Galactic Archaeology surveys with

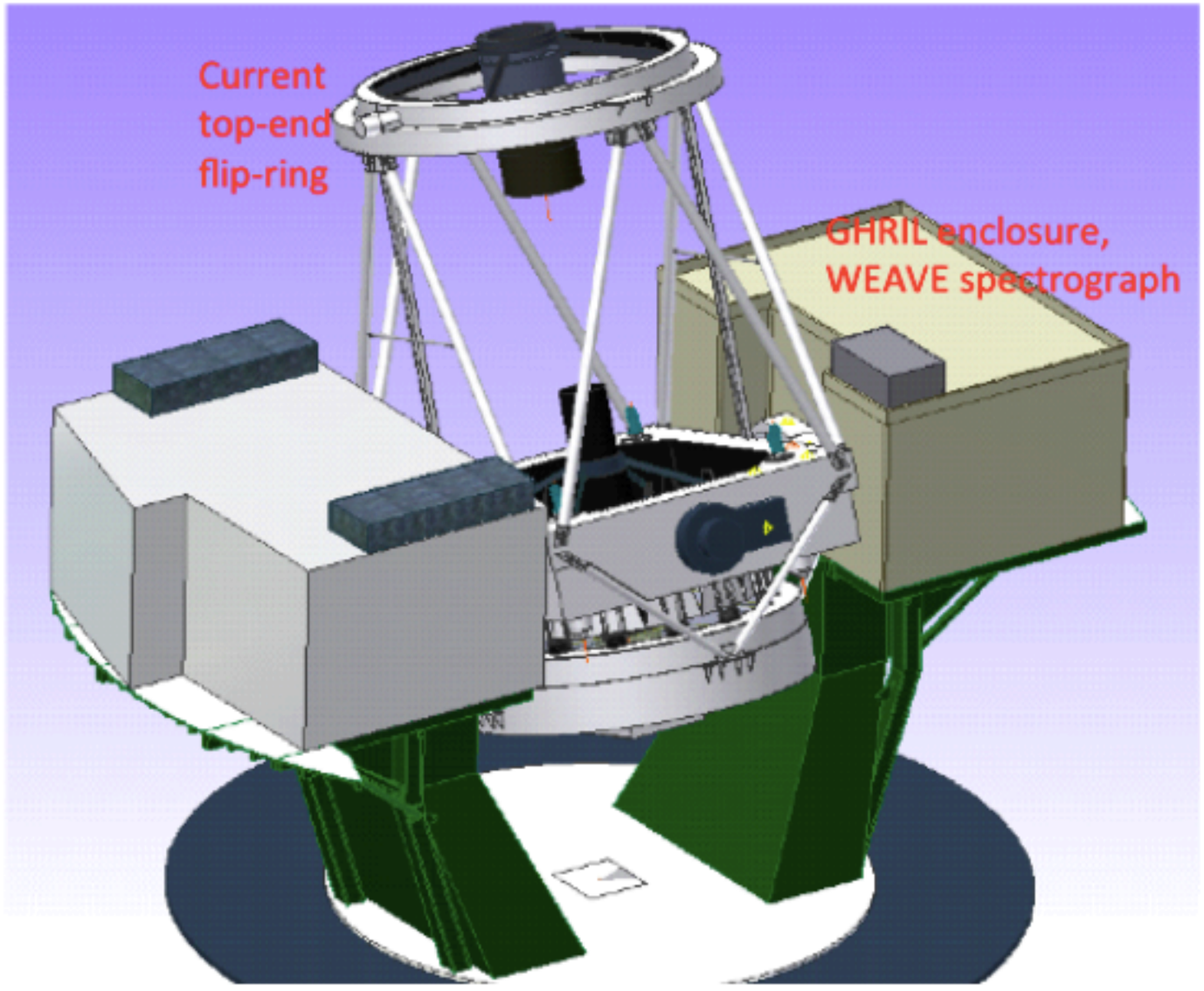
@WHT

Mathias Schultheis and the WEAVE team

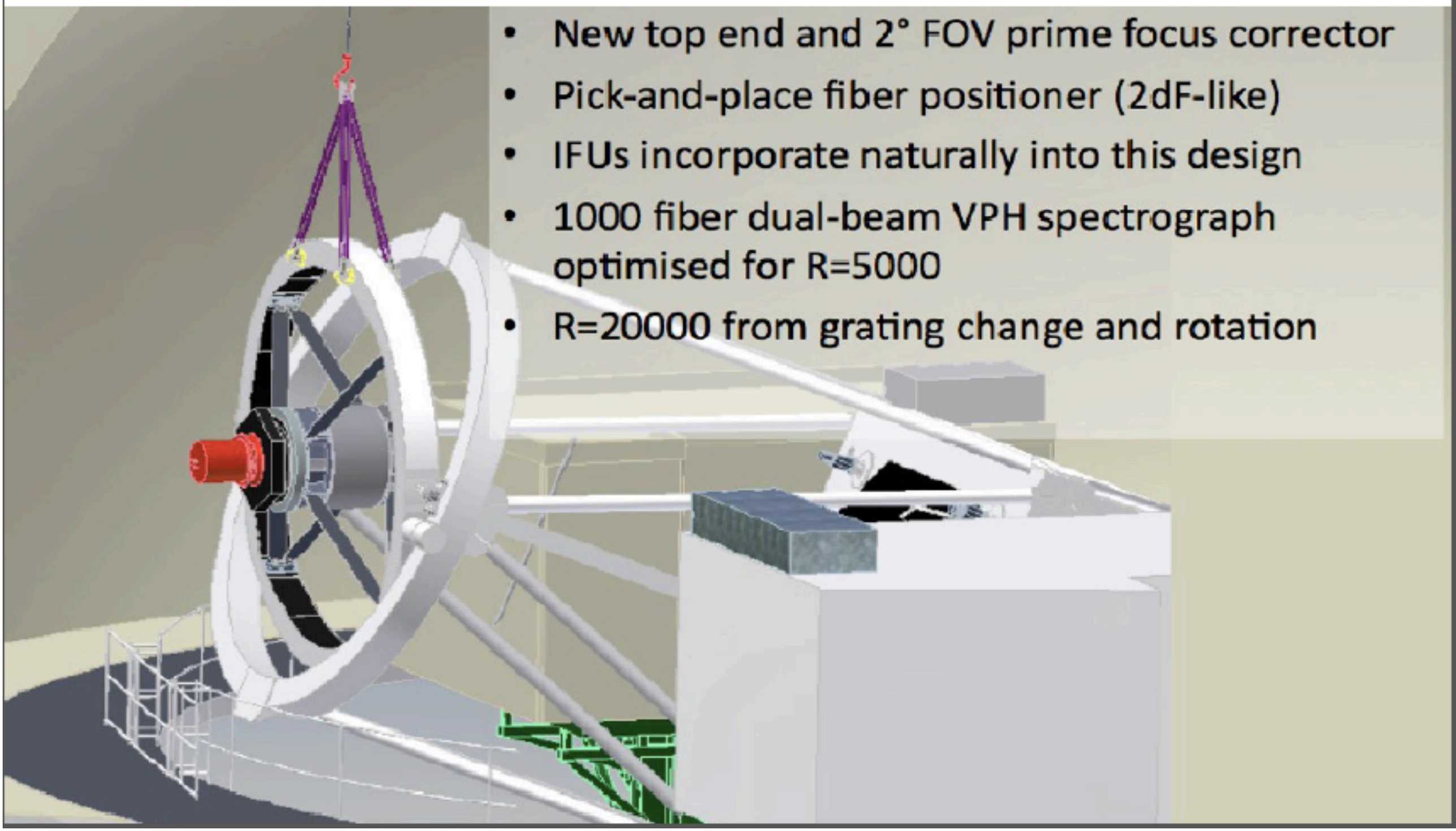
On behalf of the WEAVE GA survey team: V. Hill, T. Antoja, C. Babusiaux, G. Battaglia, V. Belokurov, B. Famaey, S. Feltzing, A. Helmi, M. Irwin, D. Montes, M., A. Vallenari, N. Walton

Over 90 scientists in GA Science Team

WEAVE: A new facility instrument for the WHT



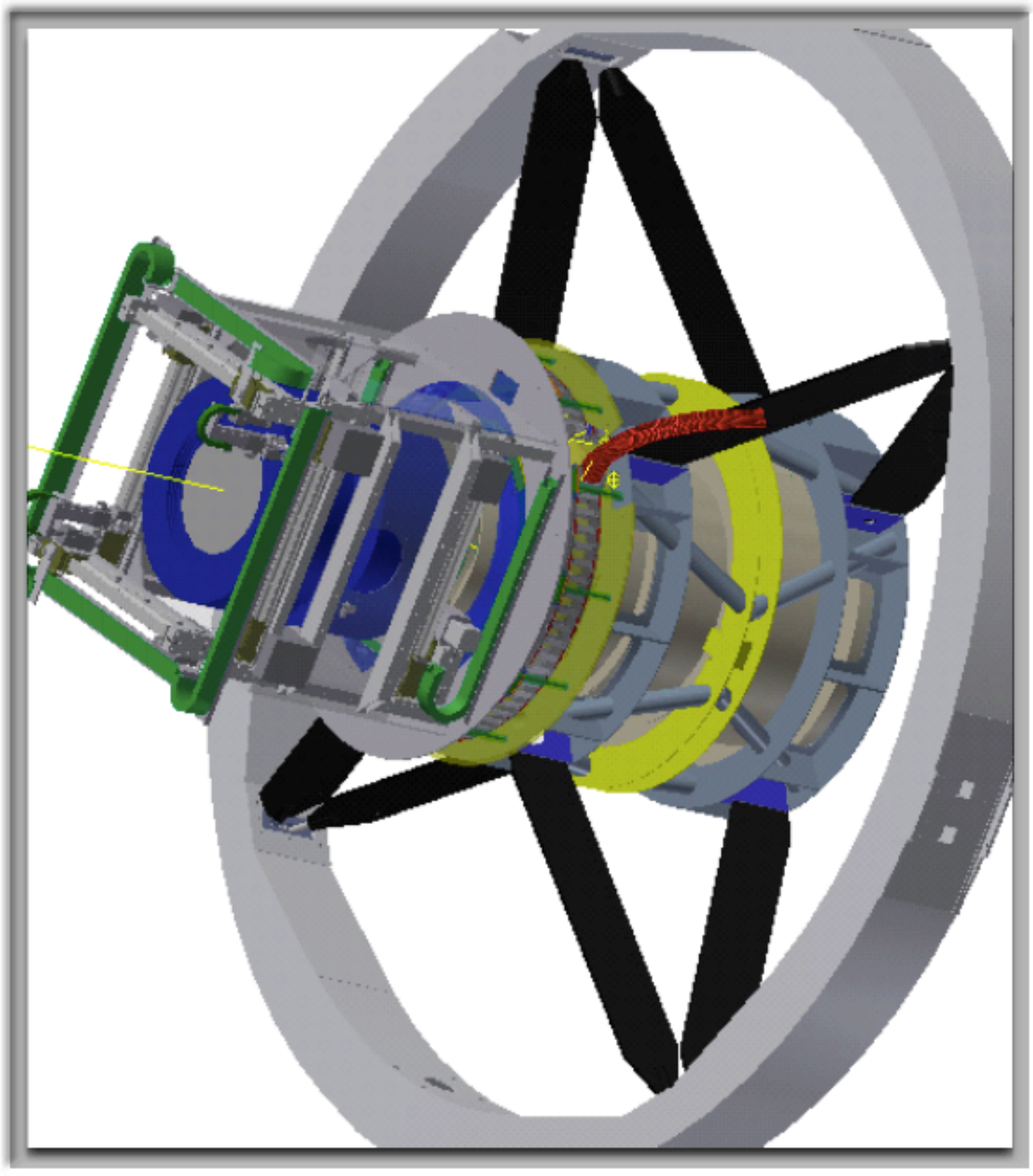
Instrument overview

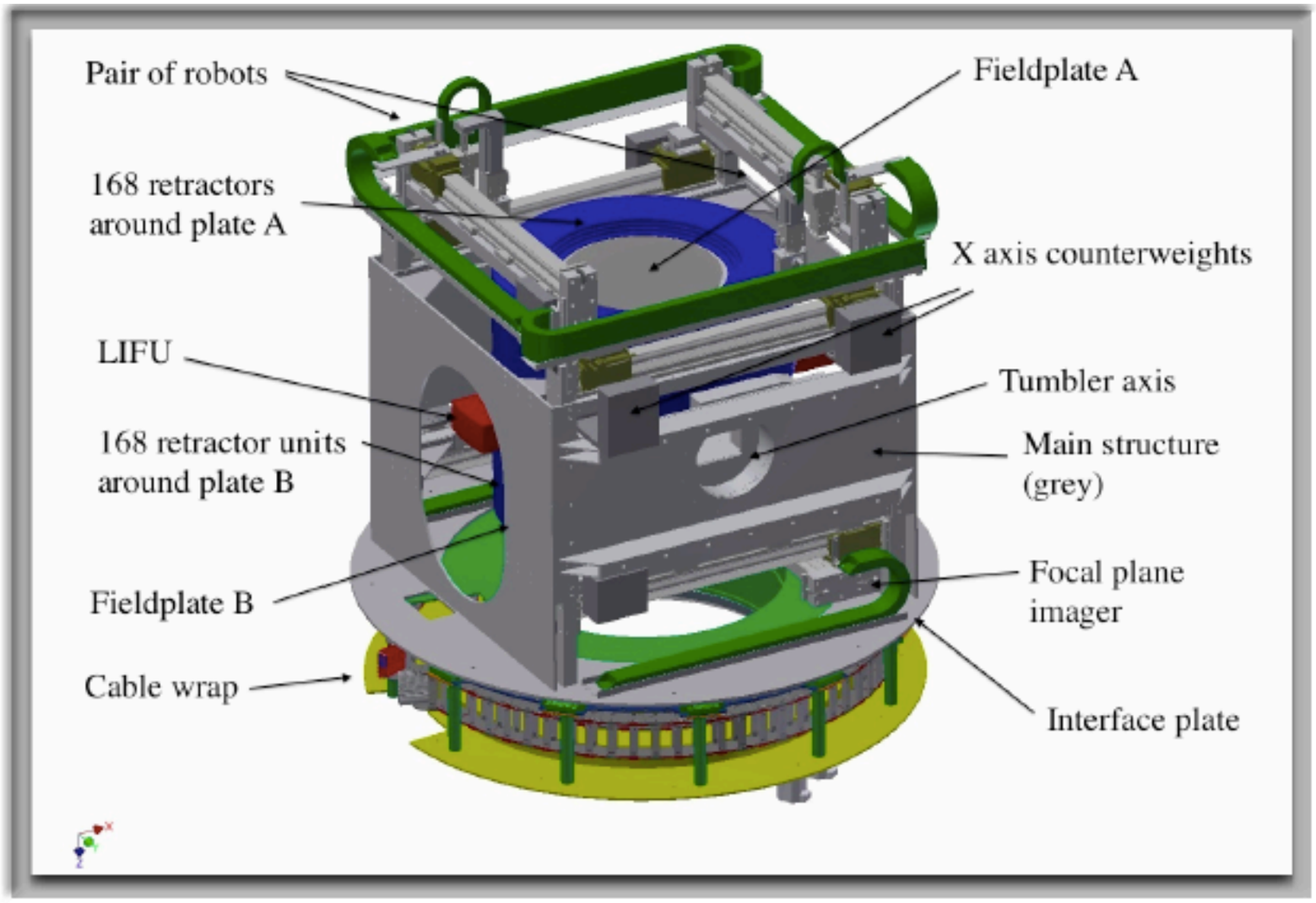


- New top end and 2° FOV prime focus corrector
- Pick-and-place fiber positioner (2dF-like)
- IFUs incorporate naturally into this design
- 1000 fiber dual-beam VPH spectrograph optimised for R=5000
- R=20000 from grating change and rotation

New top end

with positioner mounted



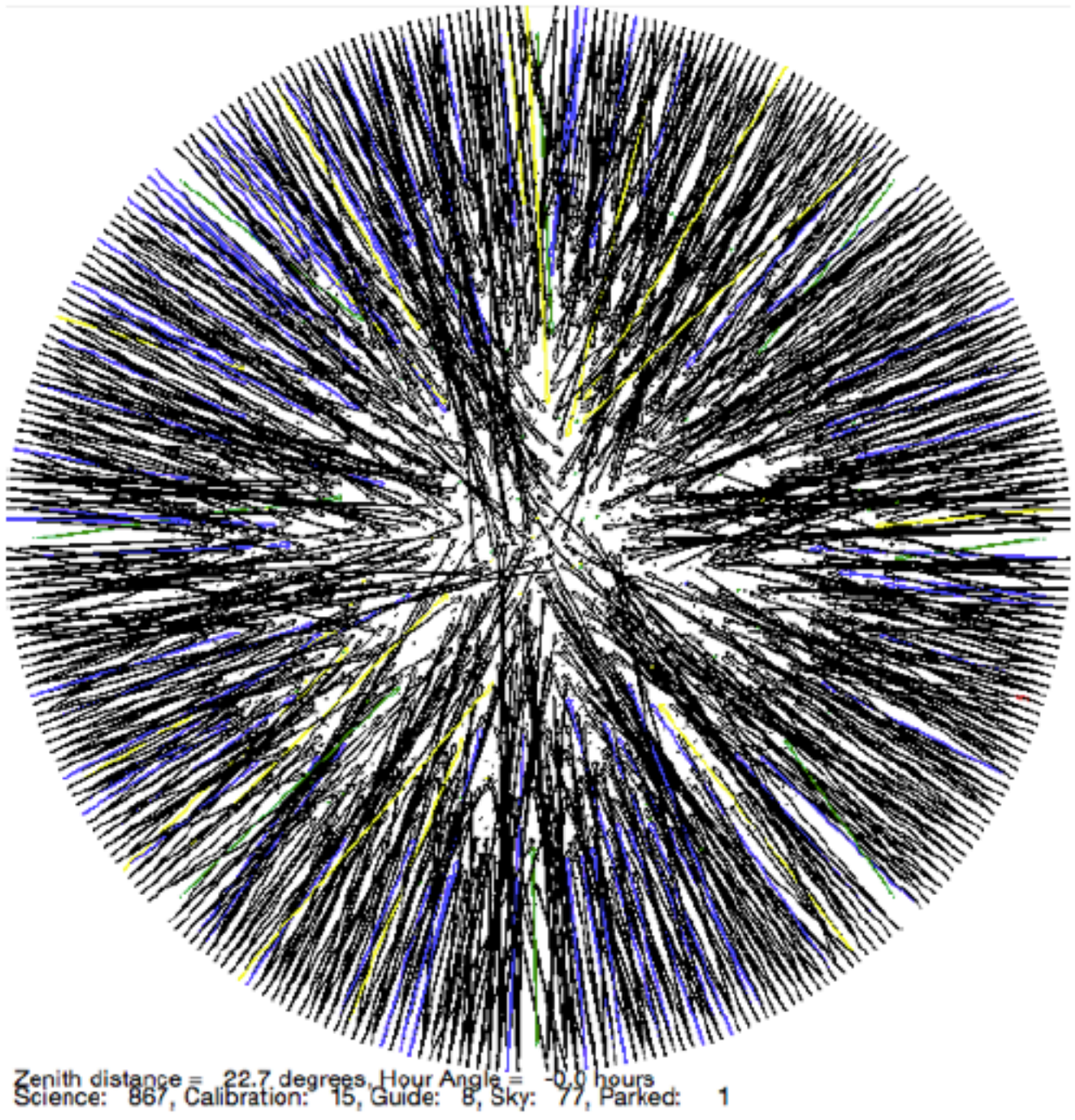


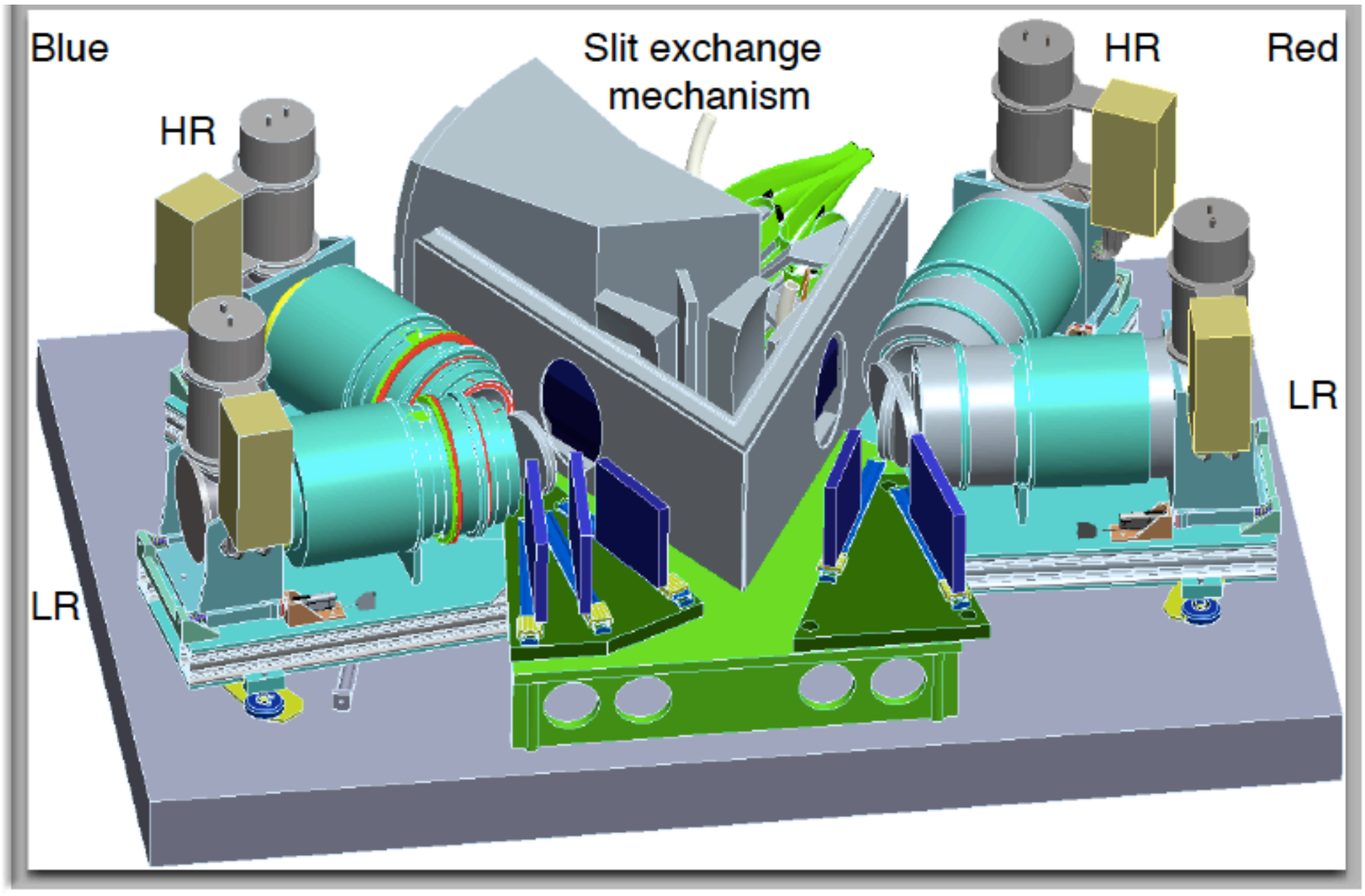
Fibre positioner system

2dF-style tumbler, two robots, ~1000 fibres/plate
(plus 20 miniIFUs on one plate)
Large IFU in red box

Fibre placement

- 100% of fibres placed in simulation of cluster core
- ~8500 fibre crossings(!)
- ~1800 moves in <55 minutes with two robots
- 8 coherent guide fibre bundles (5″⌀, marked in green)





Spectrograph

Two arms split at 595 nm

Switchable from low- to high-resolution

Glass & 3/4 of CCDs in hand!

Project Structure

UK
NL
ES
FR
IT
MX

Project Board

- Vik Dhillon, UK Representative
- TBD, UK Representative
- Wilfried Boland, Dutch Representative, Project Board Chair
- Johan Knapen, IAC Representative
- Jordi Torra, Spanish Representative
- Denis Mourard, CNRS Representative
- Ronald Stark, Dutch Representative
- Marc Balcells, ING Representative
- Filippo Zerbi, INAF Representaive

Project Executive

- National PI: Antonella Vallenari (INAF-Padova)
- Principal Investigator: Gavin Dalton (RAL/Oxford)
- Co-PI (PS): Scott Trager (Rijksuniversiteit Groningen)
- National PI: Esperanza Carrasco (INAOE)
- Co-PI: Alfonso López Aguerri (IAC)
- Project Manager: Don Carlos Abrams (ING)
- National PI: Piercarlo Bonifacio (Observatoire de Paris)
- Systems Engineering: Kevin Middleton (RAL)
- Instrument Scientist: Chris Benn (ING)
- Project Support: Lourdes González (ING)
- Deputy Project Manager: Johan Pragt (NOVA)

System Managers

Two-degree Prime Focus: Kevin Dee (ING)	Fibre Positioner System: Ian Lewis (Oxford)	Fibre Systems: Frédéric Sayède (Observatoire de Paris)
Spectrograph System: Johan Pragt (NOVA)	WEAVE Control System: Sergio Picó (ING)	Core Processing System: Nicholas Walton (Cambridge)
Advanced Processing System: Carlos Allende (IAC)	WHT Support Facilities: Juerg Rey (ING)	WEAVE Archive System: Marcello Lodi (INAF-TNG)

Science Teams

- Galactic Archaeology: Vanessa Hill (OCA)
- Stellar Circumstellar Interstellar: Janet Drew (Hertfordshire)
- Galaxy Clusters: José Alfonso López Aguerri (IAC)
- Galaxy Evolution: Bianca Poggianti (INAF-Padova)
- WEAVE-LOFAR: Dan Smith (Hertfordshire)
- WEAVE-QSO: Mat Pieri (LAM)

Drawn by	Don Carlos Abrams			**Project**	WEAVE
Date	27/08/2015	**Doc No**	WEAVE-MAN-009.1	**Title**	Project Management Team Structure
Version	1.6	**Size**	A4	**Location**	http://www.ing.iac.es/bscw/bscw.cgi/239635

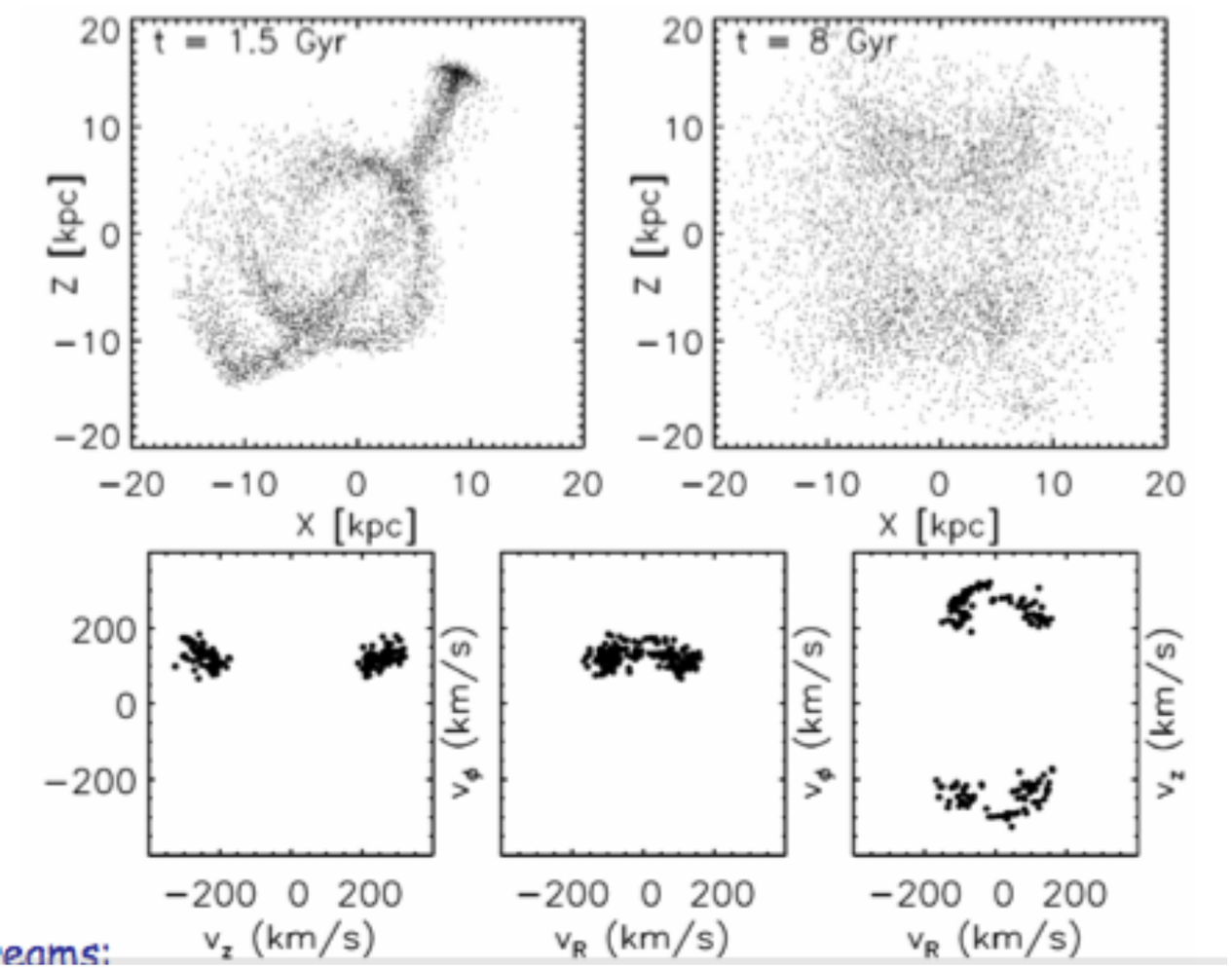
Specifications

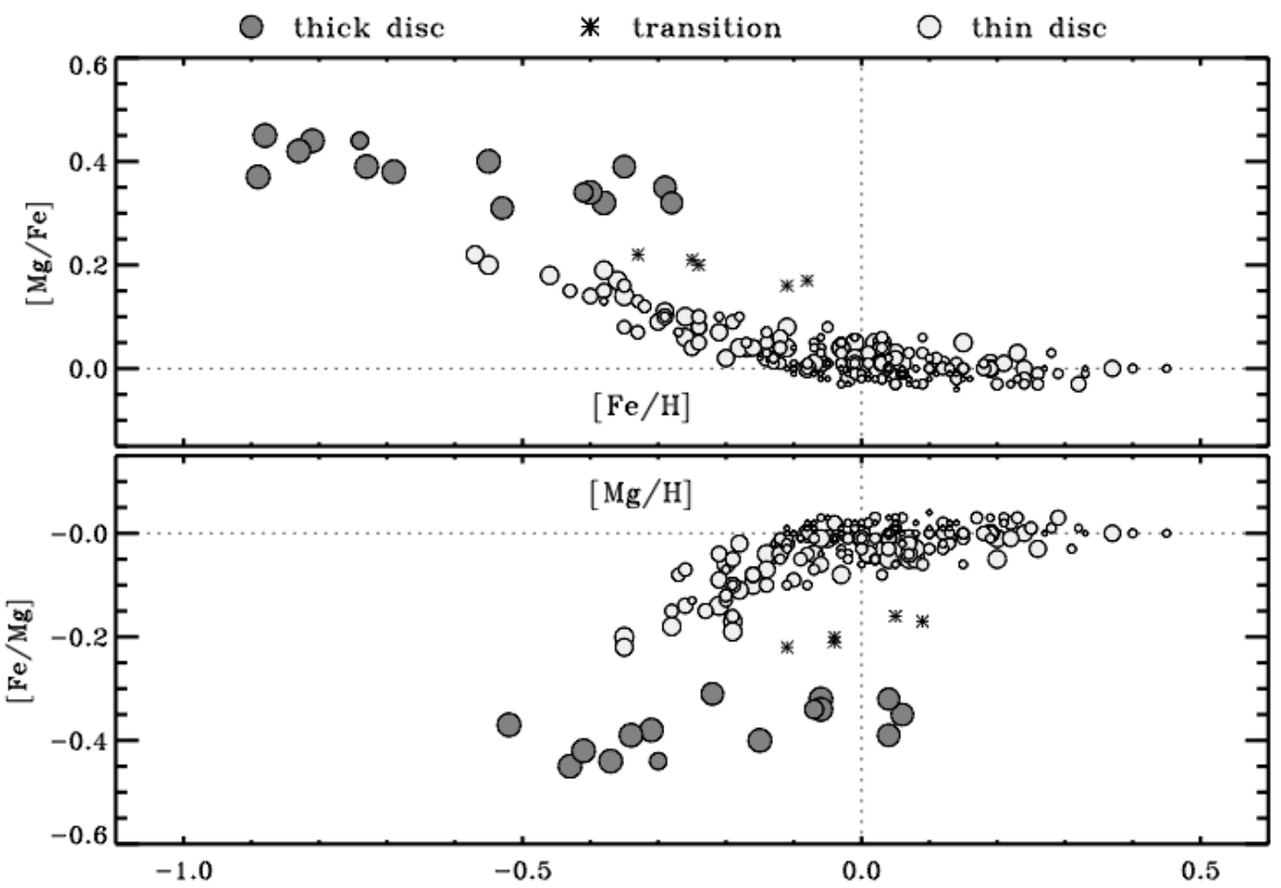
Telescope, diameter	WHT, 4.2m
Field of view	2º diameter (3.1degree^2)
Number of fibers	1000
Fiber size	1.3”
Number of small IFUs, size	~25, 9”x12” (1.3” spaxels)
Large IFU size	~1.5’x1’ (2.6” spaxels)
LR resolution	5 000 (at band center)
LR wavelength coverage	370–1000 (nm)
HR resolution	20 000 (at band center)
HR wavelength coverage	388-435, 600–678 (nm)

