4MOST and future synergies with HRMOS

Thomas Bensby

Lund Observatory

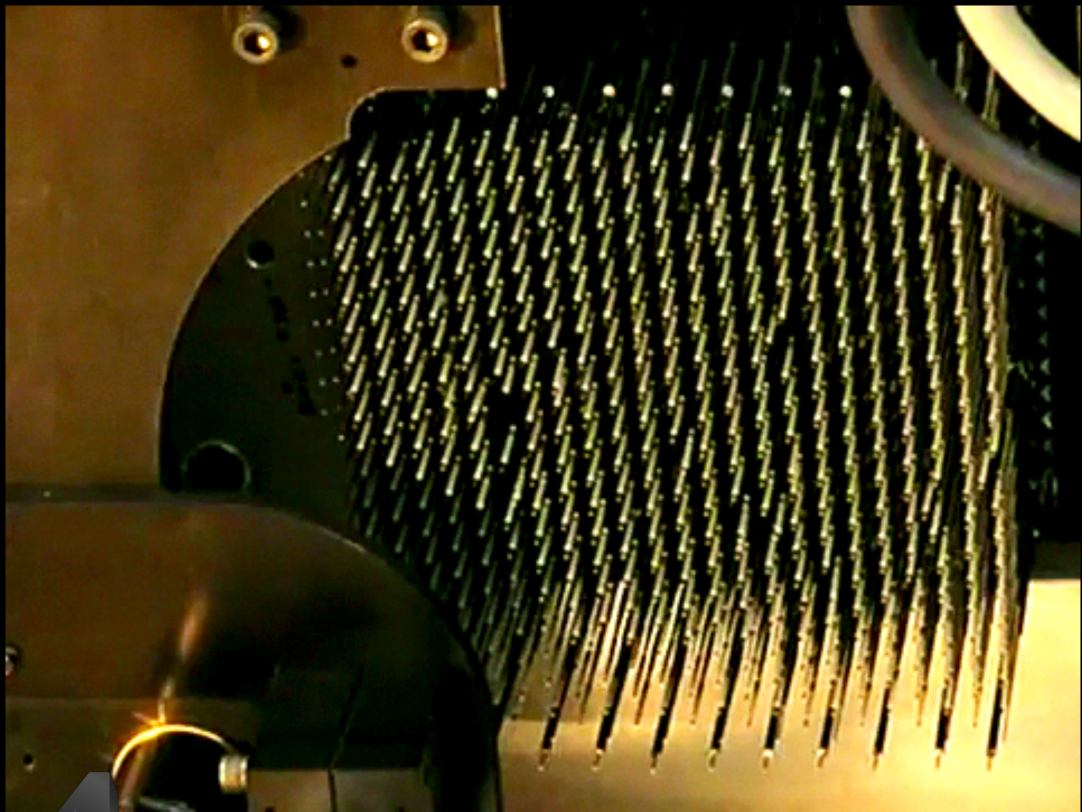
LUND UNIVERSITY

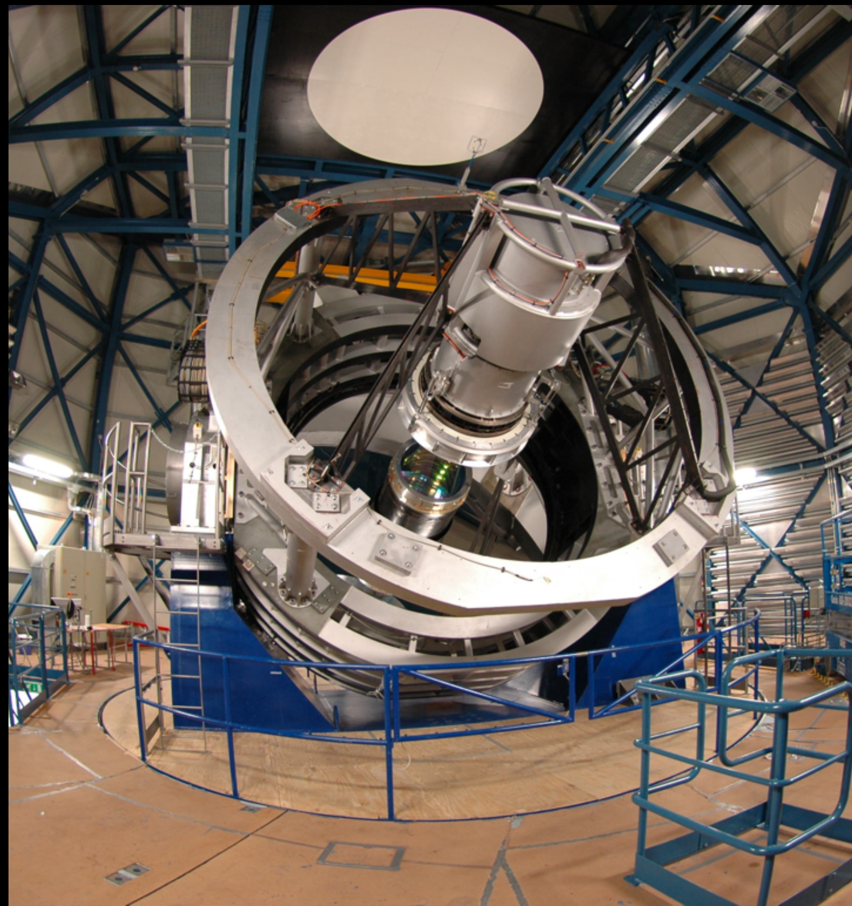

Paranal
VLT - future home of HRMOS?
Vista - future home of 4MOST

4MOST

de Jong, et al. "4MOST: Project overview and information for the first call for proposal", *The Messenger, 2019*

- To be placed on the ESO VISTA 4-m telescope on Paranal
- 2400 fibres (1600 LR & 800 HR)
- 4 deg^2 field of view
- First light 2024
- 5+5 years





AIP
AAO
CRAL
Universität Hamburg
LUND UNIVERSITY
UPPSALA UNIVERSITET
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Lancaster University
University of Portsmouth
UNIVERSITY OF CAMBRIDGE
ZAH
MPE
UNIVERSITY OF Southampton
ESO
Queen's University Belfast
NOVA
ASTRON
rijksuniversiteit groningen
l'Observatoire de Paris
GEPI

4MOST - wavelength coverage

- *High-Resolution Spectrograph (812 fibres) R20,000*
    - *Blue: 3926-4355 Å*
    - *Green: 5160-5730 Å*
    - *Red: 6060-6810 Å*

