Scientific workflow in astrophysics

White dwarfs in open clusters

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An analysis of four stellar rings

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About 50 years ago, one thousand ring-like structures (called stellar-rings) were discovered by Isserstedt (1968). They were believed to be groups of young stars formed by shell-like triggered star formation, which would make them excellent tracers of spiral arms, for example. Neglected for 40 years, we used highly accurate kinematic, astrometric, and photometric data to investigate the four most prominent stellar rings. The aim is to investigate if those structures are indeed physically related groups of stars. We used proper motions and parallaxes from the Gaia DR2 to calculate distances and to search for common properties. Color-magnitude diagrams using $BVJHK_s$ measurements were investigated and isochrones fitted. None of the four stellar rings consists of a physically related group of young stars. The location of stars in the line-of-sight mimics a ring-like structure on the sky. The color-magnitude diagrams are typical for an integrated field population and not for a young star cluster, for example. The currently available data are sufficient to analyze ring-like structures with a high statistical significance. This allows a new search for such structures

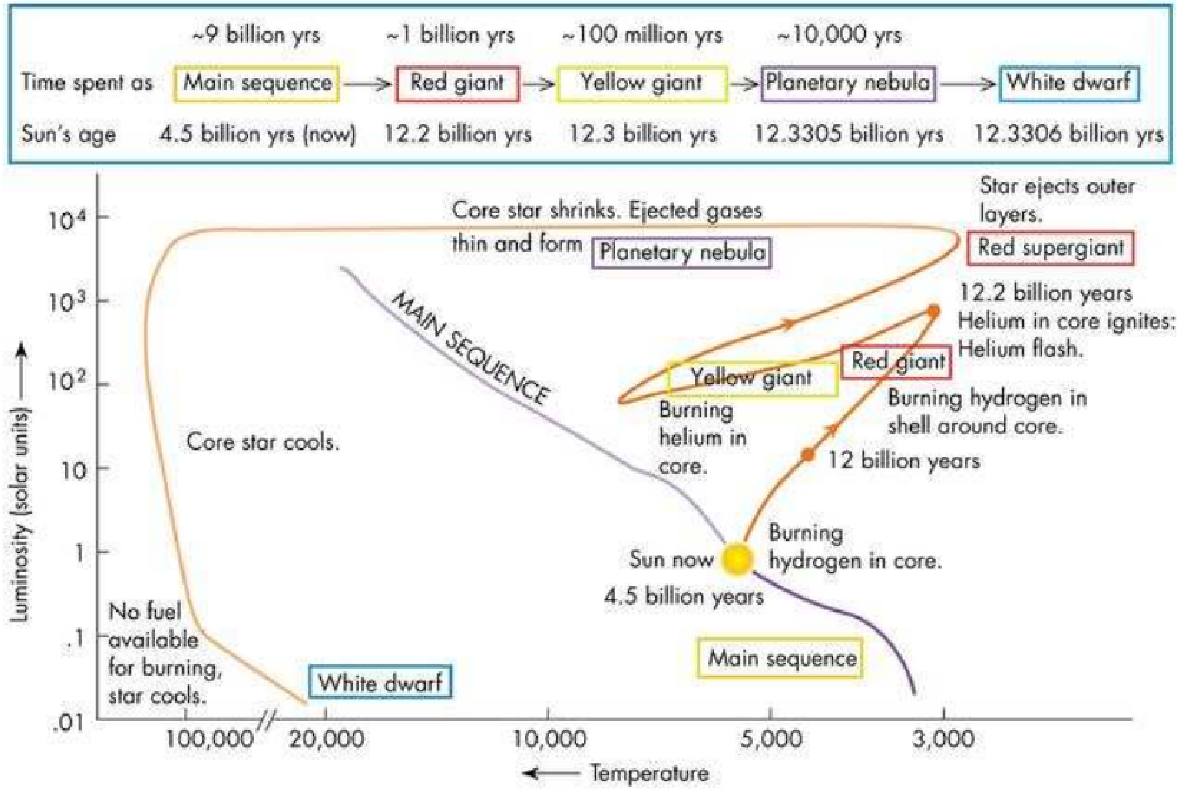


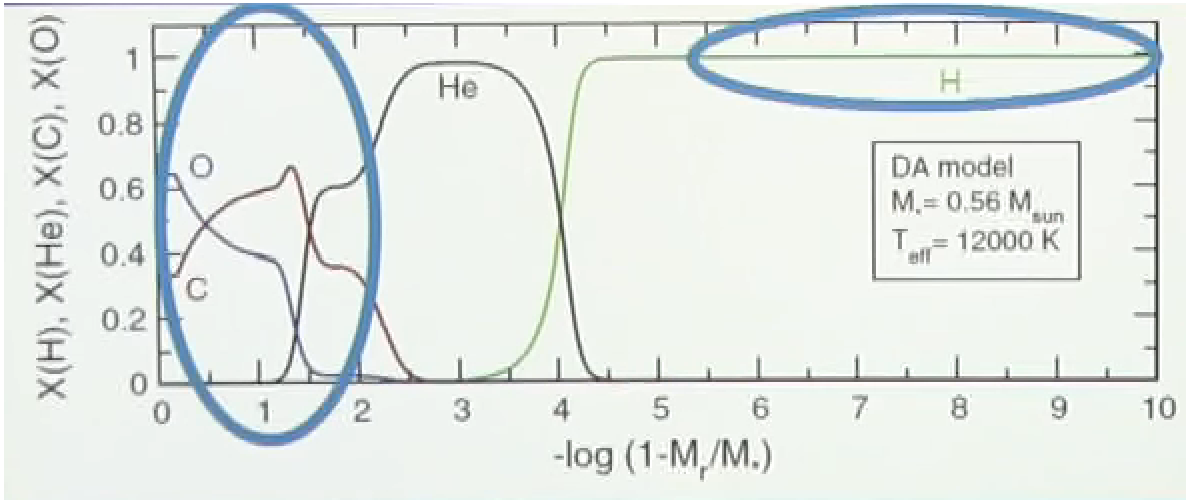
Figure 1.1: A Hertzsprung-Russell diagram is shown with the main sequence, post main sequence stellar evolutionary phases, and white dwarf cooling phase indicated. The evolution shown is for a 1 $M_\odot$ star.

Credit: Kalirai (2000)

- Over 99% of stars will eventually end up as white dwarfs (WDs)
- Many interesting properties: mainly from degenerate matter, cool in a very predictable way

C/O core

WD atmosphere (H or He, 10^{-14} M_{sun})



Althaus+ (2010)