The WEAVE Primary Science Surveys

- There are six primary science cases for WEAVE:
  - Galactic Archaeology
  - Stellar, Circumstellar, and Interstellar Physics
  - Galaxy Clusters
  - Galaxy Evolution
  - WEAVE-LOFAR
  - WEAVE-QSOs

Galactic Archaeology in the Gaia era





Fuhrmann et al. 2008 Hipparcos Distances

- Kinematics + chemistry of stars enable to unravel the complex history of the MW assembly and internal evolution
- Learnt many things from SEGUE, RAVE, GES, APOGEE (Vr + chemistry + approx. ground-based Vt & isochrone D)
- Now Gaia's will revolutionize the field with exquisite geometrical D, Vt, in a unequalled volume. + ages

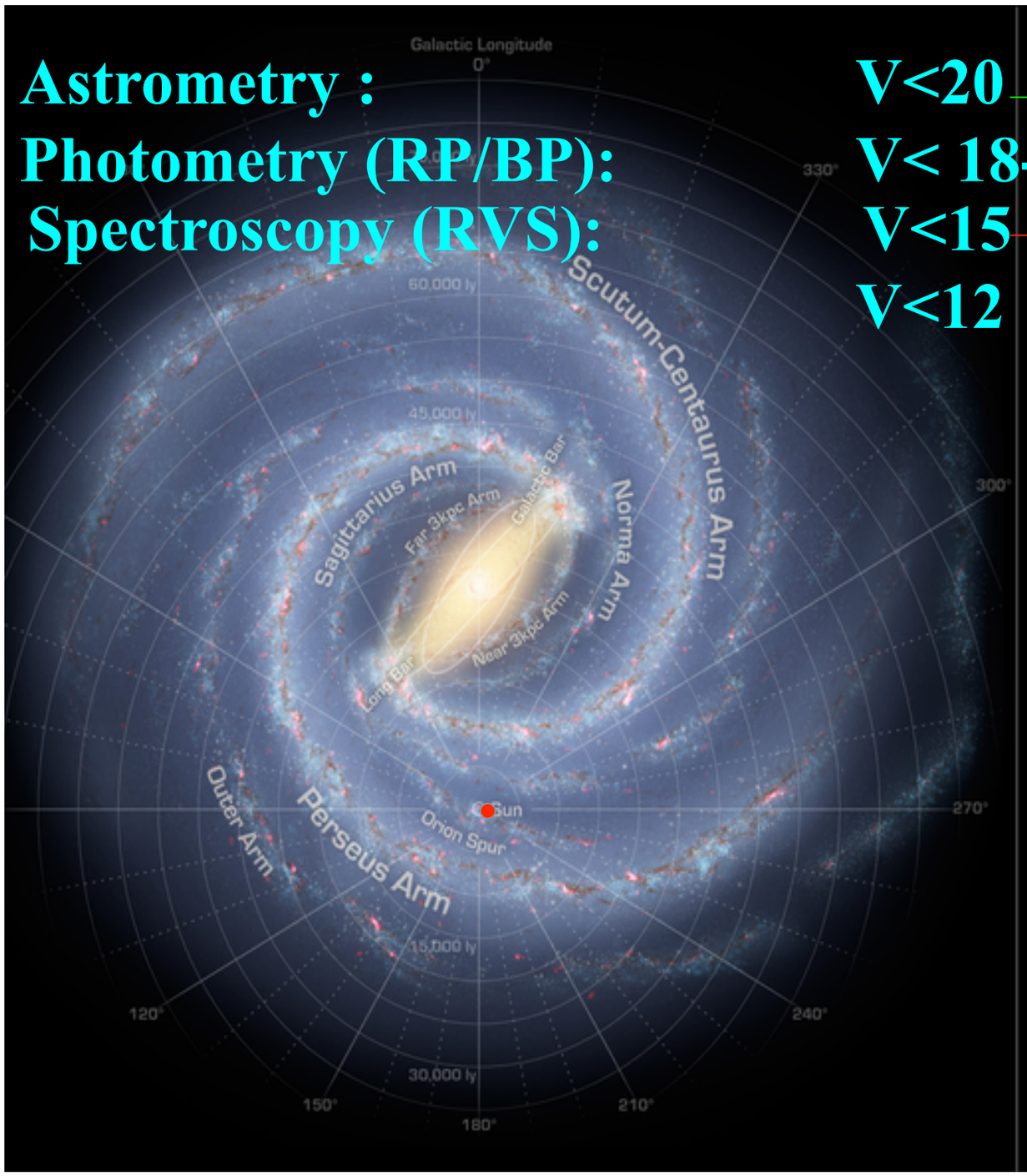
Gaia's reach: 1 bilion stars V<20

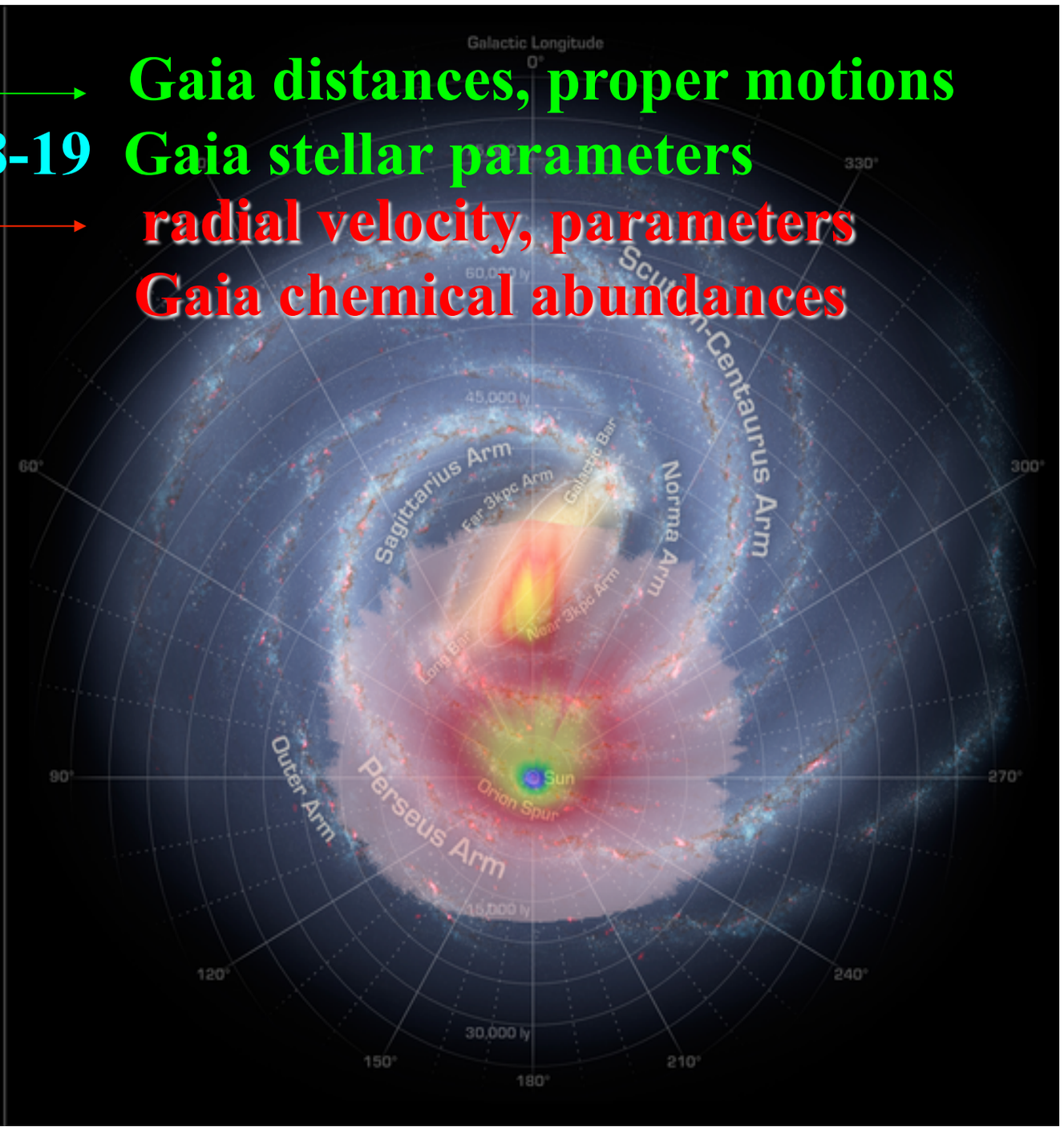
Astrometry : **V<20** → **Gaia distances, proper motions**

Photometry (RP/BP): **V< 18-19** **Gaia stellar parameters**

Spectroscopy (RVS): **V<15** → **radial velocity, parameters**

V<12 **Gaia chemical abundances**

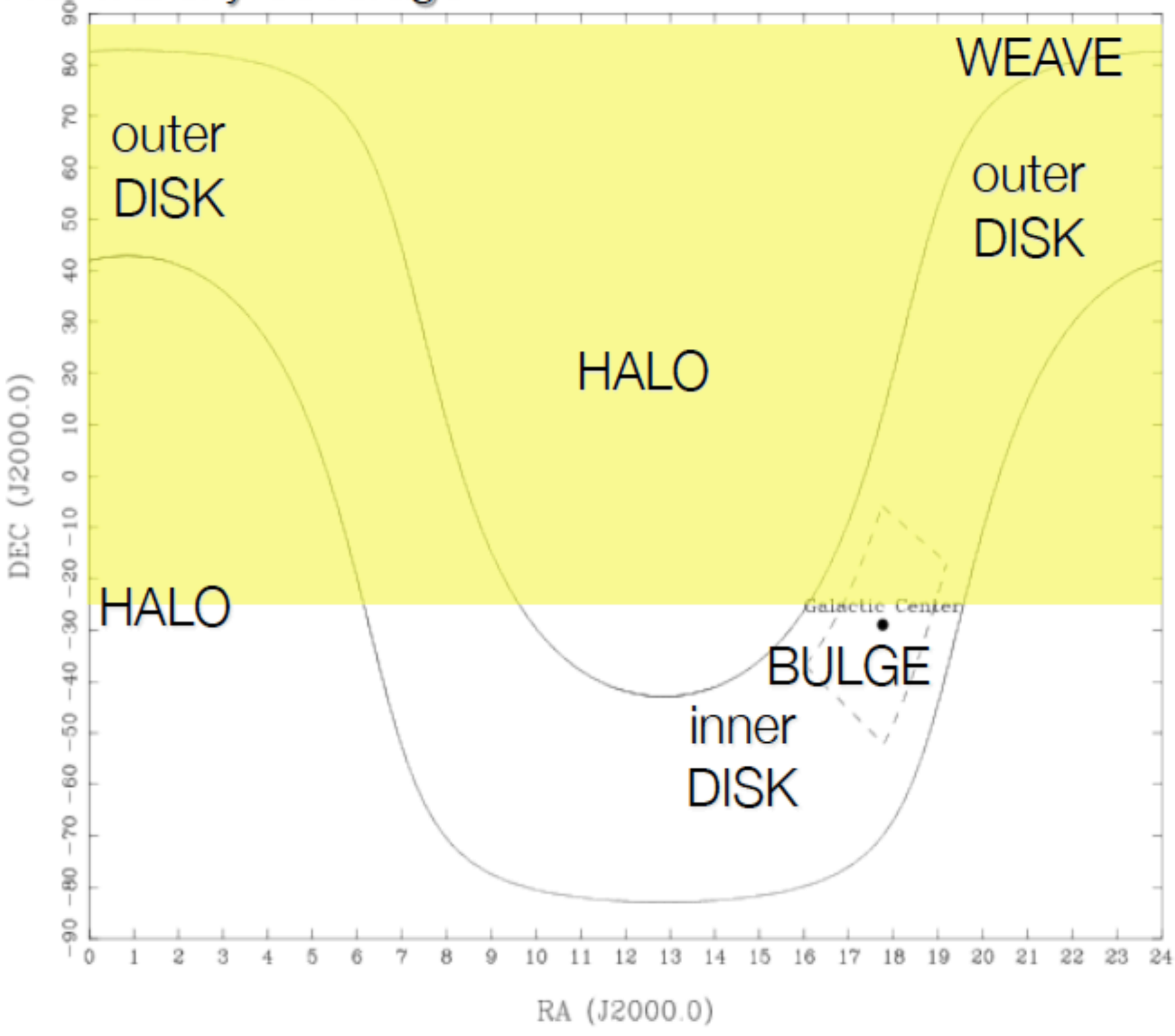




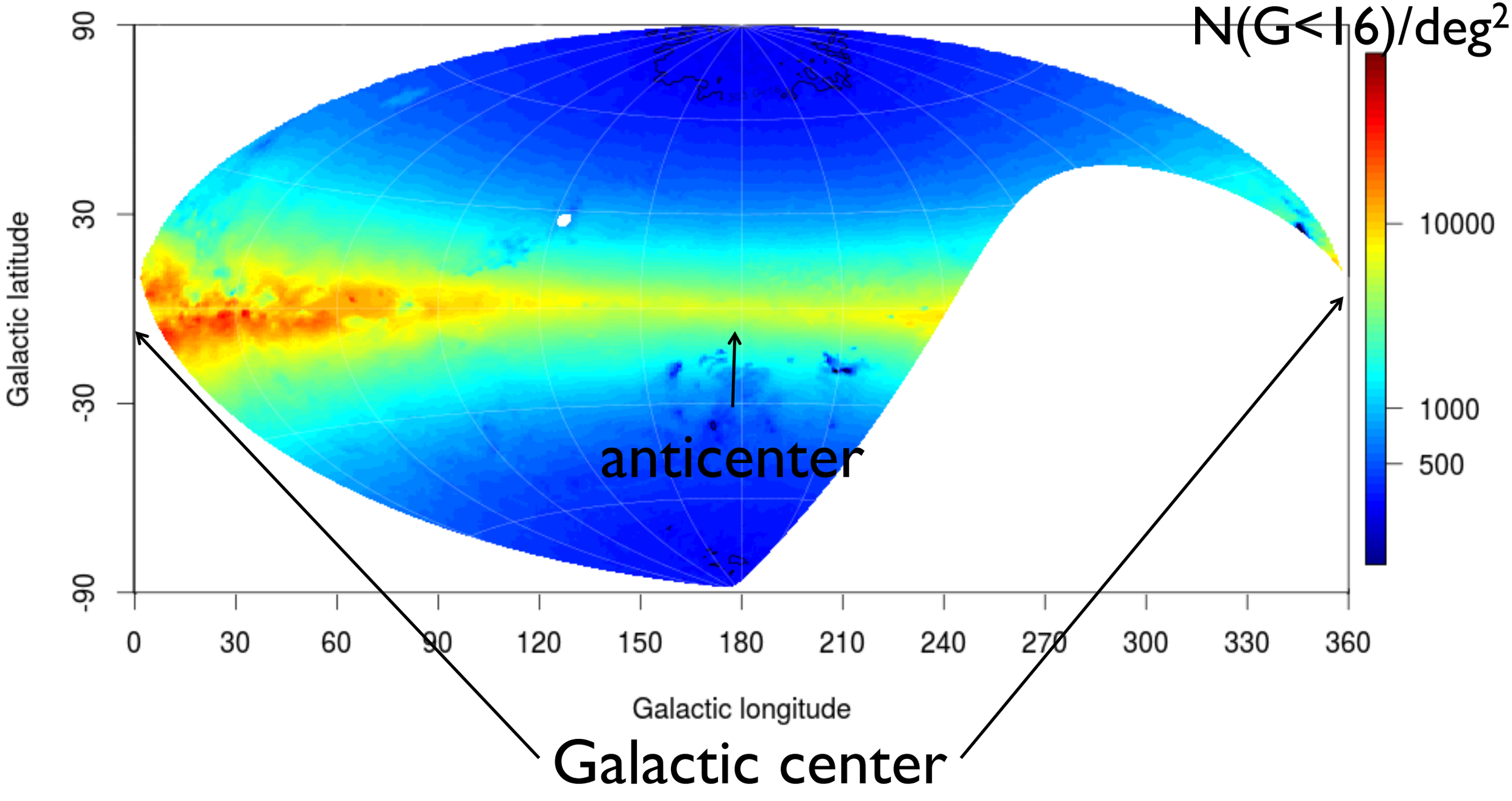
Complementing Gaia:

- A survey to acquire accurate Vr (and stellar parameters, incl. metallicity) 15<V<20
  - Defined the LR mode of WEAVE:
  - R = 5,000 in a wide range [366 – 606] nm + [579 – 959] nm
- A survey to determine accurate stellar parameters and detailed chemistry for V>12
  - Defined the HR mode of WEAVE:
  - R = 20,000 in two windows [404 – 465] nm or [473 – 545] nm + [595 – 685] nm
- Wide field high multiplex MOS: 950 fibers per 2° Ø field, or 3.14deg^2 + Dual arm spectrograph

WEAVE sky coverage



WEAVE: a northern facility

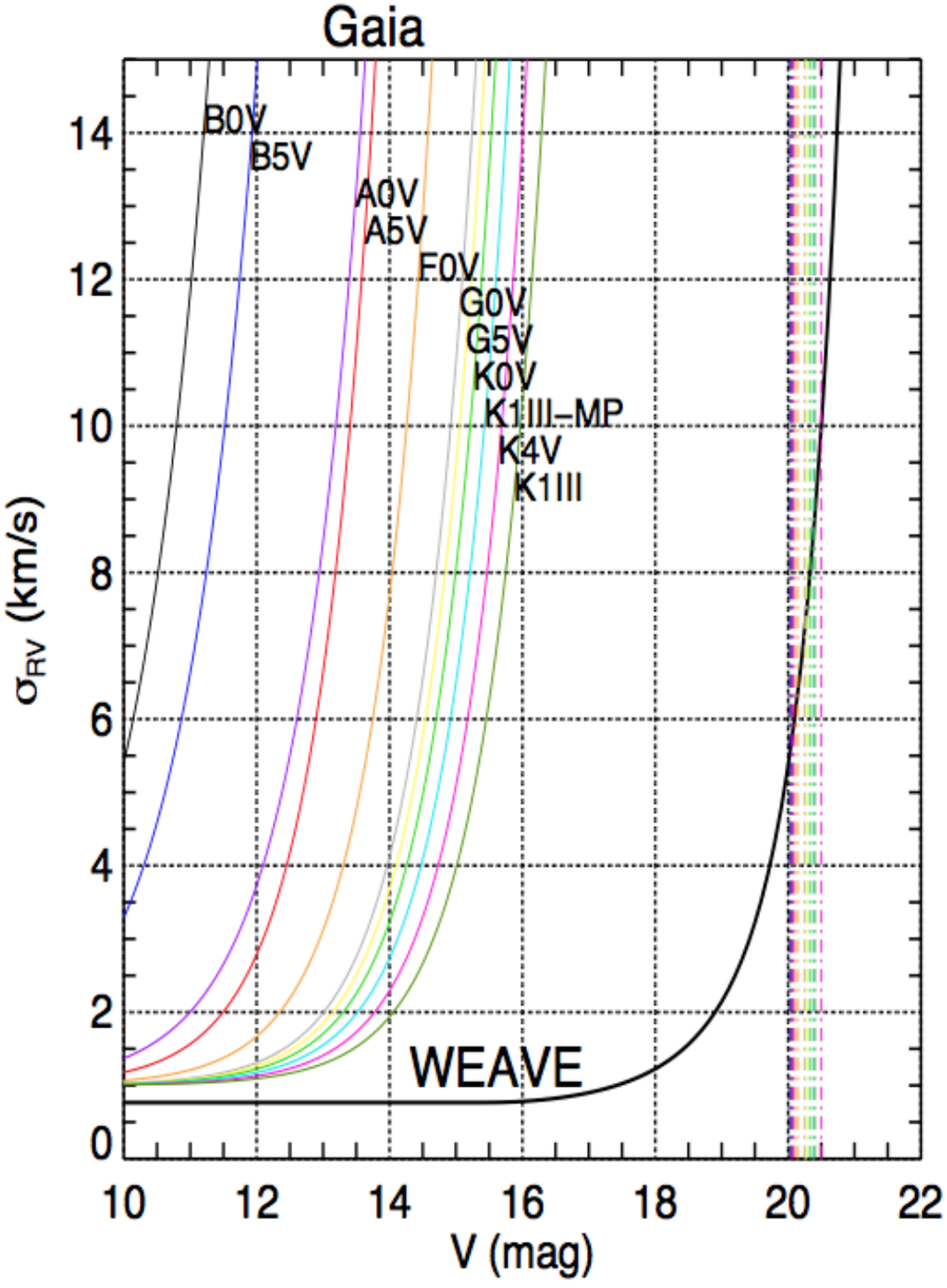


WEAVE is the only HR Xwide field Xmultiplex optical facility in the north !

WEAVE LR surveys

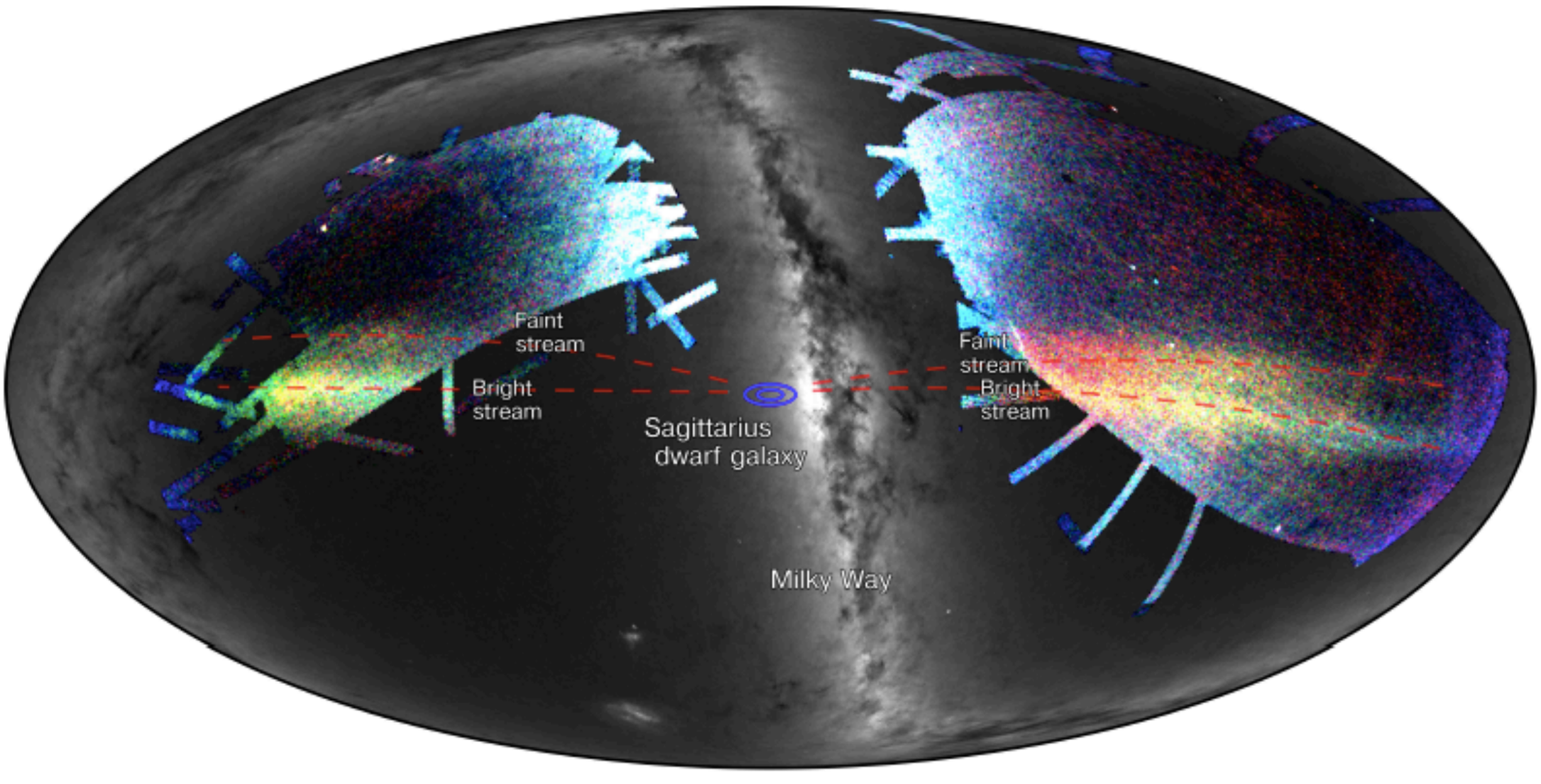
Two main LR survey areas:

1. A high latitude survey mapping the assembly of the stellar halo (total mass, content, substructures…)
2. A galactic plane experiment to constrain the disc potential, including departures from axisymetry (spiral arms, bar, …)



WEAVE can measure Vr to $\sigma(v_r)$<5 km/s at V=20 in 1hr, i.e. *closely matching the Gaia astrometric and photometric limits*

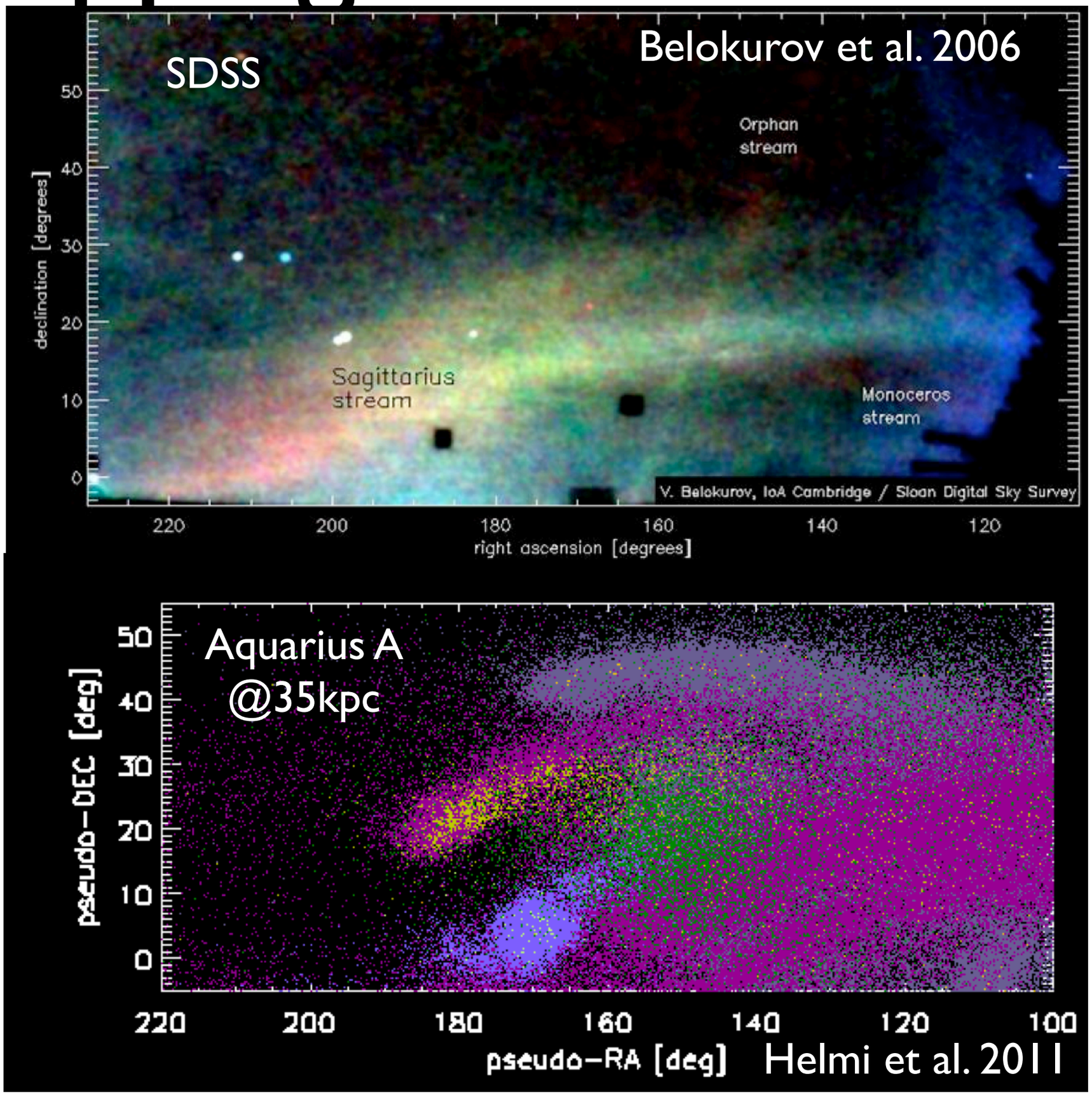
- The halo records the **formation history** of the MW
  - outer halo (>20 kpc): streams detected as overdensities easily in imaging surveys (long mixing timescales)
  - inner halo (10-20 kpc): merged components are well-mixed, need chemodynamics



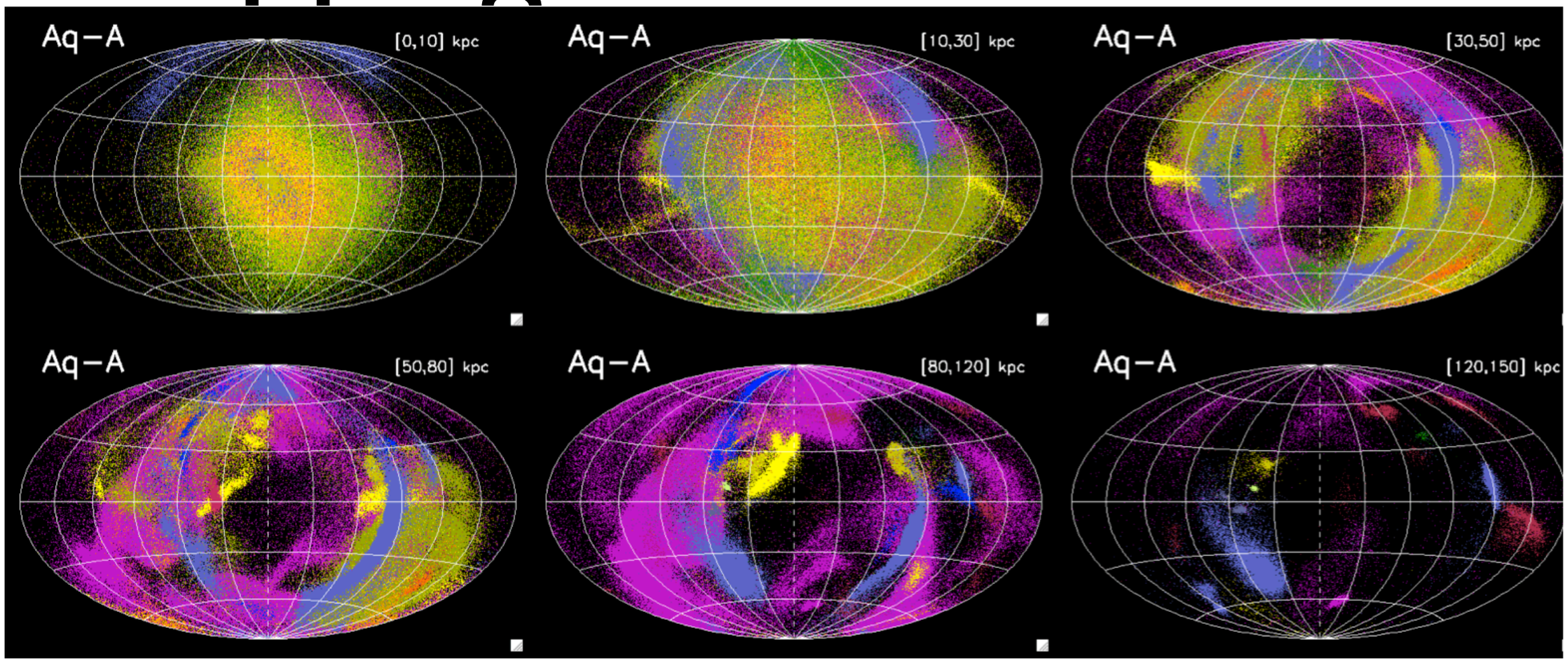
LR-halo survey goals & means

Goal 1. Formation scenarios: in-situ or accreted stellar halo?
Goal 2. Outer halo survey with RGB stars
Goal 3. Total mass of the MW out to 200 kpc (Jeans analysis)
Goal 4. The shape of the Galactic gravitational potential within 50–100 kpc with tidal streams
Goal 5. Lumpiness of the Galactic dark matter (20–50 kpc)
Goal 6. Chemo-dynamics of Milky Way dwarf satellite galaxies & effect of binary stars on dark-matter estimates
Goal 7. Star-formation and metal enrichment histories of disrupted dwarf satellites and of ultra-faint galaxies.
Goal 8. Metal-poor stars and the earliest phases of metal-enrichment.

