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Stellar Clusters in the 4MOST footprint

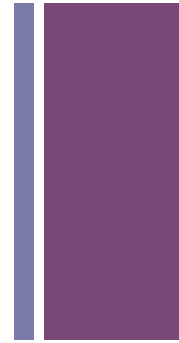


Team

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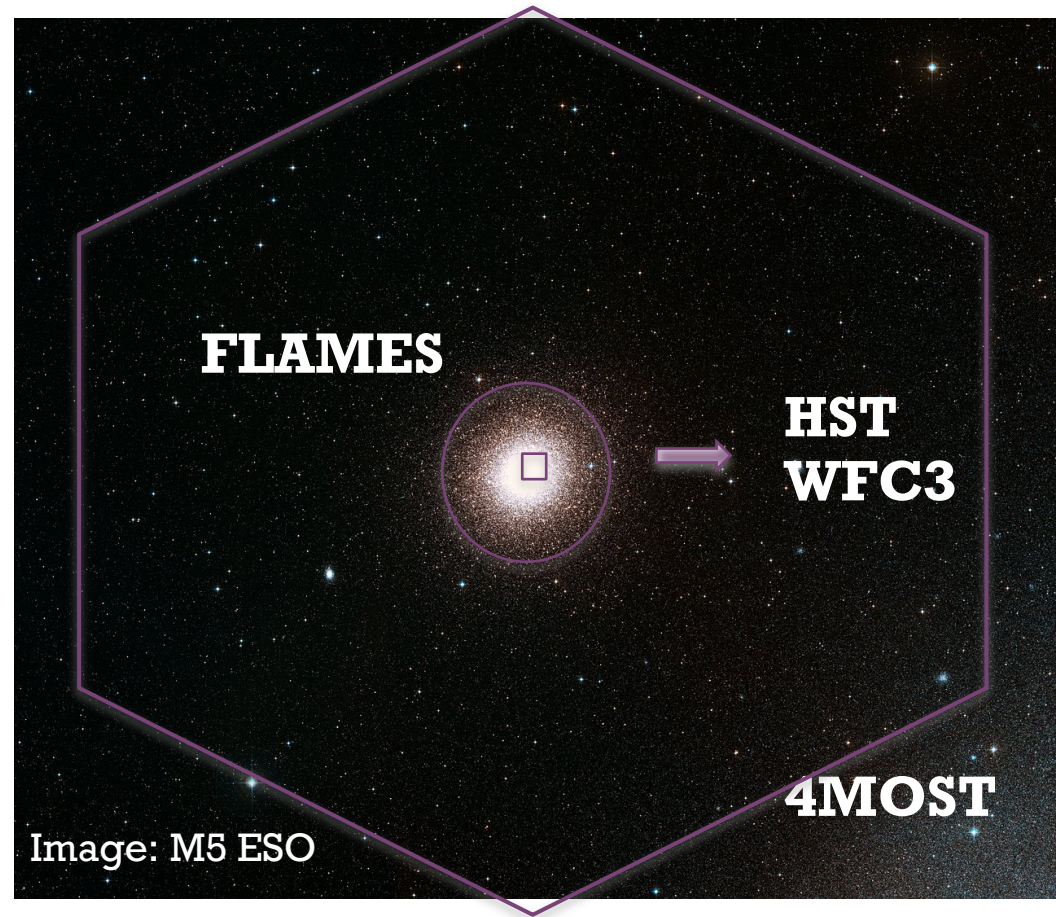
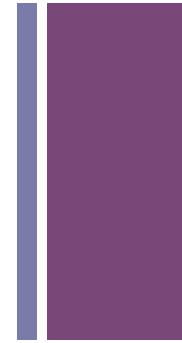
+ Why Stellar Clusters?

- SCs formation and disruption: Study of SCs key step to understand how star form and populate the Galaxy;
- Stellar Evolution: Ideal benchmarks for more detailed models;
- SCs and the Galaxy: allow constraints on timescales and insight on the Galactic components and their buildup;
- SCs and the MCs: probe effect of environment of SCs formation and evolution



Why 4MOST?

