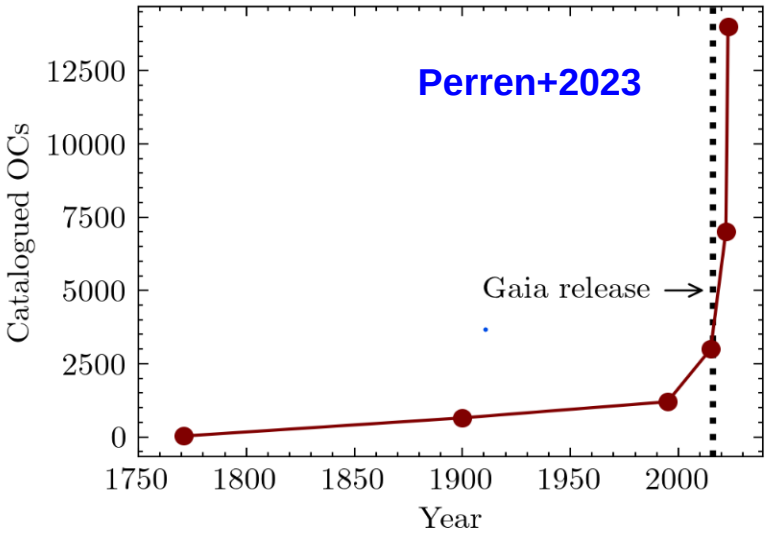
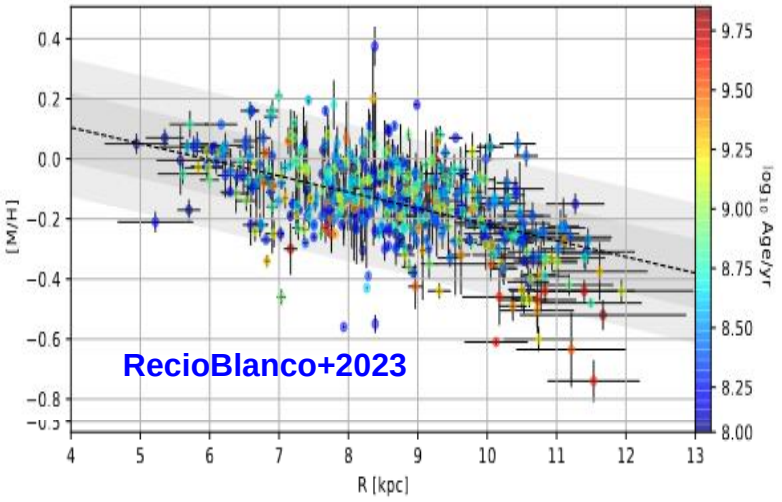
The bright future of open clusters

Antonella Vallenari
INAF, Osservatorio di Padova, Italy

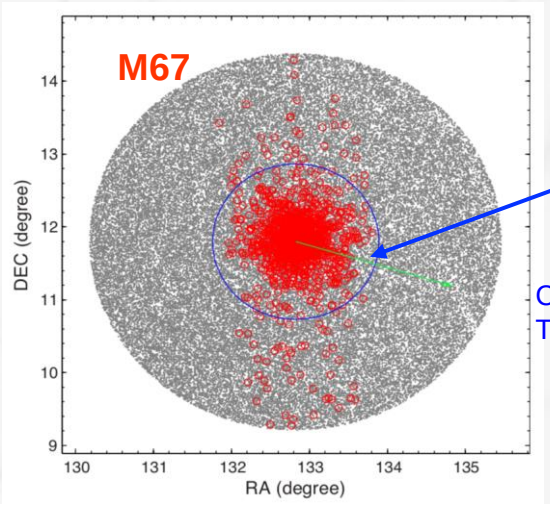
Gaia Data Release contribution

- Gaia has changed our view of clusters and open clusters
- Census revision: Cantat+ 2018, 2020 Castro-Ginard et al.(2021); Tarricq et al. (2021), Badawy et al(2022), Hao et al (2022), Kounkel+ (2020)…Hunt&Reffert(2023) with 7000 Ocs, Perren +(2023) with 14,000 OCs
- Membership, parallaxes, proper motions, and radial velocities (Cantat et al 2018, 2020), Soubiran et al 2018, Fu+(2022, 386OC Vrad), Perren+2023
- Age revision: Gaia collab, van Leeuwen+, 2017, 2018, Cantat+2018, Bossini +2018, Cantat-Gaudin+(2018, 2020); Castro-Ginard et al.(2021); Tarricq et al. (2021), Anders et al (2021),… Perren+(2020), Dias+2021
- DR3 data:
  - Astrophysical parameters from BP/RP (Andrae+2023) for G<19
  - Radial velocities down to G=14 (Katz+2023)
  - Chemical abundances (up to 12 elements) for about 1600 stars in 500 OCs (Recio-Blanco+2023): flattening of gradient at young ages