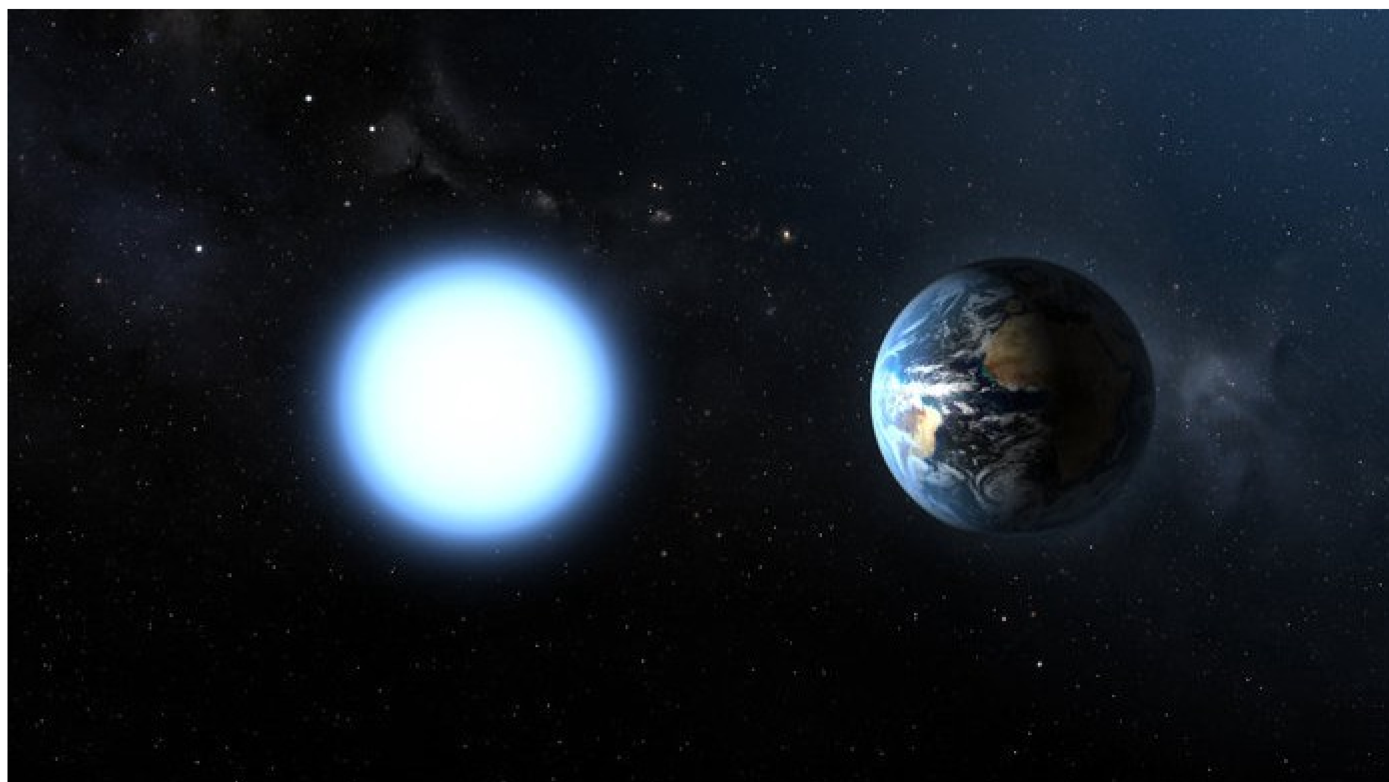
R scales with $M^{-1/3}$

Mass: less than 1.44 M_{sun} (majority around 0.6 M_{sun})

