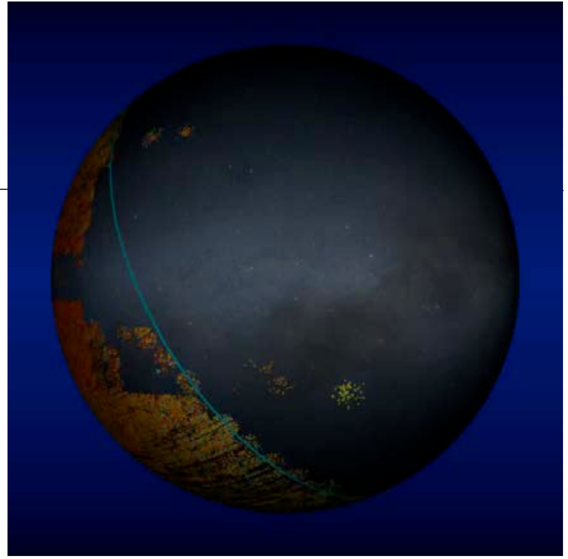
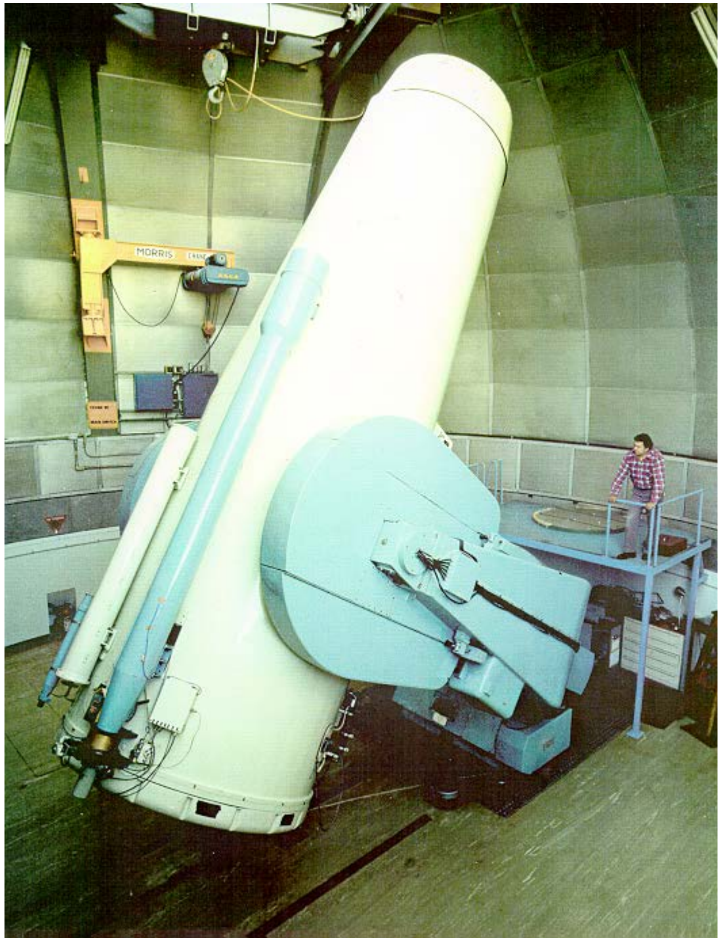
RAVE as a Gaia precursor: what to expect from the RVS?

The RAVE Survey

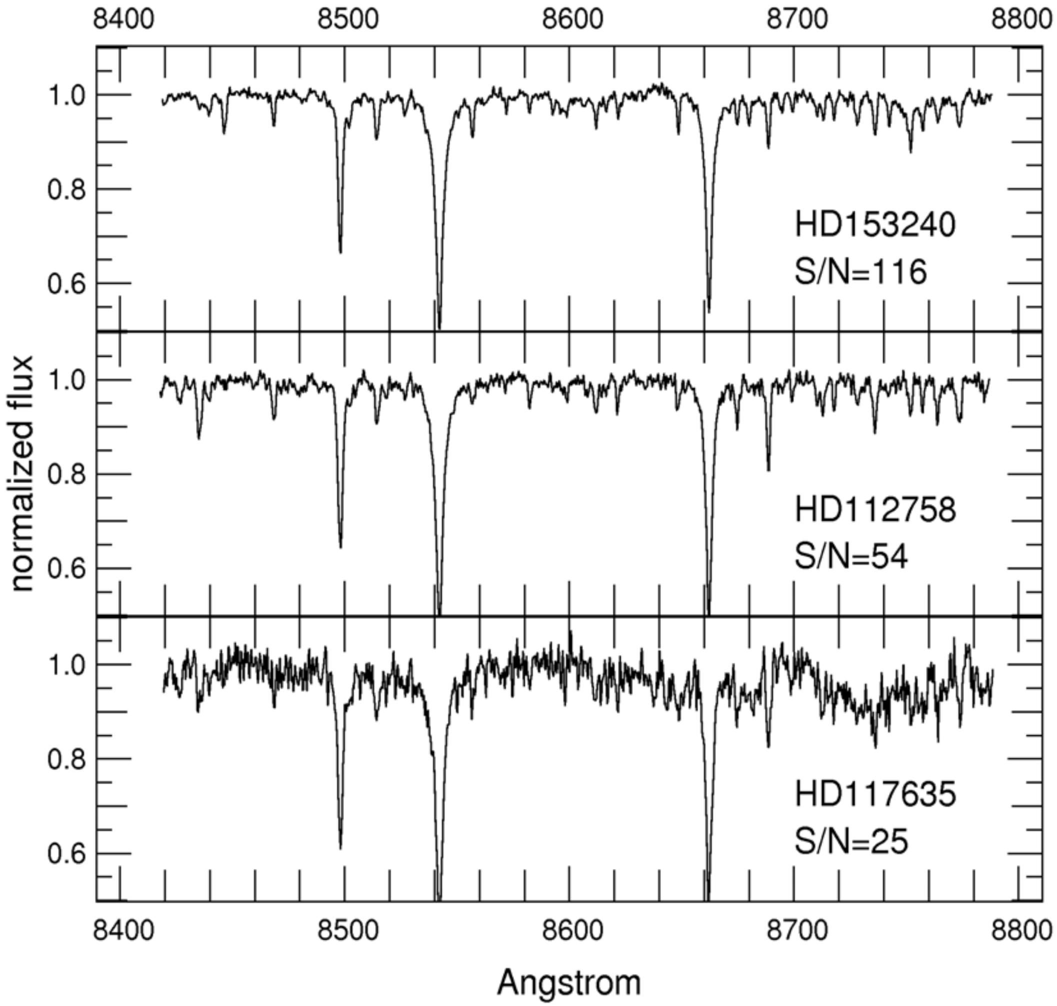


- Spectroscopic high latitude survey of the MW
  - $9 < I < 13$
- GAIA spectral range and resolution
  - Ca triplet region (8400-8800Å), R_{eff}=7500
- 6dF at the 1.2m UKST in Australia
  - 100-120 fibres
  - 38 sqdeg FoV
- Scheduled operation: 4/2003 – 4/2013
  - 7 nights per lunation up to 8/2005
  - 25 nights per lunation since 8/2005
- 574,630 spectra for 483,330 stars
  - catalogue of 40000 active stars



Spectra

λ range: 8410-8795Å (Gaia wavelength range)
Resolution R=7500 at 8600Å; Dispersion = 0.4Å/pix



From the RAVE spectra we obtain:

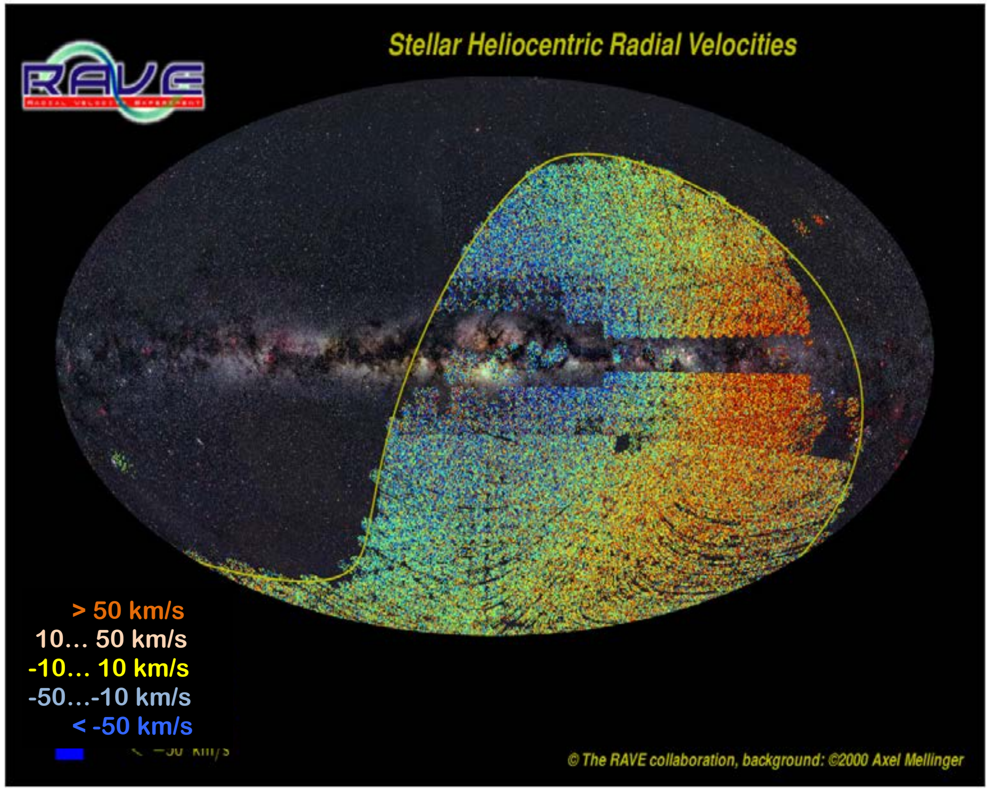
- radial velocities
- stellar parameters (effective temperature, gravity and metallicity)
- chemical abundances
- RAVE + photometry
- distances