Mapping the stellar halo



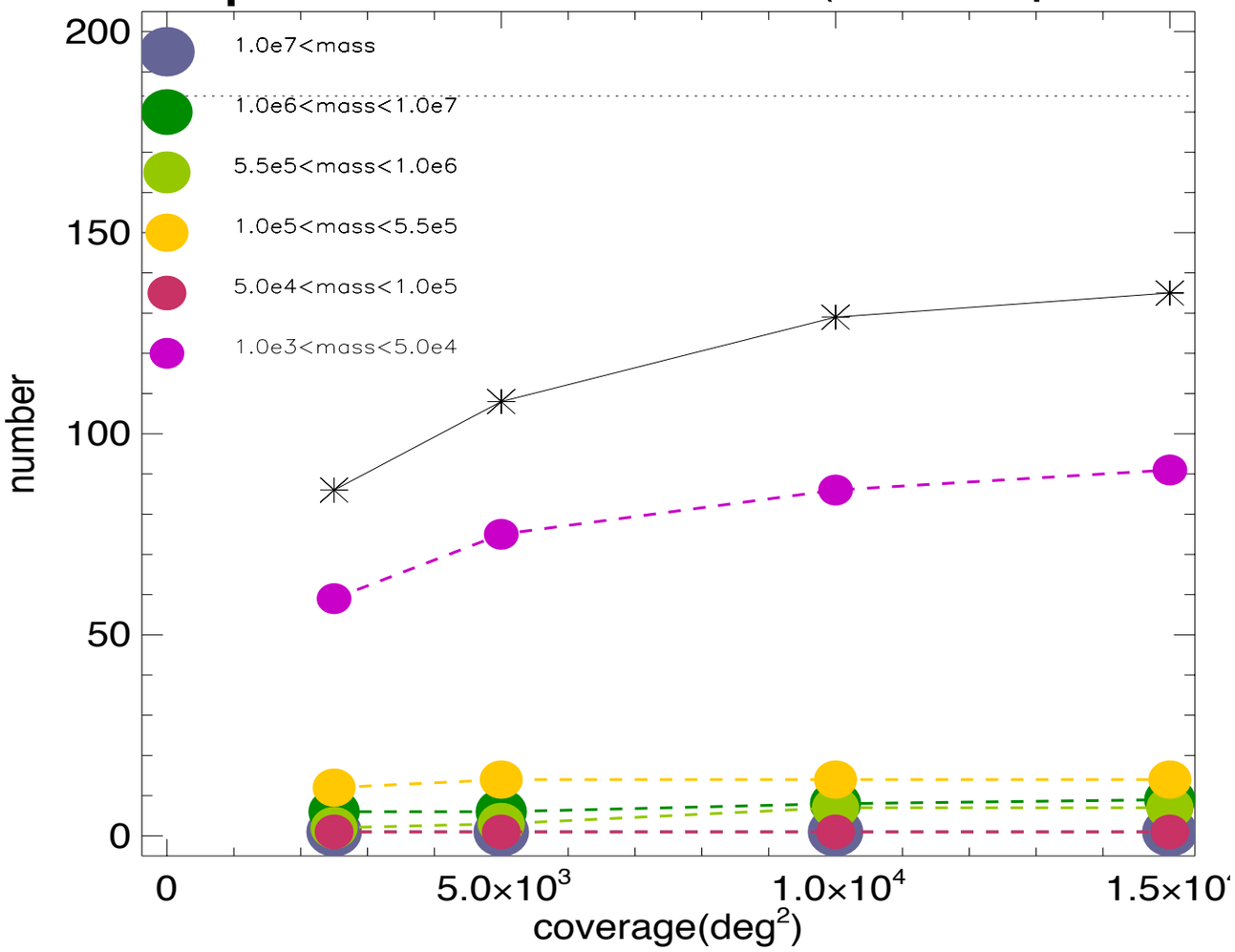
Mapping the stellar halo

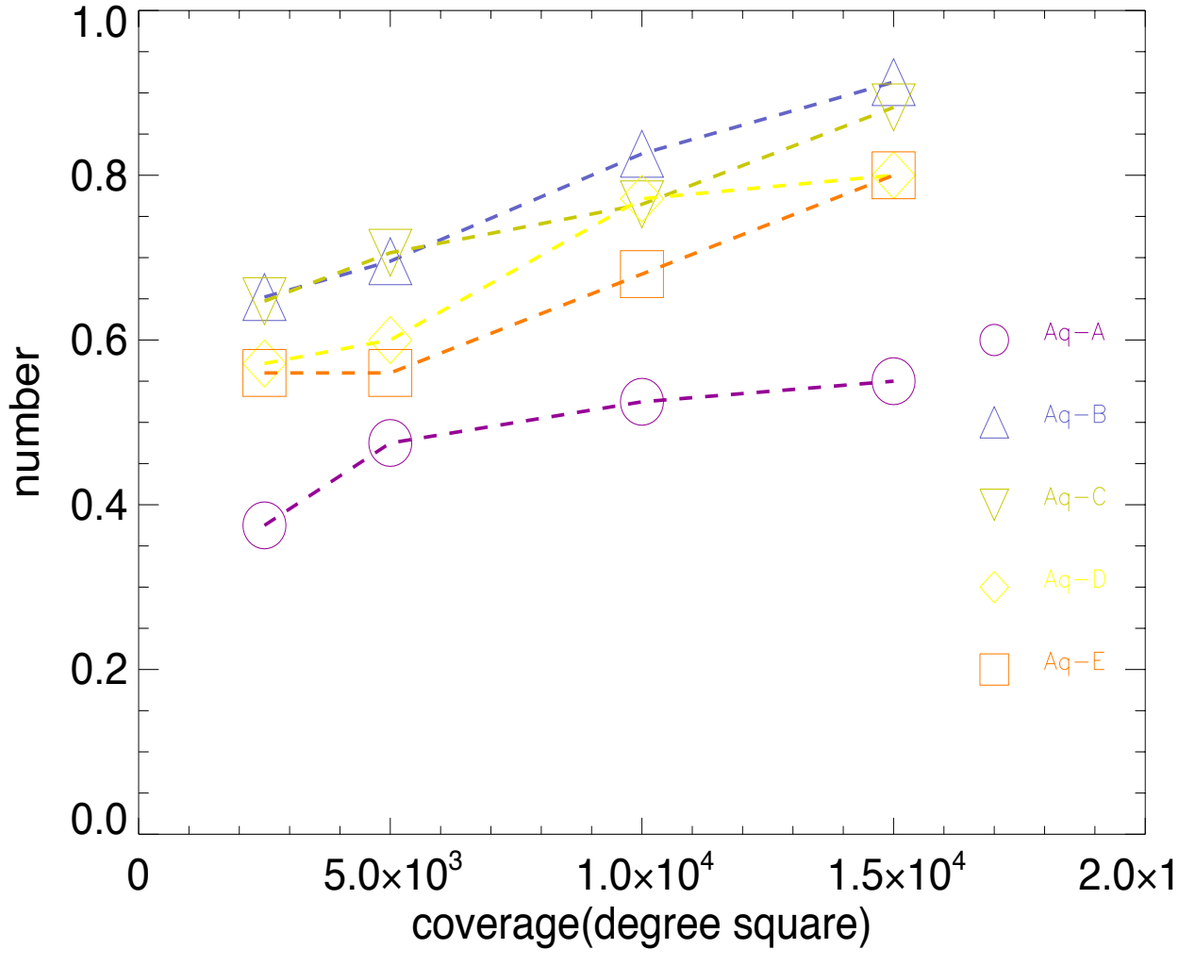


- Aquarius simulations (Helmi et al. 2011): most merger traces found D [10-30]kpc.
- Chemo-dynamical information for streams fundamental in the inner halo to identify accretions and characterize their parent.

Area coverage

Aquarius simulations (see Cooper et al. 2010, Helmi et al. 2011), giants 15<V<21

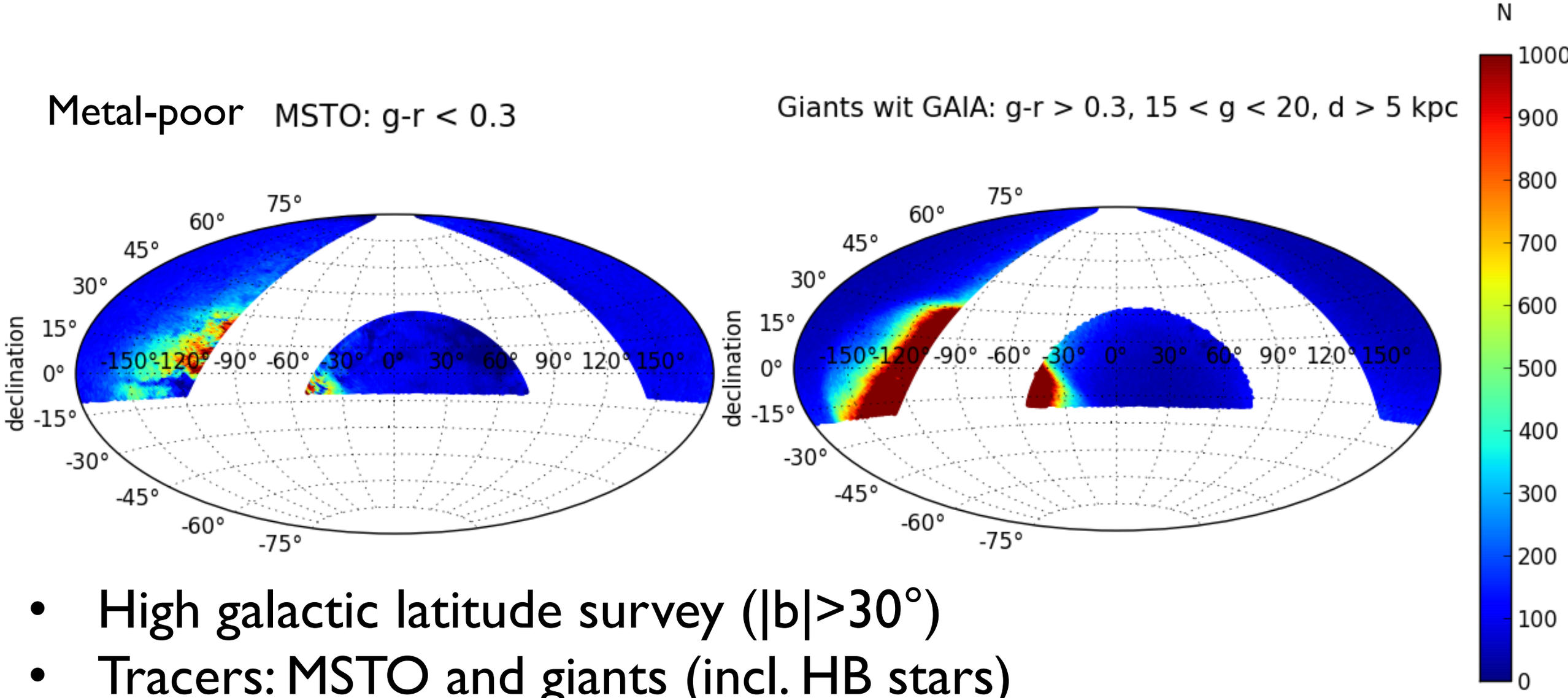




Minimum number of streams and reasonably high completeness imply ≥ 10,000deg^2

…allow for modelling uncertainties…..

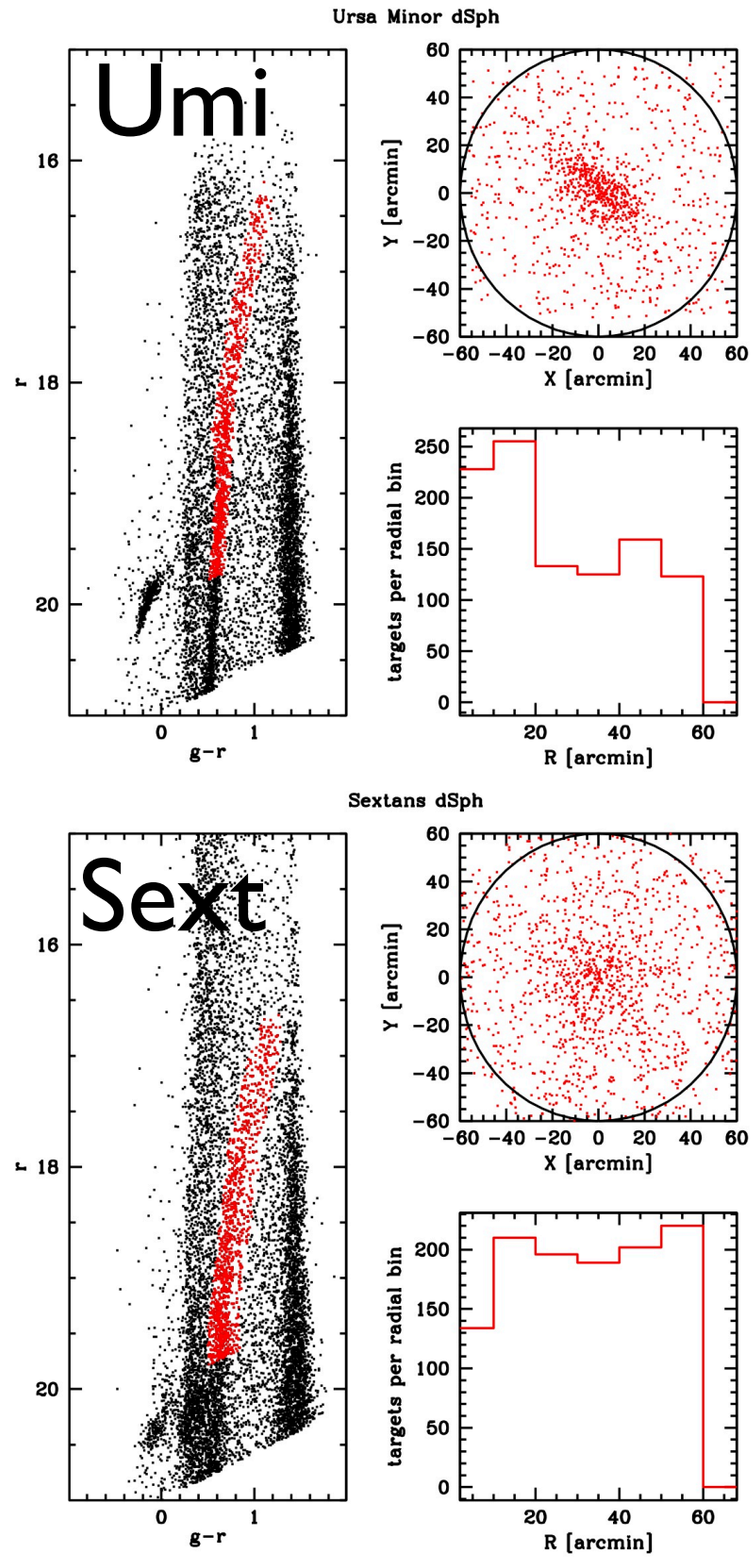
LR halo « wide » survey: 10,000deg^2



- High galactic latitude survey (|b|>30°)
- Tracers: MSTO and giants (incl. HB stars)
- Densities always >500s/WEAVE field, allow for combining with cosmological surveys (LOFAR samples, QSOs)
- Main outcome expected: 4.10^5 halo giants out to ~100kpc and 5. 10^5 halo MSTO out to ~30kpc
- By-product: thick disc ! expect ~10^6 thick disc stars.

LR halo « pointed survey »

- Pointed survey : follow-up of known streams and a few dSph galaxies (chemo-dynamical characterization) down to V=21.
- Need to go deep to enhance the number of members
- Total of ~300deg2



LR Disc survey: fundamental dynamics experiment

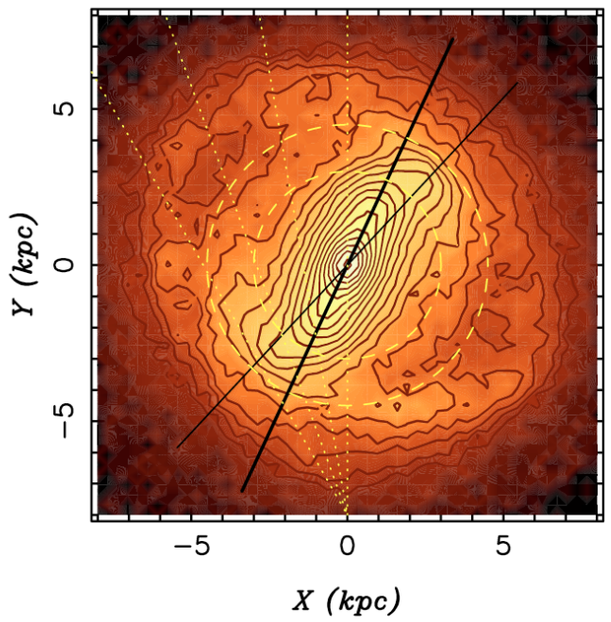
Discriminate fundamental aspects of galactic disc dynamics: moving groups, velocity elipsoid accross the disc ➔ probe the axisymetric potential + non-axisymetric terms (bar, spiral arms). Implications for radial migration.

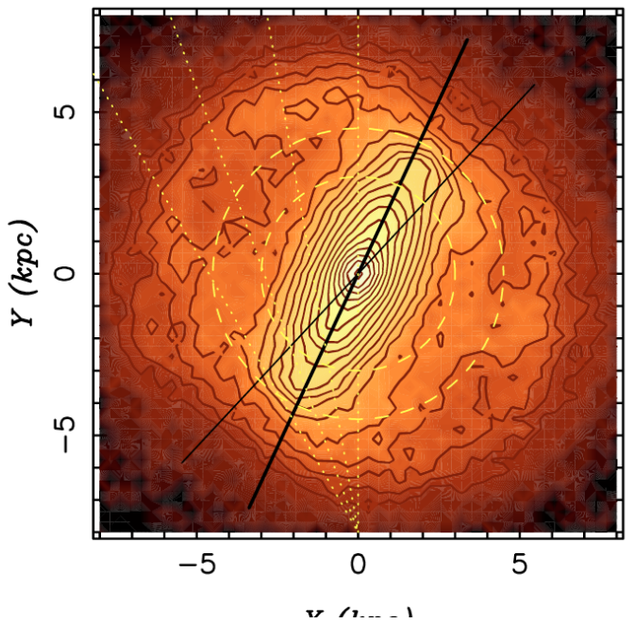
<u>Needs:</u>

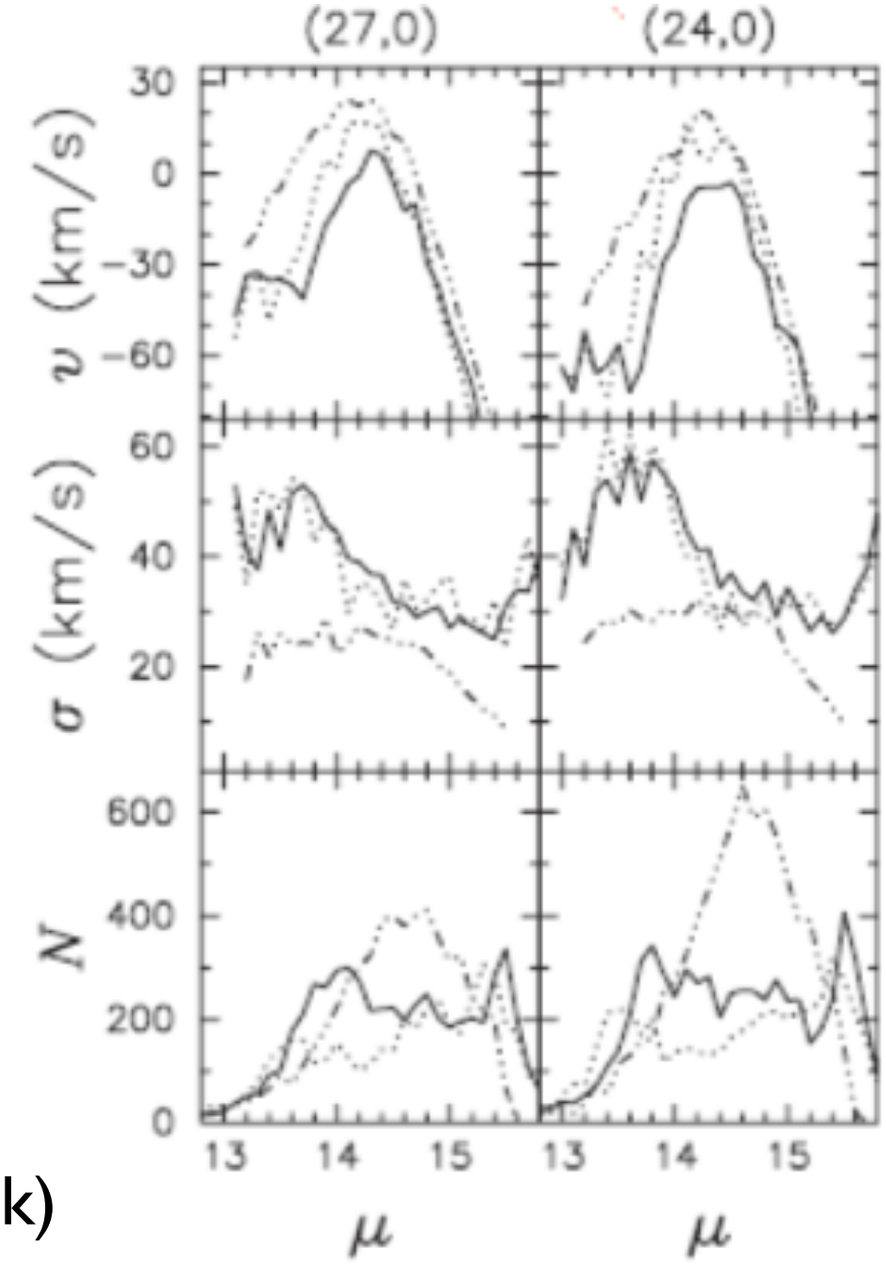
- Vr to ~2 km/s (dynamical streams with amplitudes/separations of 5-10 km/s)
- Dense tracers (<Vr> to 1-5km/s in various distance bins), reaching across significant disc fraction ➔ use Red clump stars
- Large area in the galactic plane (avoid peculiar signatures)

LR Disc survey: the long bar vs COBE/DIRBE

kinematic signatures of different types of bars







Bar with leading ends

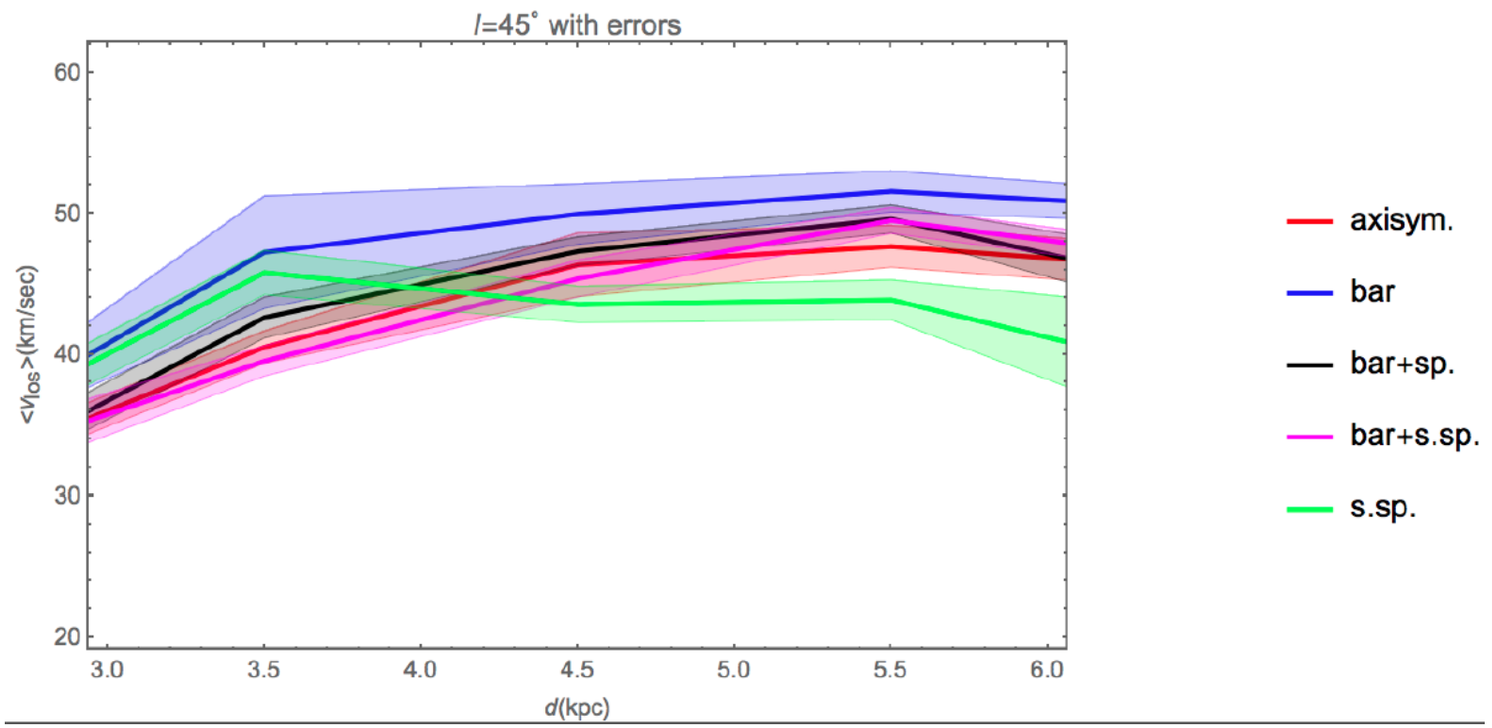
Bar with straight ends

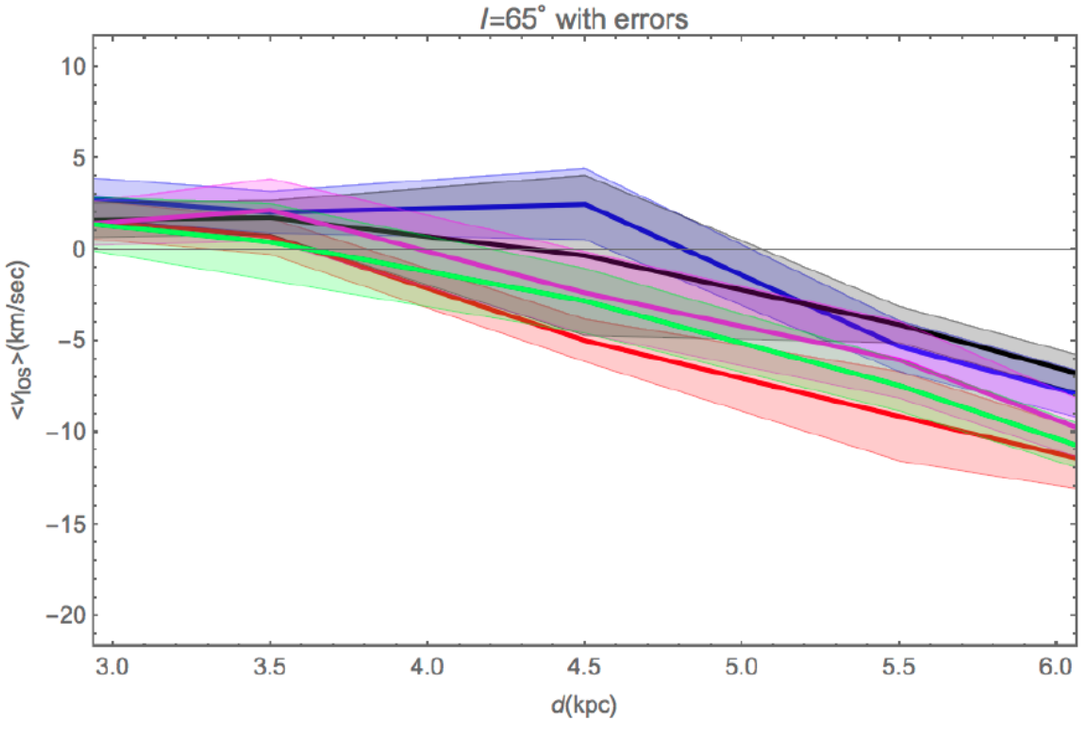
No bar (exponential disk)

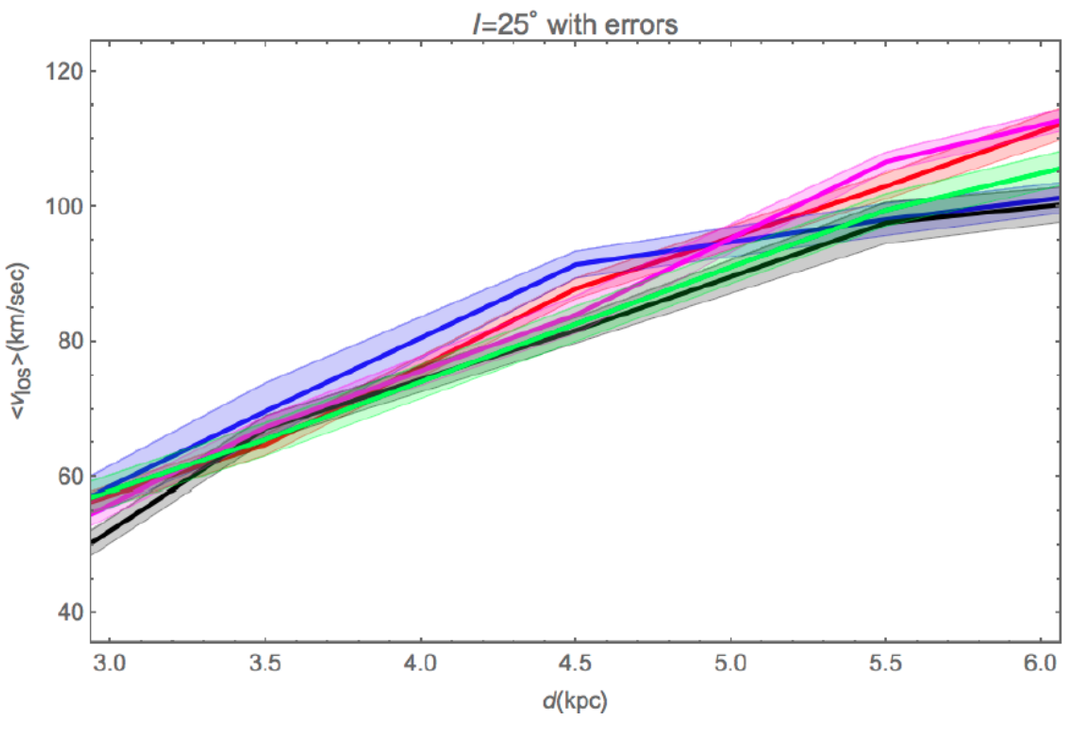
Martinez-Valpuesta & Gerhard (2011)

