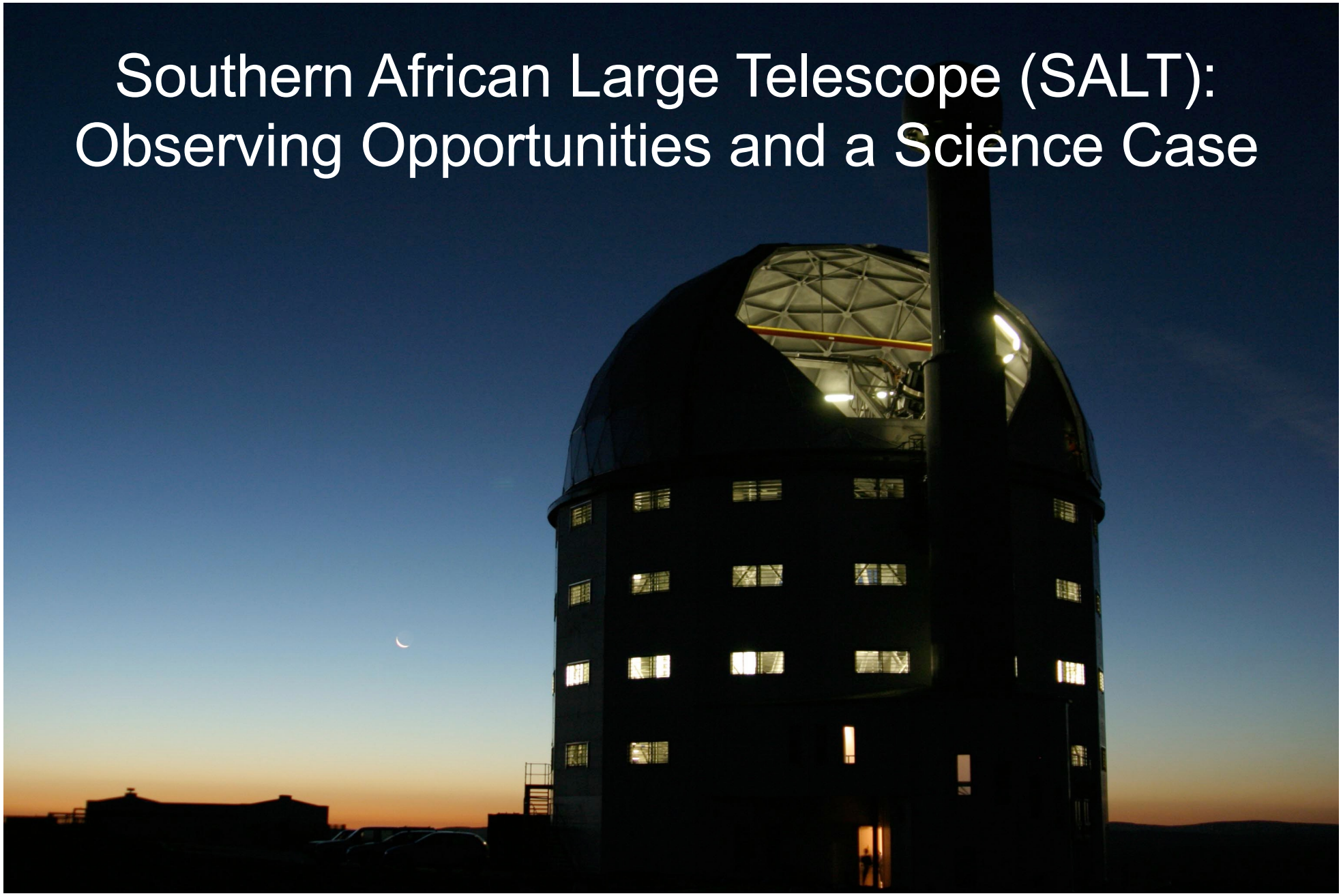
Southern African Large Telescope (SALT): Observing Opportunities and a Science Case



Prof. Brian Chaboyer, Chair, SALT Board of Directors

SALT

10m class optical telescope, the largest in the Southern Hemisphere

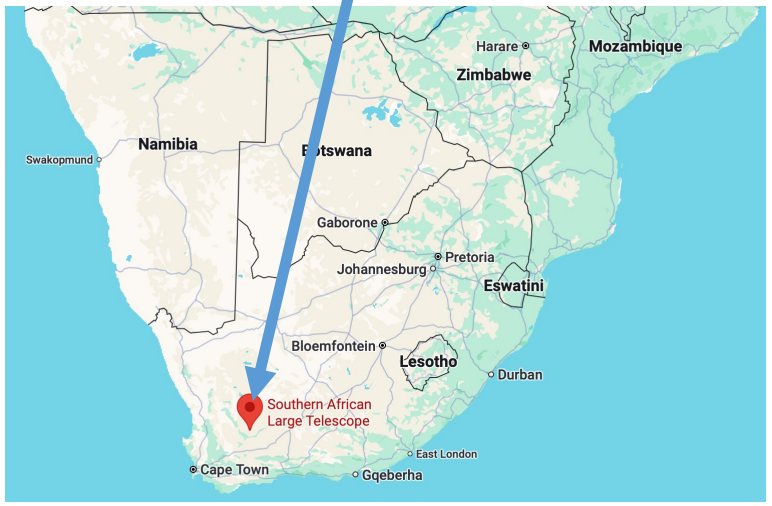
Private telescope, observing time only for PIs in partner institutions/counties

- South Africa (~52%)
- USA (4 institutions; ~29%)
- Poland (NCAC lead institution; ~10%)
- India (IUCAA; ~7%)
- UK (Armagh Observatory; ~2%)

SALT is governed by a Board of Directors; each partner institution has 1 board member, while South Africa has 2 mandated board representatives plus 2 who serve by board invitation (total board membership is 10)

SALT has signed an operations management agreement with the South African Astronomical Observatory (SAAO)

SALT director is jointly appointed by SAAO and SALT board



Observing Opportunites

- South African time **is open to any PI from an African institution** (encouraged to have a South African co-I)
- Proposal is reviewed by the South African Time Allocation Committee, who make the decision about awarding time for each submitted proposal

- SALT is actively looking for **operations partners** – institutions/countries who are purchase guaranteed time on SALT for a period of time (typically 3 to 5 years)
- Cost of purchase is based upon the current operations cost of SALT, plus an investment into the SALT development fund
- Current operations cost is about ZAR 37,000 per hour (~$2,300 USD per hour).
- Operations partners who purchase ~> 6% of observing time are eligible to request a seat on the SALT Board of Directors (subject to Board approval)

SALT Proposal Workshop
24 March 2026 @ 6pm

A practical workshop designed to familiarise emerging astronomers with SALT proposal tools through guided, hands-on proposal development.

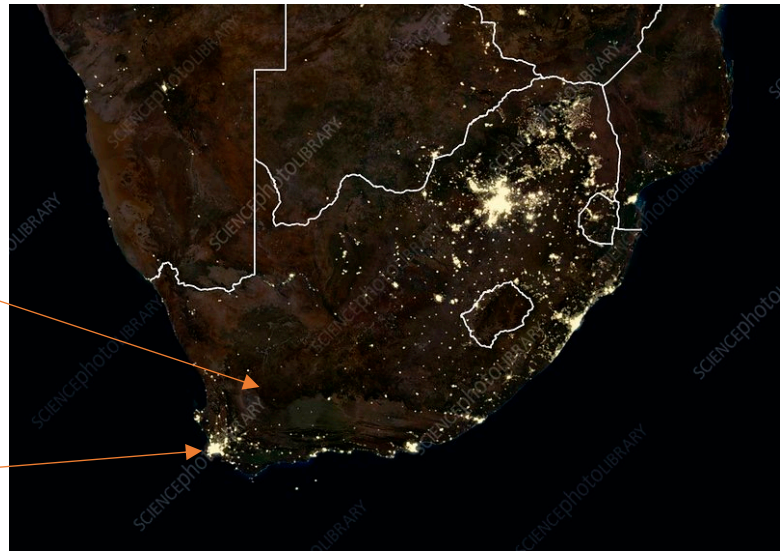
More details can be found at
https://astronomers.salt.ac.za/afas-workshop-2026/

We look forward to see you!

Danièl Groenewald, Head of SALT Astronomy
AfAS – Botswana, March 2026

Why Sutherland?

