4MOST – 4m Multi-Object Spectroscopic Telescope

Marica Valentini (AIP)

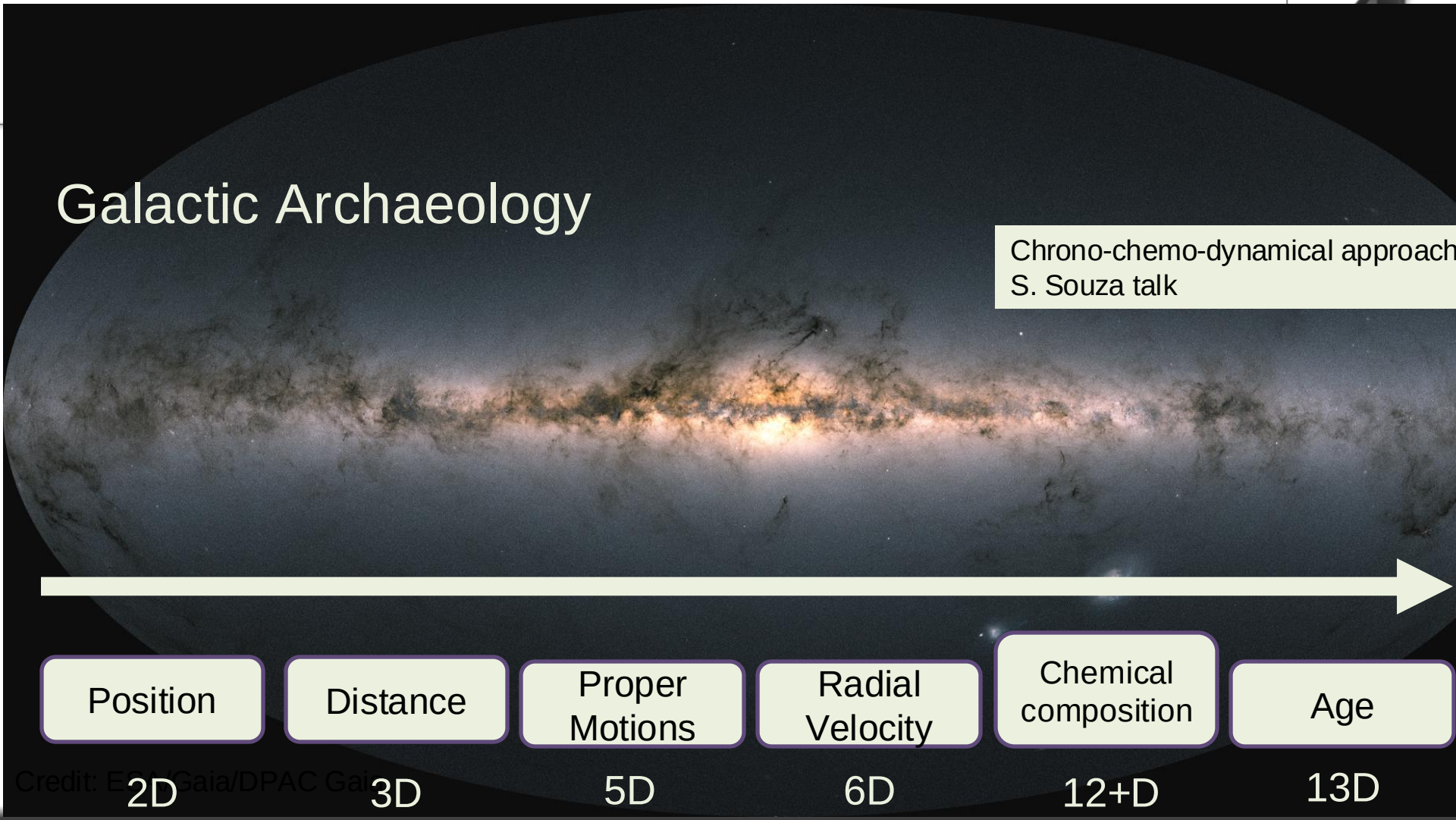
S3 – seismic RG subsurveys
IWG3 lead
S1,2,4 member , IWG6/7 commissioning

24 May 2024

www.4MOST.eu

Galactic Archaeology

Chrono-chemo-dynamical approach
S. Souza talk

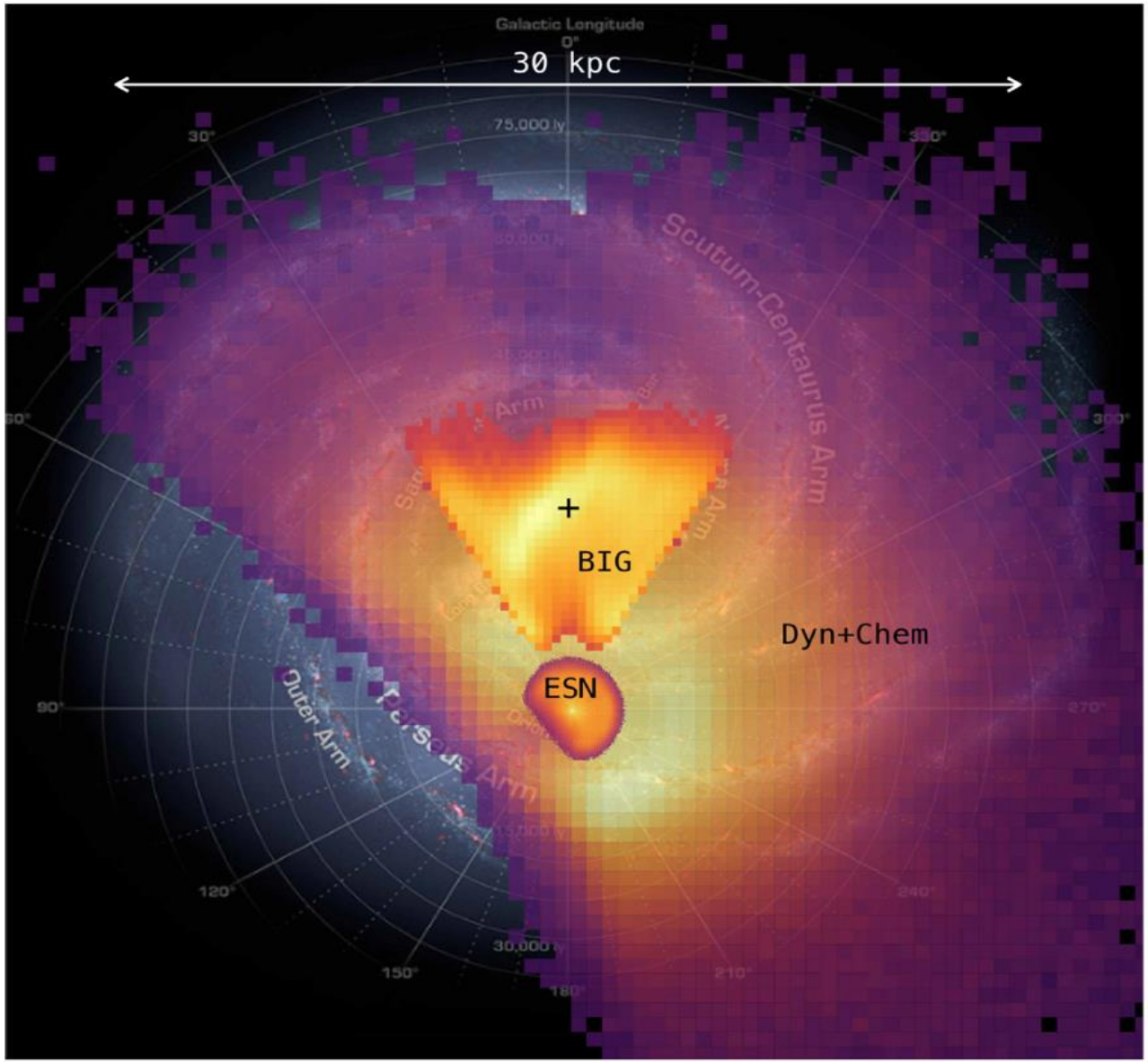


Credit: ESA/Gaia/DPAC Gaia

Galactic Archaeology

Position	Distance	Proper Motions	Radial Velocity	Chemical composition	Age
2D	3D	5D	6D	12+D	13D

Credit: ESA/Gaia/DPAC Gaia



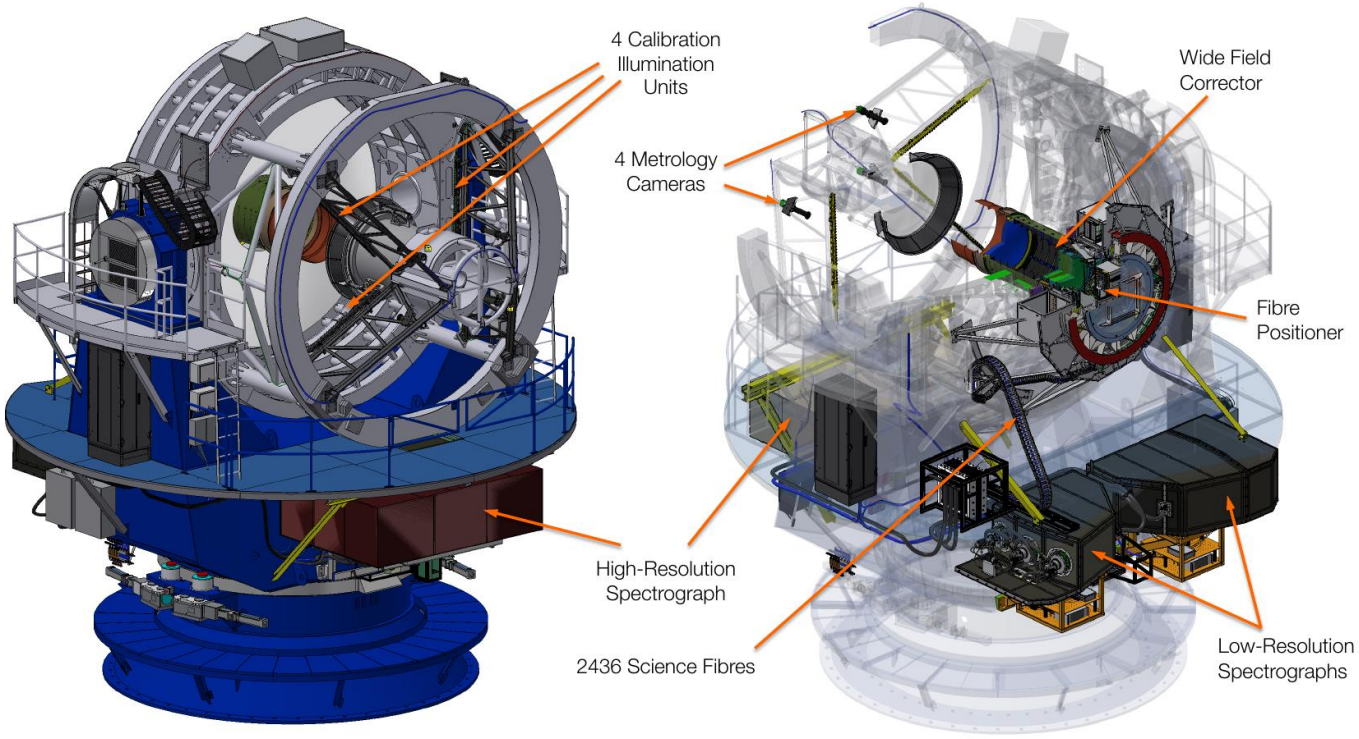
See:
C. Chiappini talk
A. Queiroz talk

T. Bensby poster (S4)
E. Starkenburg and C. Worley (S1)

4MIDABLE-LR
LOW RESOLUTION DISK AND BULGE
(S3 – Pis: C. Chiappini, I. Minchev)

