APOGEE and the Open Cluster Chemical Abundance and Mapping (OCCAM) Survey

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for the APOGEE team
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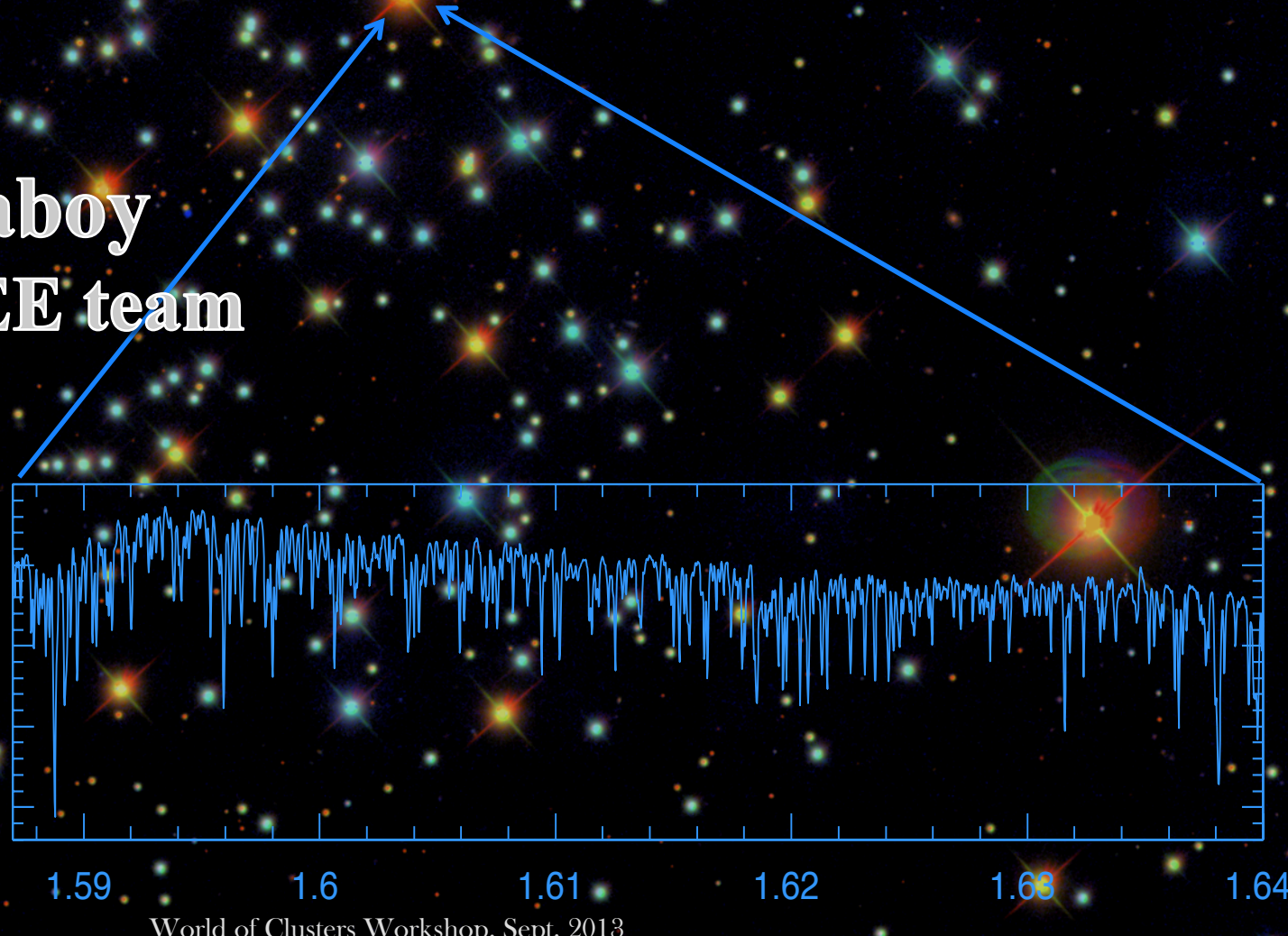


World of Clusters Workshop, Sept. 2013

Sloan Digital Sky Survey III

http://www.sdss3.org

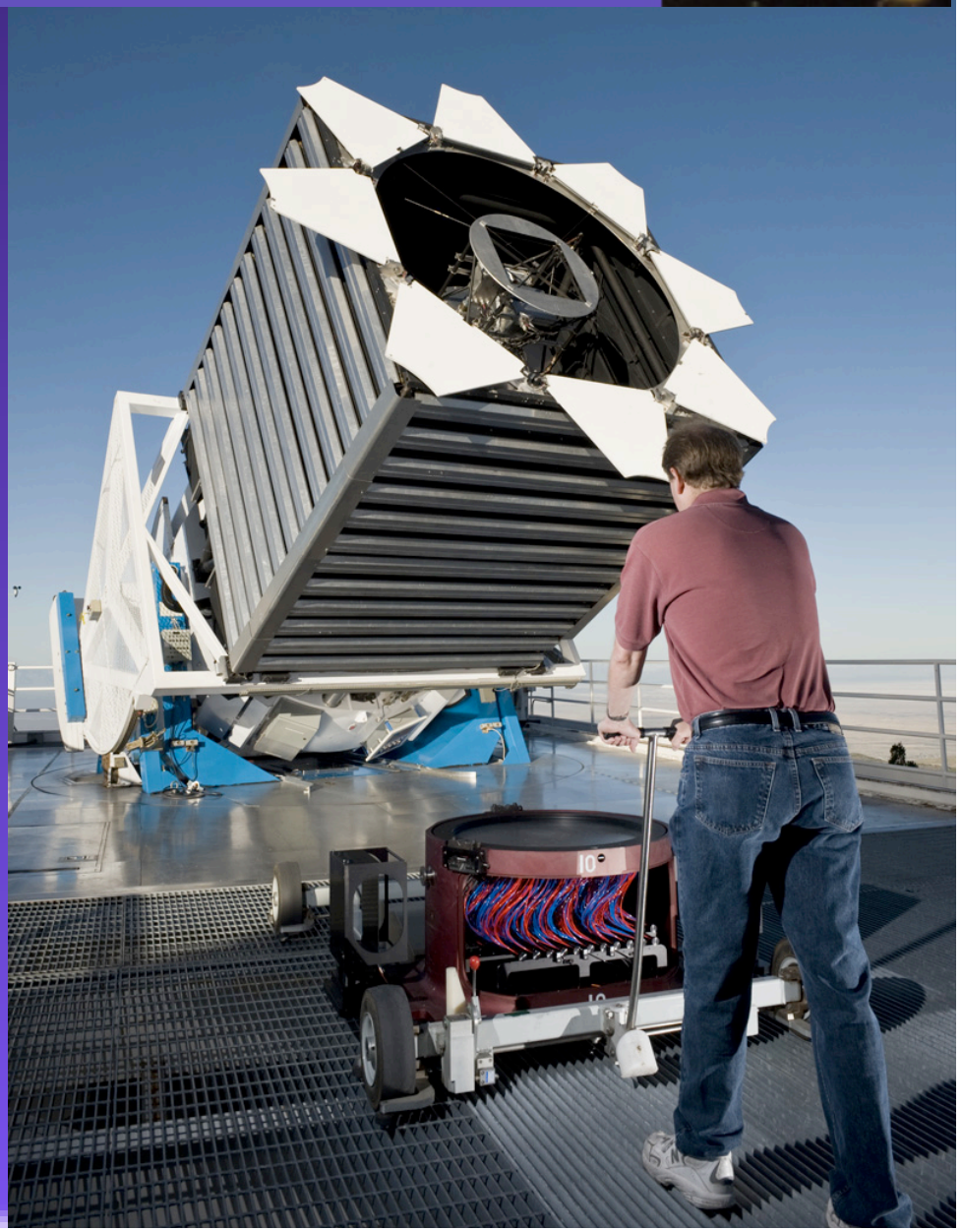
SDSSIII

APOGEE: an infrared, high resolution spectroscopic survey of the stellar populations of the Galaxy

BOSS: will measure the cosmic distance scale via clustering in the large-scale galaxy distribution and the Lyman-α forest

SEGUE-2: will map the structure, kinematics, and chemical evolution of the outer Milky Way disk and halo

MARVELS: will probe the population of giant planets via radial velocity monitoring of 1,000's of stars



at a Glance

- Bright time: May/June 2011 to July 2014 (3 year survey)
- 300 fibers, $R = \lambda/\Delta\lambda > 22{,}500$, cryogenic spectrograph
- H-band: 1.51-1.68μm
- S/N = 100/pixel @ H (1.6μm) = 12.2 mag.
- Typical RV uncertainty ~ 150 m/s
- ~100,000 2MASS/WISE selected stars probing all Galactic populations (Bulge, Disk, Halo)

Precision abundances (0.1 dex) for ~15 chemical elements

- Key Elements : Fe, C, N, O, Ca, Al, Si, Mg
- Important Elements : Na, S, Mn, Ti
- Good Elements : V, K, Ni

Observing the Bulge

First APOGEE+Sloan 2.5-m observations of Galactic bulge, May 2011.
(in full moon, at >2 airmasses, and towards lights of El Paso).