4th public data release

Kordopatis et al. 2013

- Intermediate resolution (R~7500)
- 425 561 stars,
- 482 430 spectra

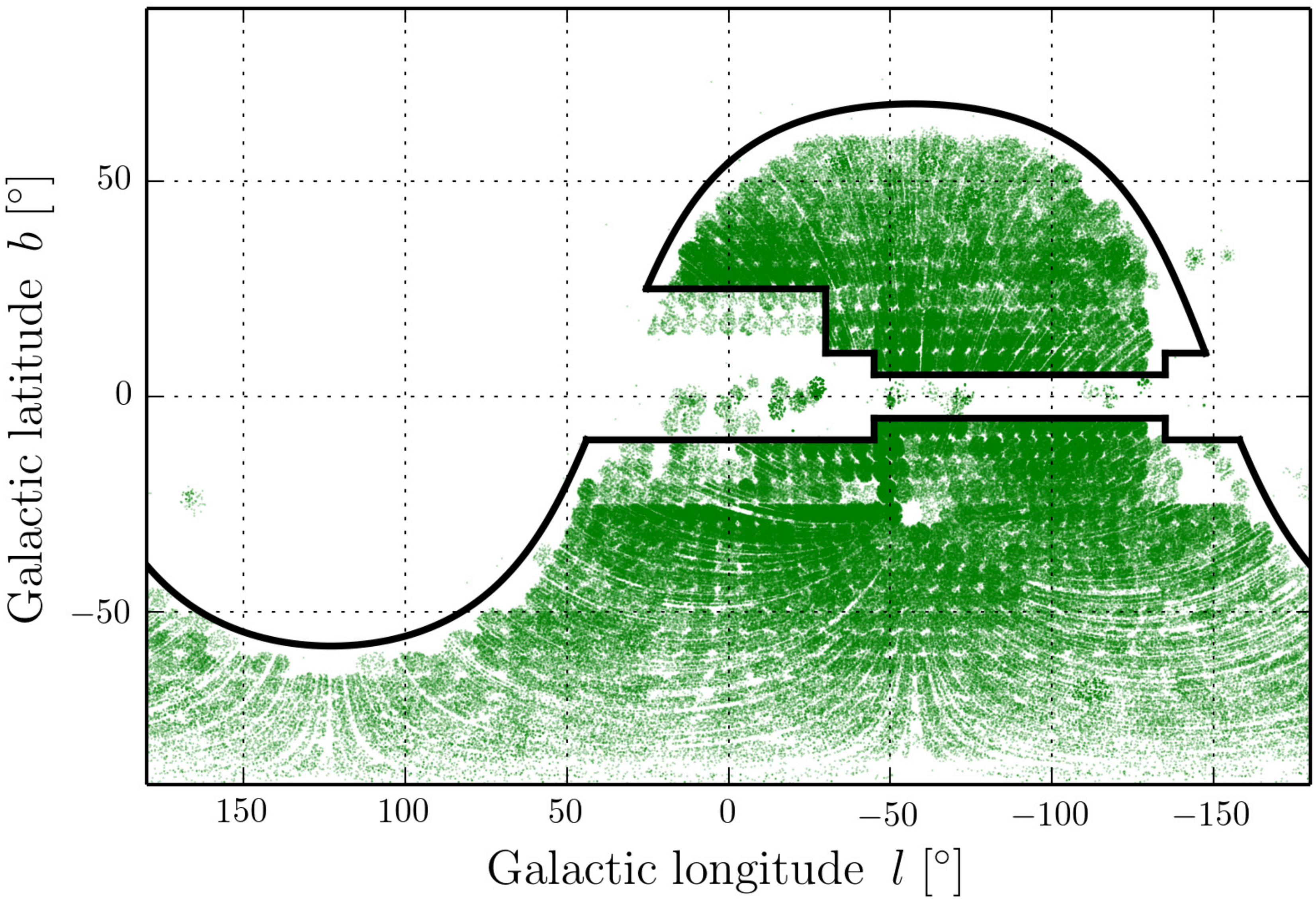
  (DR3: 77 461 stars)
- 9 < I < 12 mag

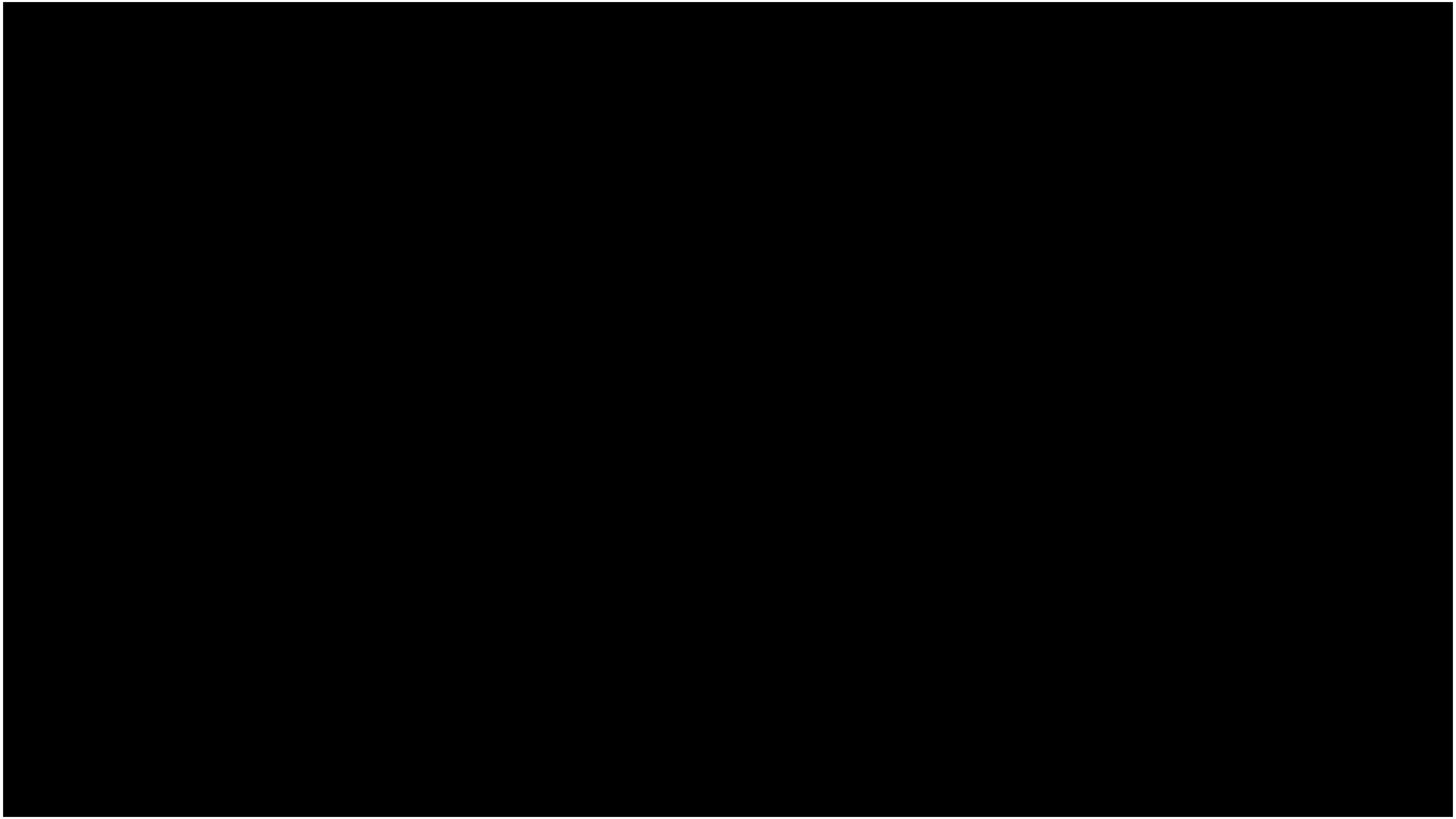


Database:

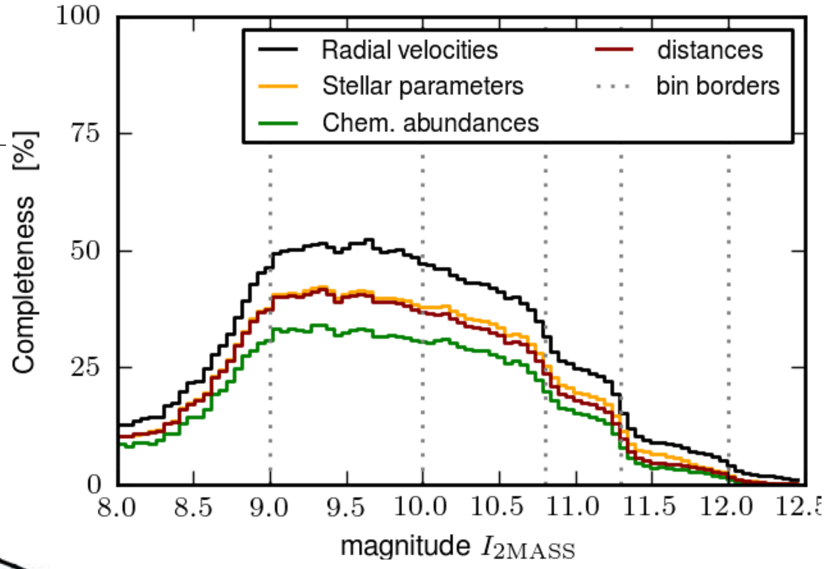
- ✓ Radial velocities
- ✓ Spectral morphological flags
- ✓ T_{eff}, logg, [M/H]
- ✓ Mg, *Al, Si, Ti, Ni, Fe*
- ✓ Line-of-sight Distances
- ✓ Photometry:
  DENIS, USNOB, 2MASS, APASS
- ✓ Proper motions:
  UCAC4, PPMX, PPMXL, Tycho-2, SPM4