4MOST – The instrument

www.4most.eu



ESO spectroscopic Public Survey

VISTA telescope (Chile)

FoV: 4.2 degree^2

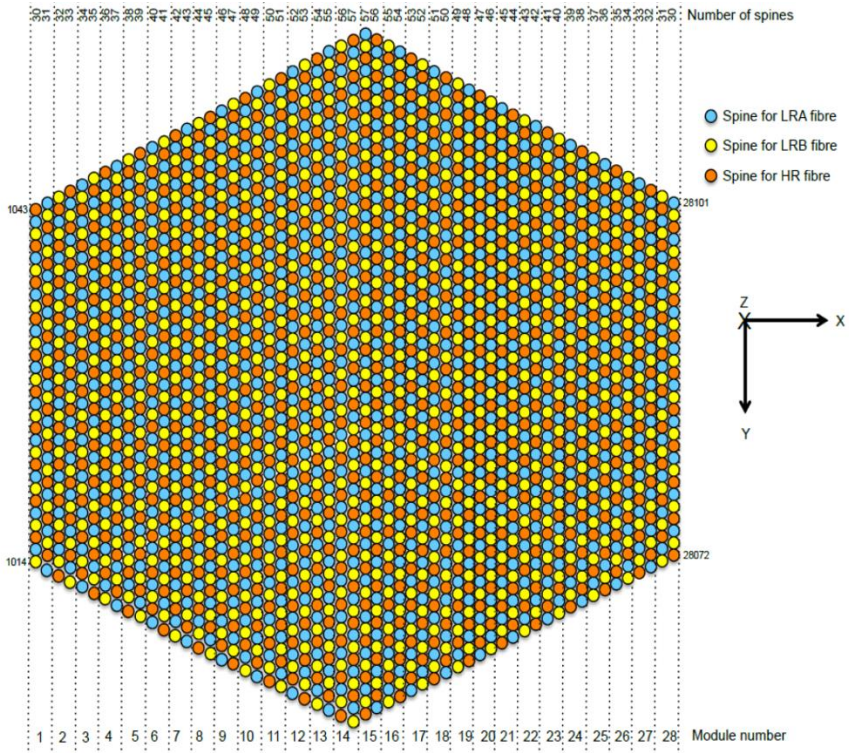
2,436 fibers per pointing

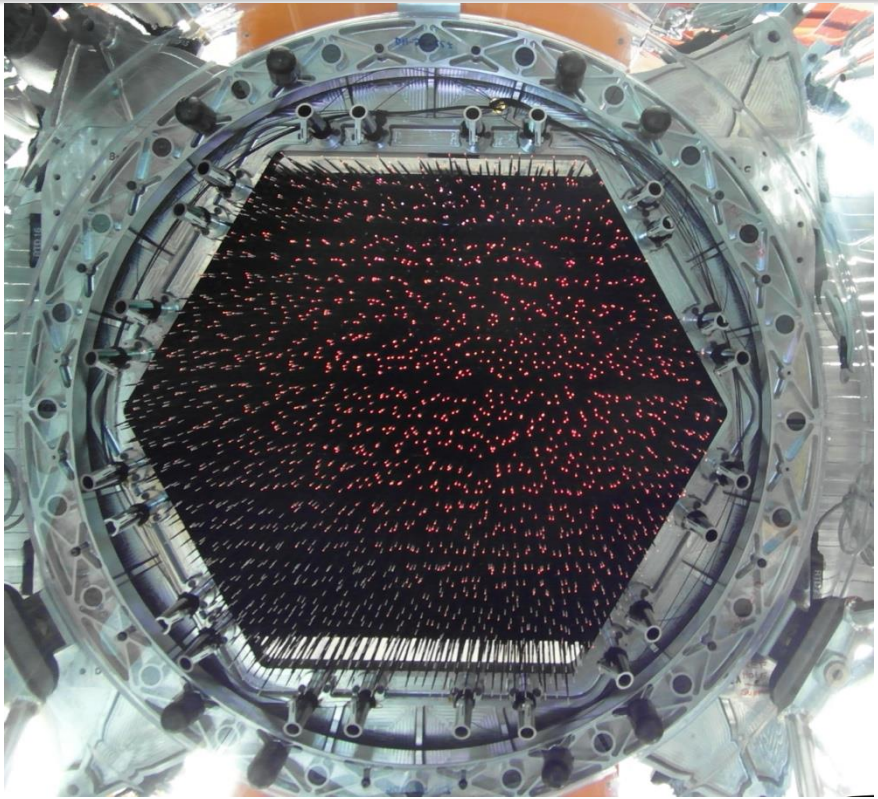
2 Resolutions:
- LR : 1624 Fibers
- HR : 812 Fibers

5 years survey

GALACTIC + EXTRAGALACTIC SCIENCE SHARING THE FOCAL PLANE

4MOST – The Instrument





Fiber size: 1.65 arcsec$^{2.}$ Min. distance fibers: 15 arcsec. + 36 calibration fibers + 12 guide bundles + 24 fiducial (metrology)