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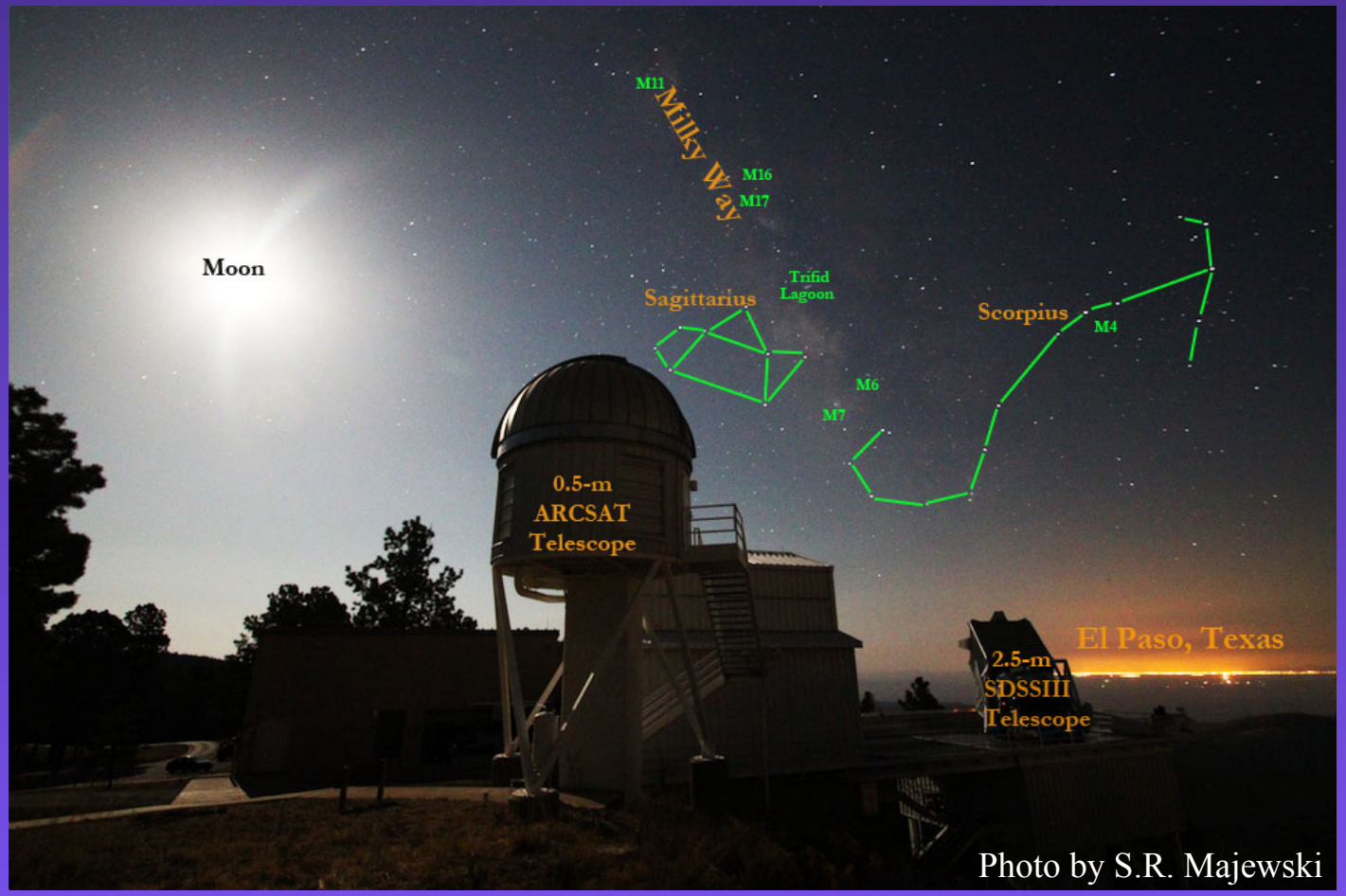
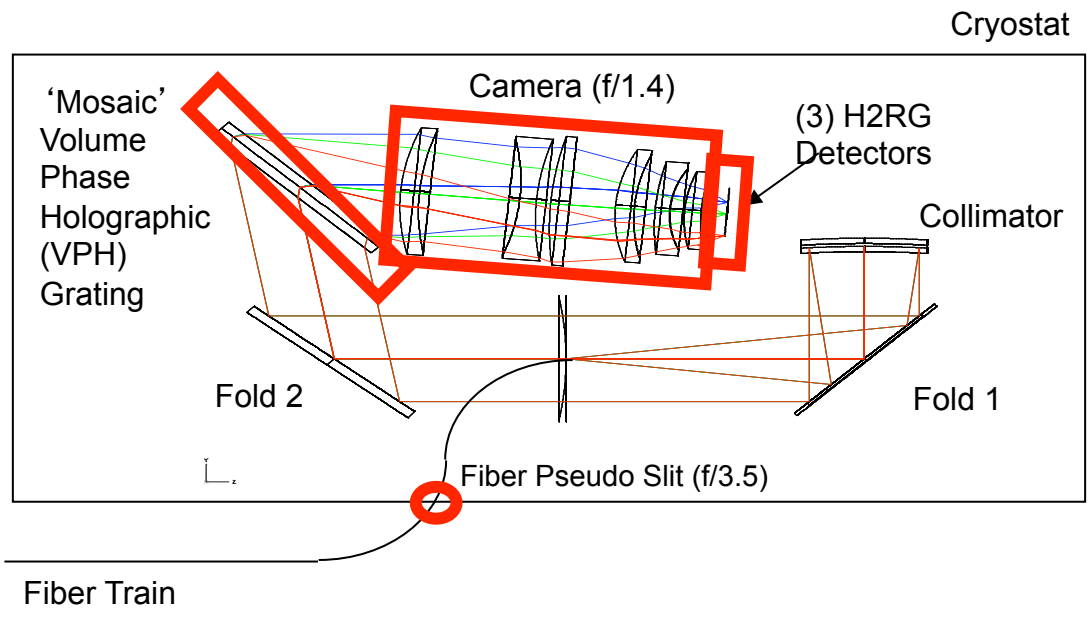
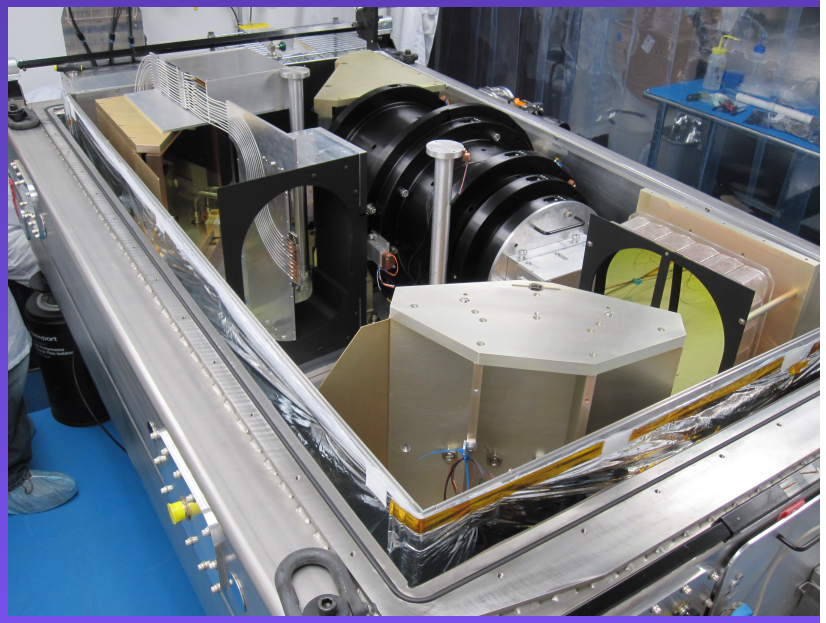


The APOGEE Instrument

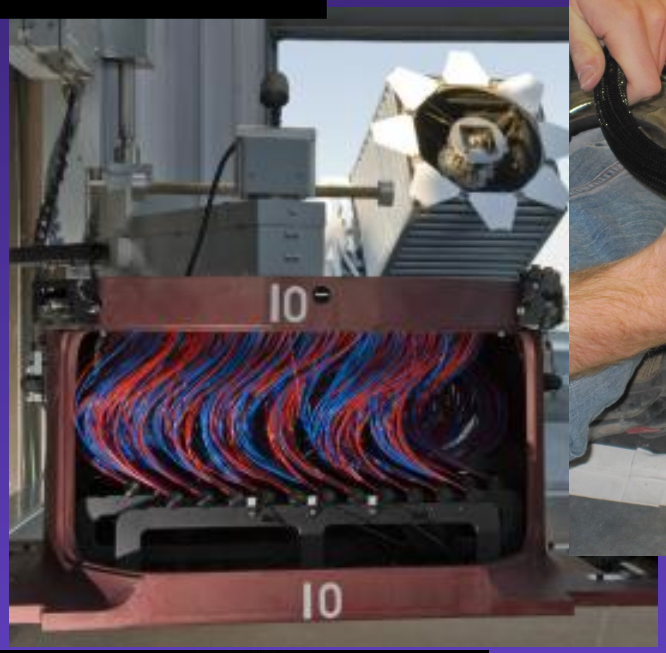
2.5-meter

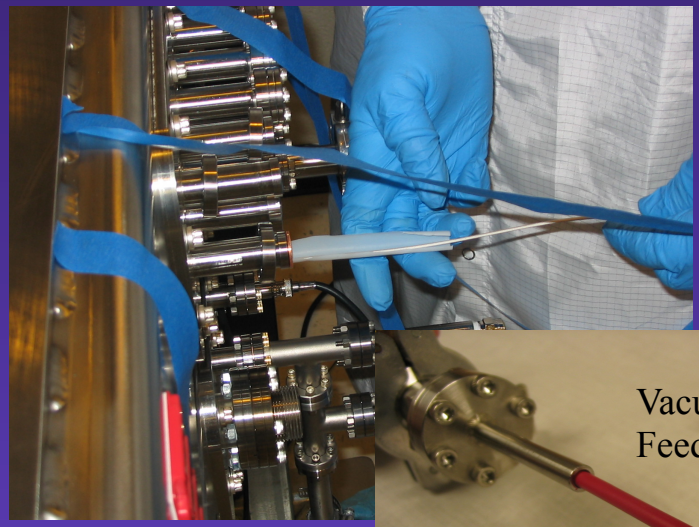
APOGEE

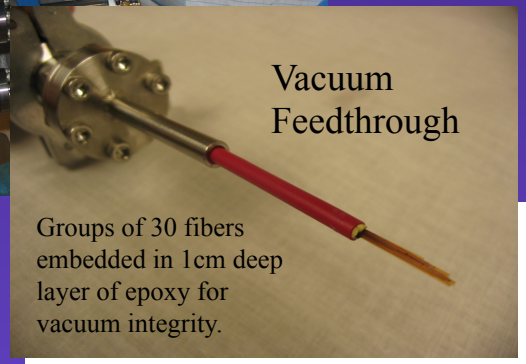




APOGEE Novel Technologies

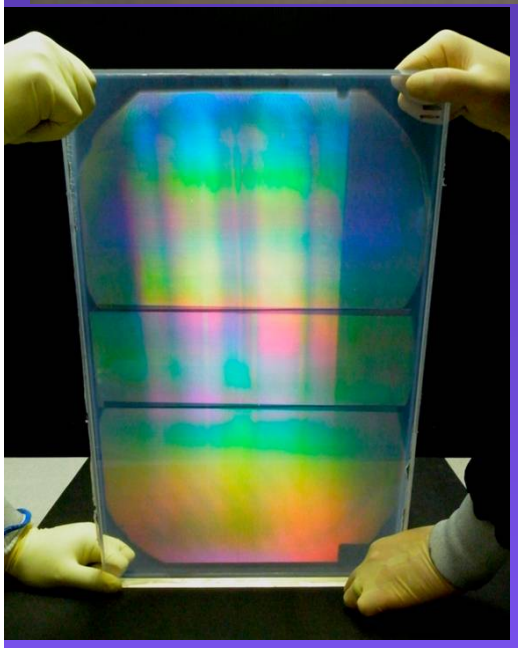


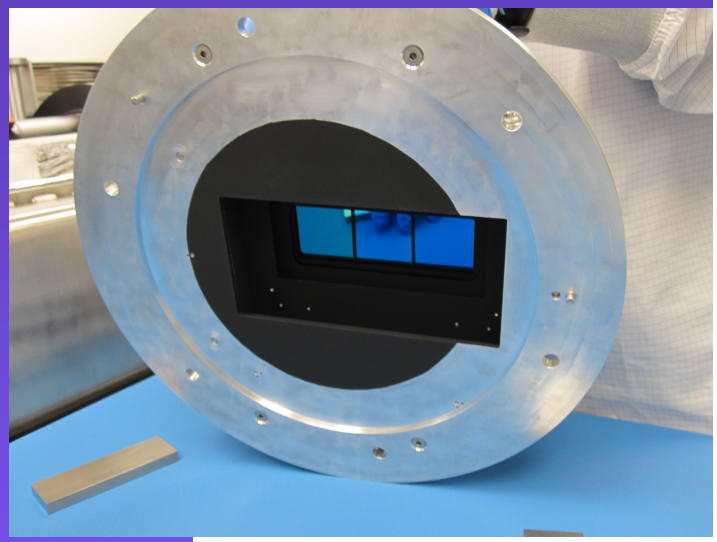




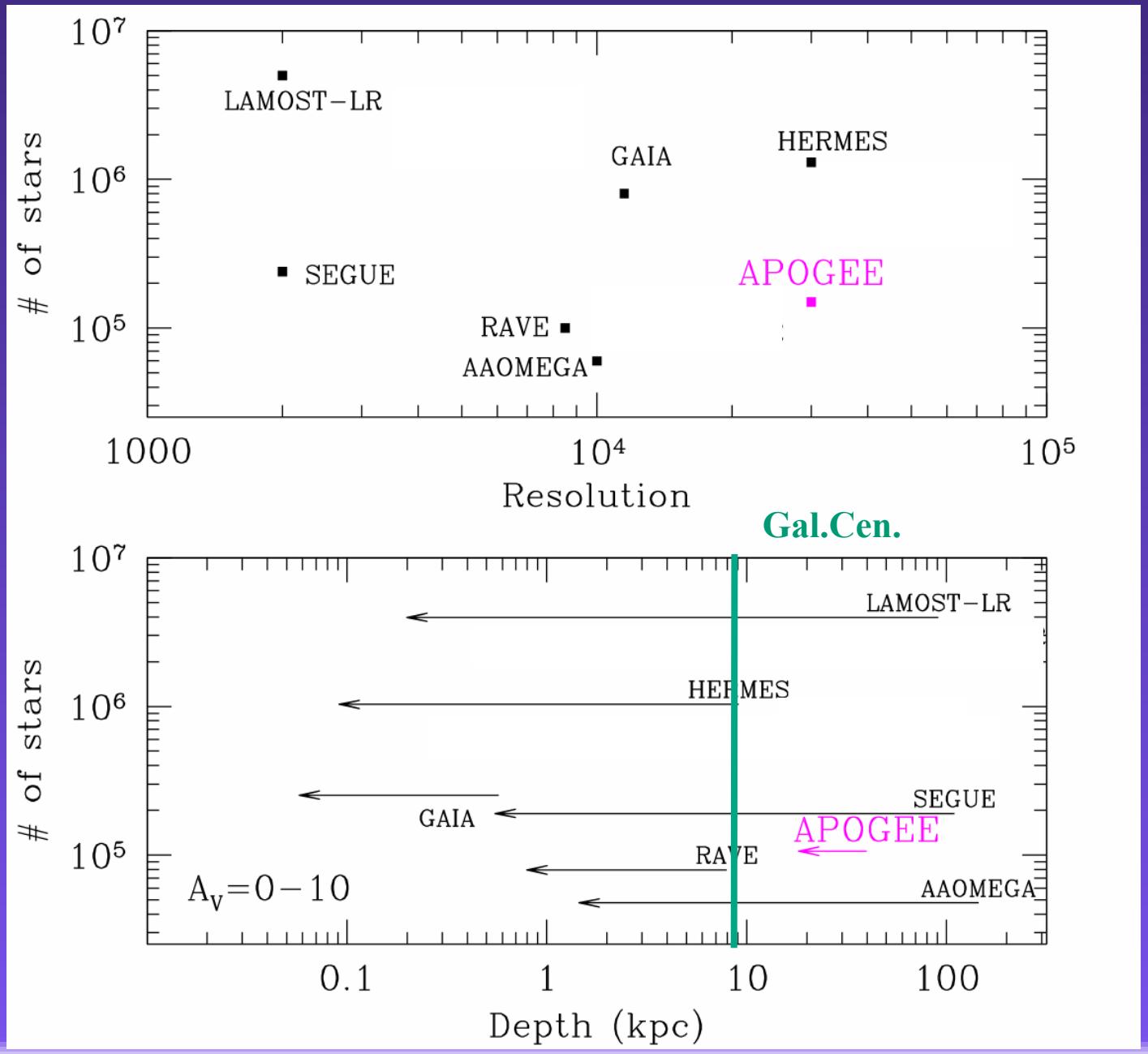
Vacuum Feedthrough

Groups of 30 fibers embedded in 1cm deep layer of epoxy for vacuum integrity.