LR Disc survey: spiral arms + bar

distance error 20% and <5000 particles

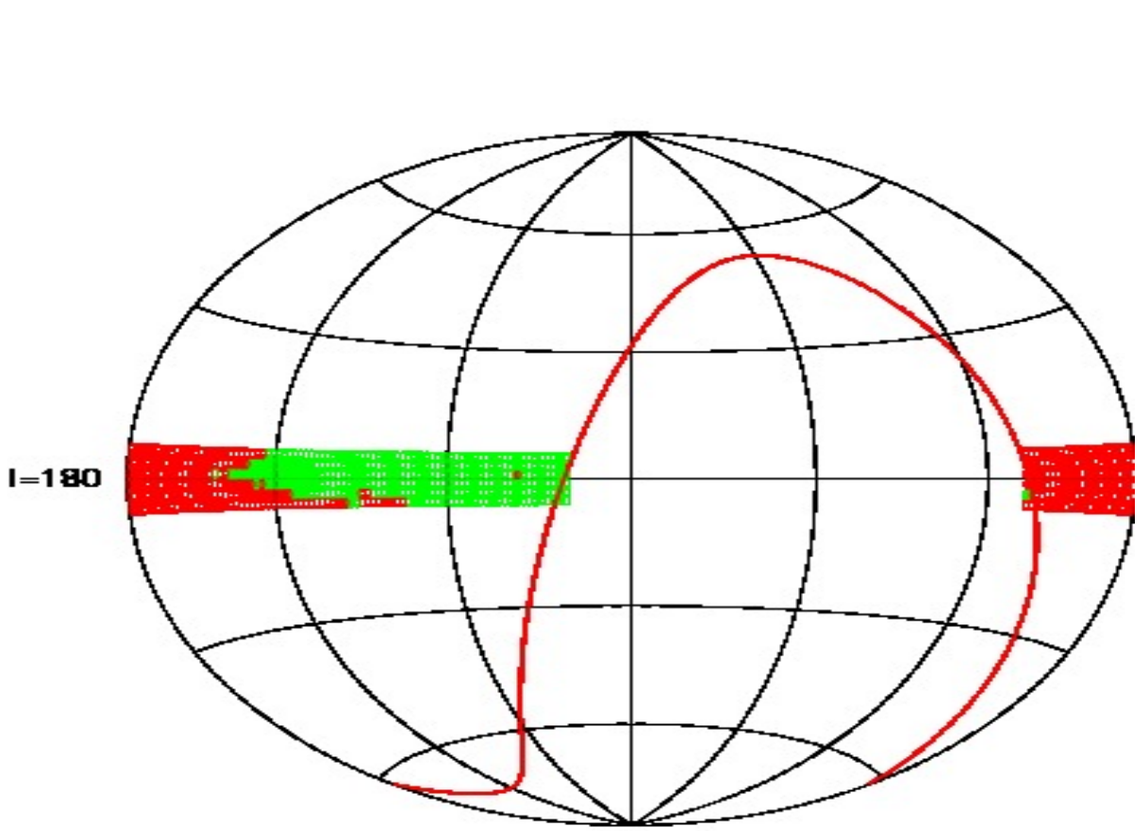


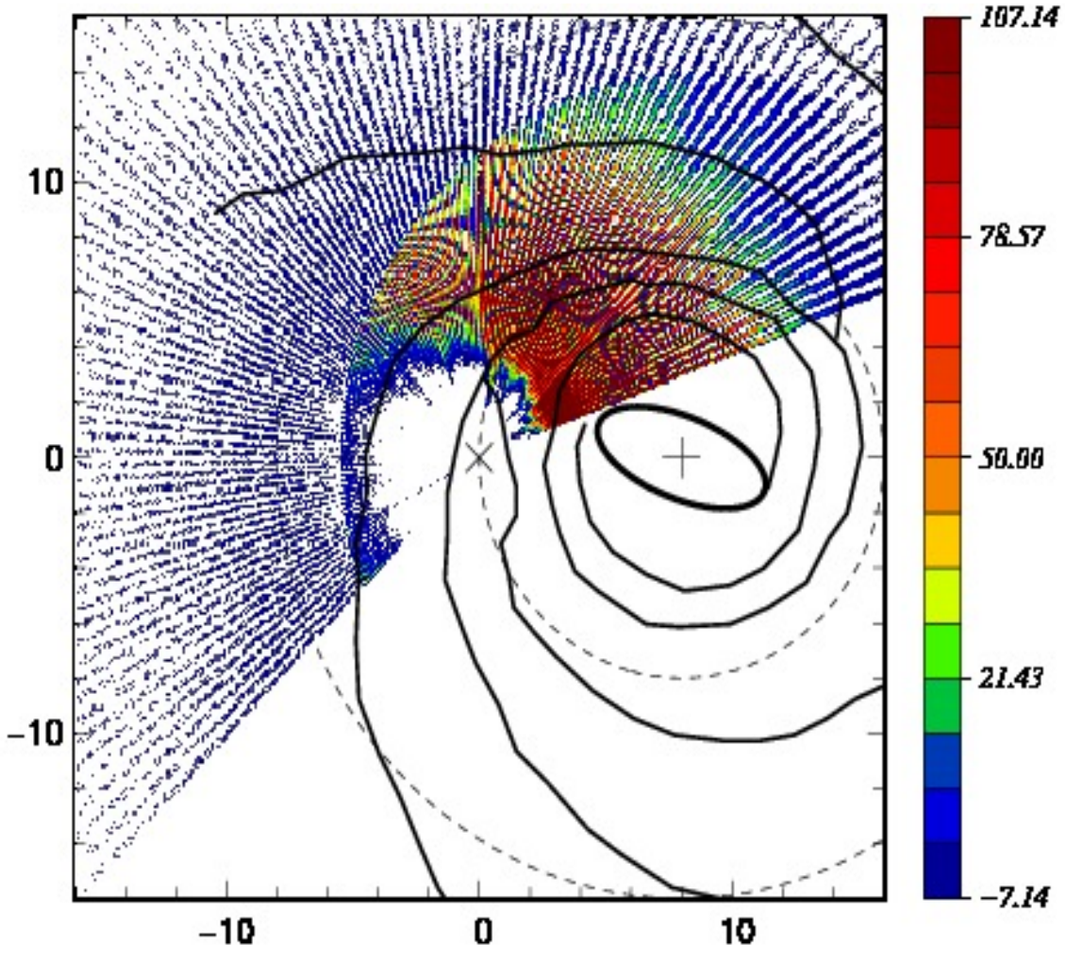




LR Disc survey: goals & means

Discriminate fundamental aspects of galactic disc dynamics: moving groups, velocity elipsoid accross the disc
➔ probe the axisymetric potential + non-axisymetric terms (bar, spiral arms). Implications for radial migration.





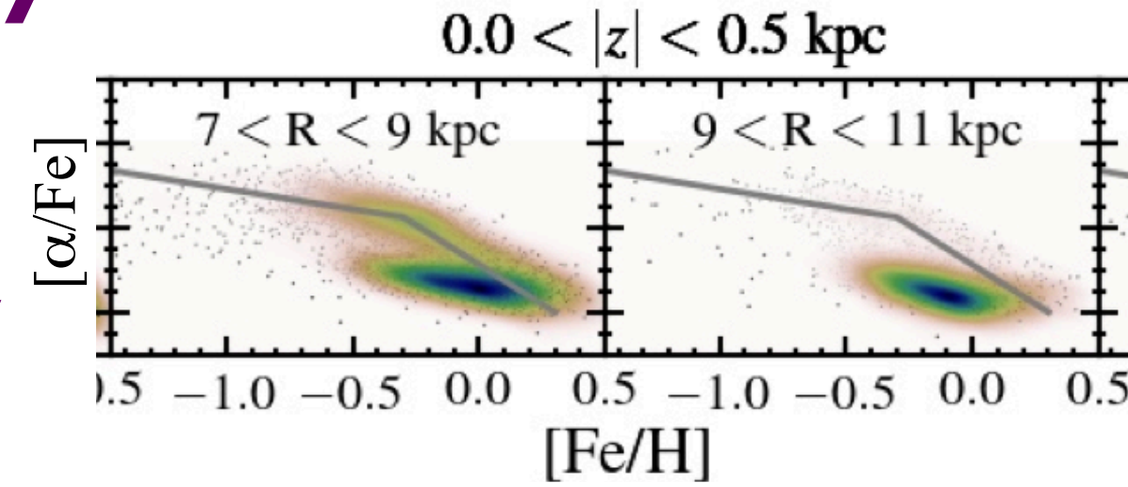
➢For a total of ~1.5 10^6 stars

WEAVE HR surveys

Three main HR surveys concentrating on chemical tagging/labelling the oldest MW populations :

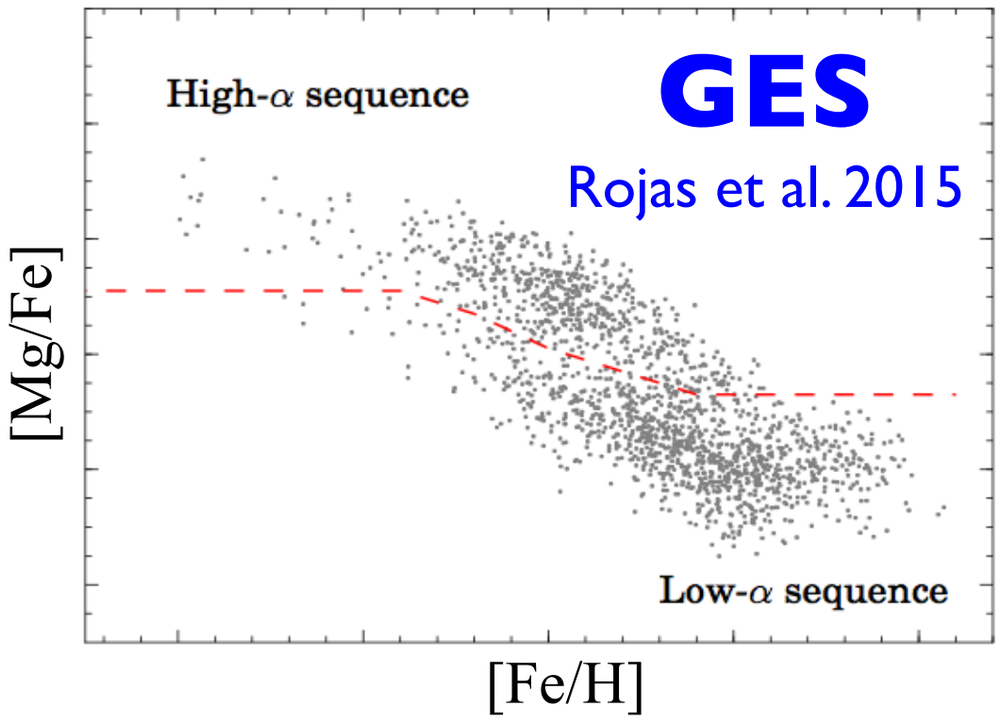
1. A high latitude survey searching for streams in the stellar halo
2. A intermediate latitude survey mapping the thick away from the solar vicinity
3. Open Clusters survey (complementary to GES)

APOGEE, Hayden et al. 2015



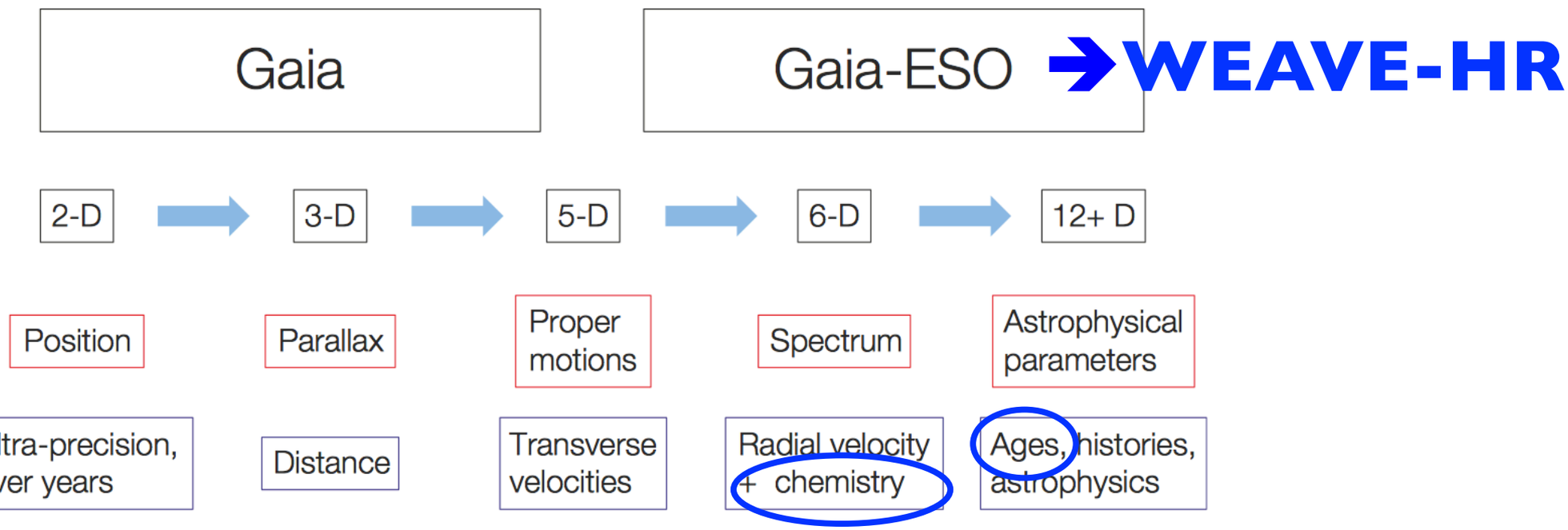
GES

Rojas et al. 2015



WEAVE can measure stellar parameters and individual abundances in all main nucleosynthetic channels to V=16, i.e. *closely matching the Gaia's most precise sphere (distances, ages)*

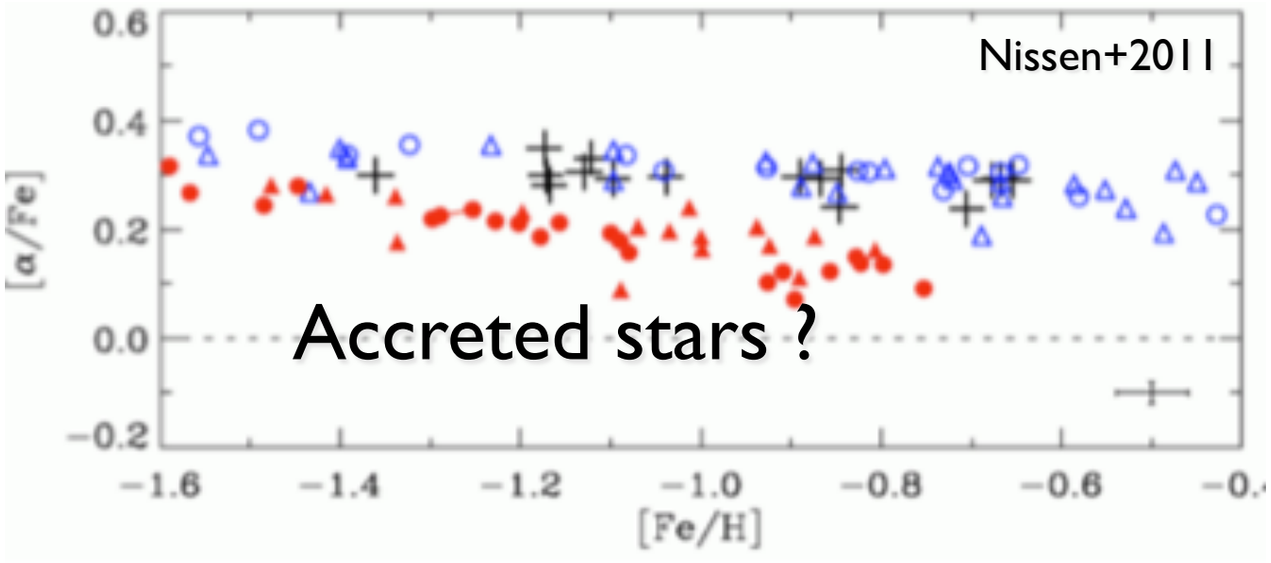
HR survey

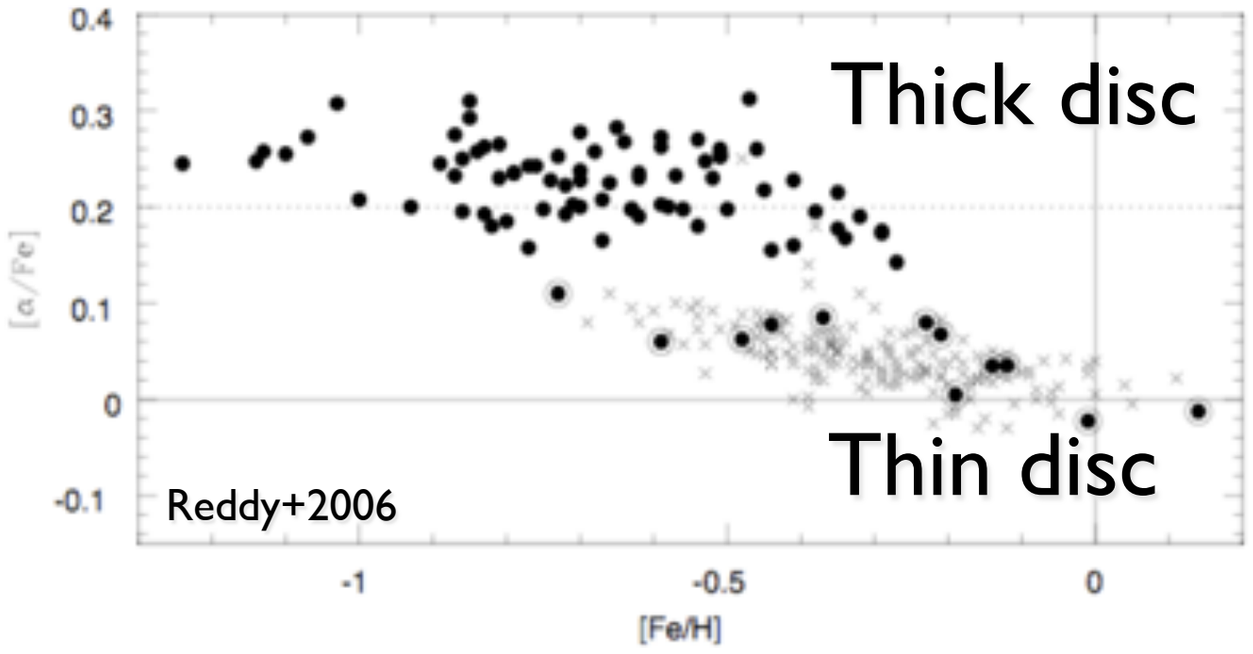


Gilmore et al. 2012

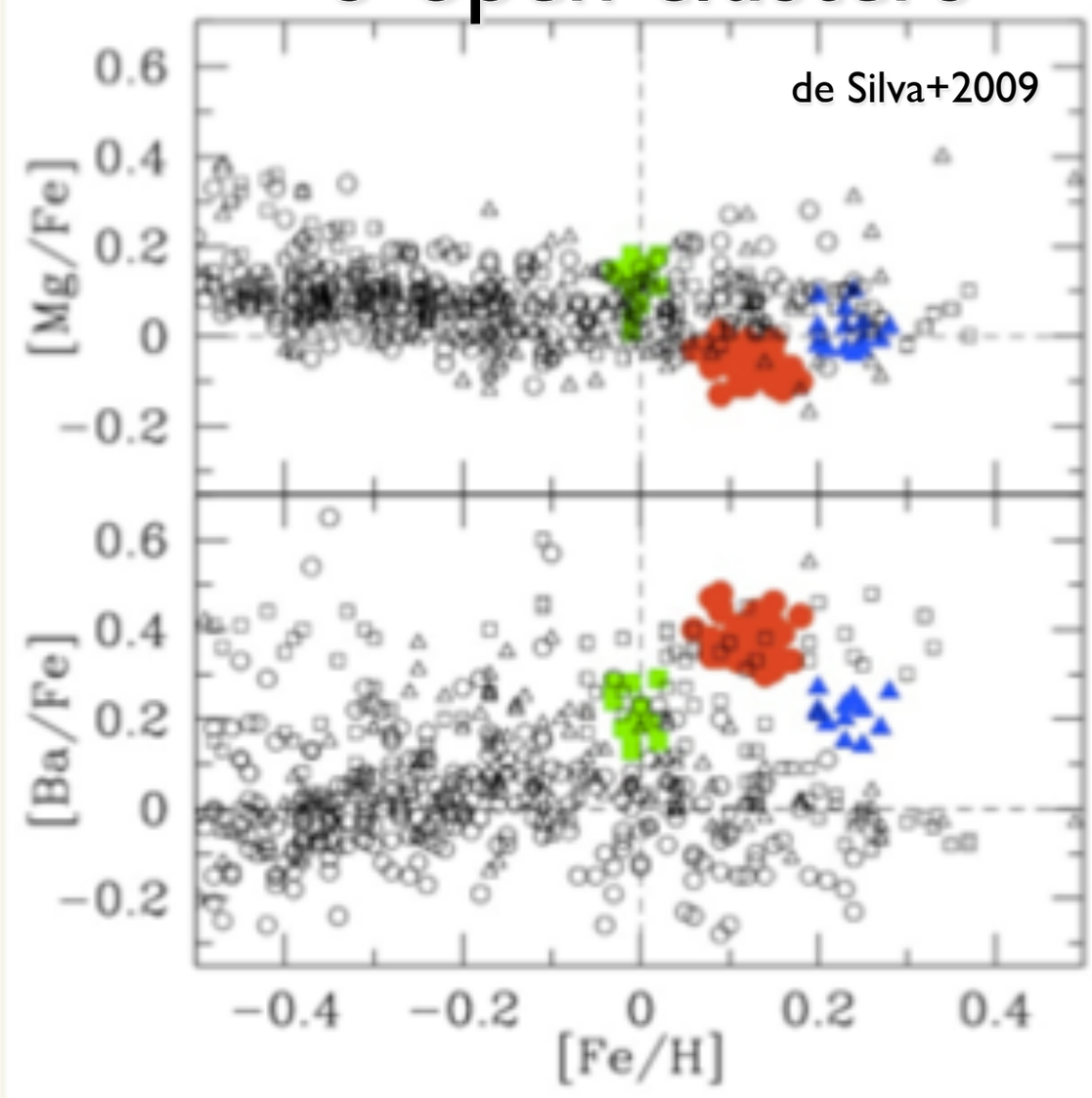
- Chemical labelling / tagging with all main nucleosynthetic channels
- Combine (spectroscopic) stellar parameters with Gaia distances to constrain ages

WEAVE at R=20,000: chemical tagging/labelling

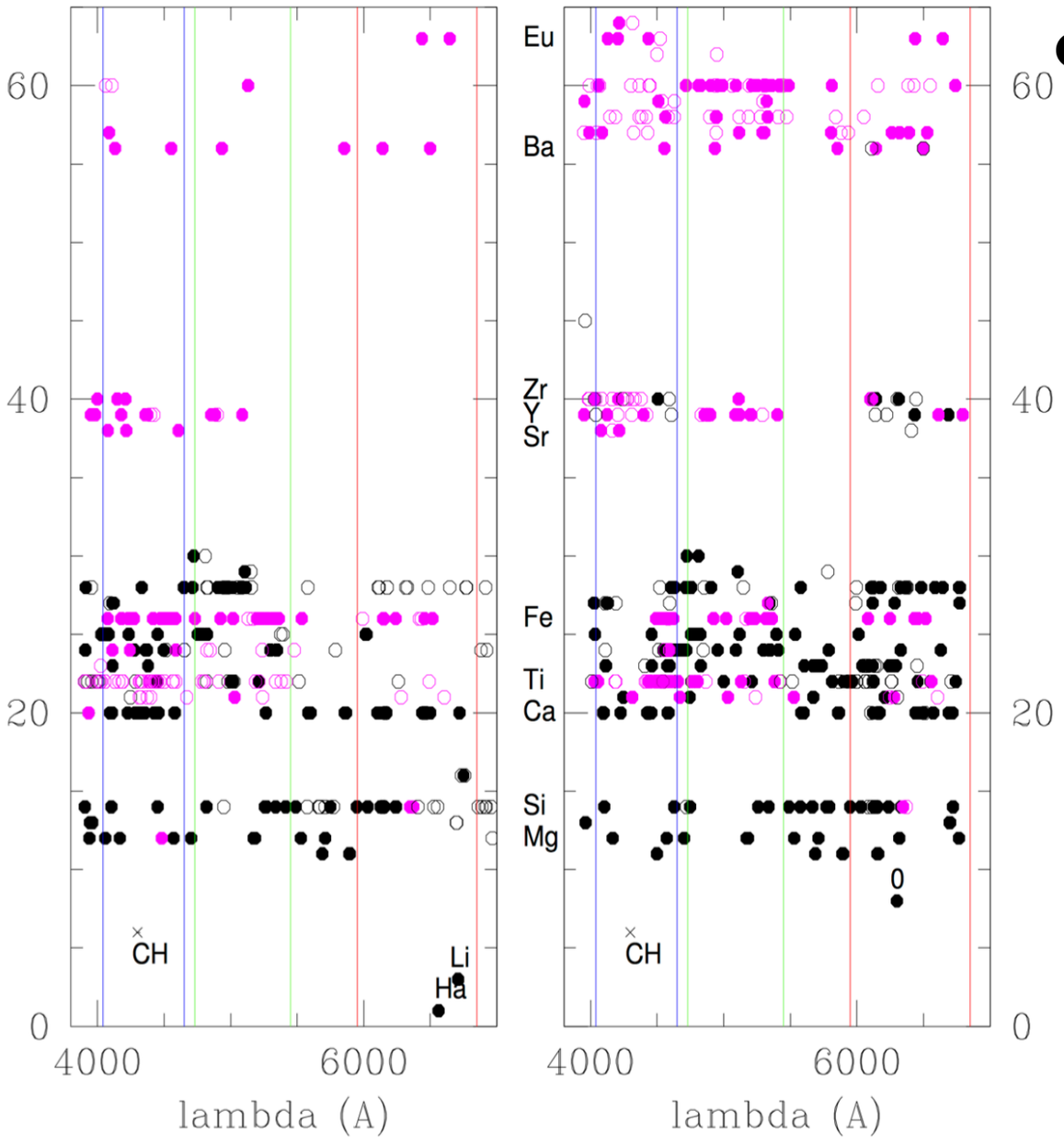




3 open clusters

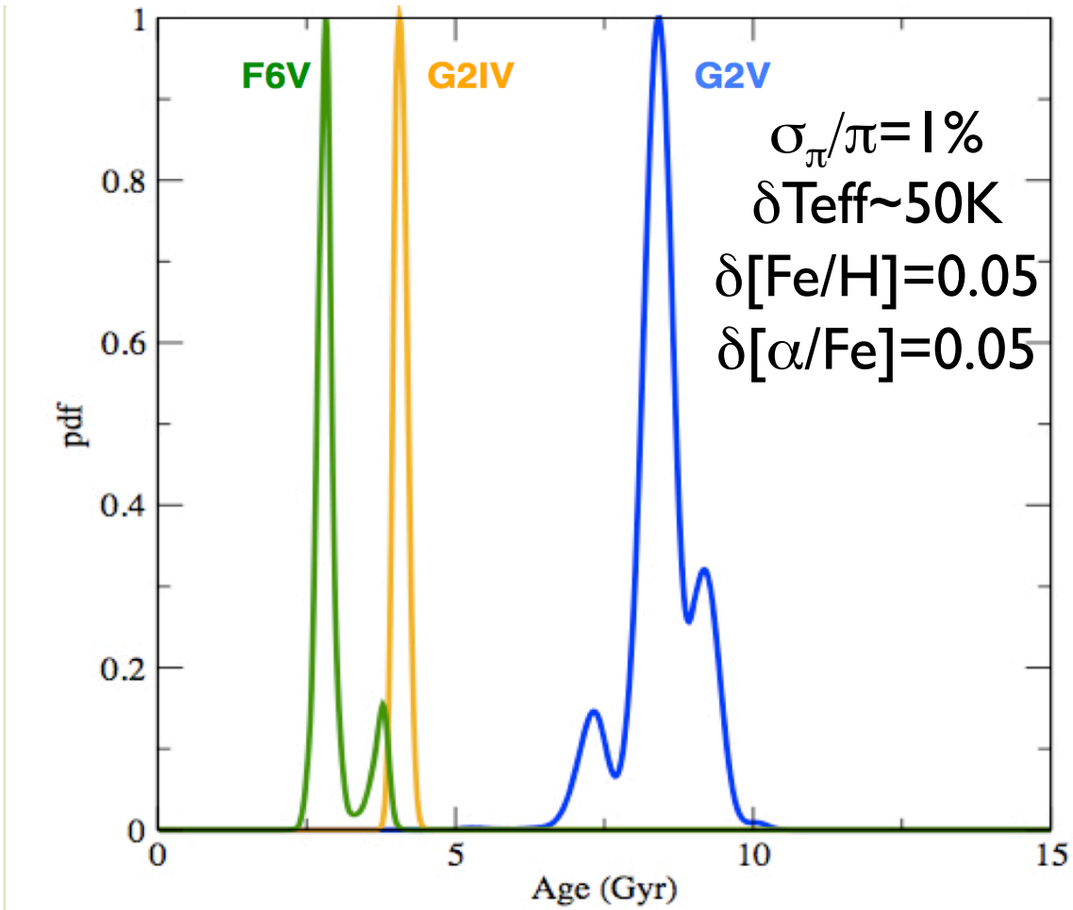


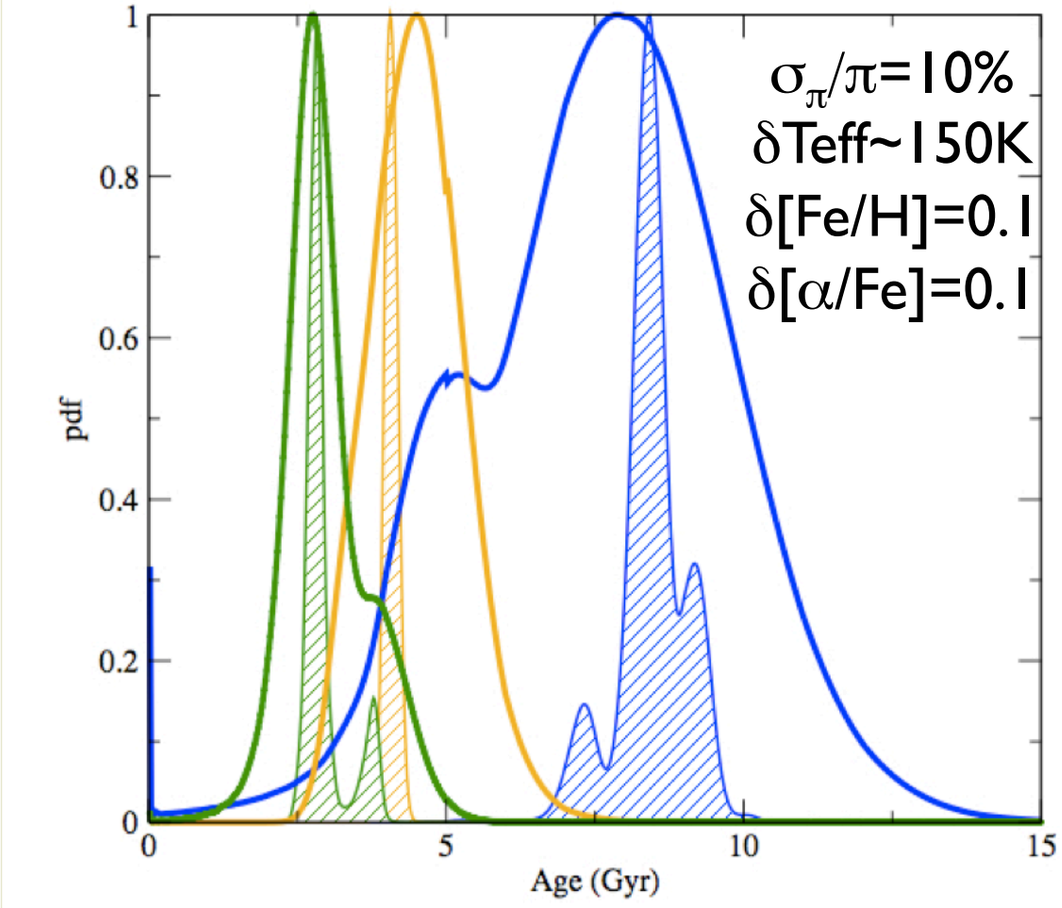
Elemental abundances



- Nucleosynthetic chanels : iron peak (Fe, Ni, Cr, Co, Zn), alpha elements (C, Mg, Si, Ca, [OI]…), neutron-capture slow and rapid elements (Zr, Y, Sr, Ba, La, Nd, Eu), odd elements (Na, Al, Sc)

