Gaia and Gaia Follow-up projects

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Outline

- The Gaia Mission
  - satellite status
  - Data release update
- Gaia follow-up spectroscopic projects
  - WEAVE: where are we with the project
  - 4MOST → Lorenzo
  - SPA

Gaia Mission Status

- Launched in 2013
- 10 y of data
- End of operations Jan 2025
- DR3 in 2022 (Gaia Collaboration, Vallenari et al, 2023, 1712 cit)
- Preparing DR4
  - Not before mid-2026
- Gaia DR5 targeted not before the end of 2030
- Final release of the mission
  - All data, raw and processed, & tools
- Next astrometric mission preparation: Gaia-NIR

Gaia Recent result: 33 Mo BH

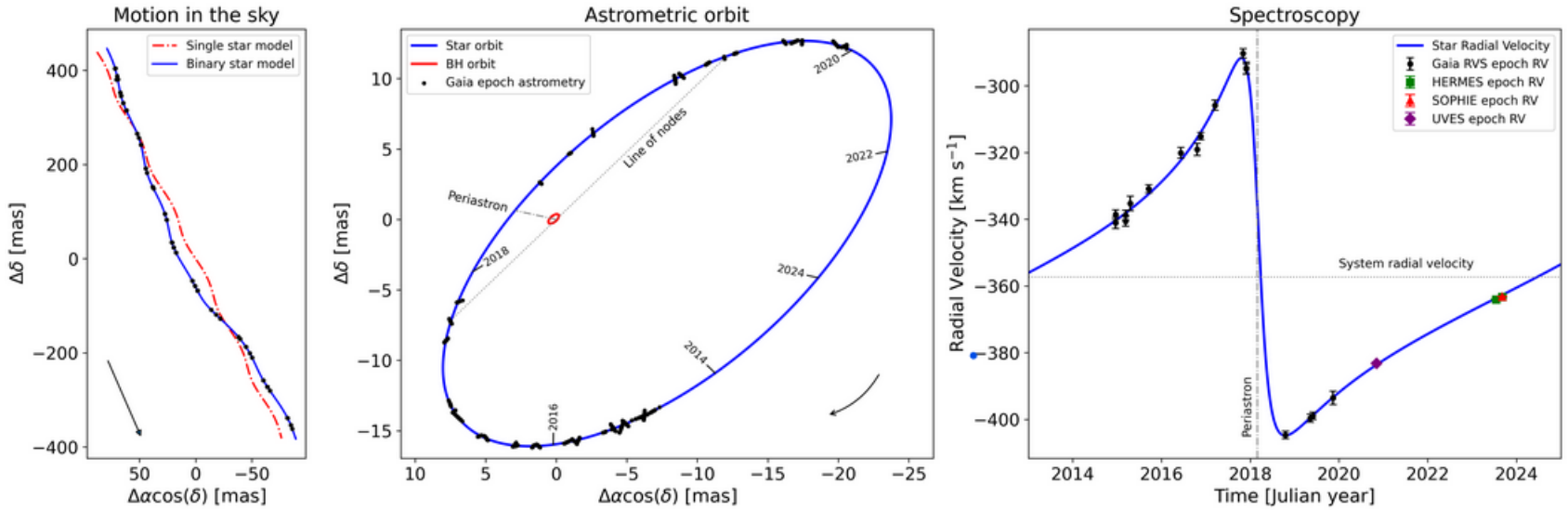


Figure 1. A view of Gaia BH3 and its companion star, with the system's motion on the sky (on the left), their orbits as projected on the sky (in the middle), and the evolution of the radial velocity of the companion star (on the right). Gaia's observations, both astrometry (left and middle) and spectroscopy (right) were taken between 25 July 2014 and 20 January 2020, making a total time span of 5.5 years of observations. The same time span on which Gaia Data Release 4 will be based. The spectroscopic view also shows ground-based radial velocities taken in November 2020 and July 2023. Credits: ESA/Gaia/DPAC - CC BY-SA 3.0 IGO. Acknowledgements: Created by Pasquale Panuzzo.

(Gaia Collab, Panuzzo et al 2023)

Gaia DR4

- Final release for the nominal mission, 66 months of data
- Including a 6 months period of reverse direction of the satellite precession
- To mitigate degeneracy between AC stellar motion and parallax
- Full Epoch data: epoch astrometry, broad band photometry, radial velocity, BPRP, RVS,
- Full astrometric, photometric, and radial-velocity catalogues, variable-stars and non-single-star solutions, classification, exoplanet list, RB/RP and RVS spectra, photometry in crowded field, SIF photometry
- Status: astrometry ✓
  - Radial velocities ✓
  - Photometry ✓
  - Variables, Binaries, final version of parameters → on the way
- OaPD: Management, Validation, Stellar parameters, variables

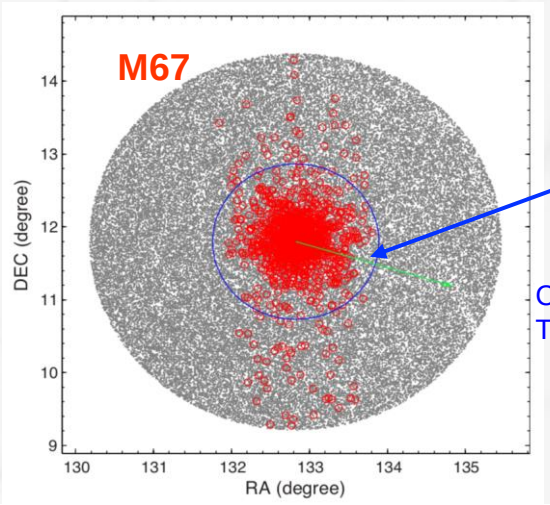
→ See A. Brown's talk at EAS S4, session C, Monday 1 July