SDSS-III/APOGEE in the Context of other "Galactic Archaeology" Surveys



A_V

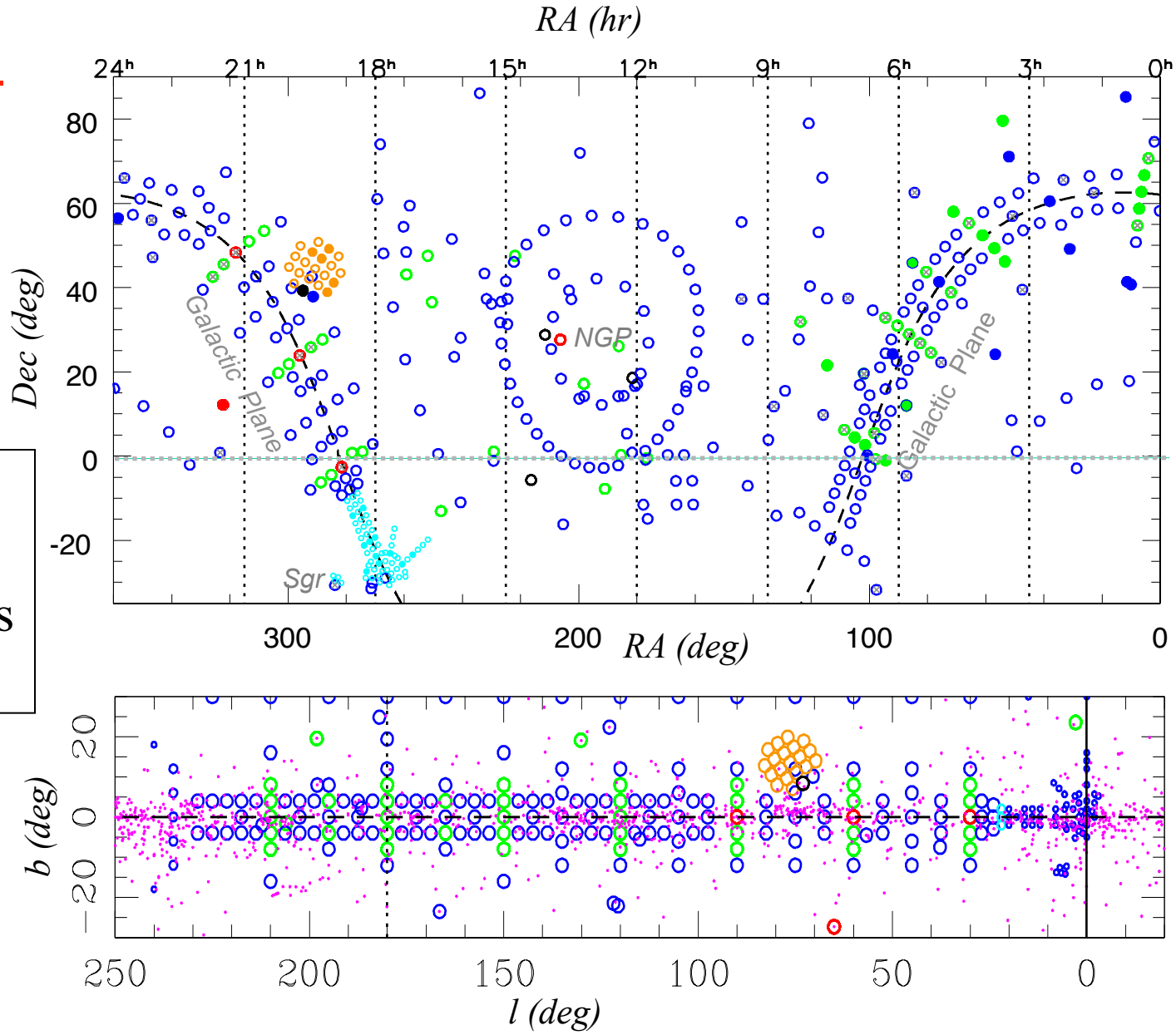
10 5

APOGEE Fields

Field Center Plan:

24 hour
12 hour
3 hour (science)
3 hour (calibration)
1 hour

~343 fields
~600 star clusters
~116,000 science stars
Kepler fields



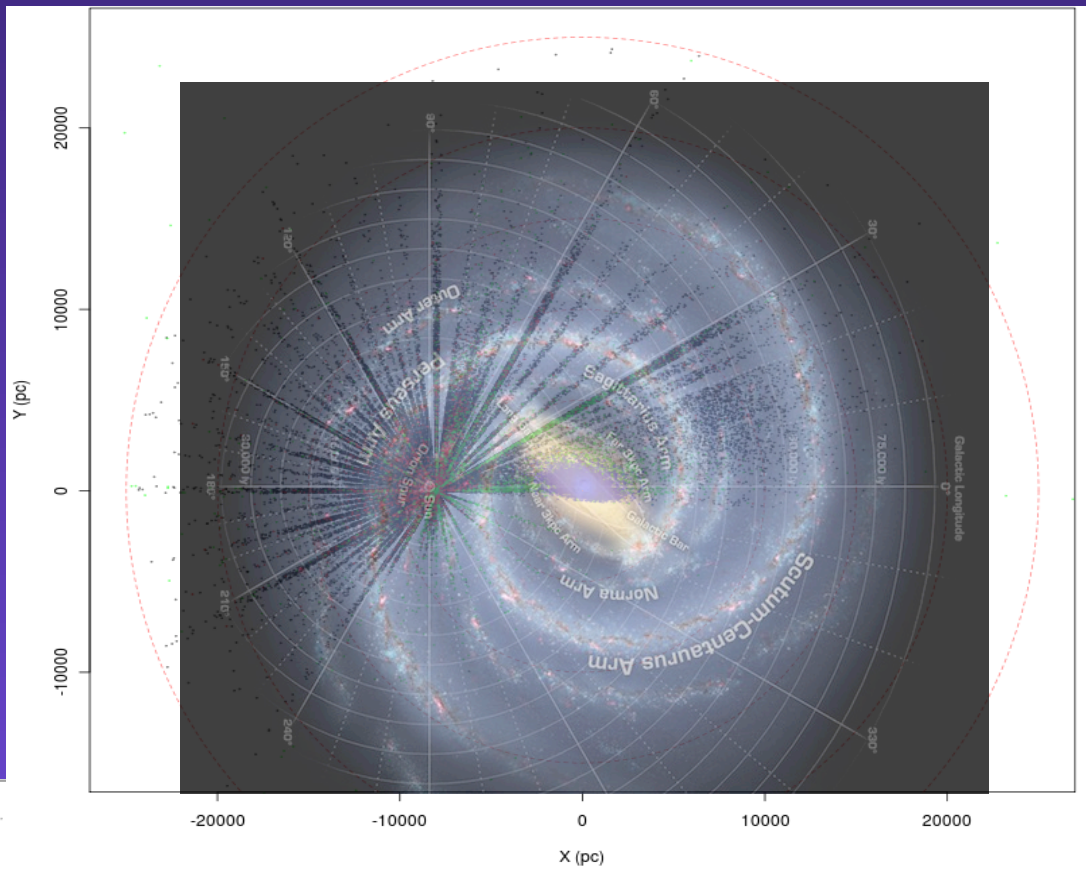
3-hr
1-hr (Bulge
12-hr
Completed
2 x 1-hr (Kepler)
6-hr
24-hr
Started Plates

