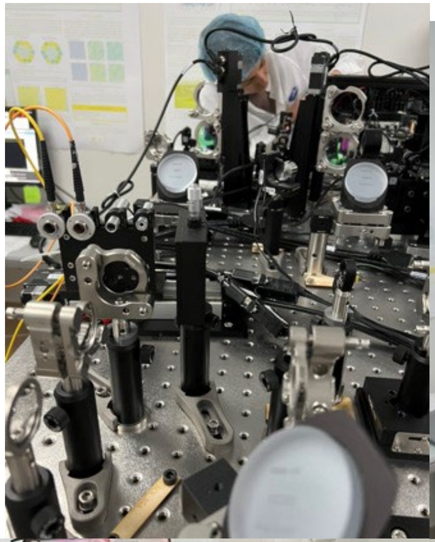
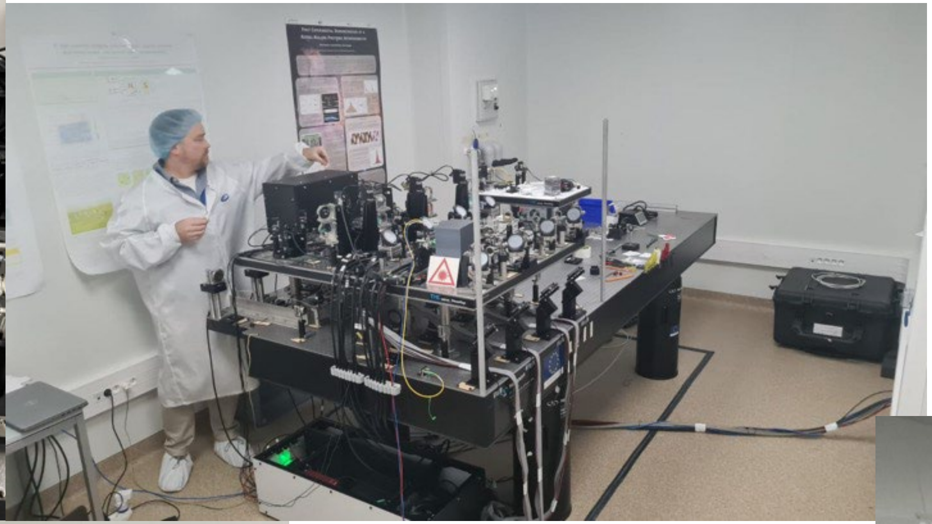
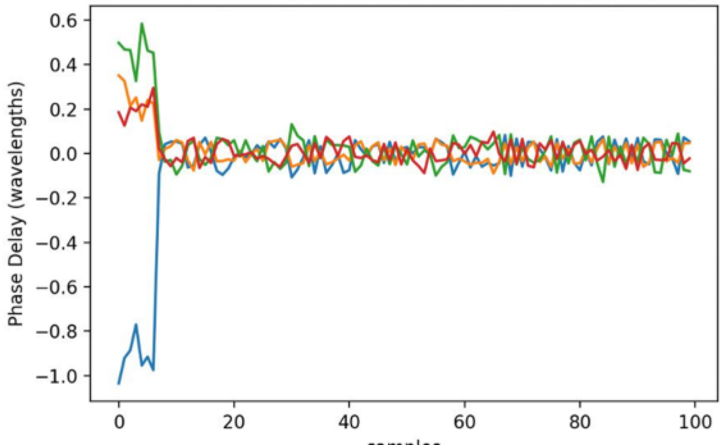
Uncoupling Gaia's blended binaries with Heimdallr and CHARA: precision masses for Galactic archaeology

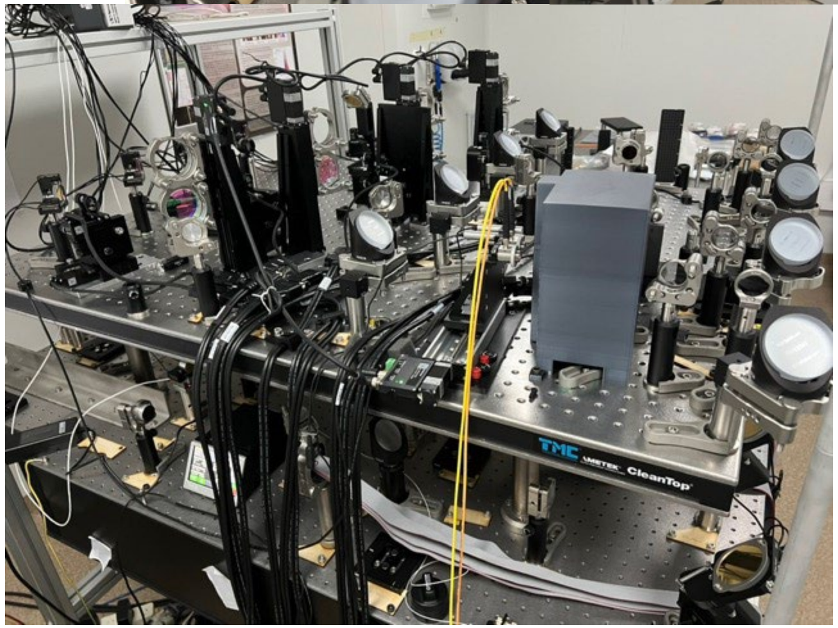
Mike Ireland for the Asgard Team

(OCA, USyd, Leuven, Exeter, …)

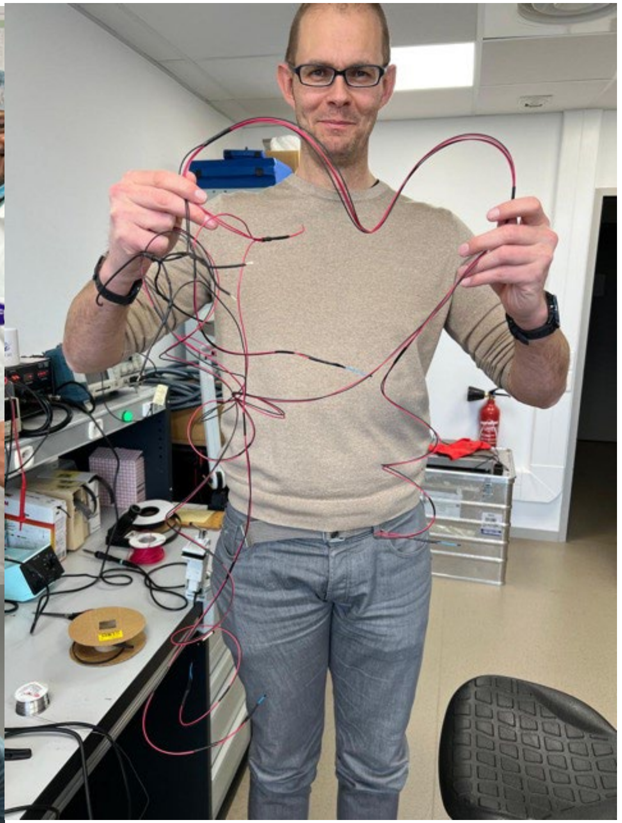








Apologies for not being 100% at this meeting every day – a little pre-occupied lately!