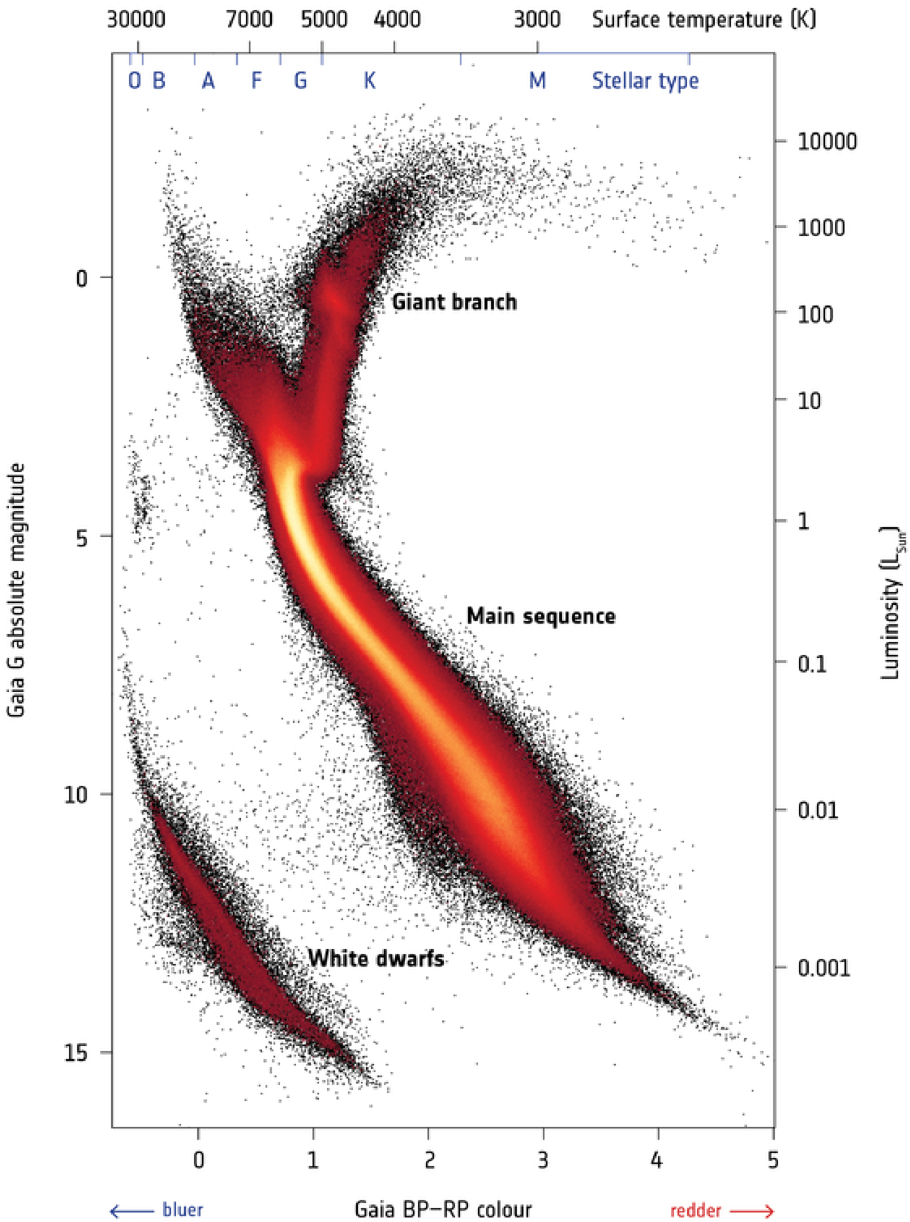
Radius: about 10^4 km

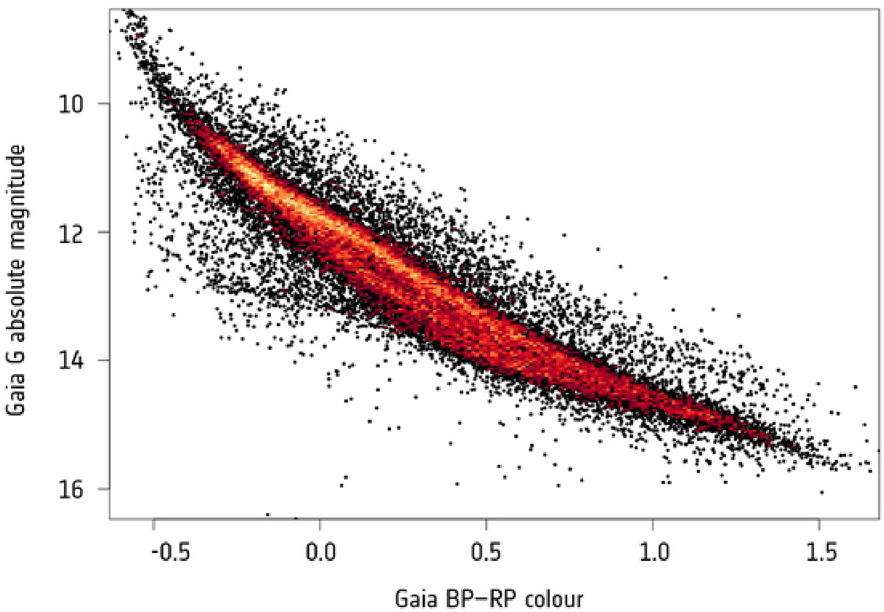
g: 10^6 m/s^2

Escape speed: 0.02 c



→ GAIA'S HERTZSPRUNG-RUSSELL DIAGRAM





No. of Wds known:
Y 1999: ~2000 objects
Y 2017: > 30 000 (just before Gaia DR2)
Y 2019: ~ 260 000 (Gaia DR2)
Future: $13*10^6$ (LSST)

Credit: ESA/Gaia/DPAC

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A *Gaia* Data Release 2 catalogue of white dwarfs and a comparison with SDSS