Gaia Follow-up projects: OCs

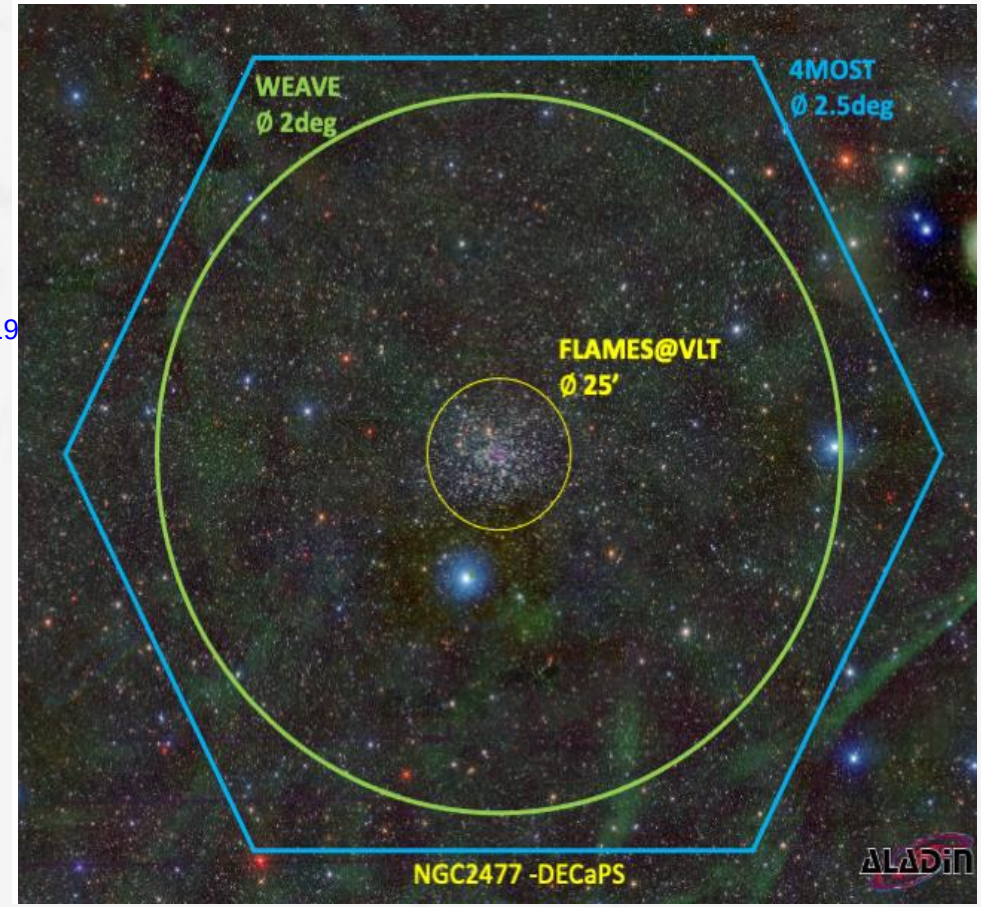
- Goals:
- how clusters form, evolve, dissolve, and populate the Milky Way;
- calibrate complex physics that affects stellar evolution→ ages
- formation and evolution of the Galaxy with unparalleled statistics in inner and outer disk
- WEAVE, Italian PI: AV
  - Ocs spectroscopic survey, PI AV, 300 Ocs
- 4MOST → Lorenzo
  - About 1800 Ocs spectroscopic survey, PIs: Lucatello, Bragaglia, Vallenari
- HR: SPA@TNG, OsTTA@NOT,@VLT, @LBT: in collaboration with Bologna, Catania, Firenze (Origlia, Bragaglia, Carrera, Magrini, Frasca) →stellar evolution + calibration

(+ Padova involved in additional extragalactic project in WEAVE)

To progress we need a large field



Carrera+ 2019, Gao 2020,
Tarricq+2021, Meingast+2019



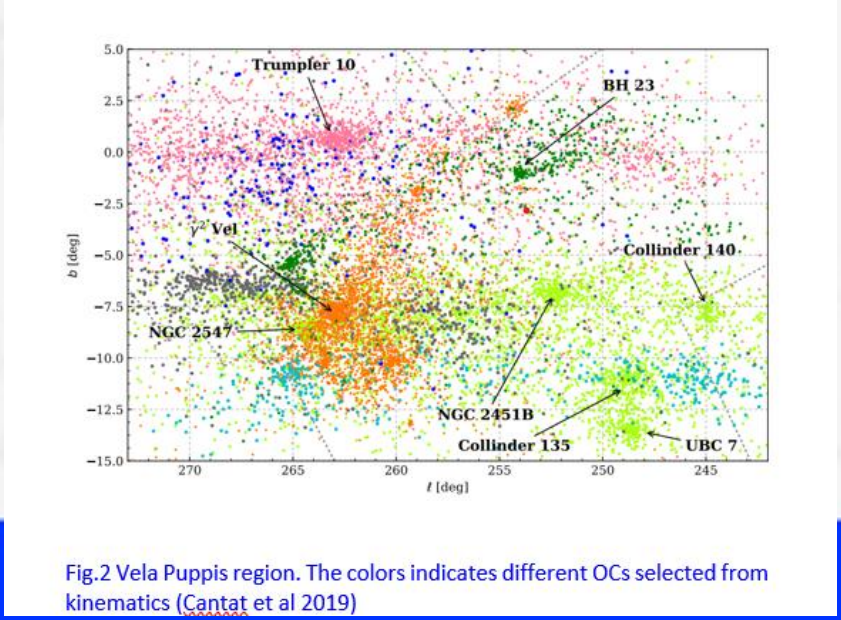
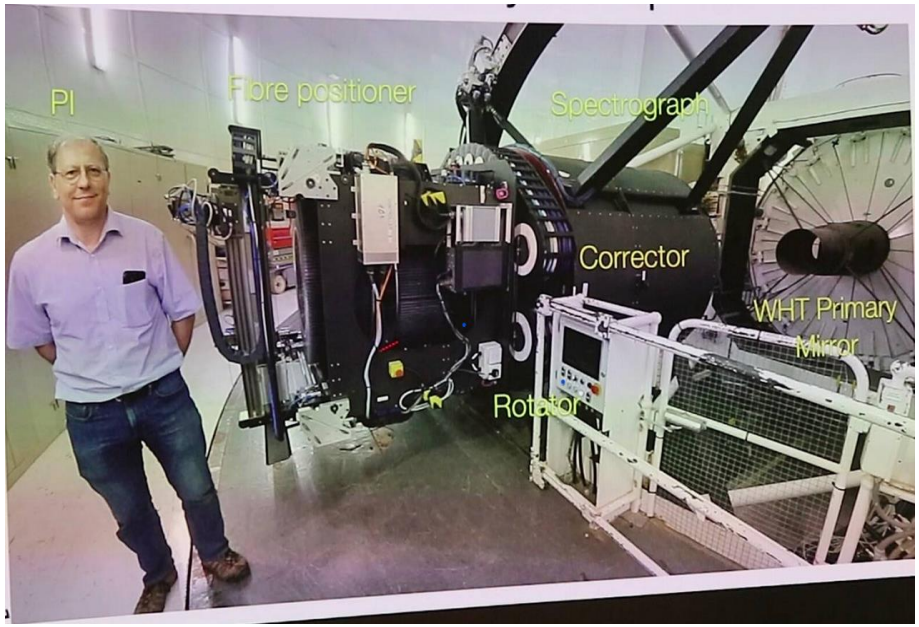
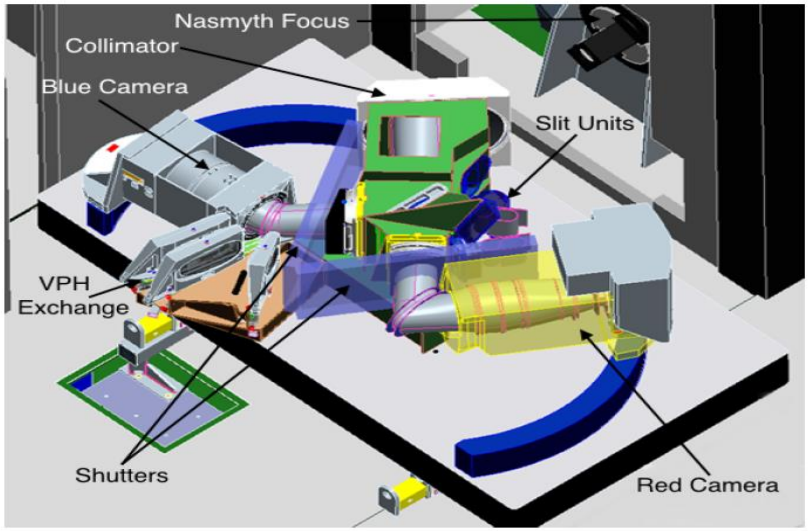