Thanks to the OCA team especially for enabling the success so far after many challenges!

+ many others, inc Sebastien Morel, Yan Caujolle, Chrisophe Bailet…

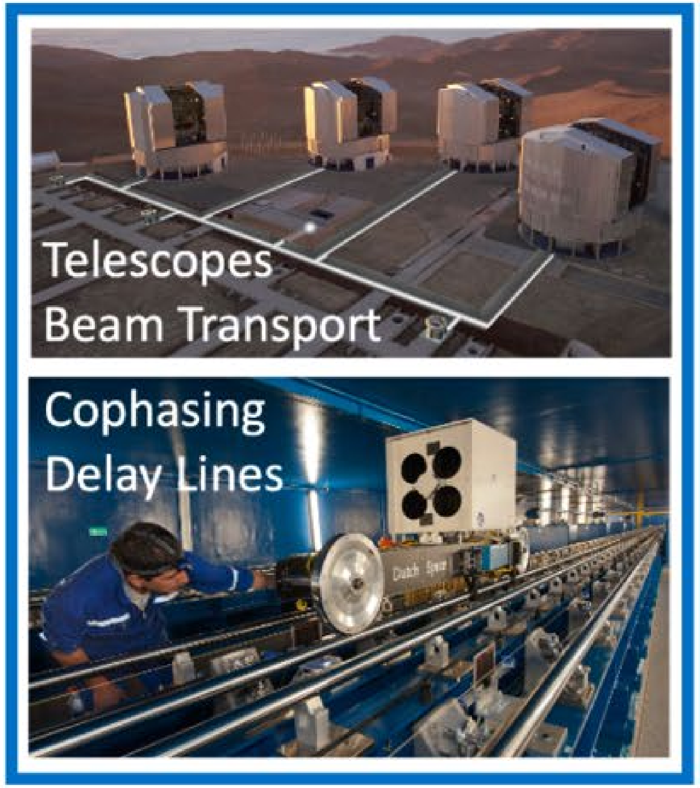
And earlier (+later) support from Peter Tuthill & team, Stephane Lagarde…

Context

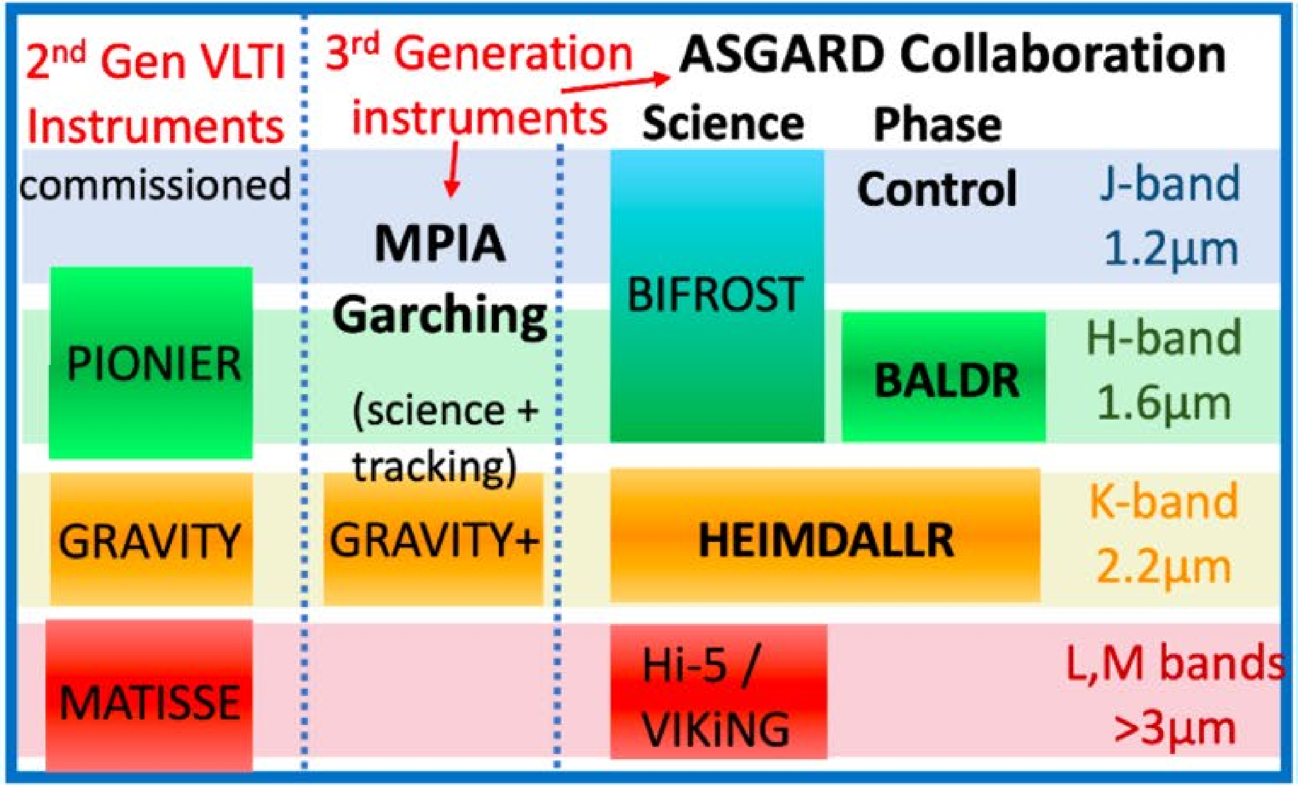
VLT is highly successful with 2nd gen instruments, but is missing:

- High contrast imaging for exoplanet detection at mas scales.
- Sensitivity-optimized beam combination.
- J band operation
- Adaptive optics that enables J and H.