Gaia's reach: ages





Stellar type relevant for isochrone ages : MSTO and subgiants (FG stars)

σ_π/π<1% (10^6*)

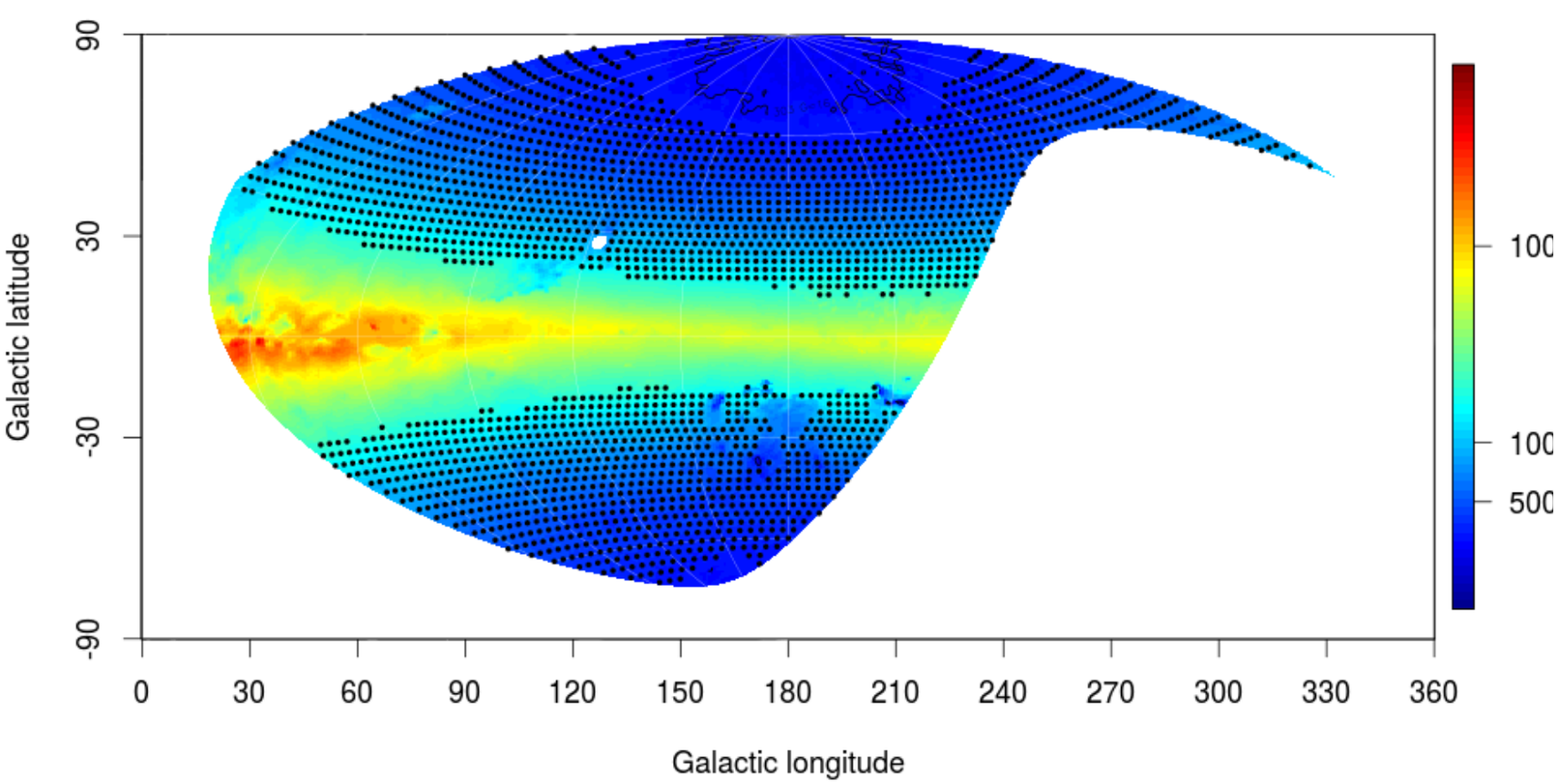
σ_π/π<10% (150.10^6*)

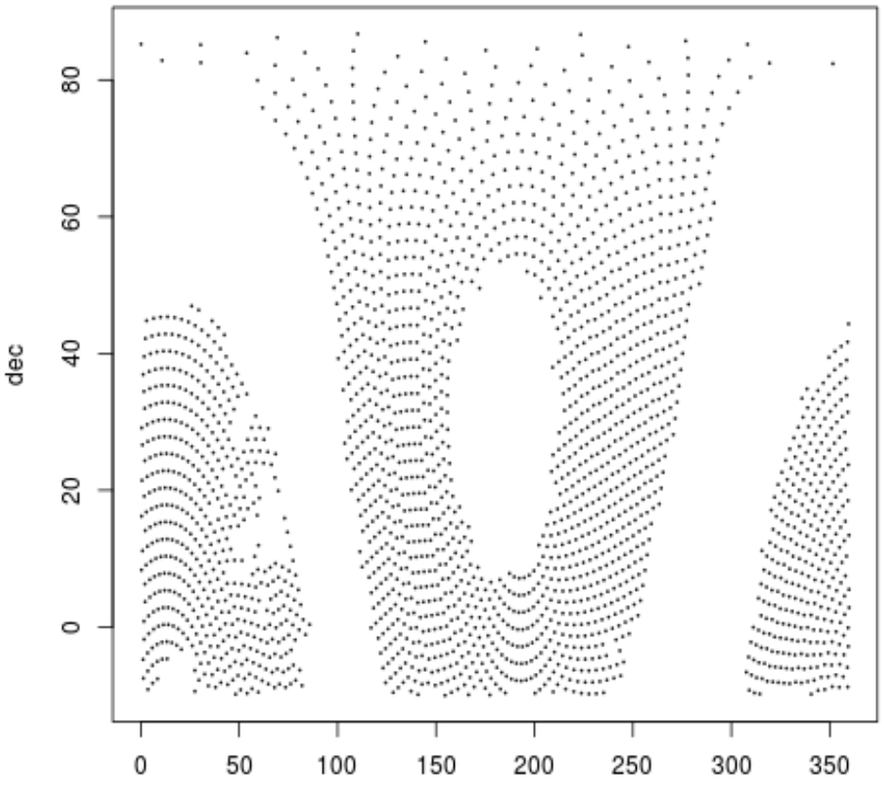
1-2 kpc

3-4 kpc

	Gaia only					Gaia + Ground-Spectro			
Vmag	σdistance	σteff (RVS)	σteff (BPRP)	σage	σ[α/Fe]	σdistance (Gaia)	σteff	σage	σ[α/Fe]
13-14	1%	100 K	150 K	~5%	0.10dex	1%	50 K	~3%	0.05dex
16-17	10%	-	250 K	~25%	-	10%	50 K	~15%	0.05dex

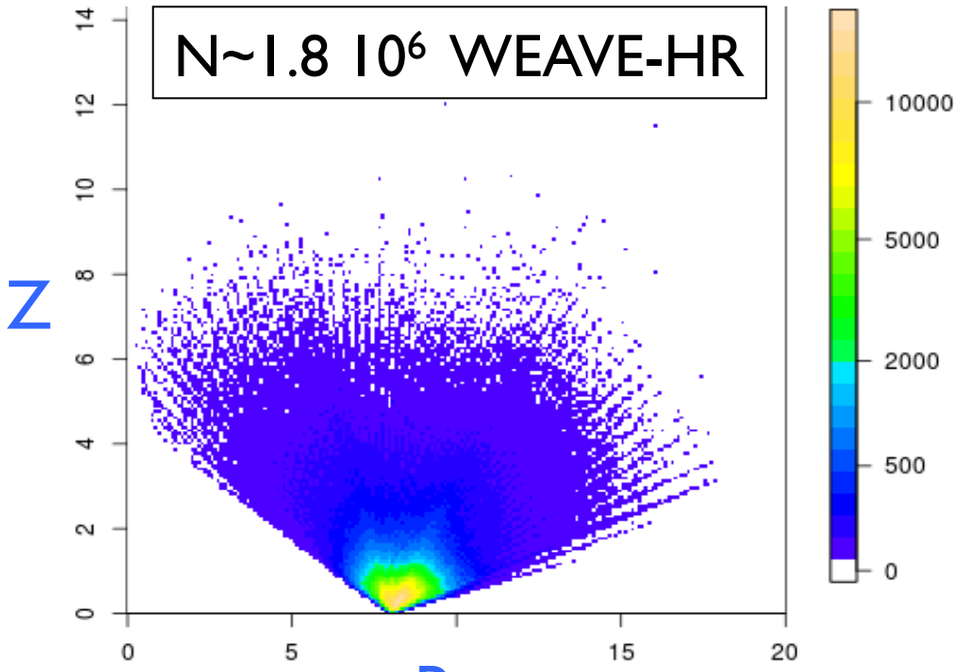
HR baseline survey

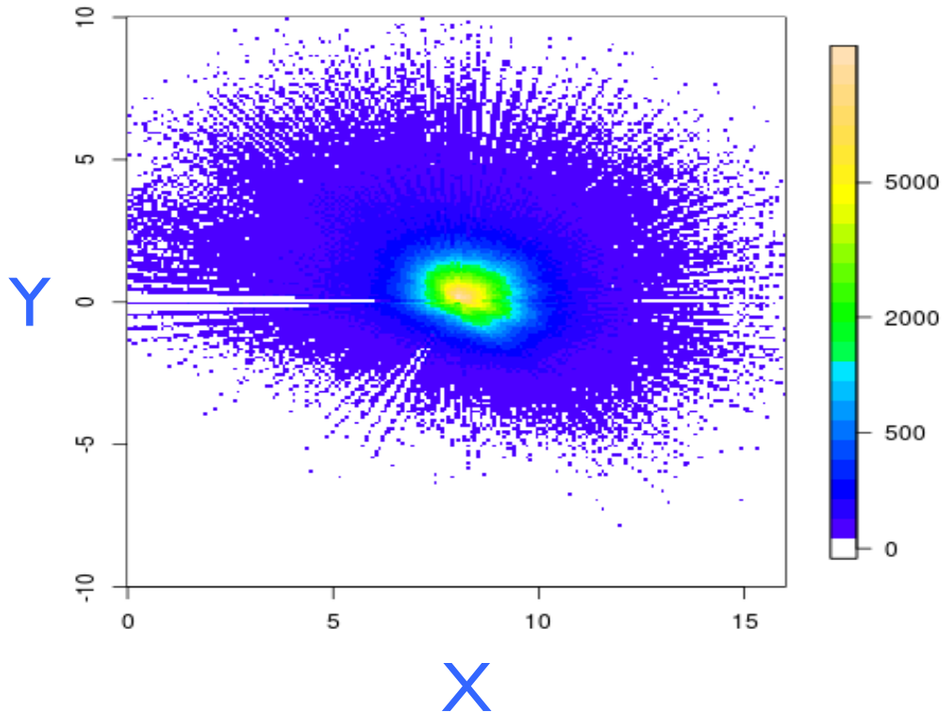


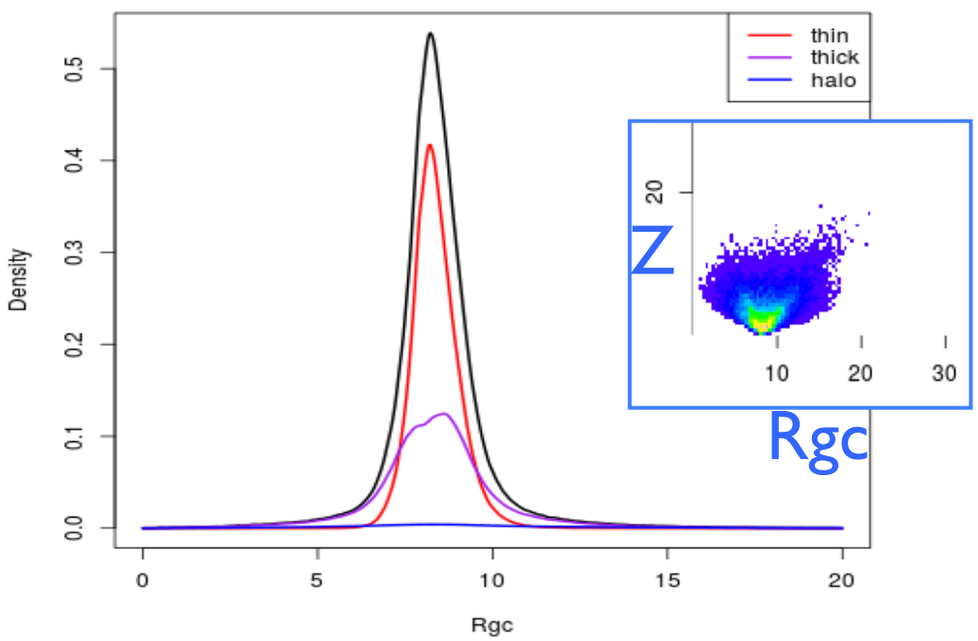


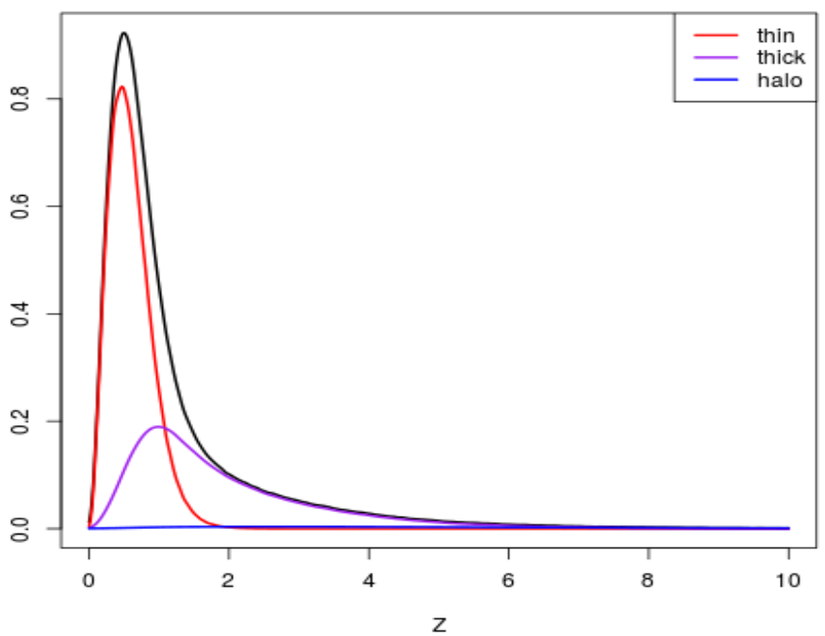
- 5,000 deg^2, with 30<|b|~60° (halo, to reach 5.10^5 giants) + 1,800 deg^2 with 15<|b|<30° to insure Rgc,Z coverage of discs
- Targets: MSTO (age sphere) + giants (halo), selected from Gaia (M_G)

HR *baseline* survey return





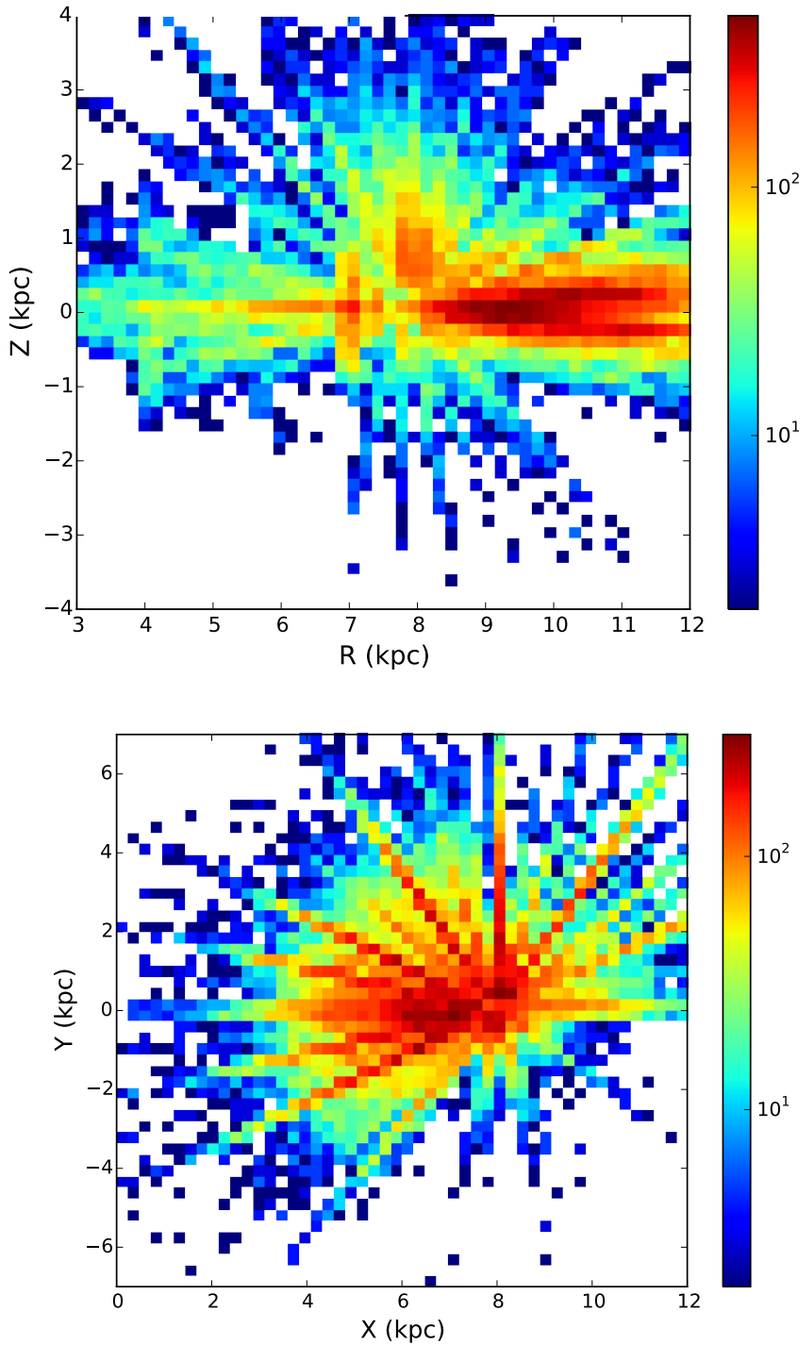




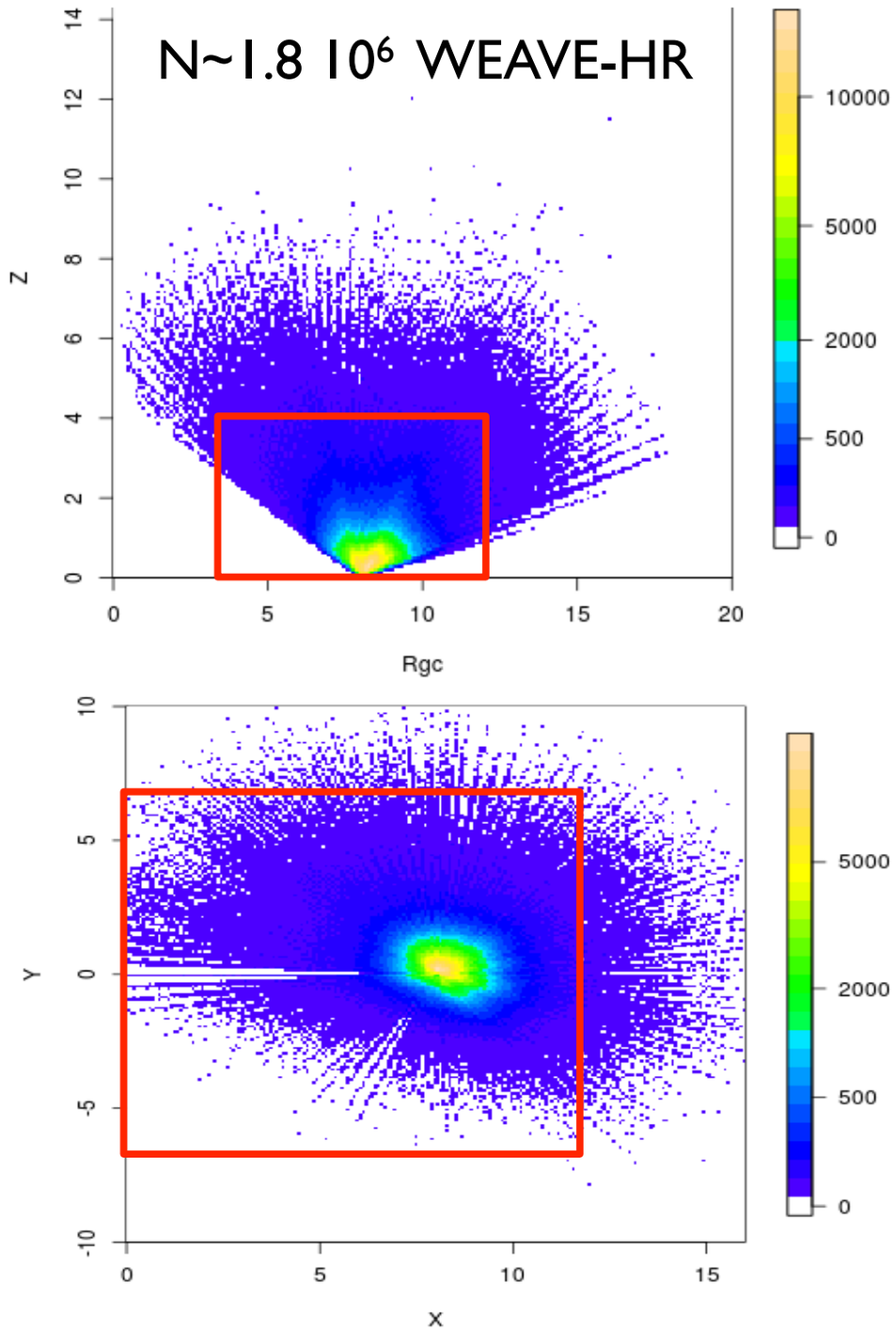
N_{halo}~6.10^4
N_{thick}~8.10^5
N_{thin}~1.10^6

APOGEE - WEAVE - GES

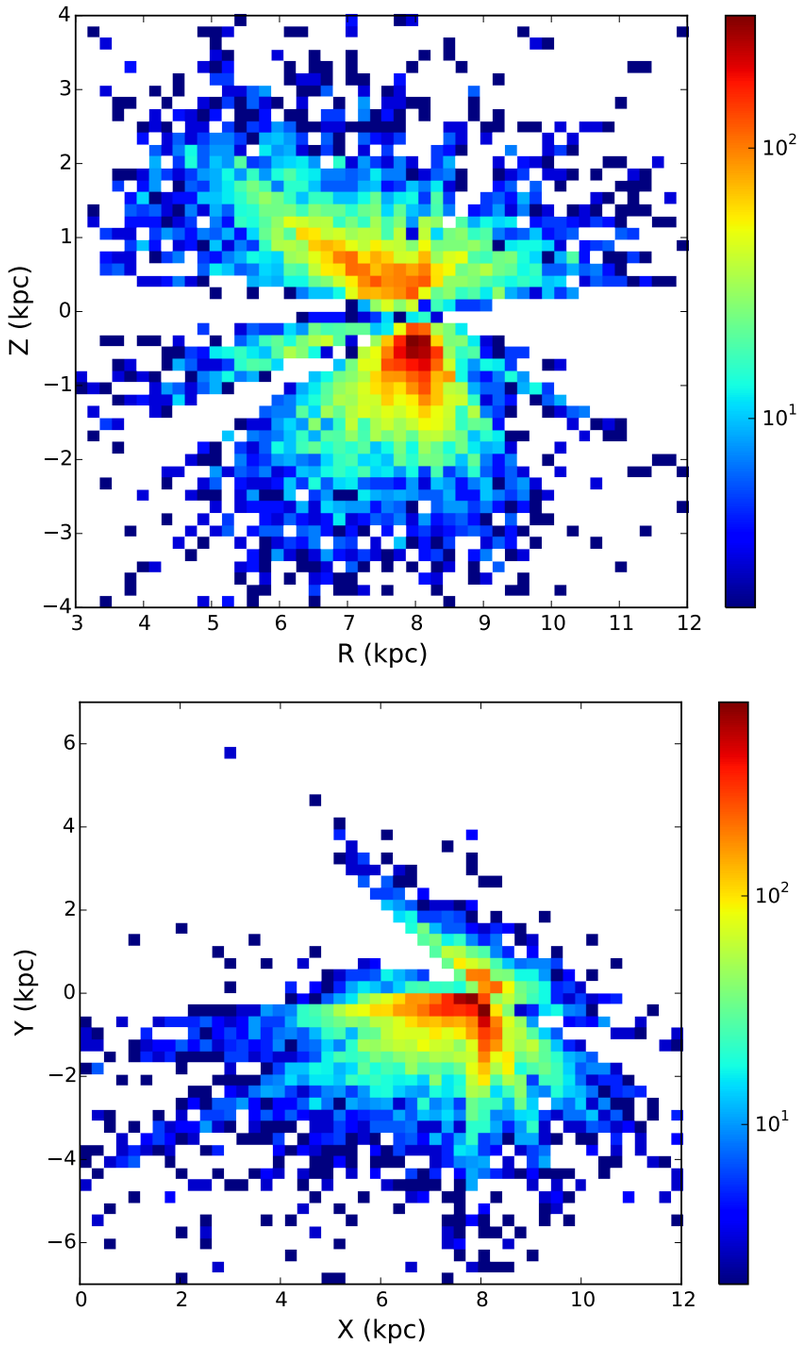
N=72348



N~1.8 10^6 WEAVE-HR



N=26138



APOGEE

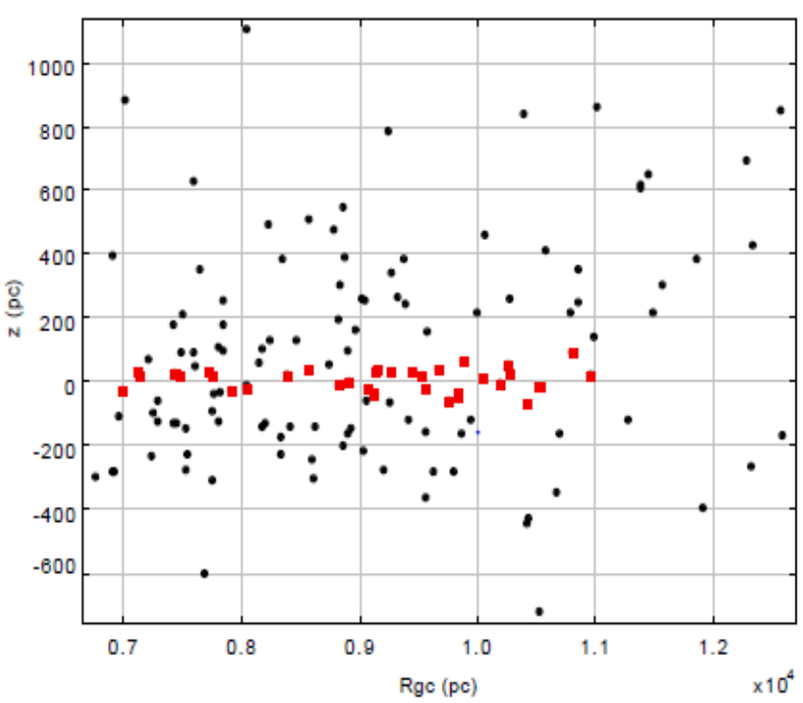
Cortesy G. Kordopatis

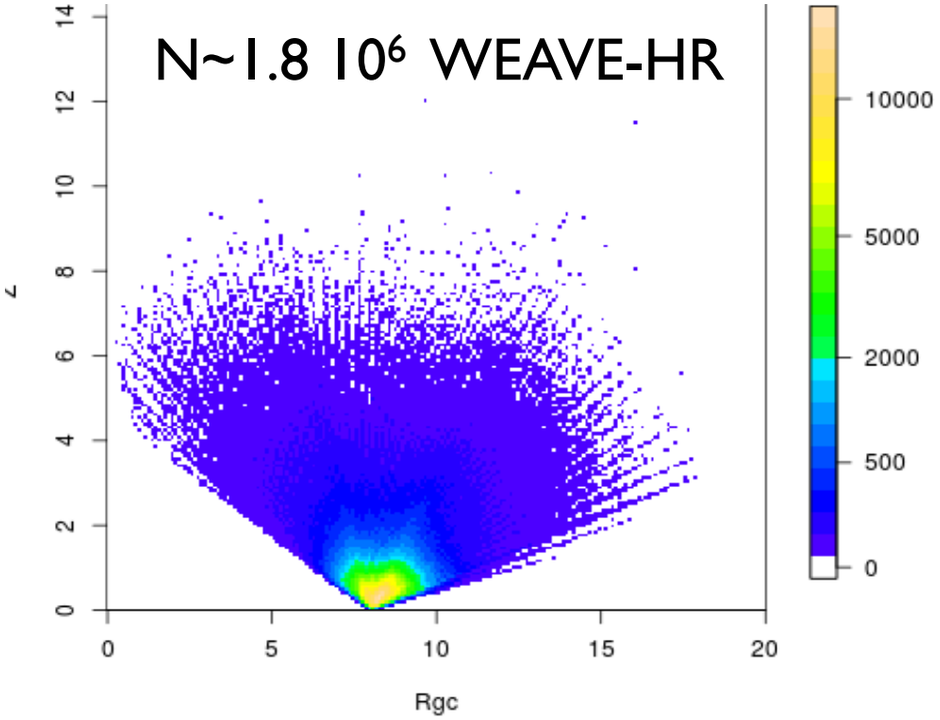
WEAVE

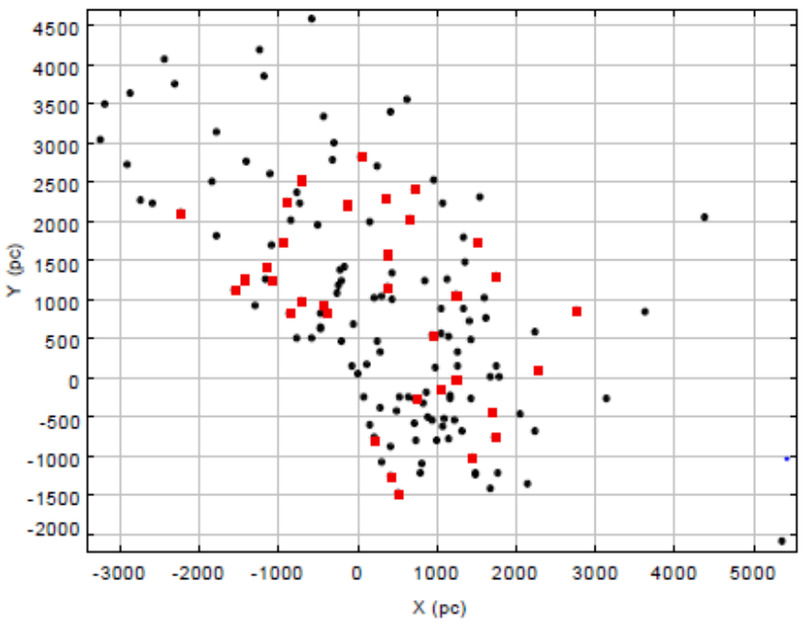
(R,Z) 100x75 pc; (X,Y) 80x100pc

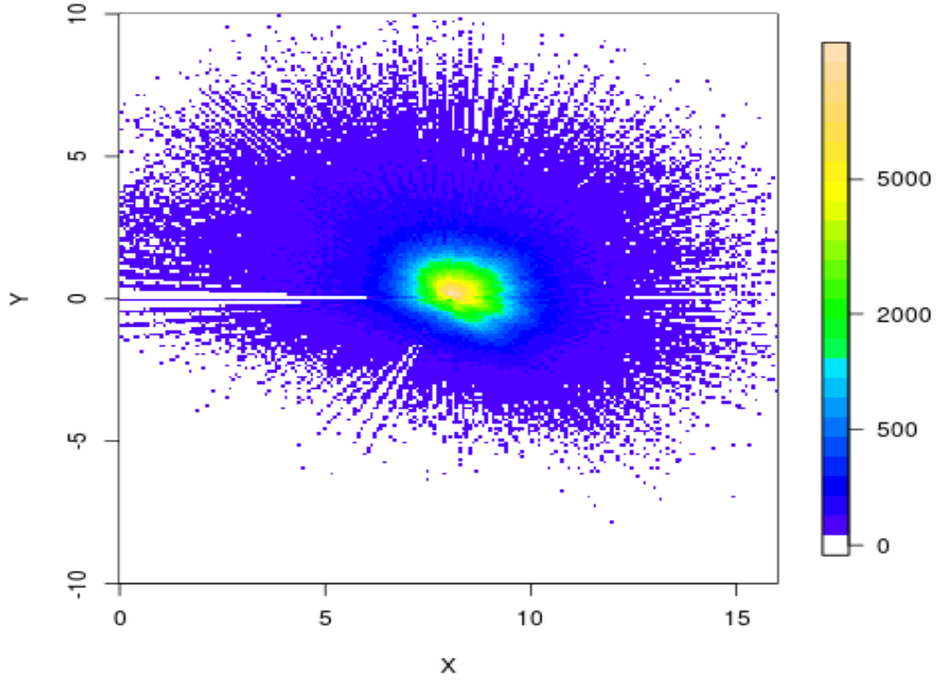
GES

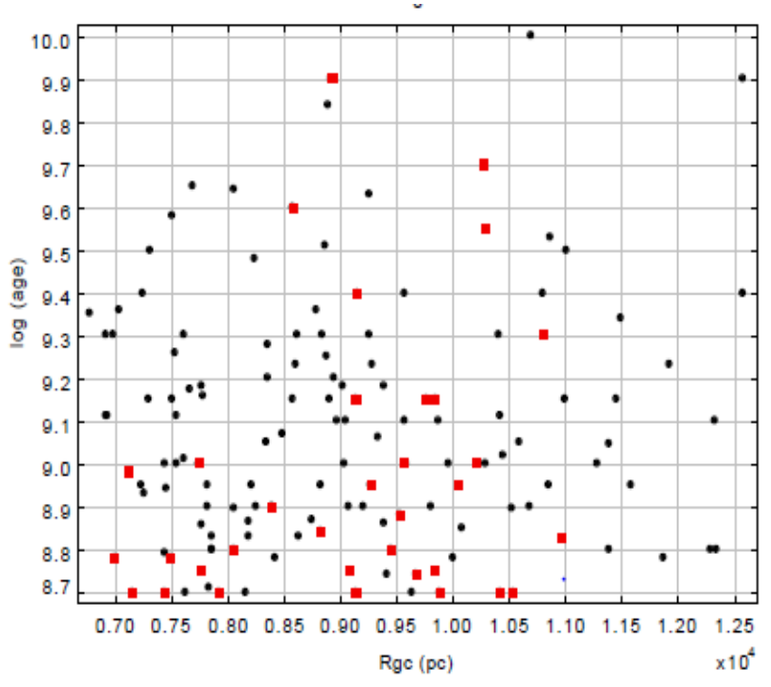
Old Open Cluster survey











WEAVE- « old » OCs

WEAVE

(R,Z) 100x75 pc; (X,Y) 80x100pc

Galactic Archaeology surveys with

@WHT

Timelines

2014-2015-early 2016: FDRs
October 2015: Survey science Review sucessful
11/2017: WEAVE 1st light
Q1/Q2 2018: start of the surveys
2018-2022(+): Surveys opérations

WEAVE status & timeline

- PDR: successful 3/2013
  - PFC optics PDR successful 11/2012; data systems PDR 6/2014; WAS PDR successful 4/2015
- FDR: 11/2014–10/2015
  - PFC optics FDR successful; Spectrograph optics + full FDRs successful; Positioner FDR successful; CPS/APS FDRs successful; other system FDRs staggered until beginning 2016
- Science & Surveys Review: successful 10/2015
- Construction complete: Q3/2017
- Assembly and integration at WHT complete: Q3/2017
- First engineering light: Q3/2017
- First science light: Q4/2017
- Surveys begin: Q1/2018
  - 5 years at 70% of total available nights (=236 nights/year) *guaranteed* + more?