- *Low-Resolution spectrograph (1624 fibres) R=5000-7000*
    - *4000-8850 Å*

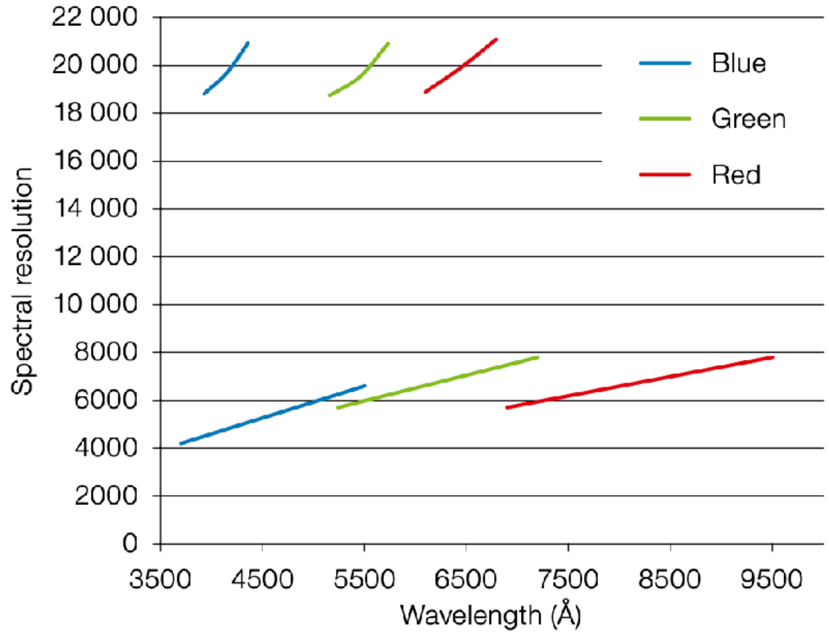


Figure 2. Spectral resolution in the three channels of the 4MOST High-Resolution (HRS, upper lines) and Low-Resolution Spectrographs (LRS; lower lines).

de Jong (2019)

4MOST - point source sensitivities

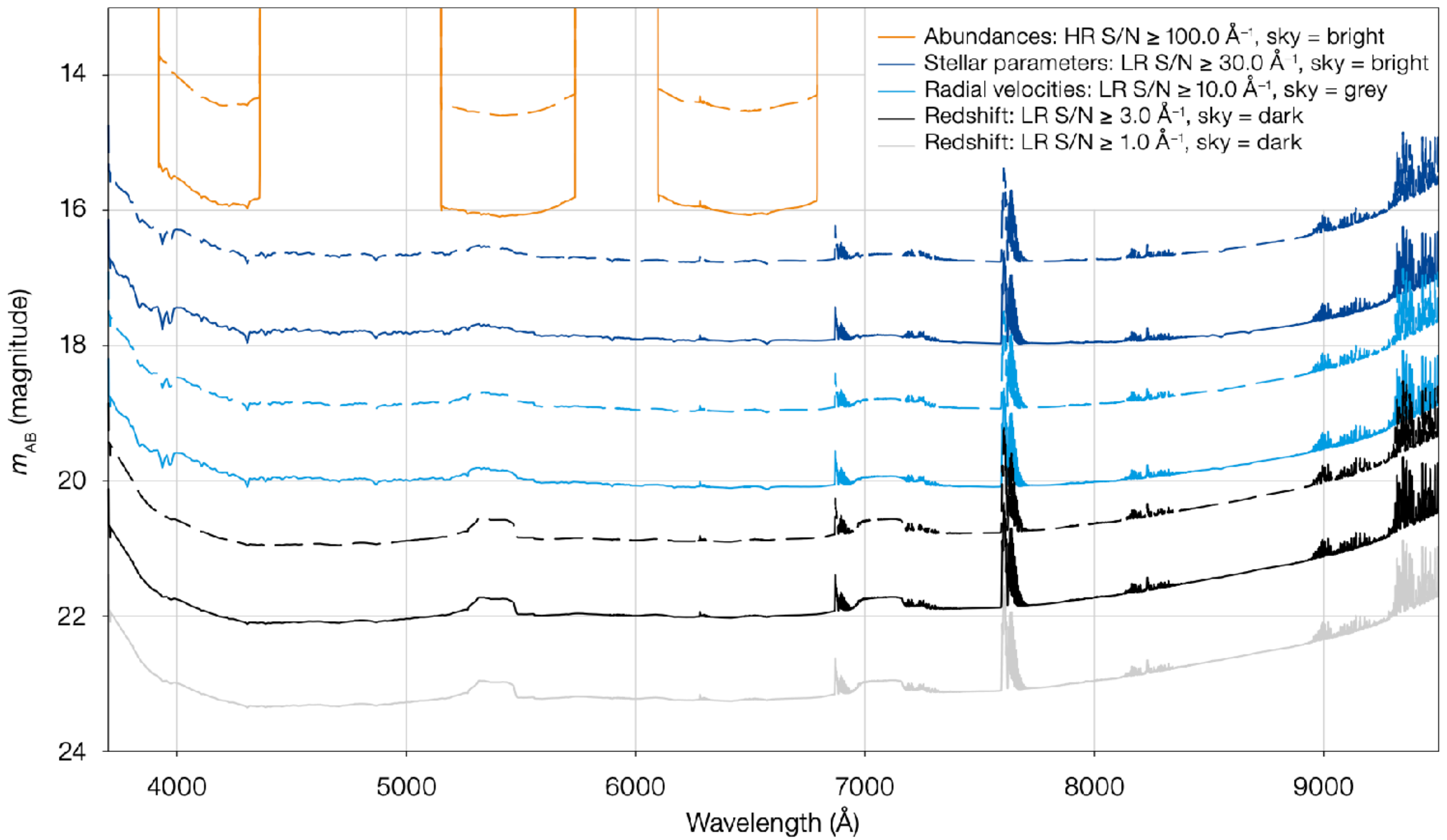


Figure 3. The expected 4MOST point-source sensitivities for the signal-to-noise levels and lunar conditions indicated in the legend. The solid lines are for a total exposure time of 120 minutes, whereas the dashed lines are the limits for 20-minute exposures. The approximate conversion to signal-to-noise per pixel is obtained by dividing the HRS values by 3.3 and the LRS values by 1.7. For clarity, sky emission lines are removed — this mostly affects results redward of 7000 Å. Mean (not median) seeing conditions, airmass values, fibre quality and positioning errors, etc., are used, in order to ensure that this plot is representative for an entire 4MOST survey, not just for the optimal conditions. Typical science cases for obtaining detailed elemental abundances of stars (orange), stellar parameters and some elemental abundances (dark blue), stellar radial velocities (light blue), and galaxy and AGN redshifts (black: 90% complete, grey: 50% complete) are shown.

de Jong (2019)

120 min exposure: solid lines
20 min exposures: dashed lines

SNR values given per Å.

