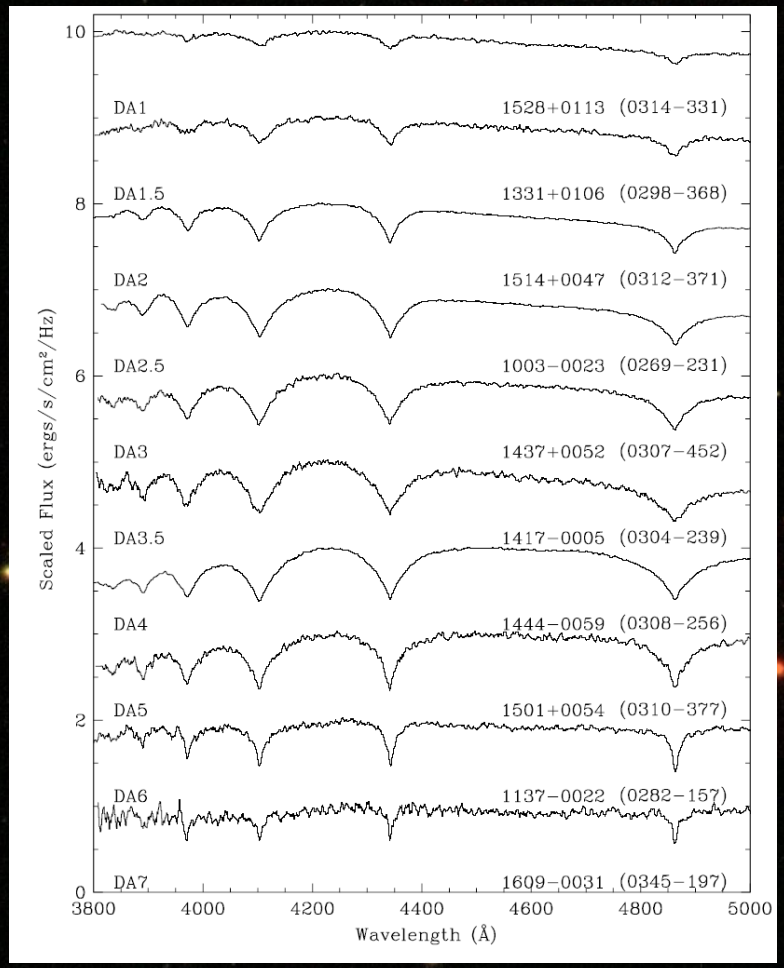
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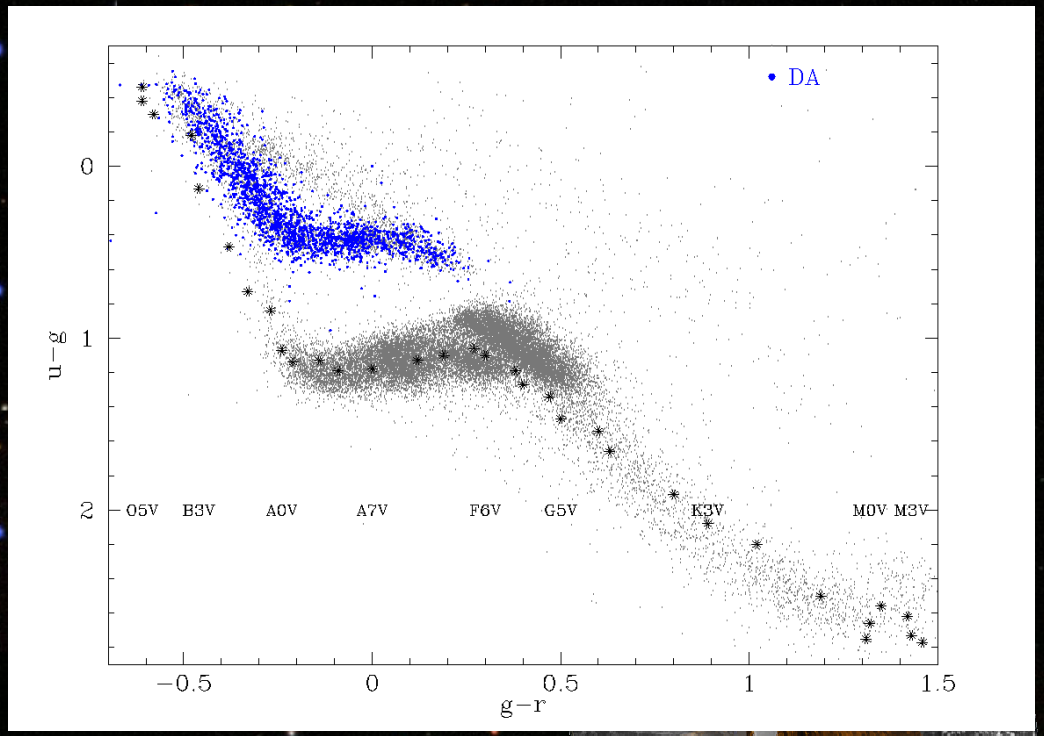
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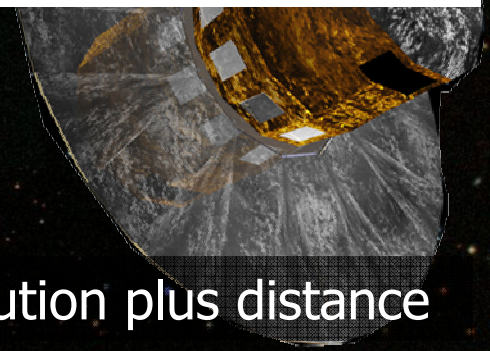
3. The need for intensive ground-based follow-up