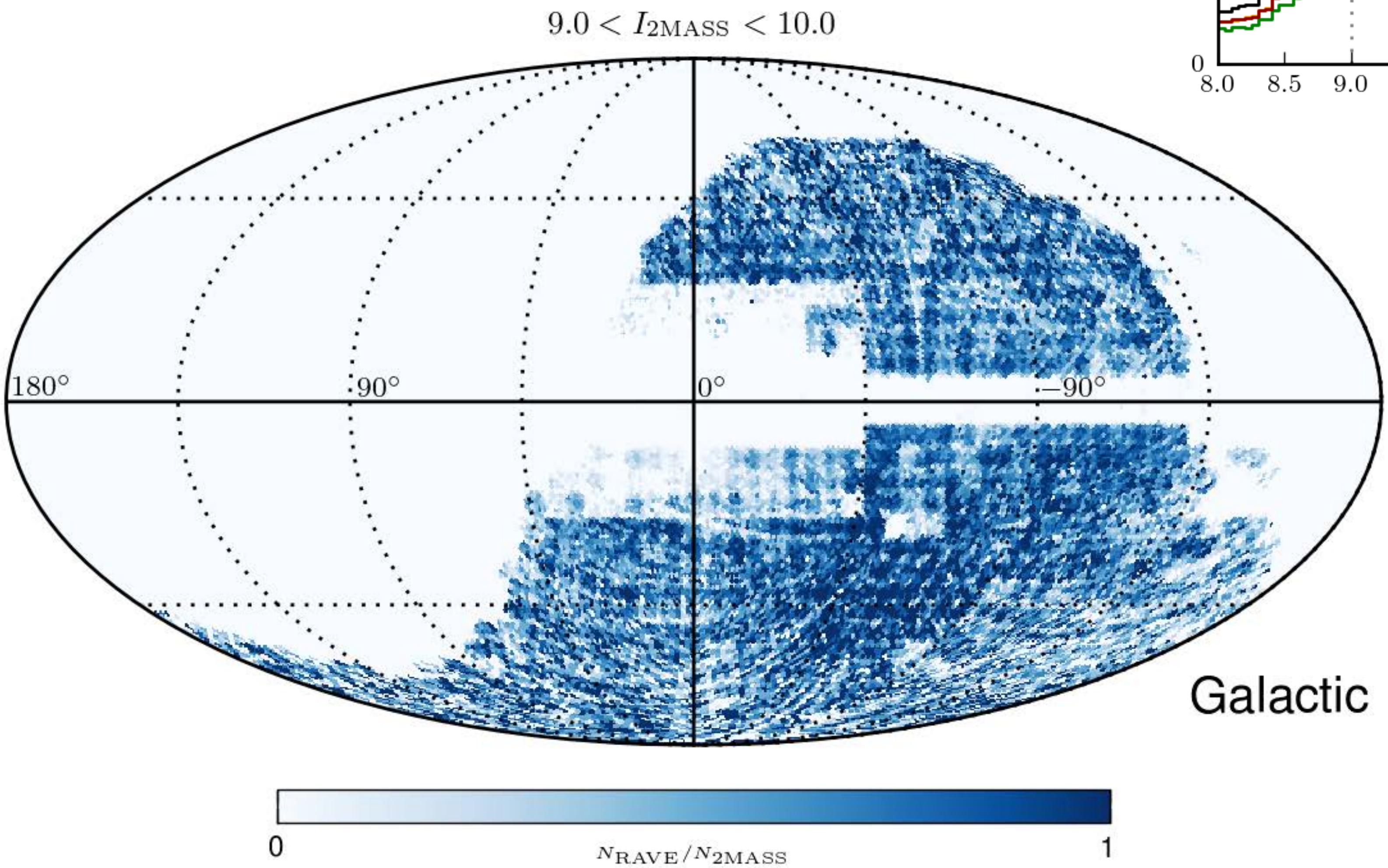
RAVE selection function: DR4 footprint



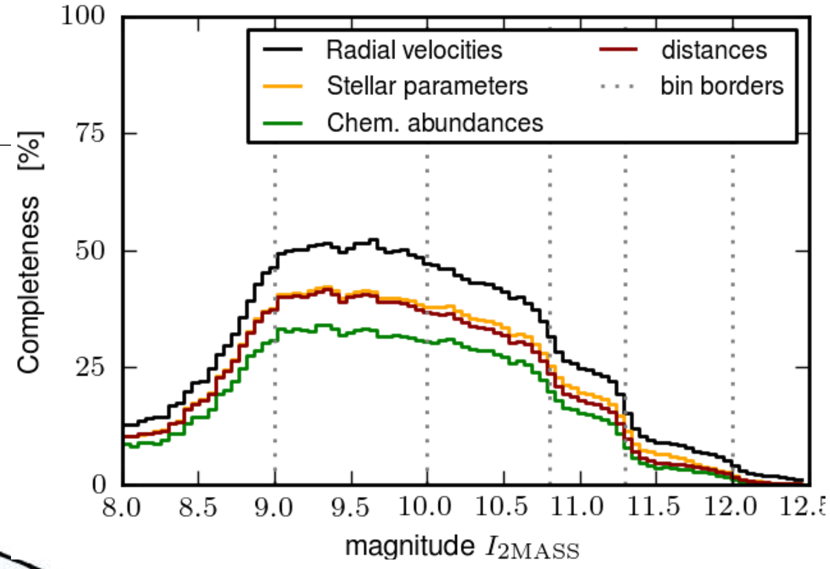


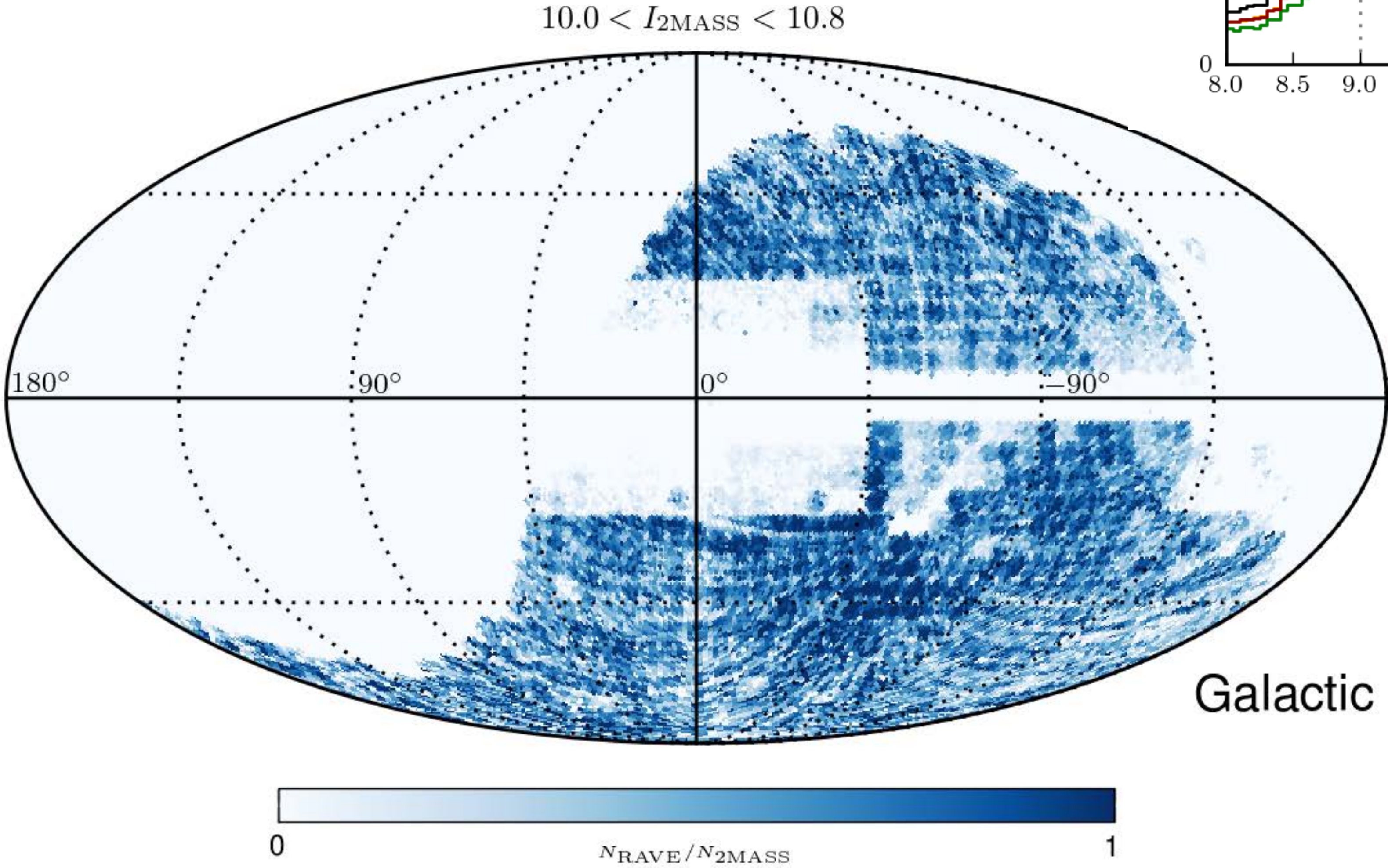
RAVE completeness



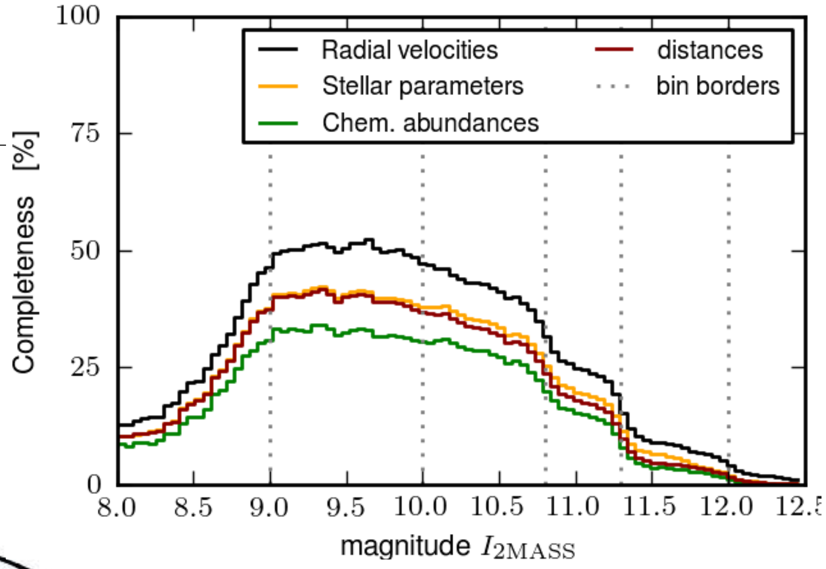


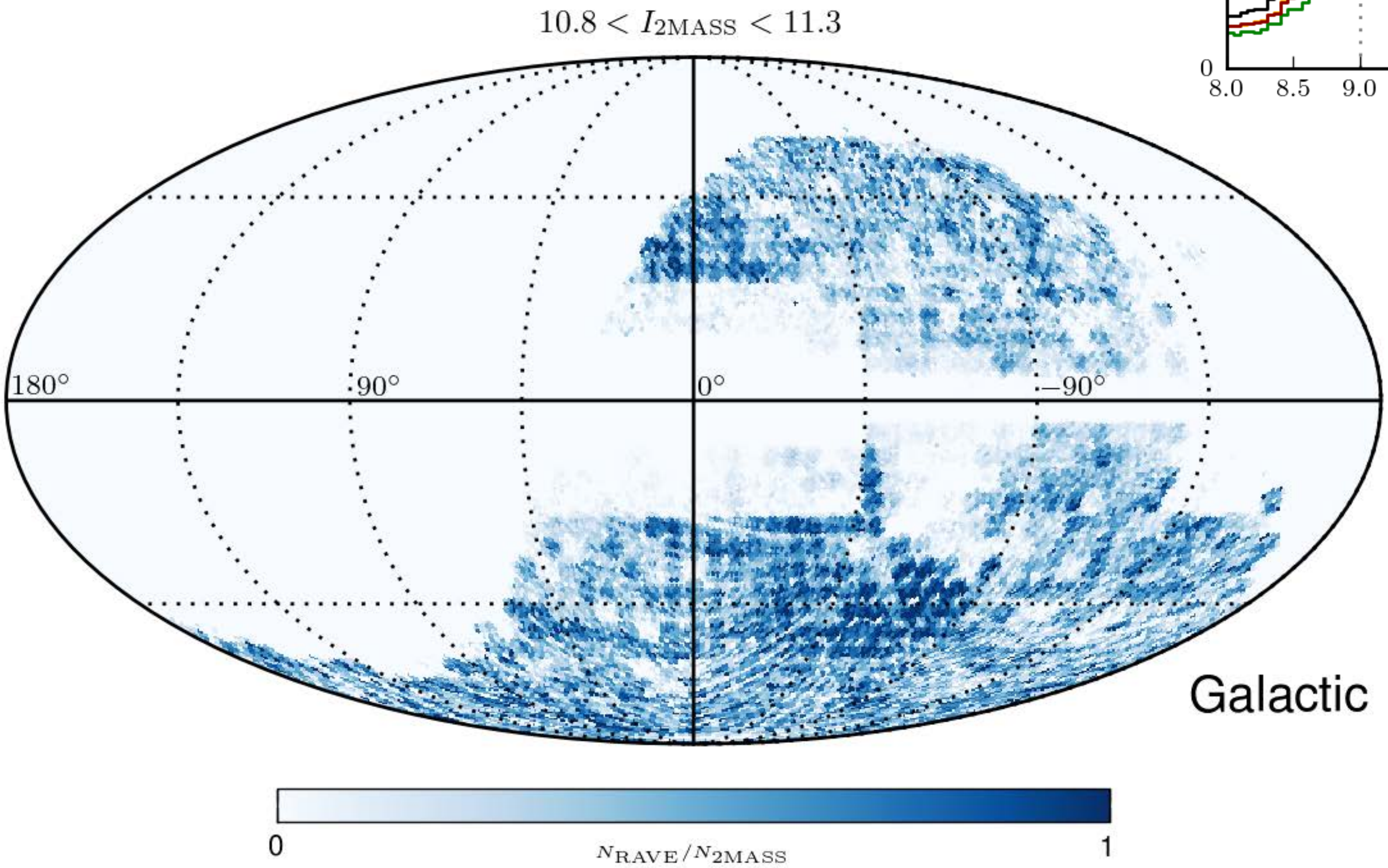
completeness



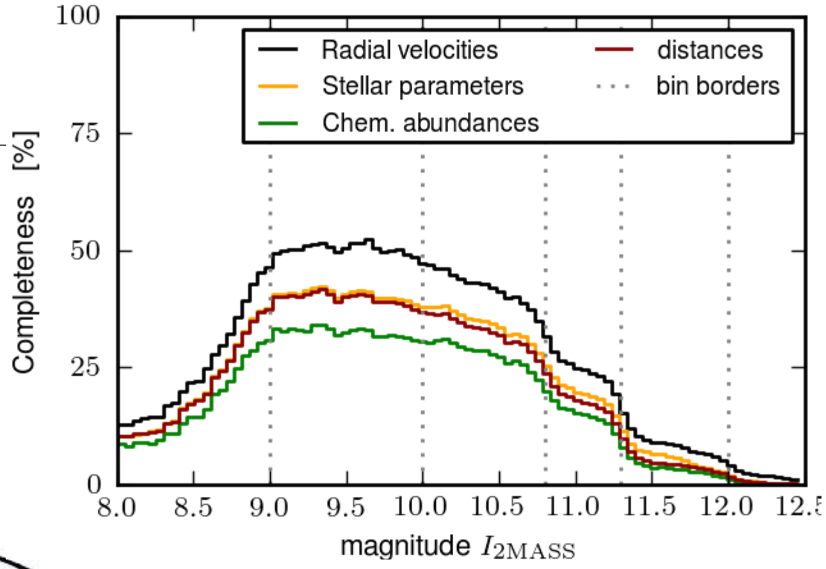


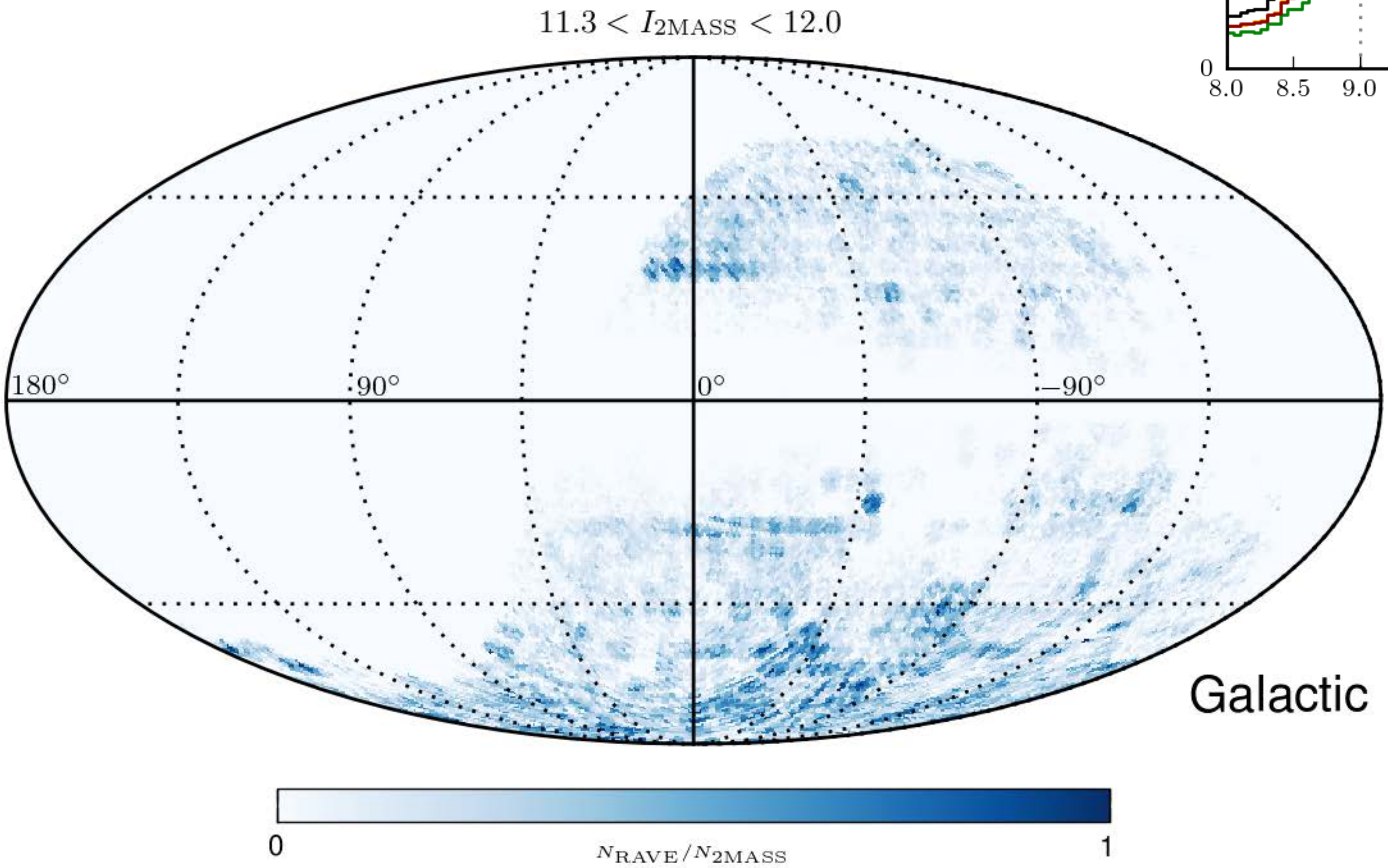
RAVE completeness





completeness





Galactic

RAVE DR4 vs Gaia

RAVE DR4

- R~7500
- 425 561 stars,
- 482 430 spectra

  (DR3: 77 461 stars)
- 9 < I< 12 mag

Gaia:

R~11 500 for bright targets

R~7 000 for faintest targets

Same λ coverage (CaII triplet)

~10^7 -- 10^8 targets with spectra

Database:

✓ Radial velocities

✓ Spectral morphological flags

✓ T_{eff}, logg, [M/H]

✓ Mg, *Al, Si, Ti, Ni, Fe*

✓ Line-of-sight Distances

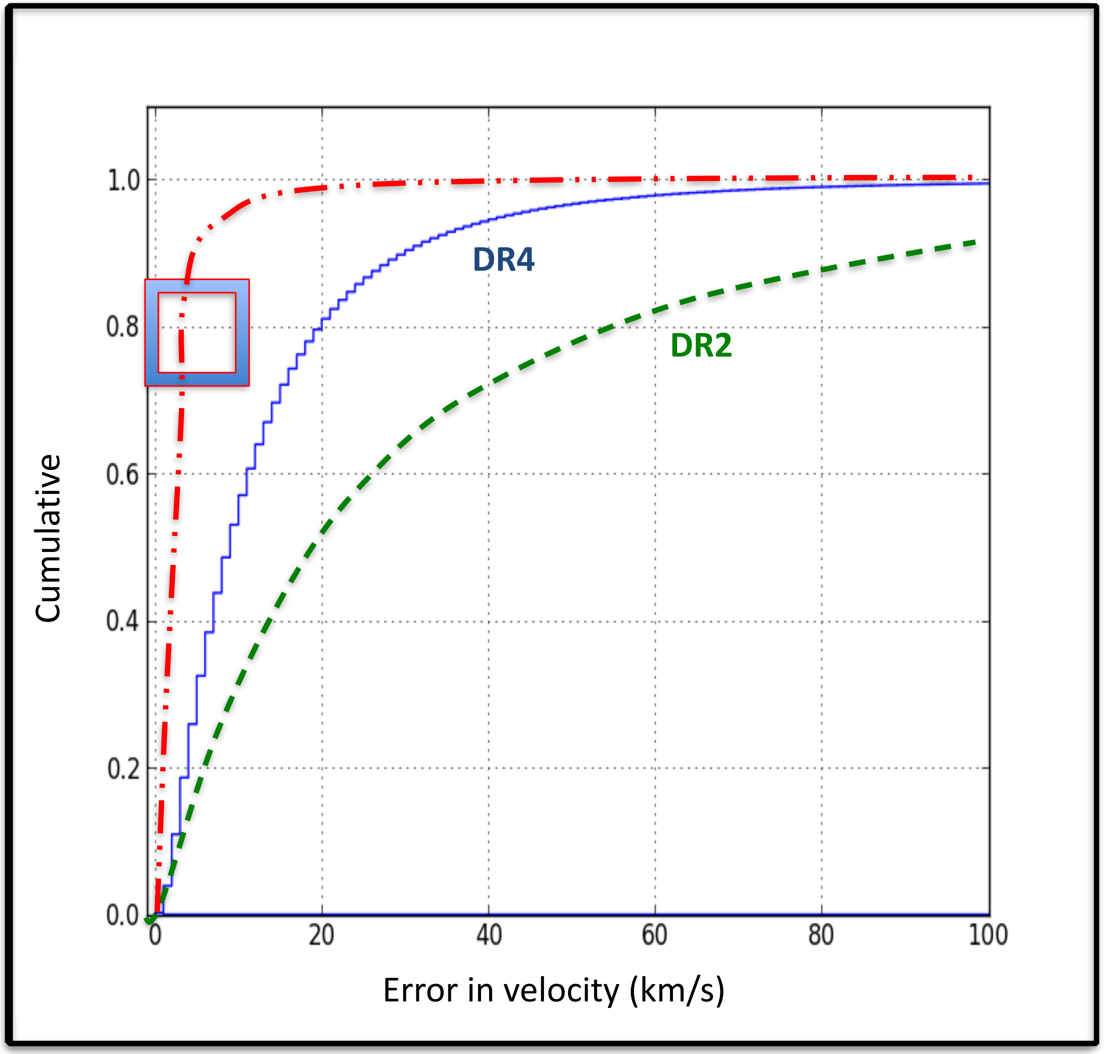
✓ Photometry:

DENIS, USNOB, 2MASS, APASS

✓ Proper motions:

UCAC4, PPMX, PPMXL, Tycho-2, SPM4

RAVE's Galactic 3D velocity errors



Combination of:

Distance errors ~~(<30%)~~ (<10%)

+Errors in RV

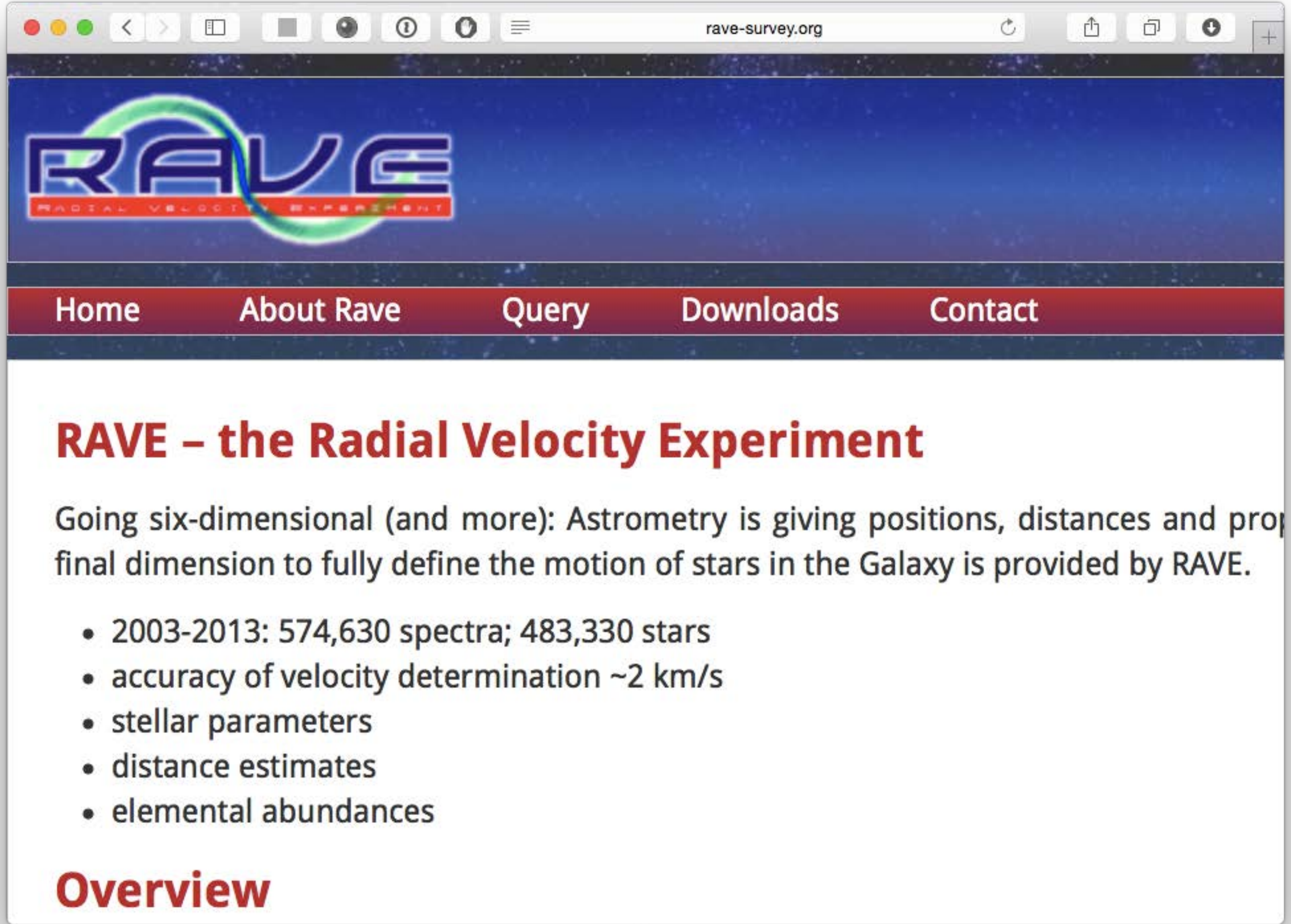
(95% of the stars $\Delta V_{rad} < 4$ km s^{-1})

+Errors in proper motions

~~(~3 mas yr^{-1})~~ 50 μas yr^{-1}

RAVE: 80 % of the stars with $\Delta V < 20$ km s^{-1}

Gaia: 80 % of the stars with $\Delta V < 5$ km s^{-1}



RAVE – the Radial Velocity Experiment

Going six-dimensional (and more): Astrometry is giving positions, distances and pro
final dimension to fully define the motion of stars in the Galaxy is provided by RAVE.

- 2003-2013: 574,630 spectra; 483,330 stars
- accuracy of velocity determination ~2 km/s
- stellar parameters
- distance estimates
- elemental abundances

Overview

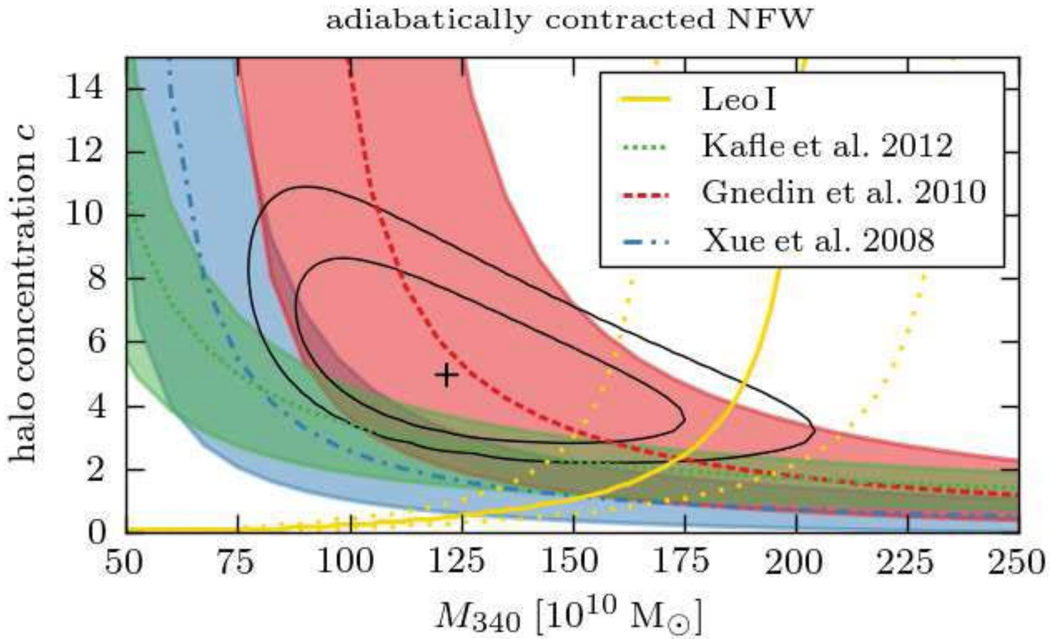
Some recent Applications

Escape speed of the Milky Way at the Solar Circle

- Leonard & Tremaine (1990):
  - consider distribution function f(E)
  - $f \rightarrow 0$ as $E \rightarrow \Phi(r_{vir}) \Rightarrow n(v) \propto (v_{esc}-v)^k$
- Consequently for line of sight:

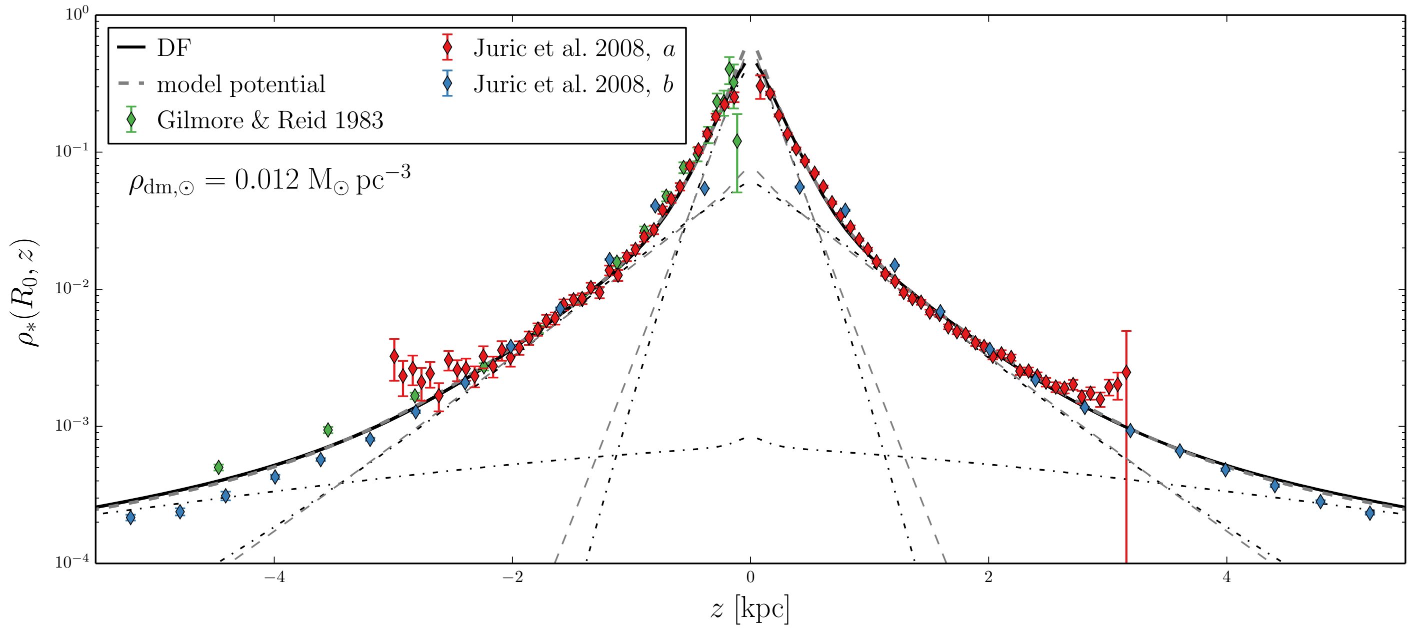
$$n(v_{\|}) \propto (v_{esc} - v_{\|})^{k+1}$$

- Dependence verified via cosmological simulations
- Measure distribution $n(v_{\|})$ for high velocity stars with RAVE on counterrotating orbits
- Piffl et al (2014a):
  $493\text{km/s} < v_{esc} < 587\text{km/s}$
  $1.1\times10^{12}M_{\odot} < M_{200} < 2.1\times10^{12}M_{\odot}$

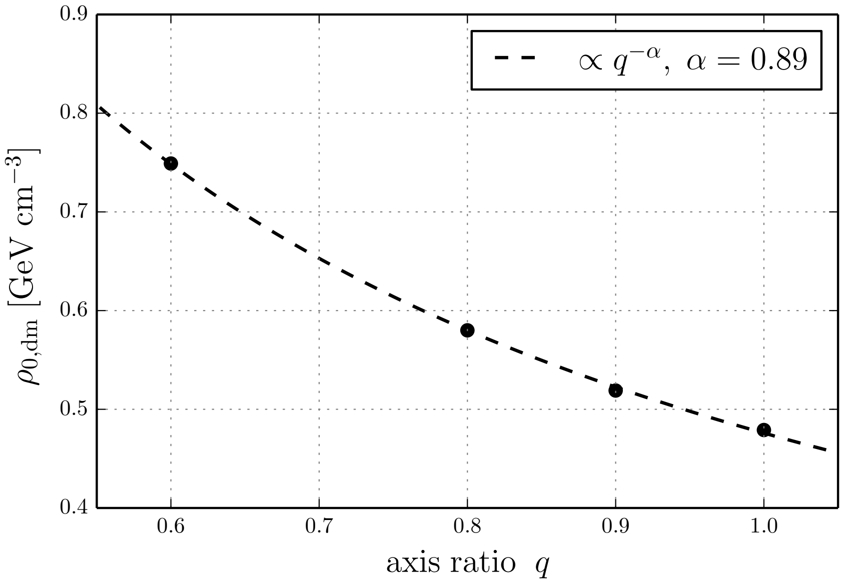


Dark mass in the solar neighborhood (Piffl et al 2014)

- Mass Model:
  - three exponential disks
  - flattened bulge
  - NFW dark matter halo
- Binney 2012 model for kinematics (incl. stellar halo)
- Model fit to vertical RAVE data