Fig.2 Vela Puppis region. The colors indicates different OCs selected from kinematics (Cantat et al 2019)

→ **WEAVE & 4MOST Cluster surveys**

What's next: WEAVE@WHT





- WEAVE : only HR multifibre in the Northern Hemisphere for Surveys
- 4m WHT telescope
- 2 deg diameter
- HR(R=20000); LR(R=5000)
- Blue(Green)+Red ;4040A-6850 A
- 960 fibers x field (Plate A &B)
- Multiplex per pointing 960 (Blue(Green) + Re
- Cannot observe HR and LR at once
- Interfibre minimum distance: 60 arcsec
- Fiber size 1.3 arcsec
- Pointing time 40 min
- miniIFU (790fibres)+LIFU(589 fibre)

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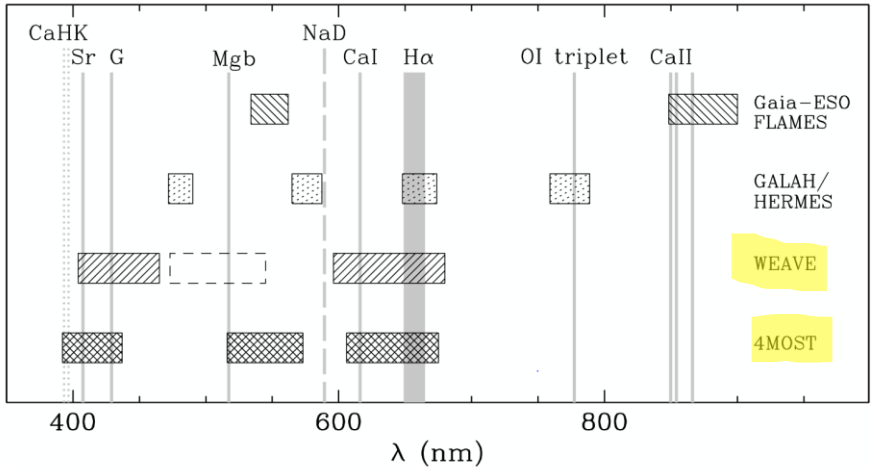
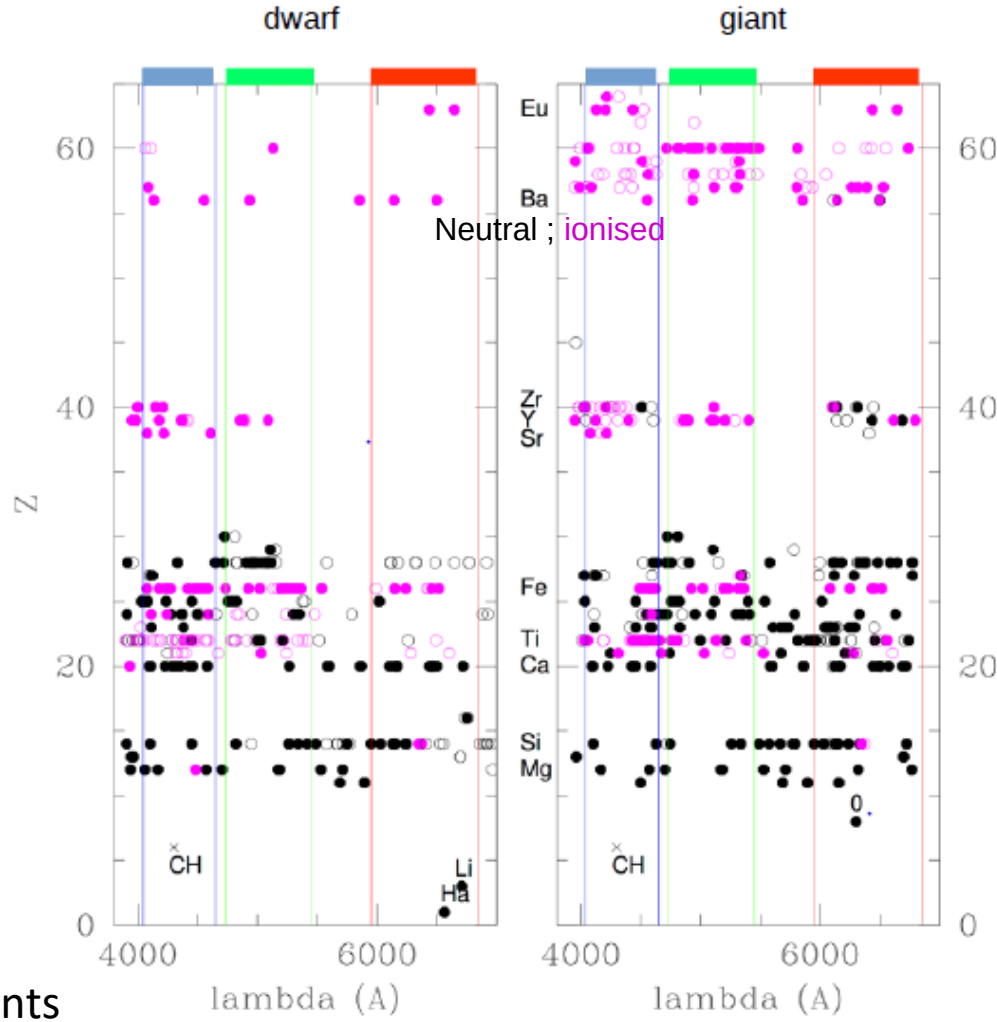