~75% of WDs have hydrogen-rich atmospheres

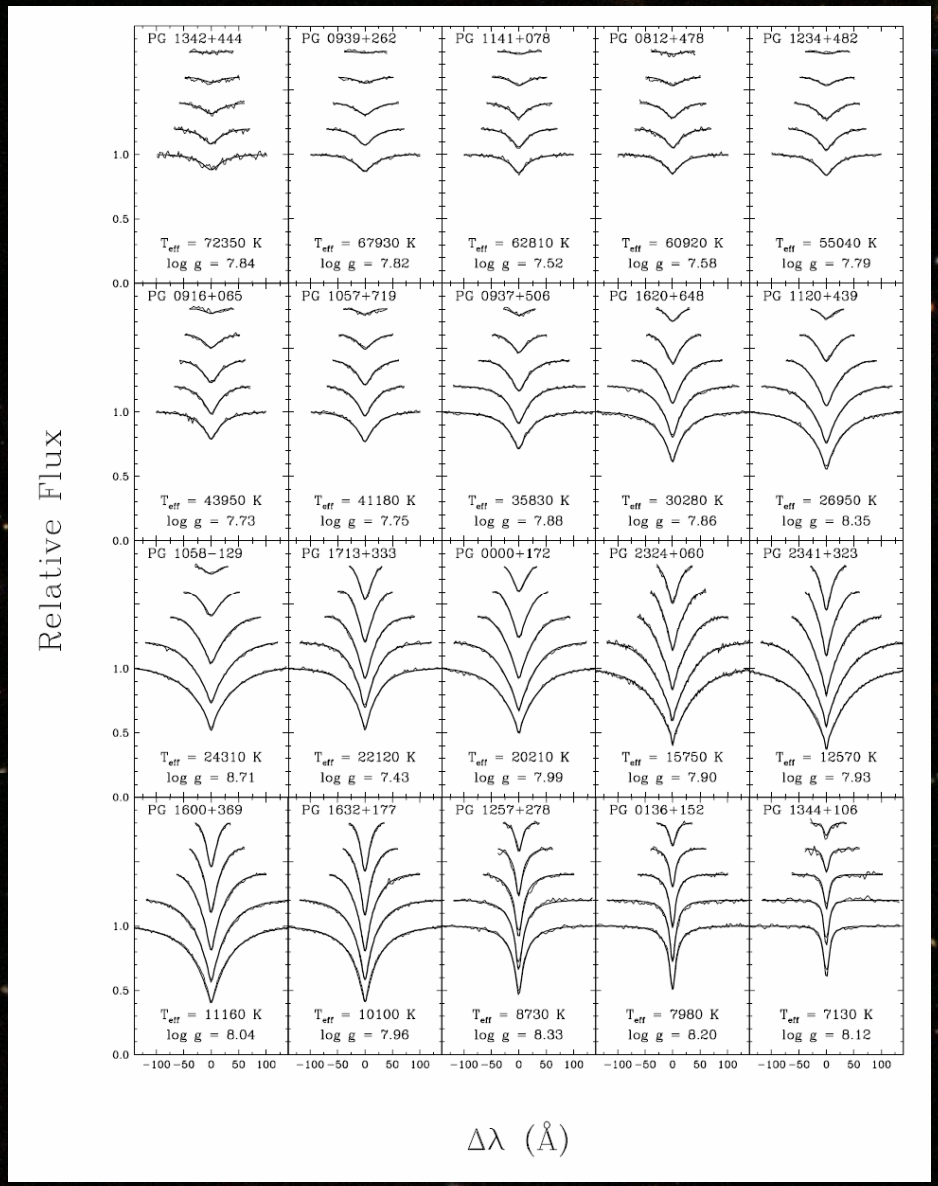




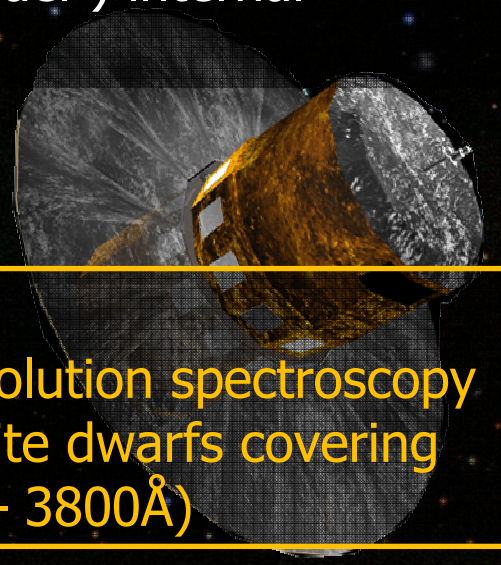


Easily recognised from GAIA spectral energy distribution plus distance

WD parameter determination

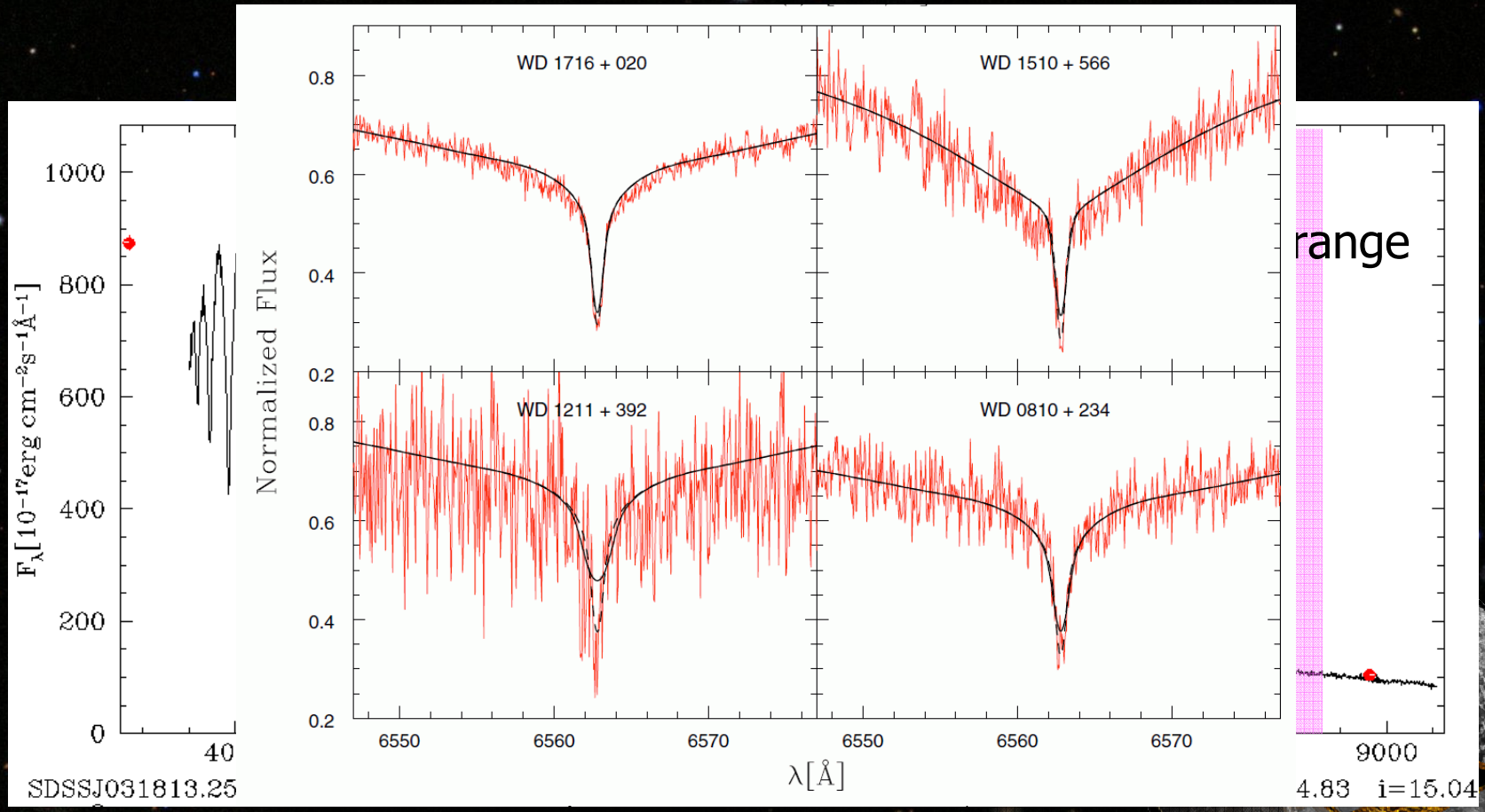