Results



Model potential parameters		
$\Sigma_{0,\mathrm{thin}}$	570.7	$\mathrm{M}_\odot\,\mathrm{pc}^{-2}$
$\Sigma_{0,\mathrm{thick}}$	251.0	$\mathrm{M}_\odot\,\mathrm{pc}^{-2}$
R_d	2.68	kpc
$z_{\mathrm{d,thin}}$	0.20	kpc
$z_{\mathrm{d,thick}}$	0.70	kpc
$\Sigma_{0,\mathrm{gas}}$	94.5	$\mathrm{M}_\odot\,\mathrm{pc}^{-2}$
$R_{\mathrm{d,gas}}$	5.36	kpc
$\rho_{0,\mathrm{dm}}$	0.01816	$\mathrm{M}_\odot\,\mathrm{pc}^{-3}$
$r_{0,\mathrm{dm}}$	14.4	kpc
DF parameters		
$\sigma_{r,\mathrm{thin}}$	33.9	$\mathrm{km\,s}^{-1}$
$\sigma_{z,\mathrm{thin}}$	24.9	$\mathrm{km\,s}^{-1}$
$R_{\sigma,r,\mathrm{thin}}$	9.0	kpc
$R_{\sigma,z,\mathrm{thin}}$	9.0	kpc
$\sigma_{r,\mathrm{thick}}$	50.5	$\mathrm{km\,s}^{-1}$
$\sigma_{z,\mathrm{thick}}$	48.7	$\mathrm{km\,s}^{-1}$
$R_{\sigma,r,\mathrm{thick}}$	12.9	kpc
$R_{\sigma,z,\mathrm{thick}}$	4.1	kpc
F_{thick}	0.460	
F_{halo}	0.026	

$$\varrho_\mathrm{DM} = 0.0126 \times q^{-0.89}\mathrm{M}_\odot\,\mathrm{pc}^{-3} \pm 10\%$$

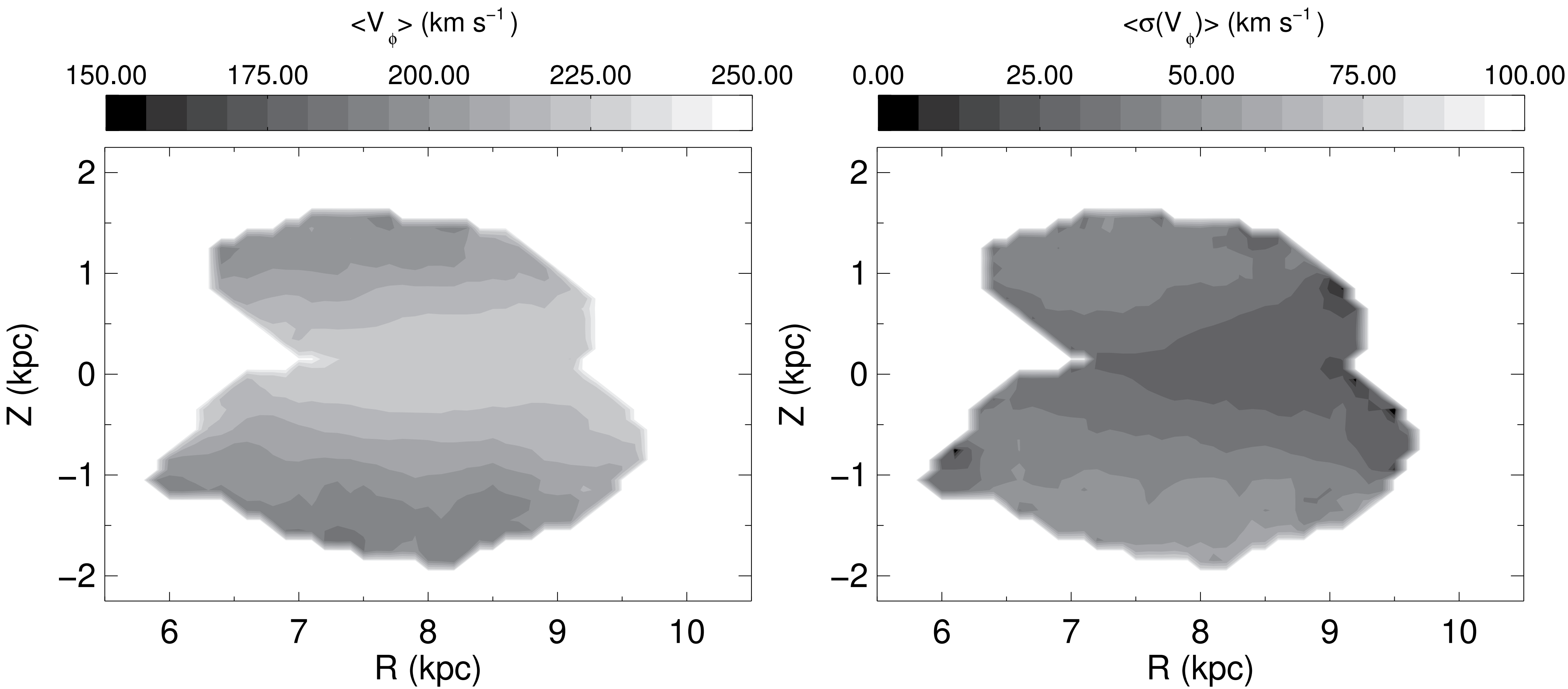
$$\Sigma_\mathrm{DM}(< 0.9\mathrm{kpc}) = (69 \pm 10)\,\mathrm{M}_\odot\,\mathrm{pc}^{-2}$$

$$M_\mathrm{DM}(< R_0) = (6.0 \pm 0.9) \times 10^{10}\,\mathrm{M}_\odot$$

$$M_\mathrm{vir} = (1.3 \pm 0.1) \times 10^{12}\,\mathrm{M}_\odot$$

- 46% of the radial force at R_0 provided by baryons
- Bienamyé et al (2014): RAVE stars towards Galactic Pole, red clump distances: $\varrho_\mathrm{DM}(R=R_0,z=0) = 0.0143\mathrm{M}_\odot\mathrm{pc}^{-3}$

Williams et al., 2013



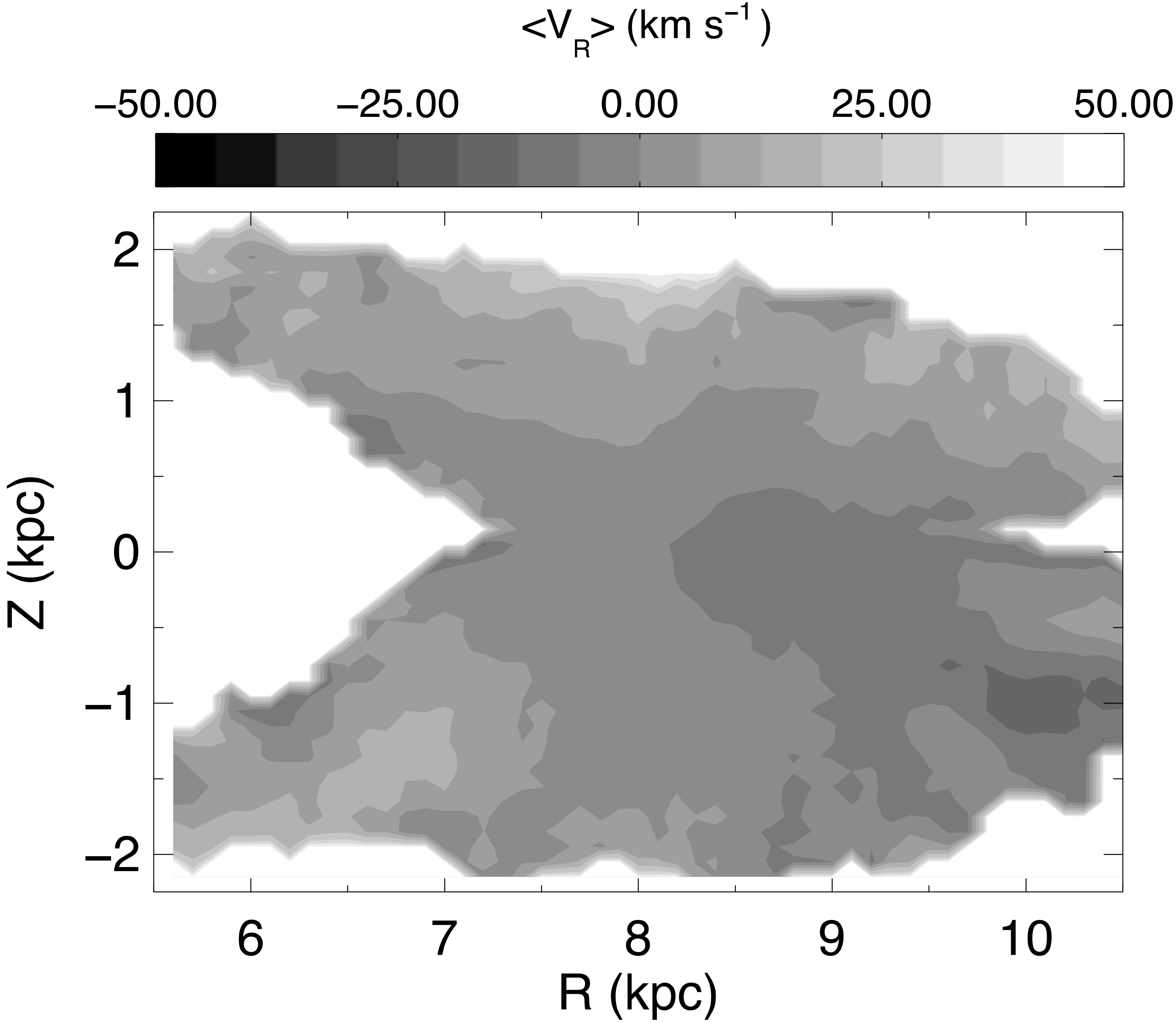
$$V_\phi = 225 + \left(-31.2 + 2.6\frac{R - R_0}{\mathrm{kpc}}\right)\left|\frac{Z}{\mathrm{kpc}}\right|^{1.06} \mathrm{km\,s^{-1}}$$

$$\sigma_\phi = 27.4 - 5.0\frac{R - R_0}{\mathrm{kpc}} + 12.4\left(\frac{Z}{\mathrm{kpc}}\right)^2 \mathrm{km\,s^{-1}}$$

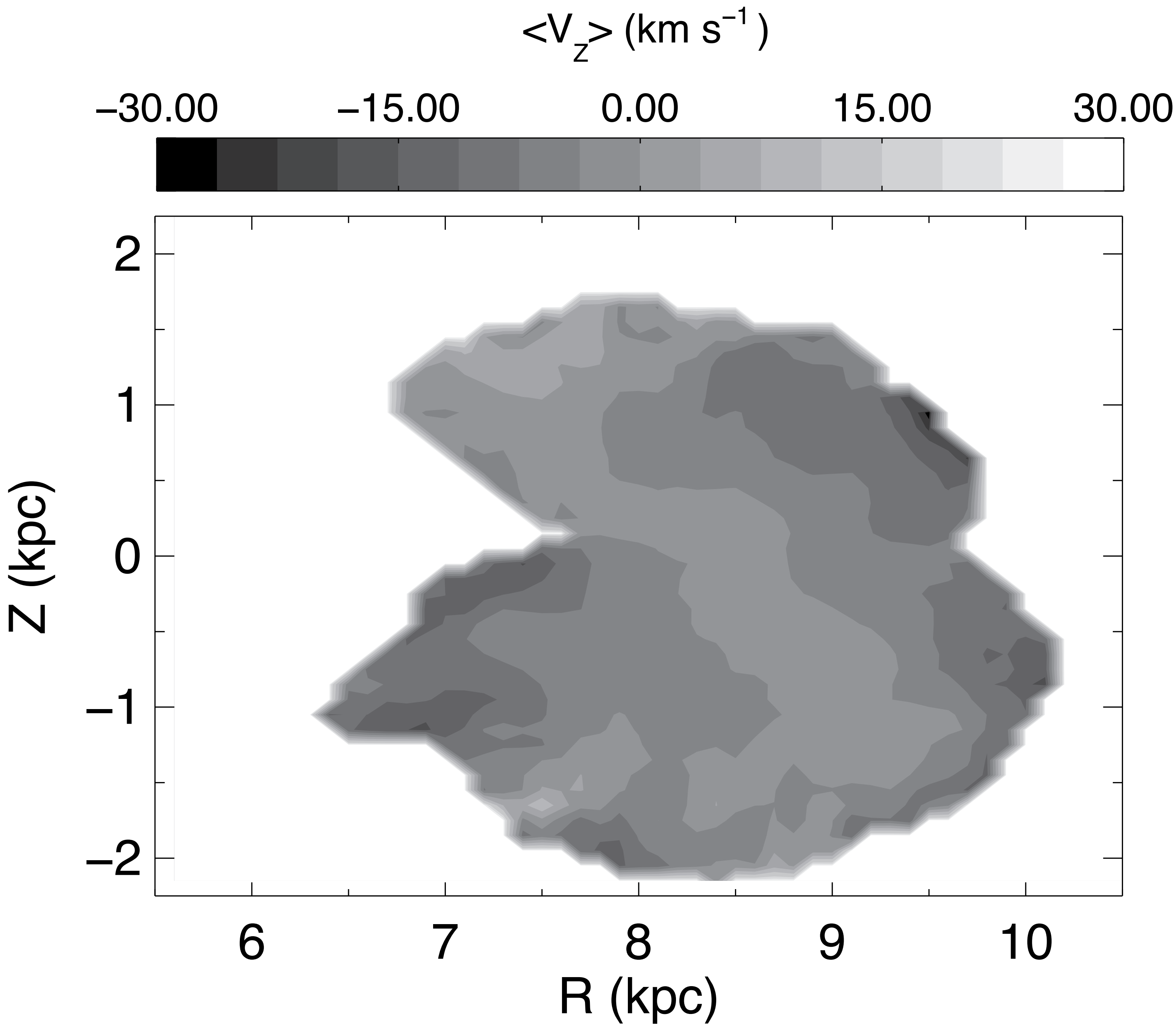
$$\sigma_R = 38.6 - 3.0\frac{R - R_0}{\mathrm{kpc}} + 12.5\left(\frac{Z}{\mathrm{kpc}}\right)^2 \mathrm{km\,s^{-1}}$$

$$\sigma_Z = 16.2 - 3.1\frac{R - R_0}{\mathrm{kpc}} + 8.2\left(\frac{Z}{\mathrm{kpc}}\right)^2 \mathrm{km\,s^{-1}}$$