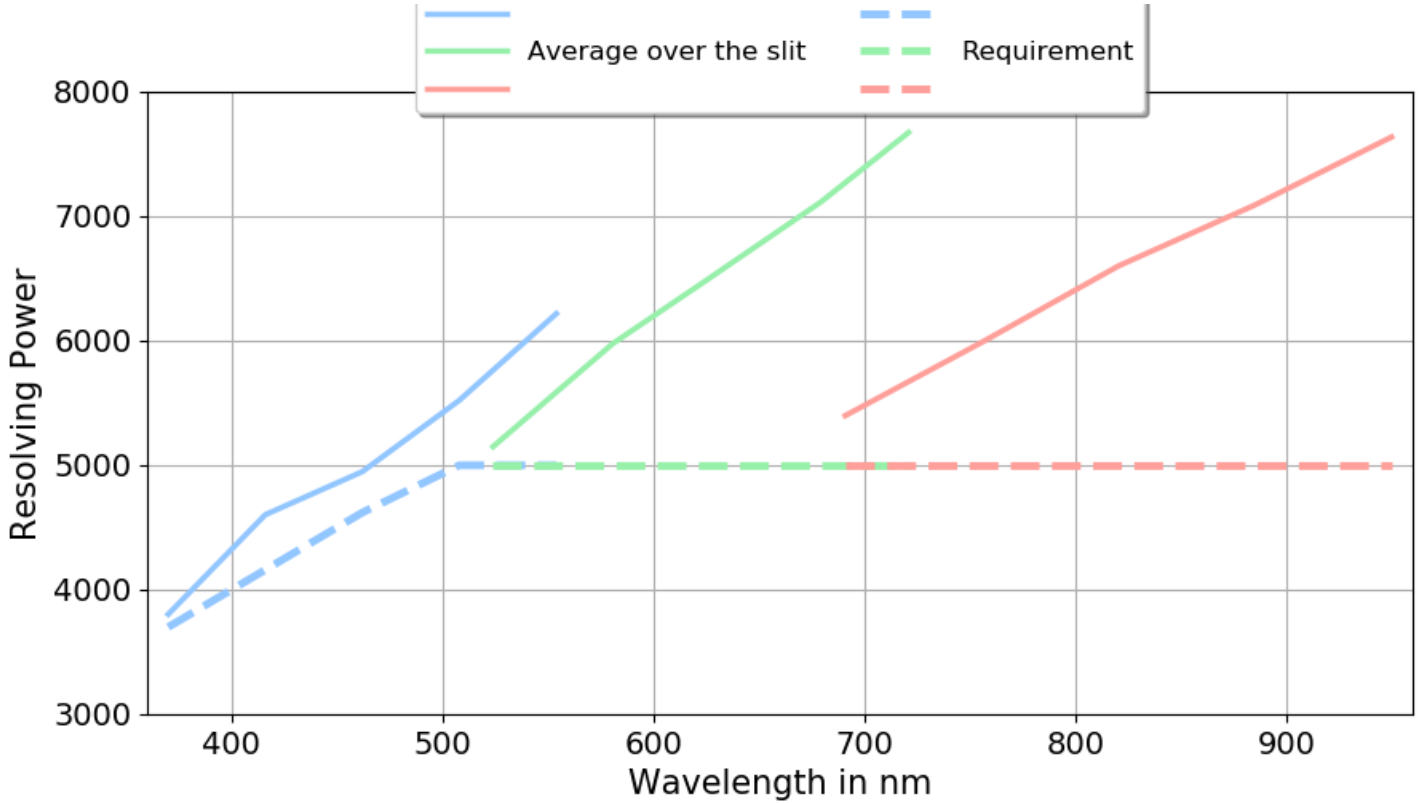
4MOST – LR

3 arms spectrograph
1624 Fibers
R> 4,000 – 7,800

370 – 950 nm

812 science fibers per spectrograph

2 mirrored spectrographs



4MOST – HR

B : 392.6 – 435.5 nm

516 – 573 nm

610 – 679 nm

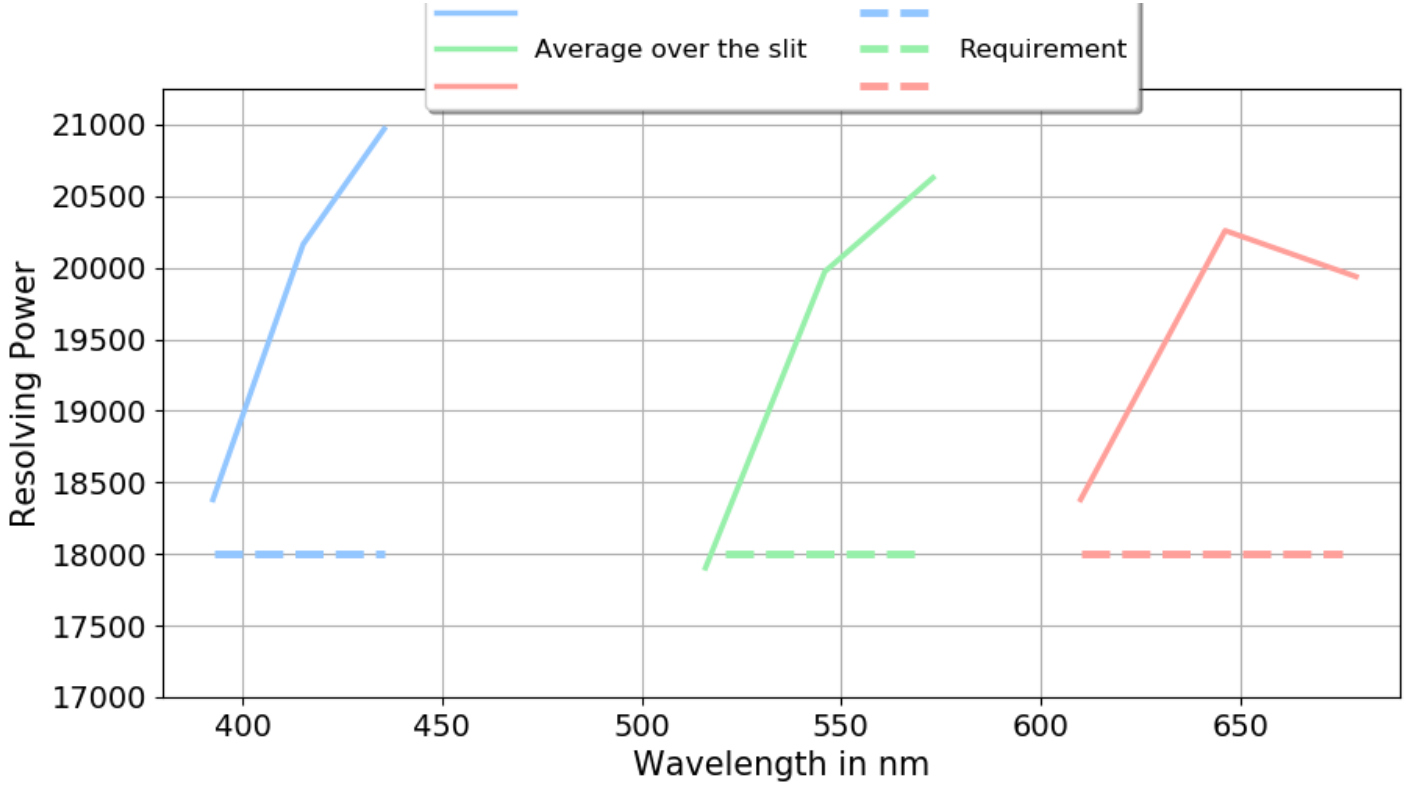
3 arms spectrograph

812 Fibers
R> 18,500

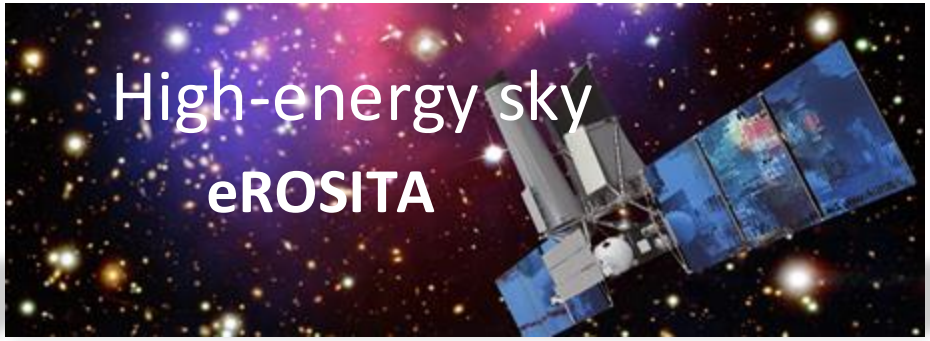
B : 392 – 435 nm
G : 516 – 573 nm
R : 610 – 679 nm