To progress we need spectroscopy on large FoV



Tidal radius

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

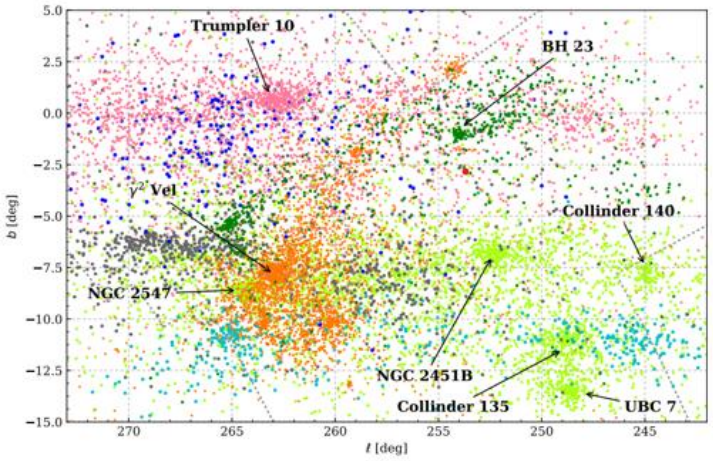
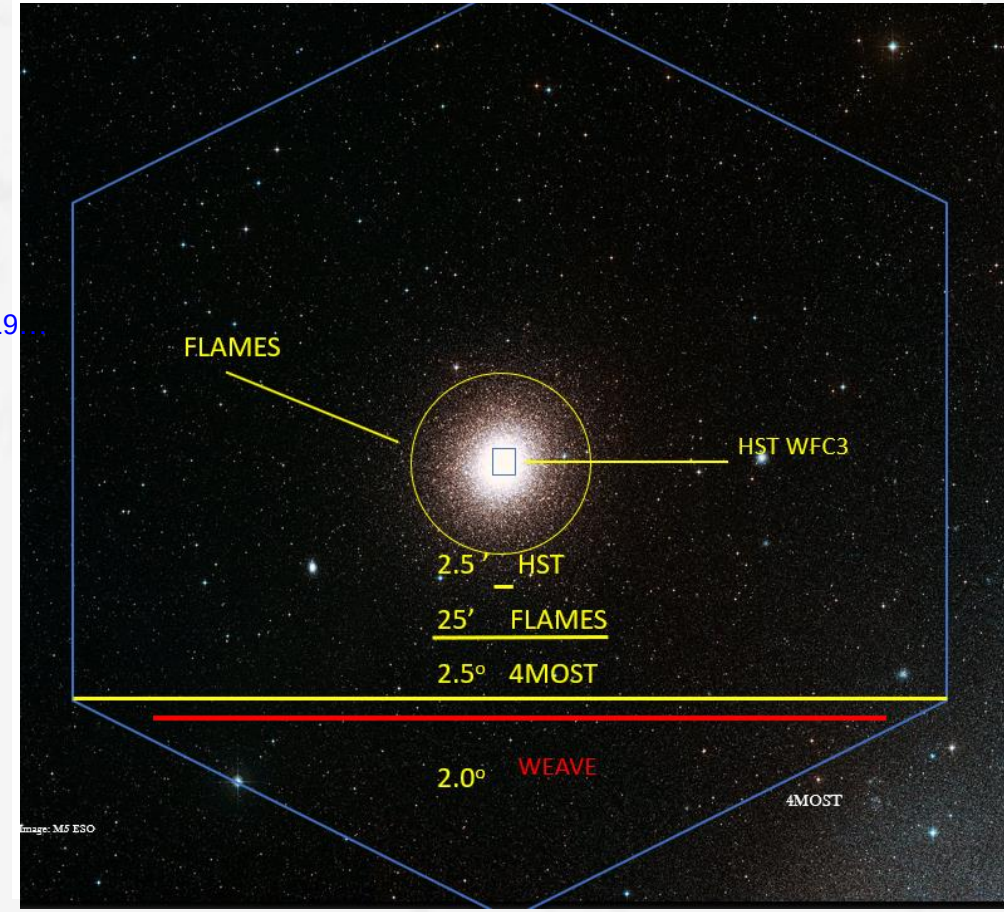


Fig.2 Vela Puppis region. The colors indicates different OCs selected from kinematics (Cantat et al 2019)



→ **WEAVE & 4MOST OC surveys**

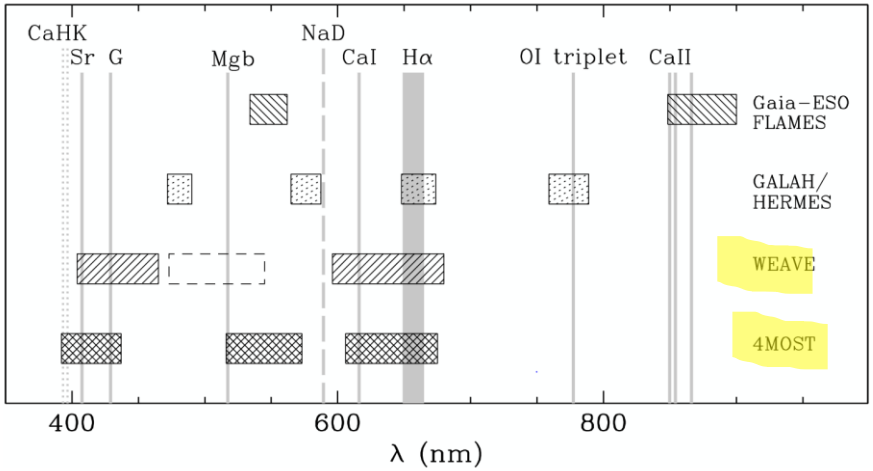
What's next: WEAVE &4MOST

- WEAVE : only HR multifibre in the North
- 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
- Cannot observe HR and LR at once
- fibre minimum distance: 60 arcsec
- Fiber size 1.3 arcsec
- Pointing time 40 min
- miniIFU (790fibres)+LIFU(589 fibre)