Divide by 3.3 to get to per pixel for HR
Divide by 1.7 to get to per pixel for LR

4MOST - consortium surveys

- *S1 - Milky Way Halo low-resolution survey*
  PI: Starkenburg & Irwin
- *S2 - Milky Way Halo high-resolution survey*
  PI: Christlieb
- *S3 - Milky Way Disk and bulge low-resolution survey (4MIDABLE-LR)*
  PI: Chiappini & Minchev
- *S4 - Milky Way Disk and bulge high-resolution survey (4MIDABLE-HR)*
  PI: Bensby & Bergemann
- *S5 - eRosita Galaxy cluster redshift survey*
  PI: Comparat
- *S6 - Active galactic nuclei survey*
  PI: Merloni
- *S7 - Wide area VISTA extra-galactic survey (WAVES)*
  PI: Driver & Liske
- *S8 - Cosmology redshift survey*
  PI: Kneib & Richard
- *S9 - 1001 Magellanic fields survey*
  PI: Cioni
- *S10 - The time domain extragalactic survey (TIDES)*
  PI: Sullivan

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  PI: Cioni
- *S10 - The time domain ex agalactic survey (TIDES)*
  PI: Sullivan

+ Community surveys (TBD soon)

4MIDABLE

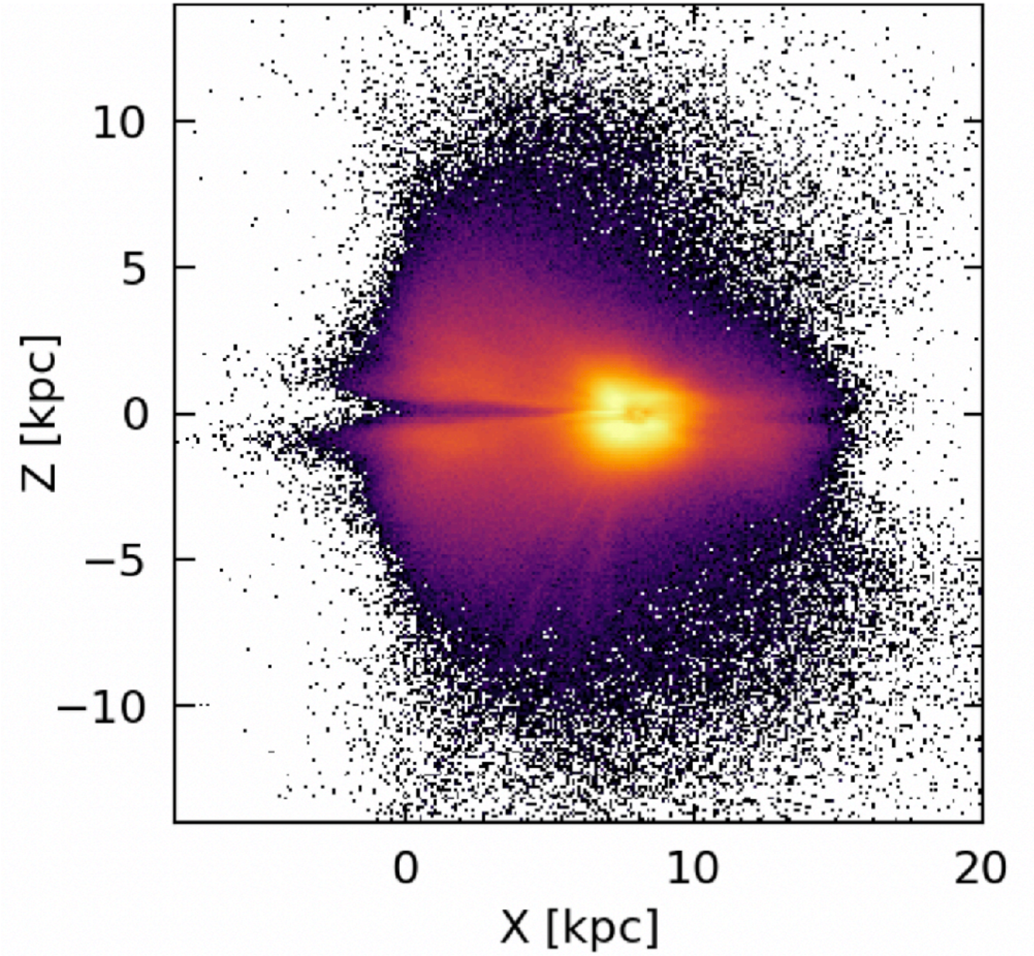
4MOST MIlky way Disk And BuLgE High-Resolution survey

