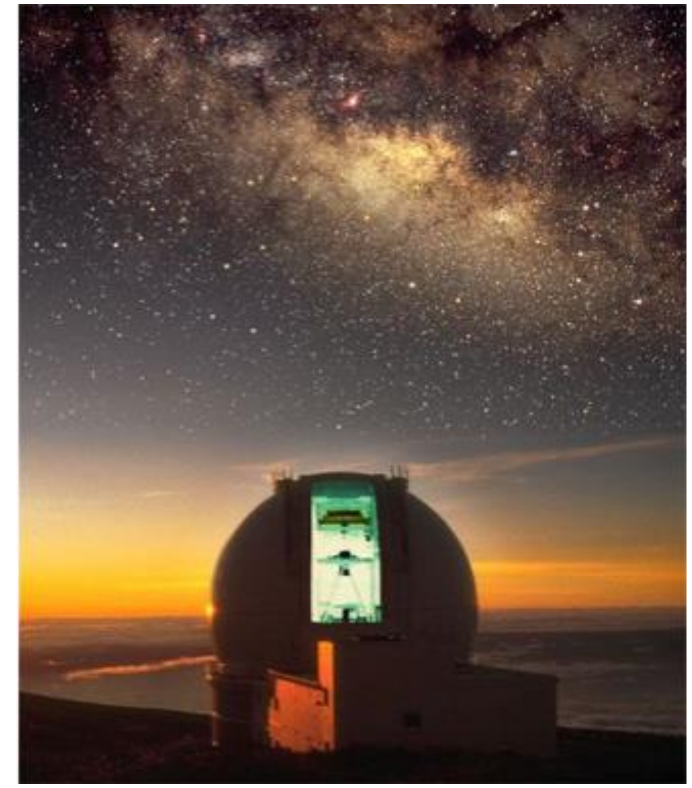
Galactic Archaeology surveys



@WHT

Vanessa Hill

Observatoire de la Côte d'Azur

& the WEAVE science team (incl. A. Helmi, S. Feltzing, N. Walton and teams in FR, NL, UK, ES, IT)