Nicola Pietro Gentile Fusillo,[1⋆] Pier-Emmanuel Tremblay,[1] Boris T. Gänsicke,[1] Christopher J. Manser,[1] Tim Cunningham,[1] Elena Cukanovaite,[1] Mark Hollands,[1] Thomas Marsh,[1] Roberto Raddi,[2] Stefan Jordan,[3] Silvia Toonen,[4] Stephan Geier,[5] Martin Barstow,[6] and Jeffrey D. Cummings[7]
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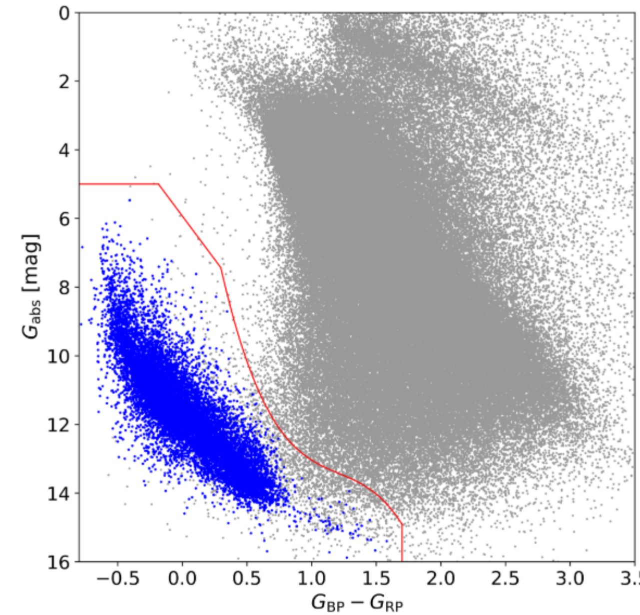