Dark skies!
No strong seasonal weather impact on observing



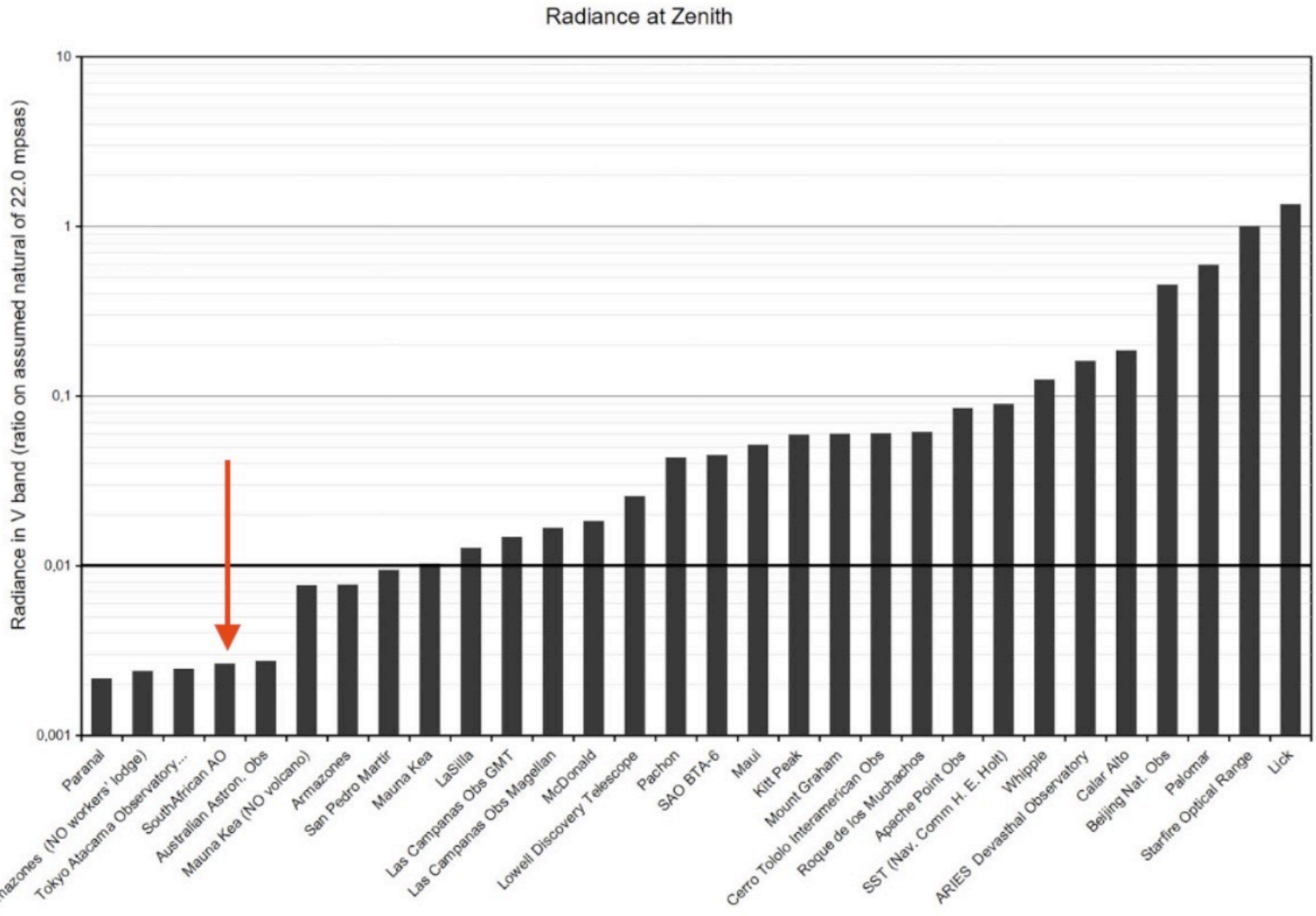
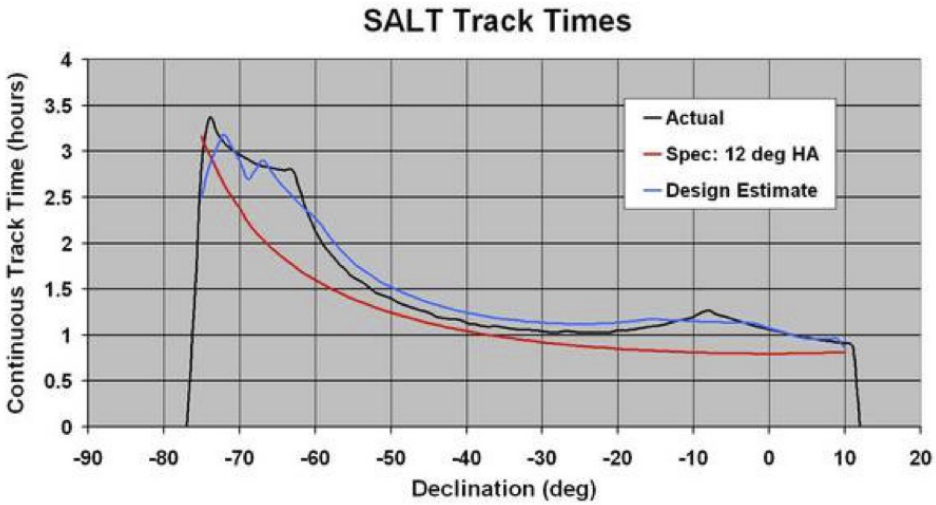


Figure 1. Night sky brightness of all professional observatories in the world. The SALT-site at the SAAO/Sutherland is seen to be among the very darkest together with the VLT and EELT sites in Atacama, and the AAO in Australia. From Falchi et al. (2023), see details therein.

SALT – the telescope

SALT: a fixed altitude telescope

- 91 x 1m primary mirror array, 11m across in diameter.
- Edge sensors keep mirrors aligned for > 1 week.
- Fixed in altitude:
  - Observations typically ~1 hour long enabled by a tracker at prime focus
  - Variable effective area (7 to 9m)
  - Fully queue scheduled
  - Variable effective area makes absolute photometry and deep imaging (flat fielding) difficult; SALT is primarily a **spectroscopic telescope**



How does SALT work?

- PIs apply for time on SALT (directly to SALT using the PIPT), with a scientific case – what exactly do they want to do, how, what for, how long they need.. Two calls per year.
- Proposals are reviewed by AstroOps for technical issues, and then scientifically by the Time Allocation Committees (TACs) of each partner
- Time is allocated per proposal, in priority class (0=must do urgently, 3=lowest priority)
- PIs then take their allocated time and priority and split it into observation blocks *that fit in the visibility windows*
- All the observation blocks are put in a queue. Blocks remain in the queue until they are observed and accepted by the SALT Astronomer, or the semester ends. ***There is no carry over to next semester, but can re-apply***
- The SALT Astronomer + SALT Operator at the telescope take all the observations (work in one week shifts)

WHAT HAPPENS TO SALT DATA?

- Transferred to CT immediately.
- Pipelined and placed on PIs ftp site, PIs notified via email. Usually < 24 hours, faster access to raw data if requested.
- Very efficient and responsive SALT helpline: salthelp@salt.ac.za
- Night summary (and random posts) in the SALT blog: http://saltastro.blogspot.com
- Data held in SALT Data Archive, available once data are public from archive website: https://ssda.saao.ac.za

WHAT ARE SALT'S SPECIALTIES?

Telescope: Large collecting power.

Site: Skies are very dark (22 mag/arcsec^2). Seeing only modest (median 1.4")

- Diffuse low-surface-brightness spectroscopy.
- Objects above background also observed very efficiently.
- Can change instruments and observing modes during pointing.
- Blocks can be submitted independently at any time -> Rapid reaction to ToOs.
- Some rare modes for large telescopes (Polarimetry, high-time resolution)

• **SALT is a *spectroscopic survey telescope.* Most efficient programs are surveys with large pools of targets over the sky.**

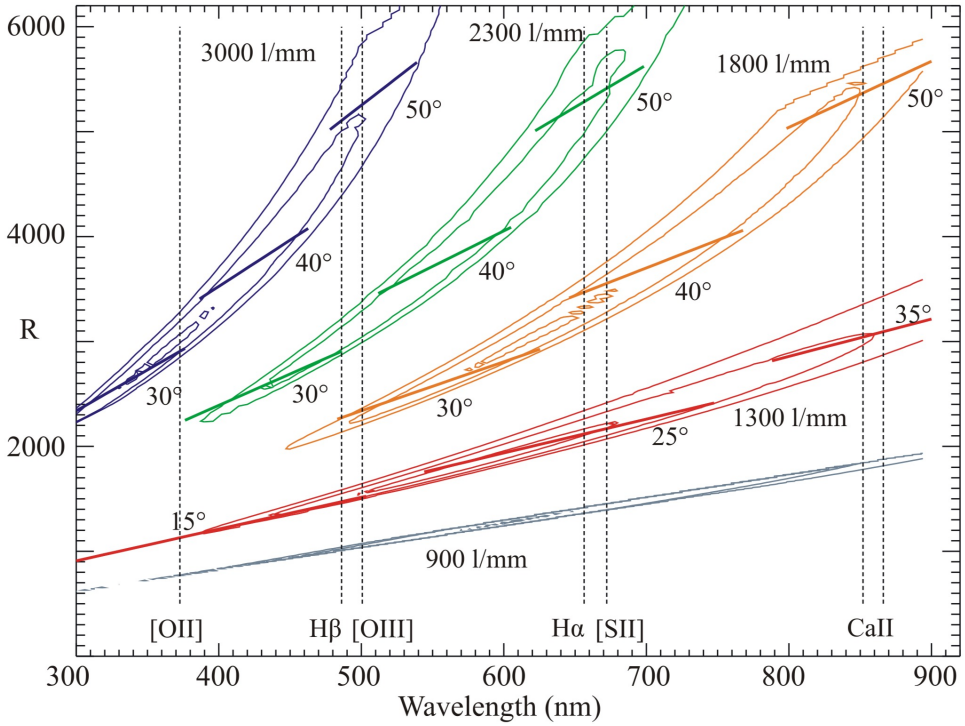
SALT CURRENT INSTRUMENTS

- A versatile low to medium resolution spectrograph
- A single fiber, dual beam high resolution echelle spectrograph

RSS: Robert Stobie Spectrograph

- Imaging, long slit and multi-object spectroscopy
- Low to Medium resolution, *R* ~800 to 10,000
- Wide range of resolution and wavelength coverage.
- Imaging, polarimetric and spectropolarimetric modes
- *High Time resolution* ~100 ms spectroscopy

The work-horse instrument on SALT for good weather/dark Moon



RECENT UPGRADE: RSS SLITMASK IFUs

- Integral Field Unit (IFU) maps onto a slitmask that fits in the regular RSS slitmask magazine
- First unit (SMI-200) in operation. Uses 200 micron fibres with 309 0.9-arcsec diameter fibre cores covering an elongated hexagonal footprint of 18 x 23 arcsec. Suffers from throughput issues
- Next: SMI-300. Hardware complete, on-sky testing in a month. Throughput issues solved
- SMI-300 covers 18x29 sq arcsec with 212 object + 38 sky fibers, each of which covers 1.3 arcseconds