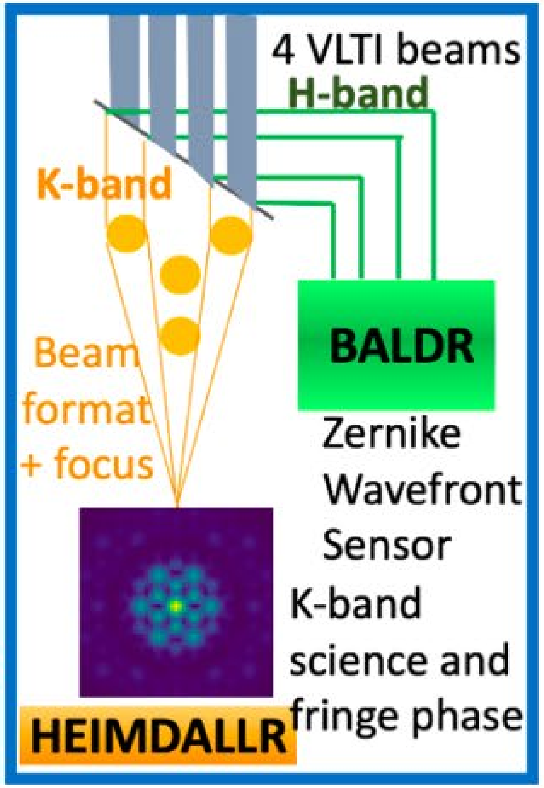
VLT Interferometer



Beam Combiners

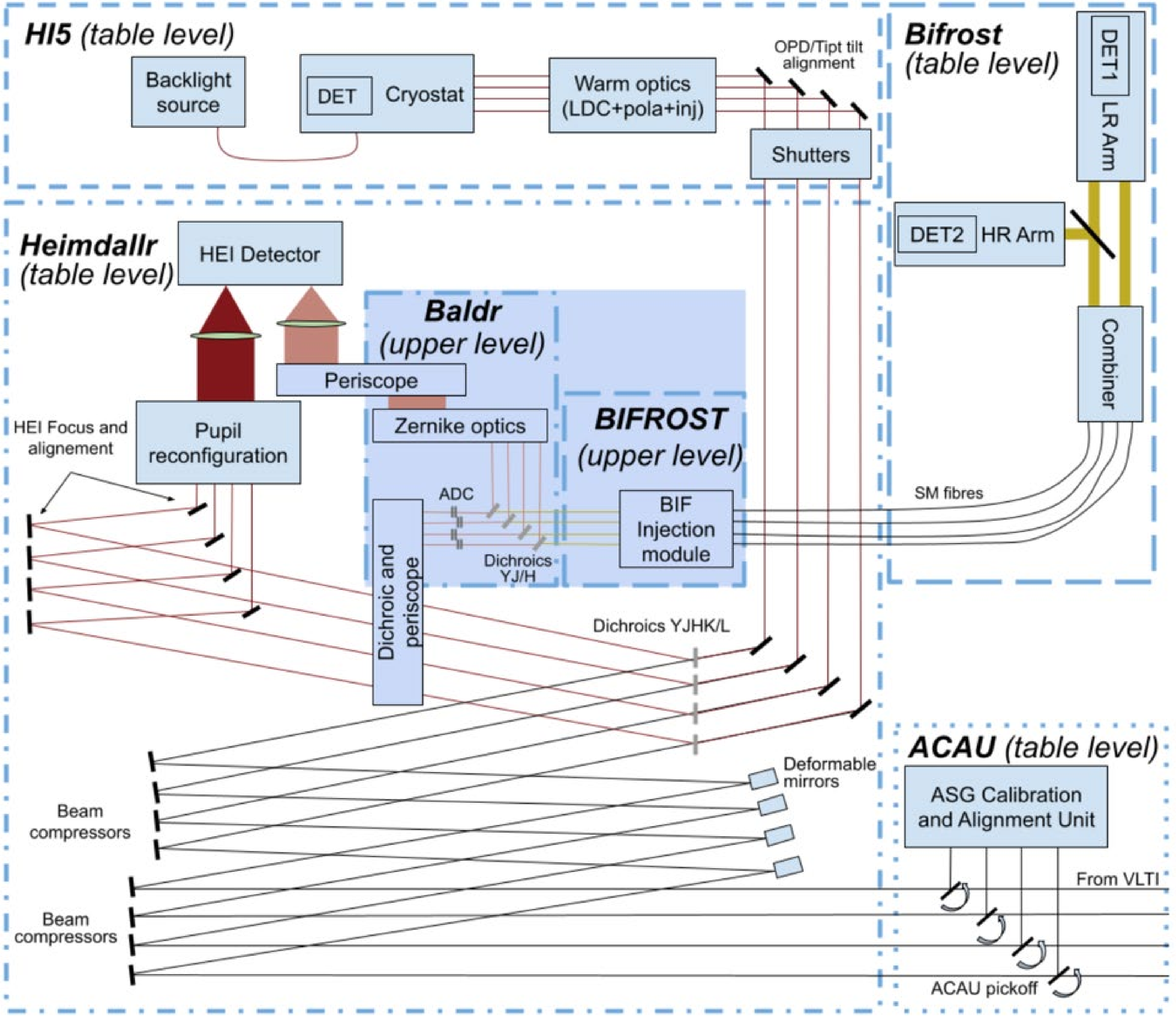


Heimdallr + Baldr

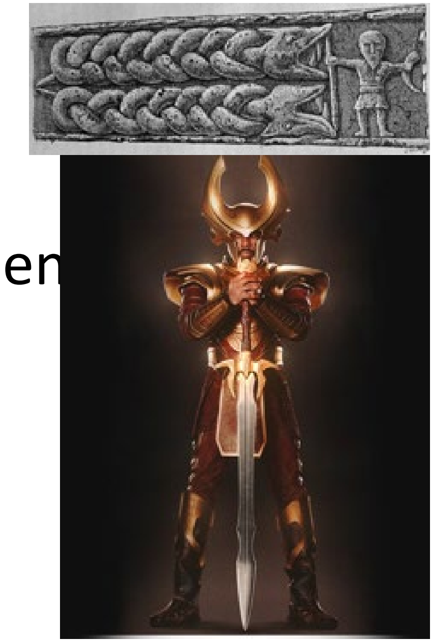


Heimdallr and Baldr

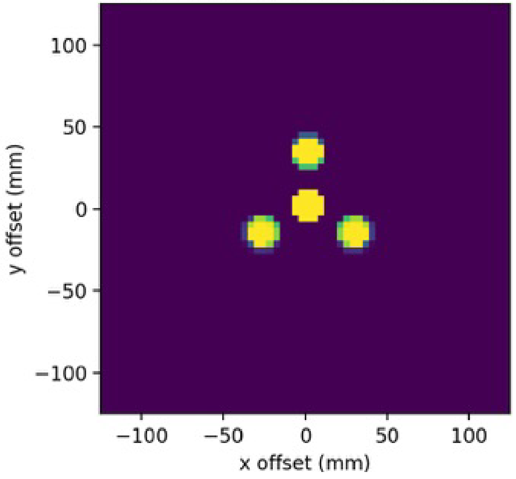
- Heimdallr and Baldr together provide fringe tracking and adaptive optics for the Asgard suite.
- Heimdallr also provides broad-band (1.95-2.15 and 2.15-2.35 microns) 4-telescope visibilities and closure phases.
- We anticipate very quick observing sequences for Heimdallr (AT acquisition + 5 minutes) enabling surveys.

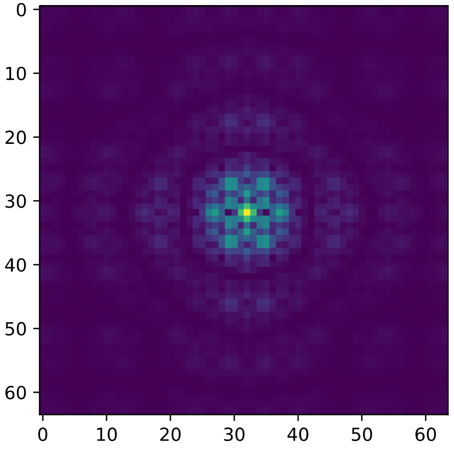


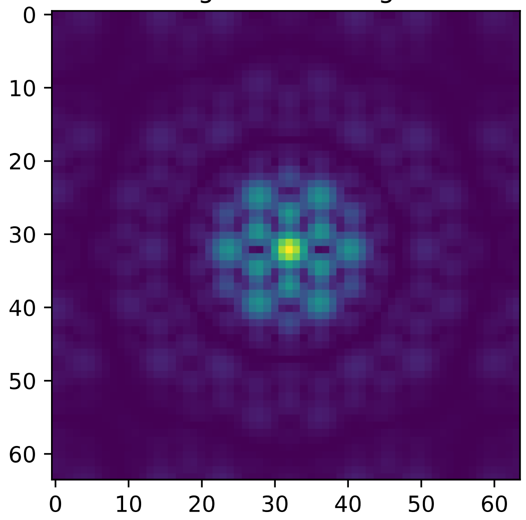
Heimdallr[1] Concept



- By turning VLTI into an aperture-mask interferometry experimen in 2 wavelengths covering K:
    - Sensitivity is maximised
    - Tilt, pupil alignment and focus are simultaneously sensed.
- High-Efficiency Multiaxial Do-it ALL Recombiner







[1]Also the guardian of the Bifröst bridge to Asgard.

Linkage to CHARA

- Much of the team (e.g. Stefan, Peter, me) have strong links to CHARA.
- Generally, we've agreed to be an team open to new scientific collaborations as much as resources allow (hint – new collaborators that can help with pipelines and observing in the future would be great!).
- There are now 1 main optical/IR interferometers in each hemisphere, so collaborating on impactful all-sky surveys is important!

Galaxies

The co-evolution of the Universe and galaxies within it is often studies by looking at populations as a function of redshift.

Our own "Milky Way" galaxy is a typical galaxy, and we can study its history in much more detail, giving a timeline through *galactic archaeology.*