Feltzing 2020



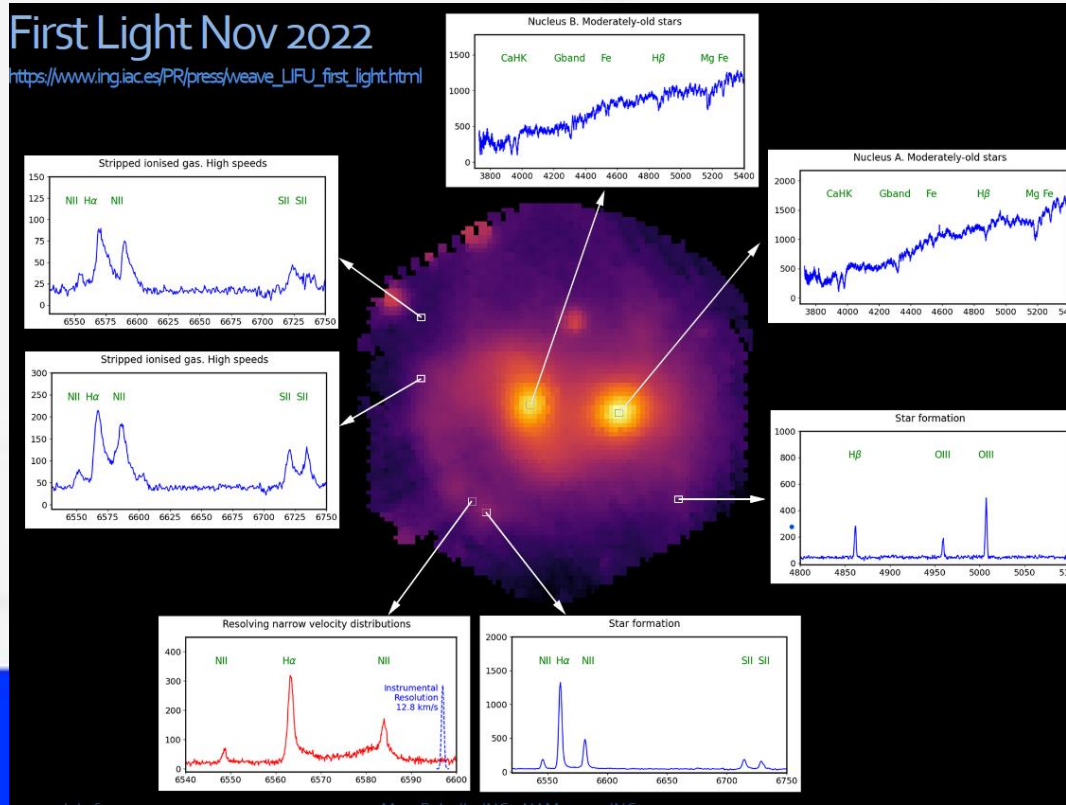
WEAVE Science Book (2020)

- Nucleosynthetic chanels :
  - Lithium → young objects
  - iron peak (Fe, Ni, Cr, Co, Zn),
  - alpha elements (C, Mg, Si, Ca, [OI]…),
  - neutron-capture slow and rapid elements (Zr, Y, Sr, Ba, La, Nd,Eu),
  - odd elements (Na, Al, Sc)