Structure and evolution of the Galactic disk and bulge

Thomas Bensby (Lund), **Maria Bergemann** (MPIA),
and the 4MIDABLE-HR Team

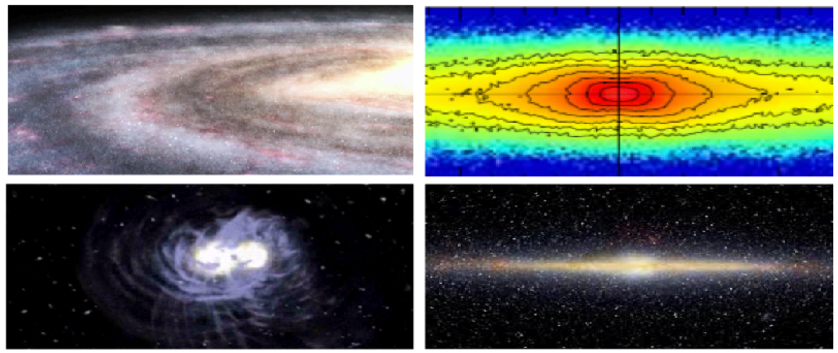
Disk & Bulge high-res survey

Bensby & Bergemann+ 2019



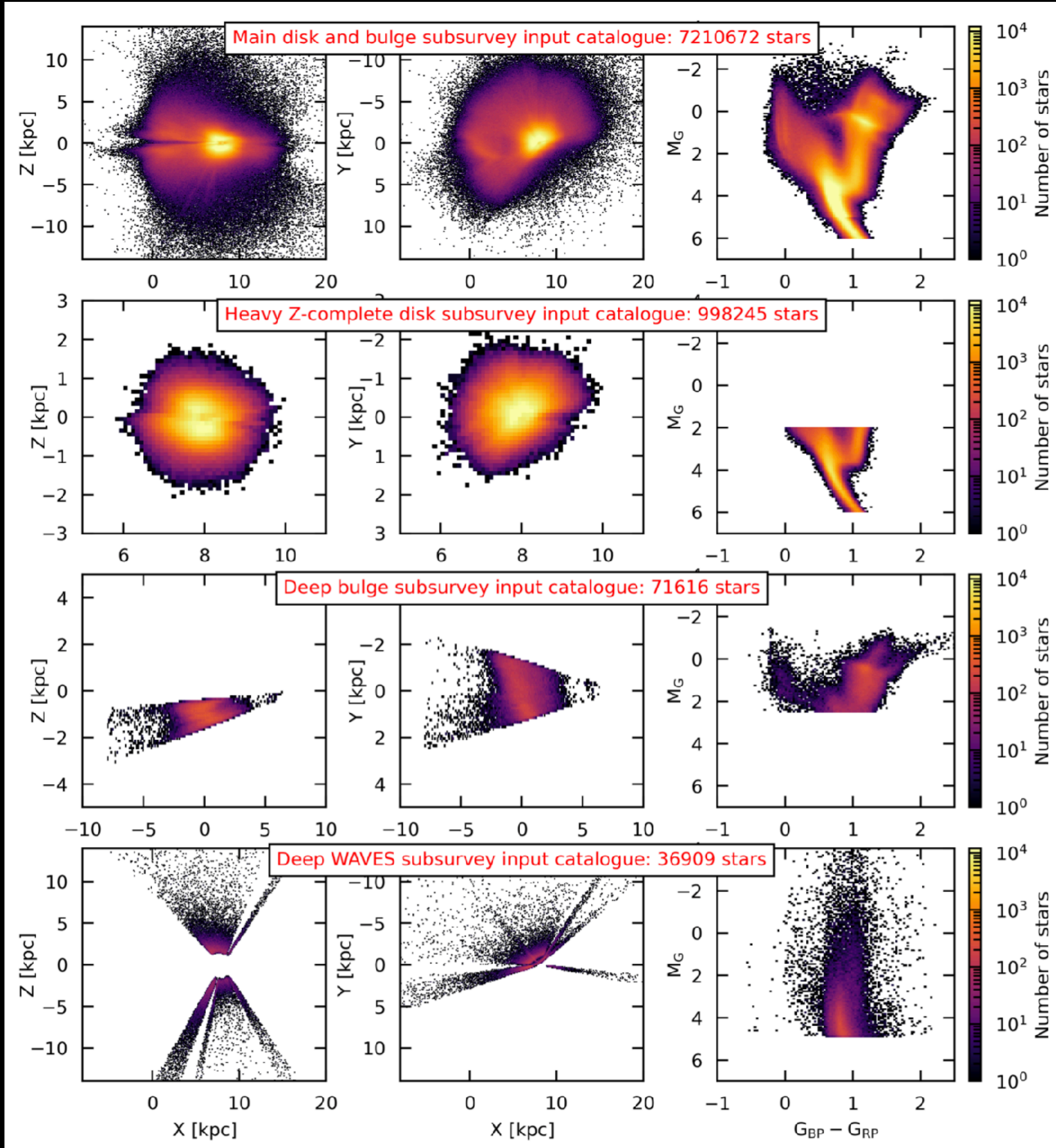
Spectra of > 3 million stars at R = 20.000

- Galactic discs: radial migration, mergers, oscillations
- Classical or pseudo-bulge or both
- Stellar physics



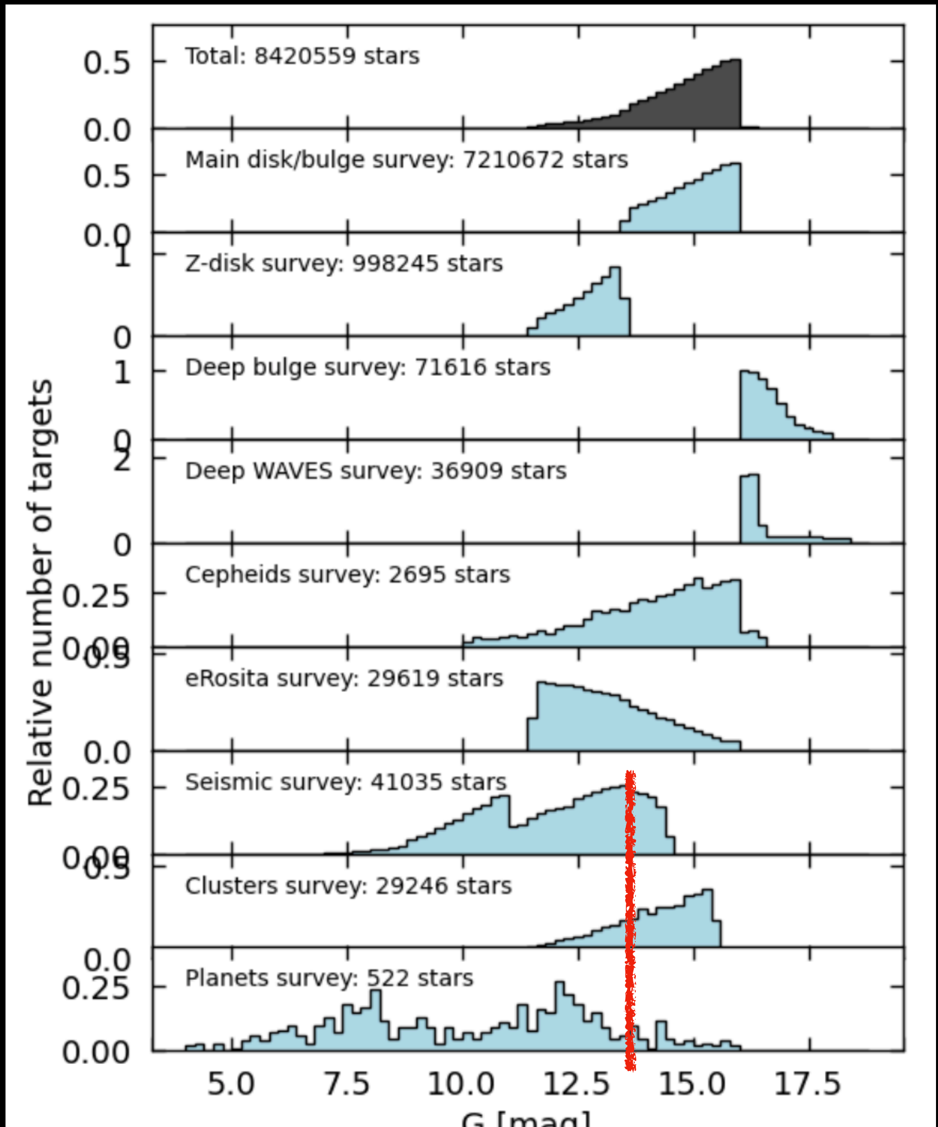
Science applications: *stellar physics, dark matter distribution, spiral arm dynamics, stellar siblings, mass function, exoplanet hosts, star cluster evolution and dissolution, history of chemical elements, …*