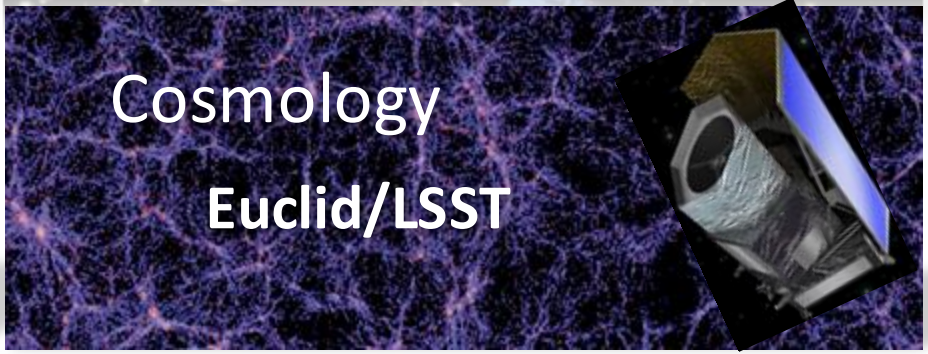
812 science fibers

1 spectrograph



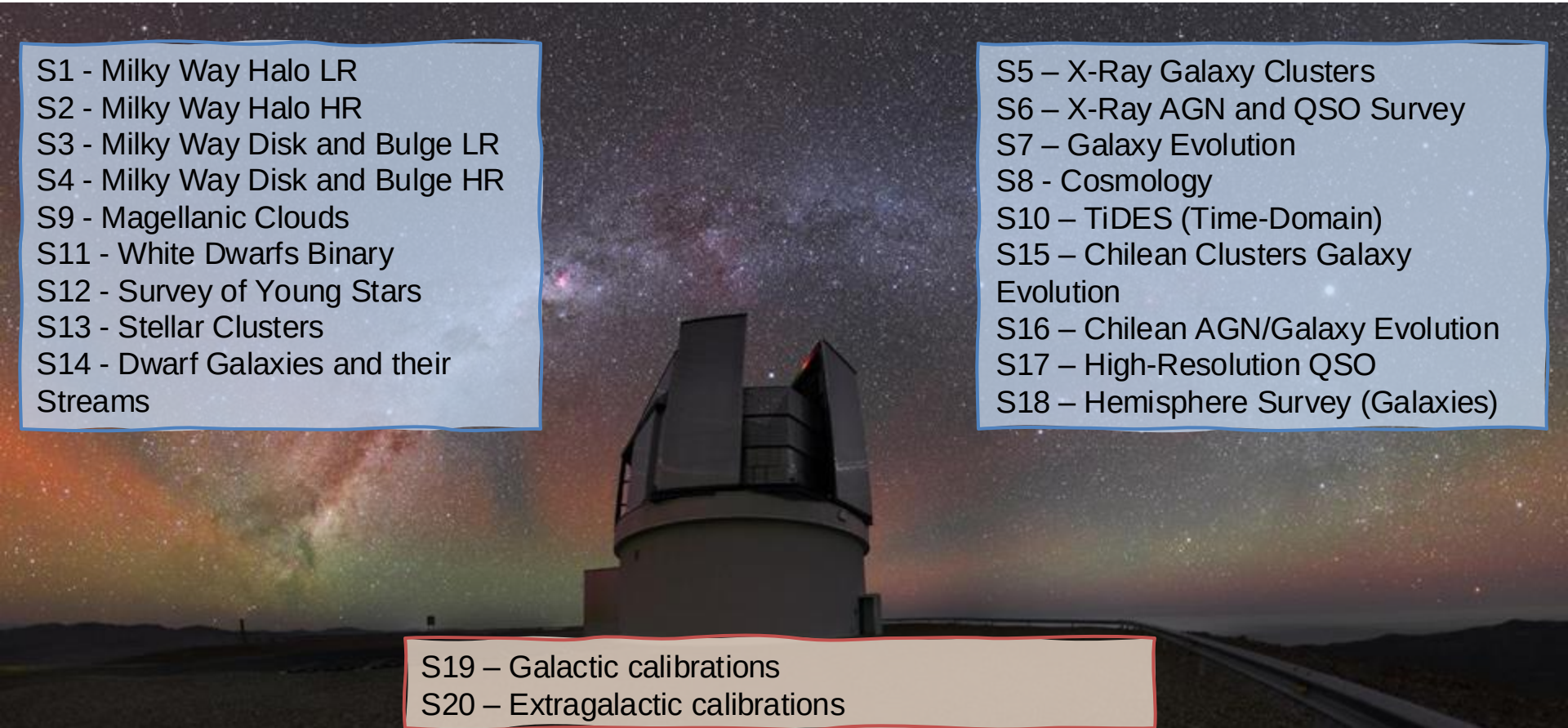
4MOST – The Science





4MOST – The Science

18 Surveys (Description of consortium surveys: Messenger 175: The 4MOST Issue)

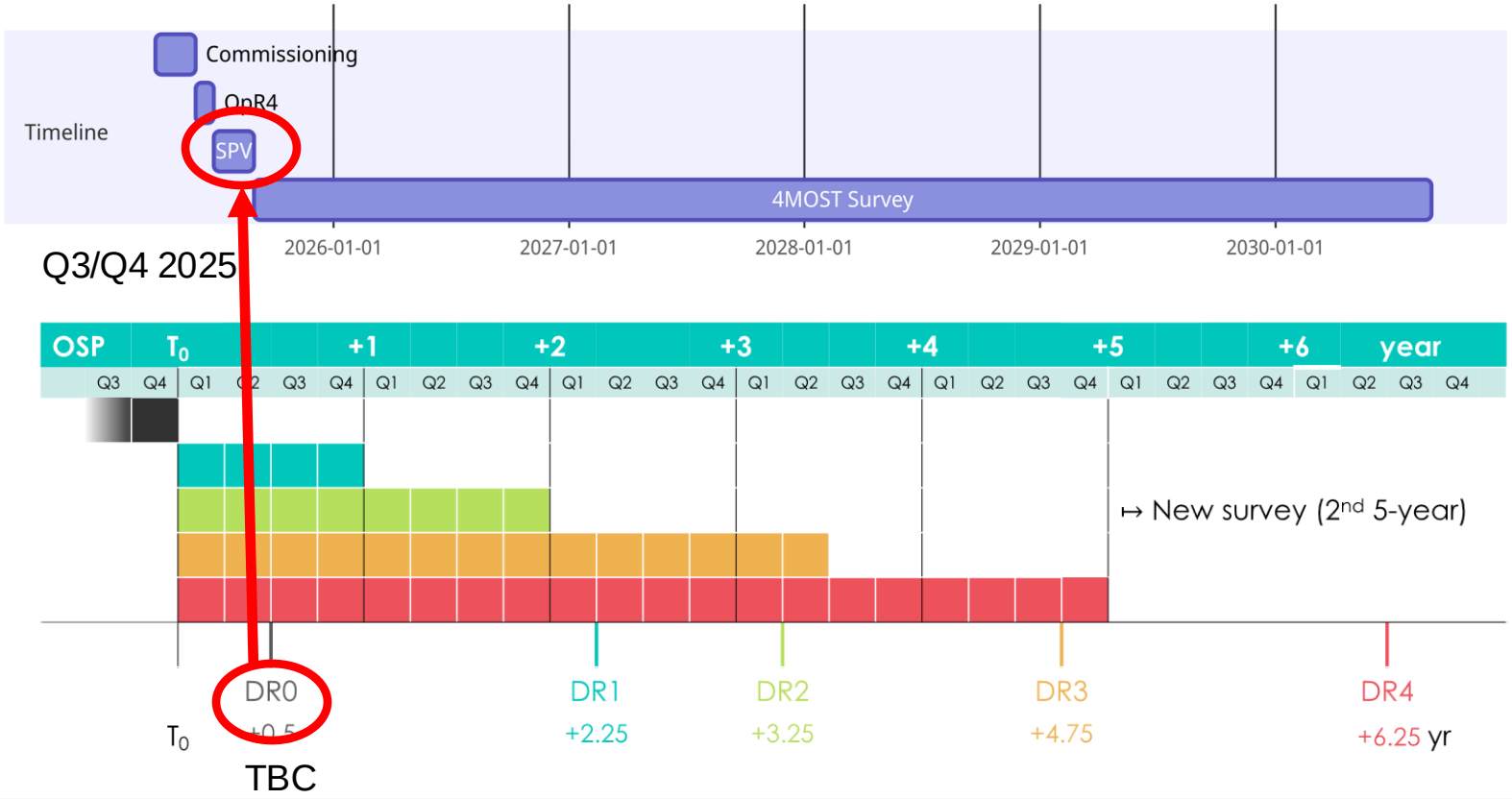


S1 - Milky Way Halo LR
S2 - Milky Way Halo HR
S3 - Milky Way Disk and Bulge LR
S4 - Milky Way Disk and Bulge HR
S9 - Magellanic Clouds
S11 - White Dwarfs Binary
S12 - Survey of Young Stars
S13 - Stellar Clusters
S14 - Dwarf Galaxies and their Streams

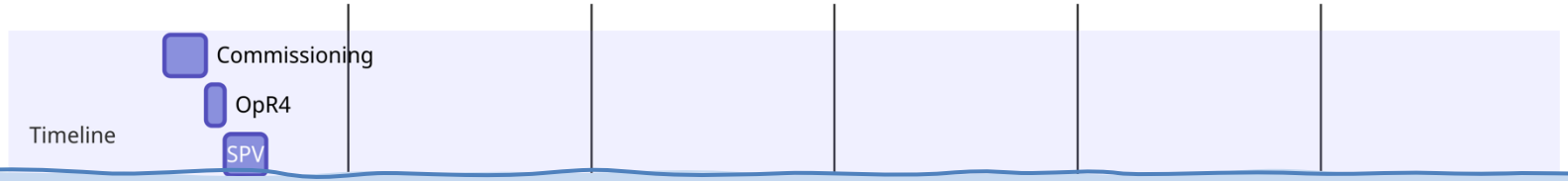
S5 – X-Ray Galaxy Clusters
S6 – X-Ray AGN and QSO Survey
S7 – Galaxy Evolution
S8 - Cosmology
S10 – TiDES (Time-Domain)
S15 – Chilean Clusters Galaxy Evolution
S16 – Chilean AGN/Galaxy Evolution
S17 – High-Resolution QSO
S18 – Hemisphere Survey (Galaxies)

S19 – Galactic calibrations
S20 – Extragalactic calibrations

4MOST – Timeline & Deliverables

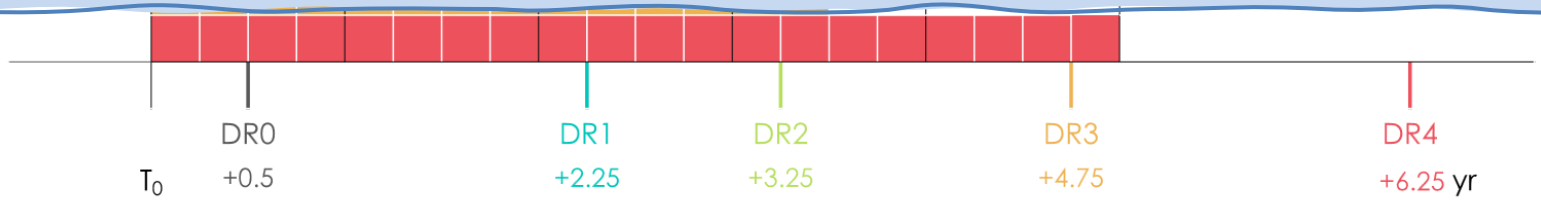


4MOST – Timeline & Deliverables



4MOST will deliver:

- *Redshifts* of AGN and galaxies (also in galaxy clusters)
  - *Radial velocities* of ≤1 km/s accuracy
- *Stellar parameters* with <0.15 (*) dex accuracy of any Gaia star
- *Abundances* of up to 15 chemical elements
- *Spectra* (raw and reduced)

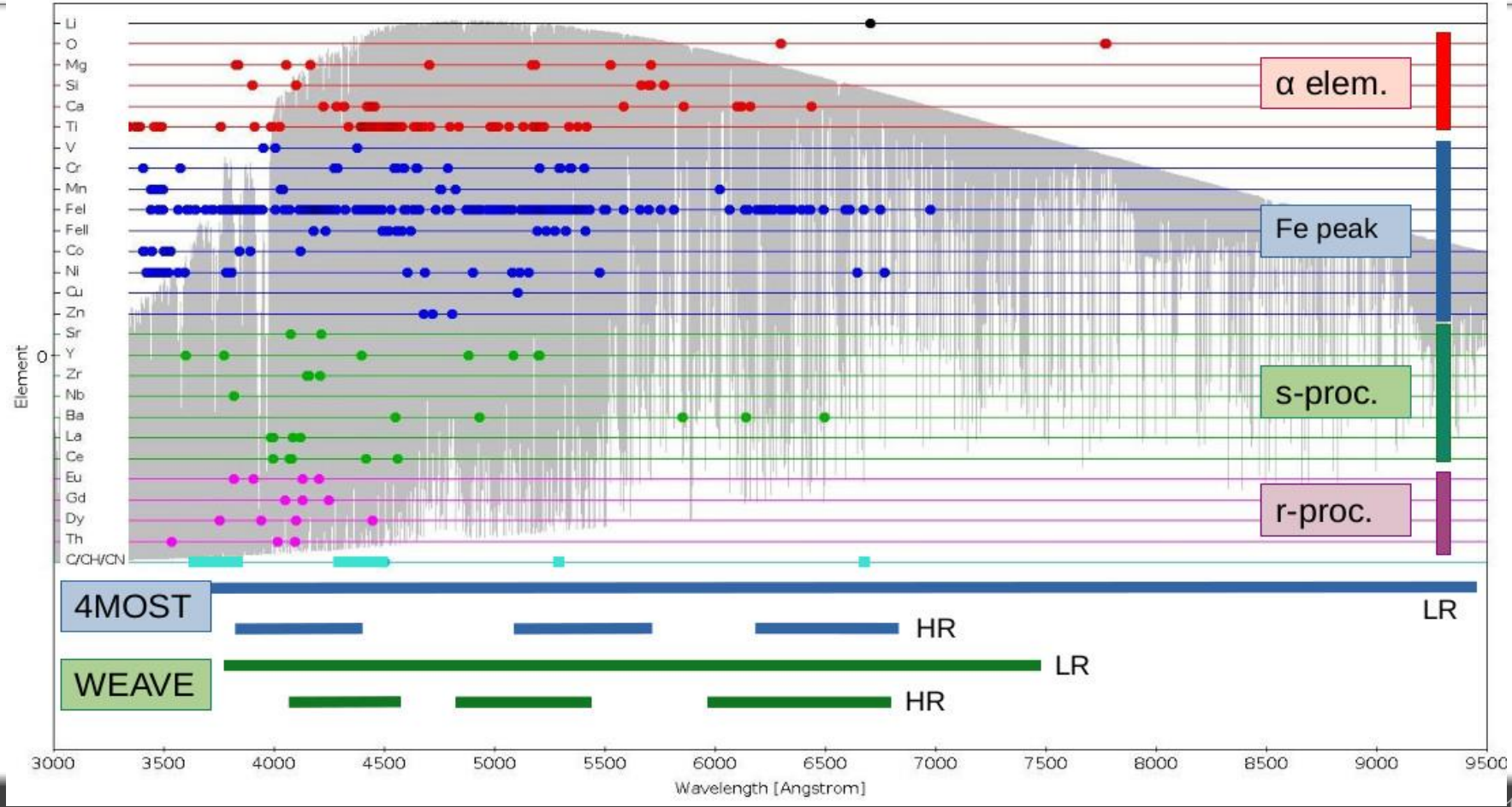


Galactic Archaeology

Position	Distance	Proper Motions	Radial Velocity	Chemical composition	Age
2D	3D	5D	6D	12+D	13D

Credit: ESA/Gaia/DPAC Gaia

4MOST - Spectra



Survey Program Verification

To assess whether the data it will collect is useful for the scientific investigations of the surveys.