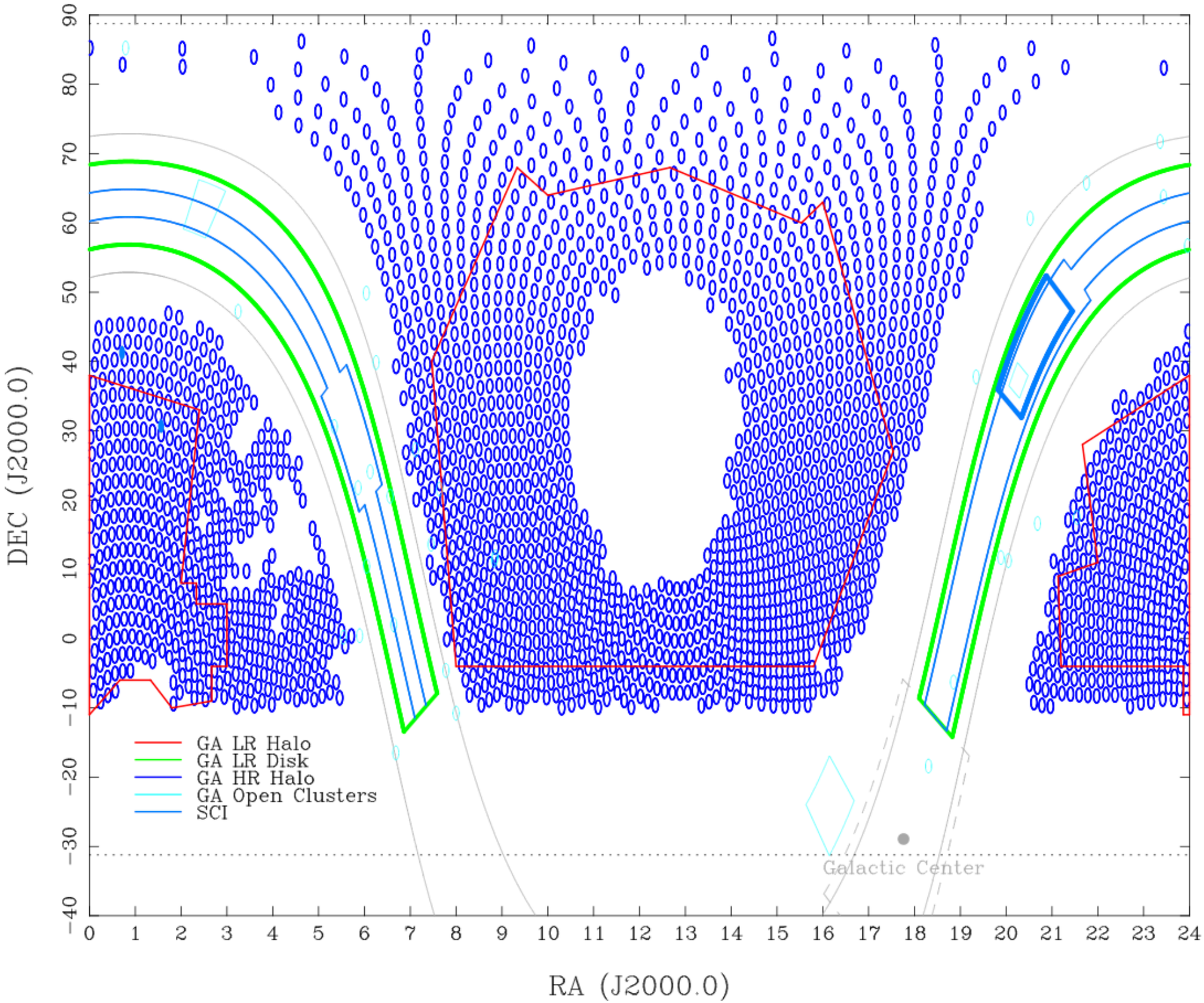
LR halo: EMPS

- Extremely metal-poor stars: rare objects, trace primordial nucleosynthesis (Li) and first stars nucleosynthetic signatures
- Low-number densities (needle in haystack): [Fe/H]<-3 are ~2-7% of all halo stars (eg. Ryan&Norris 1991, Ahn etal. 2013) ➔ expect a 1 to a few stars per deg2 with 14<g<20, or up to a few tens per WEAVE fov, depending on efficency of candidate selection. ➔ easy to include in WEAVE LR (or HR)
- Gaia's harvest: to be expected for DR3+ (not DR2)
- Other sources for high-probability candidates: collaborations
  - ✓ SDSS (what will be left for follow-up in 2018?)
  - ✓ Pristine@CFHT narrow-band filter (Starkenburg, Martin et al.)
  - ✓ LAMOST low-res spectroscopy (R=2,000), V~12-17

LR halo: ISM

- Common goal (with different tracers) of the LR and HR GA surveys: map the interstellar medium, using atomic and/or DIB in the line of sight of all stars of the surveys

Combined stellar footprint



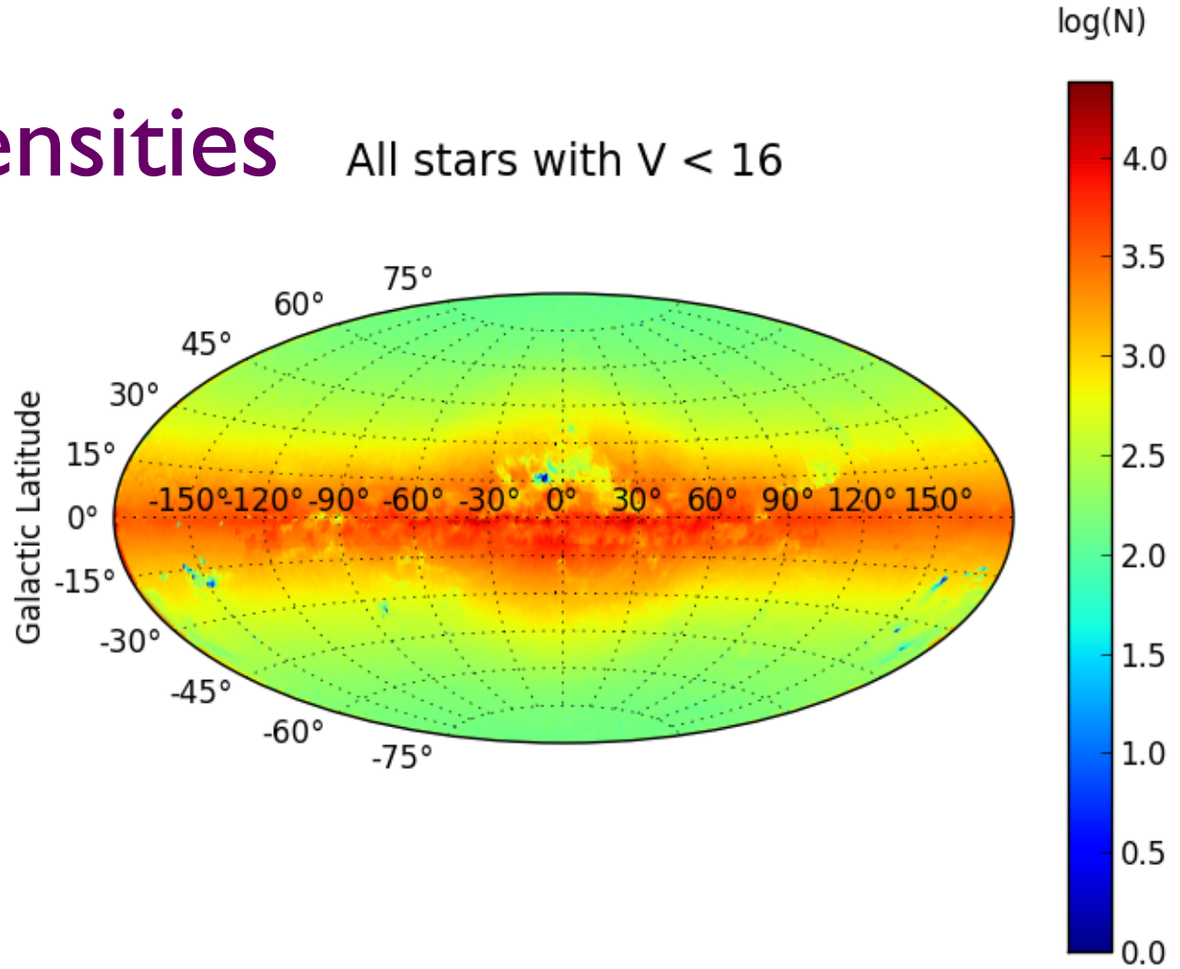
HR survey: goals & means

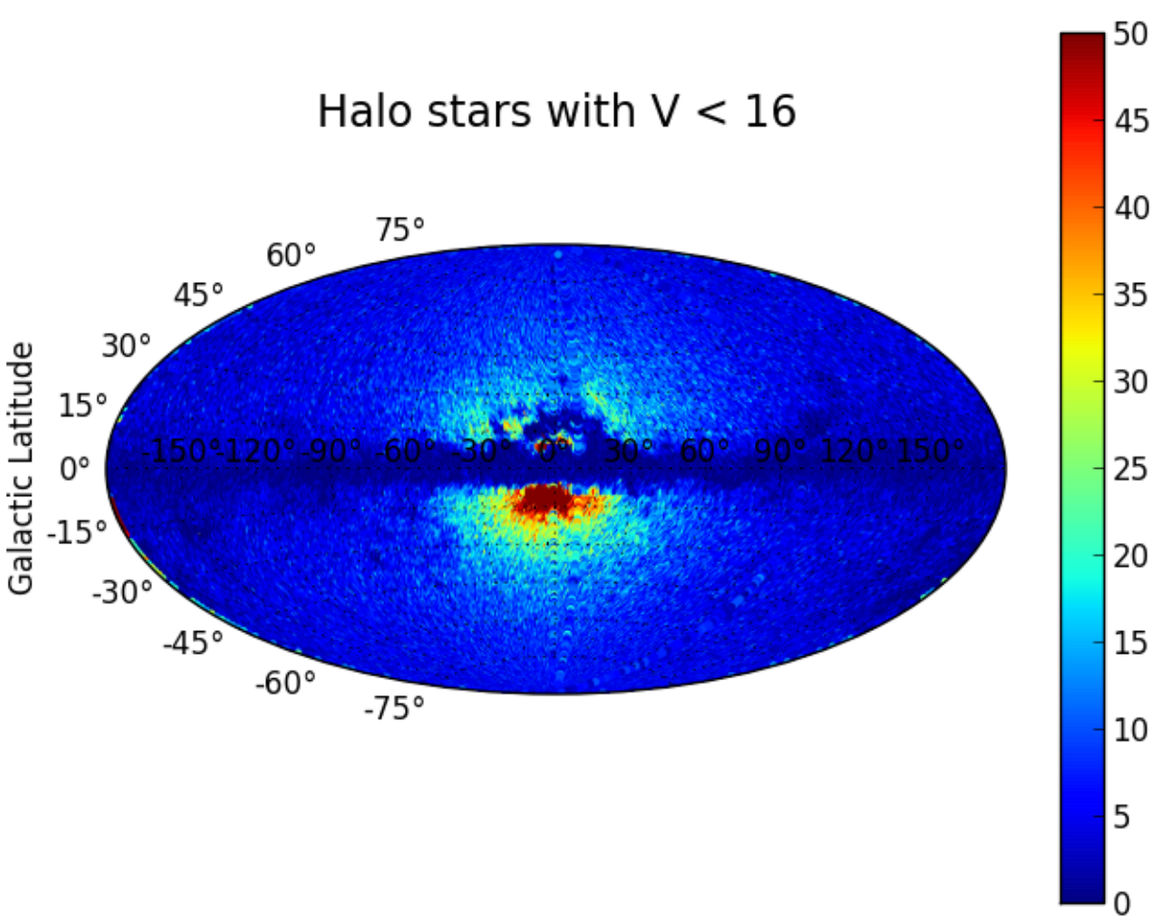
Probe the MW main populations history (mass assembly, internal evolution):

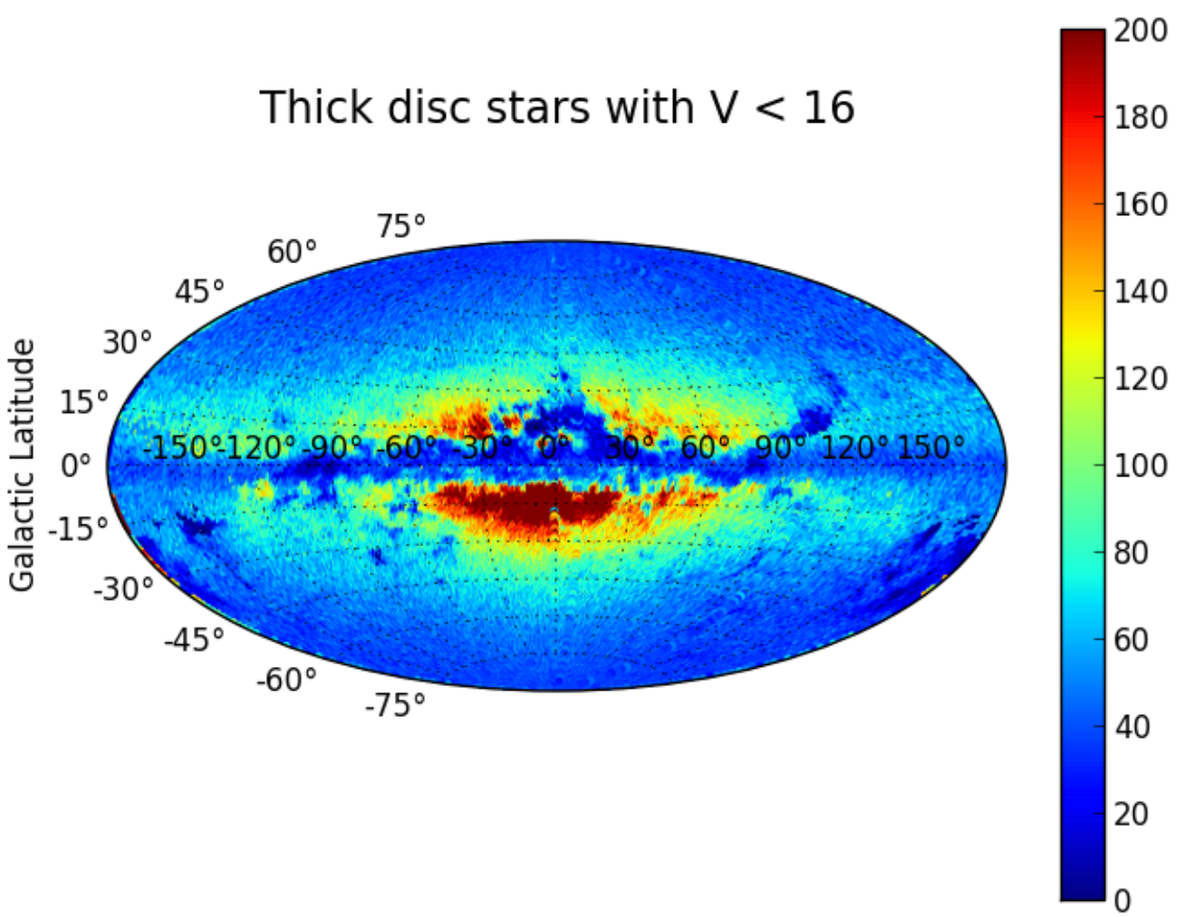
- **Goal 1.** Probing the assembly of the Galactic populations (thin & thick discs, halo) with chemical labelling and ages
- **Goal 2.** Chemical labelling of streams, groups and substructures in the Galactic halo

  - 12<V<16(-17) survey of 6800deg^2 15°<|b|>60°, of old MSTO stars and giants, incl. ~5.10^5 halo giants |b|>30°, and and thin/thick disc stars covering Rgc – Z plane.

WEAVE HR densities



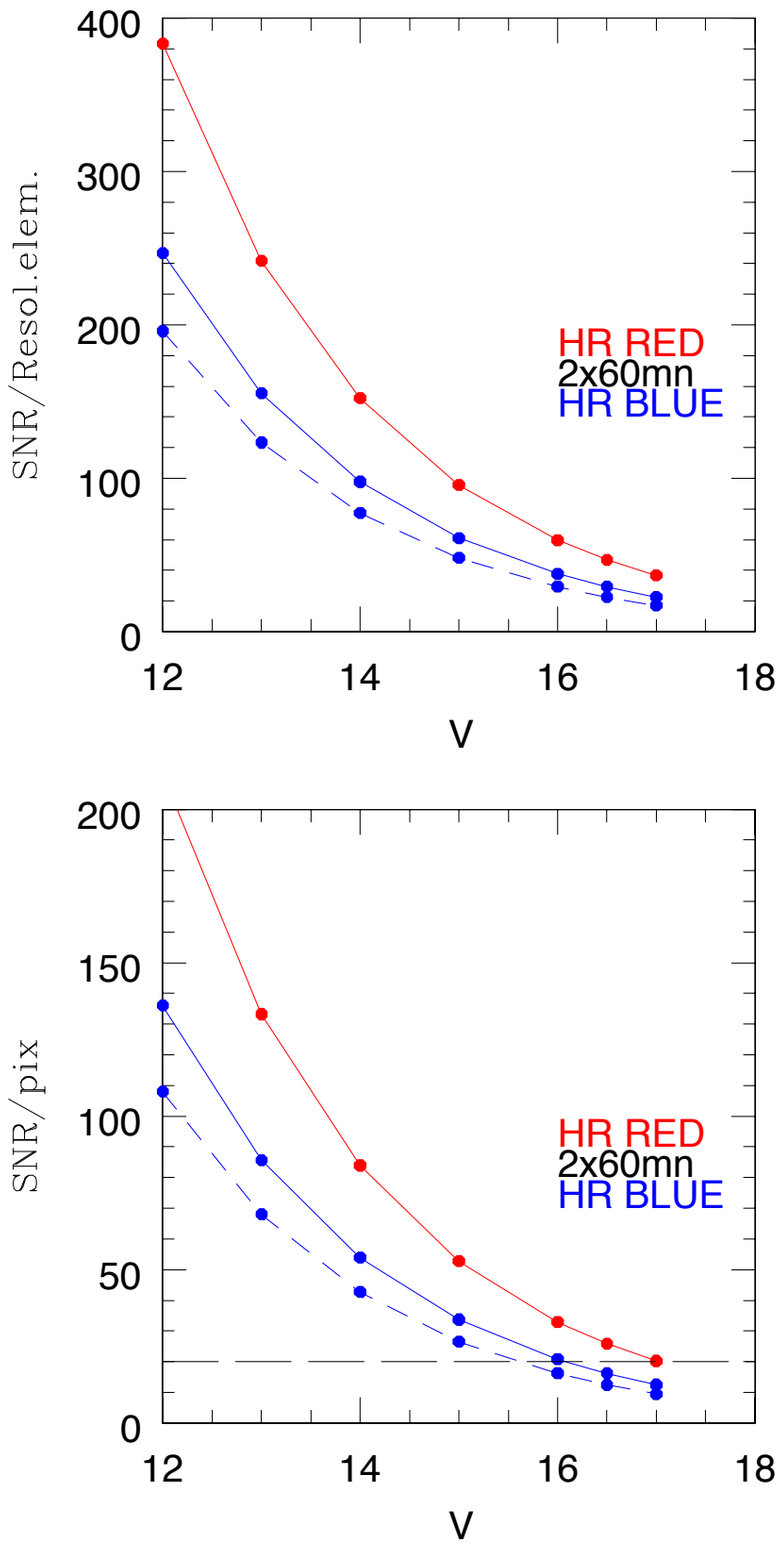


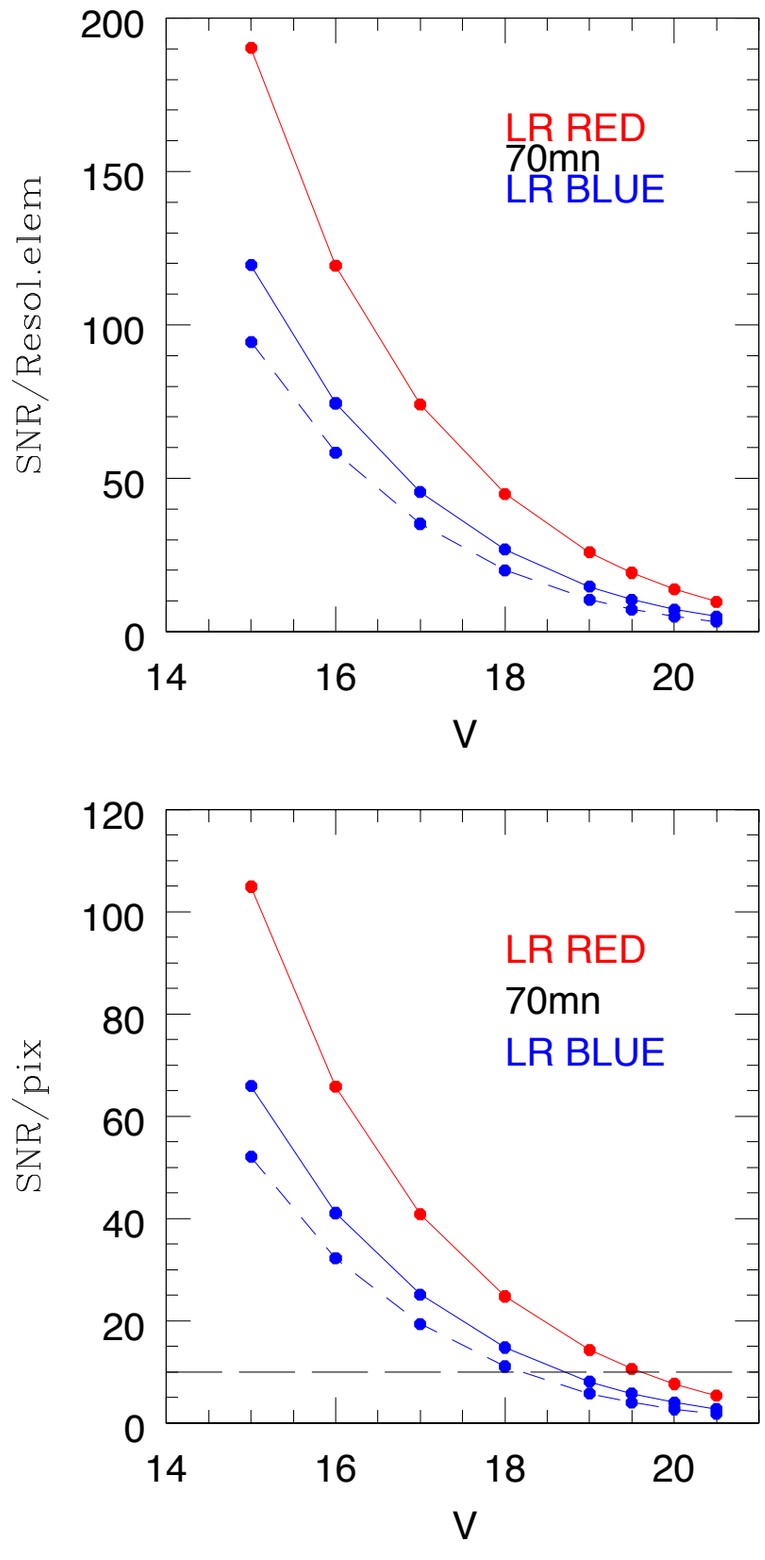


GA Surveys

Survey	Desirable	Optimal	Essential
LR Halo 15<V<20-21	• 15,000 deg^2; • all stars; • densities 2000-6000 per WEAVE fov	• 10,000 deg2 |b|>30-40°; • selected targets Giants and MSTO; • densities 600-1300 per WEAVE fov.	• 10,000 deg2 |b|>30-40°; • selected targets Giants (1st priority: all available) and MSTO (sampling among these candidates); • densities 600-700 per WEAVE fov
LR Disc Dynamics 16-17<V<20	• 280+540 line-of-sight towards the inner+outer galaxy • 12/4 pointings in each los respectively	• 280+540 line-of-sight towards the inner+outer galaxy • 6/2 pointings in each los respectively	• 210+405 line-of-sight towards the inner+outer galaxy • 5/1 pointings in each los respectively
HR Chemo-dynamics 12<V<16-18 HR Chemo-dynamics	• Full sky |b|>15°; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • selected targets Giants and MSTO; • densities 800-2000 targets.