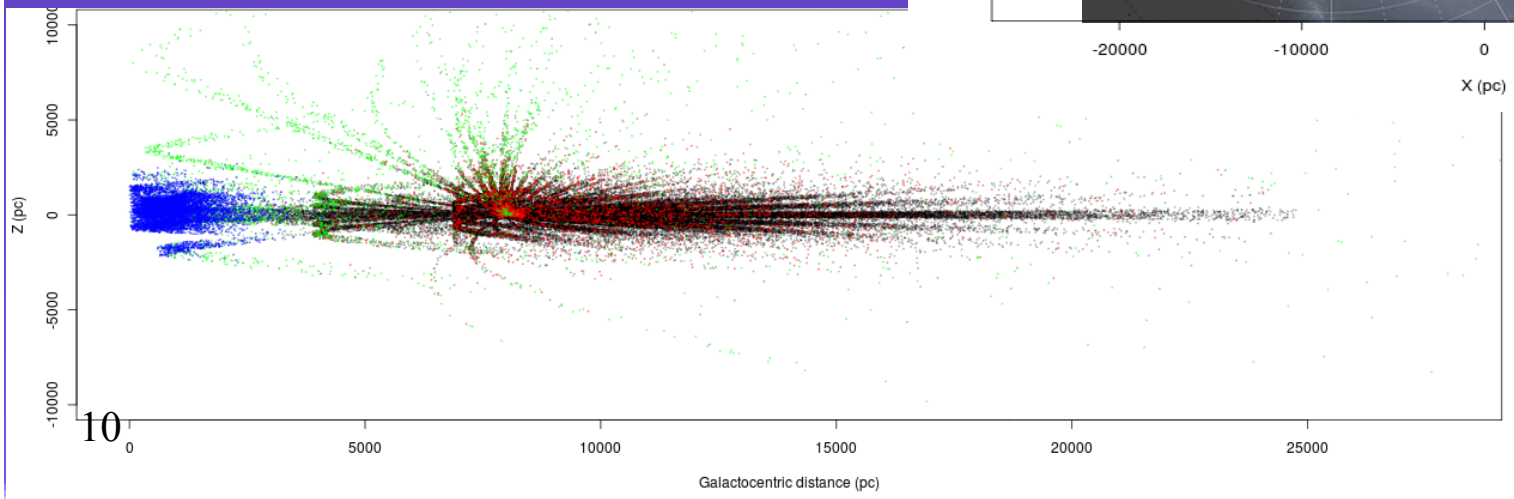
Anticipated Spatial Distribution

For currently selected fields

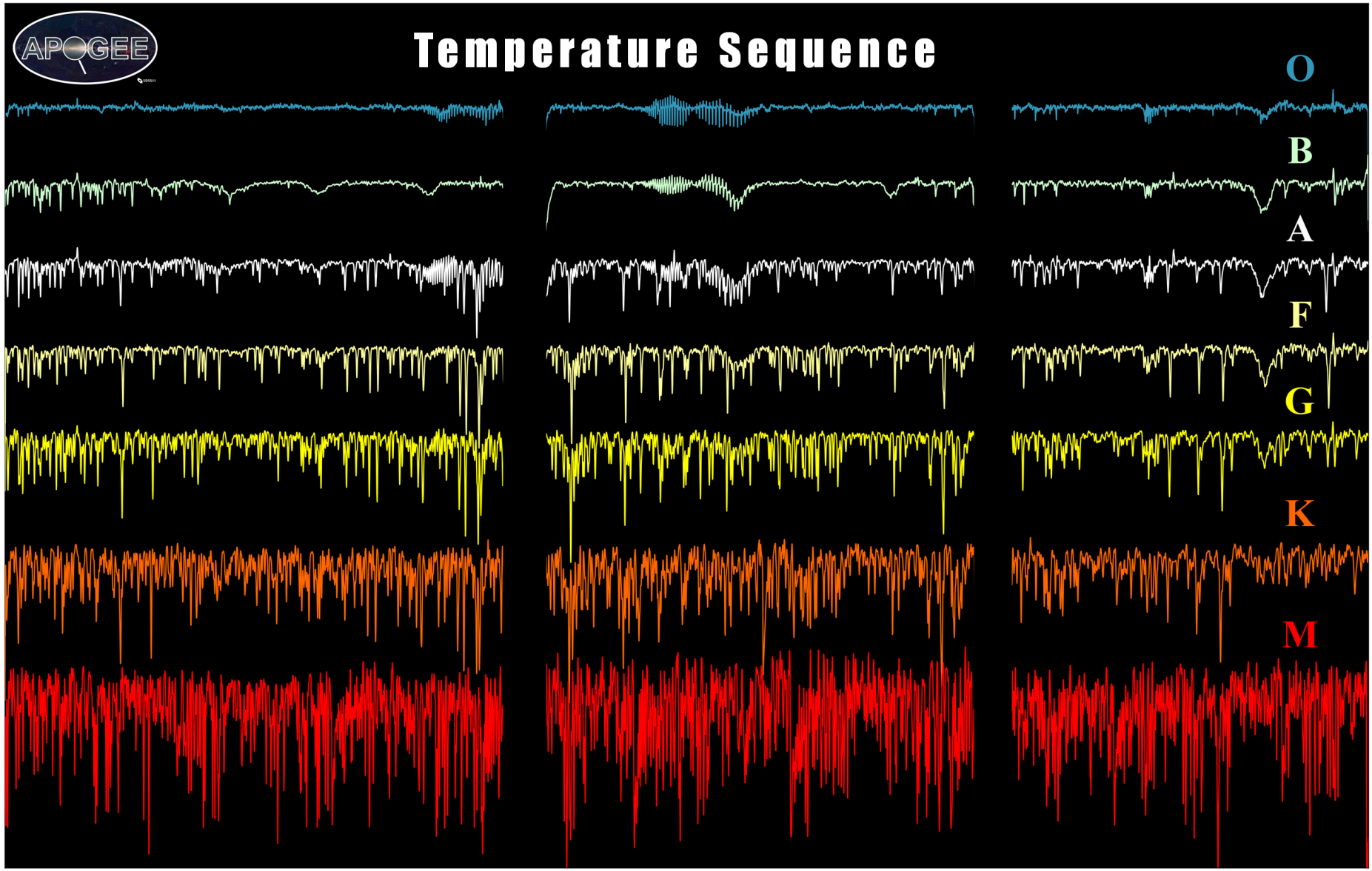
Bulge	*8000 stars*
Thin disk	*74100 stars*
Thick disk	*4300 stars*
Halo	*14500 stars*

~80% giants





Sample APOGEE Spectra



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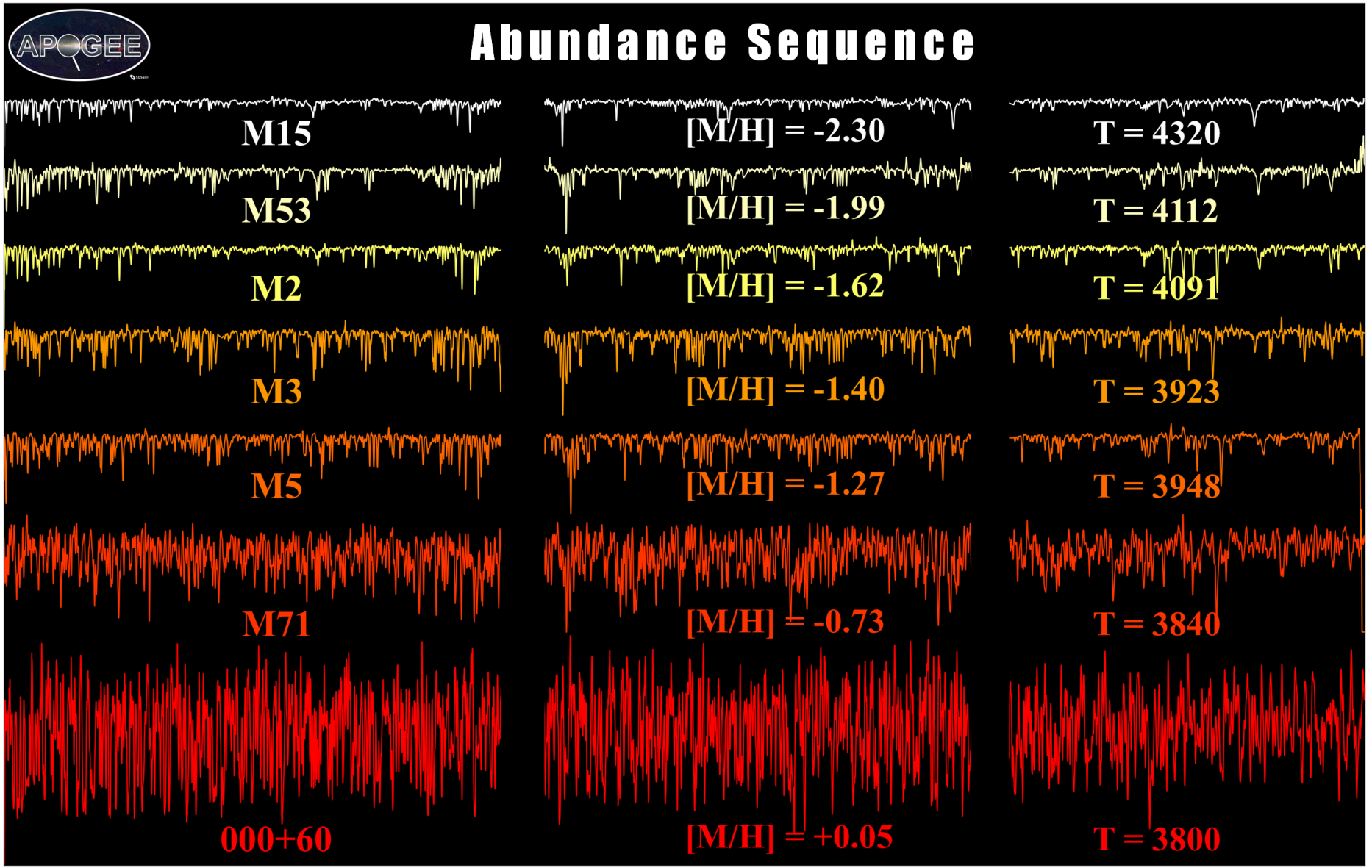


APOGEE Observations to Date

APOGEE Survey Observations to date:

~1400 "successful" visits (~1 hour each)

> 400 completed survey plates

>300,000 stellar spectra

> 365 days with data taken since May 2011

DR10 – Already Public (July 2013)

Commissioning & Year 1 Survey Data

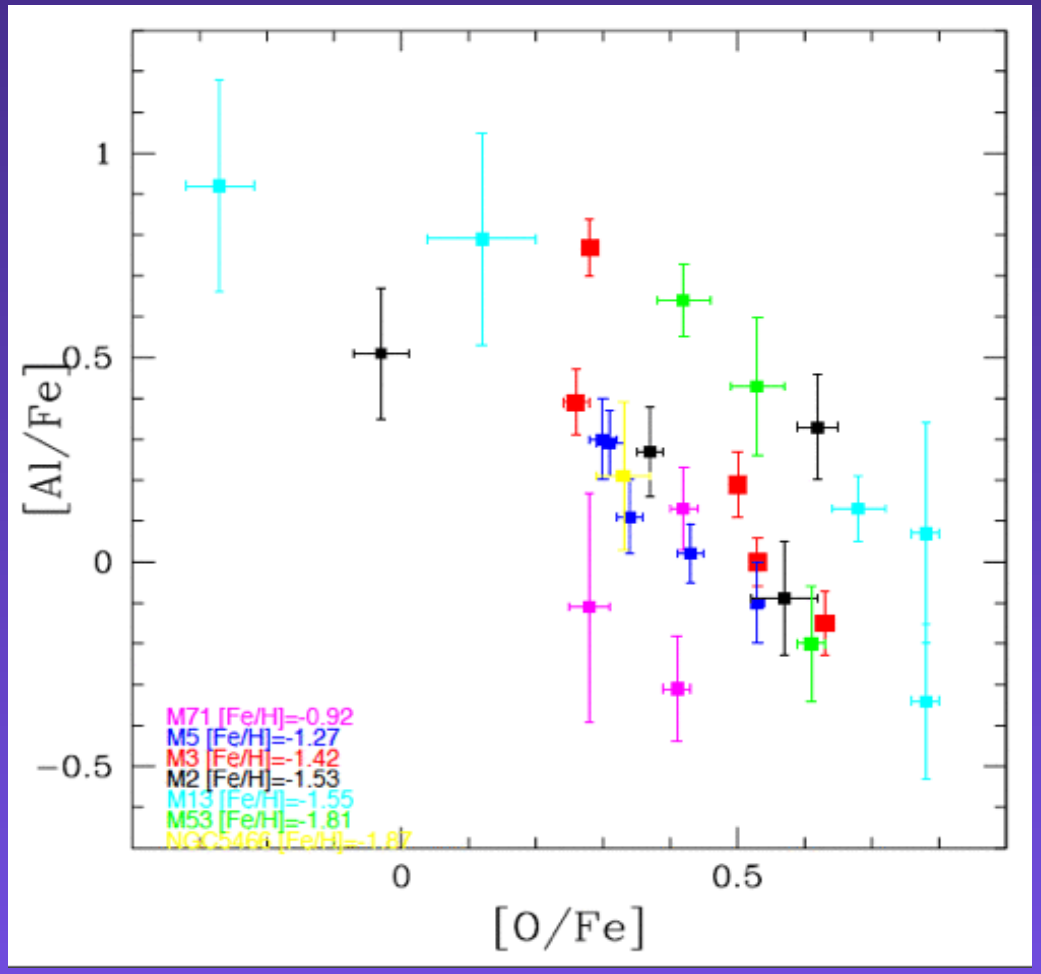
684 plate visits

281 plates

178,000 spectra

APOGEE Globular Clusters

- Globular cluster chemistry *(Shetrone, Smith et al., in prep)*

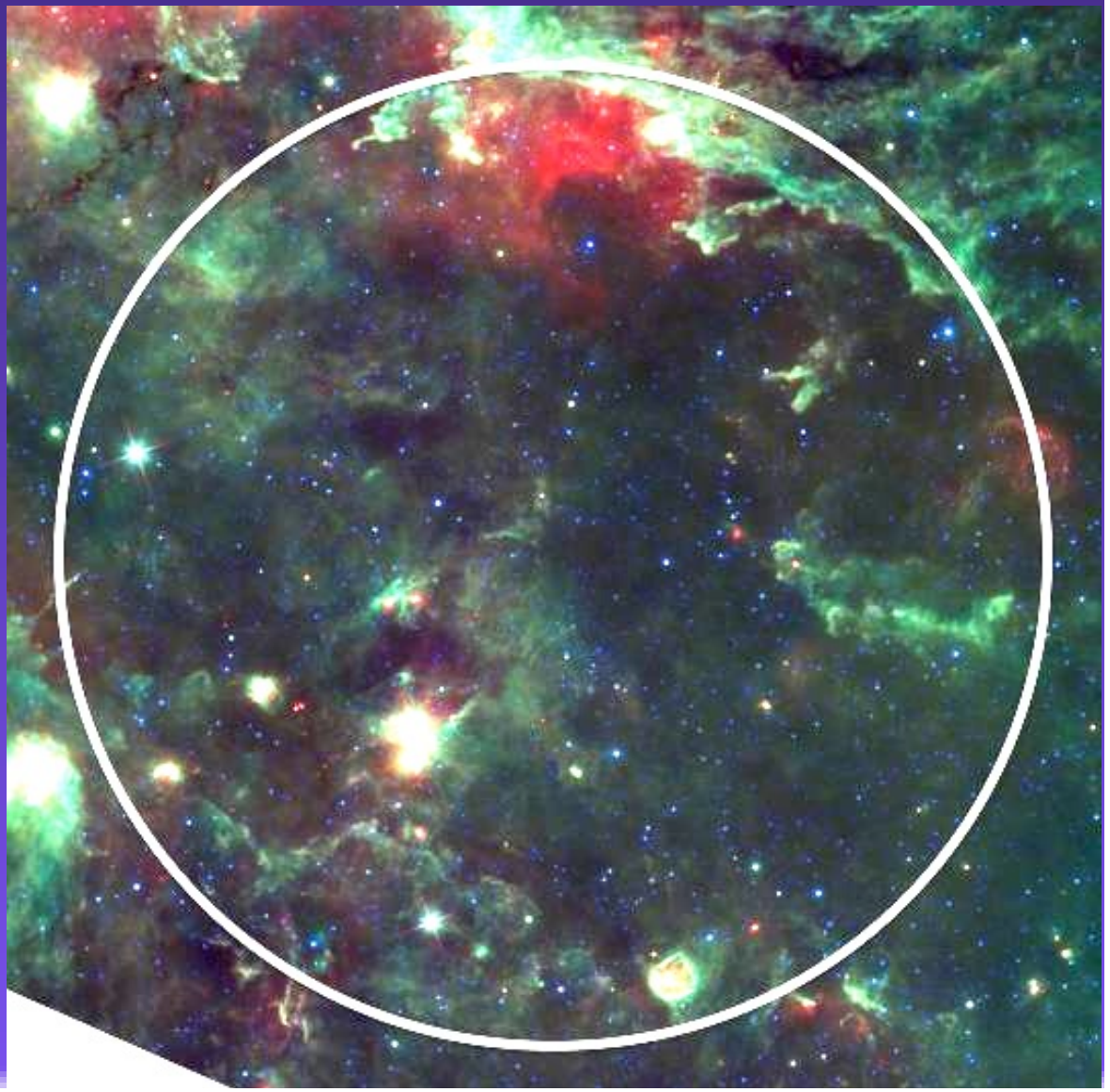


- Al-O anticorrelation (from manual reduction of selected stars).
- Many more globular/open clusters and stars/cluster available.