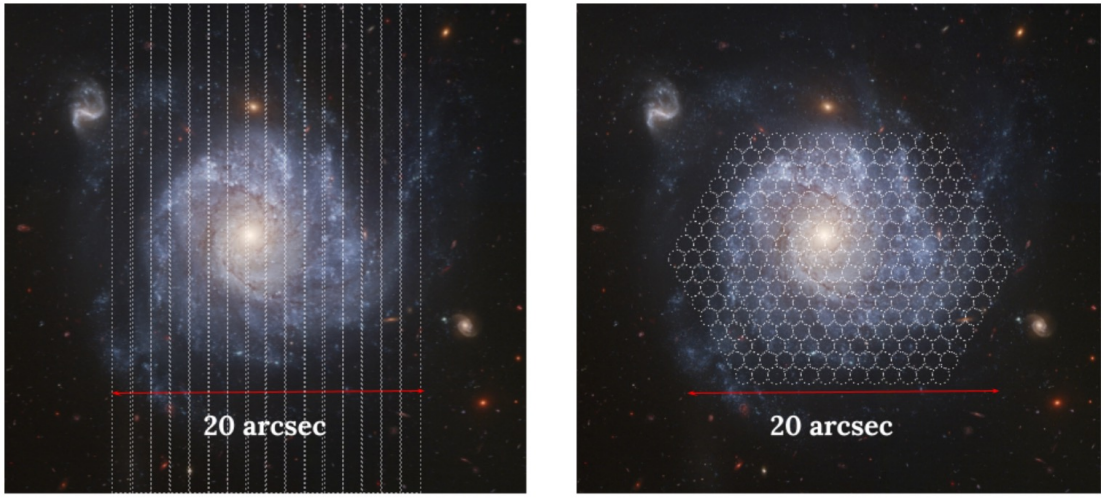
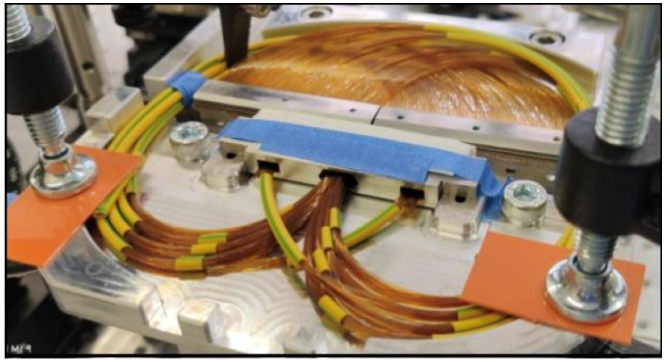


Figure 1: Difference in spatial coverage for extended sources for 16 x 1.3 arcsec long slit exposures (left) versus one SMI-200 exposure (right). I.e., the 1.3 arcsec longslit would require 16 exposures to cover the same area of the galaxy covered by SMI-200 in a single exposure.



HRS: High Resolution Spectrograph

Durham University

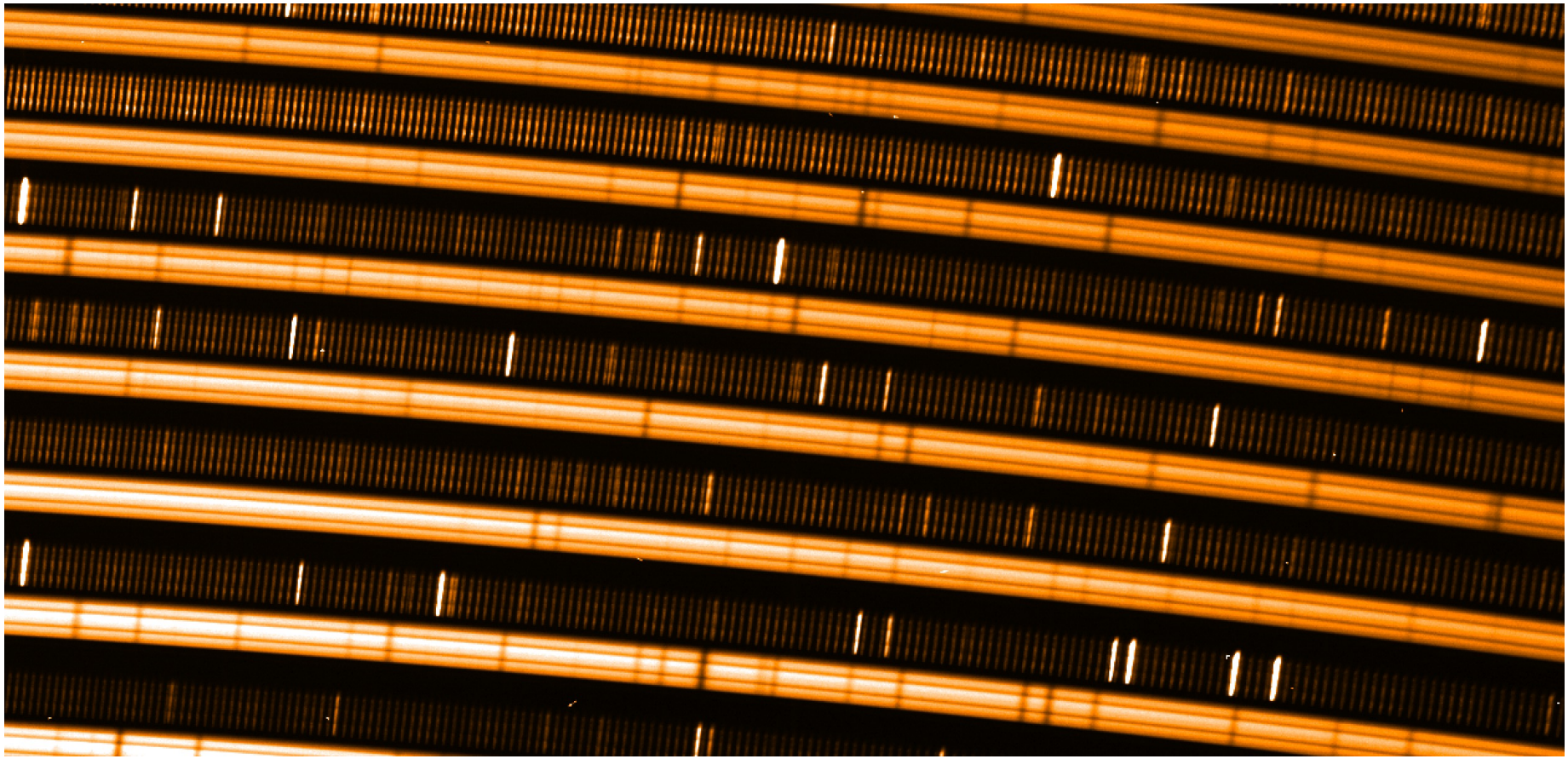
- Fibre fed (object + sky) dual beam echelle (390 – 880nm)
- Low Resolution (LR) – R ~ 14 000
- Medium Resolution (MR) – R ~ 40 000
- High Resolution (HR) – R ~ 65 000

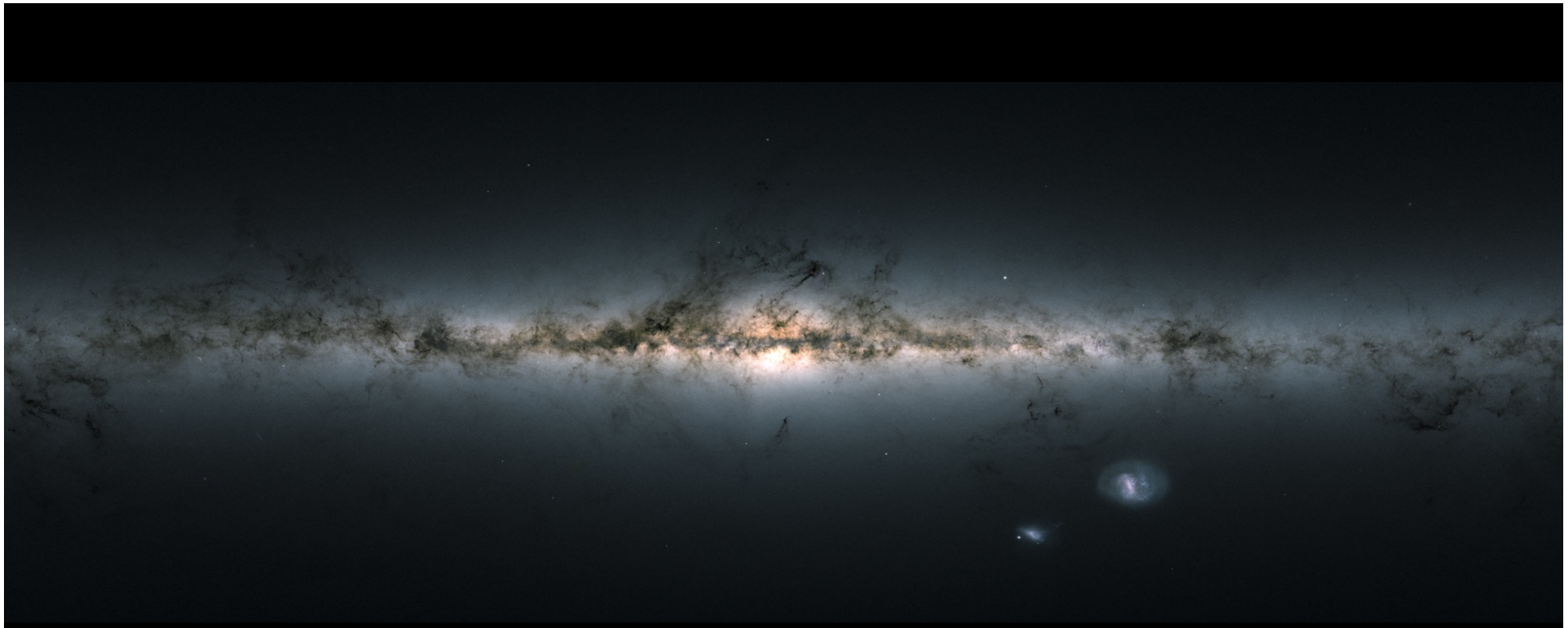
- High Stability Mode – same resolution as HR, but with highest wavelength accuracy, down to 5-10 m/s using our Iodine Cell or ThAr for calibrations [exoplanet science]

Workhorse instrument for poorer weather/bright Moon

HRS: Laser Frequency Comb

- Goal Increase HS mode precision to ~1m/s
- Hardware installation complete Dec 2025
  - Component failure soon after (not operational)
  - Does not quite meet spec
- Expected to be completed and begin commissioning June/July 2026
- Full turn-key solution by Dec 2026 (operational improvement only)