- Wide field is key: allow to probe outskirts
- Gaia gives indication on membership
- 4MOST data yield uniformly derived:
 - Atmospheric parameters
 - Abundances of elements probing all nucleosynthetic channels (Fe-peak, alphas, n- and p- capture)
 - Radial velocities
- Highly complementary with GES, APOGEE and WEAVE



+ Immediate Objectives of the Survey

- I. Homogeneous chemo-dynamical (all nucleosynthetic channels, Fe-peak, alpha, n-capture) characterisation for 120 GCs in the MW and MCs with HR spectra for ~40 stars per cluster for a total of ~6.6K stars. RVs and atmospheric parameters with LR for ~28K stars in 131 GCs (including tidal tails). **5X** larger than previous samples.
- II. Homogeneous chemo-dynamic characterization with HRS for ~80K stars distributed across all the known OCs visible from the South (~1700 OCs). RV and atmospheric parameters for ~160K more stars with LRS. **10X** larger than previous samples.
- III. Derive the dynamics and atmospheric parameters of ~10K stars in 46 VYCs in nearby SFR with LRS, where stars are still in the pre-main sequence phase (PMS), and study low-mass PMS stars from already dissolved VYC. Assess activity indicators and Li abundance for 7K stars with HRS.

+ Scientific aims of the Survey

- I. Investigate the interplay between Stellar Clusters and their environment;
- II. Study tails and identify through chemo-dynamical tagging the stars lost from SCs (or belonging to dissolving/dissolved clusters), probing their role in the build up of the Galactic components;
- III. Provide a representative sample of PMS stars (both still in their native VYC and already lost), a key evolutionary phase to understand star, planet and cluster formation and evolution;
- IV. Characterise SC velocity fields in 3 dimensions, investigate their dispersions (and rotation) as a function of radius, probing for the first time the outskirts, including tidal tails;
- V. Determine key characteristics (such as composition, kinematics and, in GCs, incidence of the multiple population phenomenon) across a wide range of cluster properties (including tidal tails);
- VI. Define a uniform metallicity scale from $[\text{Fe}/\text{H}] = -2.5$ to ~ 0.3 dex, for dwarfs and giants, for stars of a large range of age (i.e. mass), providing an ideal sample for both internal calibration of the Galactic CSs and for cross-calibration with other large Surveys.