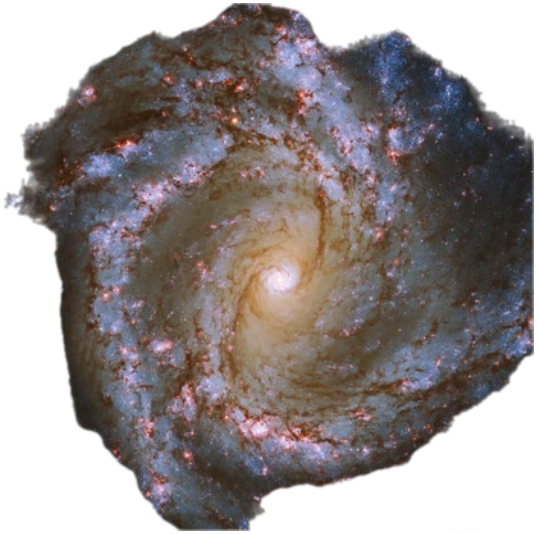
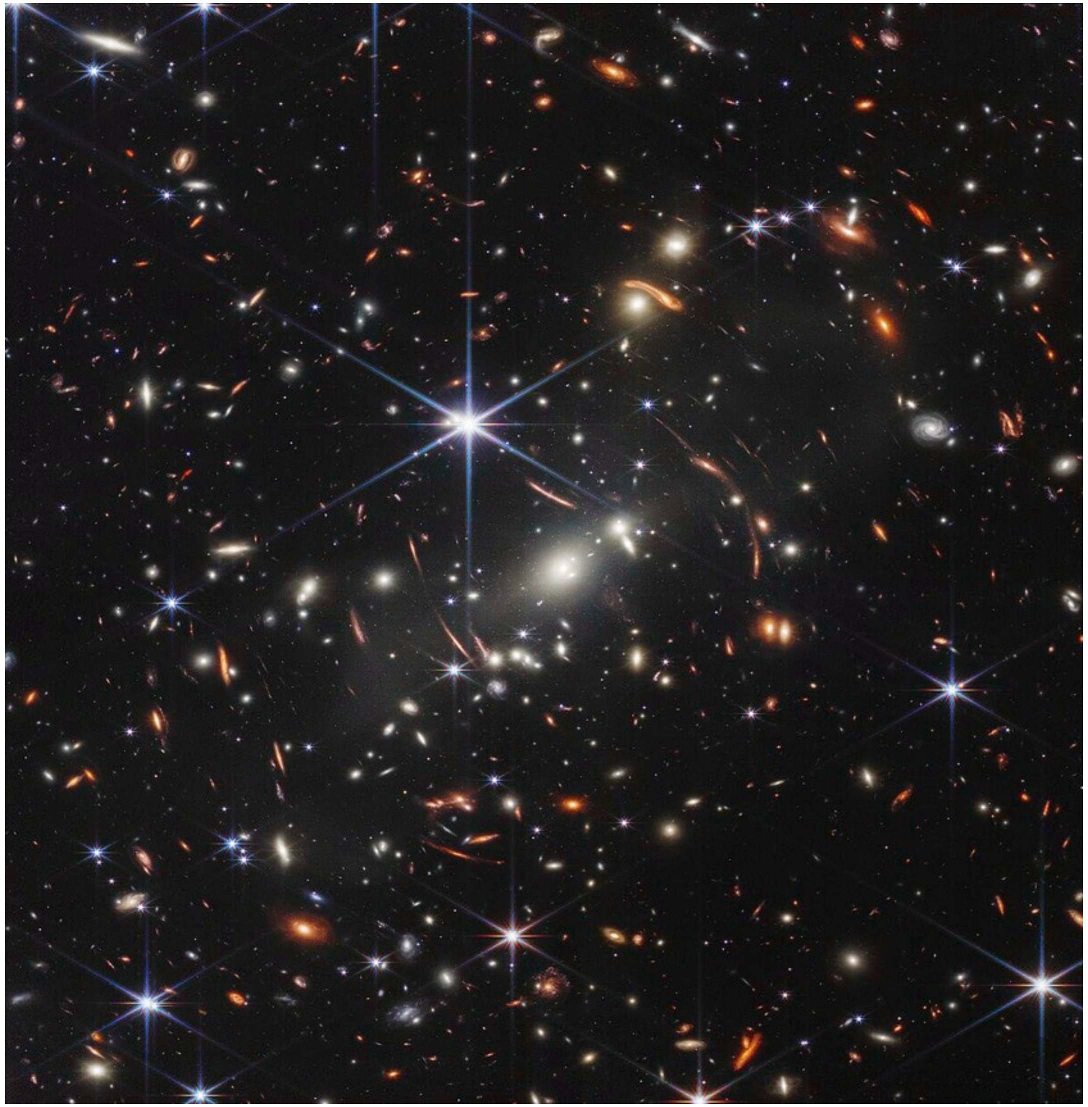
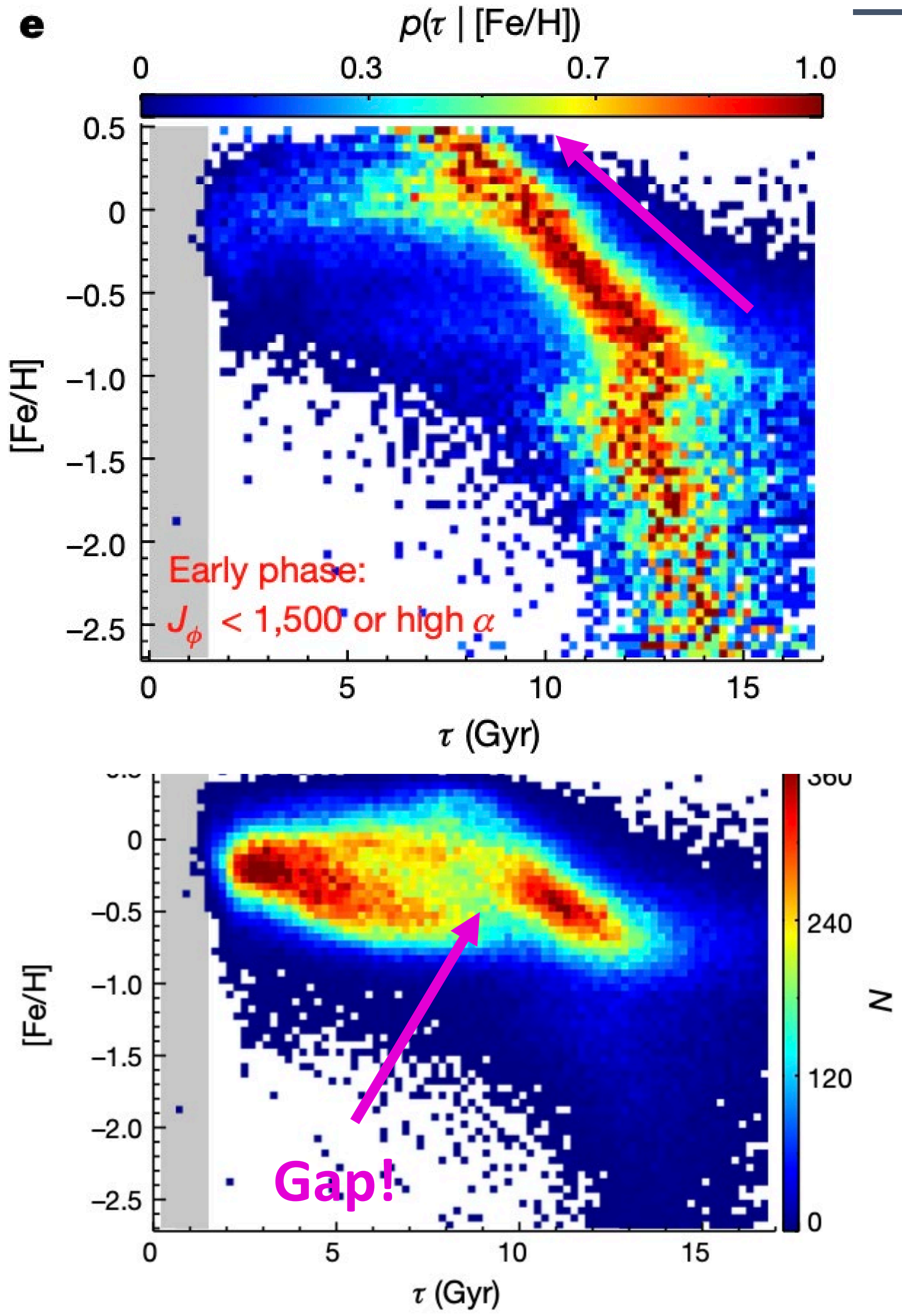