4MIDABLE-HR



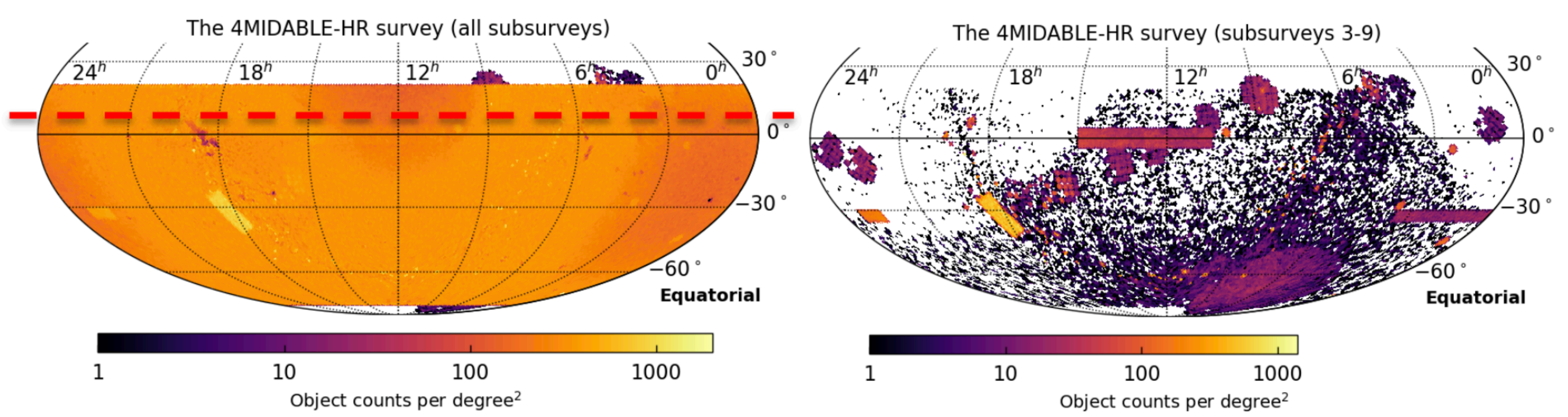
Main disk and bulge subsurvey input catalogue: 7210672 stars
Heavy Z-complete disk subsurvey input catalogue: 998245 stars
Deep bulge subsurvey input catalogue: 71616 stars
Deep WAVES subsurvey input catalogue: 36909 stars
Z [kpc]
Y [kpc]
M_G
Number of stars
X [kpc]
$G_{BP} - G_{RP}$

4MIDABLE-HR subsurveys



1. *Disk/bulge SNR>100 Å^{-1}*
2. *Z-disk SNR>250 Å^{-1}*
3. *Deep bulge SNR>100 Å^{-1}*
4. *Deep WAVES SNR>100 Å^{-1}*
5. *Cepheids SNR>100 Å^{-1}*
6. *eRosita SNR>100 Å^{-1}*
7. *Seismic SNR>100 Å^{-1} or SNR>250 Å^{-1}*
8. *Clusters SNR>100 Å^{-1} or SNR>250 Å^{-1}*
9. *Planets SNR>100 Å^{-1} or SNR>250 Å^{-1}*

4MIDABLE-HR



The 4MIDABLE-HR survey (all subsurveys)
24h
18h
12h
6h
0h
30°
0°
−30°
−60°
Equatorial
1
10
100
1000
Object counts per degree²
The 4MIDABLE-HR survey (subsurveys 3-9)
24h
18h
12h
6h
0h
30°
0°
−30°
−60°
Equatorial
1
10
100
1000
Object counts per degree²

4MIDABLE-HR

Taking advantage of high signal-to-noise (S/N) spectra obtained in three windows: 3926–4355 Å, 5160–5730 Å, and 6100–6790 Å, which allows elements of all main nucleosynthesis channels to be targeted, we will determine abundances of more than 30 elements with a precision better than 0.1 dex

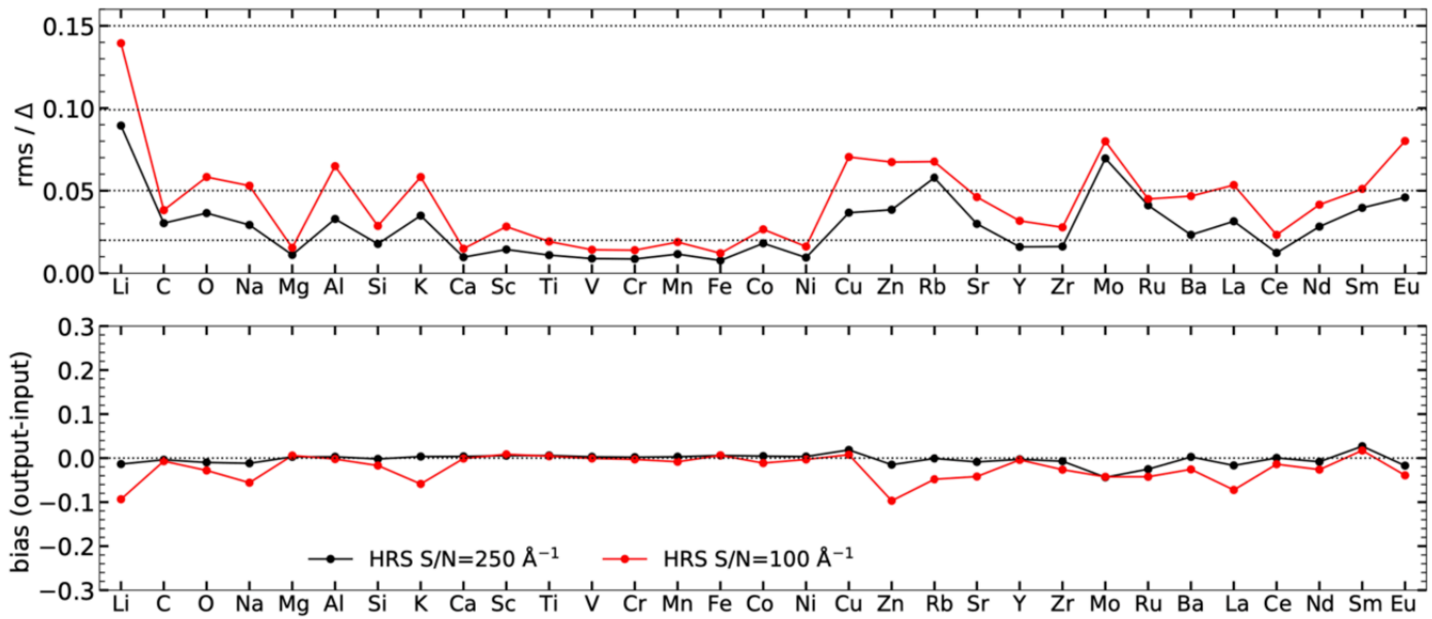
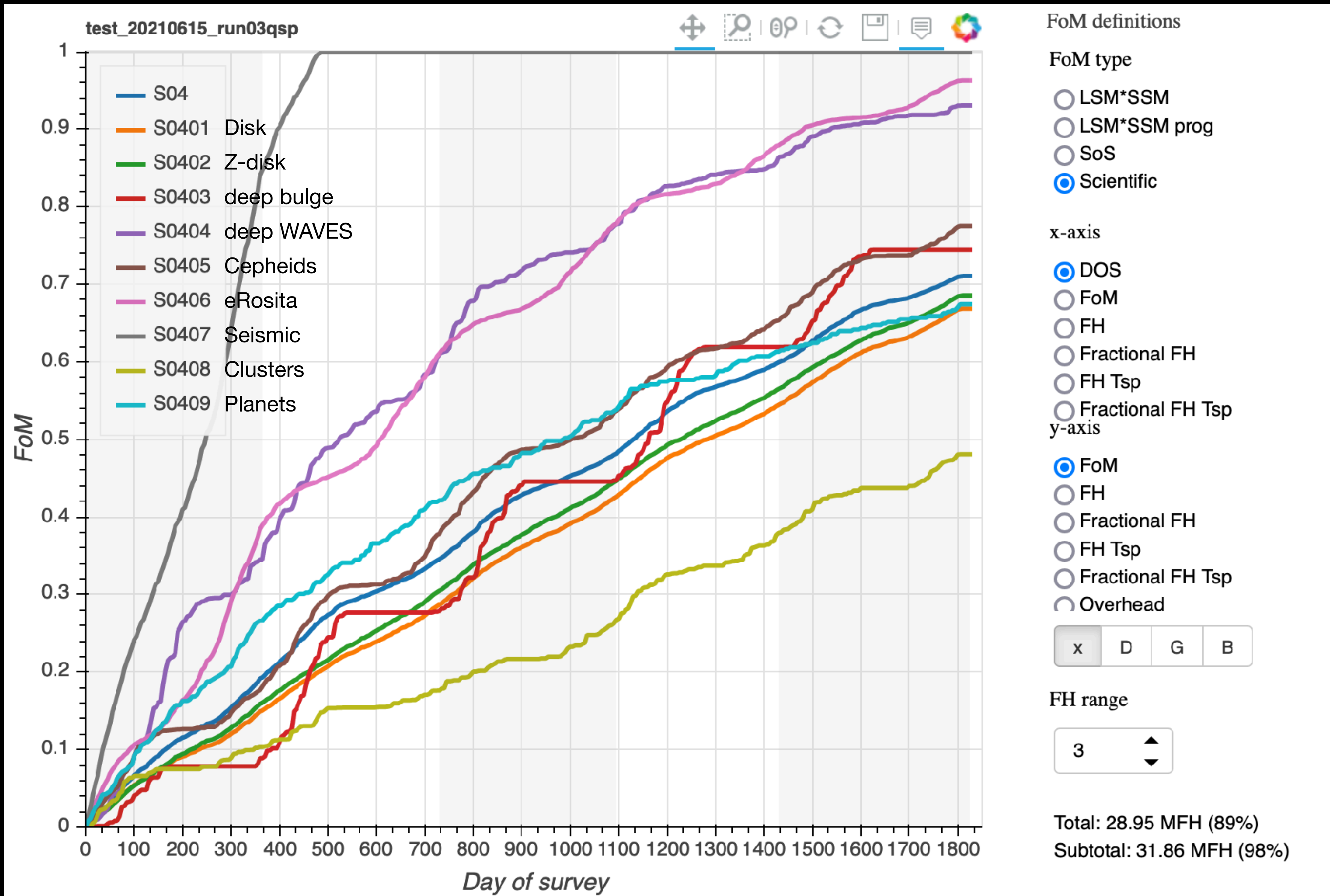