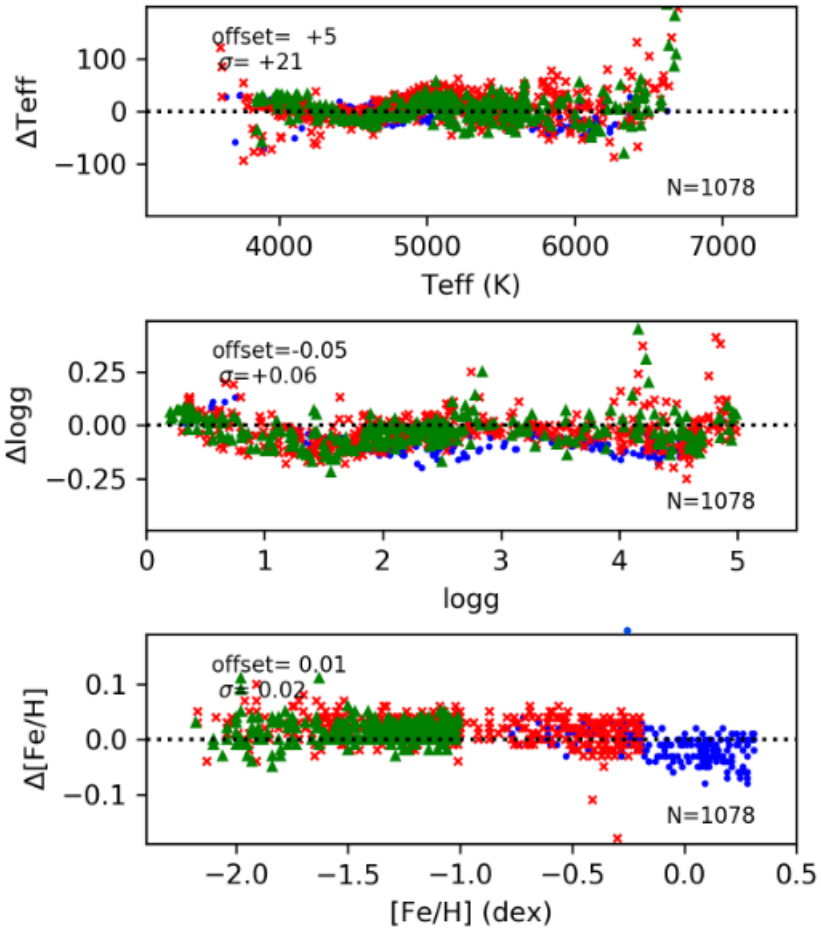
- 4MOST
- 4m VISTA telescope
- 2.5deg diameter FOV
- HR=20,000; LR=5000
- Blue,Green, Red
- 812 high-res (HR) fibres
- 1624 low-res (LR) fibres
- Fibre multiplex per pointing ~2400