Williams et al., 2013

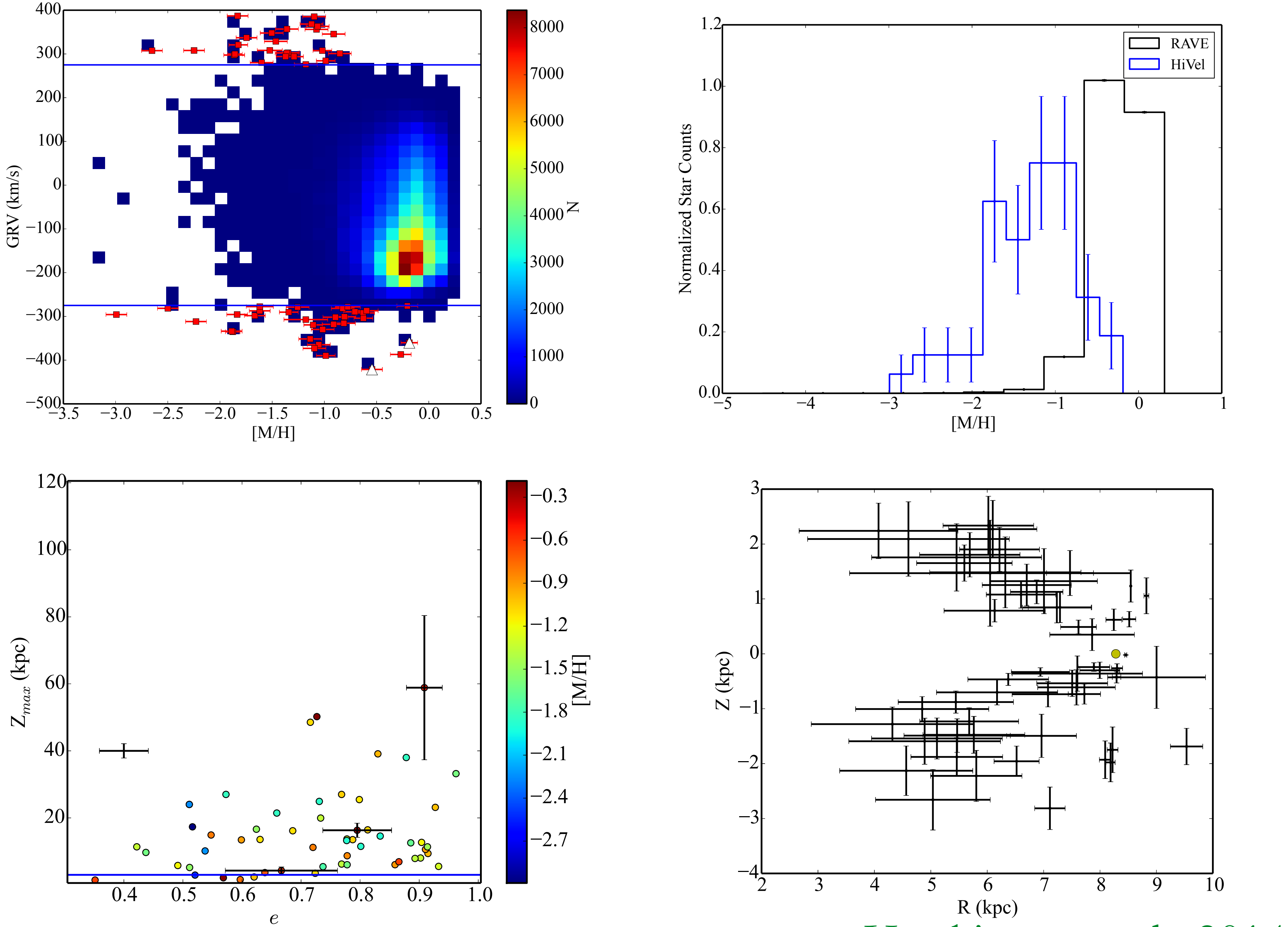


Williams et al., 2013



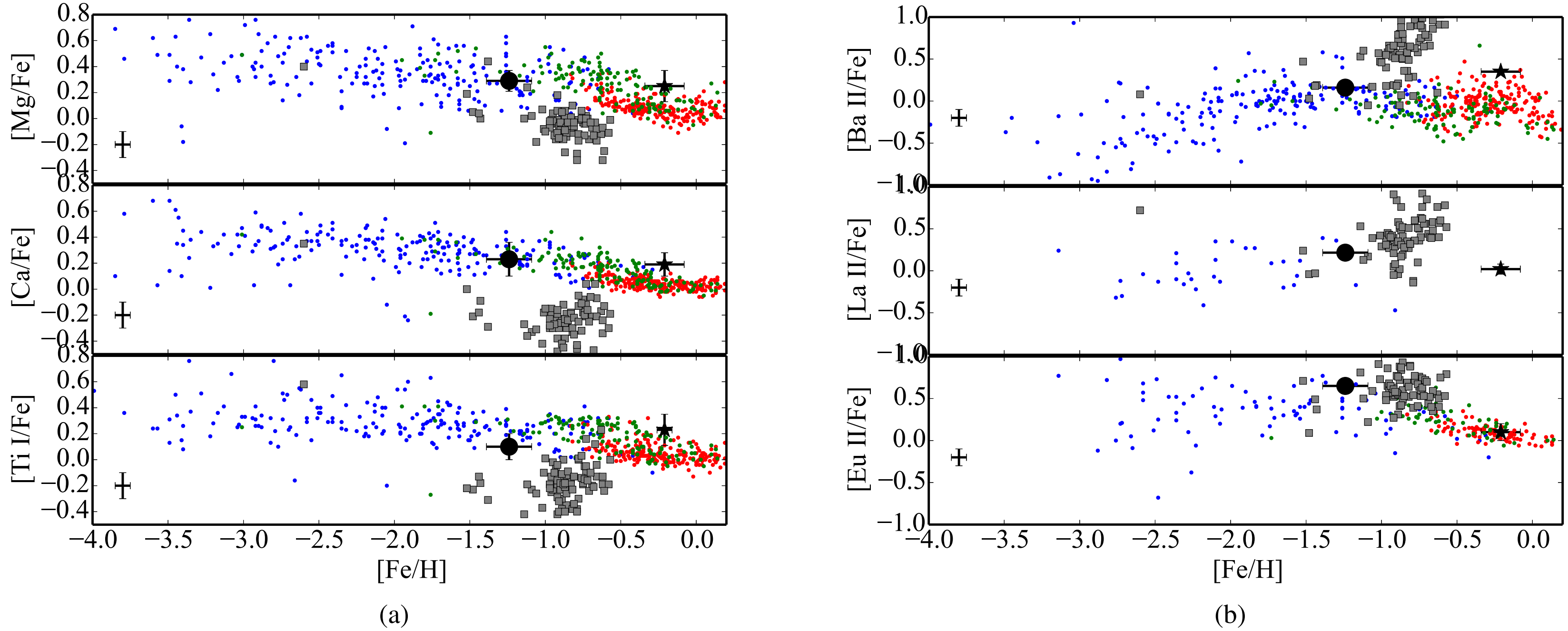
High velocity stars in RAVE

RADIAL VELOCITY EXPERIMENT



Hawkins et et al., 2014

Hyper velocity stars in RAVE



Follow-up Hires spectroscopy of two HVS candidates and comparison to Venn et al (2004)

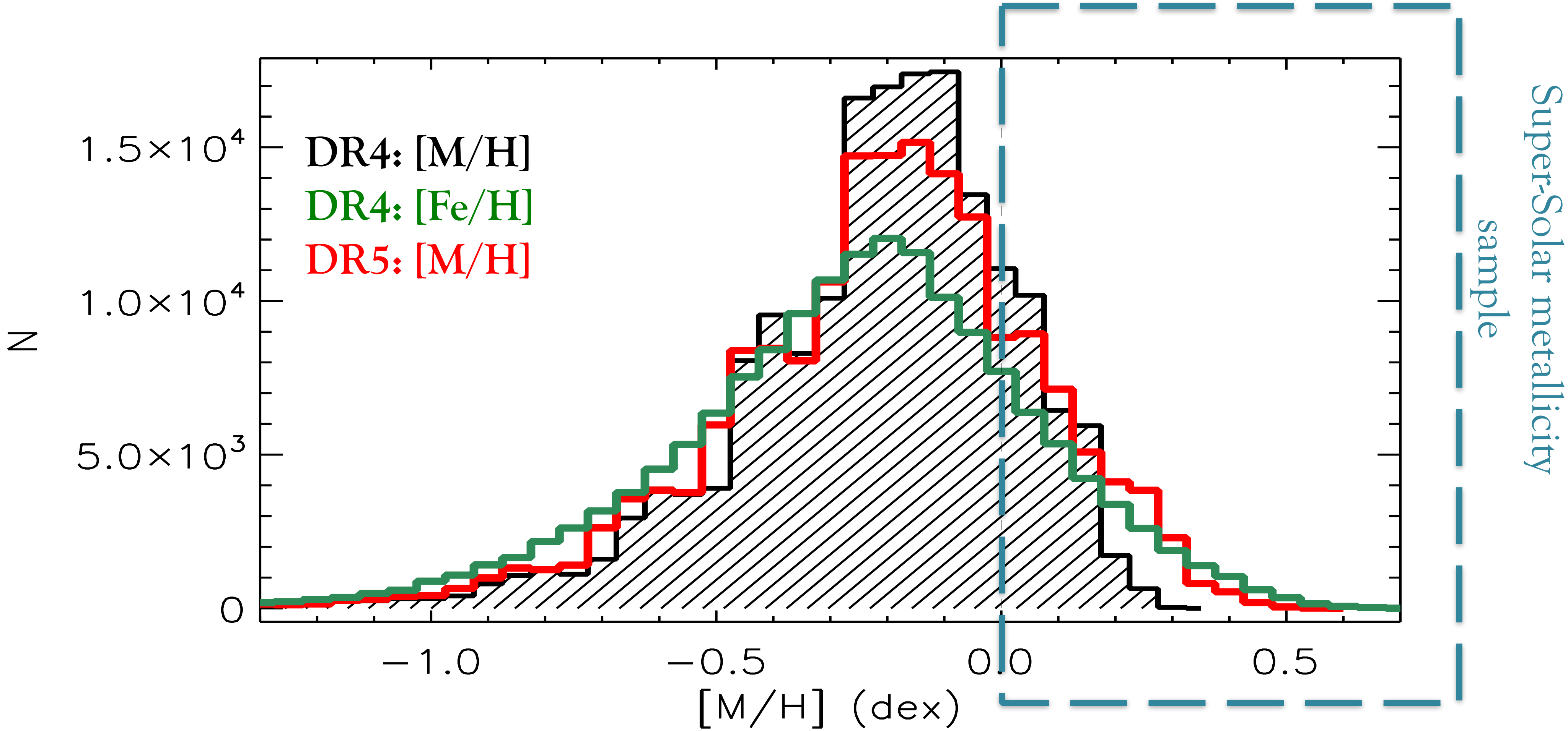
- J154401.1-162451 is chemically consistent with the halo field population or a massive dwarf galaxy
- J221759.1-051149 is chemically consistent with the Galactic thick disk ⇒ must be ejected

Hawkins et et al., 2014

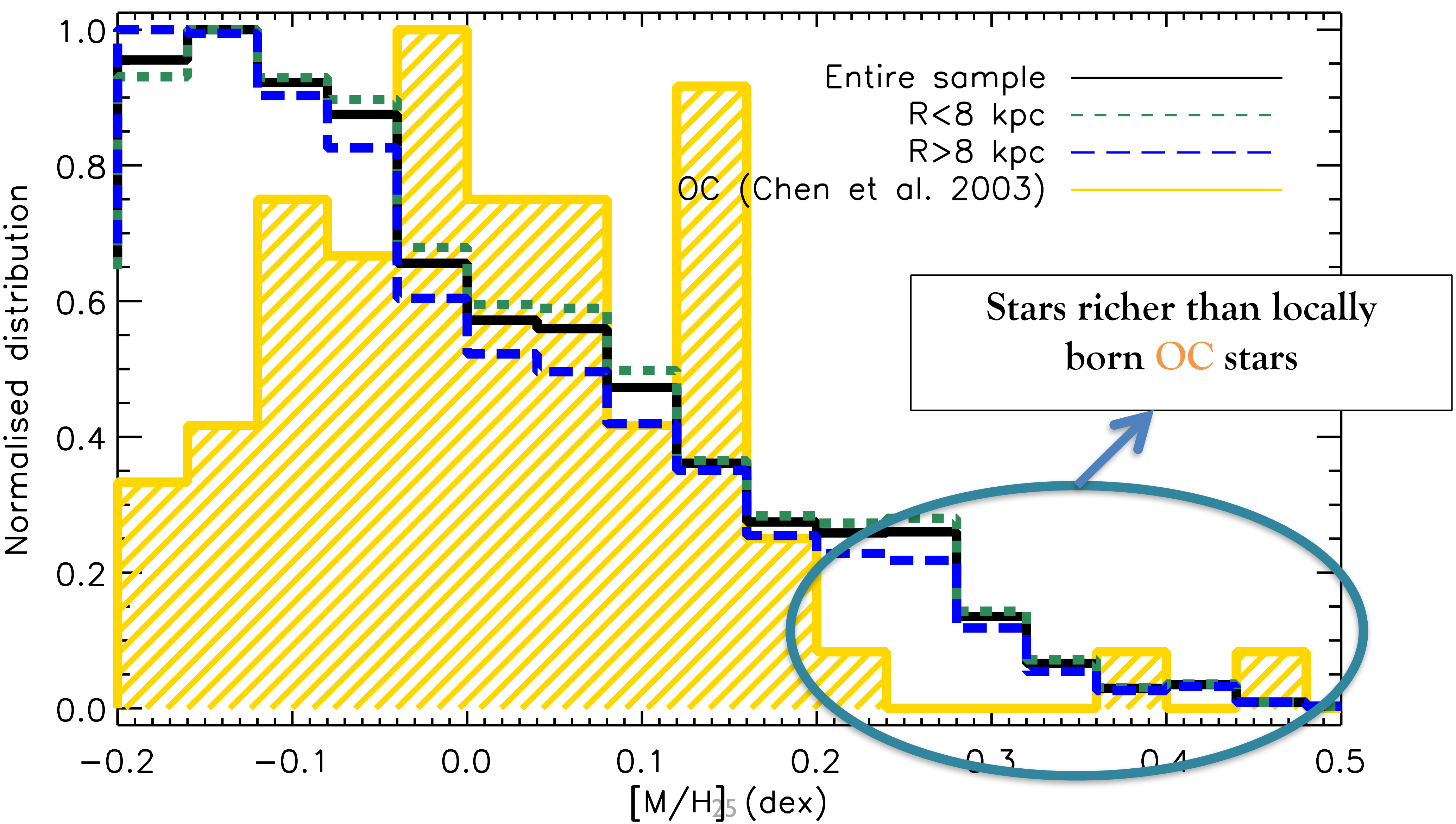
Towards RAVE DR5

- new new data, but considerable number of „problematic“ fields could be recovered
- Revised temperature priors based on optical photometry (APASS)
- Revised calibration at the metal-rich end using GaiaESO benchmark stars (Joffre et al, 2014), HARPS (Adibekyan et al 2013) and FEROS (Worley et al 2012)
- currently being explored: log g and ages from Kepler Astroseismology (see Chiappini talk)