WEAVE ETC


SNR/Resol.elem.
400
300
200
100
0
12
14
16
18
V
HR RED
2x60mn
HR BLUE

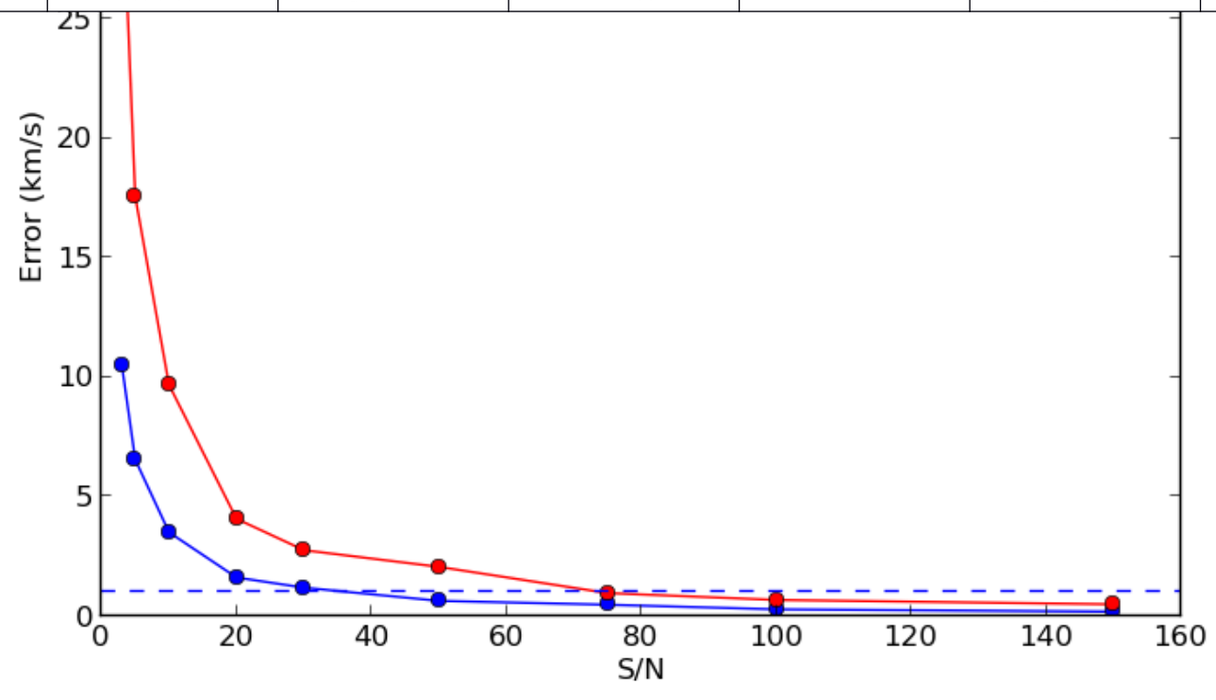

SNR/Resol.elem
200
150
100
50
0
14
16
18
20
V
LR RED
70mn
LR BLUE

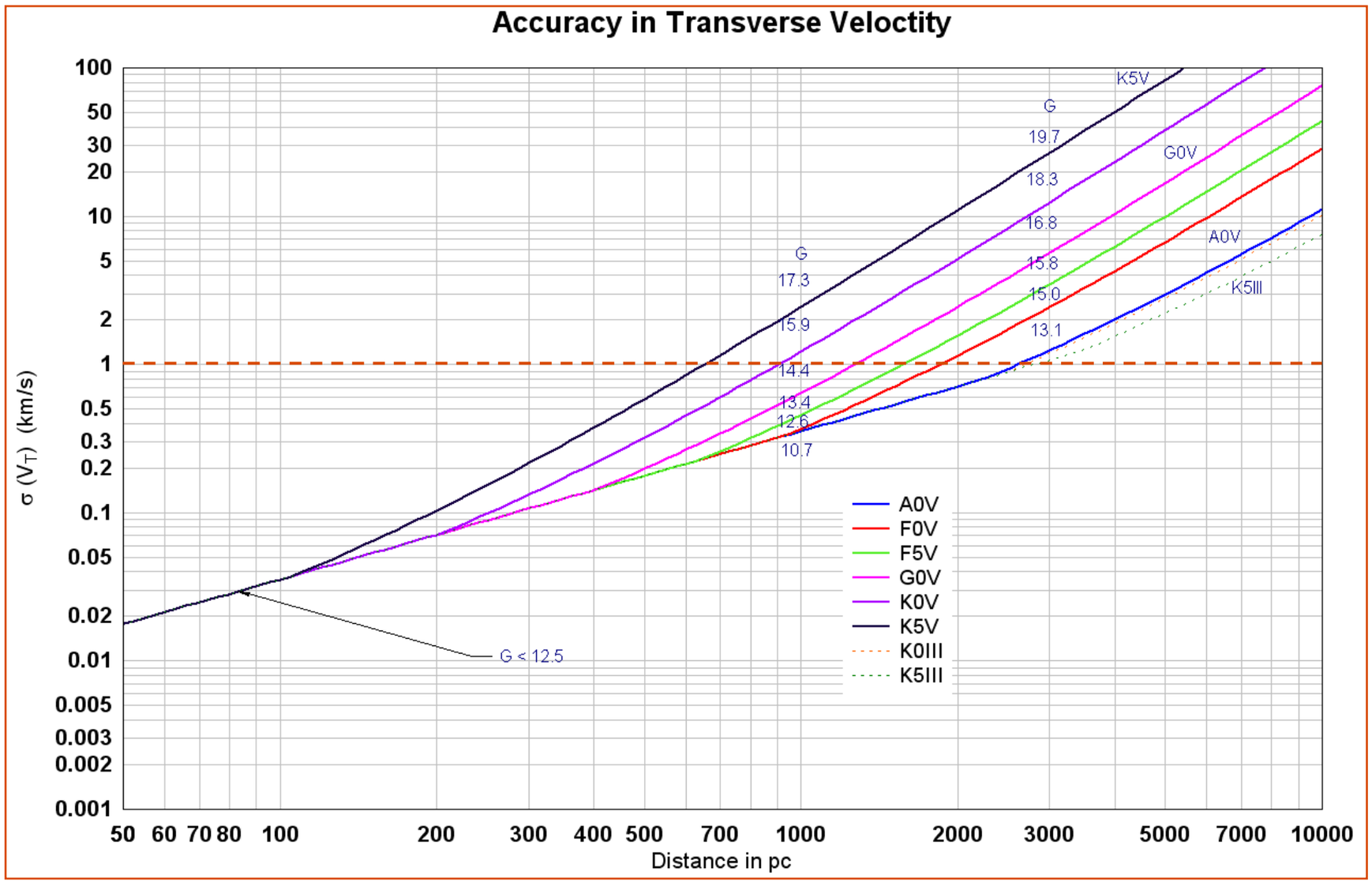
SNR/pix
200
150
100
50
0
12
14
16
18
V
HR RED
2x60mn
HR BLUE

SNR/pix
120
100
80
60
40
20
0
14
16
18
20
V
LR RED
70mn
LR BLUE

Expected WEAVE radial velocity errors

LR, 1 hour exposure, Dark time (V=21.5)						
	Blue arm			Red arm		
V	SNR/el	RV error (km/s) ETC	RV error (km/s) Fig	SNR/el	RV error (km/s) ETC	RV error (km/s) Fig
15	120.8	1.9	0.4	174.9	1.9	0.4
16	74.8	1.9	0.4	108.5	1.9	1.5
17	45.1	2	0.8	65.7	2.	1.9
18	25.9	2.9	1.4	37.9	2.7	3.4
19	13.6	5.1	2.3	20.1	4.4	4.2
20	6.5	12.9	4.5	9.7	10.3	15.3




Accuracy in Transverse Velocity
σ (V_T) (km/s)
Distance in pc
100
50
30
20
10
5
2
1
0.5
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.003
0.002
0.001
50 60 70 80 100 200 300 400 500 700 1000 2000 3000 5000 7000 10000
G
17.3
15.9
14.4
13.4
12.6
10.7
G
19.7
18.3
16.8
15.8
15.0
13.1
K5V
G0V
A0V
K5III
G < 12.5
A0V
F0V
F5V
G0V
K0V
K5V
K0III
K5III

Nominal survey parameters

Survey	Mode	No. Objects	Area (deg^2)	Nights
GA halo LR	MOS/R=5000	10^6	6500	215
GA halo HR	MOS/R=20000	$5x10^4$	2500	115
GA disk LR	MOS/R=5000	$5x10^6$	2000	90
GA disk HR	MOS/R=20000	$5x10^5$	2000	715
Clusters L1	MOS/R=5000	$3x10^4$	150	25
Clusters L1	mIFU/R=5000	10^3	150	50
Clusters L2	MOS/R=5000	10^4	30	10
Clusters L3	LIFU/R=5000	150	0.08	75
LOFAR	MOS/R=5000	$4x10^6$	10000	575
Apertif-mIFU	mIFU/R=5000	10^4	1000	290
Apertif-LIFU	LIFU/R=20000	60	0.025	60

N.B. Reduction in total time from the fact that the LOFAR and Halo surveys overlap…

Target selection

GA Surveys

Survey	Desirable	Optimal	Essential
LR Halo 15<V<20-21 LR Halo	• 15,000 deg^2; • all stars; • densities 2000-6000 per WEAVE fov	• 10,000 deg2 |b|>30-40°; • selected targets Giants and MSTO; • densities 600-1300 per WEAVE fov.	• 10,000 deg2 |b|>30-40°; • selected targets Giants (1st priority: all available) and MSTO (sampling among these candidates); • densities 600-700 per WEAVE fov
LR Disc Dynamics 16-17<V<20	• 280+540 line-of-sight towards the inner+outer galaxy • 12/4 pointings in each los respectively	• 280+540 line-of-sight towards the inner+outer galaxy • 6/2 pointings in each los respectively	• 210+405 line-of-sight towards the inner+outer galaxy • 5/1 pointings in each los respectively
HR Chemo-dynamics 12<V<16-18	• Full sky |b|>15°; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • selected targets Giants and MSTO; • densities 800-2000 targets.

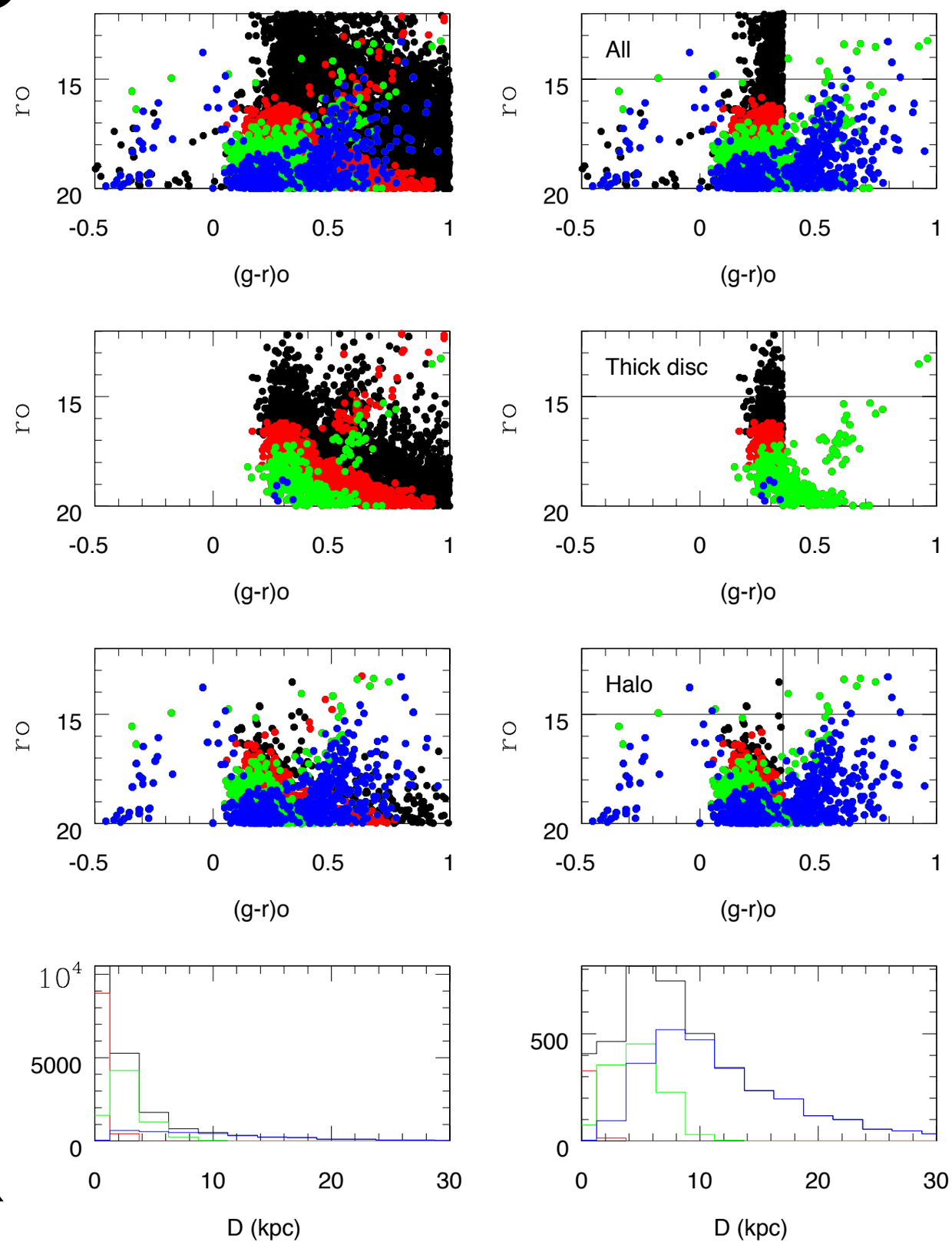
LR halo target selection

<u>Desirable:</u> all Gaia targets with no Vrad information: 15-16<G<20; typically 1,000-5,000/WEAVE fov

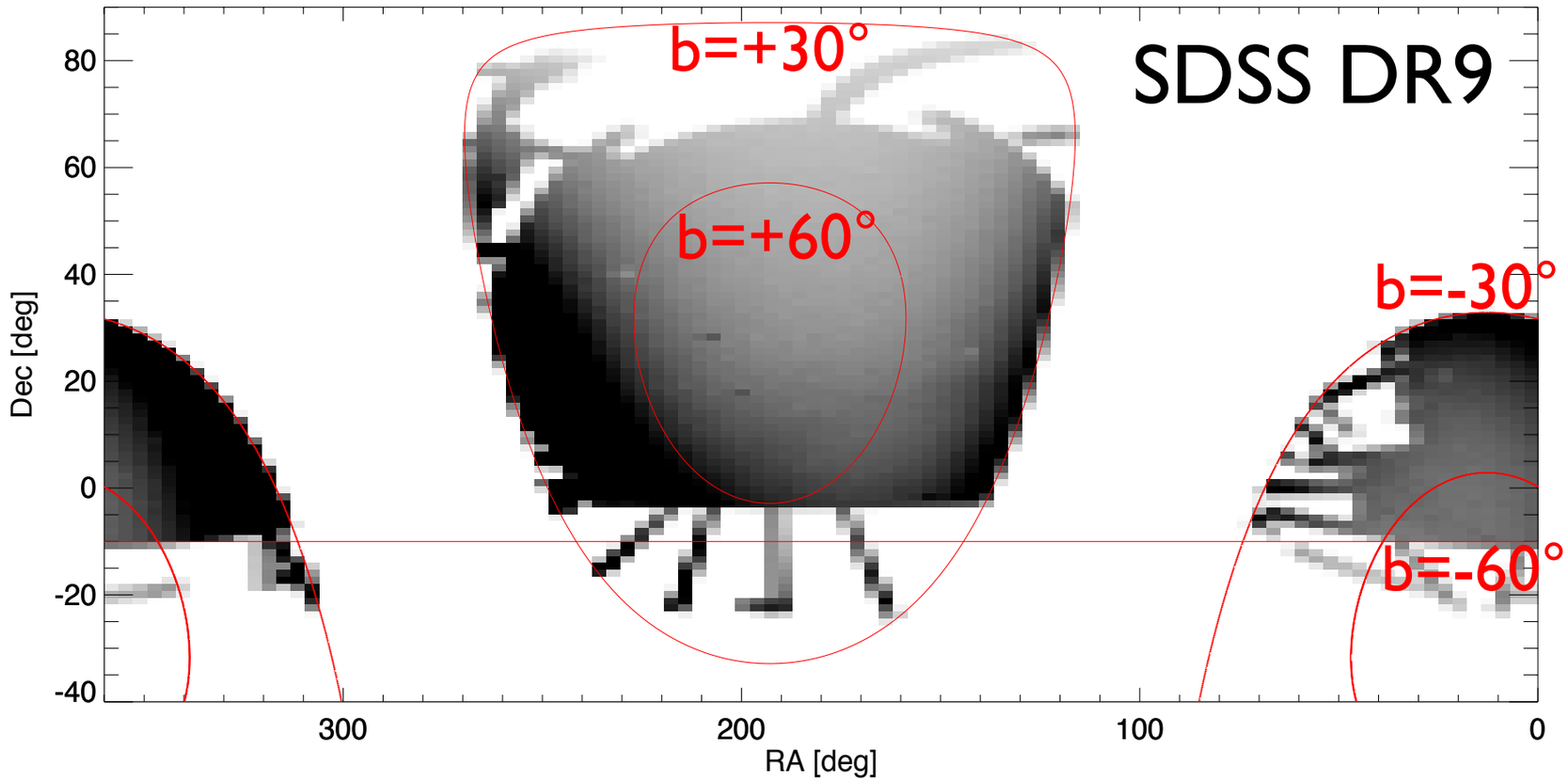
<u>Optimal strategy:</u> most relevant for the distant Halo:

- 1st prio Giants: red selection+ Gaia π & PPM; typically 200-600/ WEAVE fov
- 2nd prio MSTO: blue selection (inculdes also BHB stars); typically 400-1200/WEAVE fov

<u>Essential strategy:</u> free up to 30% fibers for QSOs / LOFAR

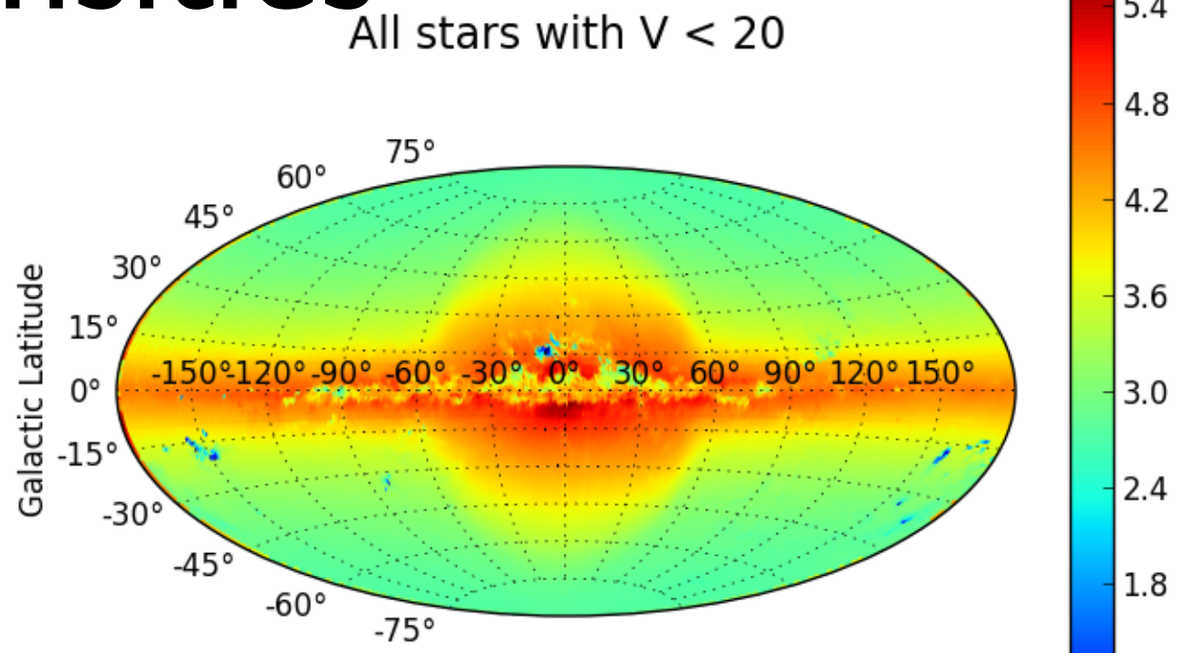


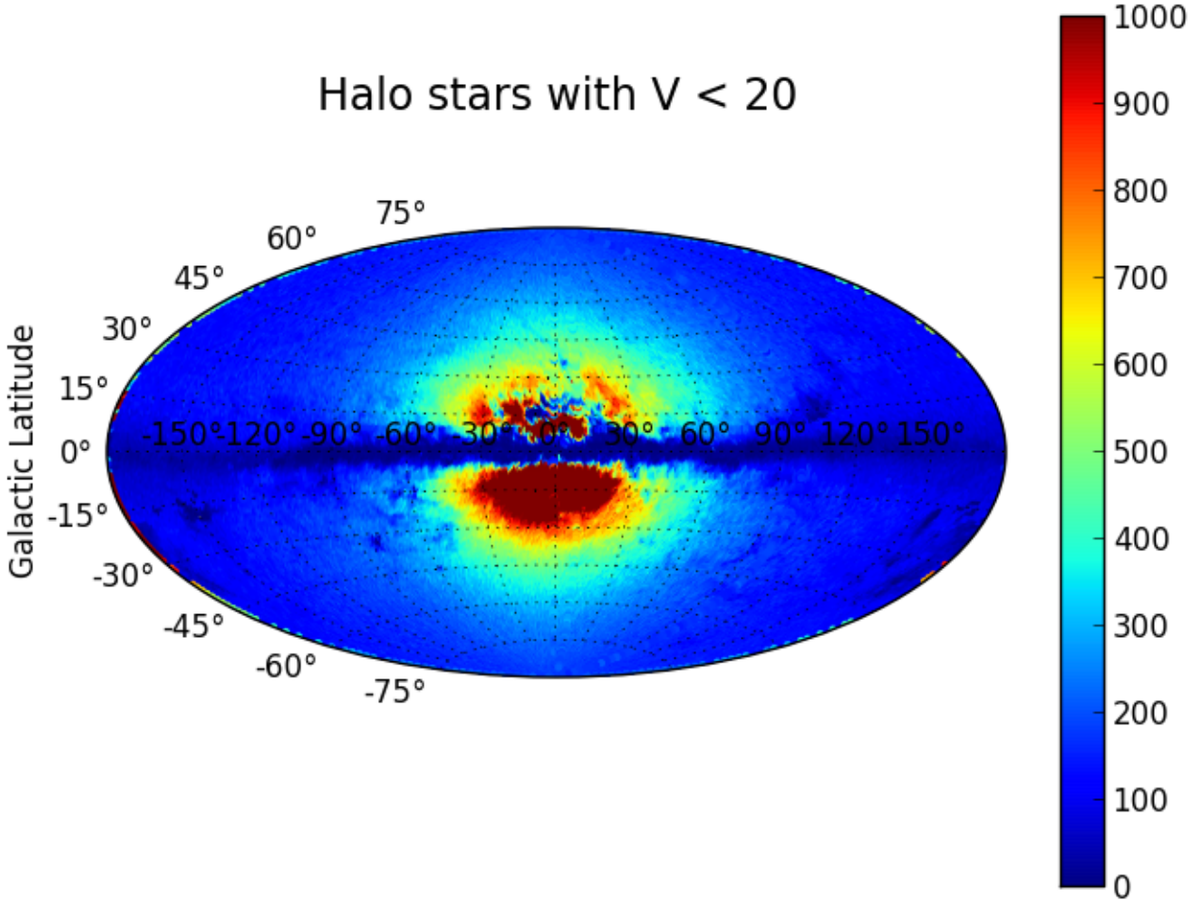
LR halo footprint

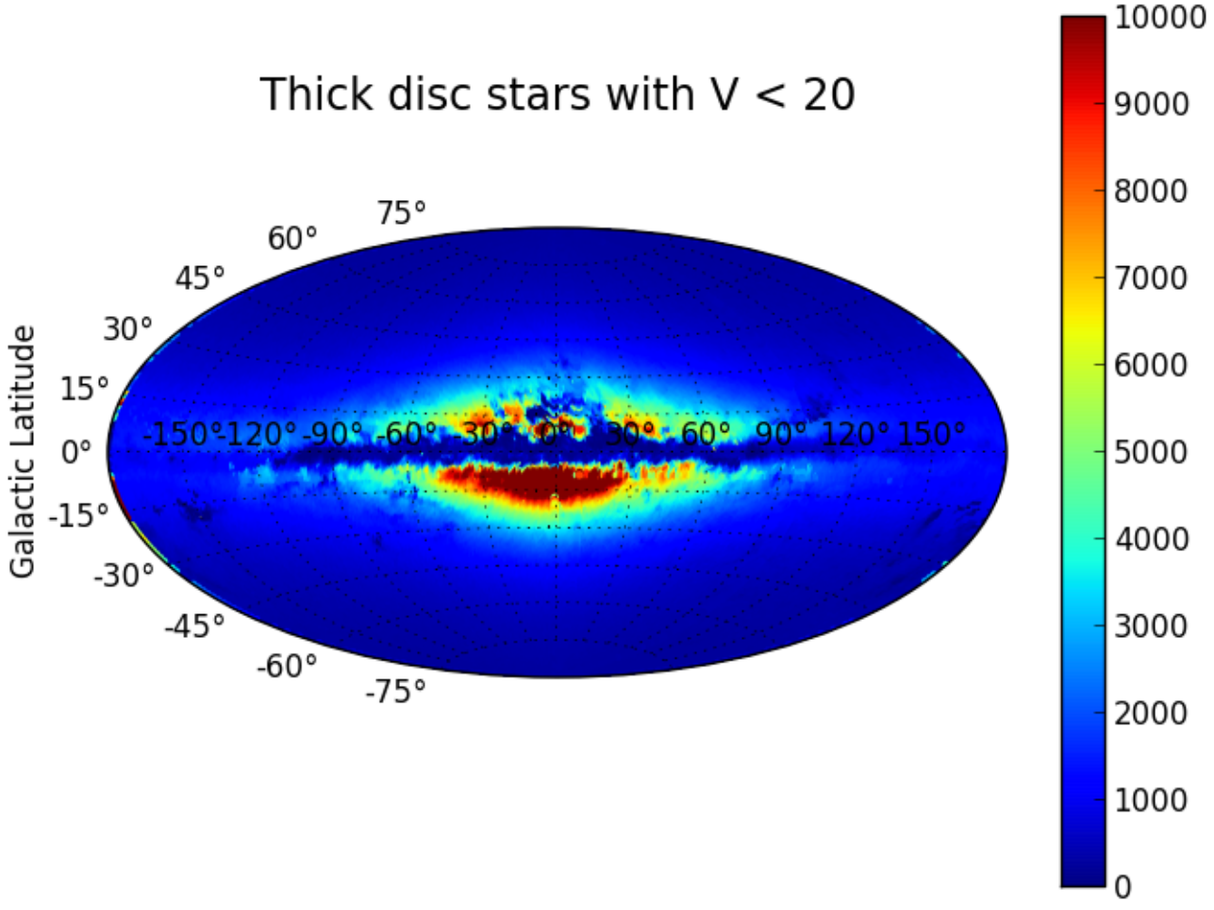


- 10,000 deg^2, with |b|>30° and DEC>-10.
- included in the total SDSS-DR9 photometric footprint (to insure gri photometry)
- to be interlaced with the HR |b|>30° footprint

LR halo densities



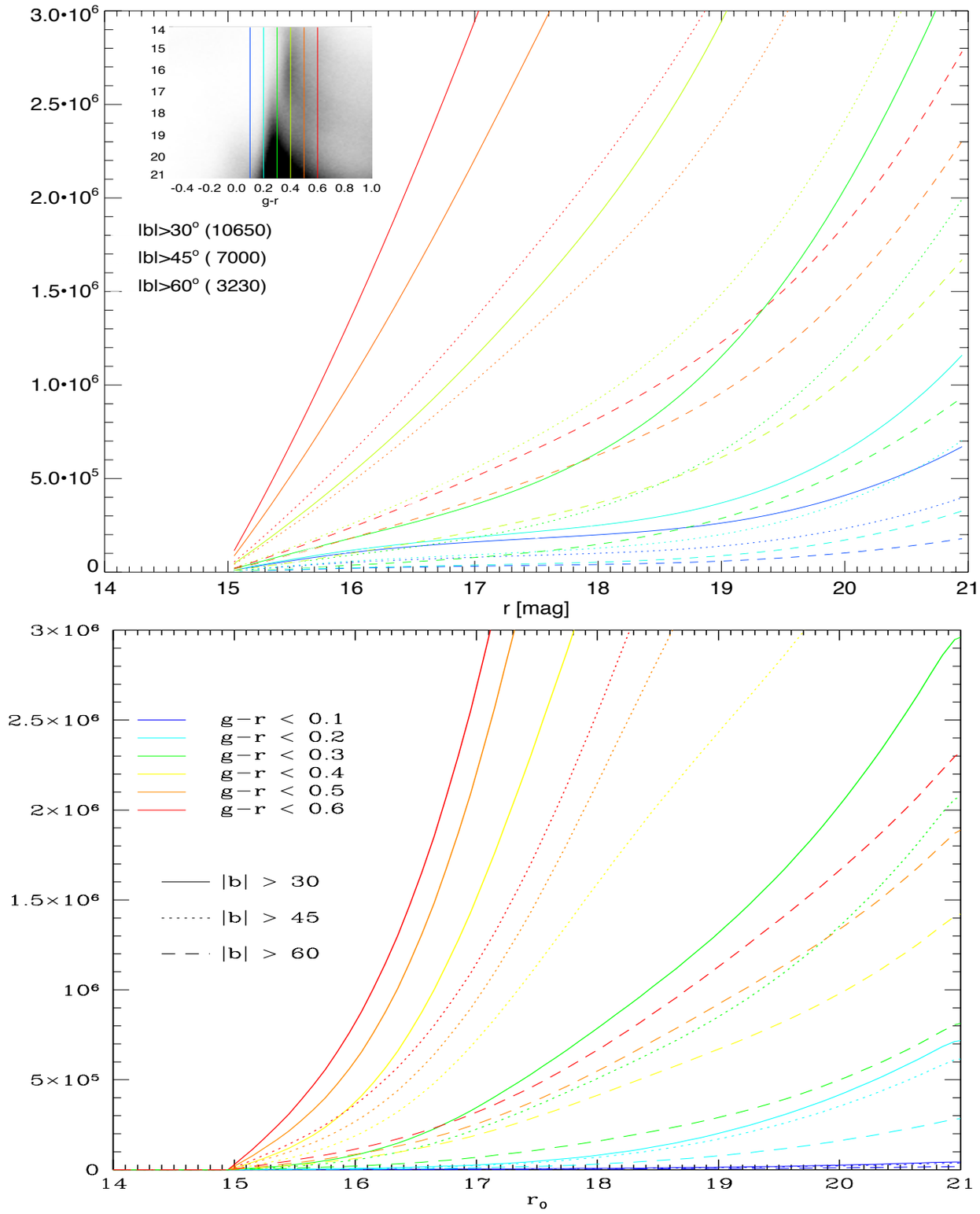




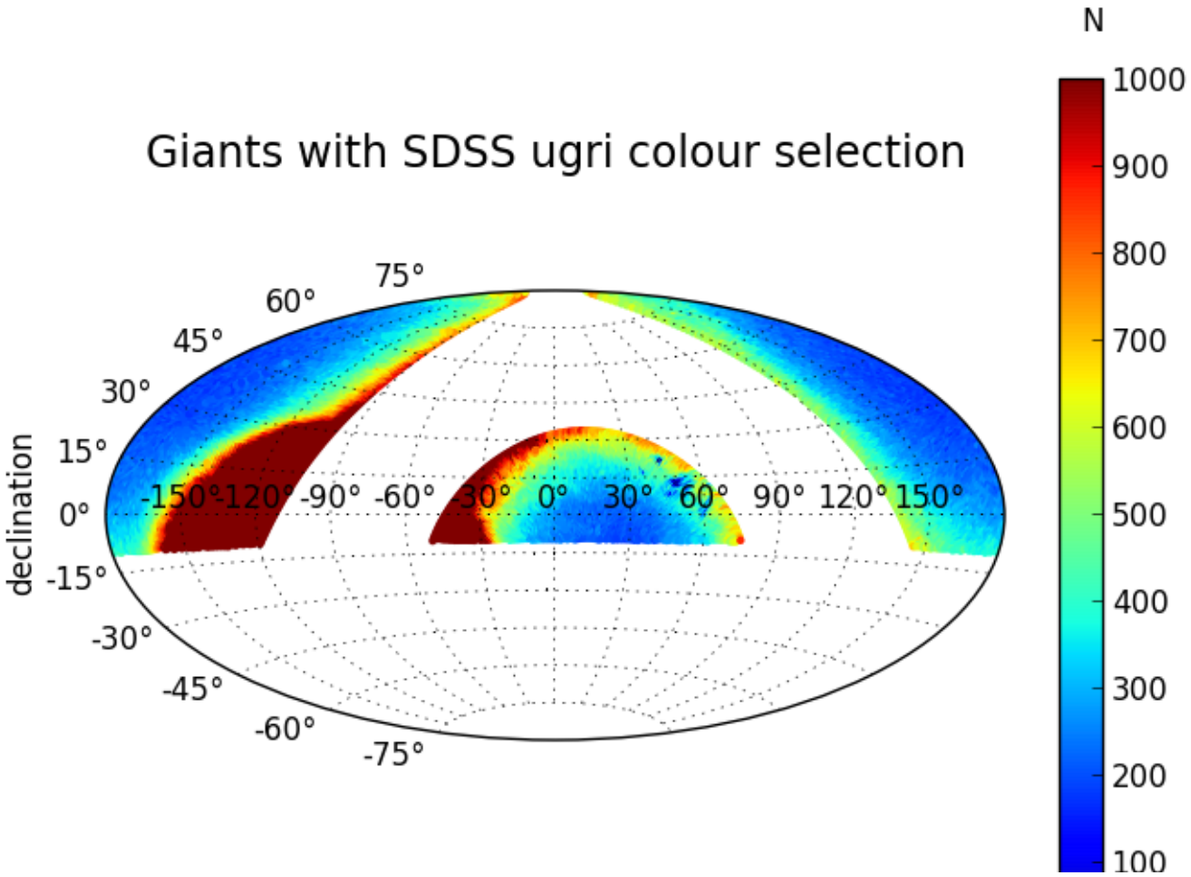
LR halo target densities

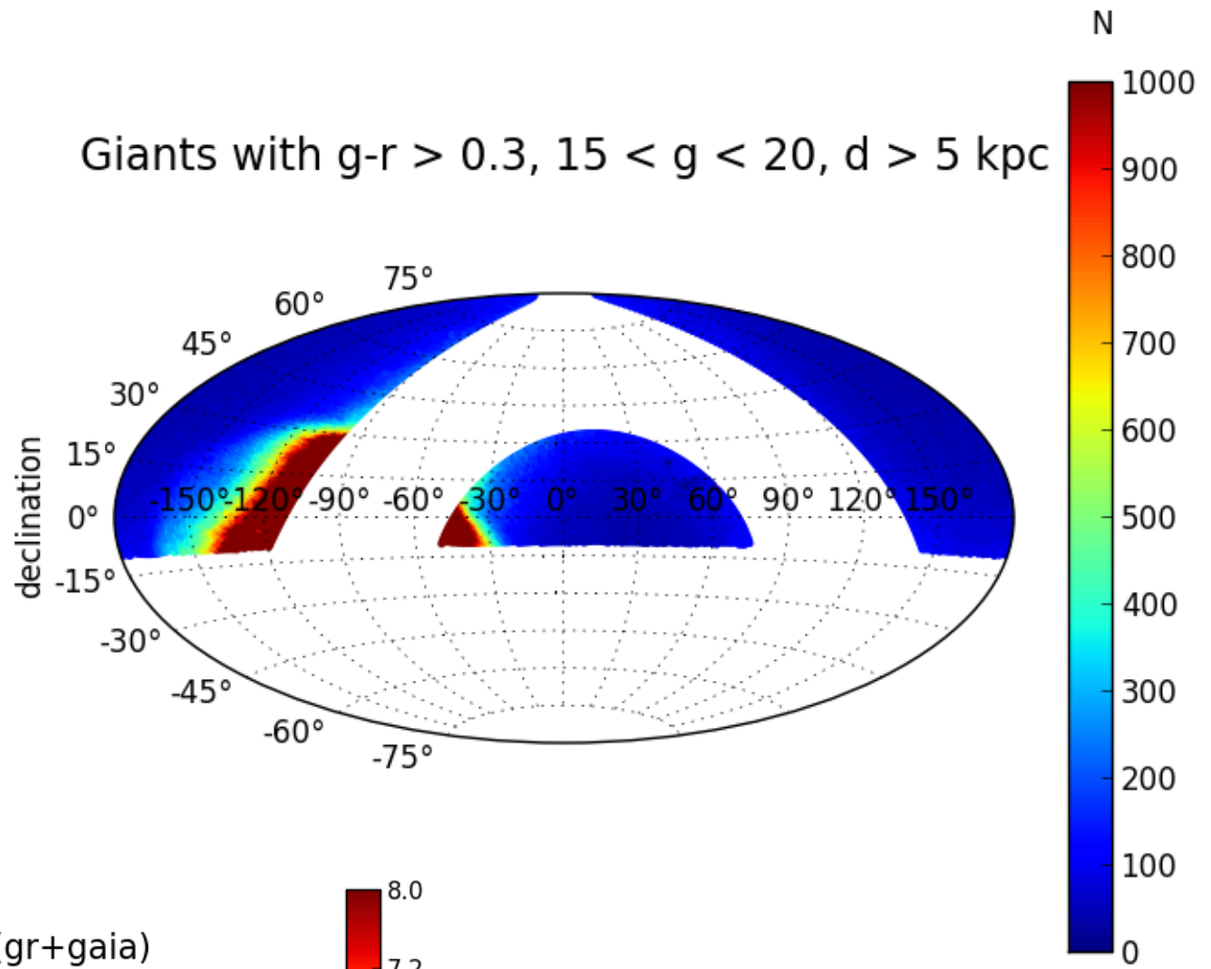
Total cumulative number of stars with (g-r)o<X, with X= 0.1 0.2 0.3 0.4 0.5 0.6 found in the SDSS-DR9 footprint with δ>-10° and |b|>Y, with Y=30, 45, 60°

- Besançon model is a fair representation of observed counts
- not perfect (shape)
- Tests in progress on SDSS stripe82 (deep and u-gri).