- Fibre minimum distance 15 arcsec
- Fibre size 1.3 arcsec

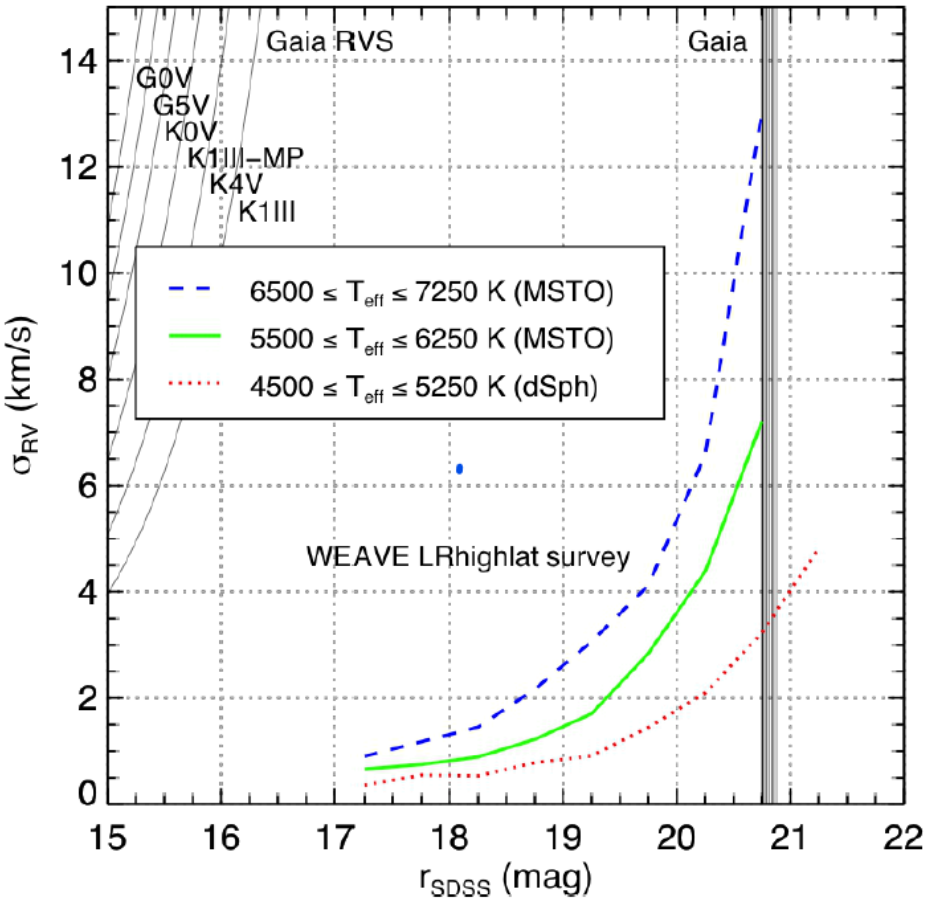


Feltzing 2020

WEAVE& 4MOST Performances



WEAVE, Boeche+2021, S/N=100, HR



WEAVE, Jin+ 2023

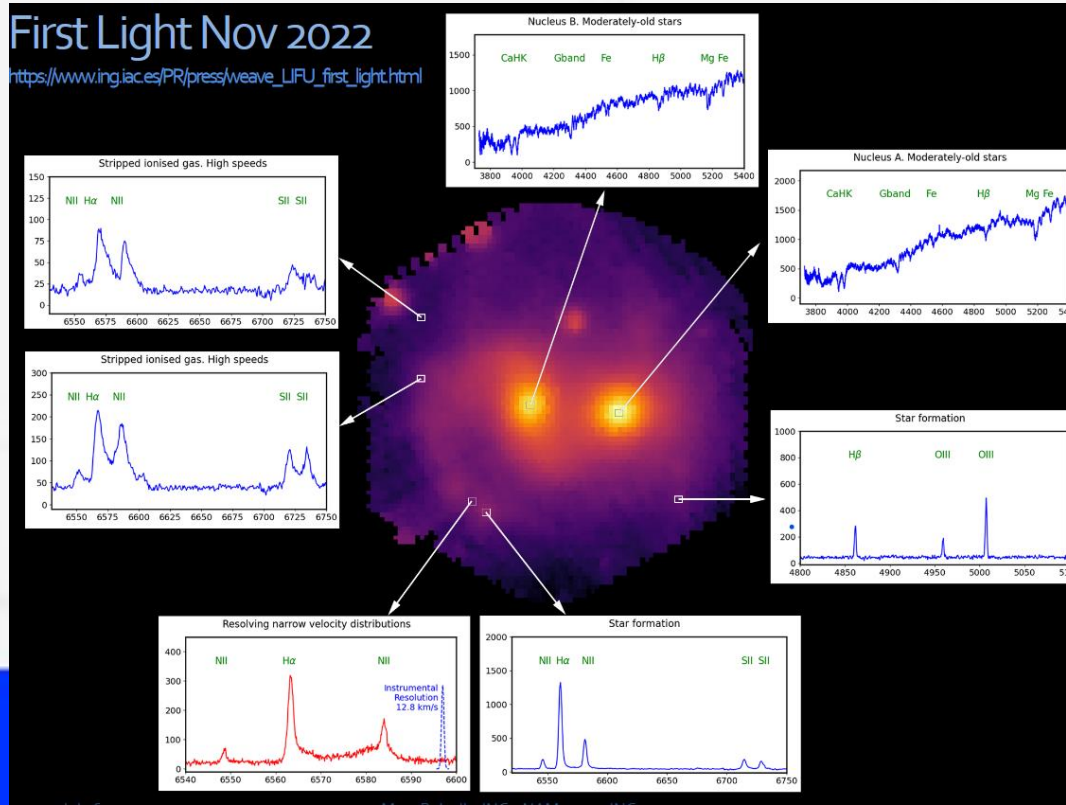
WEAVE& 4MOST Project status

WEAVE

- LIFU: First light Nov 2022
- mIFU on going commissioning
- MOS: on going commissioning
  - Science Validation: Sept. 2023
  - Survey Beg.: Oct-Nov.2023
- 8 Surveys (Galactic + Extragal)

4MOST

- Test readiness review for hardware: July 2023
- Fibre feed system local acceptance review : Ma
- Commissioning+ Survey beginning: 2024
- 10 Science programs + 15 Community Surveys

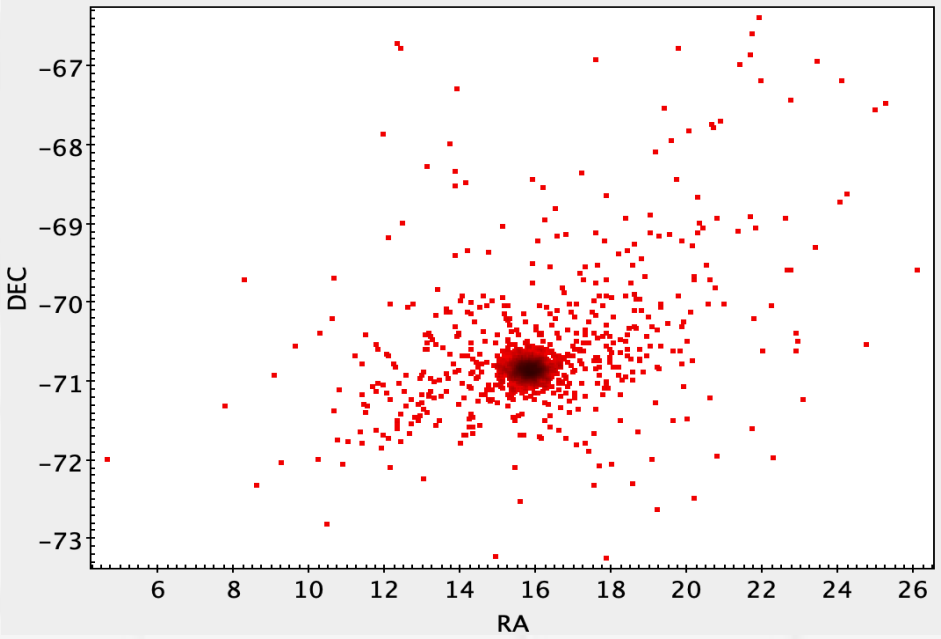


WEAVE LIFU First Light
NGC 7318a/b in Stephan's Quintet
(M. Balcells courtesy)