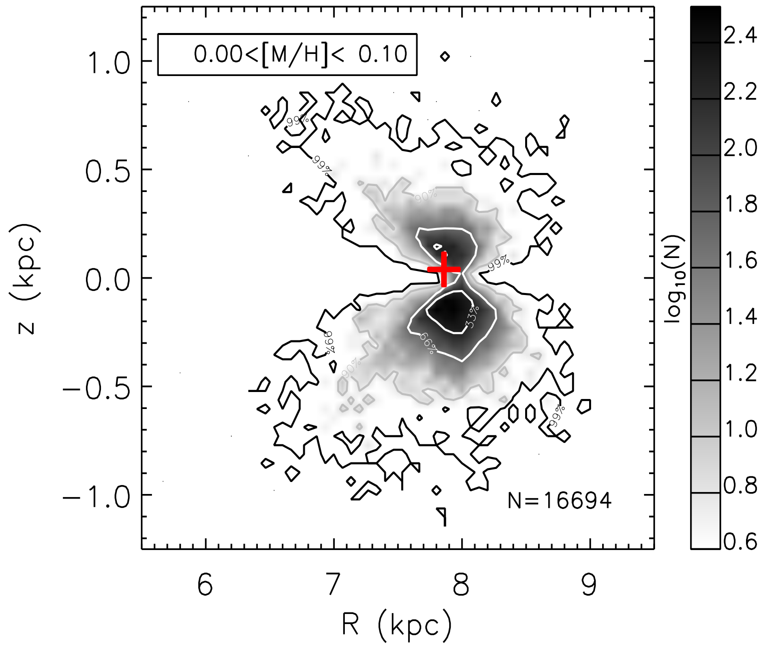
Recalibration of the metal-rich end

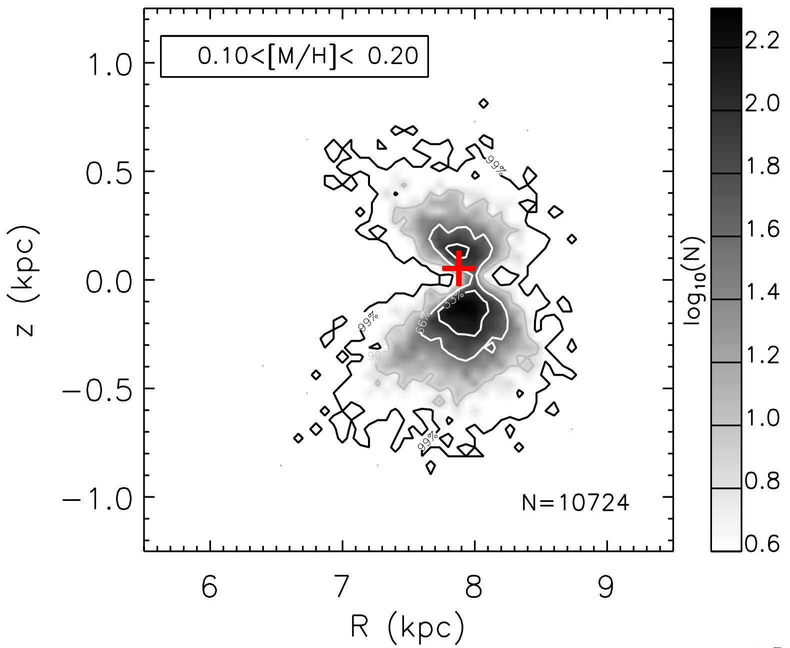


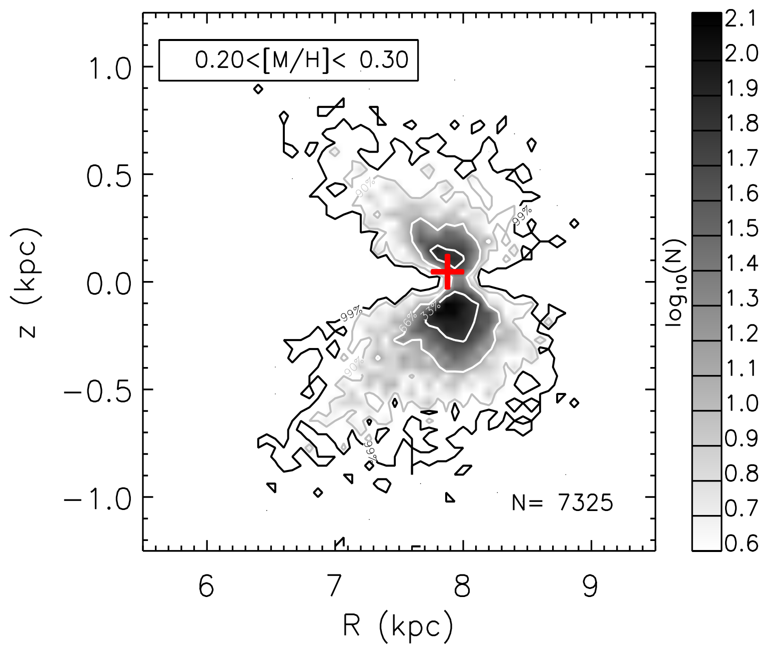
Metallicity distribution function

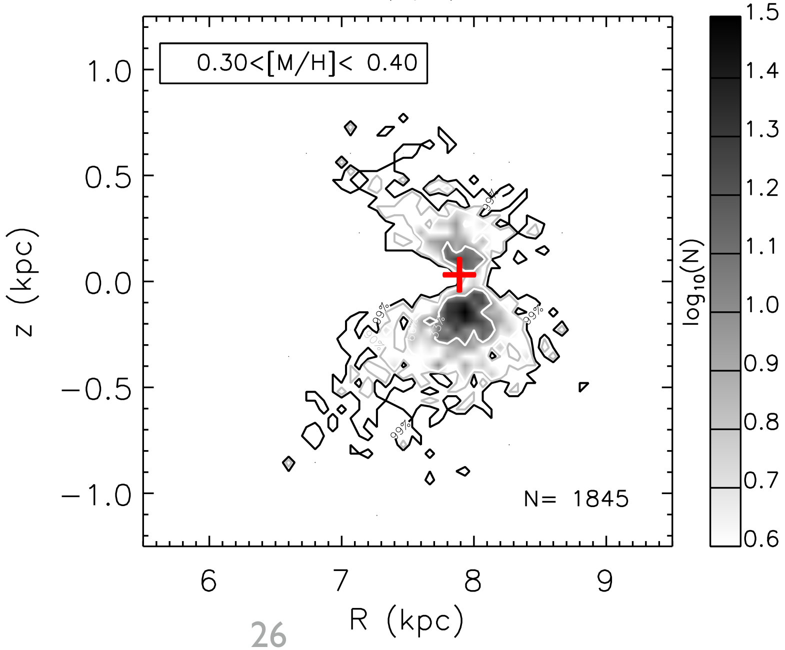


Super-Solar metallicity stars









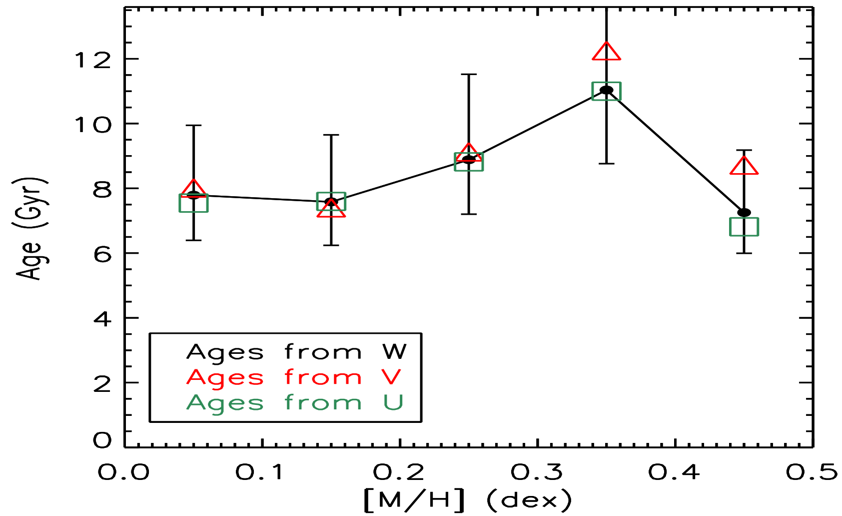
Stars mainly located close to the plane.

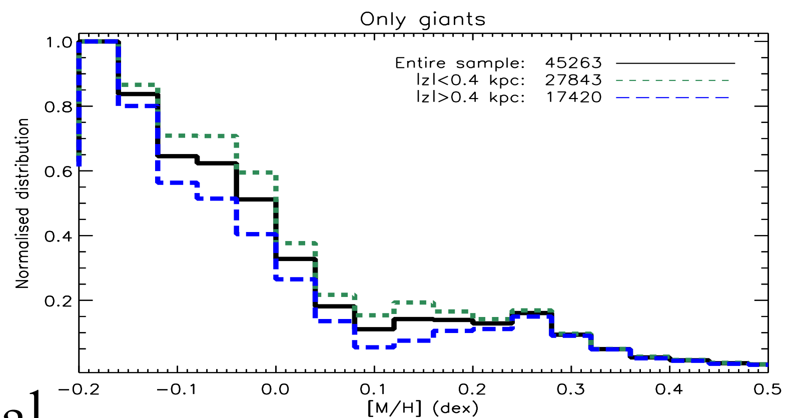
But also:

Fair amount of stars with $0.4 < z < 1$ kpc

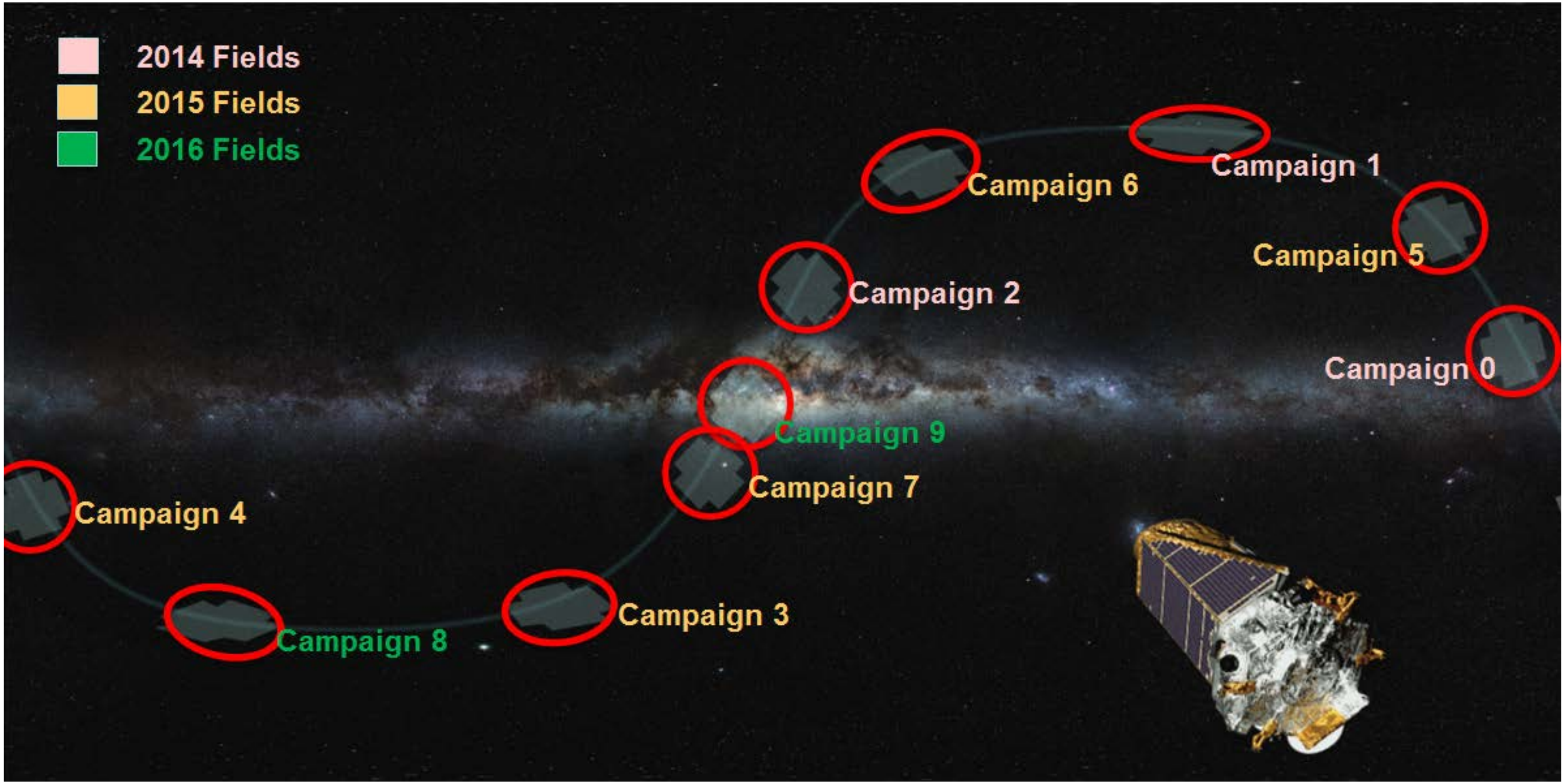
Metal rich stars in RAVE

- Super Metal-rich giants in RAVE have a “flat” MDF from 0.1 < [M/H]< 0.35 dex
- no dwarfs above 0.25 dex
- Stars formed well inside R_0 (bar/bulge region?)
- Located up to ~1 kpc from the plane
- Same distribution inner and outer Galaxy
- Circular orbits:
  - Stars scattered through co-rotational resonances with the spiral arms
  - Spirals in the MW are strong, with large spiral structure