SPV

Pipelines Calibration And Training

G. Guillaume talk

Survey strategy

Cross-Surveys

4MOST – WEAVE – SDSS V – DESI - PFS

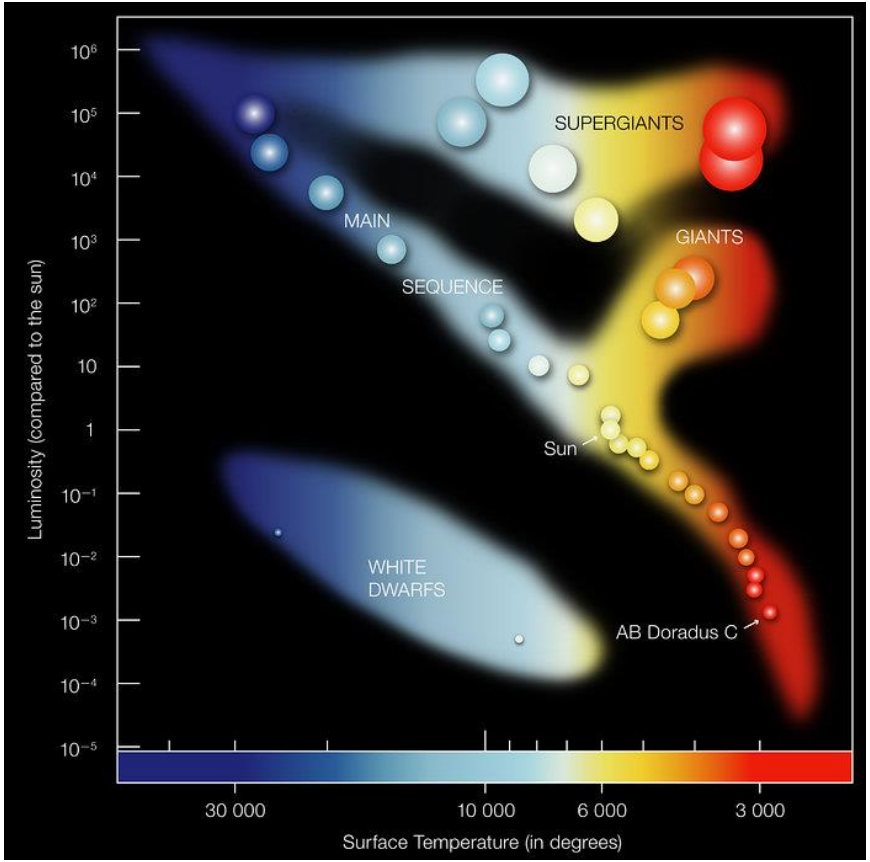
GAL Spectroscopic Pipeline (4GP)

Galactic Surveys targets different families of objects, for sampling and mapping the Milky Way.

Each family of target has its own analysis module in the GAL pipeline.

The accuracy of each module will be tested using well studied targets: the **validators**.

150,000 validators divided 14 classes



Credit: ESO

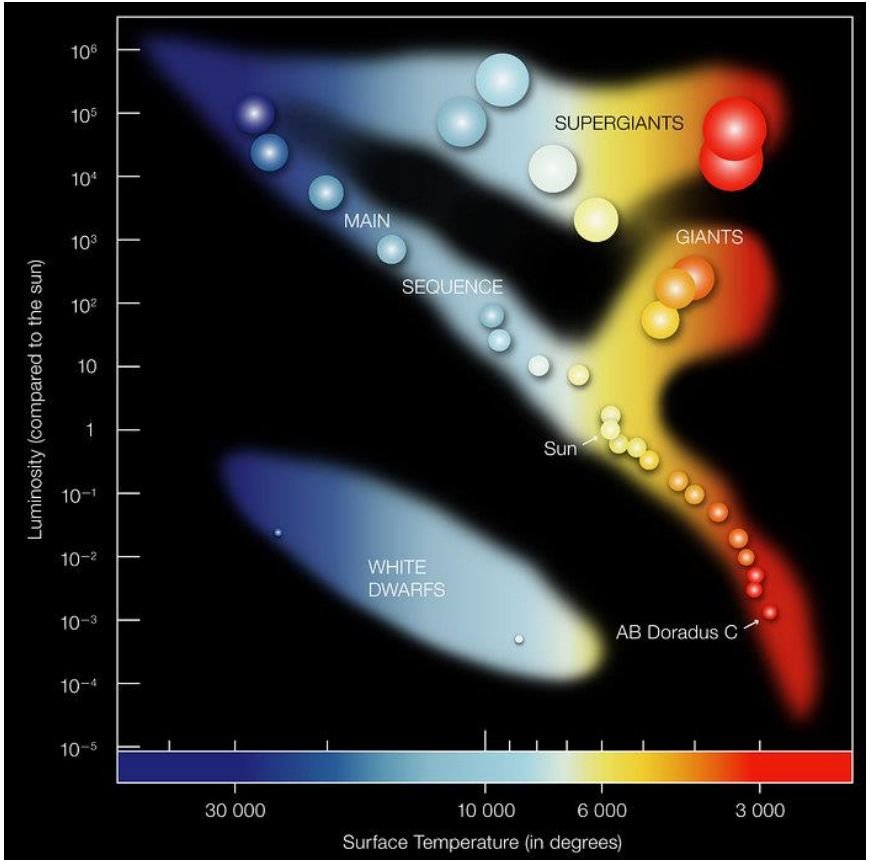
VALIDATOR CLASS	Teff range [K]	Ev. state	[Fe/H] range	Labels to be validated	Surveys
Binaries	All types	All types		Number of components for SBn (n>1),RVs, (Teff, log(g), [Fe/H] for SB1)	S1, S2, S3, S4, S9 Multiplicity WG
YSO				Activity	S1, S2, S3, S4, S9,S12,S13
O-B	8K -30K	MS - TO		Teff, log(g)	S3 and S9
WD		WD		Flux	S3
Metal -poor	3,500 - 7,500	MS to RGB	[Fe/H]<-1 dex	Teff, log(g), abundances	S1, S2, S3, S4, S9, S14
OC	3,500 - 7,500	PMS to RGB	-0.3<[Fe/H]< 0.25	Teff, log(g), abundances	S1, S2, S3, S4, S9
F-G-K	3,500 - 7,500	MS to RGB	-3 <[Fe/H]<+0.5	Teff, log(g), abundances	S1, S2, S3, S4, S9, S13,S14
Seismic RG	3,500 - 7,500	RG	-3 < [Fe/H]< 0.5	Teff, log(g), abundances	S1, S2, S3, S4, S9, S13, S14
Seismic S4	3,500 - 7,500			Teff, log(g), abundances	S4
AGB and C stars	3,000 - 4,750	AGB		Teff, log(g), abundances	S1, S2, S3, S4, S9
RR-Lyr	5,800 - 7,900	HB Stars	-3 <[Fe/H]<+0.1	Abundances	S1, S2, S3,S4,S9
Cepheids	4830-6420 K 4550-6670 K	Blue loop	-0.79<[Fe/H]<-0.13 0.43<[Fe/H]<+0.46	Abundances	S1, S2,S3,S4,S9
Solar Twins	solar	MS	solar	Teff, log(g), abundances	S1, S2,S3,S4,S9, S13
GC	3,500-7,500	MS to RGB	-2.5 <[Fe/H]< -0.25	Teff, log(g), abundances	S1, S2, S3, S4, S9, S13

Why so many targets?

S3 : 4MIDABLE LR
LOW RESOLUTION DISK AND BULGE

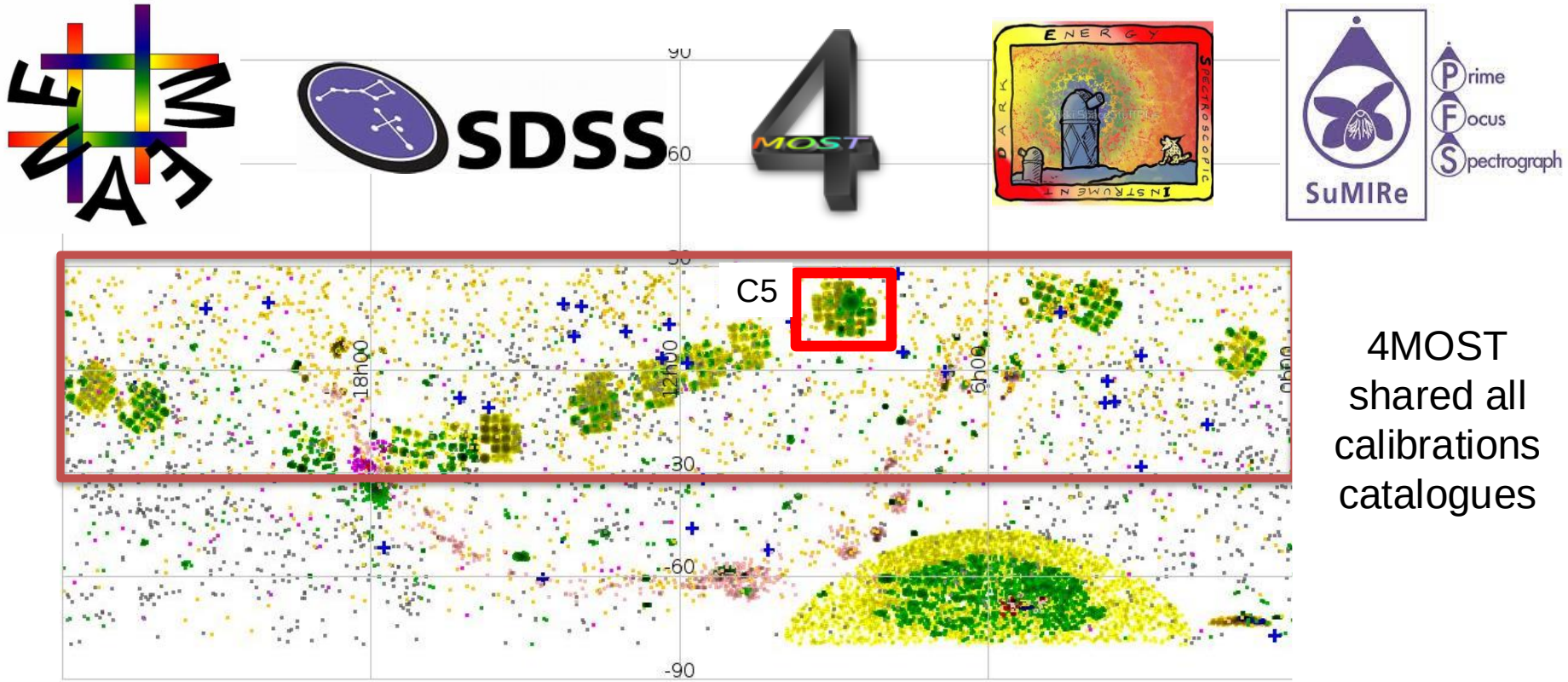
25 SUBSURVEYS

FGK + *Seismic RG*
Very Metal-Poor stars
Compact Binaries (e-Rosita)
Cepheids
White Dwarfs
Planetary Nebulae
O-B stars
Open Clusters