Image Credit – ESA/NASA



Our Galaxy

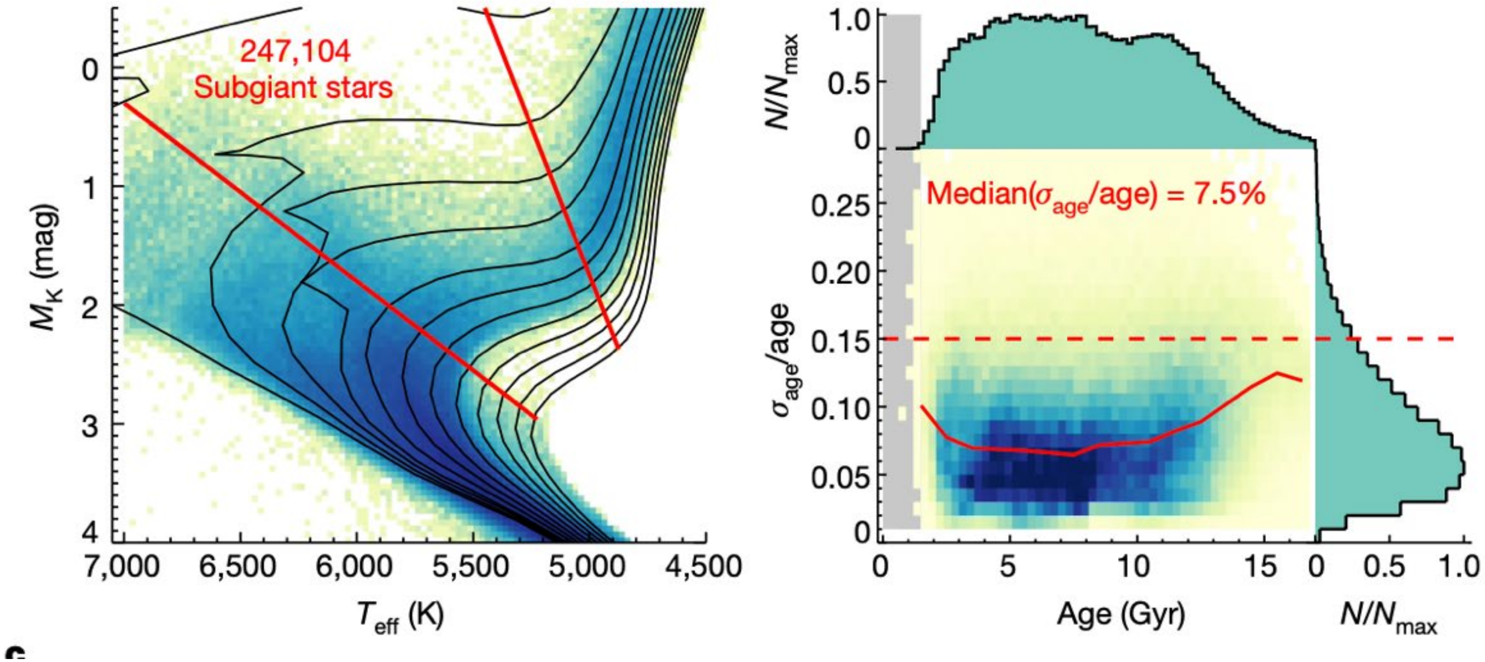
- Metal poor gas, in a much less structured environment (*irregular galaxy?)* started to form stars around 14 Gyr ago.
- The assembly of the Galaxy included violent collisions between mini-galaxies, which lost their dark matter and rapidly formed stars through these collisions, becoming globular clusters.
- This alpha-rich star formation gradually became metal rich and moved towards the center of our Galaxy, forming the bulge.
- Around 8 Gyr ago, a quiescent disk was formed, with a metallicity gradient - at a given age, metal rich stars come from inner parts of the Galaxy, and metal poor stars come from outer parts of the Galaxy.



Xiang and Rix (2022)

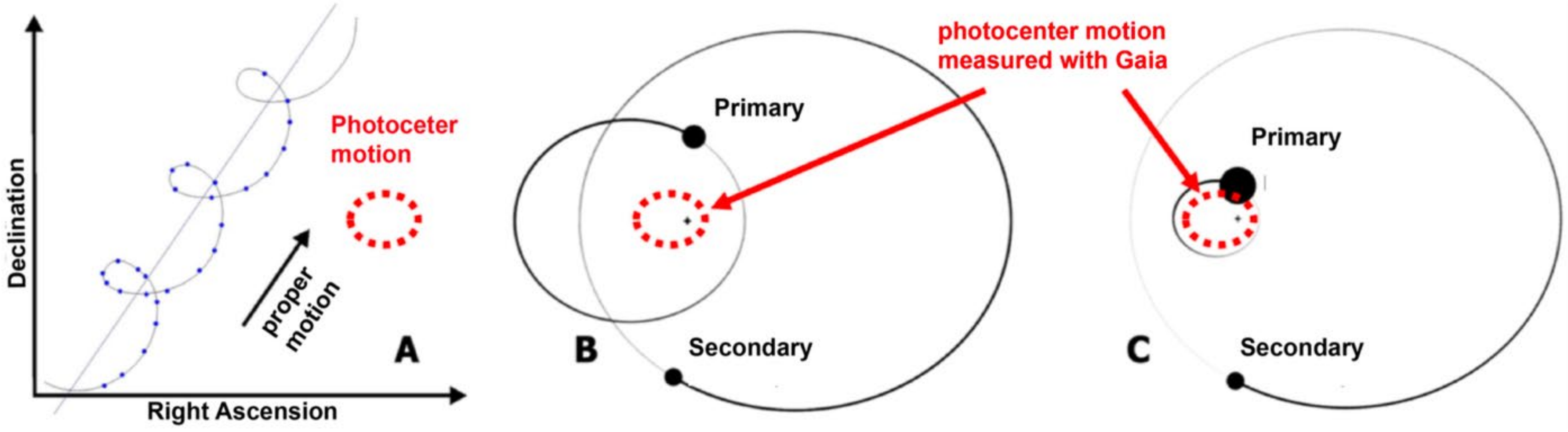
Stellar Ages

- Ages are critical for Galactic archaeology! Individual stars with a measured metallicity only give a good age as a subgiant star (for stars less than ~1.3 solar masses, i.e. those that evolve with ho Hertzsprung gap).
- The principle that mass for an evolved star gives age is simple – mass is the amount of nuclear fuel that was available to burn, so all that is needed is the luminosity history (models + observations).