The Open Cluster Chemical Abundance and Mapping (OCCAM) Survey

(Frinchaboy et al., *in prep*)

WISE image of APOGEE first light field.



The Open Cluster Chemical Abundance and Mapping (OCCAM) Survey

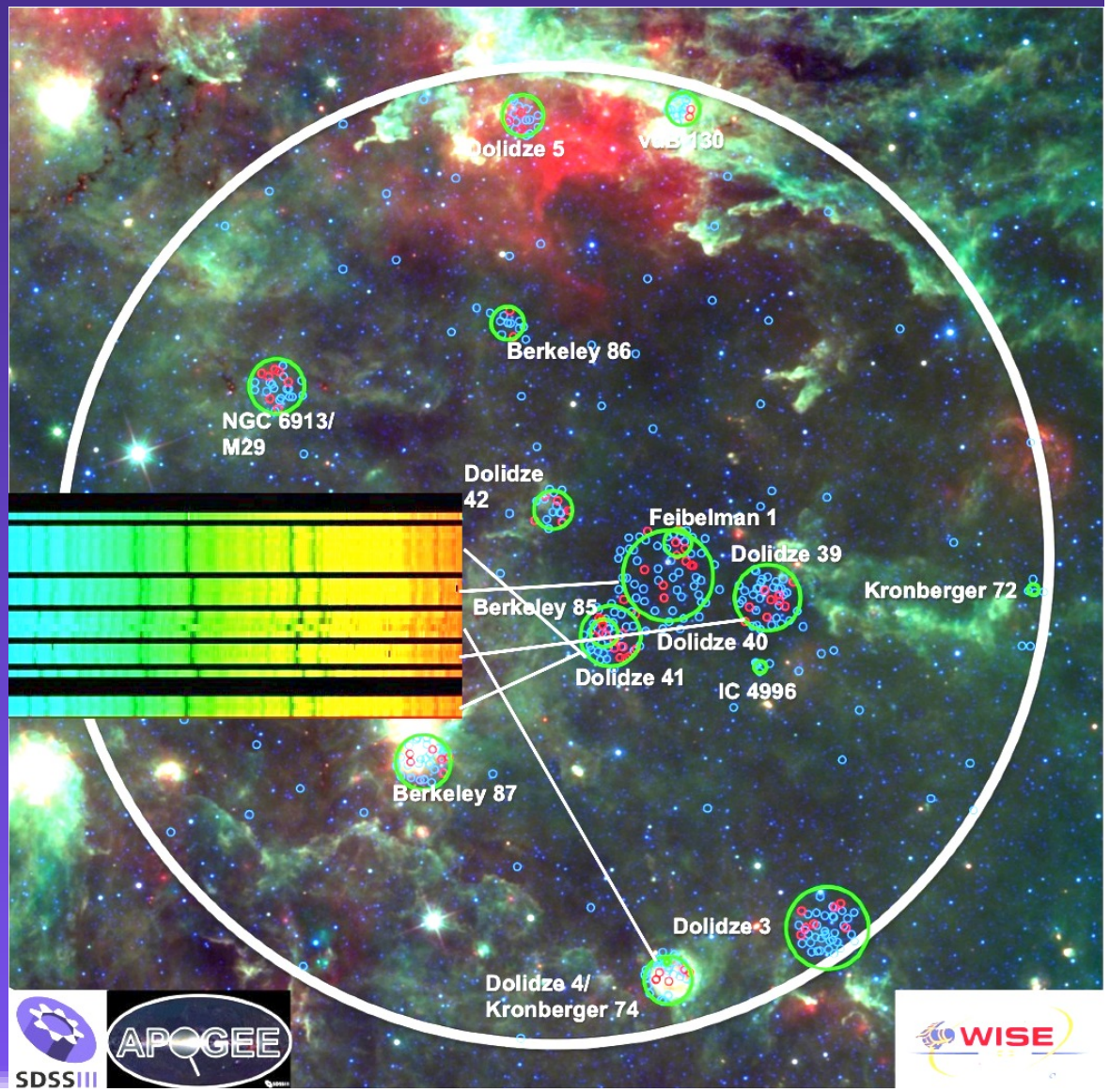
(Frinchaboy et al., *in prep*)

WISE image of APOGEE first light field.

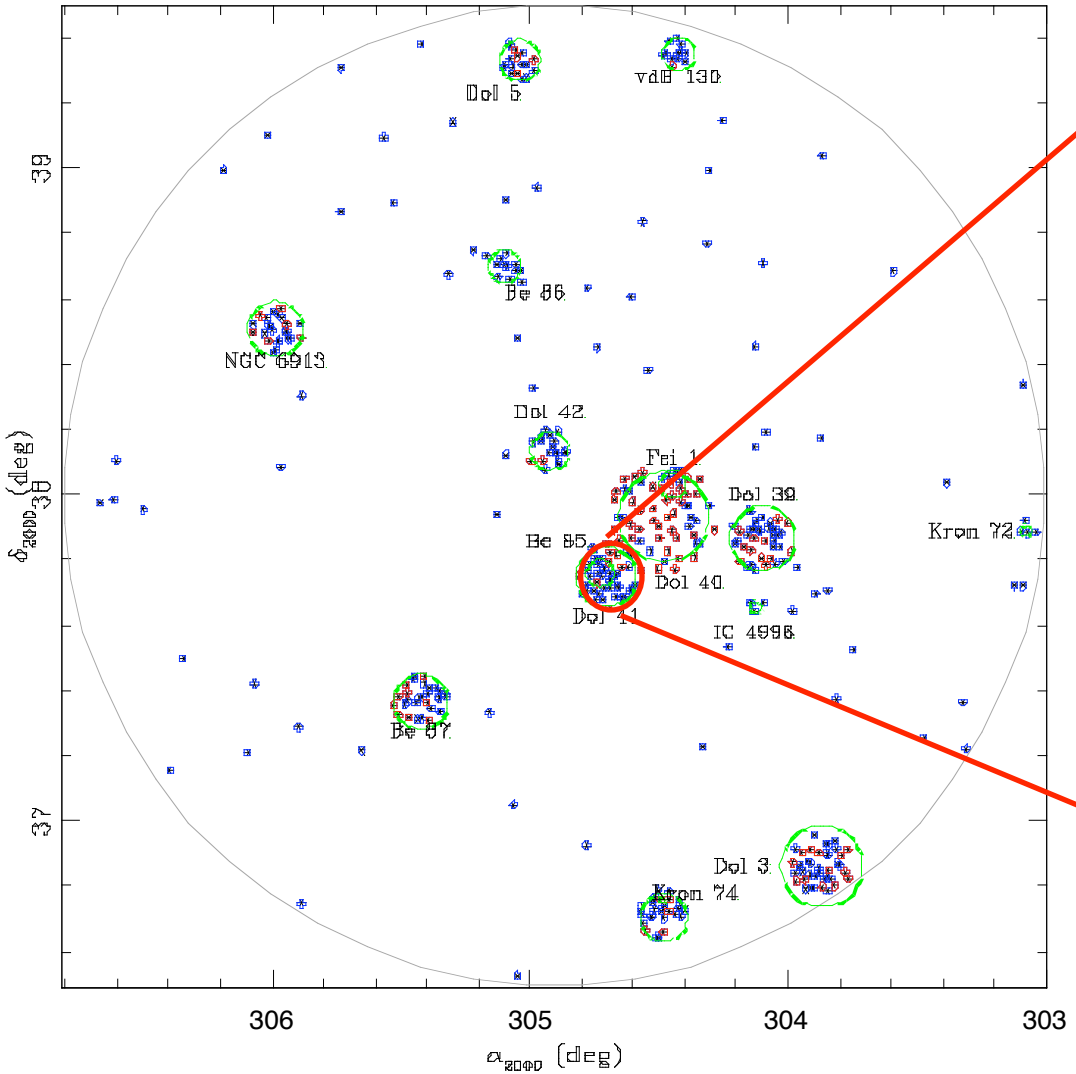
Use RVs to isolate members.

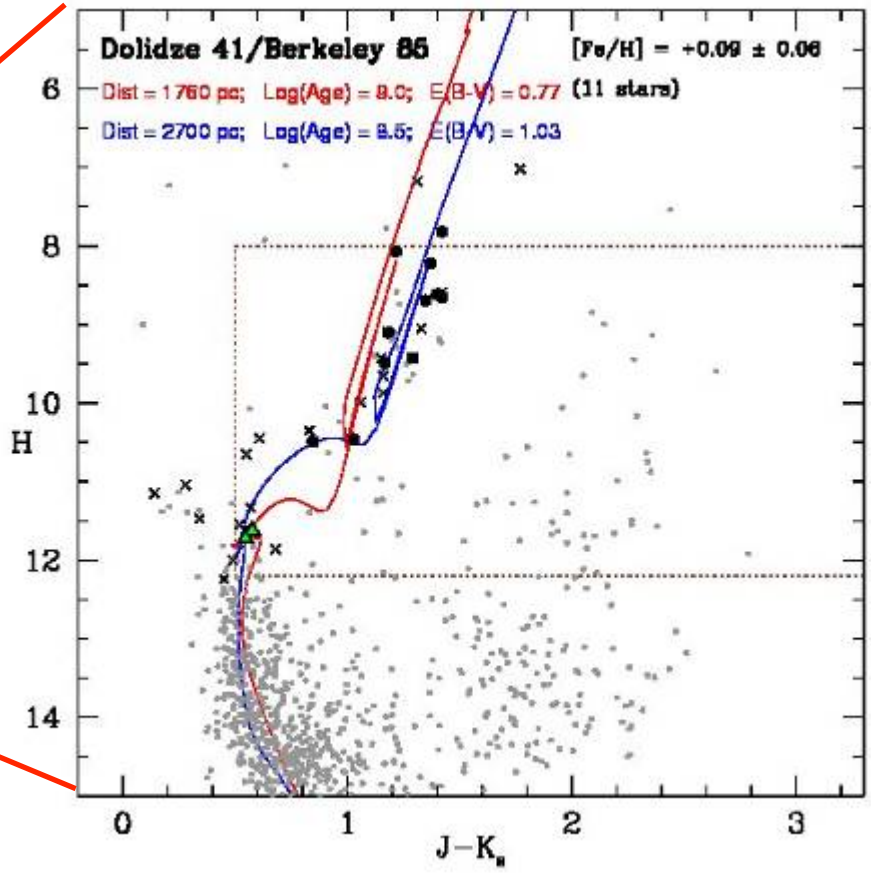
APOGEE provides Metallicities

Determine / Re-determine fundamental parameters.