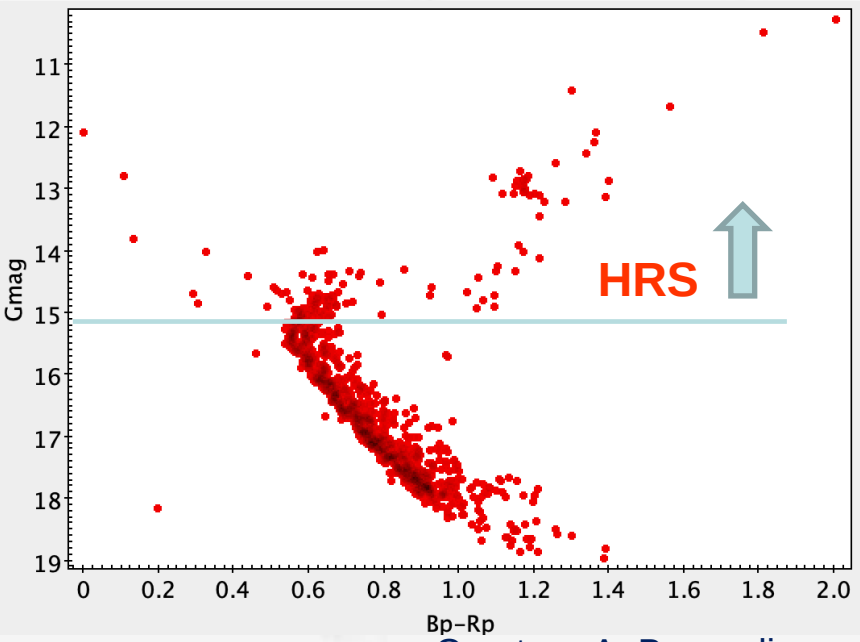
OC Survey goals

- 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
  - Red clump stars in Ocs older than 100 Myr: G=16.0 at dist=12 Kpc---→ Rg=20 Kpc