Figure 1. *Gaia* H-R diagram showing a representative sample of objects (selected randomly using the RANDOM_INDEX *Gaia* parameter) with PARALLAX_OVER_ERROR > 1 (gray points). Spectroscopically confirmed white dwarfs (from Gentile Fusillo et al. 2015a; Hollands et al. 2017) used to broadly define the white dwarf locus are over-plotted in blue. The initial cuts adopted for our selection are shown as red solid lines.

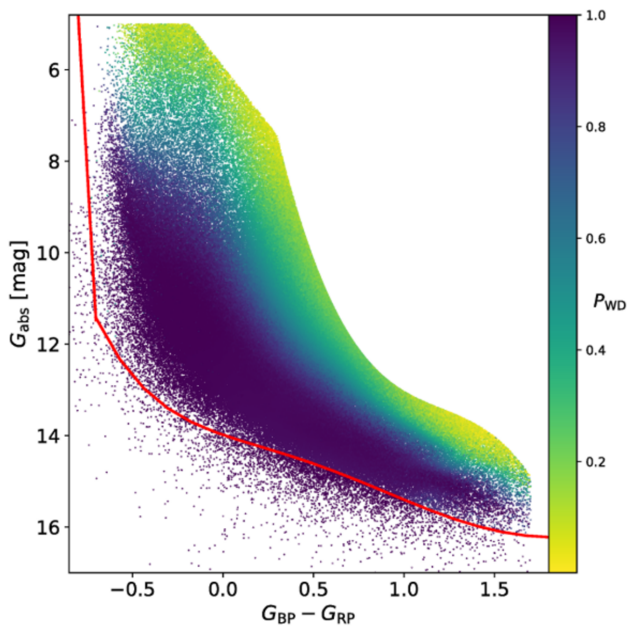

Figure 3. *Gaia* H-R diagram of all 486 641 objects in our catalogue. The colour scale indicates the $P_{\rm WD}$ of each object. All objects below and to the left of the solid red lines are assigned a $P_{\rm WD}$_FLAG.

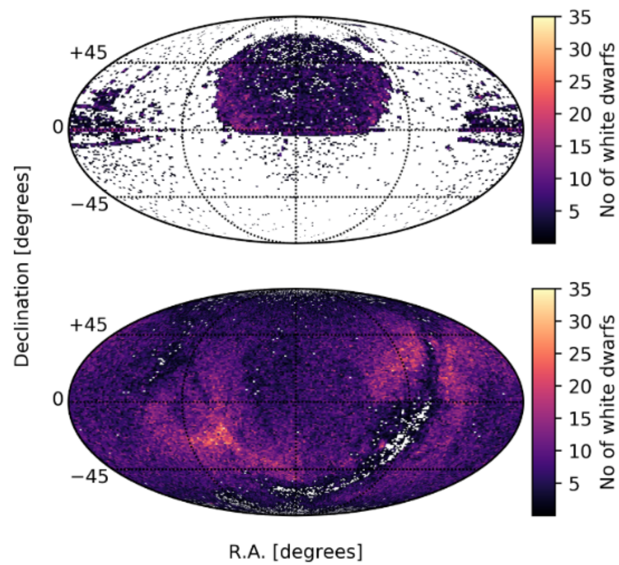

Figure 5. *Top panel:* Sky density of the ≃ 33 000 known white dwarfs before *Gaia* DR2 (Dufour et al. 2017; Kepler et al. 2016c; Hollands et al. 2017; Kilkenny et al. 2015; Gentile Fusillo et al. 2015b; Gentile Fusillo et al. 2017a). *Bottom panel:* Sky density of *Gaia* DR2 white dwarf candidates with $P_{\rm WD} > 0.75$ from the catalogue presented in this article.