New survey frontiers from new survey instruments

- Gaia: Astrometry at microarcsecond precision
  - The history of the Milky Way
- SKA Pathfinders:
  - LOFAR:
    - The history of star for
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  - Apertif:
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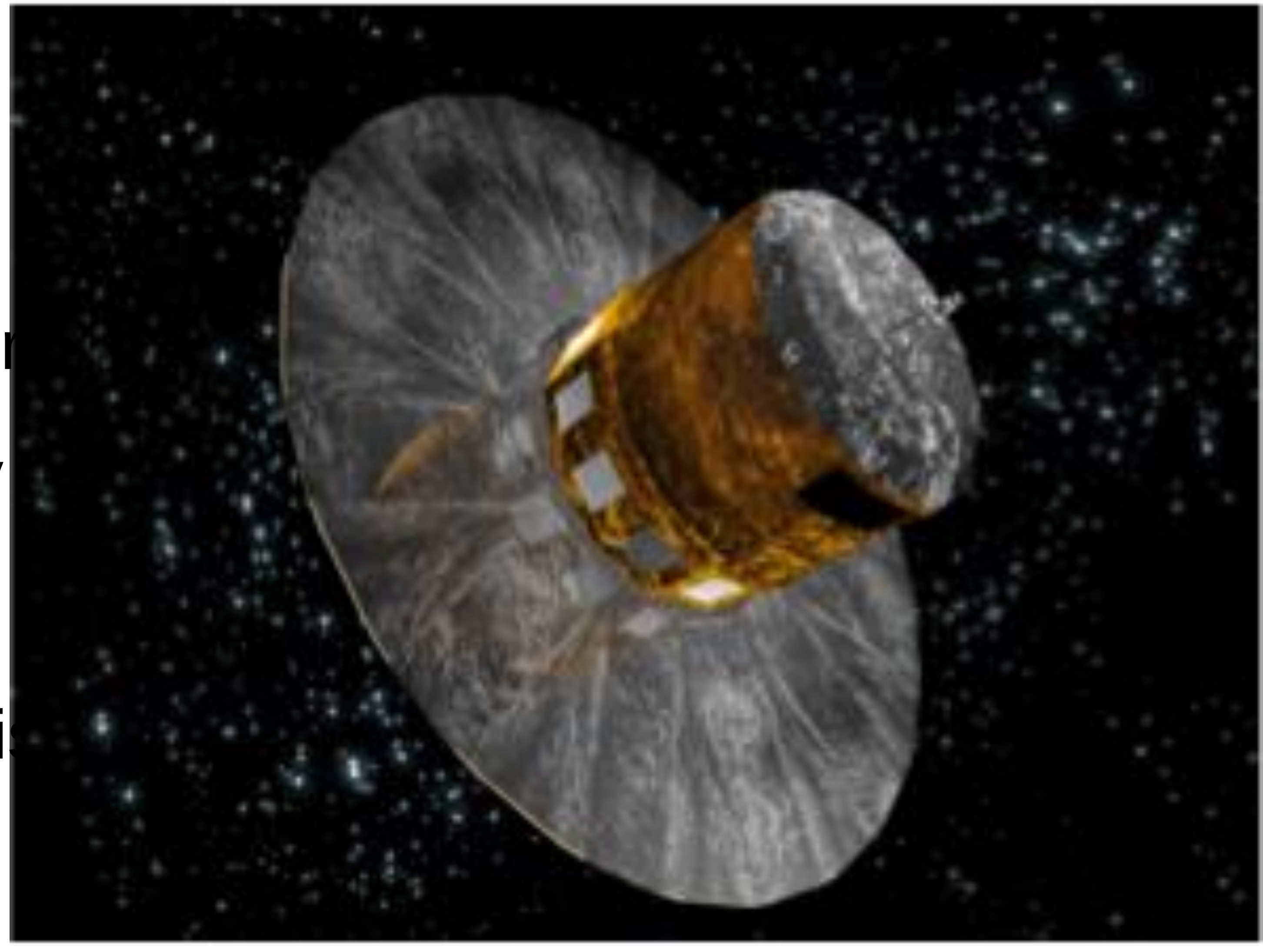
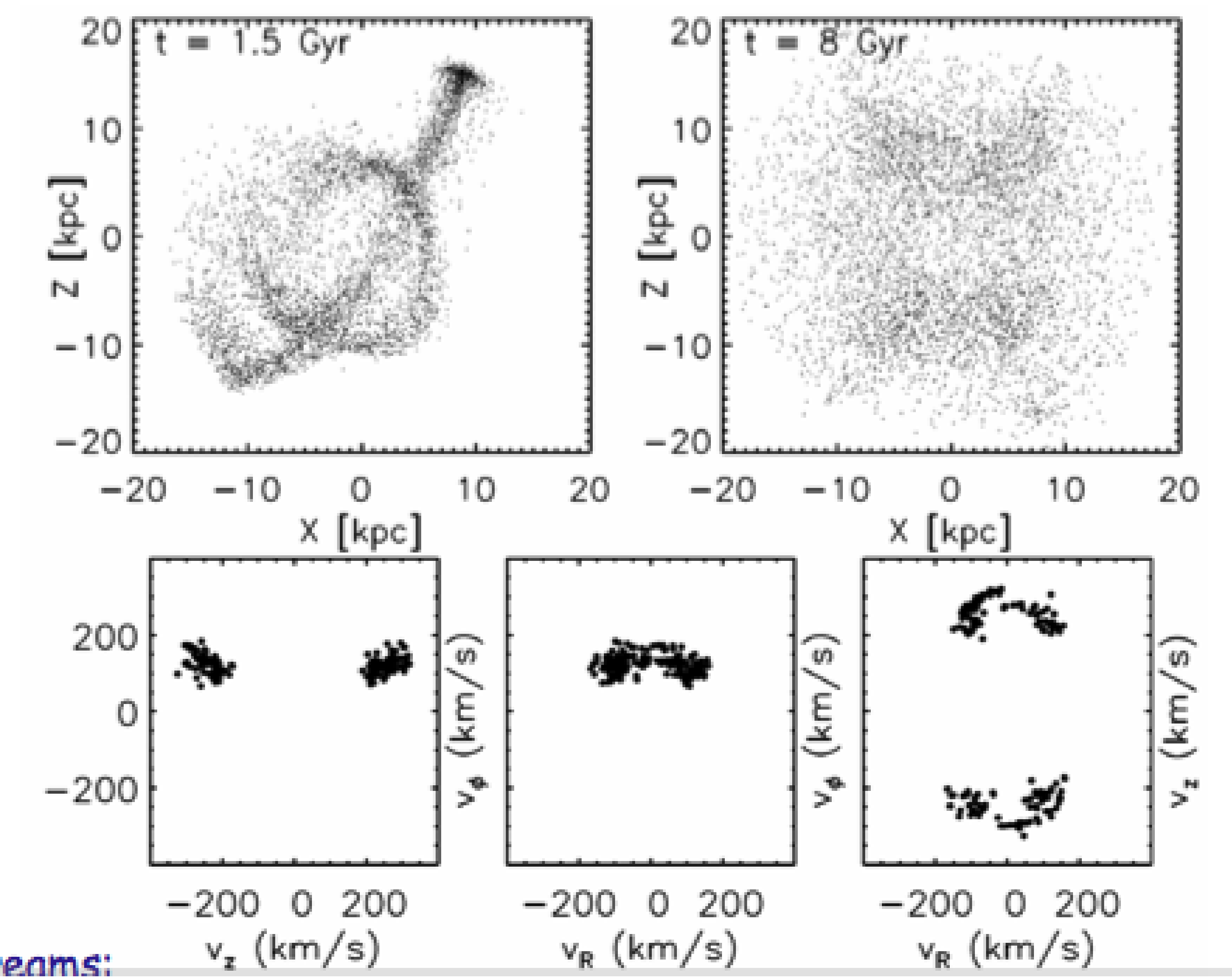
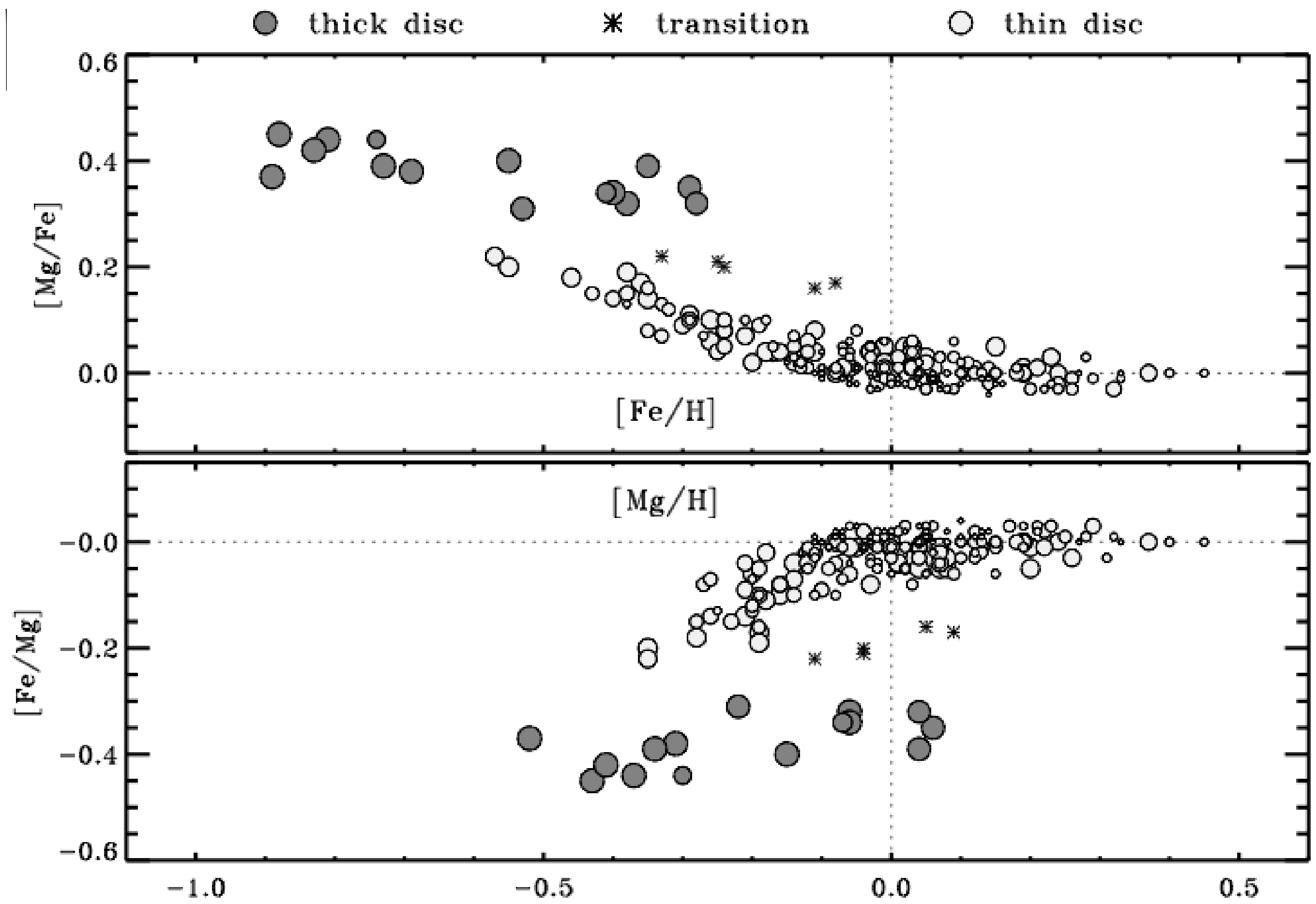