Credit: ESO

Cross-Surveys Group



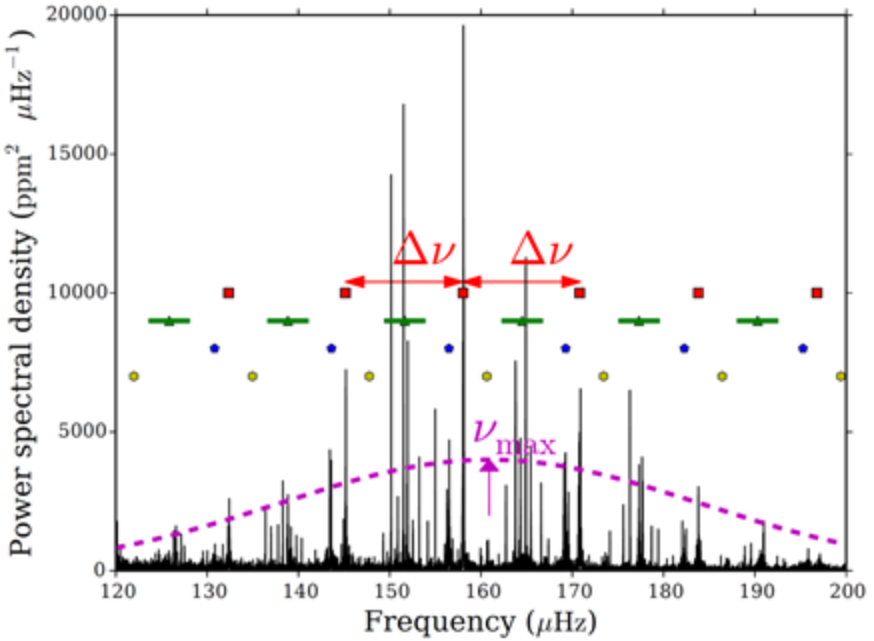
4MOST shared all calibrations catalogues

Lunch Session at the EAS2024 in Padova on July, 2nd : https://eas.unige.ch/EAS2024/session.jsp?id=LS3
2 ISSI meetings in 2022-2023 (PIs: Valentini, Guiglion)
2 ISSI meetings to come 2026-2027 (PI: Guillaume Thomas)

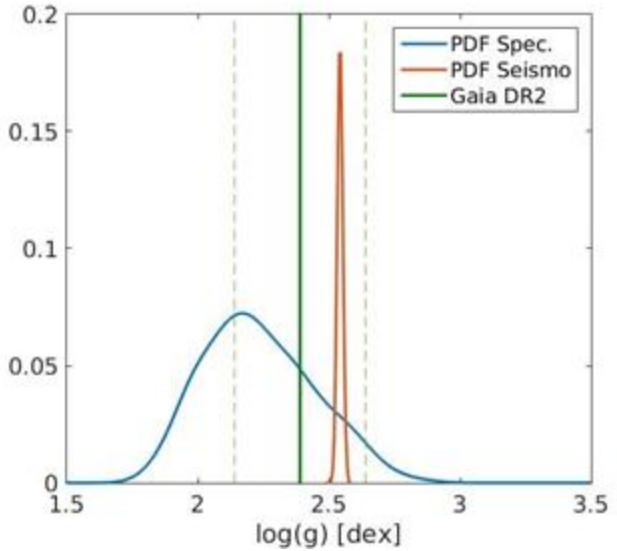
Seismic Red Giants: Calibrators

Global asteroseismic observables: Δν and ν_{max}

very good light curves : individual frequencies



KIC 12008916 - Davies & Miglio, 2016



Valentini et al. 2019 (metal-poor)

$$\log(g)_{seismo} = \log(g)_{sun} + \log\left(\frac{\nu_{max}}{\nu_{max,sun}}\right) + \frac{1}{2}\log\left(\frac{Teff}{Teff_{sun}}\right)$$

Precise log(g) σ < 0.02 dex

Galactic Archaeology

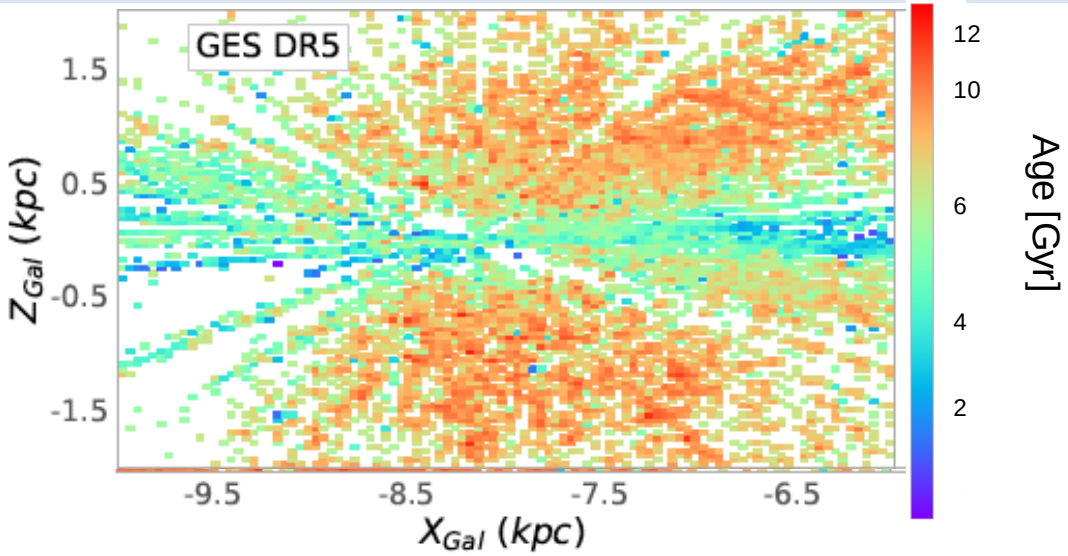
Position	Distance	Proper Motions	Radial Velocity	Chemical composition	Age
2D	3D	5D	6D	12+D	13D

Credit: ESA/Gaia/DPAC Gaia

Ages: S3-4MIDABLE survey

StarHorse
(Queiroz et al. 2018, 2020, 2023; Anders et al. 2019, 2022, 2024)

Talks: C. Chiappini, A. Queiroz, S. Nepal, G. Guiglion



Spectroscopic Surveys + Gaia DR3

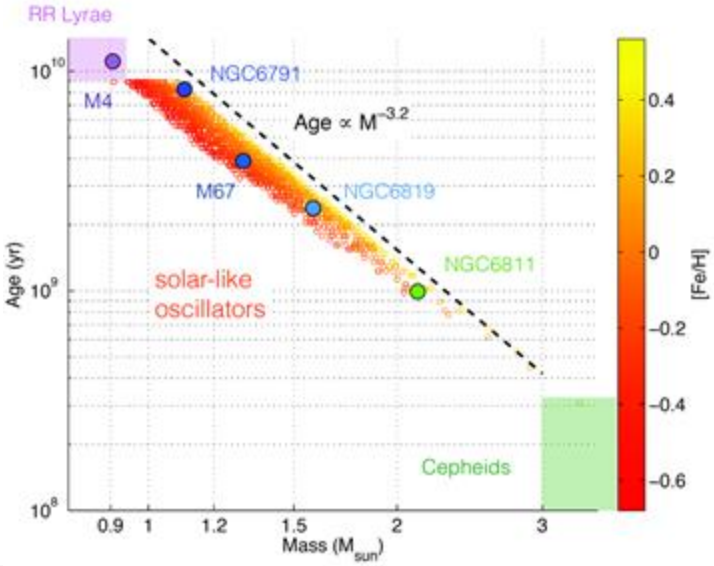
SGB

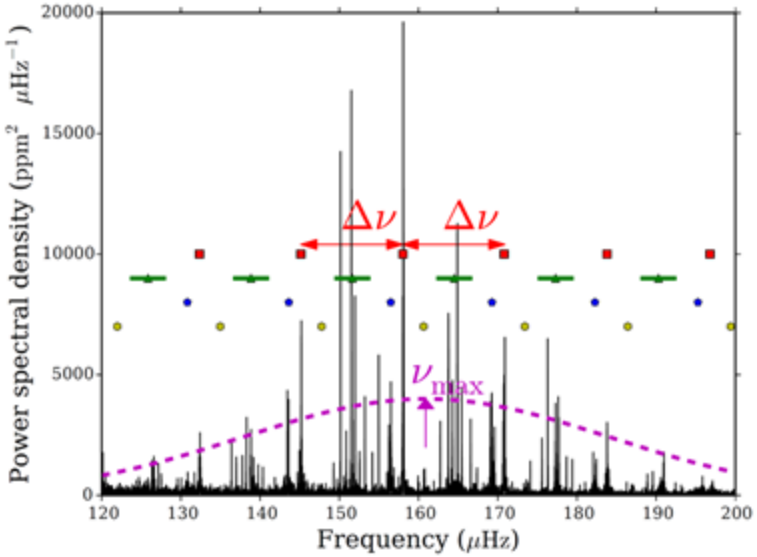
- Distance improved by 5-10%
- Error on age 8-10% (survey resolution)

Queiroz et al. 2023 StarHorse+GaiaDR3+Spectroscopic Surveys (SGB)

S3 Science Calibrators: Seismic RG

Convective motions → standing acoustic waves (pressure)
Fist detected in the Sun → Solar-like oscillations
First detected in Red Giant CoroT (de Ridder, 2009)
Oscillations → probes of stellar interior