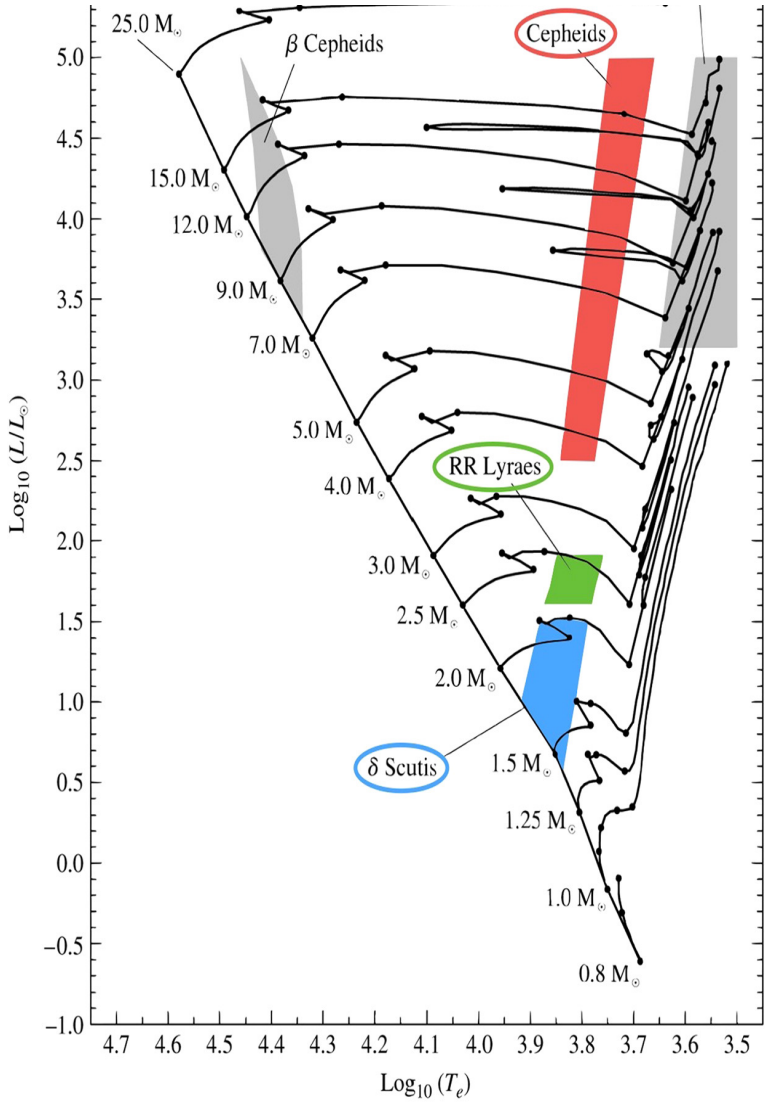


SALT Science Case: HRS Spectra of RR Lyrae Stars

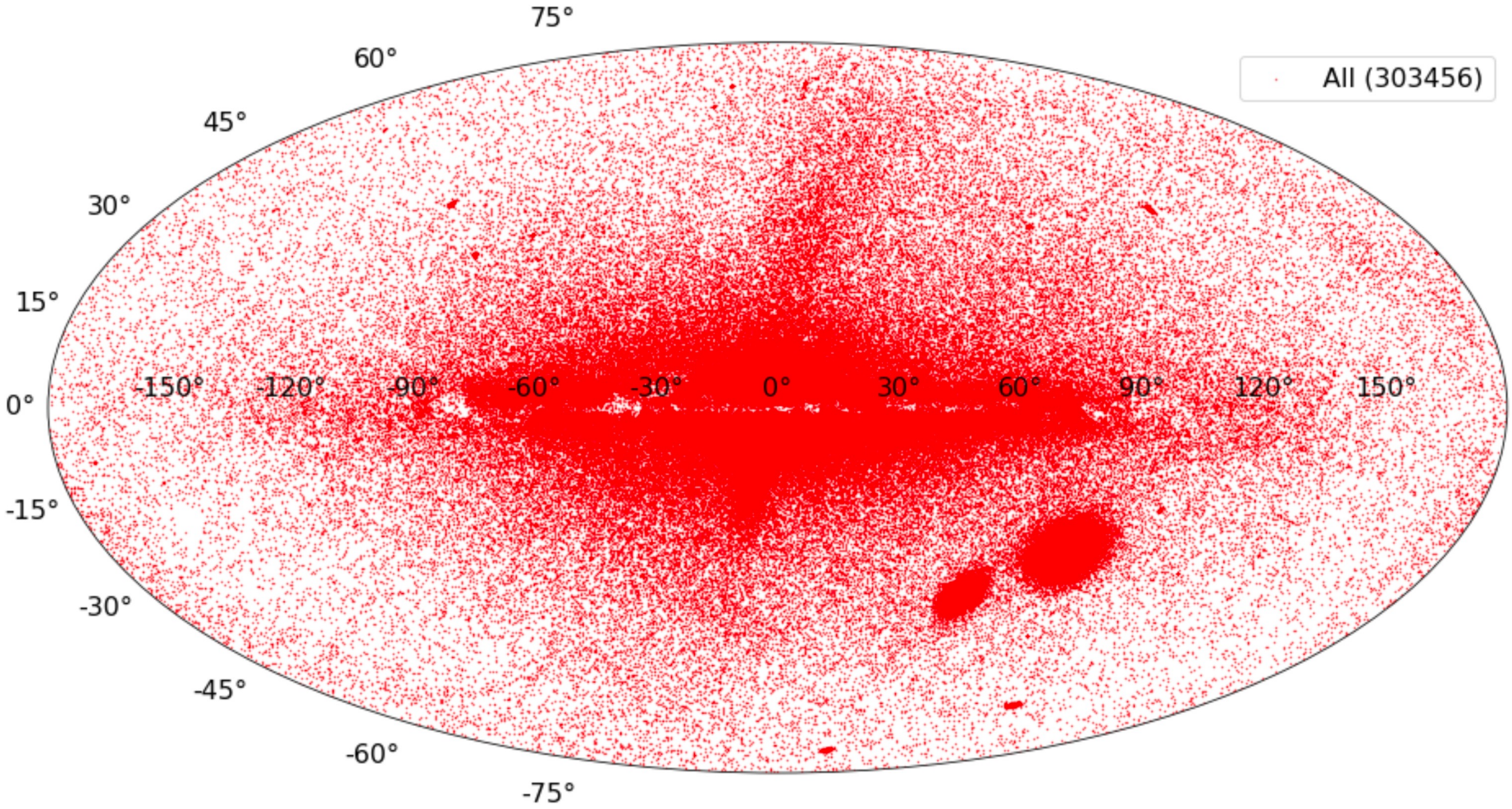
Brian Chaboyer (Dartmouth), Christina Gilligan, Joseph Mullen, Massimo Marengo, Giuseppe Bono, Clara Martìnez-Vázuqez, Bittoria Braga, Massimo Dall'Ora, Frédéric Thèvenin, Michele Fabrizio, Matteo Monelli, Juliana Crestani, Chris Sneden, G.W. Preston, …

What are RR Lyrae?

- Radially pulsating
  - Period: 1.5-24 hours
- Named after brightest prototype of their kind
- Low mass (~0.6 to 1 $M_\odot$; R ~ 5 $R_\odot$)
- Helium core burning stars in the instability strip
- Tracers of old stellar populations (Pop II)
  - Older, larger number relative to Cepheids
  - Found in MW halo/globular clusters/bulge



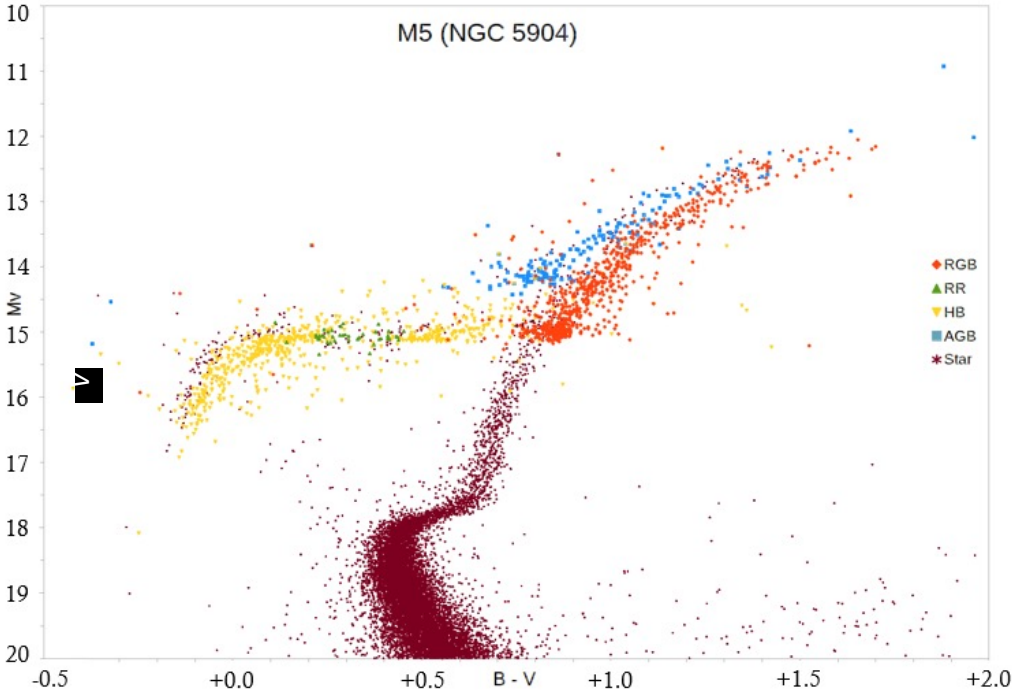
(Lamers & Levesque 2017)



RR Lyrae are great targets for SALT – over 300,000 have well characterized periods and mean magnitudes from photometric surveys and they are spread throughout the sky