tidal tails & halos



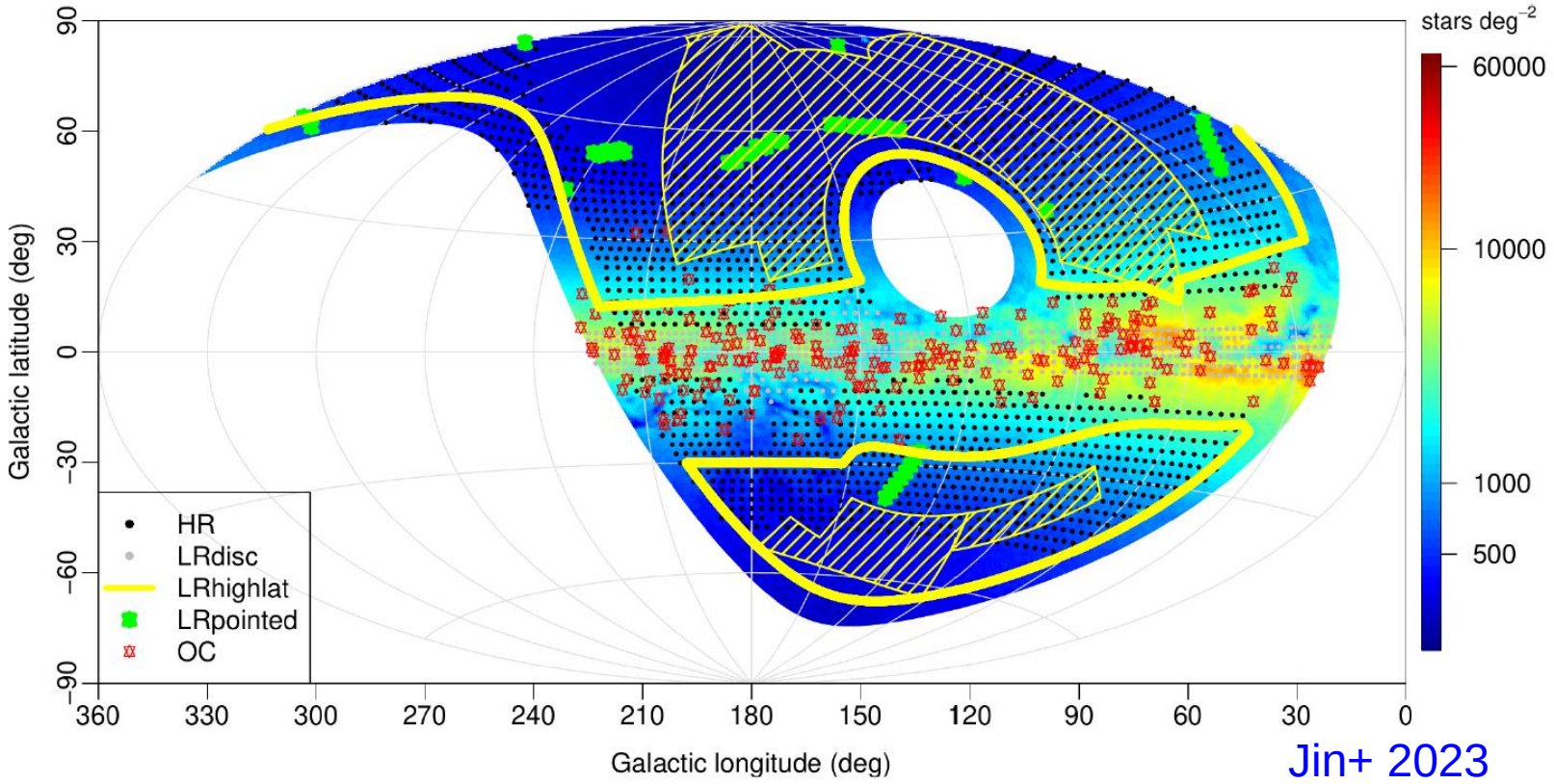
evolution of surface abundances



Courtesy A. Bragaglia

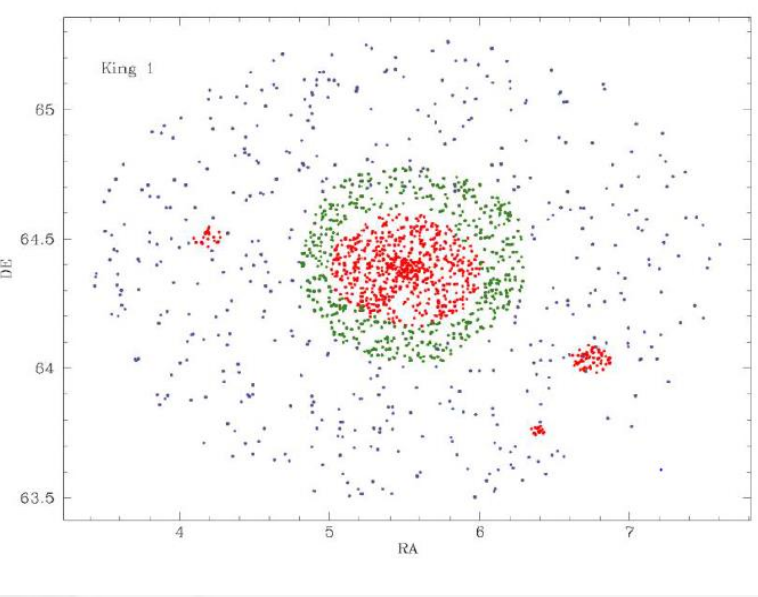
WEAVE OC Survey

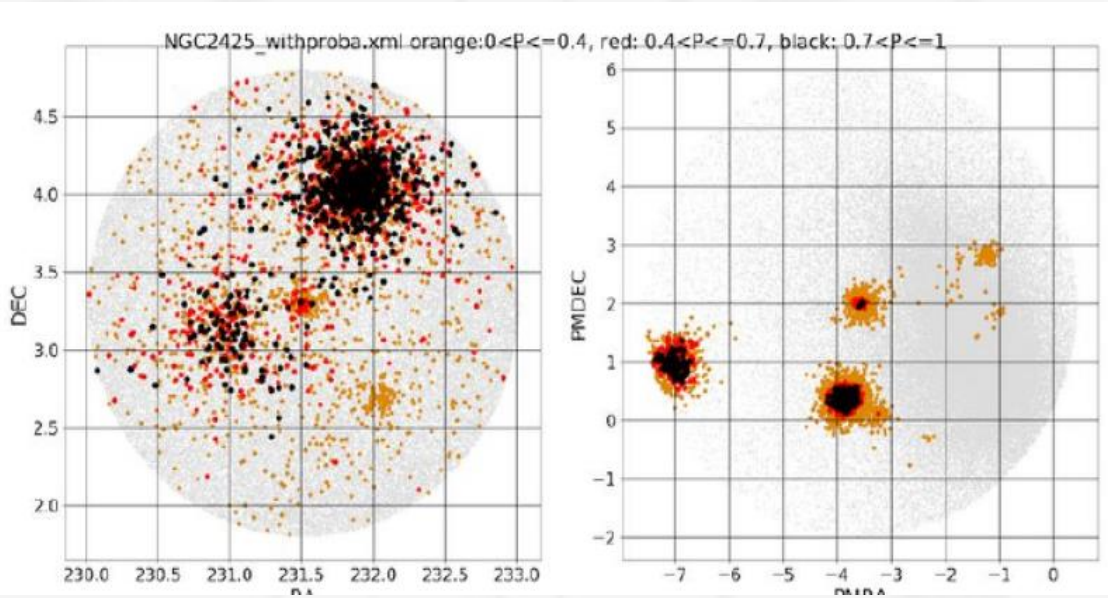
- PI: A.Vallenari, Deputy A. Bragaglia
- About 300 targets, all ages
  - OCs as tracers of the Galactic disc and of its chemical evolution:
  - 4 Rgc annuli, 4 z-slices, 3 [Fe/H] bins and 3 age bins, 2 Ocs per bin→about 300 Ocs