Fig. 4 Characteristic abundance precisions for 31 chemical elements. Top panel demonstrates the fractional statistical uncertainty, rms/Δ, of abundance determinations based on simulations of Mock 4MOST high-resolution spectra at different S/N ratios. Δ corresponds to the range of expected abundance variations at a given metallicity. Bottom panel shows that the bias of abundances typically does not exceed 0.05 dex for HR spectra.

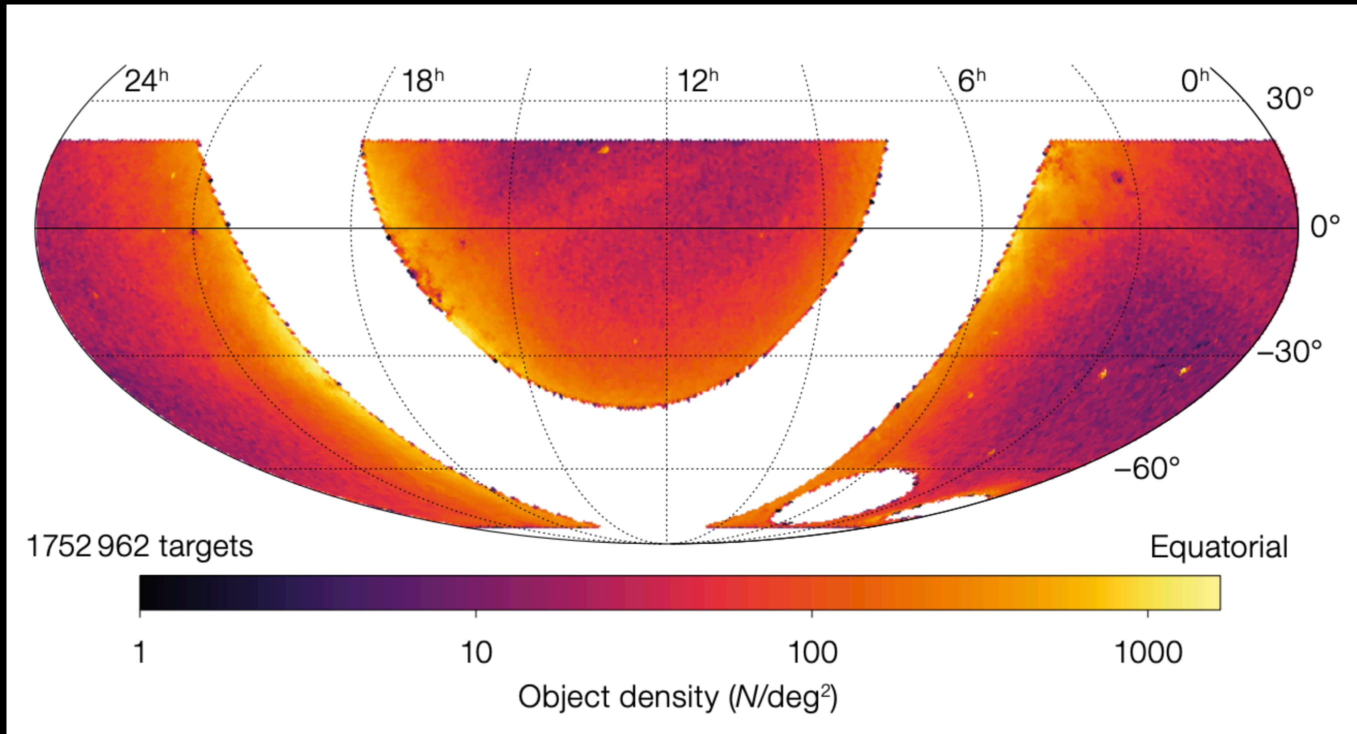
Simulations done with Payne pipeline (see e.g. Kovalev et al., 2019)