+ Target RA distribution

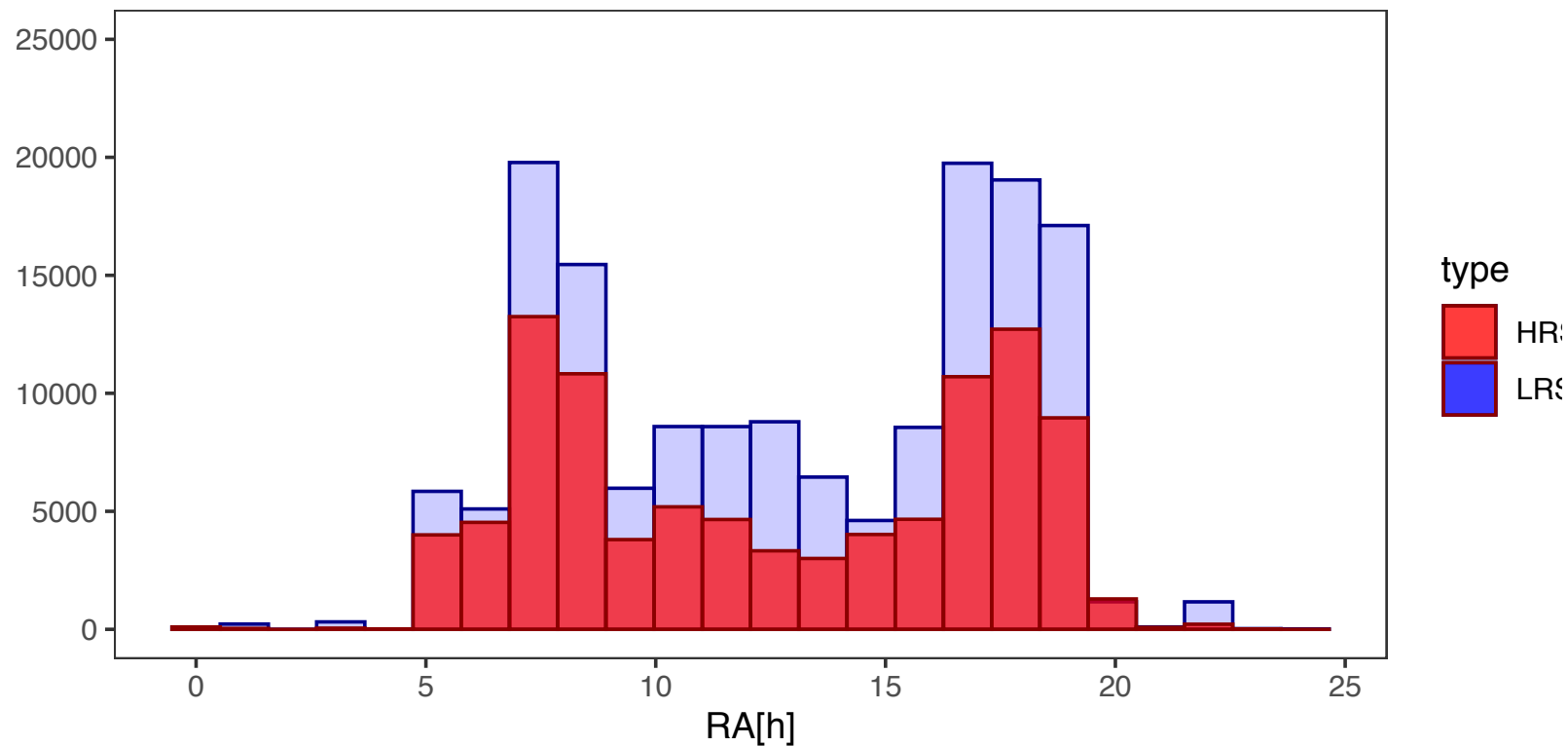
FGK and M stars

~5,000 sq deg

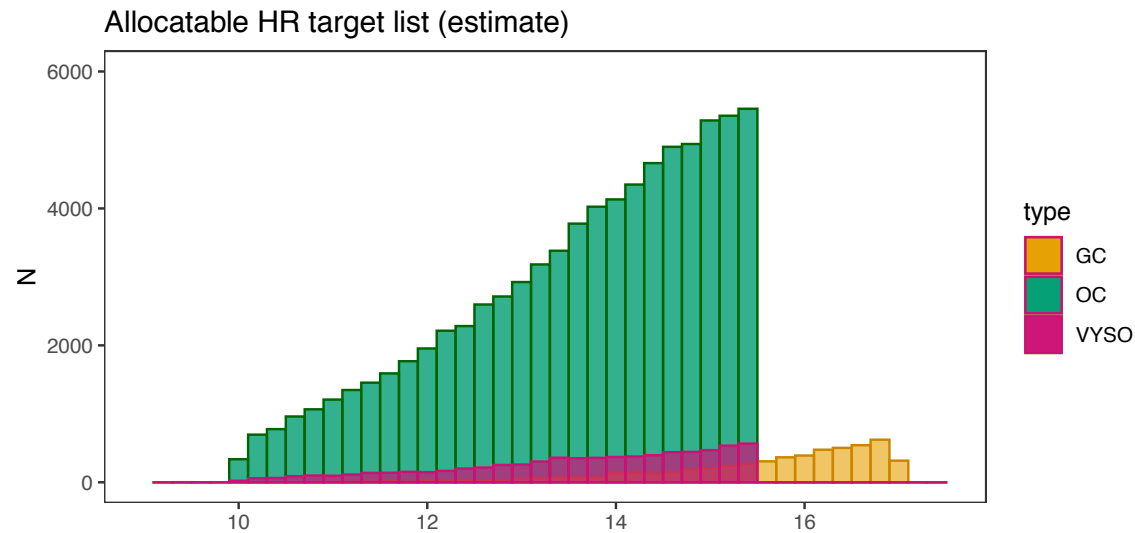
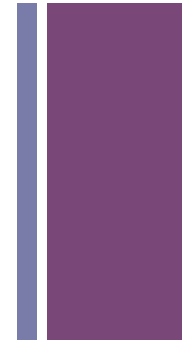
-70 < dec < 5, assuming min separation of 15" (as in Messenger paper)

Density 5-1,500 /deg² (Disk), 10-1,000/deg² (Halo and Bulge)