Jin+ 2023

Pointing Strategy for WEAVE



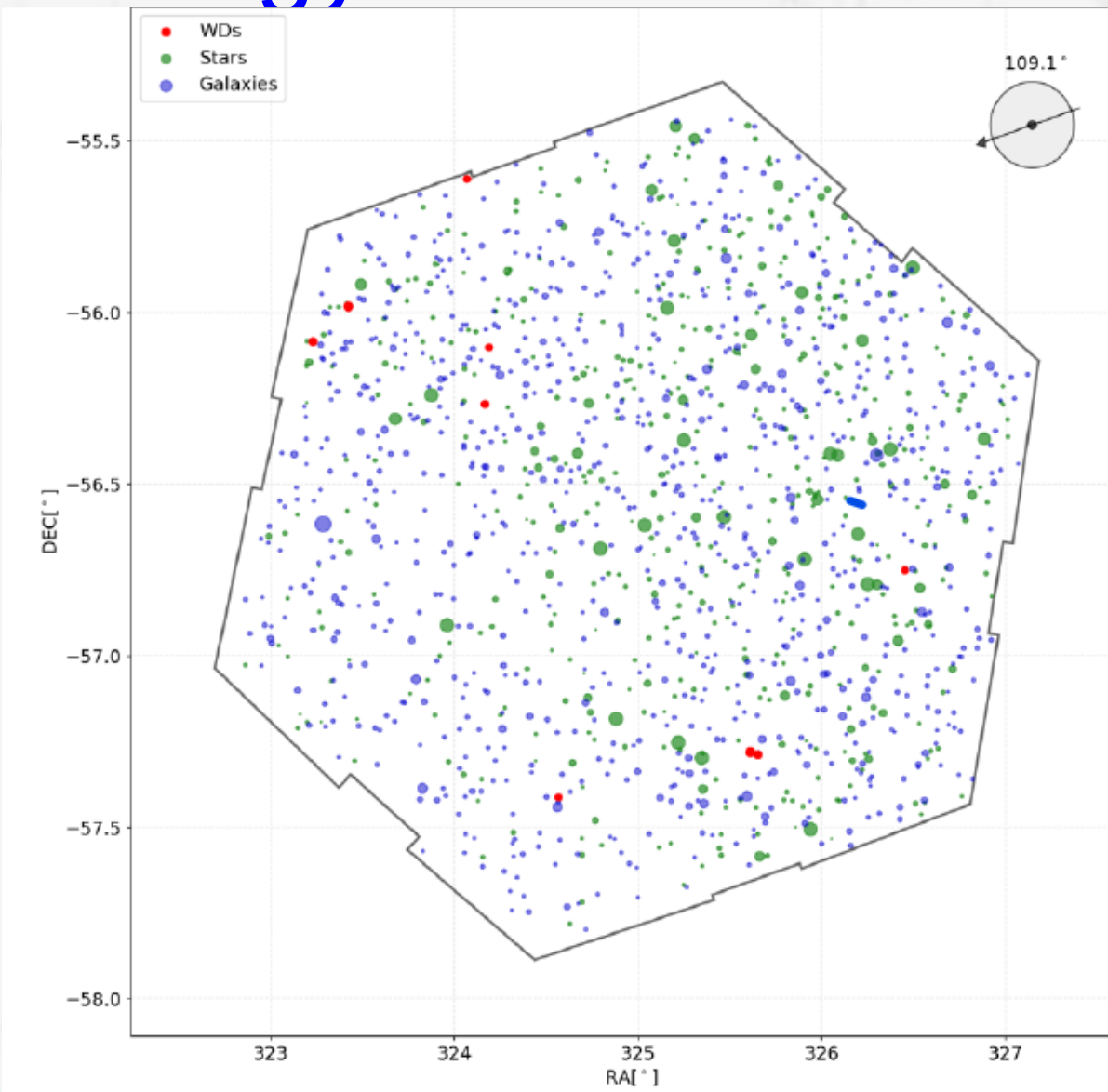


- Each pointing is mastered by only one survey (with some exceptions) → high completeness→ single Ocs, groups,
- Small compact +large diffuse Ocs → synergie with LR disk & HR disk WEAVE surveys

Pointing Strategy for 4MOST

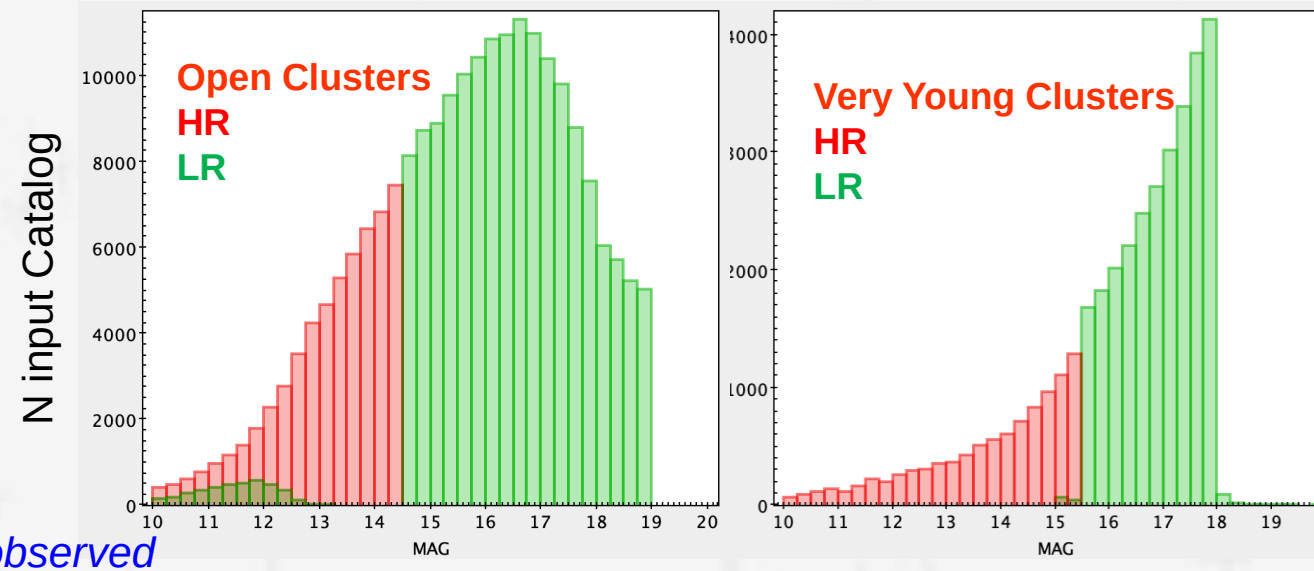
4MOST: Sharing the focal plane on almost continuous footprint