4MIDABLE-HR 5-year survey simulation



LR Halo

(Starkenburg & Irwin)



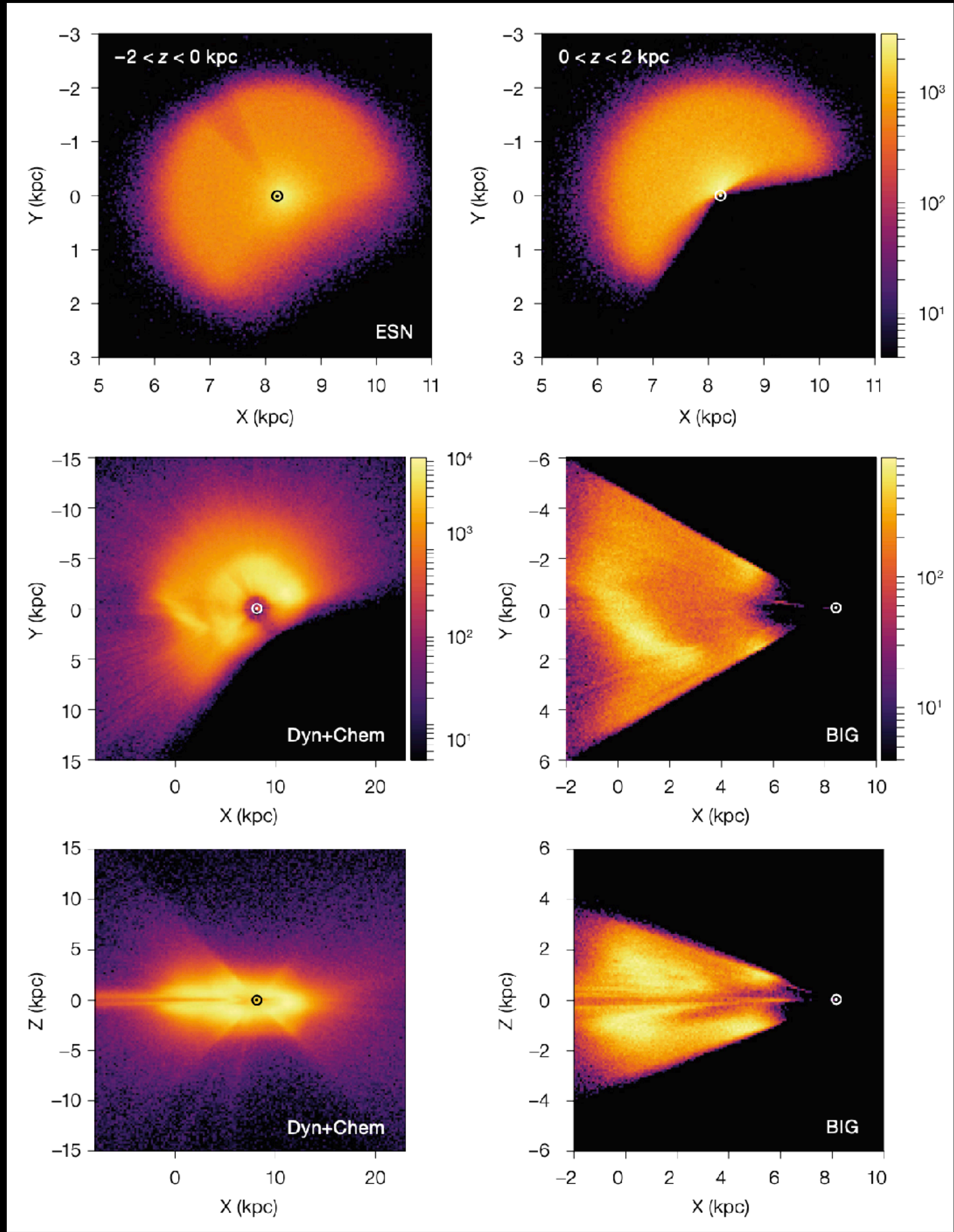
Main objectives include to quantifying the number of streams and amount of kinematic structures as a function of distance and location on the sky. Aims to determine metallicity and abundances (mainly [Mg/Fe]). Follow-up observations clearly needed of new/interesting features….

LR Bulge and Disk (4MIDABLE-LR)

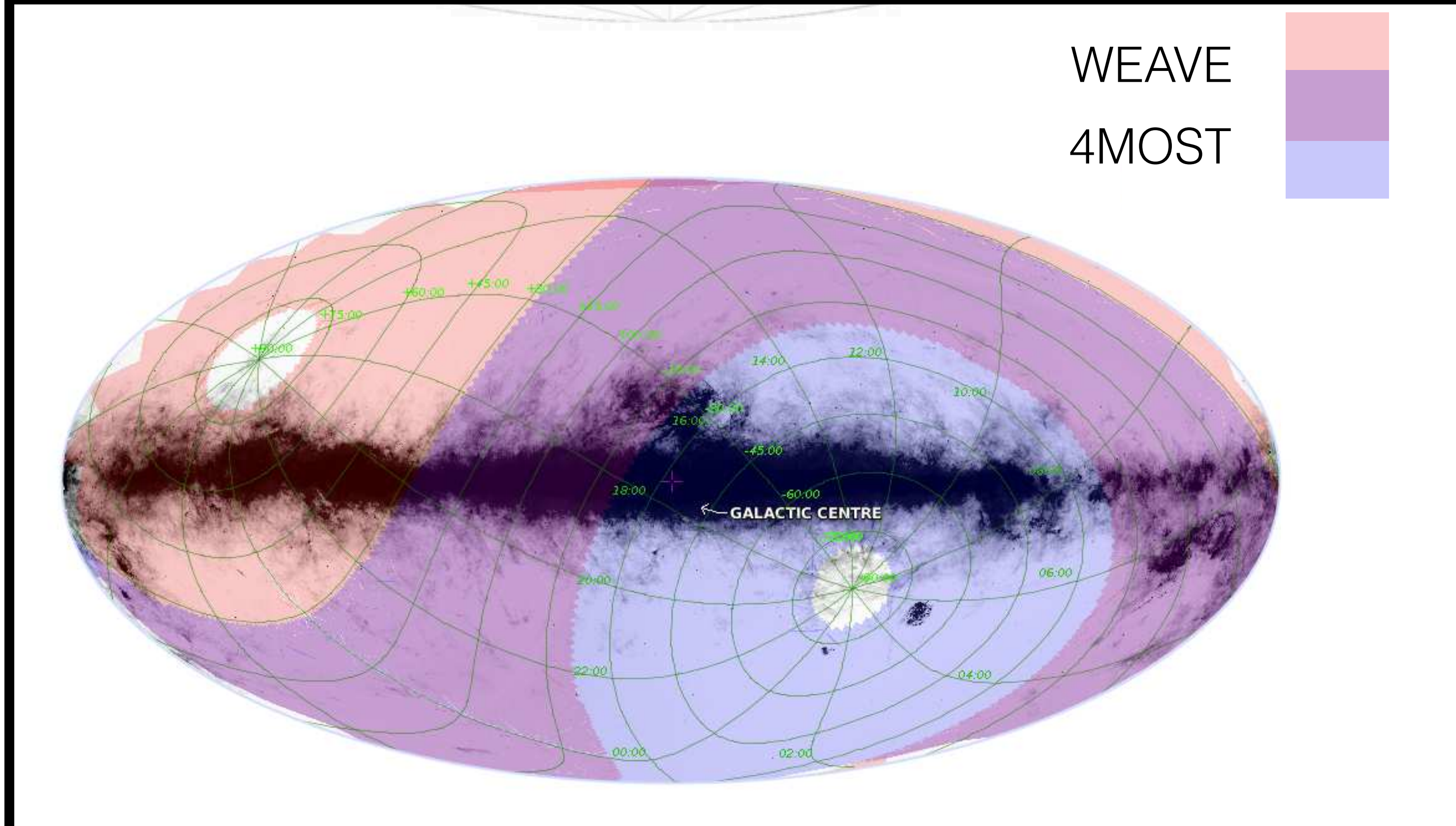
(Chiappini & Minchev)