Magnitude (*V*-band)-Metallicity relation

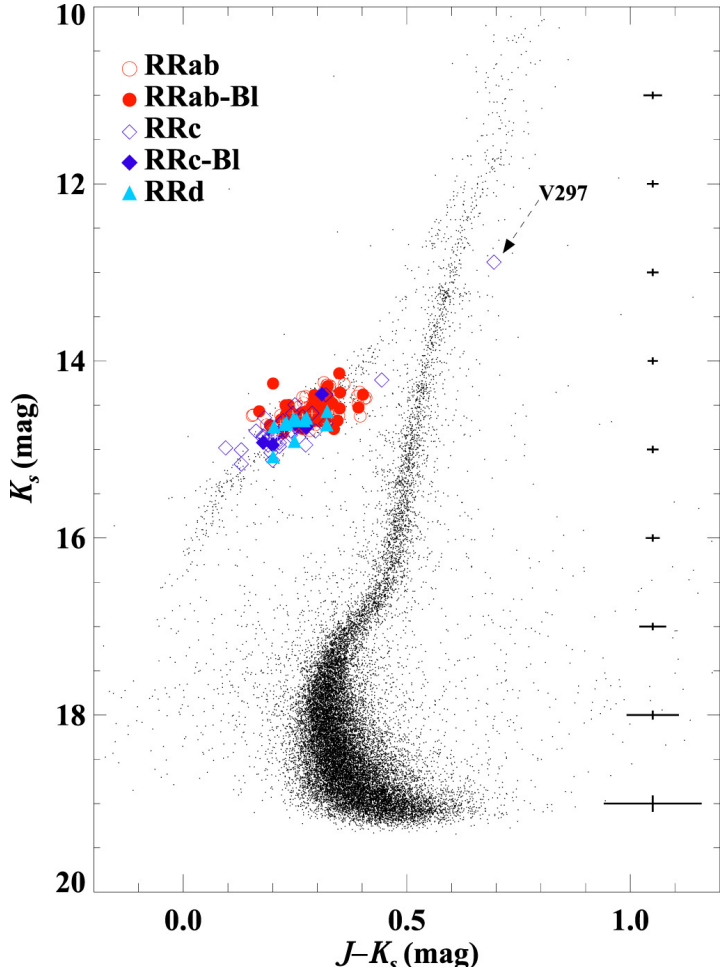
- Instability strip located in flat region of a visible colour-magnitude diagram, referred to as the Horizontal Branch HB (*V*-band)
  - $M_V \approx 0.5$
  - Small, likely linear metallicity component
- Error of 0.1-0.25 mag based on different calibrations
- Issues
  - Assumes stars are on ZAHB
  - Uncertainty in extinction



(Wikipedia-RRLyraeVariable)

Not Horizontal - Horizontal Branch

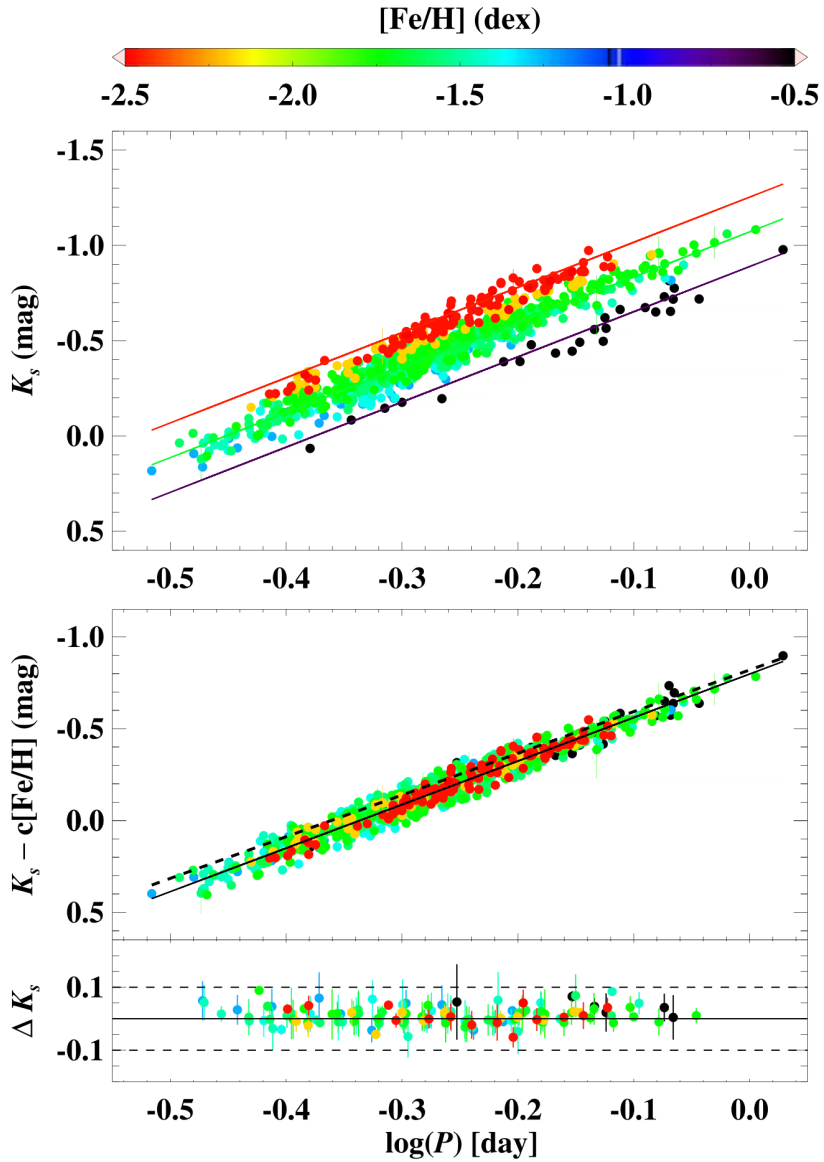
- Horizontal branch is not horizontal in the infrared!!!
  - Removes more of the temperature dependence
- Magnitude becomes correlated with period
  - Shorter period smaller luminosity
- Slope in HB increases with longer wavelength
  - Period dependence of luminosity increases with longer wavelength



(Bhardwaj et al. 2020)

Period-Luminosity-Metallicity (PLZ)

- Steeper period slope at longer wavelengths gives smaller dispersion
- Extinction negligible in infrared
- Observations in clusters indicate that for a given period and metallicity, there is a dispersion of ~ 0.03 mag in the absolute magnitude of RR Lyrae stars

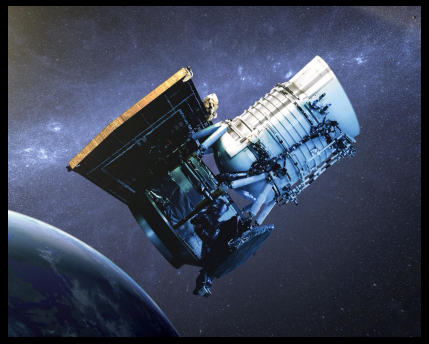


Bhardwaj+ 2023
946 RR Lyr in 11 globular clusters

Calibration of the PLZ in the Infrared

WISE (*W1* and *W2*)

- Wide-field Infrared Survey Explorer
- *W1* and *W2* bands (3.4 & 4.6 μm)
- Primary mission (Jan 2010-Feb 2011) with post-cryogenic extension (2013-present)
- Average ~230 epochs per star

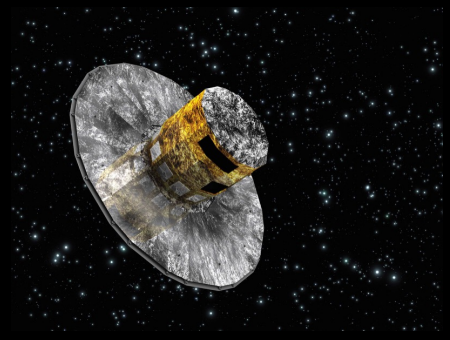


SALT

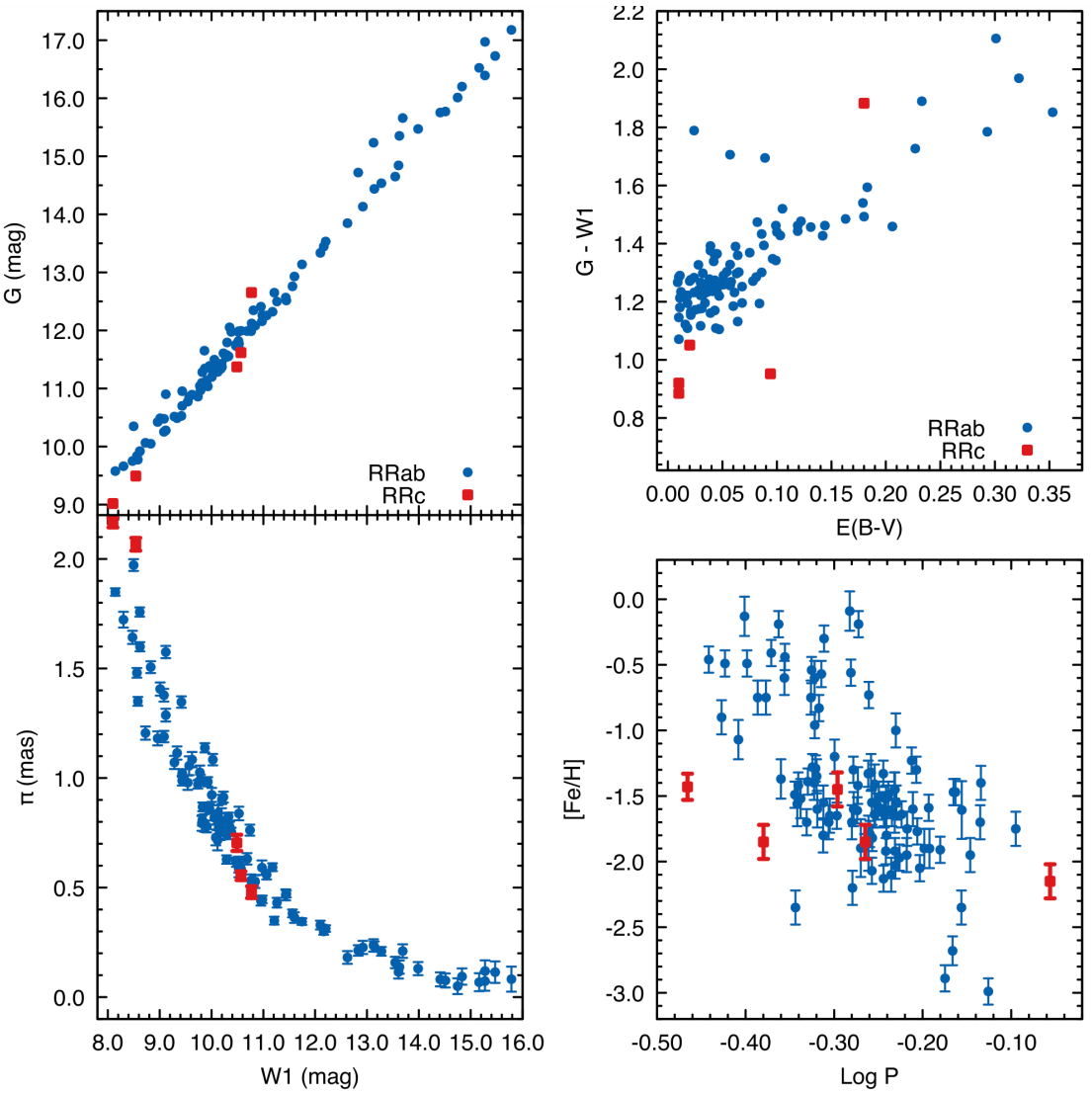
- HR spectra for 49 RR Lyrae stars obtained with SALT
- Combine with literature data to obtain a sample of 108 stars with HR abundances