A *Gaia* DR2 view of the Open Cluster population in the Milky Way

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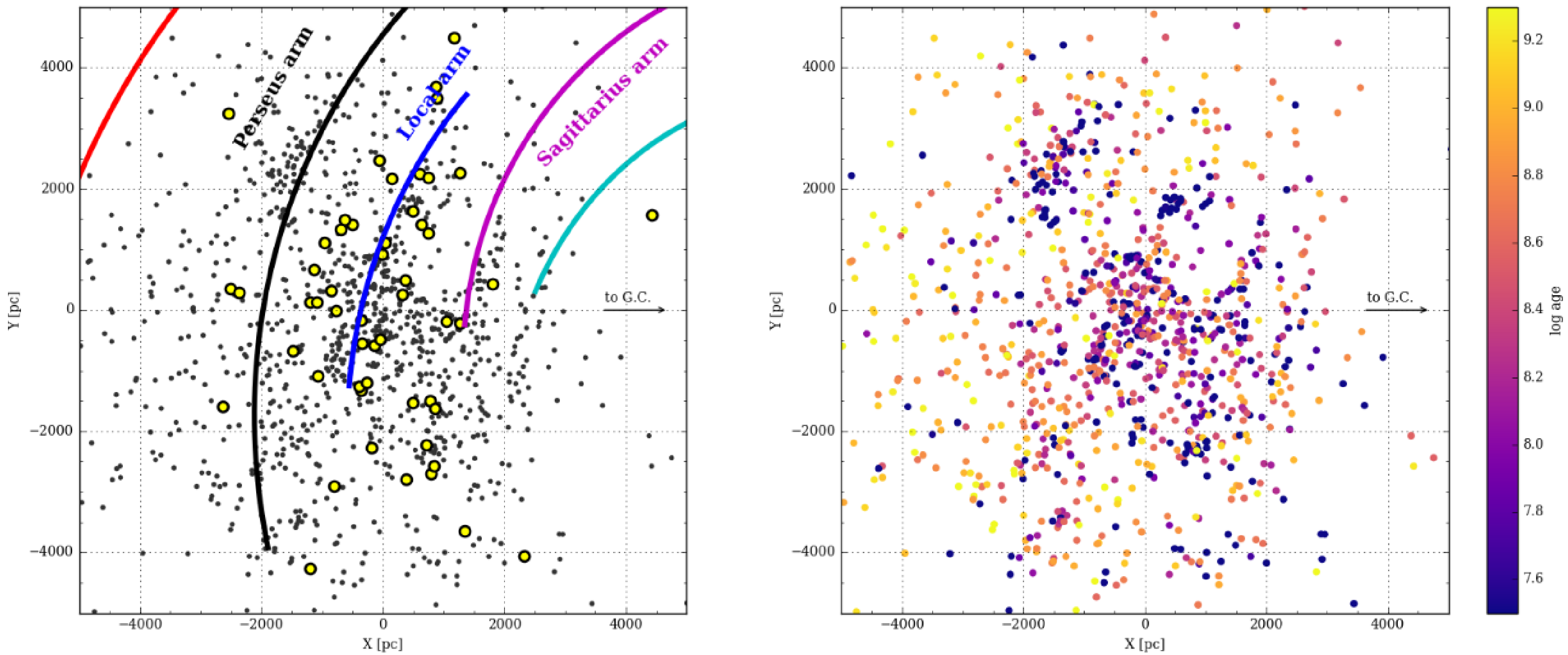
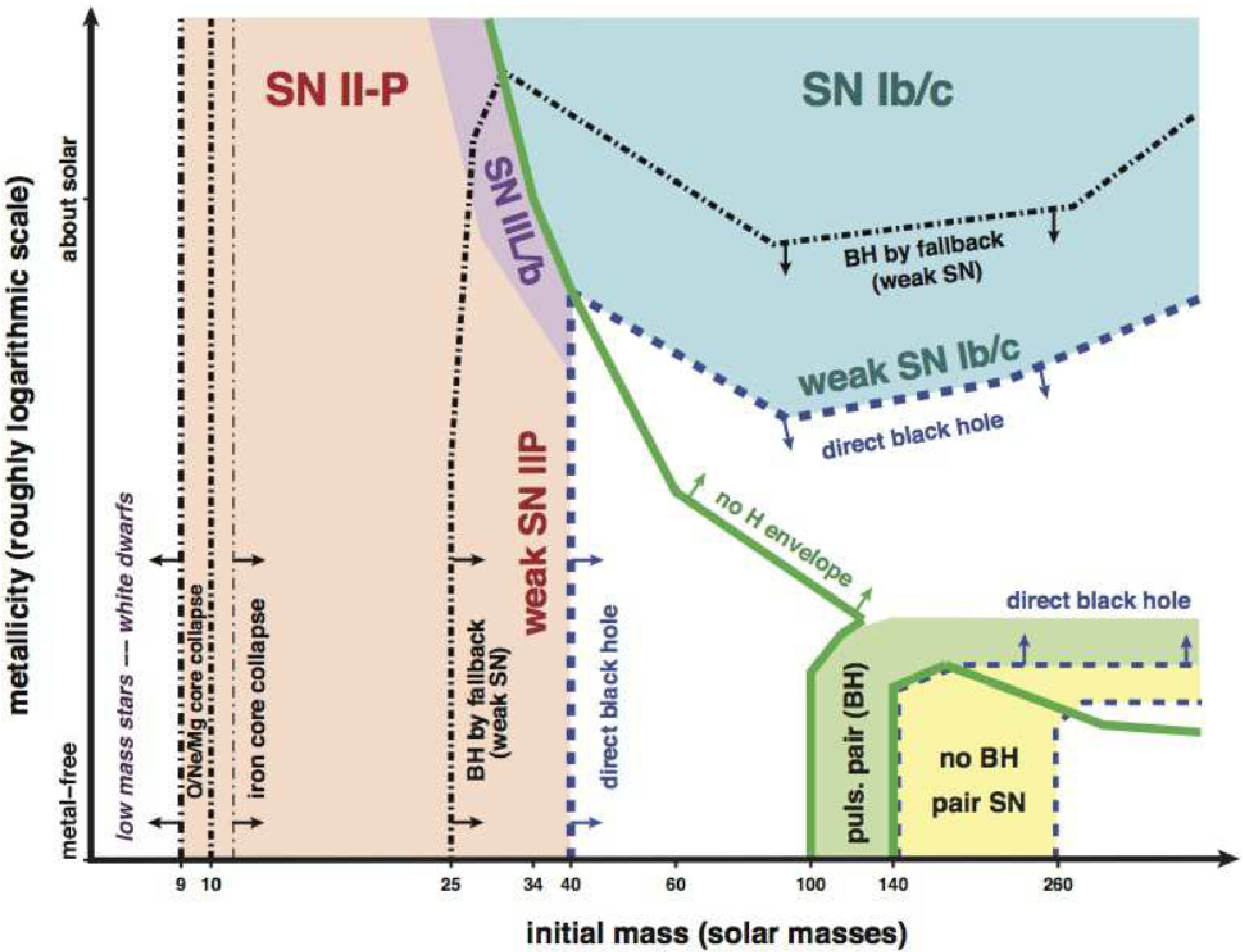