WEAVE Project status

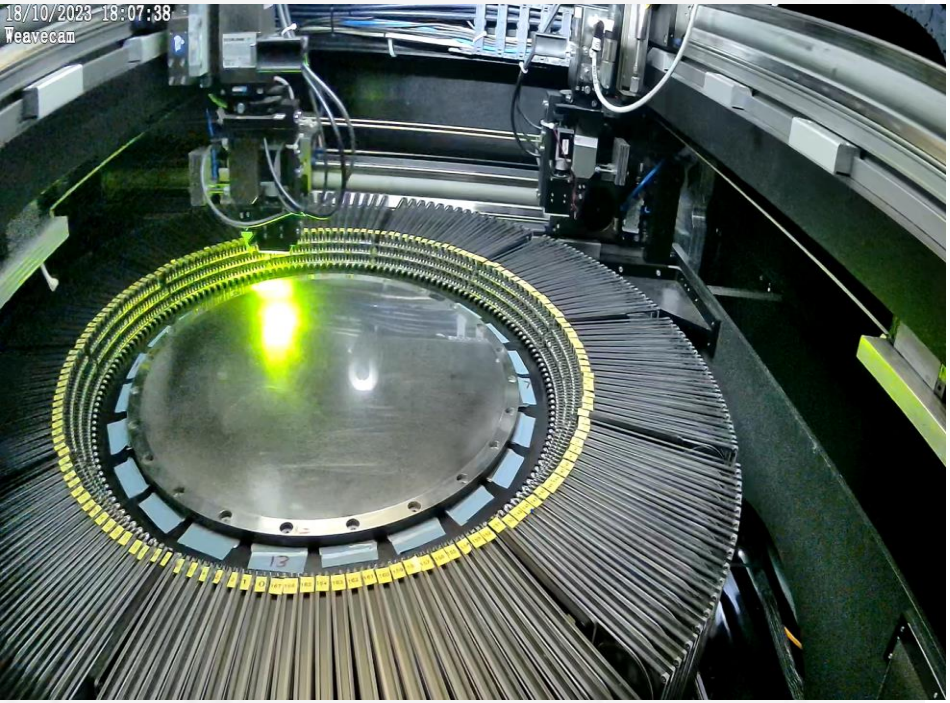
WEAVE

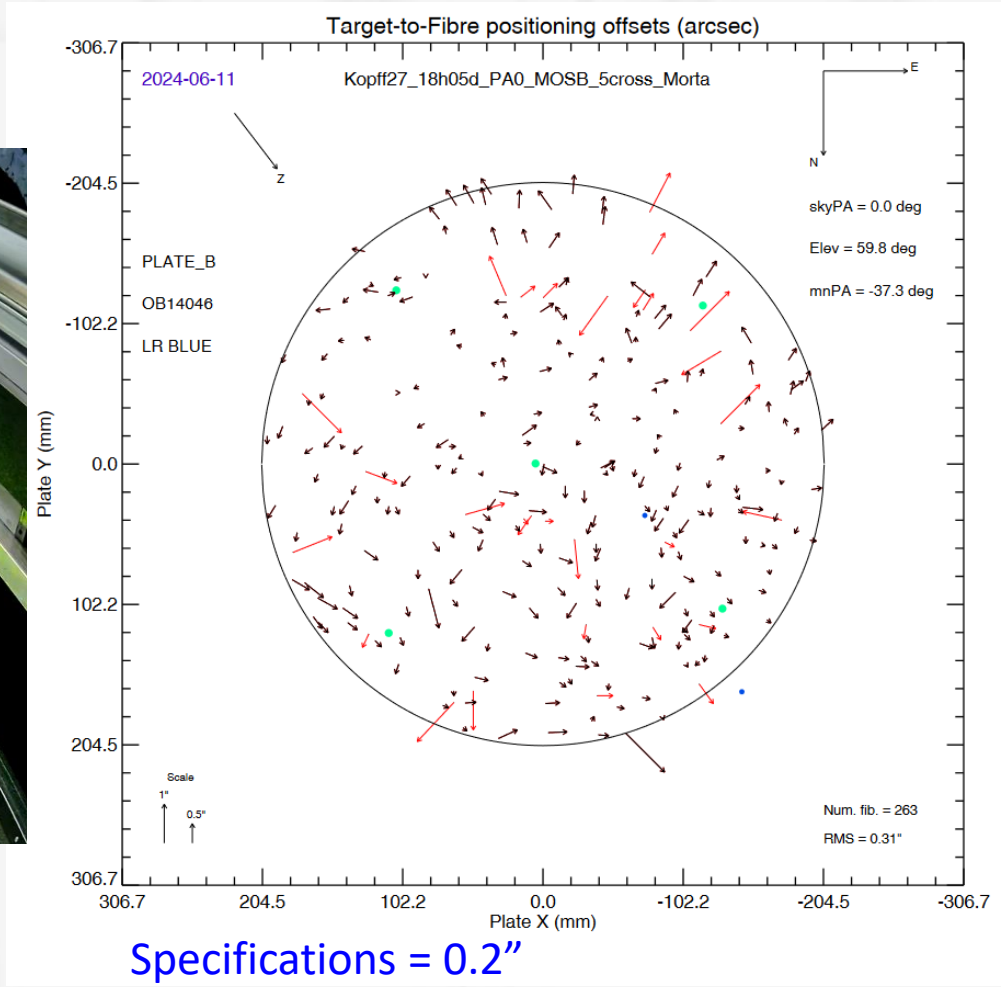
- LIFU: First light Nov 2022
  - Inauguration on Oct 30,2023
  - Science program on-going
- mIFU on going commissioning
- MOS: spectrograph alignment on going
- Spectrograph focus→ongoing
- Throughput: nominal
  - 0.21 at 4300 A
  - 0.30 at 6510 A



WEAVE LIFU First Light
NGC 7318a/b in Stephan's Quintet
Arnaudova et al 2024

Fiber positioning



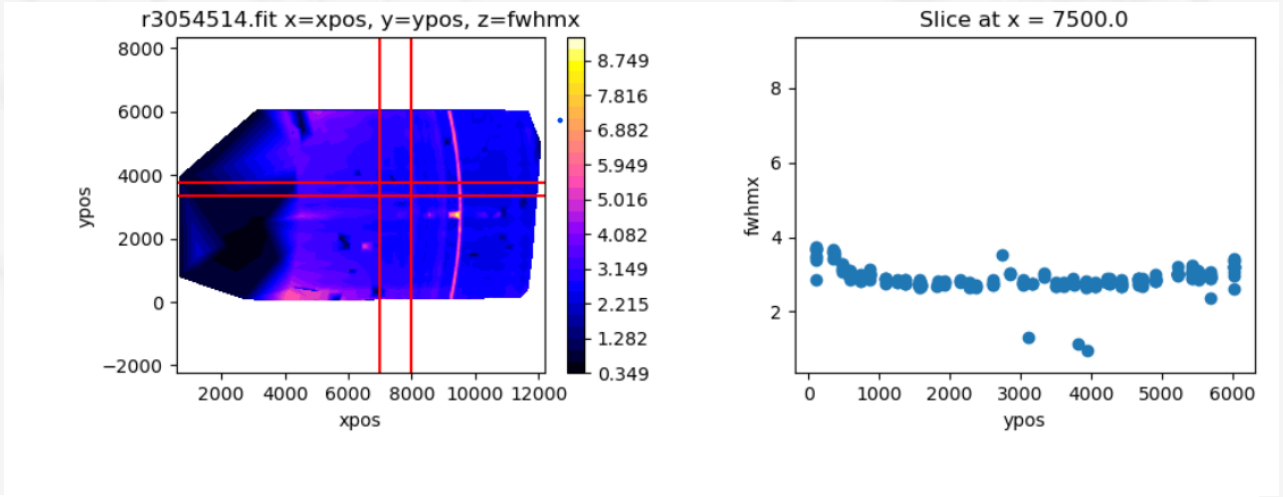


Specifications = 0.2”

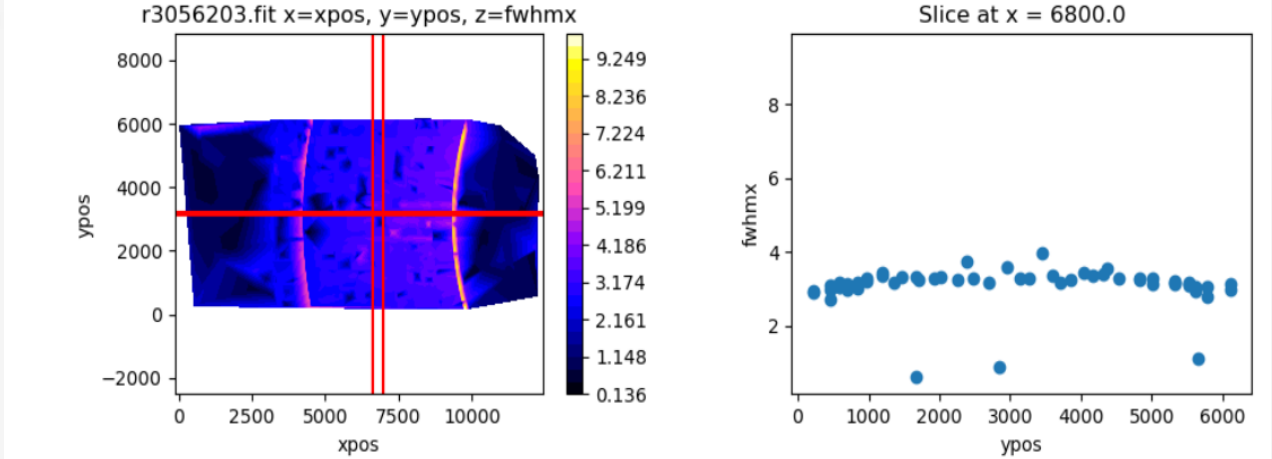
Positioner tolerance = 8 microns / 0.14"