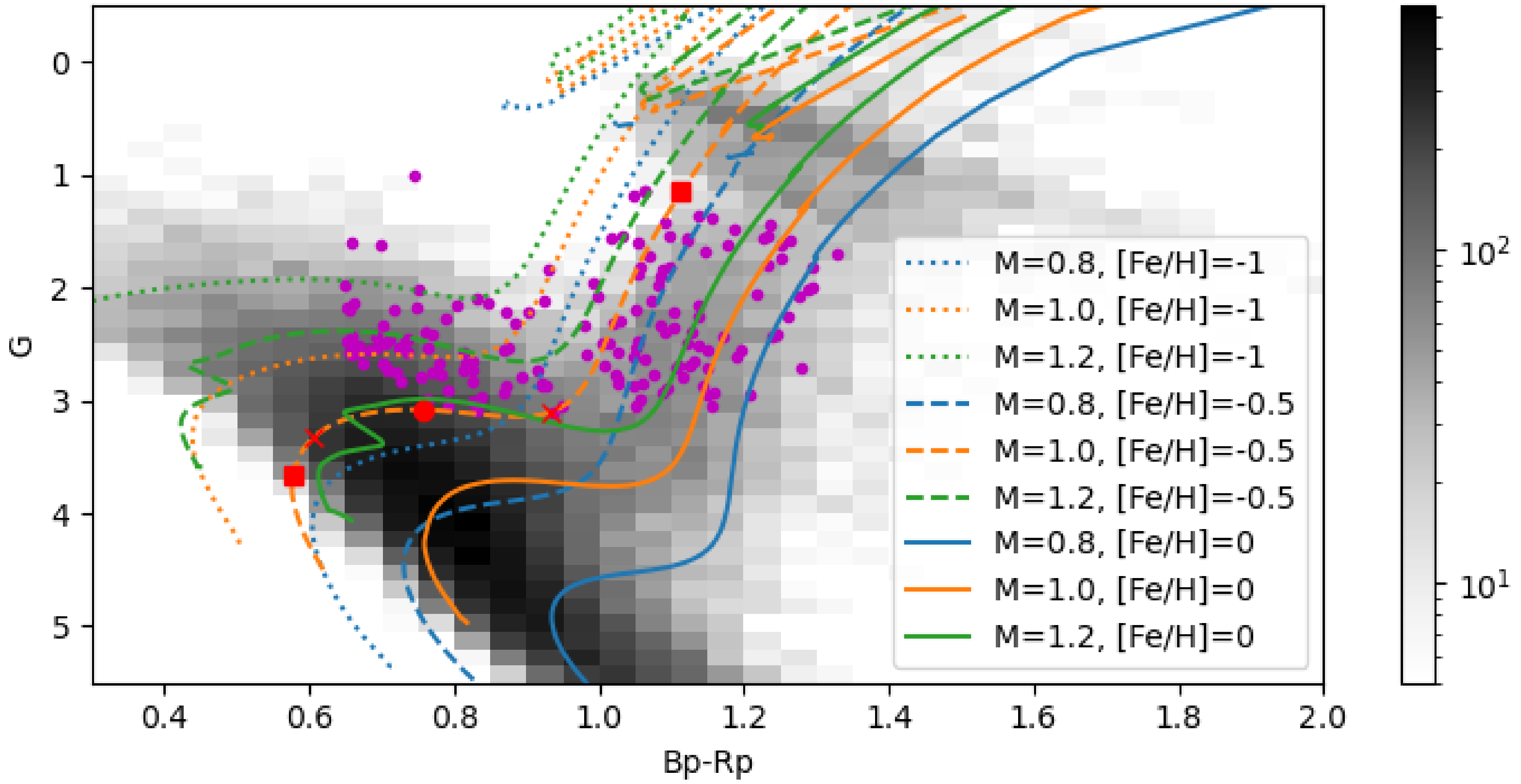
Gaia Binary Stars

- Principle is simple: Gaia measures all orbital parameters for the photocenter motion and a good parallax.
- The only missing parameters are the flux ratio and the separation – *one interferometric measurement!*
- An interferometric separation plus parallax (each measurable to <0.5%) gives semi-major axis and total mass: $M = a^3/P^2$.
- If flux ratio is small, the ratio of photocenter to interferometric semi-major axes gives $M_2/(M_1+M_2)$ directly. For moderate flux ratios there is just a little (easy) math.