The Open Cluster Chemical Abundance and Mapping (OCCAM) Survey





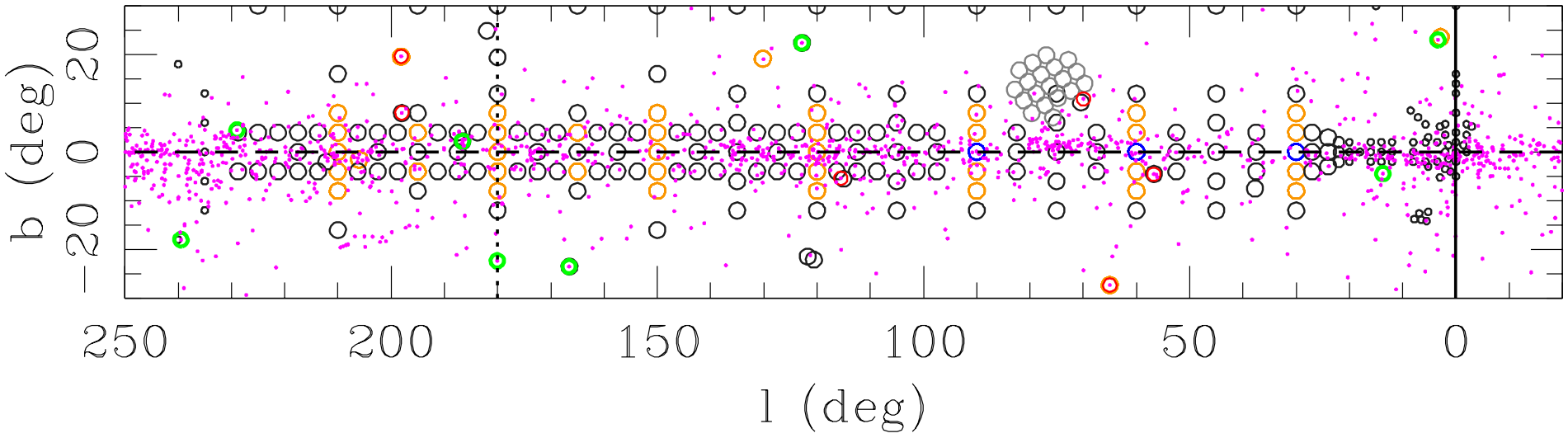
The Open Cluster Chemical Abundance and Mapping (OCCAM) Survey

PRE-APOGEE & PRE-GAIA-ESO

- Yong et al. (2012) New Data + Literature Compilation
- 68 stars in 49 clusters (All-Sky)

APOGEE DR10

- "First Pass" analysis
- 141 stars in 28 open clusters (North only)
- 22 NEW CLUSTER [Fe/H] DETERMINATIONS!



APOGEE: Galactic Abundance Gradient

Frinchaboy et al. (2013):

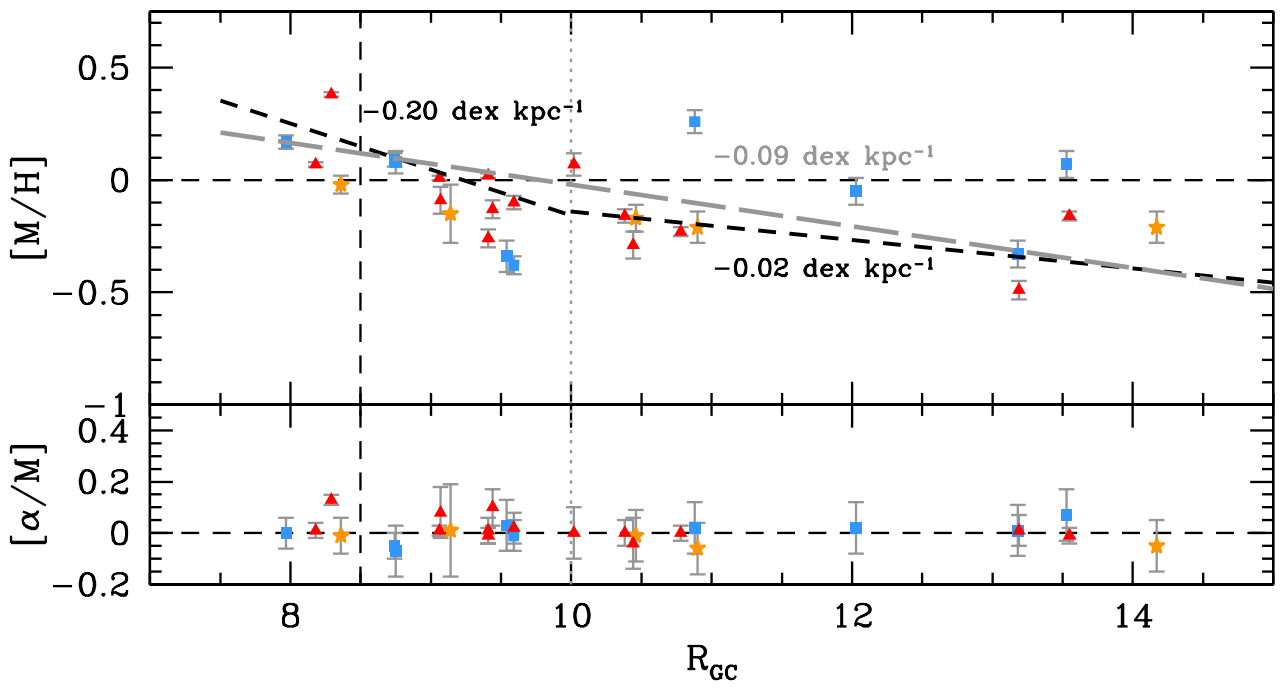
[Fe/H] Gradient

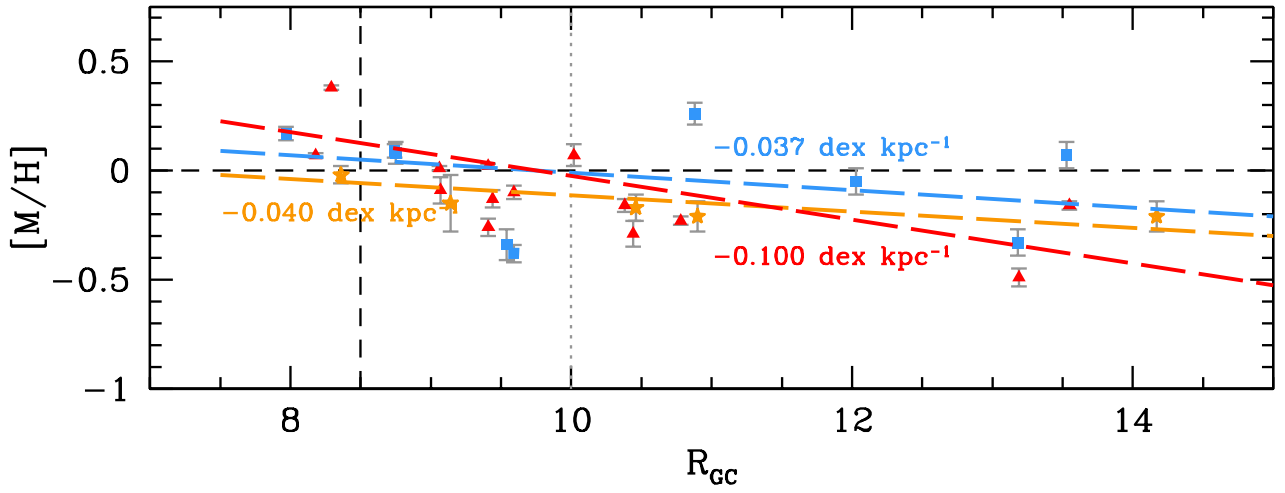
No [α/Fe] Gradient

Log(age) > 9.0

8.5 < Log(age) < 9.0

8.5 < Log(age)

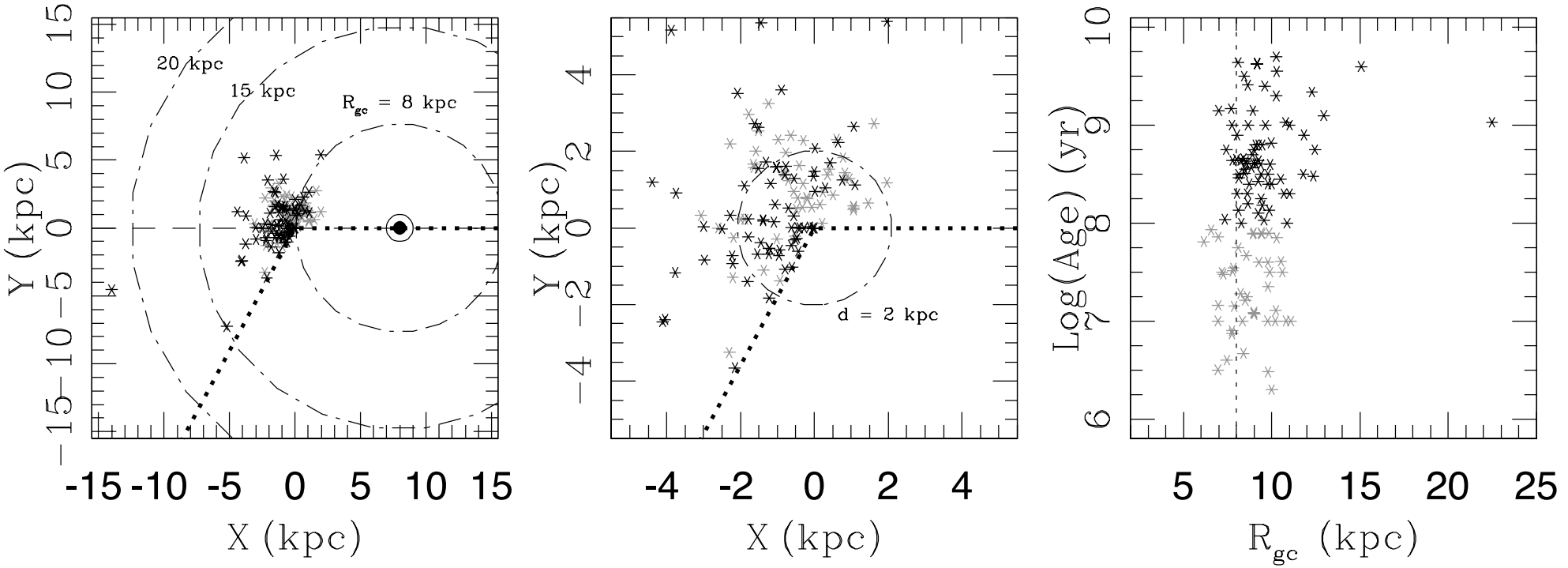




APOGEE: Galactic Gradients

(Frinchaboy et al., in prep)

- Use star clusters with reliable ages and distances.
- > 150 open cluster targets.
- Uniform analysis for many elements ([Fe/H], [α/Fe], C, N, …)

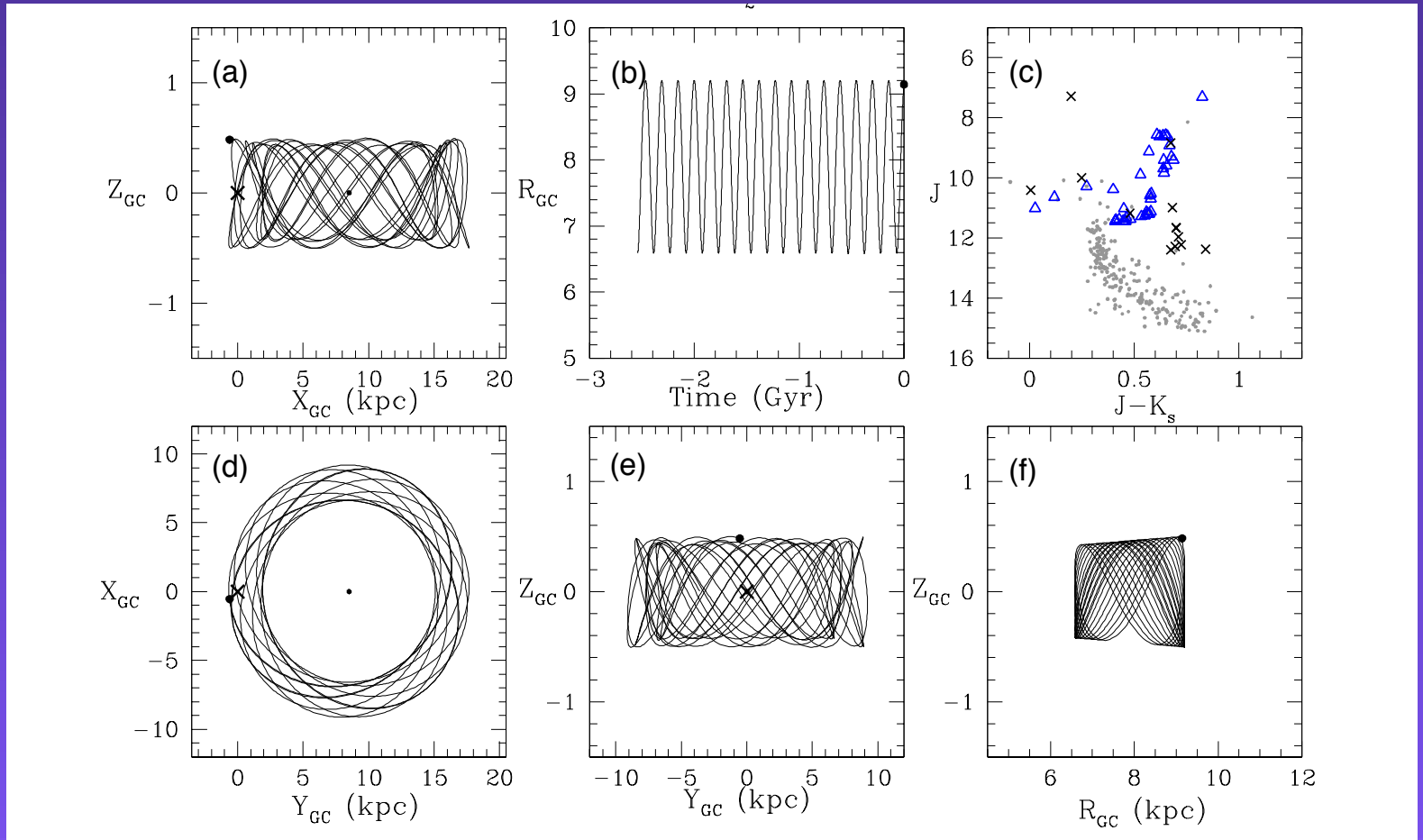


APOGEE: Galactic Gradients

(Frinchaboy et al., in prep)

- *Age-Based abundance gradients*
- *Galactic orbits for each cluster*
- *Rotation Curve and Velocity field*

THIS IS WHERE GAIA WILL HELP!