Spectrograph focus

MOS HR Blue



MOS LR Red

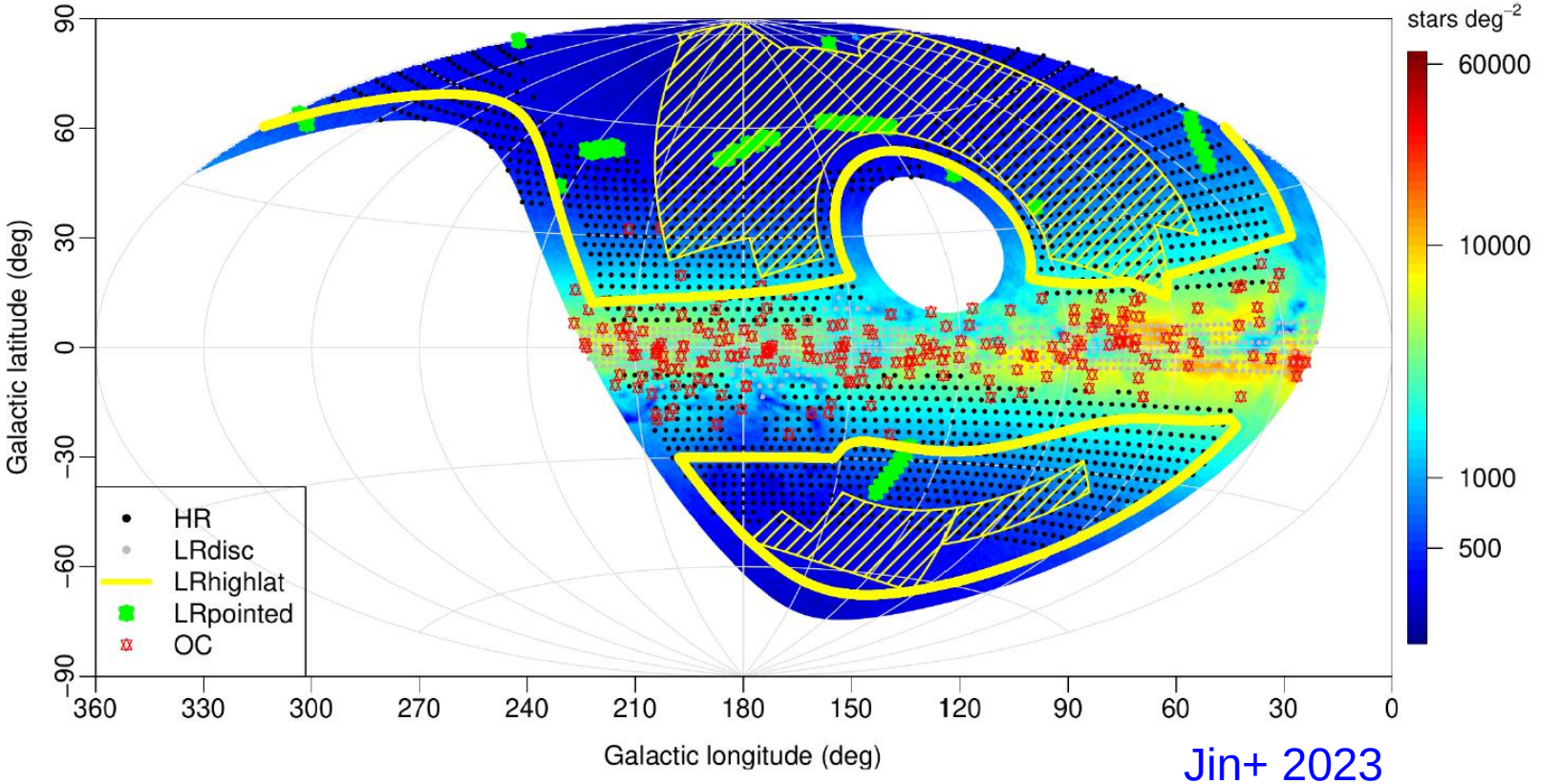


LIFU nominal

- Moderately satisfying – red nominal
- Some astigmatism beyond optical design still seen
- blue side is a little off, especially in HR

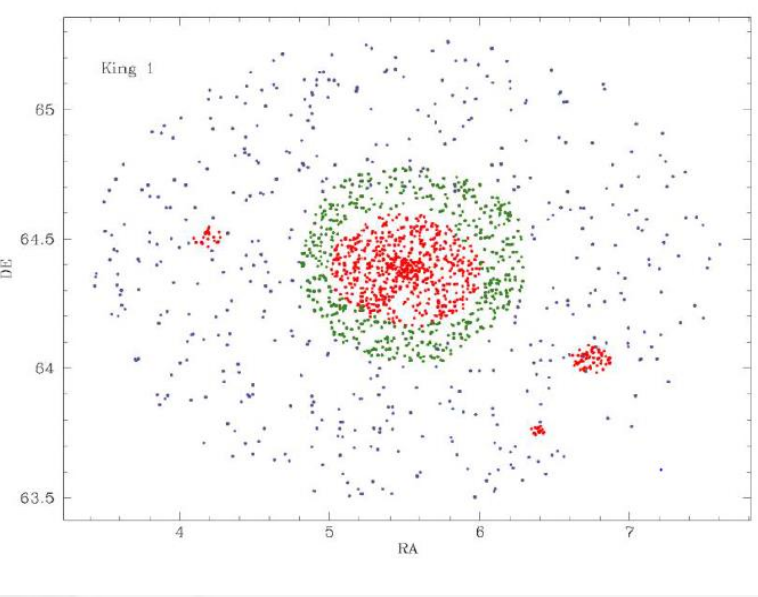
WEAVE OC Survey

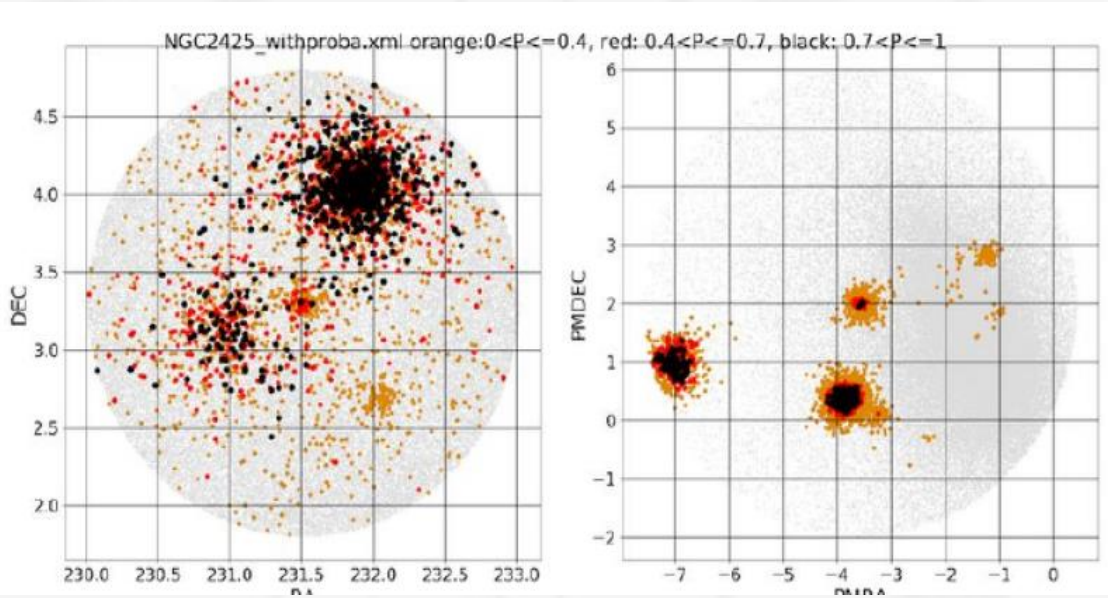
- 8 Surveys (Galactic + Extragal)
- PI: A.Vallenari, Deputy A. Bragaglia
- About 300 targets, all ages
  - OCs as tracers of the Galactic disc and of its chemical evolution:
  - 4 Rgc annuli, 4 z-slices, 3 [Fe/H] bins and 3 age bins, 2 Ocs per bin→about 300 Ocs