Fig. 9. Left: location of the OCs projected on the Galactic plane, using the distances derived in this study. Superimposed is the spiral arms model of Reid et al. (2014). The yellow dots indicate the objects newly identified in this study. Right: same sample of OCs, colour-coded by age (as listed in MWSC).

Possible science

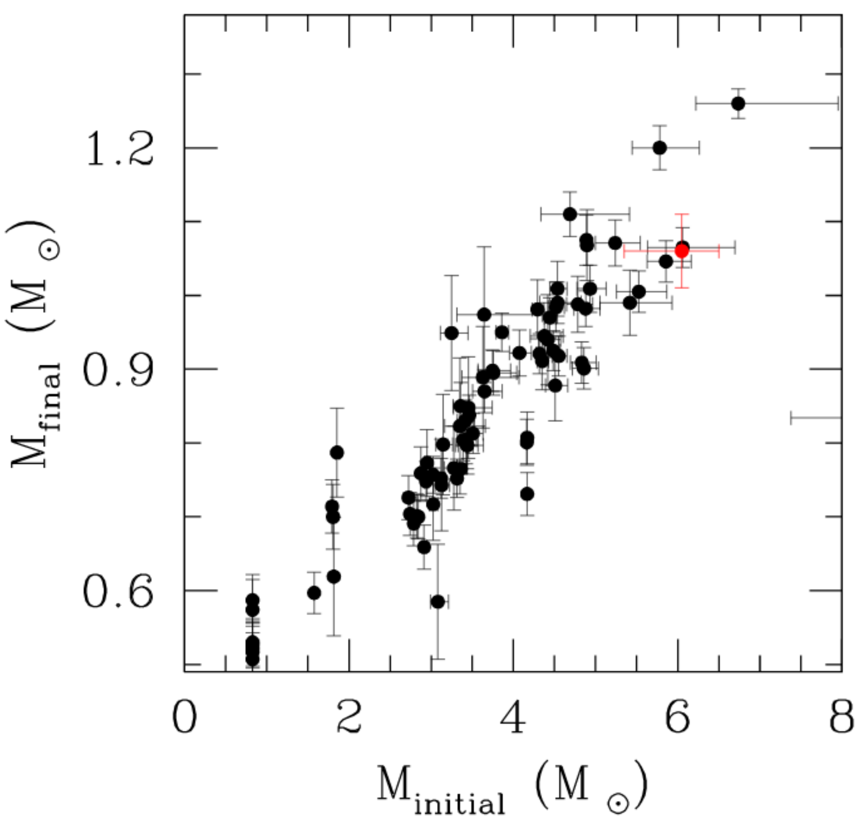
- Refinement of T_{eff} and log(g) values for the catalog WDs when matched to a cluster (more precise distance and reddening for clusters than in the field)
- Are WDs retained in the clusters? Are they hidden in binaries?
- Statistics: No. of WDs as a function of cluster parameters (age, mass...)
- Mass determination via gravitational redshift (Hyades; Pasquini+ 2019)

Supernovae



Heger+ (2003)

- How massive are stars still forming WDs?
- $T_{lif} = T_{cluster} - T_{cooling} \rightarrow$ stellar progentior mass
- Detection of neutron star binaries and single massive WDs in clusters with a turn-off mass of about 10 M_{sun} would provide a direct evidence for multiple supernova channels



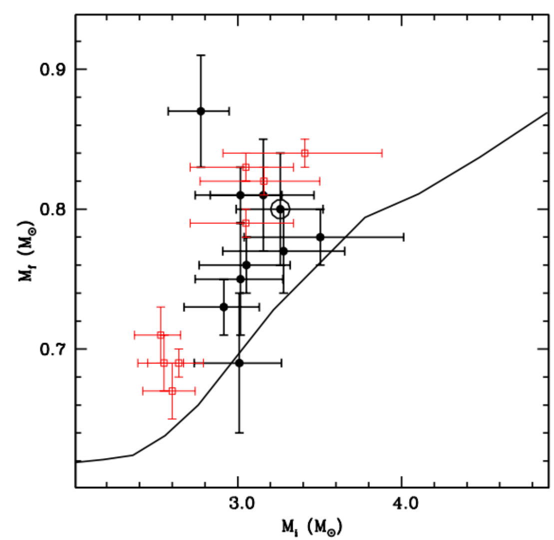


Figure 4. IFMR for Praesepe (filled circles with error bars, from Table 2). For the sake of comparison we display also the IFMR for the Hyades derived in Paper I (open squares with error bars). The solid line displays the IFMR from the Marigo et al. (2017) theoretical models. The open circle highlights the new cluster WD #662998983199228032, in case it is of DA spectral type, like the others.

Where does the boundary between the neutron stars and Wds lie? Potentially massive effects affecting large area of astrophysics!

Salaris & Bedin (2019)

Richer+ (2019)

Preliminary workflow

- Use the catalog of open clusters and white dwarfs, match them together based on positional, astrometric and distance criteria.
- Validate the white dwarfs against the open clusters
- Compute the white dwarfs and cluster parameters (e.g. mass of the progenitor, cooling age, etc.)
- Address other science cases using the catalog (if possible…)
- Write the paper. Everyone should contribute to a section of the paper based on one’s expertise.
- Submit the paper, respond to the referee’s comments

Preliminary plan for the semester

- We are flexible!
- Weekly pitch, lectures or hands-on sessions about selected aspects of the science case or analysis
- Begin to write the paper draft in ~early November, submitting it before the end of the semester