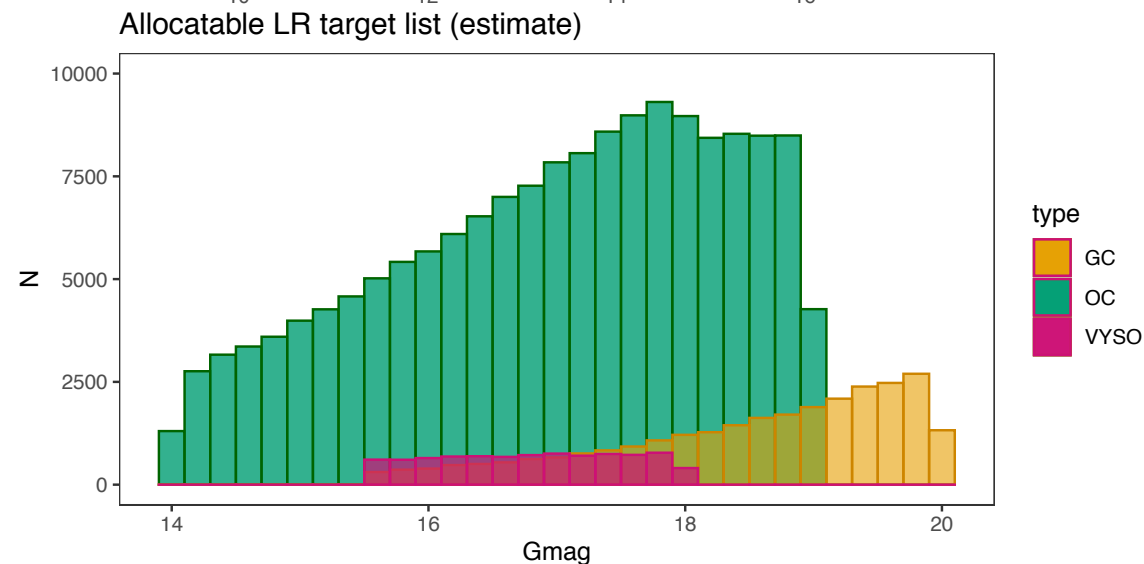
Allocatable target list (estimated)



+ Target Magnitude Distribution



Target selection is based on Gaia DR2. Note that at the faint end we expect that Gaia EDR3/DR3 will allow more accurate selection.



+ Fiber-hours request

LRS 200,500 HRS 75,700 Total 276,200 fiber-hours <5% of the available time

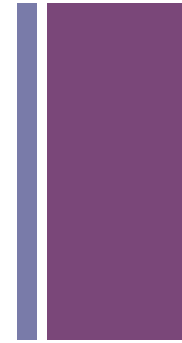
Target type	Spectrograph	G Magnitude range	Number	Exposure time	typical SNR @ 600nm	Fiber Hours	Total Fiber Hours
OCs	LRS	14-16	40,000	40m	50-100	27,000	147,000
		16-19	120,000	1h	20-40	120,000	
OCs	HRS	10-12	13,000	20m	>100	4,300	61,300
		12-14	30,000	40m	>100	20,000	
		14-15.5	37,000	1h	70	37,000	
GCs	LRS	15.5-16	1000	40m	50	670	48,000
		16-18	7,000	1h	40	7,000	
		18-20	20,000	2h	20	40,000	
GCs	HRS	≤14	600	40m	>100	400	10,400
		14-15	2,000	1h	70	2,000	
		15-17	4,000	2h	25-50	8,000	
VYC	LRS	15.0-16.5	4,500	20m	40	1,500	5,500
		16.5-17.5	3,500	40m	30	2,000	
		17.5-18.5	2,000	1h	30	2,000	
VYC	HRS	<15.5	7,000	40m	>50	5,000	5,000

+ Survey special requirements

- Cadence, observing conditions, magnitude limits, target S/N specified by the Galactic Consortium surveys are fully compatible with our requirements.
- Planned pipeline for FGK stars fulfills our requirements for OCs and GCs stars;
- Standard calibration plan for physical calibrations (wavelength, RV, flux etc)
- Extension to South (down -72) to and North (up to ~ 10) in selected fields would allow to target key clusters (e.g. 47Tuc, NGC362) and to observe cross-calibration fields with other large Surveys (e.g. WEAVE, DESI). In this case the fiber hours request would increase by $\sim 3-4K$.

+ Synergies with Consortium Surveys

- Study of SCs is highly complementary to that of the Galactic CSs;
- Collaboration with Galactic and MCs Consortium Surveys, possible contributions e.g.
 - Provides a sample sample that fulfills the bulk of the astrophysical calibration (atmospheric parameters and elemental abundances) needs of the stellar surveys -> IWG7
 - With slight northern extension, provides overlap cross-calibration fields with other large surveys -> IWG7
 - Ad-hoc pipeline to analyse VYC, could contribute to building a module -> IWG7



+ Data products

- We will use Consortium Stellar Pipeline to measure RVs, stellar parameters, and elemental abundances for FGK stars in OCs and GCs;
- For VYC will provide RVs, atmospheric parameters, Li and characterisation of properties of accretion/ejection processes and nebular contribution through the H α , [SII] and [NII] emission lines.
- We will also provide cluster membership classification for all the objects in our Survey, confirming Gaia membership of faint stars with radial velocities, and stellar ages and masses for confirmed members.