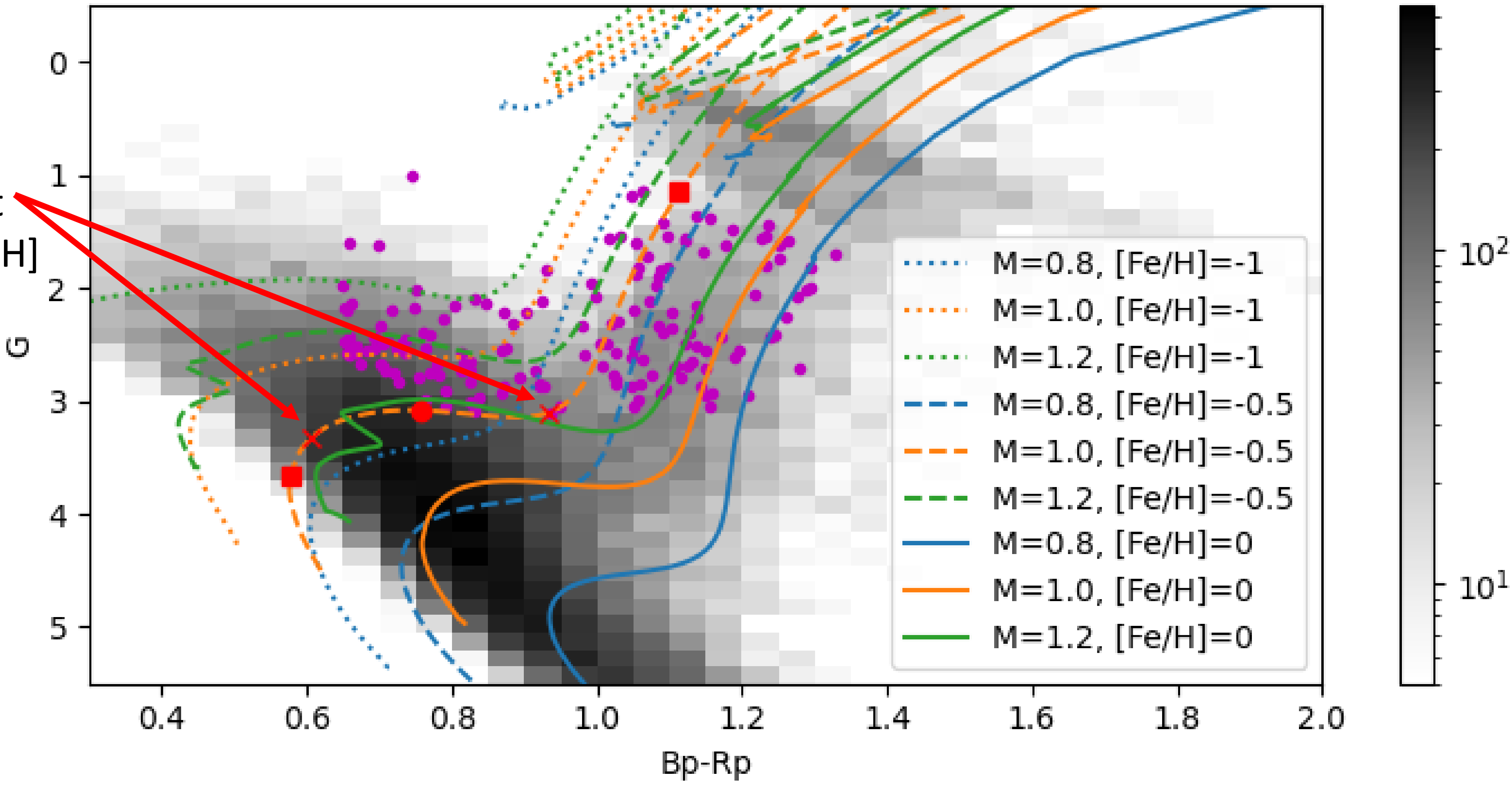
Initial Heimdallr Sample

Density – Gaia photocenter binaries brighter than G=13 with 2% periods already!



Initial Heimdallr Sample

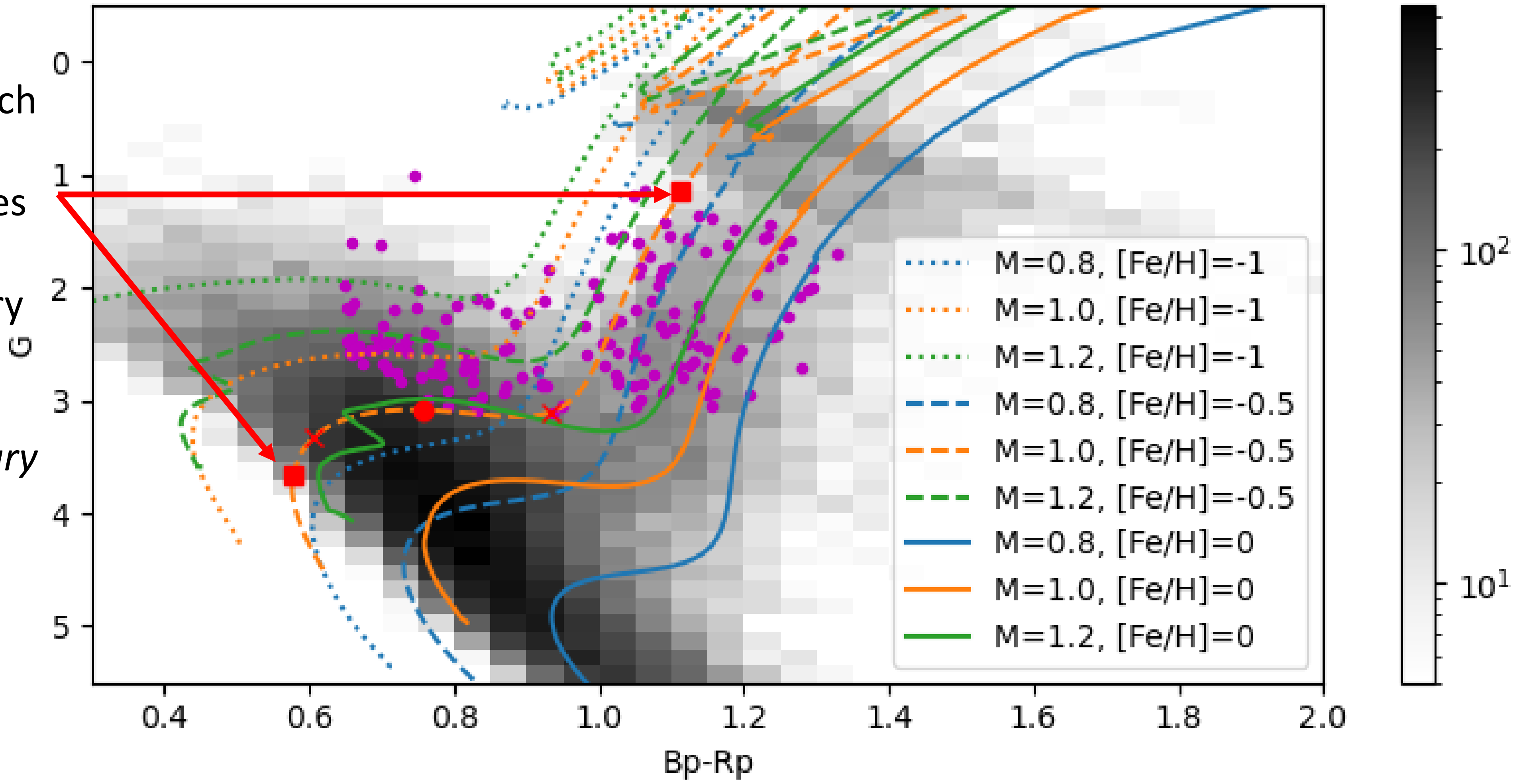
Turn-off stars: 5% ages possible (assuming perfect models) with [Fe/H] precision of 0.07, plus good Gaia distances and photometry.



Initial Heimdallr Sample

Lower Giant Branch and Upper Main Sequence: 5% ages if we can also measure a primary mass to 2%.

Needs <0.5% binary separation measurements – not hard for interferometry!



Summary / CHARA needs

- Heimdallr is not just a fringe tracker for BIFROST and NOTT, but is also a sensitive (by design) beam combiner capable of surveys.
- By surveying Gaia photocenter binaries, we can build a picture of the formation of our Galaxy (and test stellare models)
- Key needs for this kind of binary survey is the ability to do accurate snapshot binary measurements with:
  - A magnitude limit as faint as possible (targets at K=6 to K=10) – *good for Silmaril?*
  - Spatial resolution better than 1au at 200pc (100m + baselines ideal).
  - Rapid cadence as there are 100s of targets!

Thanks for listening! Questions?