Our main goals are:

- To better understand the current Milky Way disc structure and dynamics (bar, spiral arms, vertical structure, stellar radial migration, merger history).
- To study the chrono-chemo-dynamics of the disc, which, when combined with the above will allow us to recover the disc evolutionary history.
- To better understand the formation of the Milky Way bulge/bar using both chemical and kinematical information.
- To study the inner disc/bulge and disc/halo interfaces by covering a large area and ensuring high-quality chemical and kinematical information.



4MOST vs WEAVE



WEAVE:
outer disk,
anti-centre

4MOST:
inner disk, bulge

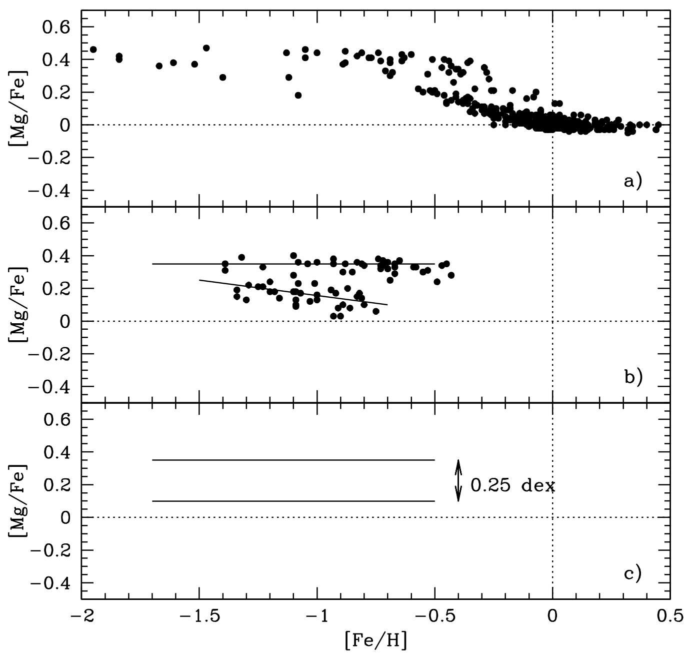
Complementary, so it is important to have cross-calibration fields

Large survey follow-up

- 4MOST (R~18000)
- WEAVE (R~18000)
- These surveys will observe millions of targets in the Milky Way bulge and disk and discover a multitude of new things
- Streams, overdensities,…..
- Follow-up observations is not possible within the surveys
- High-res and higher SNR observations will allow a better characterisation of new discoveries
- Assuming that higher R gives better precision in abundances …..

Large survey follow-up

- Better precision will lower the observed dispersion of “structures” and allow us to distinguish them from each other and from the (thin and thick) disk field stars with smaller samples



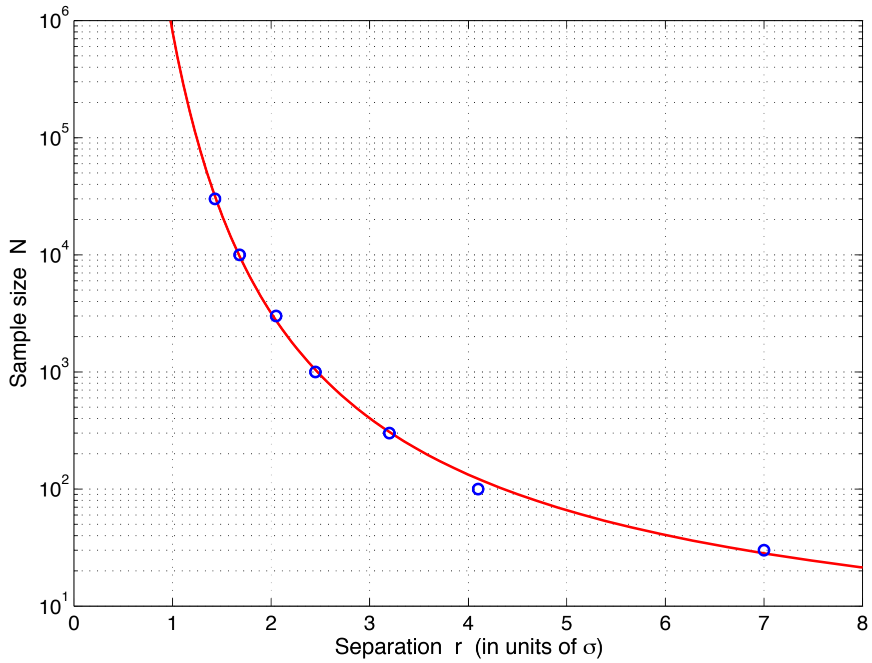


Fig. 4. Minimum sample size needed to distinguish two equal Gaussian populations, as a function of the separation of the population mean in units of the standard deviation of each population. The circles are the results from Monte-Carlo simulations as described in the text, using a K–S type test with significance level $\alpha = 0.01$ and power $1 - \beta = 0.99$. The curve is the fitted function in Eq. (2) or (3).

Lindegren & Feltzing (2013)

Large survey follow-up

- Higher precision in abundances needed (than what current large surveys provide)
- Possible to do important elements with usually very weak lines such as e.g. Eu and [OI6300] that require high resolution, and more….
- Bulge and disk poorly explored in neutron-capture elements, unclear if the large surveys will be able to provide good enough data for e.g. Eu
- +all the other excellent reasons presented at this meeting….