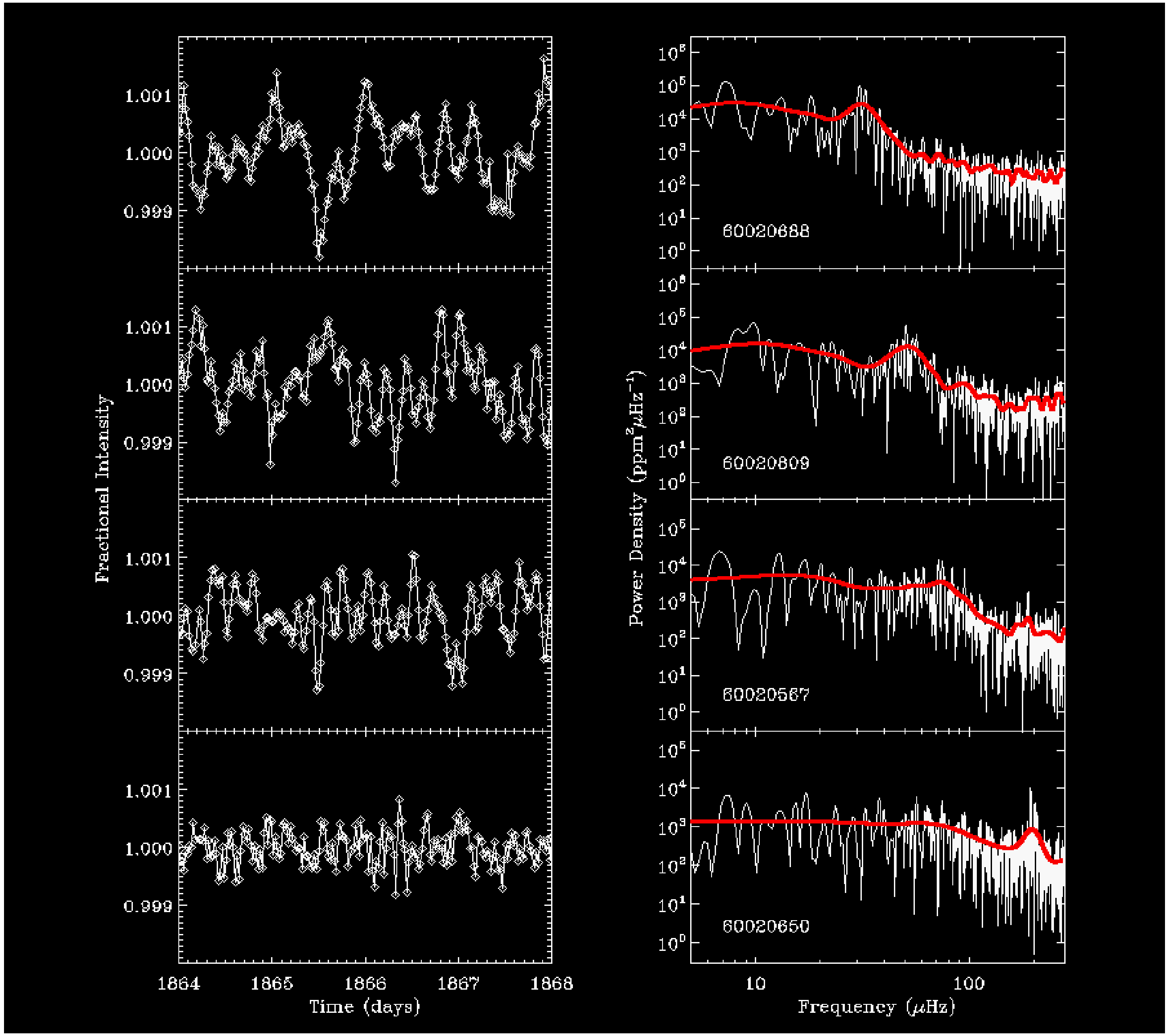
RAVE + astroseismology Kepler



Campaign	Rave Targets.	Giants
K2-Campaign 0	397	168
K2-Campaign 1	522	166
K2-Campaign 2	520	384

RAVE + astroseismology Kepler

- Oscillations in RAVE Red Giants have already been detected in K-2 campaign 0.
- Final light-curves and data for K2-campaign 1 will be available in January 2015.



"Reconstructing the Milky Ways history: Spectroscopic surveys, Asteroseismology and chemo-dynamical models"

1-5 June 2015, Bad Honnef (Germany)

`https://escience.aip.de/592-WE-Heraeus-Seminar`

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592. WE-Heraeus-Seminar – 1st to 5th June 2015

Reconstructing the Milky Way's History: Spectroscopic Surveys, Asteroseismology and Chemodynamical Models

Venue:

Physics Center Bad Honnef

Hauptstrasse 5

53604

Bad Honnef (near Bonn, Germany)

The Physics Center is run by the Deutsche Physikalische Gesellschaft e. V. (DPG) and is supported by the

Wilhelm und Else Heraeus Stiftung

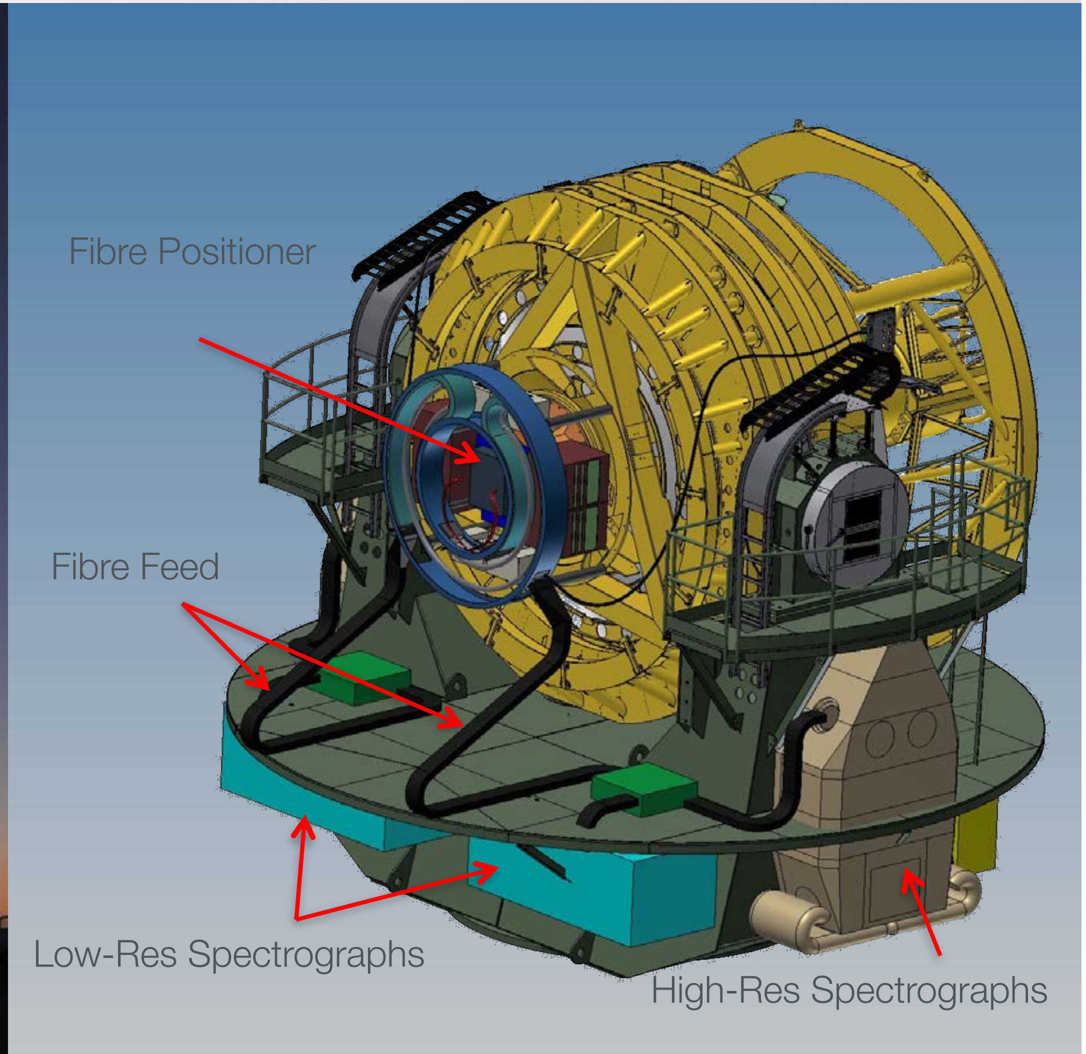
This seminar is generously funded by the Wilhelm und Else Heraeus-Stiftung.

Click here to learn more about

4MOST – 4m Multi-Object Spectroscopic Telescope

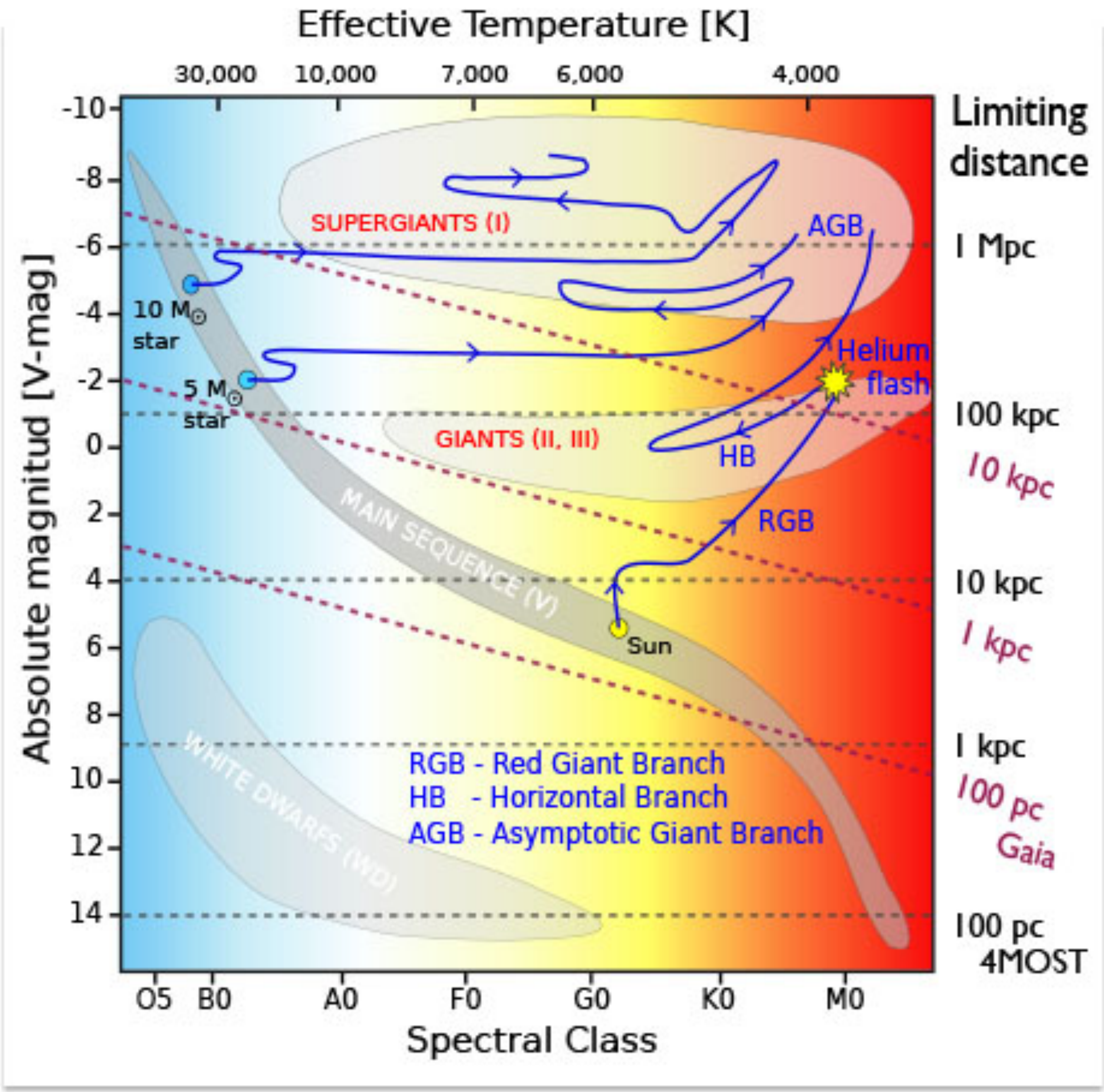
Roelof de Jong (AIP)
4MOST PI

www.4most.eu



VISTA telescope

Gaia needs spectroscopic follow-up!



4MOST extents the Gaia volume by 1000x in the red and 1 million in the blue!

Cover the bulge/halo interaction and the Magellanic Clouds

Instrument Specification

Specification	Concept Design value
Field-of-View (hexagon)	>4.0 degree^2 (⌀>2.5°)
Multiplex fiber positioner	~2400
Medium Resolution Spectrographs # Fibres Passband Velocity accuracy	R~5000-8000 1600 fibres 390-930 nm < 2 km/s
High Resolution Spectrograph # Fibres Passband Velocity accuracy	R~20,000 800 fibres 395-456.5 & 587-673 nm < 1 km/s
# of fibers in ⌀=2' circle	>3
Area (5 year survey)	>2h x 16,000 deg^2
Number of 20 min science spectra (5 year)	~100 million

Summary

- RAVE survey: more than 574,000 spectra taken
  - Radial velocities (1km/s)
  - Stellar parameters
  - Distances
  - Abundances
- Local escape speed: low Milky Way DM halo mass confirmed
- Clear correlation between chemical and kinematical signatures in the disk(s)
- Detection of large-scale asymmetries of the velocity field in the solar neighborhood
  - Apparent asymmetry above vs below the plan (wave?)
- Metal-rich end from stars that were radially migrated from the inner disk
- Next major step: Gaia & 4MOST