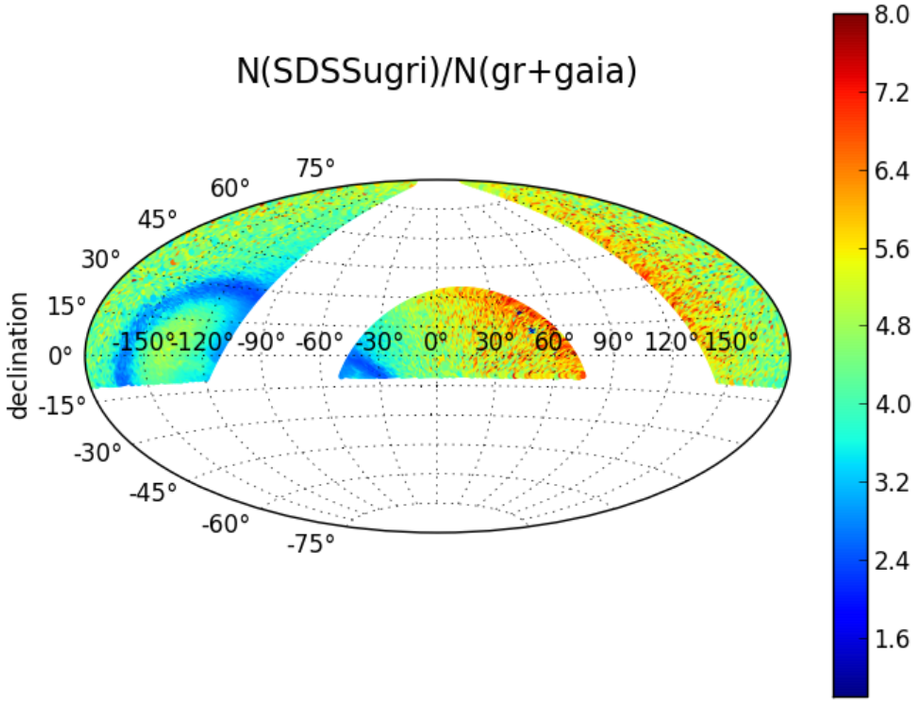


LR halo target densities: giants





|b|>30°
DEC>-10°



GA Surveys

Survey	Desirable	Optimal	Essential
LR Halo 15<V<20-21 LR Halo	• 15,000 deg^2; • all stars; • densities 2000-6000 per WEAVE fov	• 10,000 deg2 |b|>30-40°; • selected targets Giants and MSTO; • densities 600-1300 per WEAVE fov.	• 10,000 deg2 |b|>30-40°; • selected targets Giants (1st priority: all available) and MSTO (sampling among these candidates); • densities 600-700 per WEAVE fov
LR Disc Dynamics 16-17<V<20	• 280+540 line-of-sight towards the inner+outer galaxy • 12/4 pointings in each los respectively	• 280+540 line-of-sight towards the inner+outer galaxy • 6/2 pointings in each los respectively	• 210+405 line-of-sight towards the inner+outer galaxy • 5/1 pointings in each los respectively
HR Chemo-dynamics 12<V<16-18	• Full sky |b|>15°; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • selected targets Giants and MSTO; • densities 800-2000 targets.

GA Surveys

Survey	Desirable	Optimal	Essential
LR Halo 15<V<20-21	• 15,000 deg^2; • all stars; • densities 2000-6000 per WEAVE fov	• 10,000 deg2 |b|>30-40°; • selected targets Giants and MSTO; • densities 600-1300 per WEAVE fov.	• 10,000 deg2 |b|>30-40°; • selected targets Giants (1st priority: all available) and MSTO (sampling among these candidates); • densities 600-700 per WEAVE fov
LR Disc Dynamics 16-17<V<20 LR Disc	• 280+540 line-of-sight towards the inner+outer galaxy • 12/4 pointings in each los respectively	• 280+540 line-of-sight towards the inner+outer galaxy • 6/2 pointings in each los respectively	• 210+405 line-of-sight towards the inner+outer galaxy • 5/1 pointings in each los respectively
HR Chemo-dynamics 12<V<16-18	• Full sky |b|>15°; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • selected targets Giants and MSTO; • densities 800-2000 targets.

LR Disc survey: goals & means

Discriminate fundamental aspects of galactic disc dynamics: moving groups, velocity elipsoid accross the disc ➔ probe the axisymetric potential + non-axisymetric terms (bar, spiral arms). Implications for radial migration.

<u>Needs:</u>

- Vr to 1-2 km/s (dynamical streams with amplitudes/separations of 5-10 km/s)
- Dense tracers (<Vr> to 1-5km/s in various distance bins), reaching across significant disc fraction ➔ use Red clump stars
- large area (avoid peculiar signatures)

➢ LR in 210/280 (inner gal) + 405/540 (outer gal) los; red clump (RC) stars out to 6-8kpc from the sun.

➢ For a total of ~$1.5.10^6$ stars

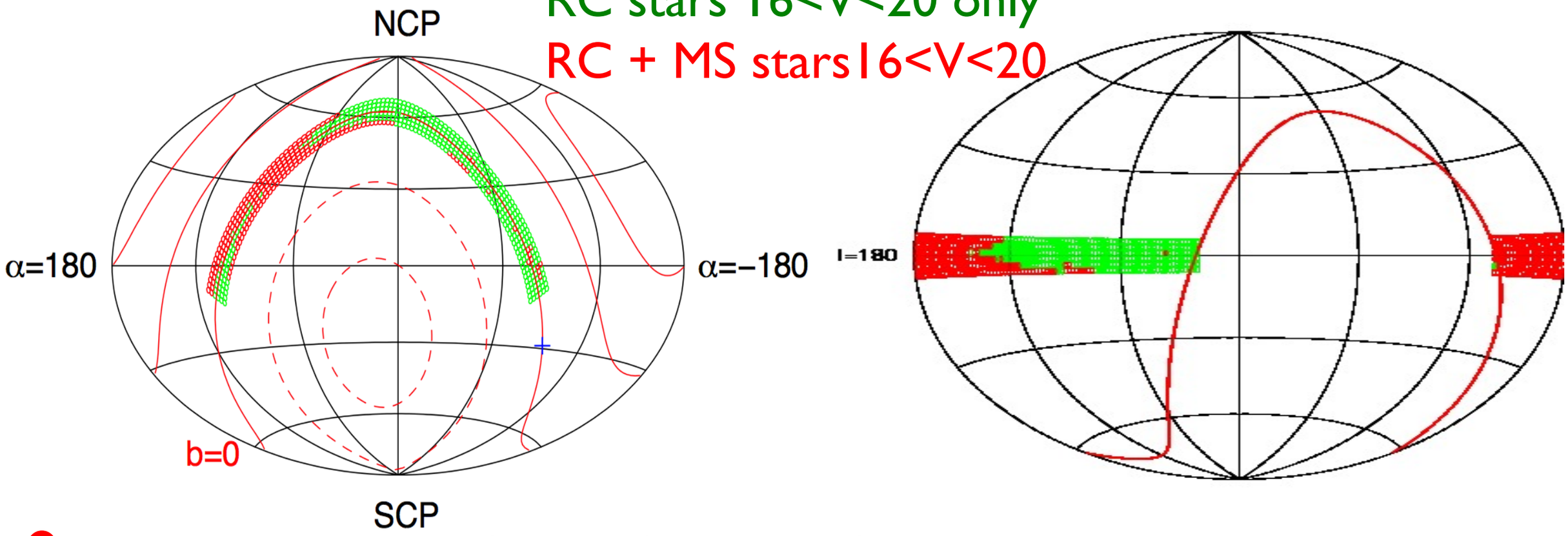
LR disc survey footprint

RA, DEC

RC stars 16<V<20 only

RC + MS stars16<V<20

l,b

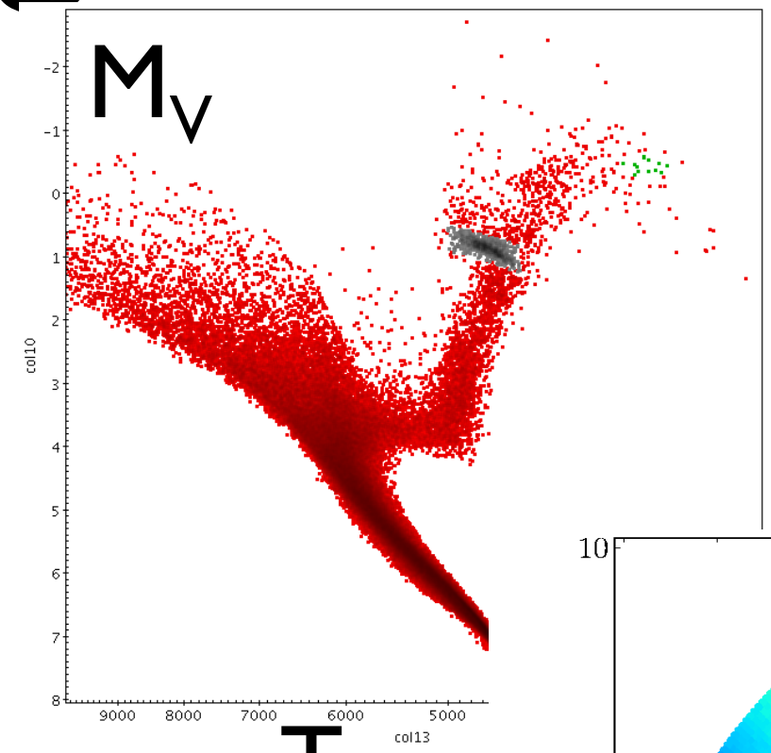


- 210(Essential)/280(Optimal/Desirable) los towards the inner galaxy (l=20-90°) ➔650/900 deg^2
- 405(Essential)/540(Optimal/Desirable) los towards the outer galaxy (l=90-225°) ➔ 1250/1700 deg^2
- All with |b|<6/8° (Essential/Optimal) and DEC>-10.

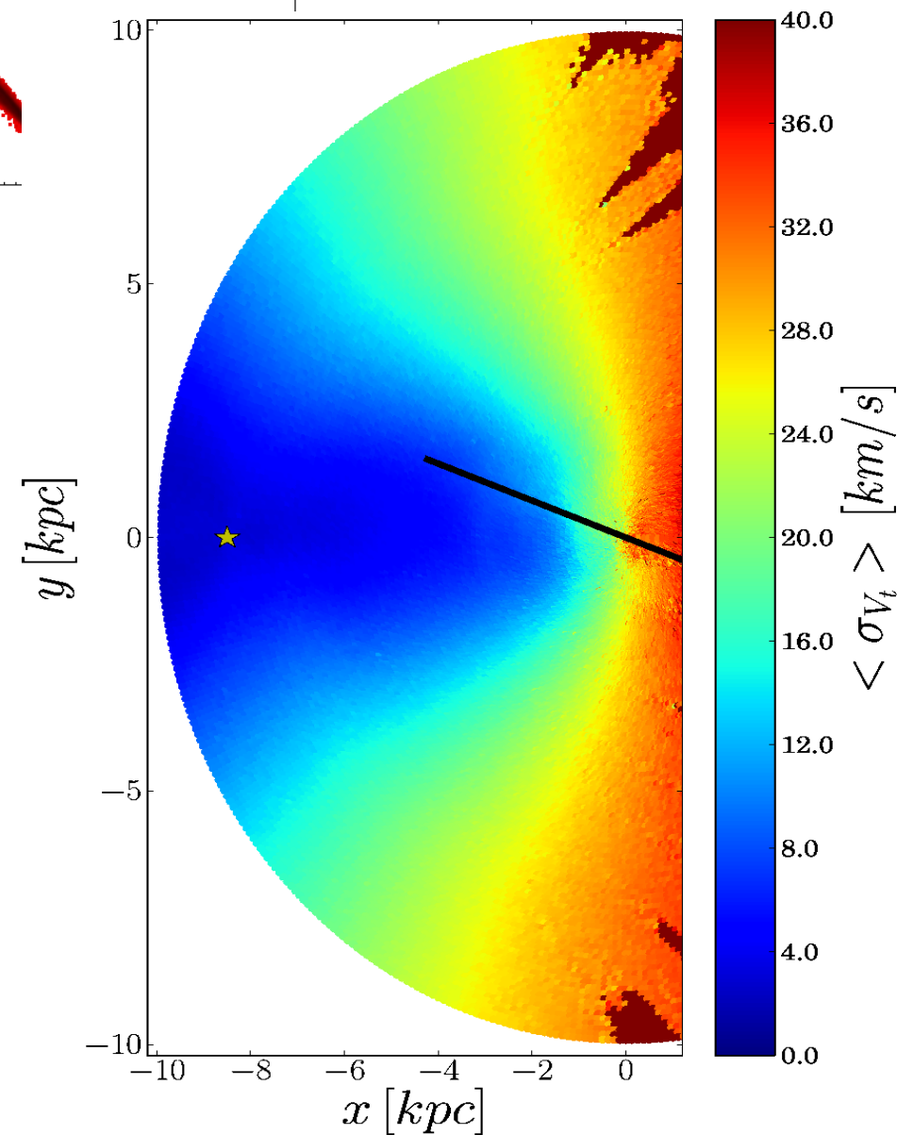
LR disc target selection

Select red clump stars (RC) as primary targets:

- Reach far in the disc
- Complement Gaia π with photometric distances



Gaia σVt for RC with photometric distance error (10%)



Desirable: 12 pointings per field in the inner galaxy and 4 in the outer galaxy

Optimal strategy: 6 pointings per field in the inner galaxy and 2 in the outer galaxy

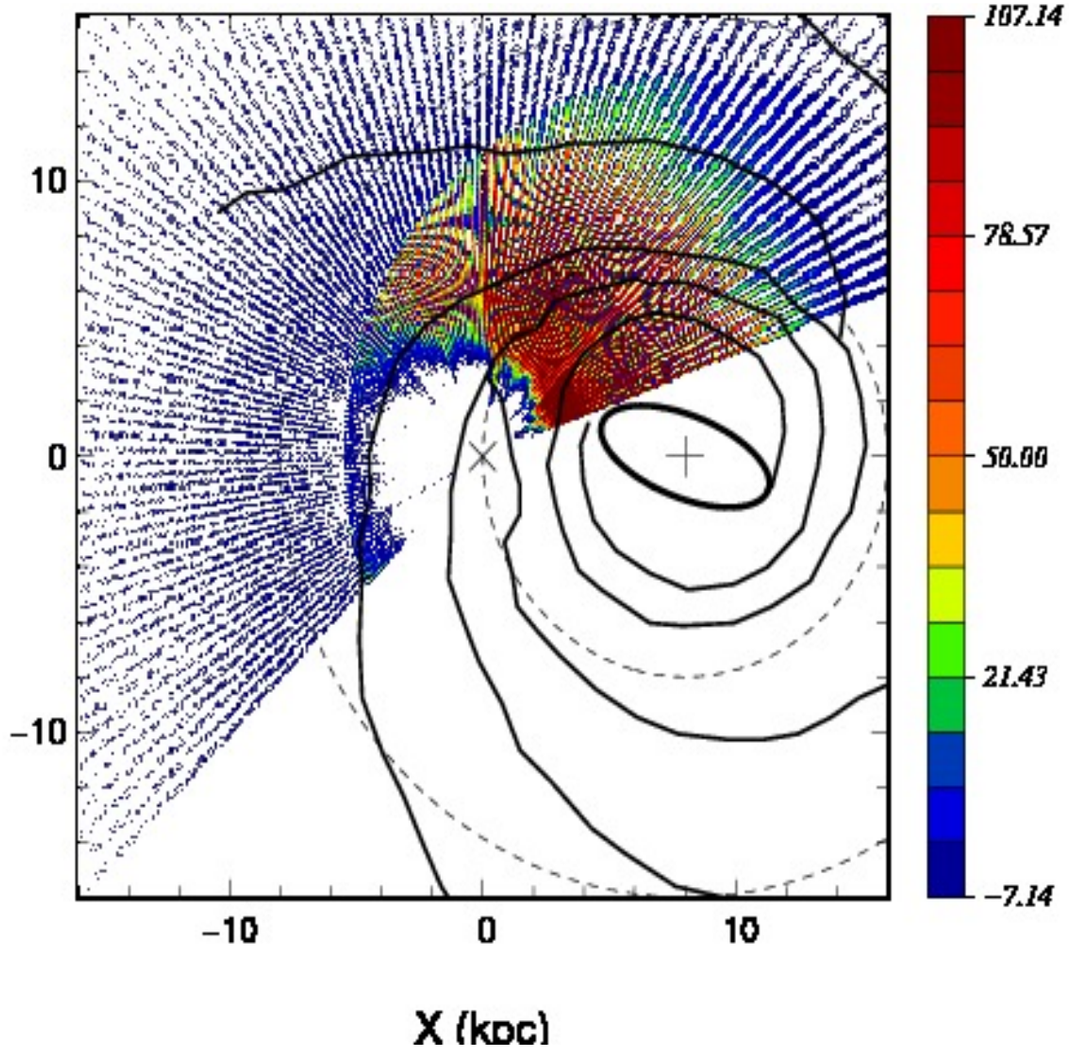
Essential strategy: 5 pointings per field in the inner galaxy and 1 in the outer galaxy

LR disc target densities

- Various means used to estimate the number of RC stars were used
  - ✓ Besançon model
  - ✓ GUMS
  - ✓ Test-particle simulations (Romero-Gómez et al. 2015)

- RC densities per WEAVE fov from 100 to 80,000 (depending on l,b) for 17<V<20 or 16<V<20 (in the lowest density fields) ➔ to be complemented by MS stars (in Gaia's σ_π/π 10% sphere)

RC targets per (100 pc)^2



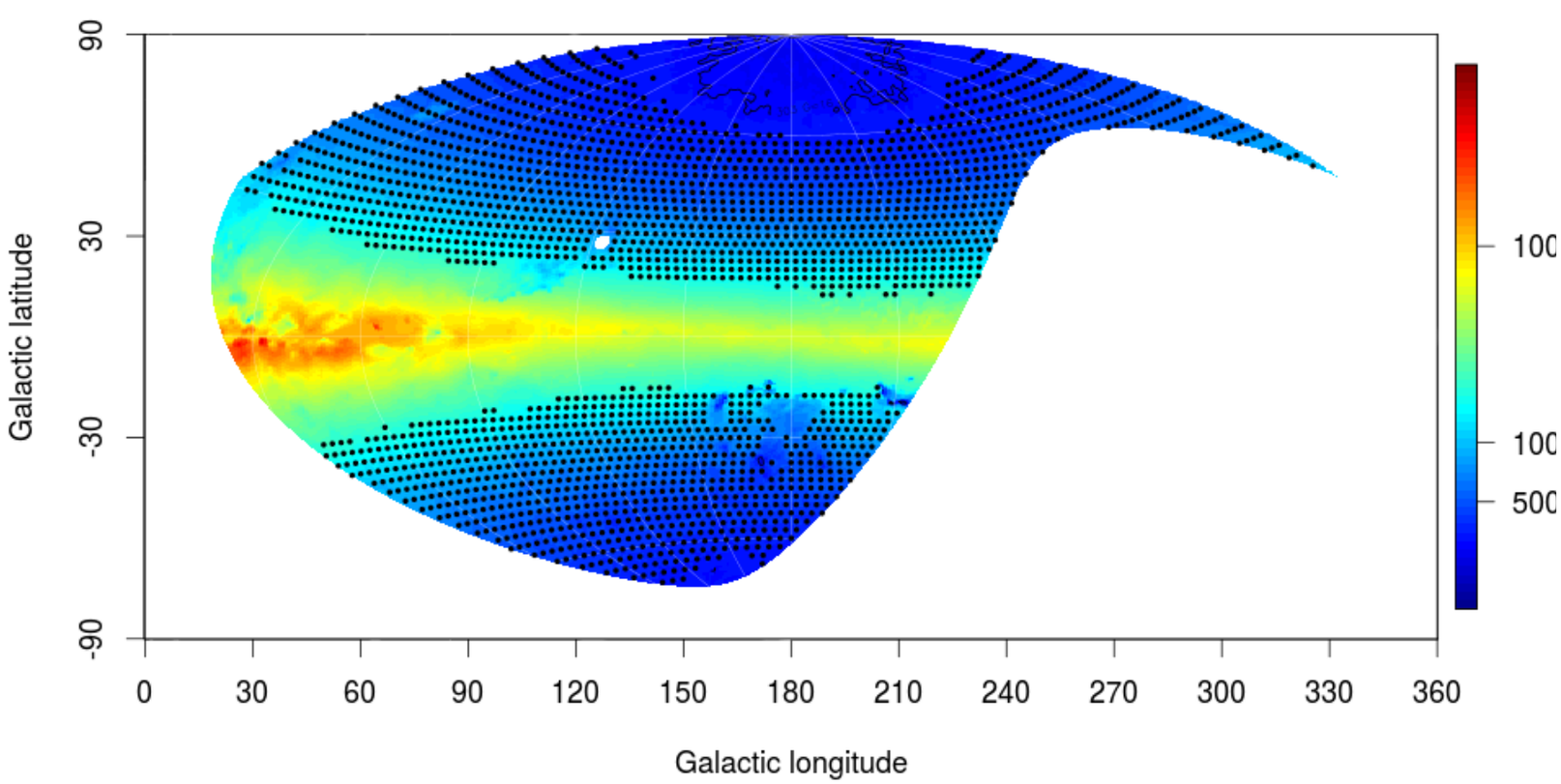
GA Surveys

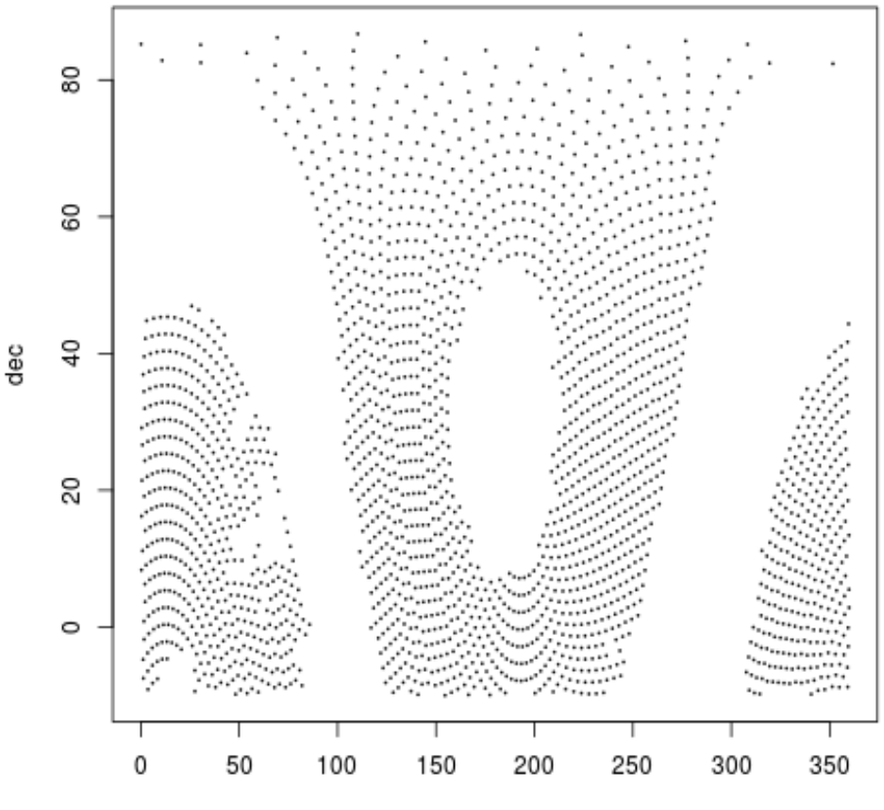
Survey	Desirable	Optimal	Essential
LR Halo 15<V<20-21	• 15,000 deg^2; • all stars; • densities 2000-6000 per WEAVE fov	• 10,000 deg2 |b|>30-40°; • selected targets Giants and MSTO; • densities 600-1300 per WEAVE fov.	• 10,000 deg2 |b|>30-40°; • selected targets Giants (1st priority: all available) and MSTO (sampling among these candidates); • densities 600-700 per WEAVE fov
LR Disc Dynamics 16-17<V<20 LR Disc	• 280+540 line-of-sight towards the inner+outer galaxy • 12/4 pointings in each los respectively	• 280+540 line-of-sight towards the inner+outer galaxy • 6/2 pointings in each los respectively	• 210+405 line-of-sight towards the inner+outer galaxy • 5/1 pointings in each los respectively
HR Chemo-dynamics 12<V<16-18	• Full sky |b|>15°; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • selected targets Giants and MSTO; • densities 800-2000 targets.

GA Surveys

Survey	Desirable	Optimal	Essential
LR Halo 15<V<20-21	• 15,000 deg^2; • all stars; • densities 2000-6000 per WEAVE fov	• 10,000 deg2 |b|>30-40°; • selected targets Giants and MSTO; • densities 600-1300 per WEAVE fov.	• 10,000 deg2 |b|>30-40°; • selected targets Giants (1st priority: all available) and MSTO (sampling among these candidates); • densities 600-700 per WEAVE fov
LR Disc Dynamics 16-17<V<20	• 280+540 line-of-sight towards the inner+outer galaxy • 12/4 pointings in each los respectively	• 280+540 line-of-sight towards the inner+outer galaxy • 6/2 pointings in each los respectively	• 210+405 line-of-sight towards the inner+outer galaxy • 5/1 pointings in each los respectively
HR Chemo-dynamics 12<V<16-18 HR Chemo-dynamics	• Full sky |b|>15°; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • all stars in Gaia catalog with 12<V<16; • densities one to to several tens of thousands	• 6,800 deg2; • selected targets Giants and MSTO; • densities 800-2000 targets.

HR footprint





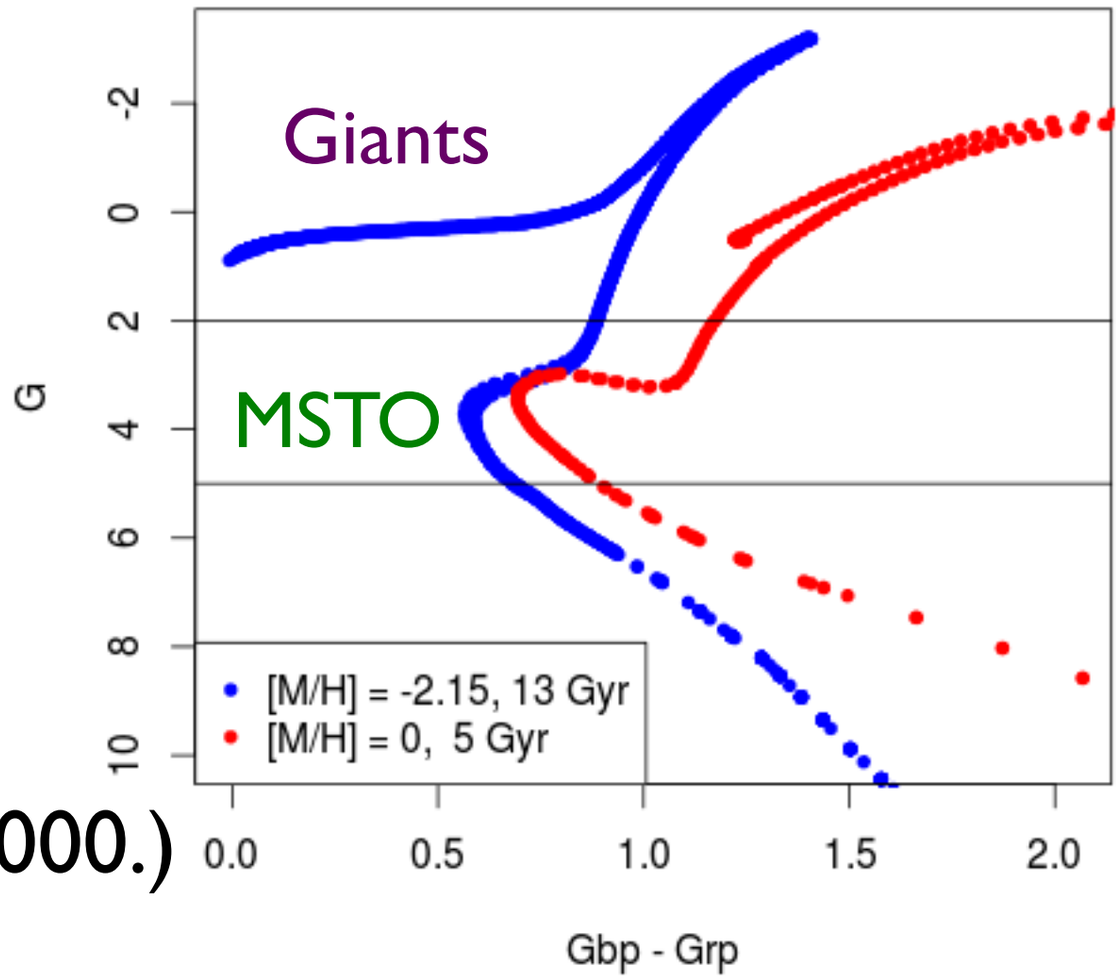
- 5,000 deg^2, with 30<|b|~60° (halo, to reach 5.10^5 giants) + 1,800 deg^2 with 15<|b|<30° to insure Rgc,Z coverage of discs [DEC>-10]
- Additionnal conditions: density>300*/deg^2; Av<1
- Gaia DR2 + PanSTARS|SDSS photometry (gri)
- to be interlaced with the LR |b|>30° footprint

HR target selection

<u>Optimal strategy:</u> all Gaia targets 12<G<16; typically 1,000-10,000/ WEAVE fov

<u>Essential strategy:</u> most relevant for age sphere (MSTO) + halo (giants): Gaia absolute mag M_G selection

$\pi < 0 \;||\; G < M_{Glim} - 5 - 5*\log_{10}((\pi - \sigma_\pi)/1000.)$



- Giants: M_{glim}=2; MSTO: M_{glim}=5;
- Typically 700-7000/WEAVE fov
- No colour selection; No specific priorities among MSTO/giants ➔ simple selection, bias easy to control.
- Extend to G~17 low π stars in low density fields

HR target densities

- $N_{MS}+N_{giants}$ typically 700-7,000/ WEAVE fov
- Where density >1,000: random sampling
- Where density lower than 1,000 (i.e. some 750deg^2 @ |b|~50-60°):
  - Reallocate fields |b|>50° to lower latitude fields ➔ ! Halo! ➔ compensate by higher priority to giants ➔ ! simple selection!
- Extend to fainter MG ➔include more nearby stars
- Extend to G~17 low π (ie distant) stars: ***baseline***