Jin+ 2023

WEAVE Targets





- Large nearby clusters within 500 pc
- Clusters with halos, coronae, tidal streams (within 2 degrees)
- Apparent groups of clusters
- Large regions with recent star formation

High resolution spectroscopy

- Bright stars in 100 Ocs within 2 Kpc at high R
- optical & NIR HR spectra of high probability OC members
- 50 OCs using GIARPS@TNG (R=115,000, 50000), 20 with FIES@NOT (R=65000) 35 with UVES@VLT (R=45000), 30 stars in NGC2099 (PEPSI@LBT) and 100+ stars in NGC2509 (FLAMES@VLT).
- Goals:
  - giant stars in a large number of nearby, unstudied OCs → metallicity [abundances], ages
  - a few ten of stars in key clusters, MS and/or giants → detailed abundances, stellar models (diffusion, mixing, rotation), testing all nucleosyntetic channels,
  - 3) “unusual” elements (e.g. He, F, P)

→ high quality sample to cross-match with large spectroscopic samples (Gaia-RVS, Gaia-ESO, APOGEE, GALAH, WEAVE, 4MOST…) and with asteroseismology samples(Kepler/K2, TESS, and soon PLATO)

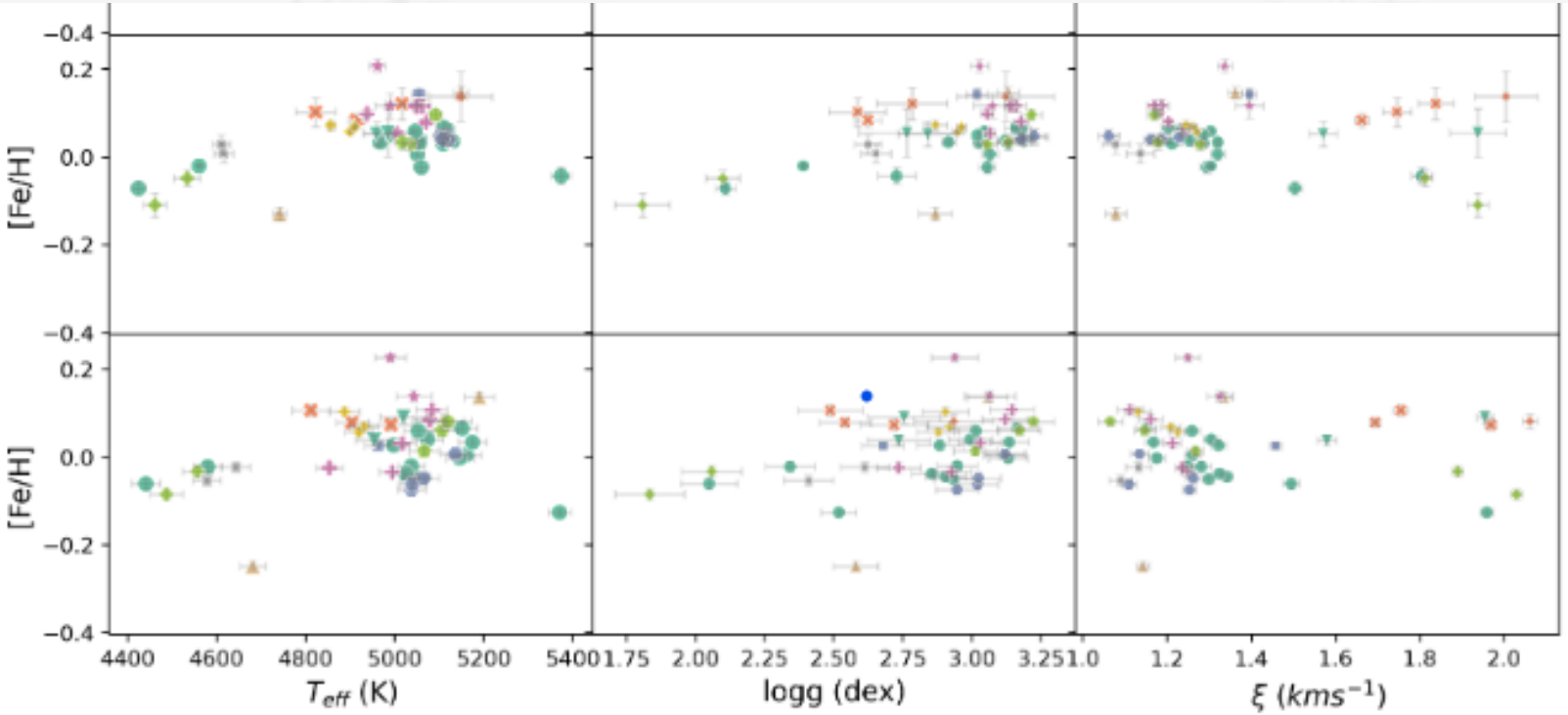


Fig. 1. [Fe/H] vs T_{eff}, log g and ξ. The colors and symbols indicate distinct open clusters. Each row from this figure represent a different test. First row: EW measured with ARES and parameters obtain with q2 using only 1 star as reference. Second row: EW measured with ARES and parameters obtain with q2 using 3 stars as references. Third row: EW measured with smhr and parameters obtain with q2 using 3 stars as references. Fourth row: EW measured with smhr and parameters obtain with LOTUS.