Gaia

- High quality parallaxes for hundreds of RR Lyrae stars



Gilligan+ 2021

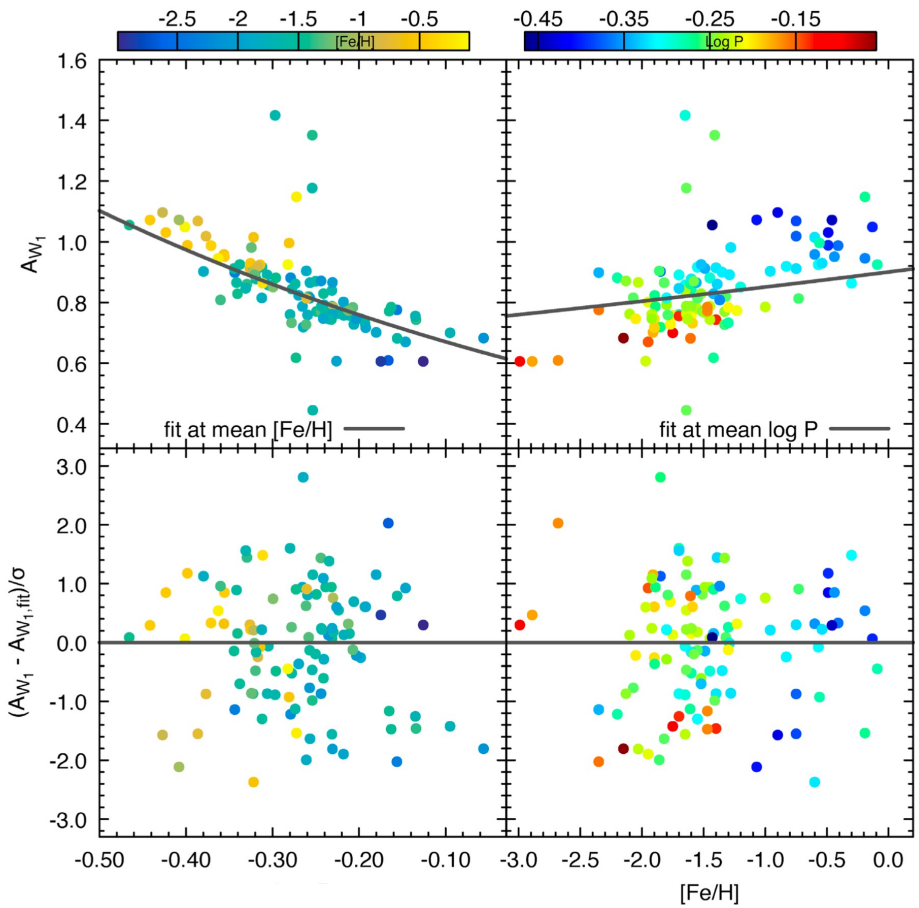


Period of RRc stars fundamentalized

P-W1-Z Calibration

Astrometric Based Luminosity

$$A_W = \varpi 10^{0.2m_0 - 2}$$



(Gilligan+ 2021)

$$M_{W1} = (-2.78 \pm 0.12)(\log P + 0.27) + (0.115 \pm 0.016)([\mathrm{Fe/H}] + 1.3) - (0.417 \pm 0.009)\,.$$

High resolution sample (6300 spectra, 143 RRLs)