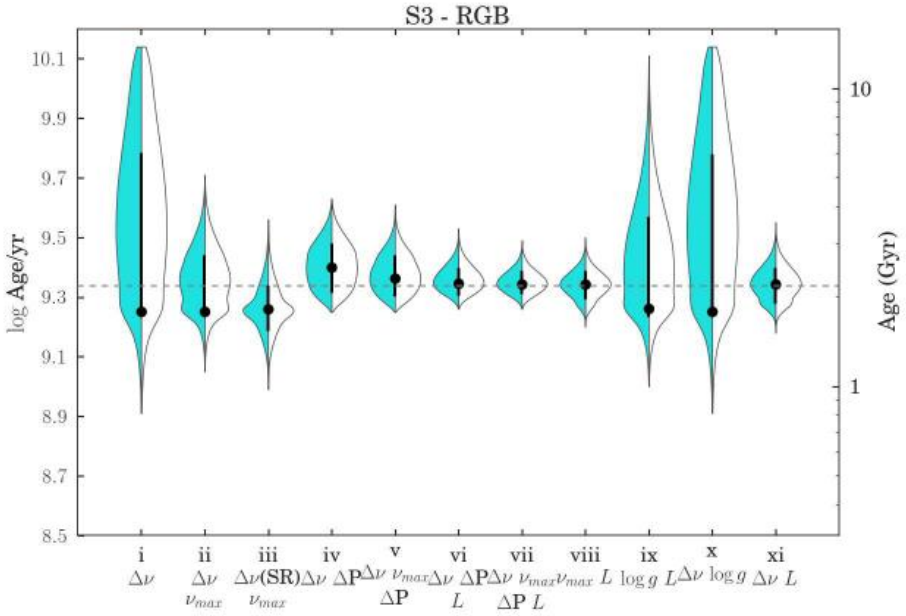


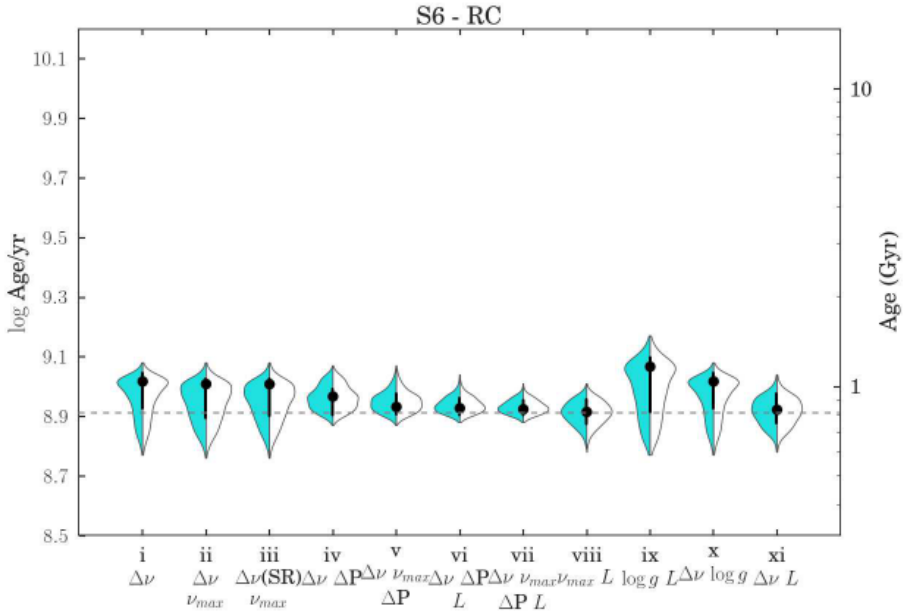
KIC 12008916 - Davies & Miglio, 2016

$$\left(\frac{\langle\Delta\nu\rangle}{\langle\Delta\nu\rangle_\odot}\right) = \mathcal{C}_{\langle\Delta\nu\rangle}\left(\frac{M}{M_\odot}\right)^{1/2}\left(\frac{R}{R_\odot}\right)^{-3/2},$$

$$\left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right) = \mathcal{C}_{\nu_{\max}}\left(\frac{M}{M_\odot}\right)\left(\frac{R}{R_\odot}\right)^{-2}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{-1/2}.$$

S3 Science Calibrators: Seismic RG





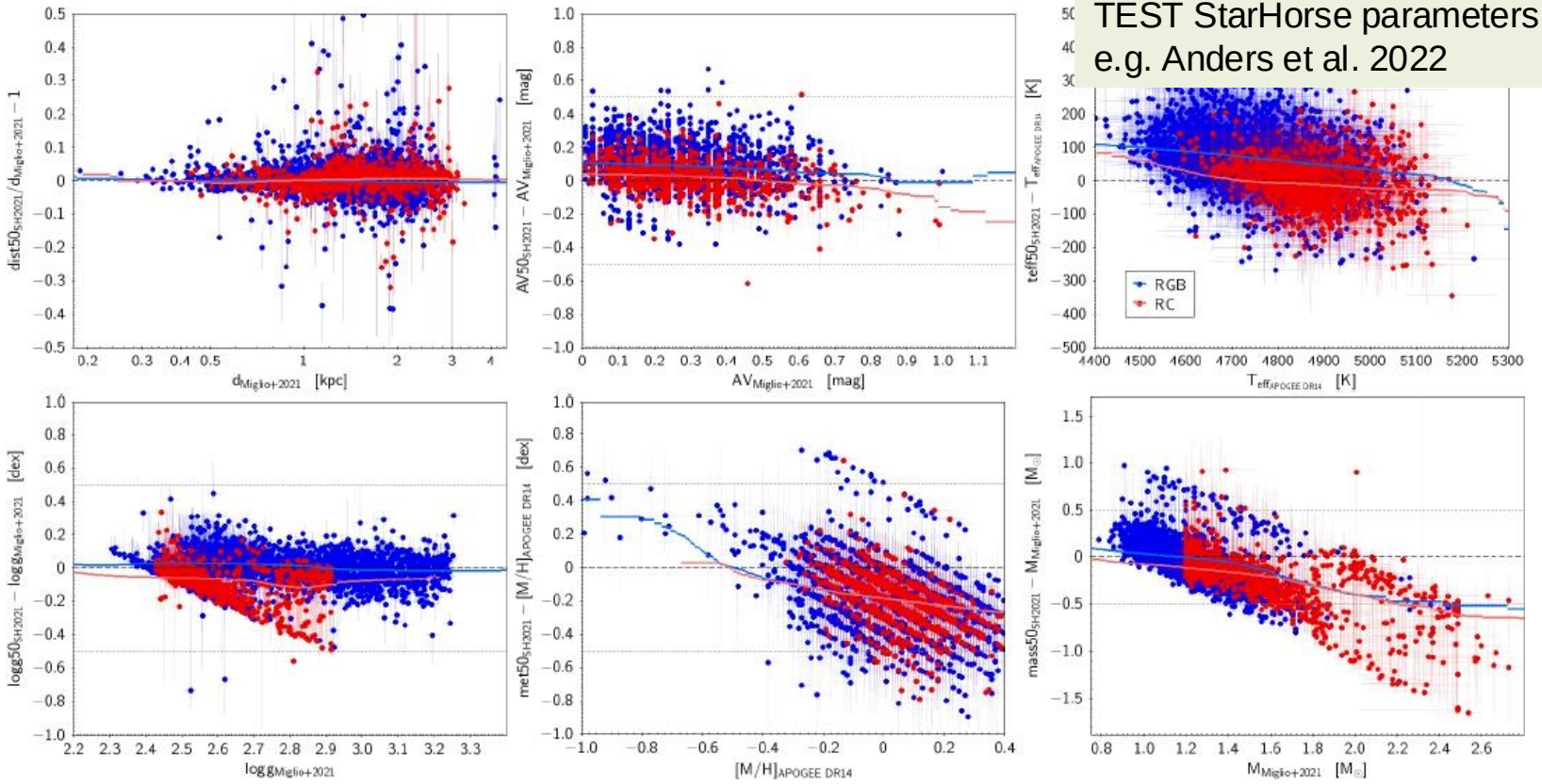
PARAM
http://stev.oapd.inaf.it/cgi-bin/param

Precision on age 11- 30%
(input data)