- Target selection and observational requirements by any survey impacts all other surveys
- OC survey is a community survey



4MOST OC Survey

- OC survey (PI: Lucatello, Vallenari, Bragaglia) on disk footprint
- All the accessible OCs and SFRs (and GCs) (frozen Catalog on May 2023)
- >100,000 in about 1800 open clusters and 80 SFR
- Only known bona fide members are selected
- No repeated observations→ no binarity information

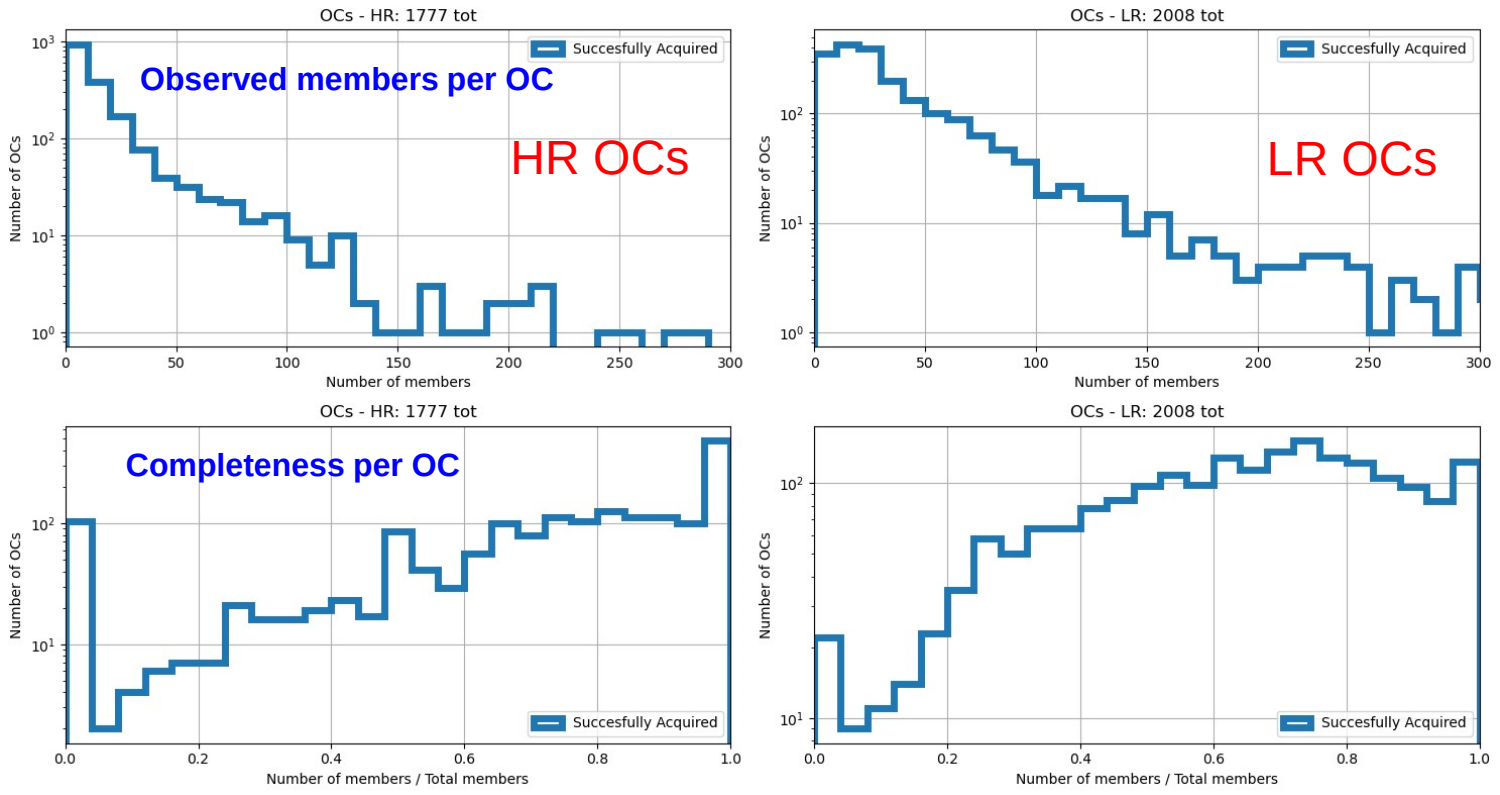


Input catalogs → successfully observed

68,000 → 40,000 stars in HRS

150,000 → 74,000 stars in LRS

How many stars in how many clusters?



In HR: 48 Ocs with > 100 stars successfully observed
In LR : 166 Ocs with N > 100 observed stars

Total N stars expected successfully observed:
100,000 stars in OCs
14,000 stars in SFR

Conclusions

- WEAVE:
  - High completeness on a limited number of clusters:
    - Internal kinematics
    - Halos
    - Tidal tails within 2 degrees
    - Chemical tagging (similar selection function)
    - Stellar evolution
    - Small number of star forming regions
- 4MOST survey:
  - High number of observed clusters with limited completeness
    - Less performant on internal kinematics, halos
    - Tidal tails over many degrees in the sky
    - Chemical tagging in synergy with the disk survey (different selection function)
    - Good coverage of young star forming regions (80 in the South)
- WEAVE+4MOST synergy will change our view of open clusters
  - Outer disk sampling (WEAVE)+ inner disk (4MOST)
  - > 2000 Ocs/SFRs for the study of disk properties (chemical gradients, age distribution, mixing, spiral structure…)
  - **High legacy value** complementing Gaia-ESO, Gaia, …