Feros

Harps

Du Pont

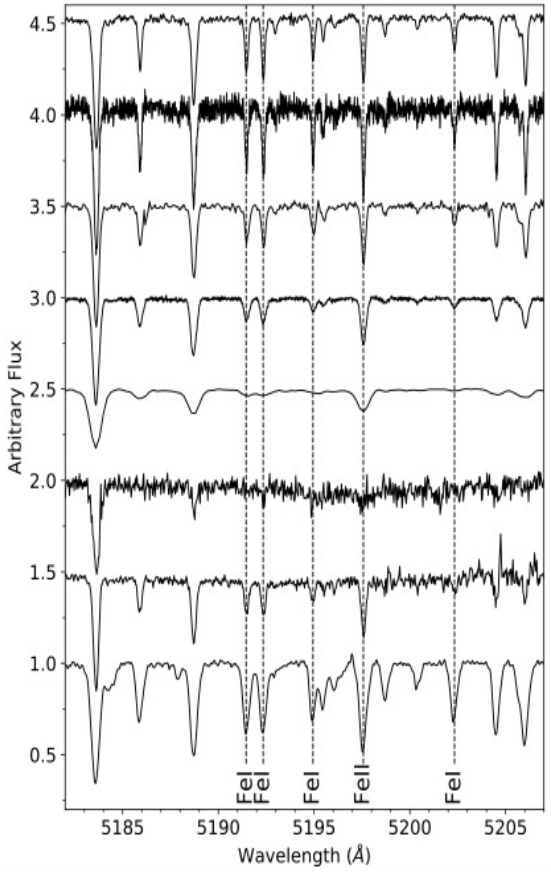
UVES

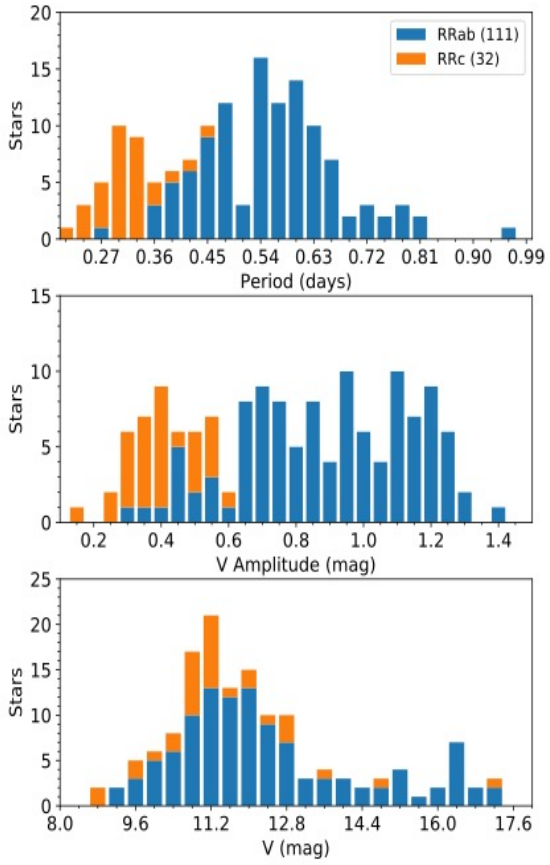
X-shooter

Subaru

Stella

SALT:
47 stars; 1/3
of the sample

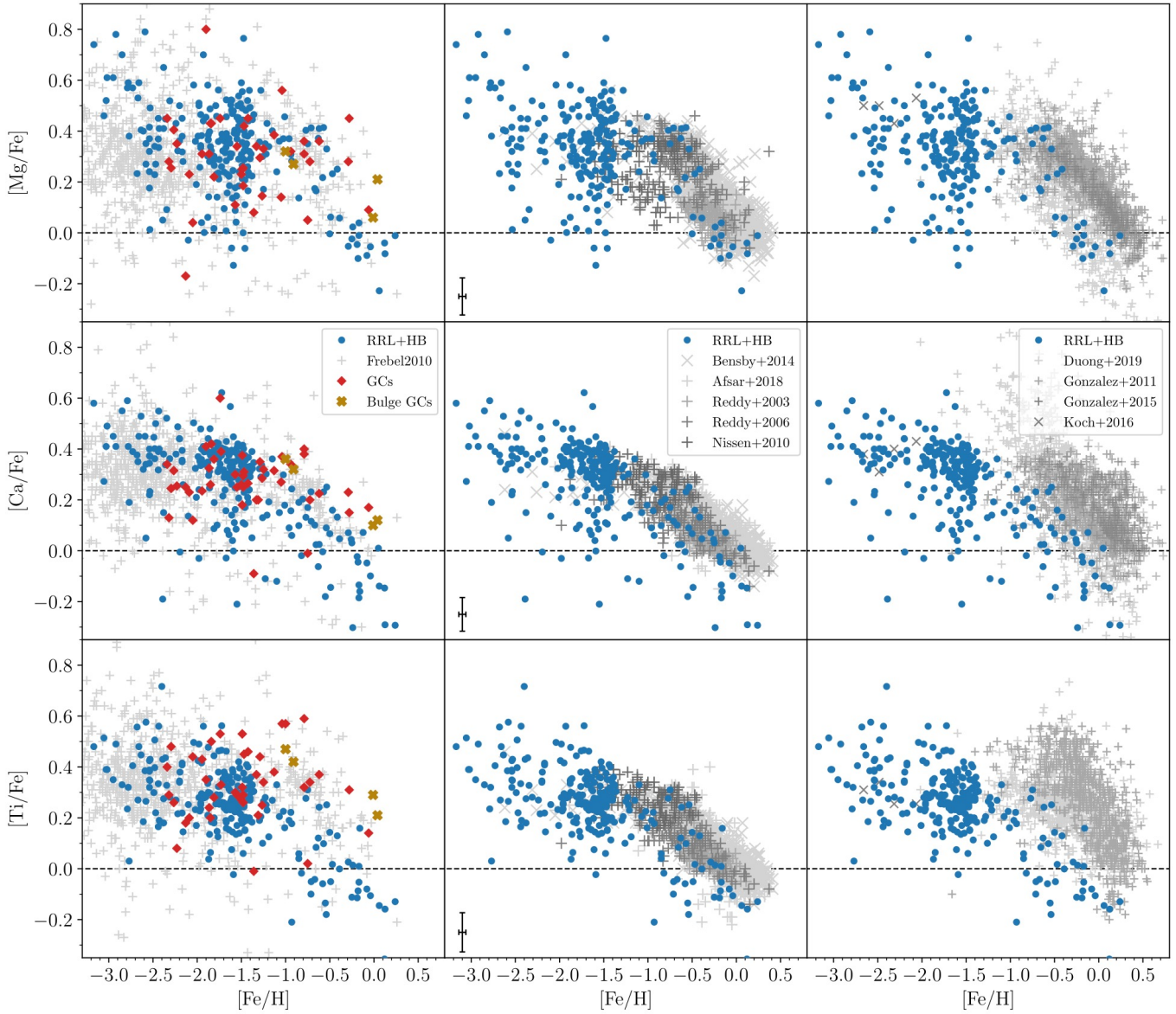




Crestani + 2021a

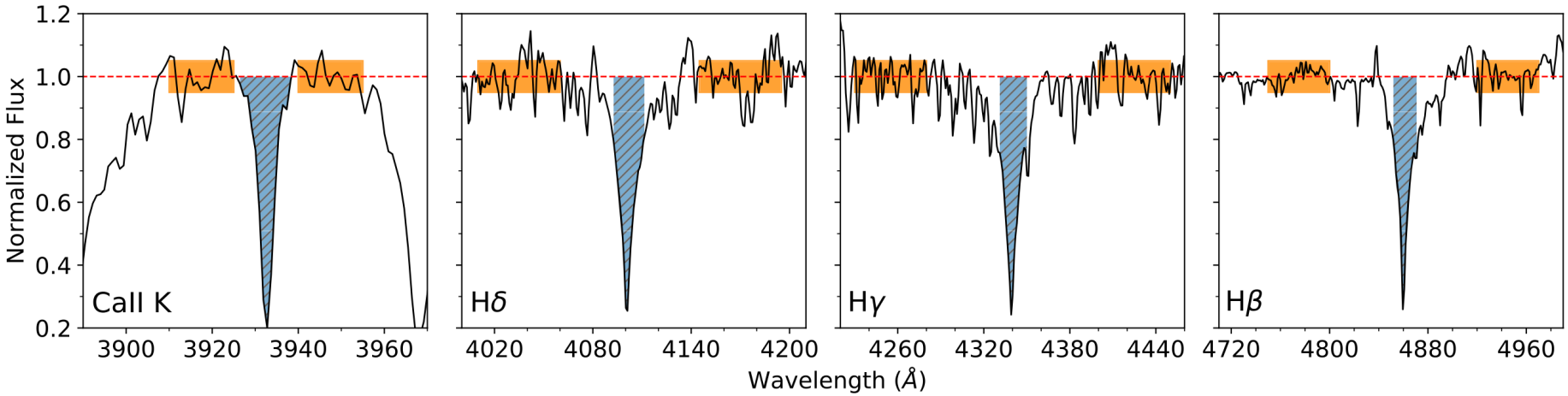
α-element abundances

Crestani + 2021a



Gray points: halo stars thin+thick disk stars bulge stars

[Fe/H] from low resolution (R~2000) spectra



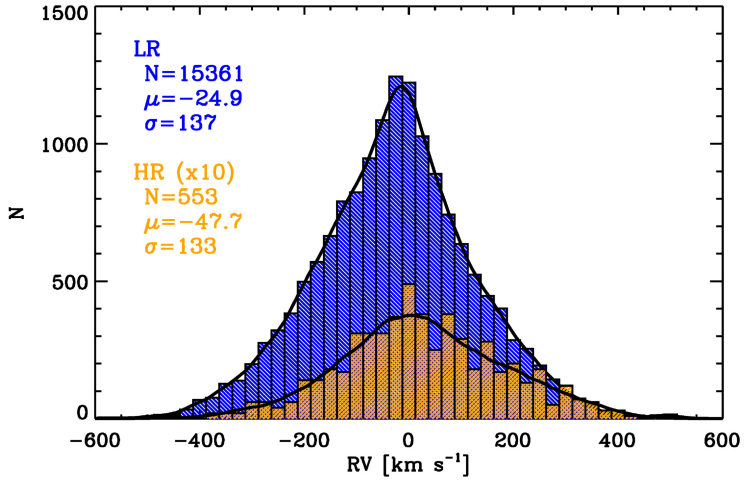
$$[\mathrm{Fe/H}]_{\Delta S} = c_0 + c_1\mathrm{K} + c_2\mathrm{H}_\delta + c_3\mathrm{H}_\gamma + c_4\mathrm{H}_\beta, \qquad (1)$$

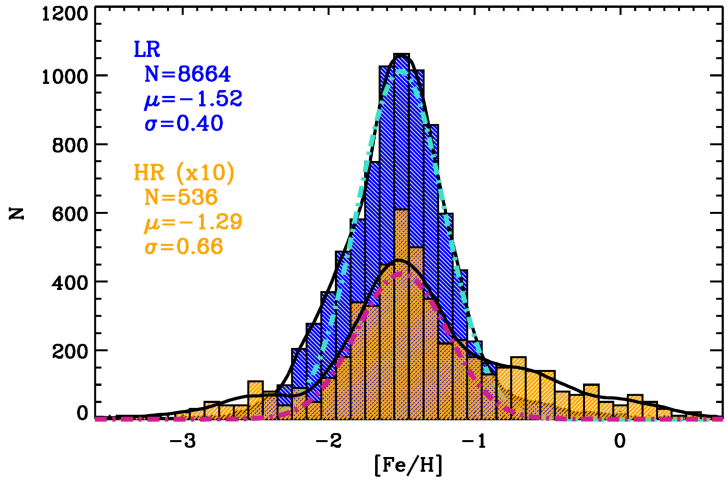
where K, H_δ, H_γ, and H_β are the equivalent widths in angstroms of the Ca II K and H lines $\sigma \sim 0.35$ dex

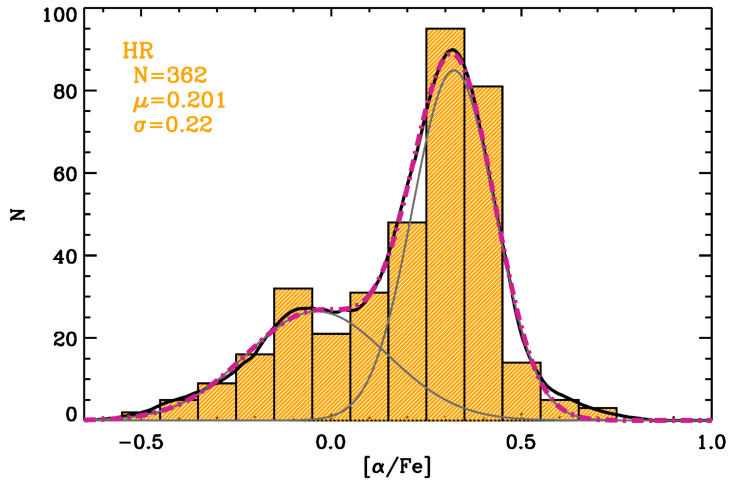
Current Spectroscopic Database

Bono+2026

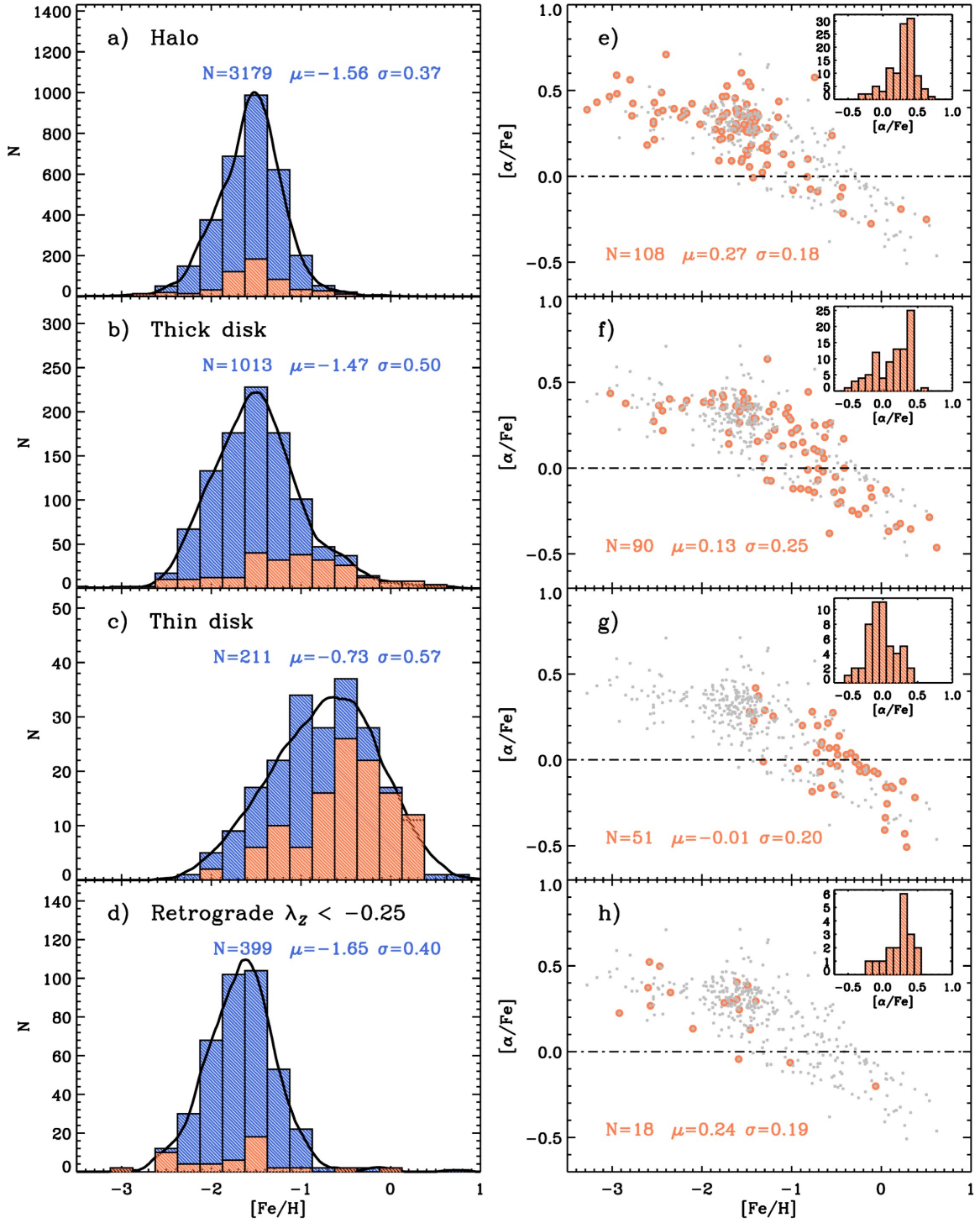
Low Resolution (LR) data calibrated with a High Resolution (HR) data all put on a uniform, homogenous system