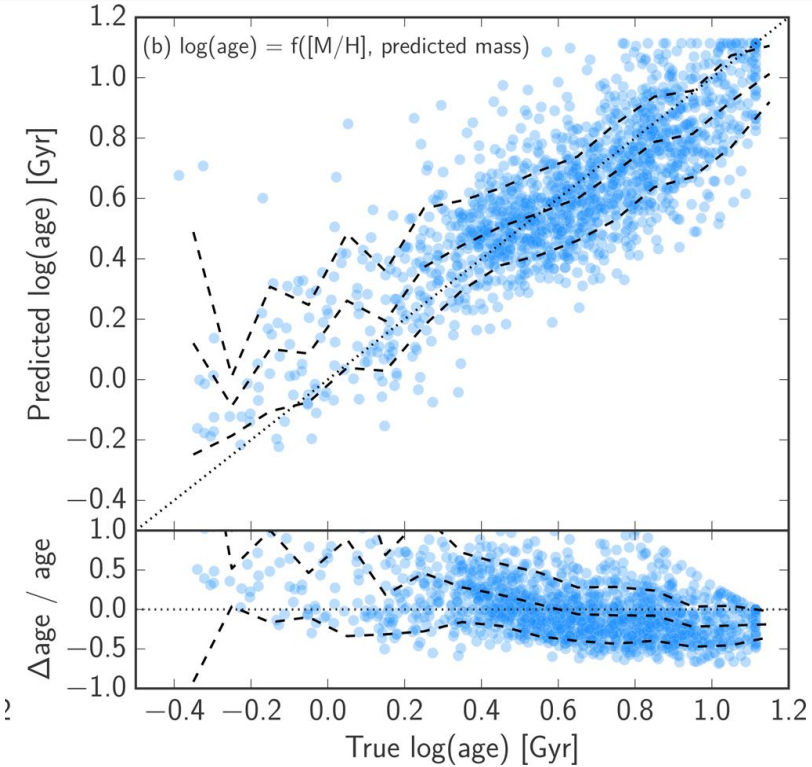
Rodrigues et al. 2017

S3 Science Calibrators: Seismic RG

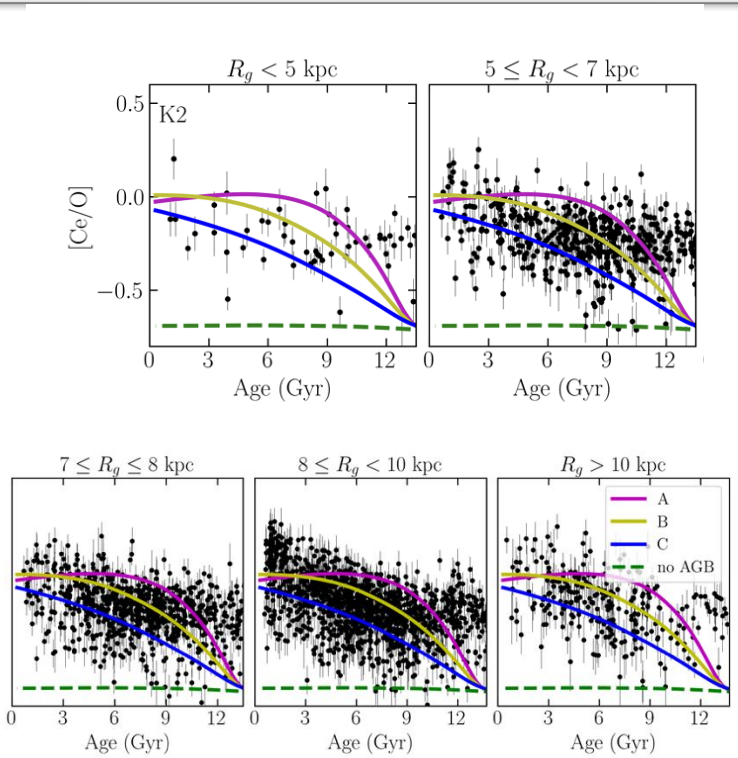
TEST StarHorse parameters
e.g. Anders et al. 2022



S3 Science Calibrators: Seismic RG



Martig et al., 2016
Kepler + APOGEE



Casali et al., 2023
K2 + APOGEE

CHEMICAL CLOCKS
G. Tautvaišienė talk
Posters 08, 51,64

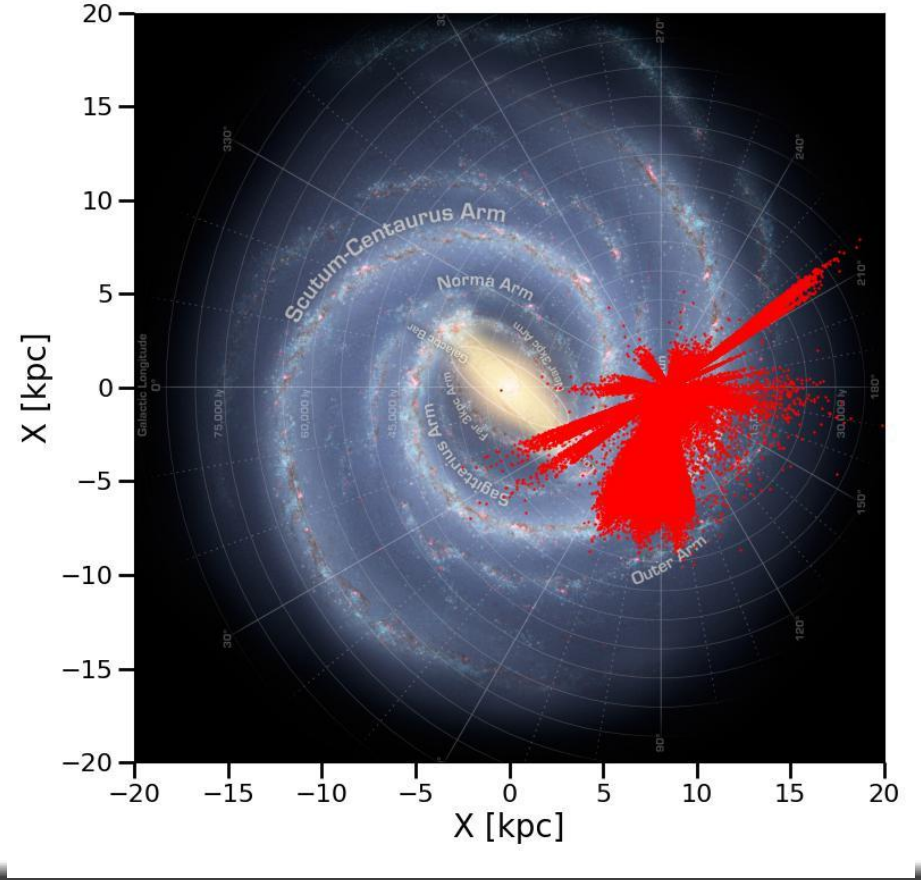
S3 Science Calibrators: Seismic RG

S3 has 7 seismic subsurveys, total 107,710 targets, divided by mission and resolution:

- K2 HR/LR
- CoRoT HR/LR
- TESS HR/LR
- *PLATO RED GIANTS HR*

GOALS:

- PIPELINE CALIBRATORS (IWG3)
- GALACTIC ARCHAEOLOGY
- AGES WITH PARAM CODE
- S3 SCIENCE CALIBRATION
- PLATO GIANTS CALIBRATORS



PIs: M. Valentini, J. Montalban

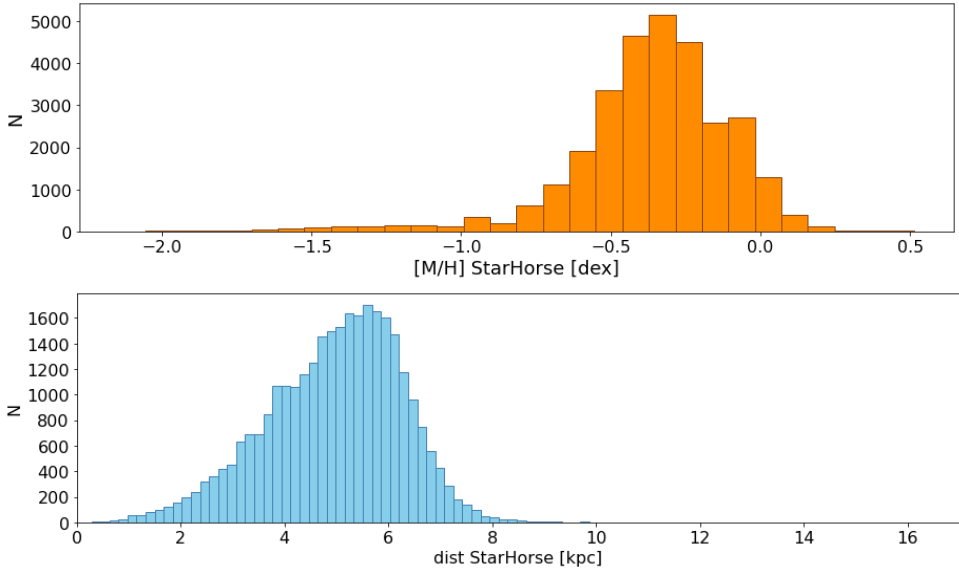
PLATO RED GIANTS

PLATO HR
30,000

PIs: D. Bossini, A. Miglio, B. Mosser, J. Montalban

- 200 red giants per mass and per Y /Z bin
- red giant branch, red clump, and secondary clump, for backtracking those with (rotationally split) mixed modes to the main sequence phase to quantify rotation and mixing profiles.

This means : 200 × 12 × 10 = 24 000 red giants with proper calibration capacity covering M ∈ [0.8, 1.9] M⊙ in steps of 0.05 M⊙, τ ∈ [0.8, 13] Gyr in steps of 1 Gyr, and covering 10 combinations of Y /Z such that Z ∈ [0.005, 0.04] is covered.



PLATO in the Southern Hemisphere can be what Kepler had been in the Northern Hemisphere (Miglio et al. 2016)

Conclusions

4MOST

Will provide atmospheric parameters and abundances for millions of targets -> chrono-chemo-dynamical analysis -> GALACTIC ARCHAEOLOGY

SPV: PIPELINE VALIDATION AND SURVEYS STRATEGY TESTS (HR/LR) -> DR0

Use iteratively seismic log(g) to measure atm. parameters and abundances

CROSS-SURVEY CALIBRATORS

In the shared target list of WEAVE, 4MOST, PSF, and SDSS-V MWM

AGES: S3 – *StarHorse* and SCIENCE CALIBRATORS

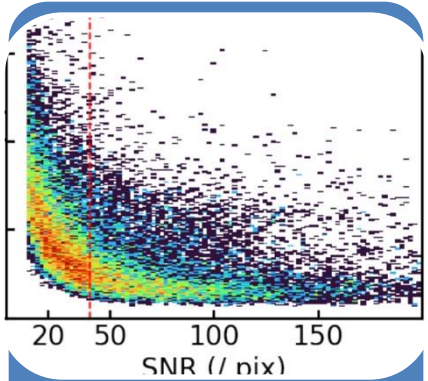
Seismic RG: age validation for StarHorse, chemical clocks calibrations

PLATO RED GIANTS

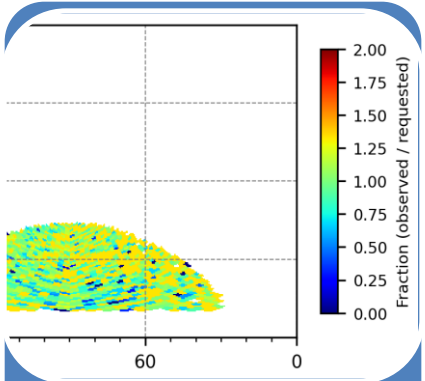
Training sample for ML


EPFL
AIP
NOVA
UH
AAO
CRAL
WARWICK
US
UPPSALA UNIVERSITET
LUND
UNIVERSITY OF HULL
University of Portsmouth
UCL
ZAH
UNIVERSITY OF WESTERN AUSTRALIA
UNIVERSITY OF CAMBRIDGE
Lancaster University
Durham University
UNIVERSITY OF Southampton
ESO
rijksuniversiteit groningen
MOST

SPV: Are we doing things right?



Measurements precision vs. spectrum quality



Target selection and goal number of targets

Targets in highly obscured regions?

Different target distribution on sky

SURVEY STRATEGY

Credit: Nepal+2023, 4MOST IWG2, ESO, ESO