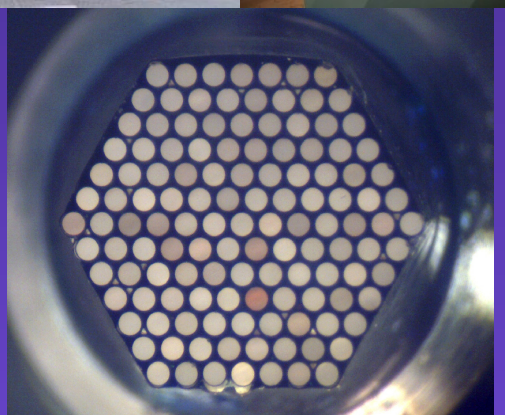


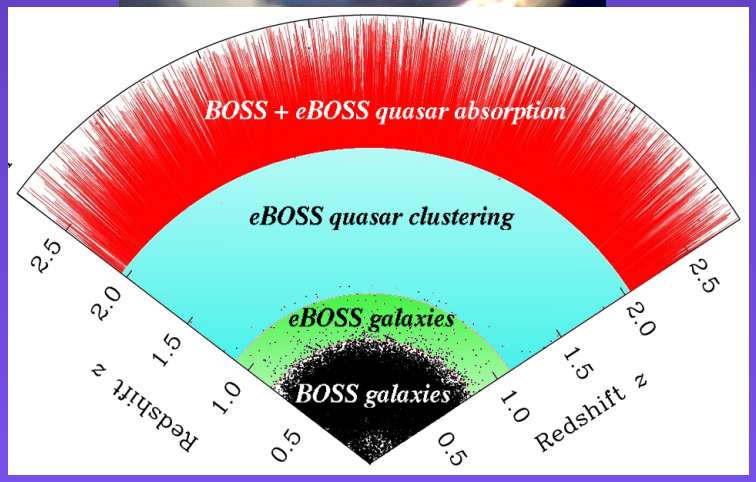
Sloan Digital Sky Survey IV

APOGEE-2: an infrared, high resolution spectroscopic survey of the stellar populations of the Galaxy from both hemispheres

MaNGA: resolved spatial spectroscopy and analysis for a sample of 10,000 galaxies

eBOSS: will measure the cosmic distance scale via clustering in the large-scale galaxy distribution and the Lyman-α forest, including time domain spectroscopy and x-ray target follow-up





Observing the Central Milky Way with APOGEE+Sloan 2.5-m

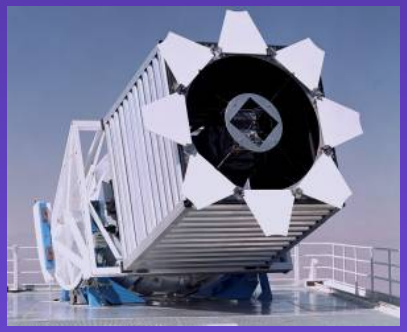
From Apache Point Observatory:

Galactic center culmination @ altitude = 28° (airmass = 2.1!)

Sky above 2 airmasses:

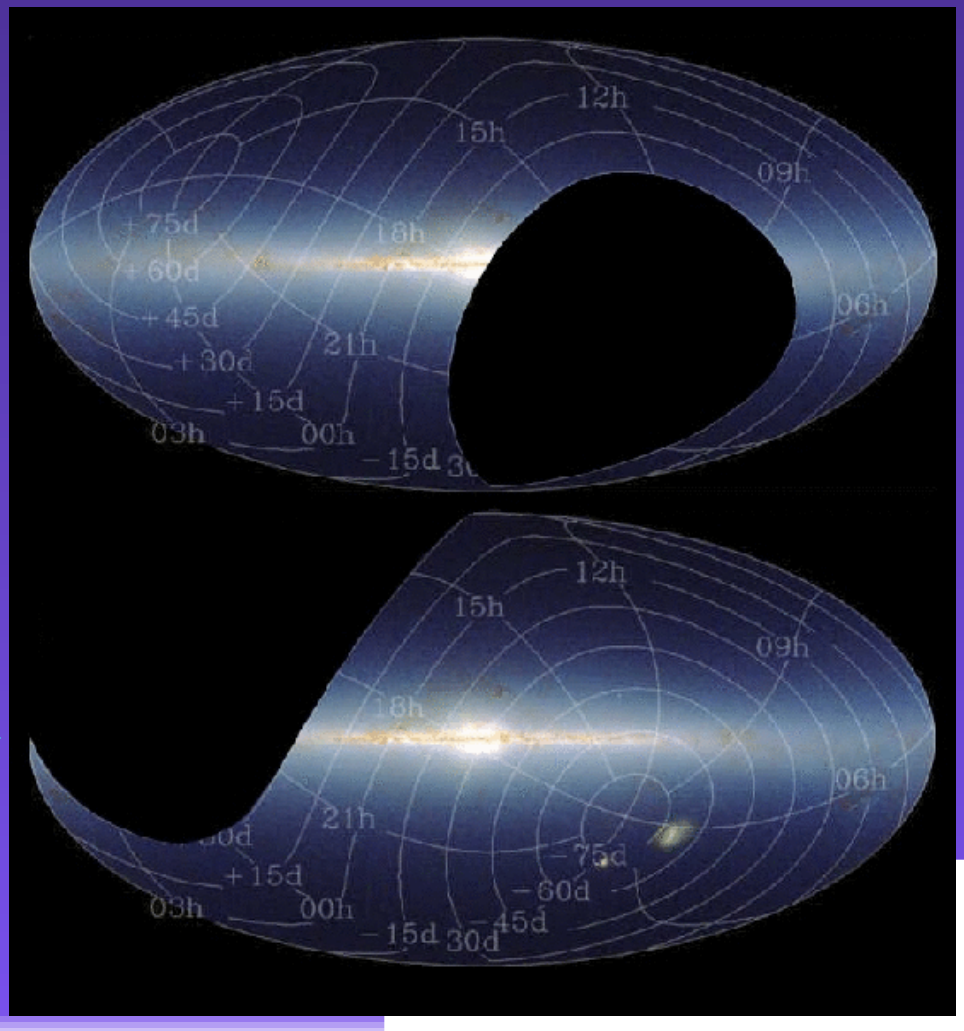
Apache Point Observatory

7 sq deg. →



Las Campanas Observatory

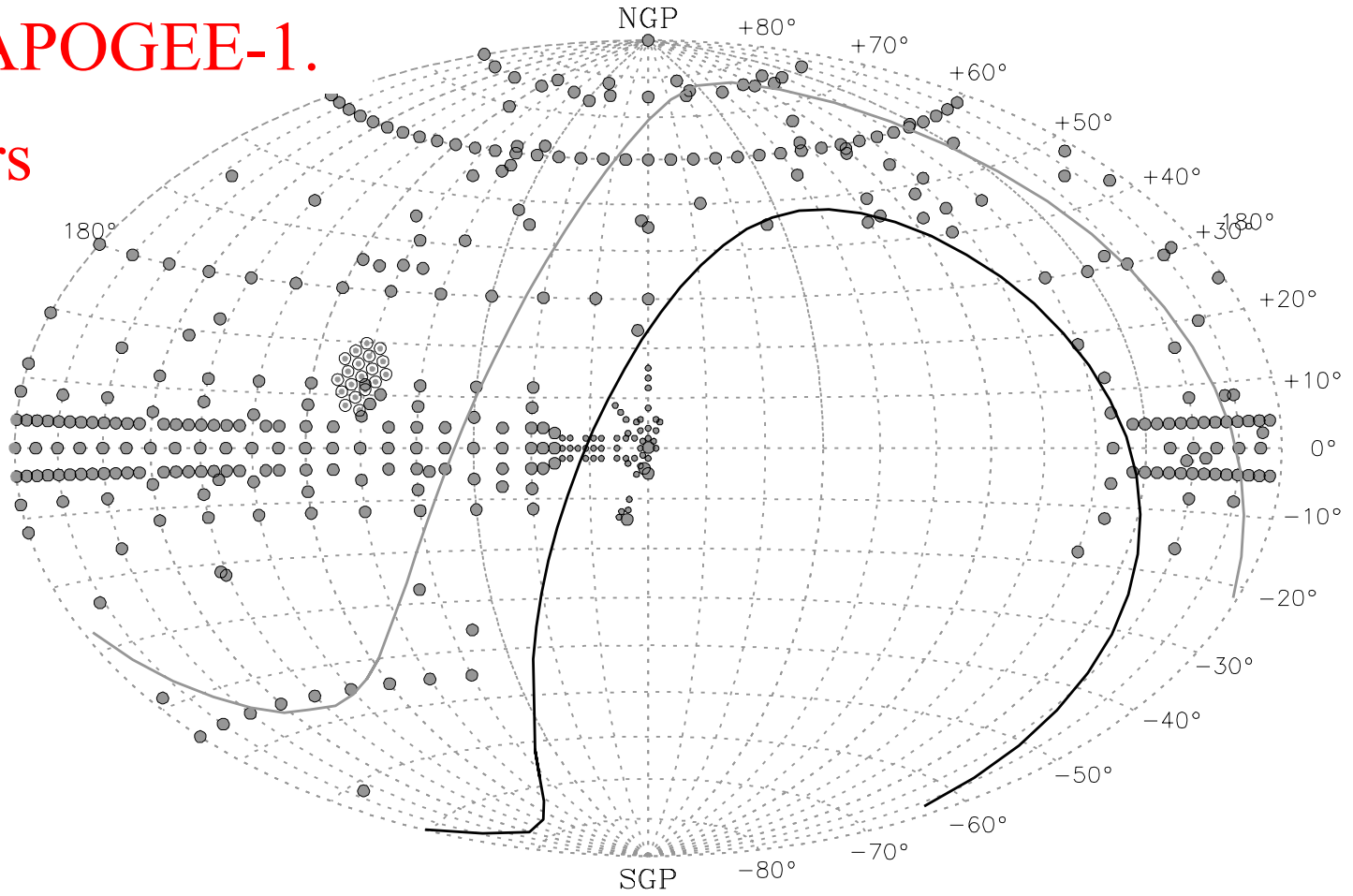
2.5 sq deg →



APOGEE-1 Sky Coverage

100,000 stars in APOGEE-1.