- Teff and log g from fitting spectral models to the Balmer lines
- Evolutionary sequences provide the cooling age
- GAIA distances provide strong checks on (model-) internal consistency



We need:
intermediate resolution spectroscopy for ~100000 white dwarfs covering Hα-H8 (6800Å – 3800Å)

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



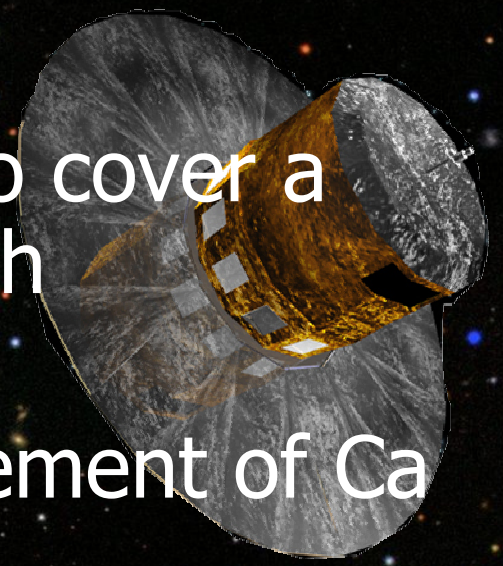
(Karl et al. 2005, A&A 434, 637; Berger et al. 2005, A&A 444, 565)

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

Number of observations/spectroscopic requirements:

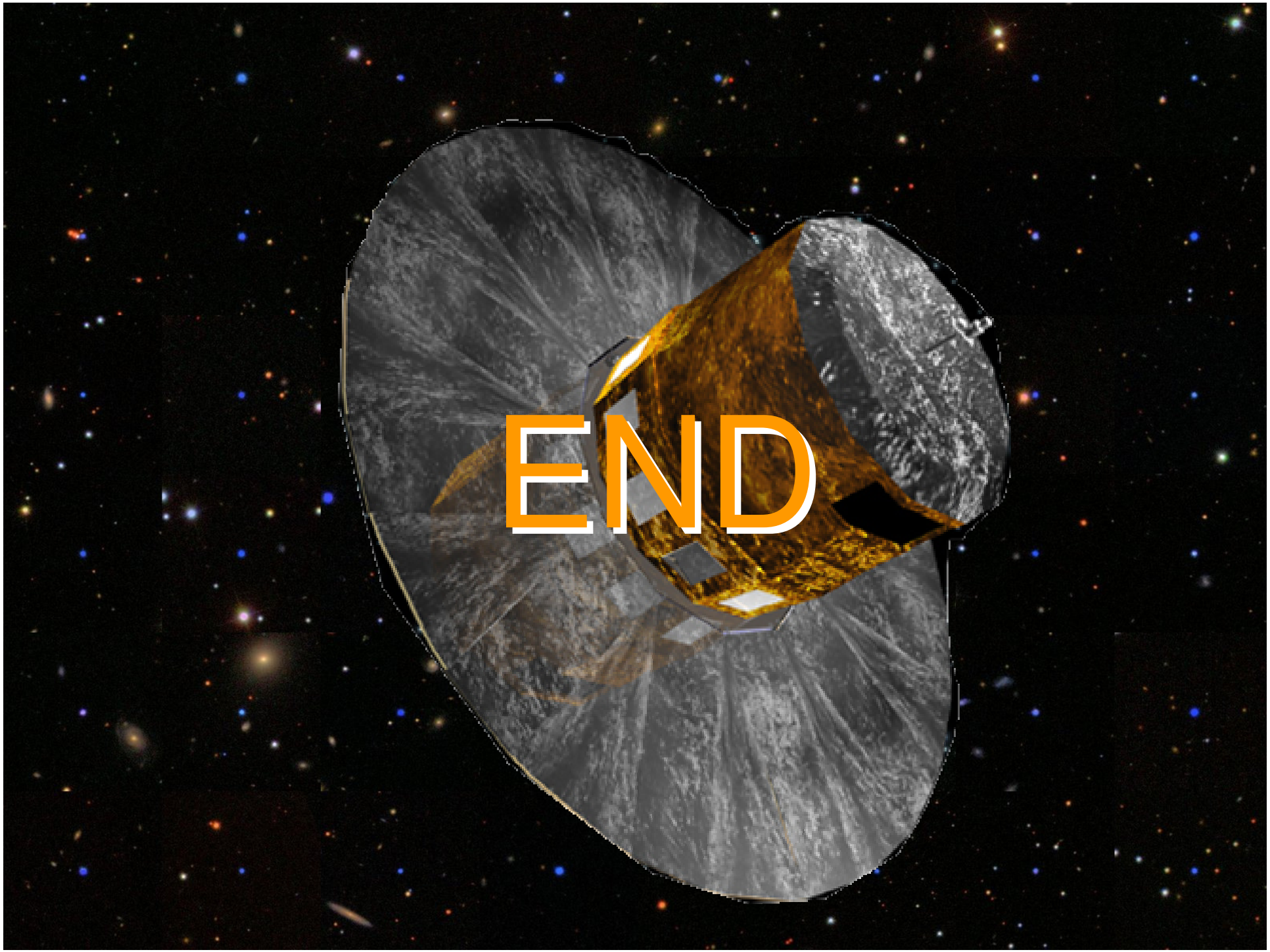
- 10 WDs per square degree
- GCDS: 1000 fibers per π □º ≈ 31 fibers for WDs (3% of all fibers)

- The higher Balmer lines carry most of the information on log g
- Therefore, we would propose to cover a spectral range 3800-6800 Å with $\lambda/\Delta\lambda \approx 5000$.
- This will also allow the measurement of Ca H+K (seen e.g. in DAZ)



Conclusions

- GAIA will identify a few 100000 white dwarfs
- From this population we will determine reliable ages for the galactic disk and the halo
- The white dwarf luminosity function of Gaia is a sensitive probe of the averaged star formation rate
- Due to their very short main-sequence lifetimes the shape of the SFR can be reconstructed from the luminosity function of massive white dwarfs
- To achieve these goals, we need R~5000 spectroscopy of ~100000 white dwarfs covering the range ~3800Å-6800Å
- There is a plethora of other science that will come out of the GAIA WD sample: constraints on the existence of WIMPS and alternative theories of gravitation, identify remnant planetary systems, probe the physics of dense plasmas, understand the origin of strongly magnetic white dwarfs...


END