Testing different methods
Deriving homogeneous abundances

M. Dal Ponte, 2024, in prep.

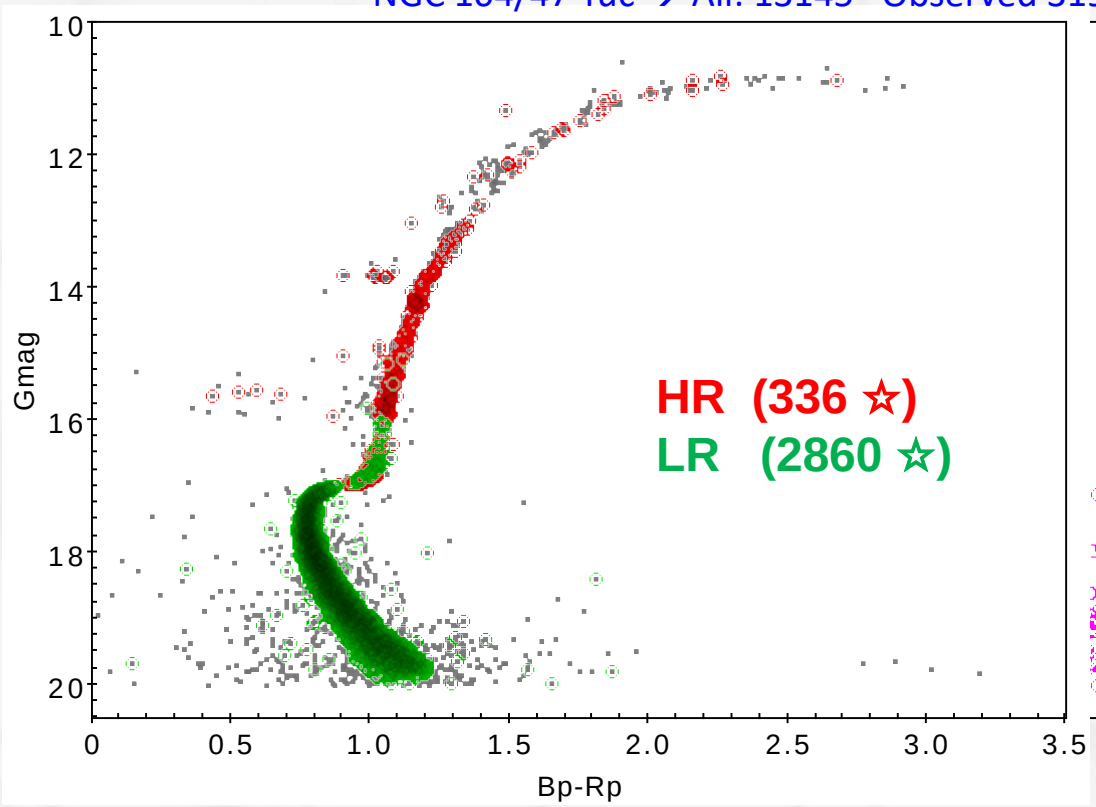
Conclusions

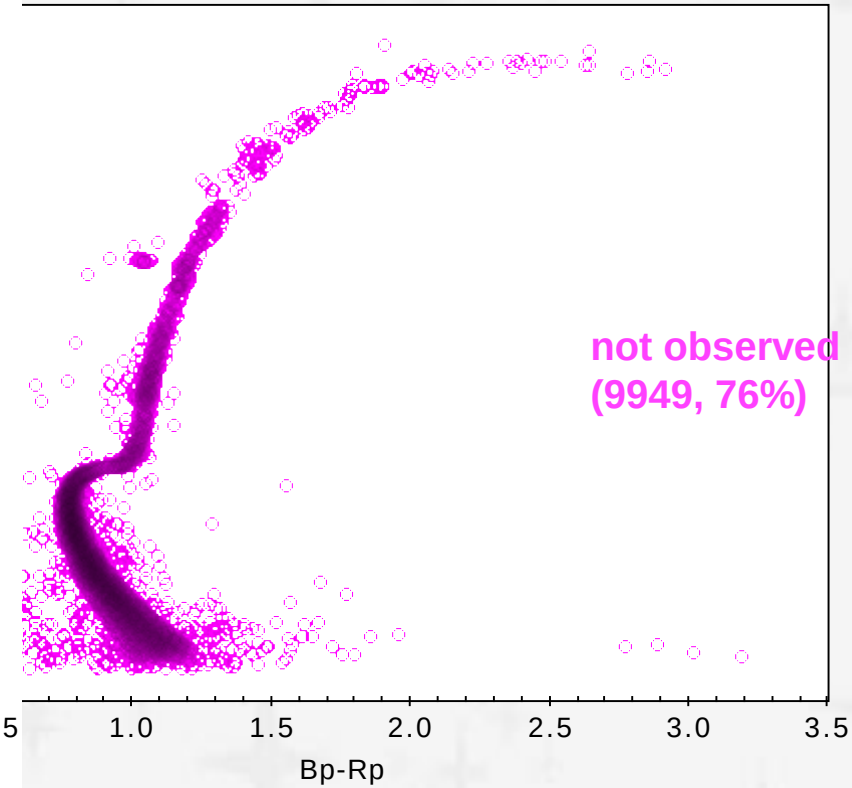
- Gaia + spectroscopic follow-up OC projects
- WEAVE (+4MOST)+ high resolution spectroscopy synergy will change our view of open clusters
- High legacy value complementing Gaia-ESO, Gaia, and with asteroseismology samples(Kepler/K2, TESS, and soon PLATO)

Spare slides

Targets - GC

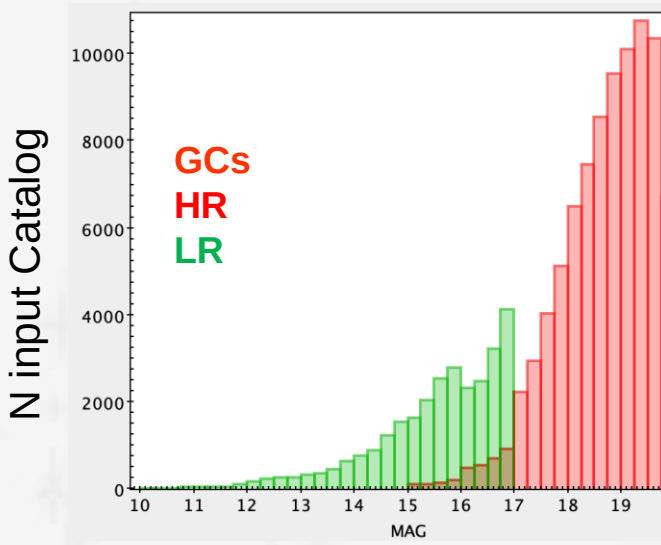
NGC 104/47 Tuc → All: 13145 Observed 3196 (24%) Not Observed (9949, 76%)





What about Globulars?

- GC survey on halo footprint
- 40,000 stars in 140 GCs (frozen Catalog on May 2023)
- Only stars outside the center
- Requested completeness 10%→ output 5%
- A few stars for chemical abundances



Input catalogs → successfully observed

12,000 → 3,700 stars in HRS

270,000 → 35,000 stars in LRS