150+ Star Clusters



APOGEE-II (6 years @ 43% observing)

- SDSS-III/APOGEE fields
- 12-hr fields
- 10-hr fields (Kepler)
- 6-hr fields
- 3-hr fields

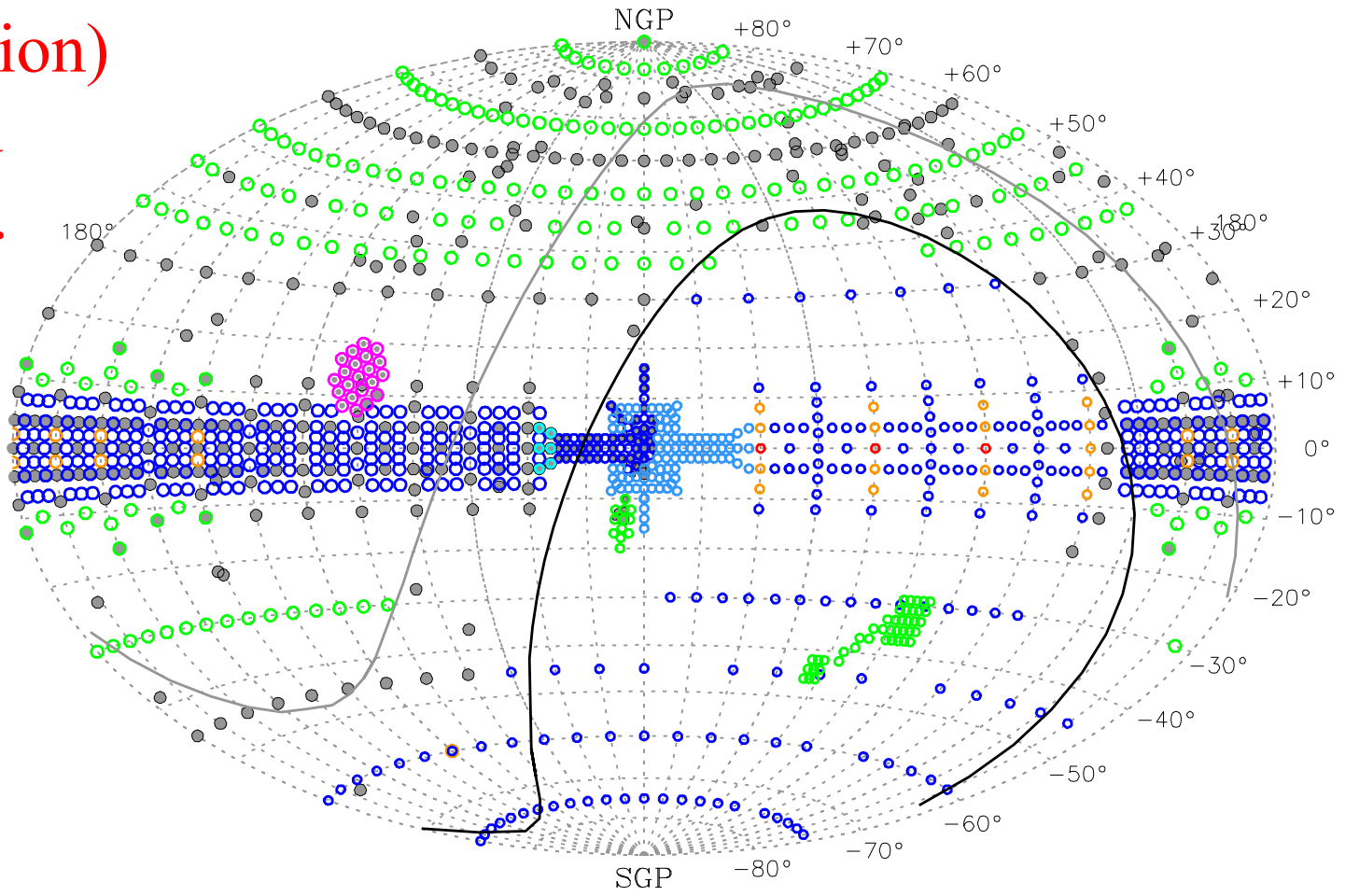
APOGEE-S (400 nights)

- SDSS-III/APOGEE fields
- 1-hr Bulge fields
- 3-hr + 1-hr Bulge fields
- 6-hr LMC/SMC & Sgr fields
- 3-hr fields
- 12-hr fields
- 24-hr fields

APOGEE-2 Sky Coverage

500,000 (1/2 million) stars in combined APOGEE-1 & -2.

Up to 1000 Star Clusters



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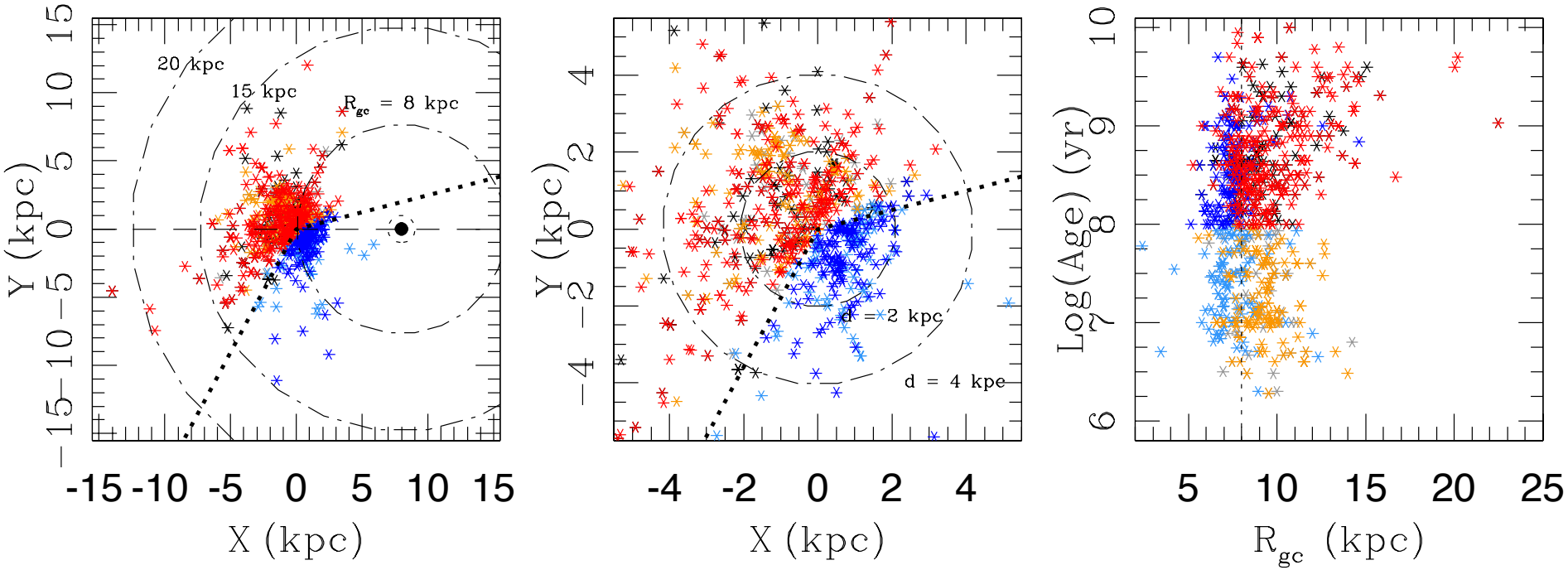
- 24-hr fields

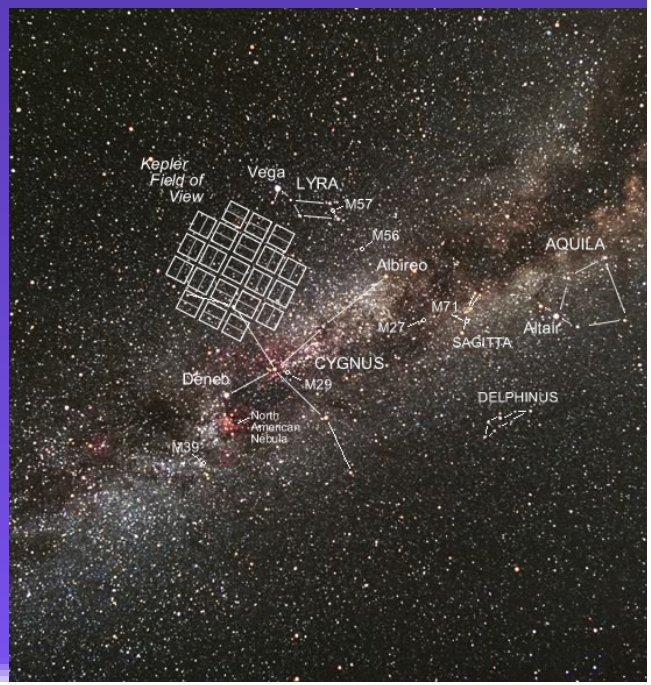
APOGEE-2: Open Clusters

- Use star clusters with reliable ages and distances.
- Up to 1000 open cluster targets.
- Uniform analysis for many elements ([Fe/H], [α/Fe], C, N, …)



Science of an APOGEE-2/North

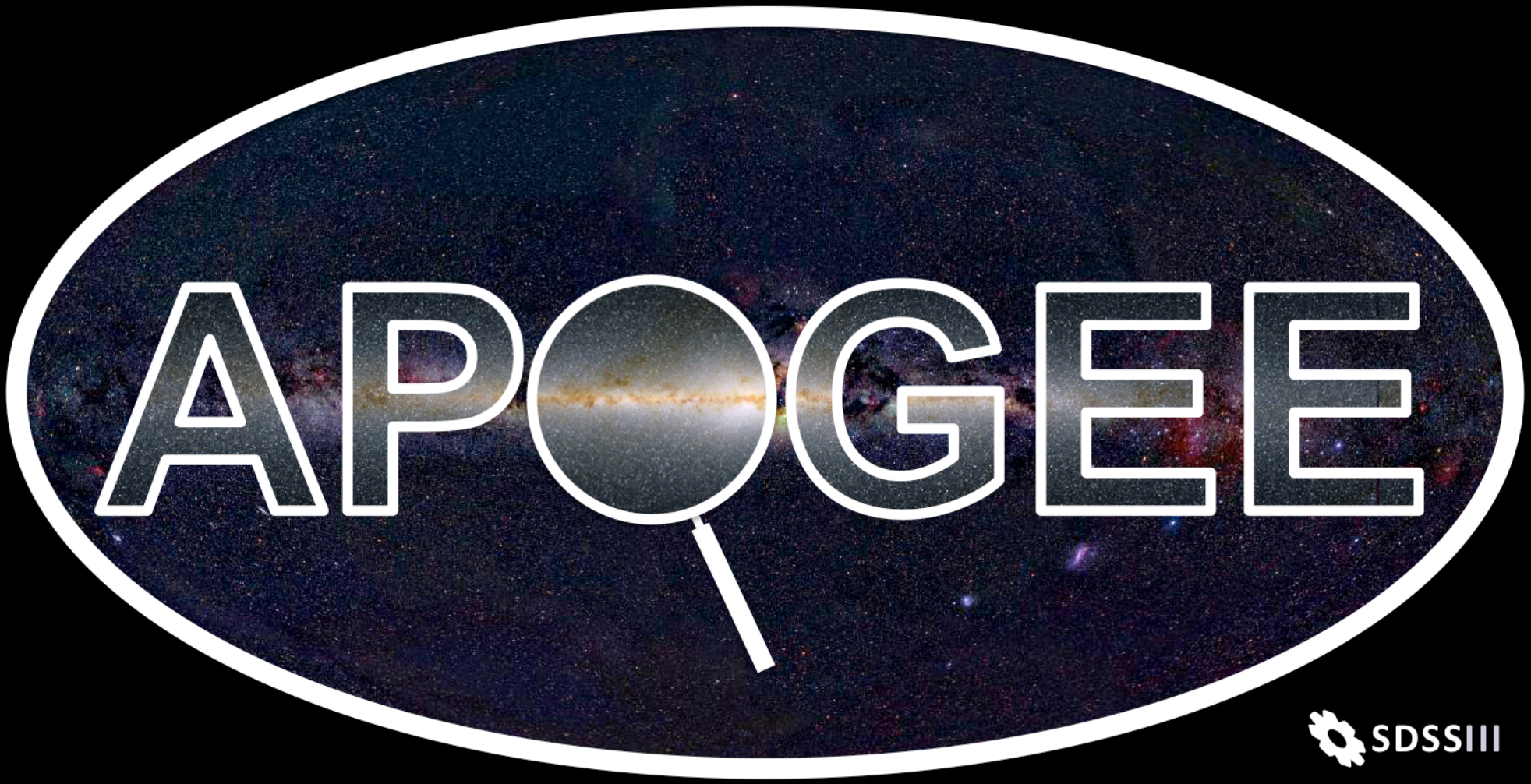
- Significantly increase open cluster, halo, thick disk outer disk samples.
- Substantially boost overall statistics, observing from Day 1.
- Opportunity for increasing time series work.
  - stellar and substellar companions leveraging RV precision.
  - both 1-m dark time & 2.5-m bright time operations continue.
- Expand extremely useful synergy with Kepler mission.
  - 10 visits per tile.
  - increase asteroseismology sample.
  - characterize planet/non-planet hosts.
  - robustly assess Kepler false alarm rate.
  - dynamical masses from elipsing binaries.
  - continue contributing to fundamental astrophysics.



Science of an APOGEE-2/South

- Significant/homogeneous surveys of 4 other Local Group galaxies:
  - Large and Small Magellanic Clouds, Sagittarius, ω Centauri
- Halo/disk substructure and (as)symmetries
  - Disk/bar/spiral arm symmetry by inclusion of III and IV quadrants.
  - Clear views of Monoceros/Canis Major/Argo (warp or tidal stream?).
  - Disk warp and disk edge/truncation.
  - Far side of the disk, beyond bulge.
  - Follow-up for southern hemisphere photometric surveys (VVV and SkyMapper).
- Star cluster chemistry (85% of GCs lie below celestial equator)
  - Metal-rich bulge/disk clusters study (not possible in north).
  - Important targets:
    e.g., 47 Tuc, NGC 288/362, N6338/N6441, Sgr & Magellanic clusters.
  - Integrated light in Magellanic clusters.

QUESTIONS?



Logo by Gail Zasowski.