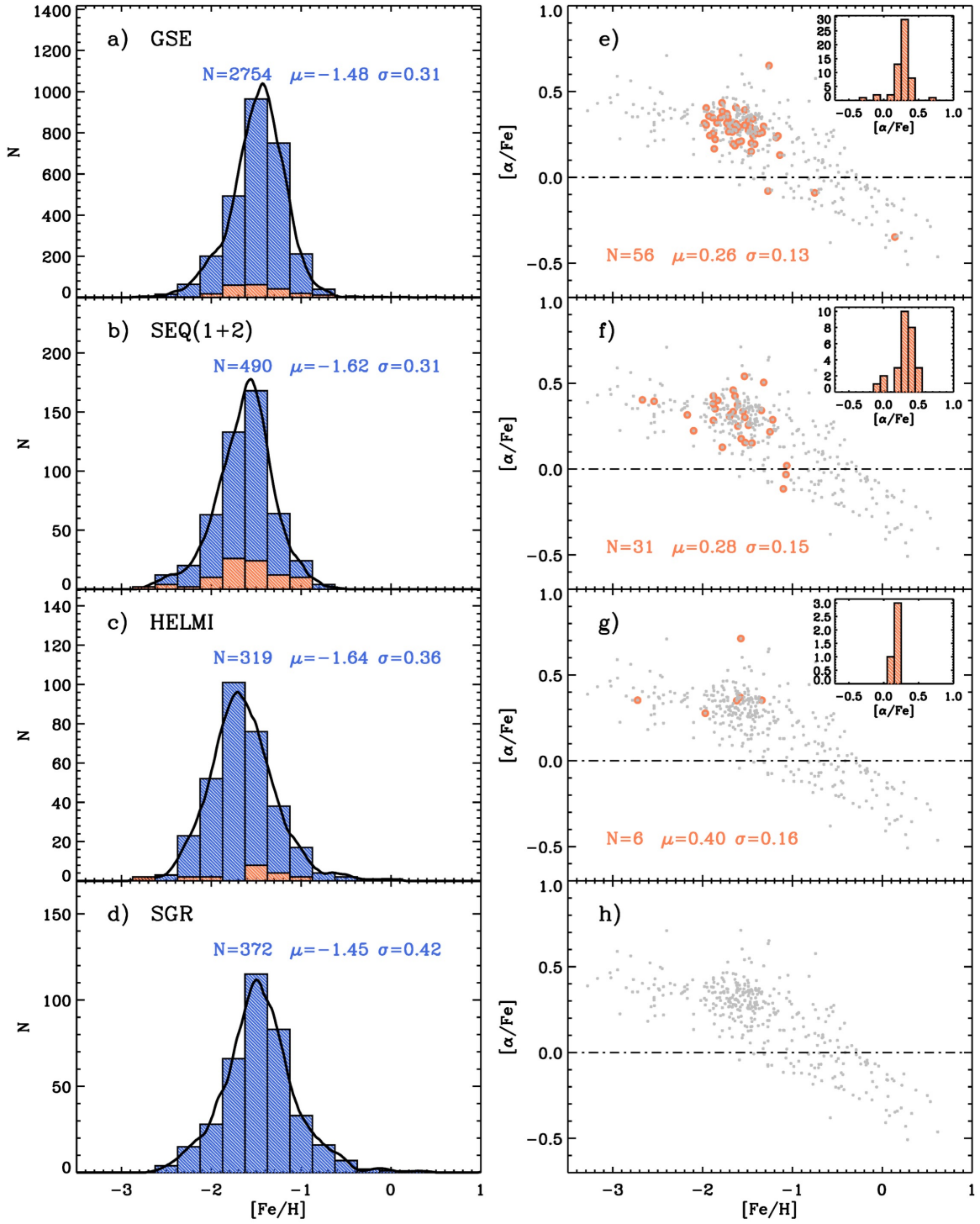




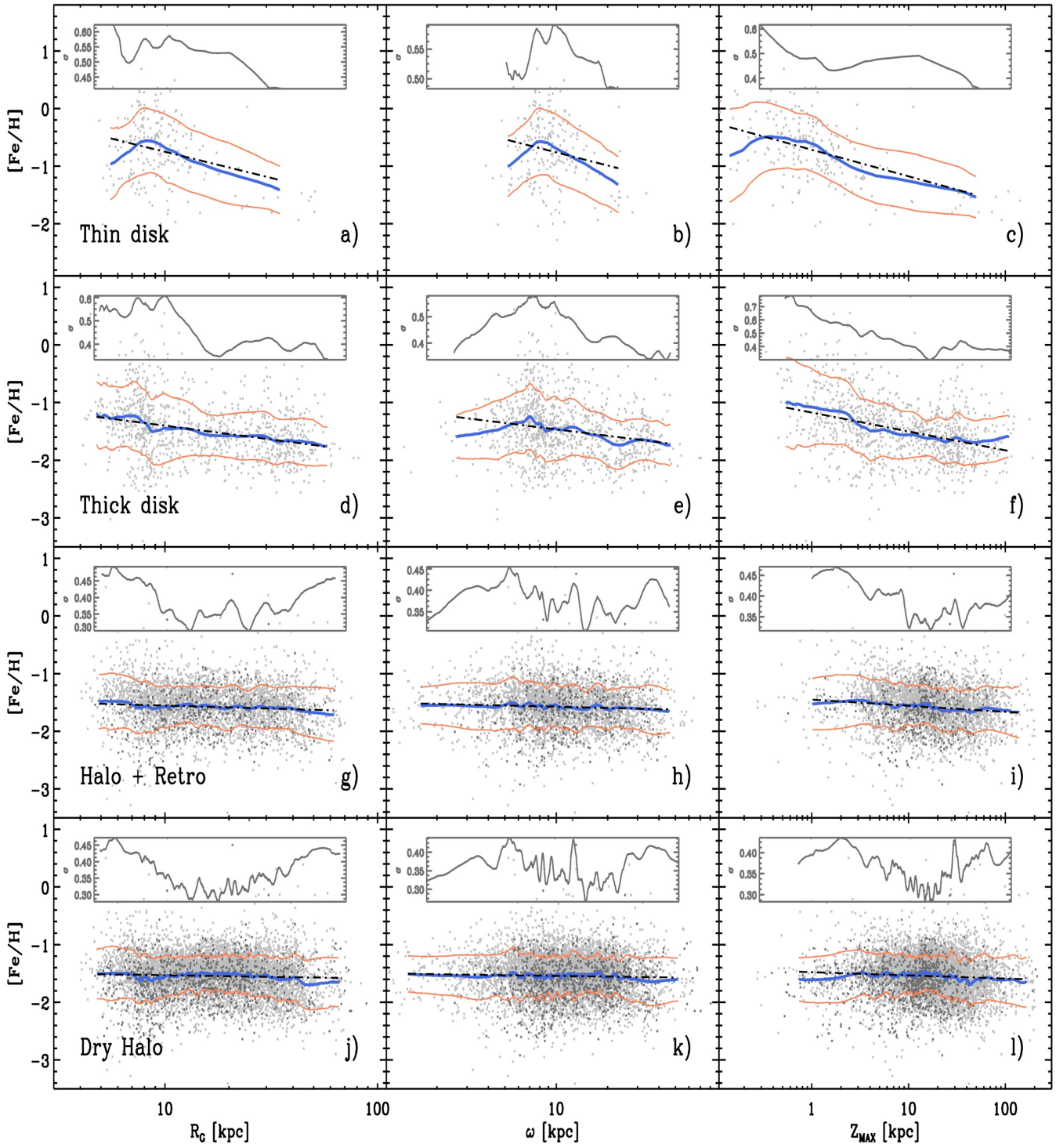
Distances from PLZ relation combined with Gaia proper motions + radial velocities (RV) used to determine kinematics and separate sample into four components: Halo, thick disk, thin disk and retrograde



RR Lyrae in Stellar Streams



Metallicity Gradients



Summary

- SALT is a fully queue observed telescope which delivers pipeline reduced data to PIs within 24 hours of observations
- African PIs can apply for SALT time through the South African TAC, and SALT is actively looking for operational partners who would buy time
- SALT is well suite to time critical observations (including transients) and spectroscopic surveys
- Relatively nearby RR Lyrae stars are good targets for SALT HRS observations
- A multi-year campaign of HRS observations, combined with observations with other telescopes has lead to a large, homogenous database of RR Lyrae stars with well determined chemical abundances
- This database has been used to study a variety of issues related to Galactic structure and formation, including determining the abundance gradients among old stars in our Galaxy.