Galactic Archaeology in the Gaia

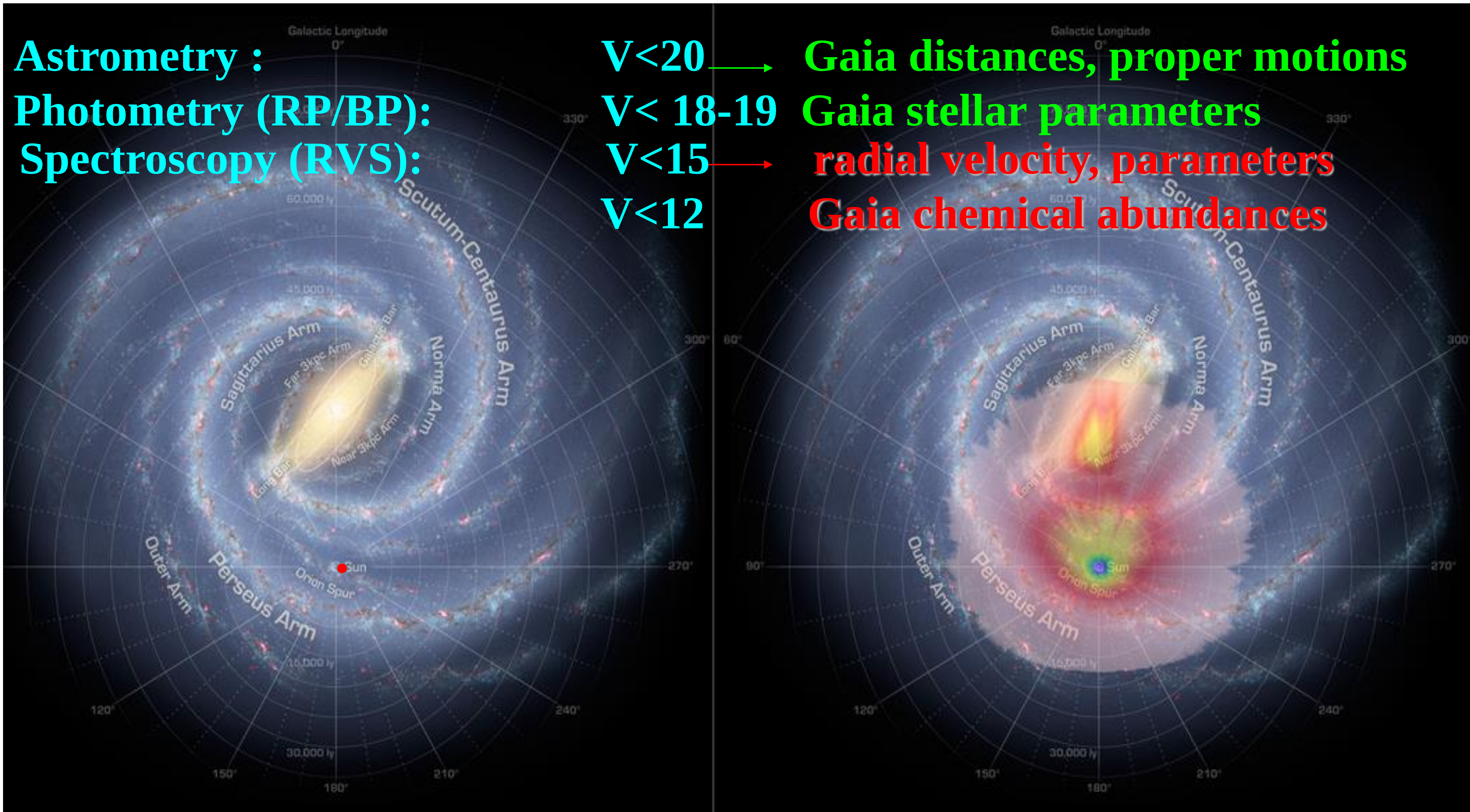




Fuhrmann et al. 2008 Hipparcos Distances

- 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 is time for Gaia's harvest with exquisite geometrical D, Vt, in a unequalled volume. + Gaia's ages.

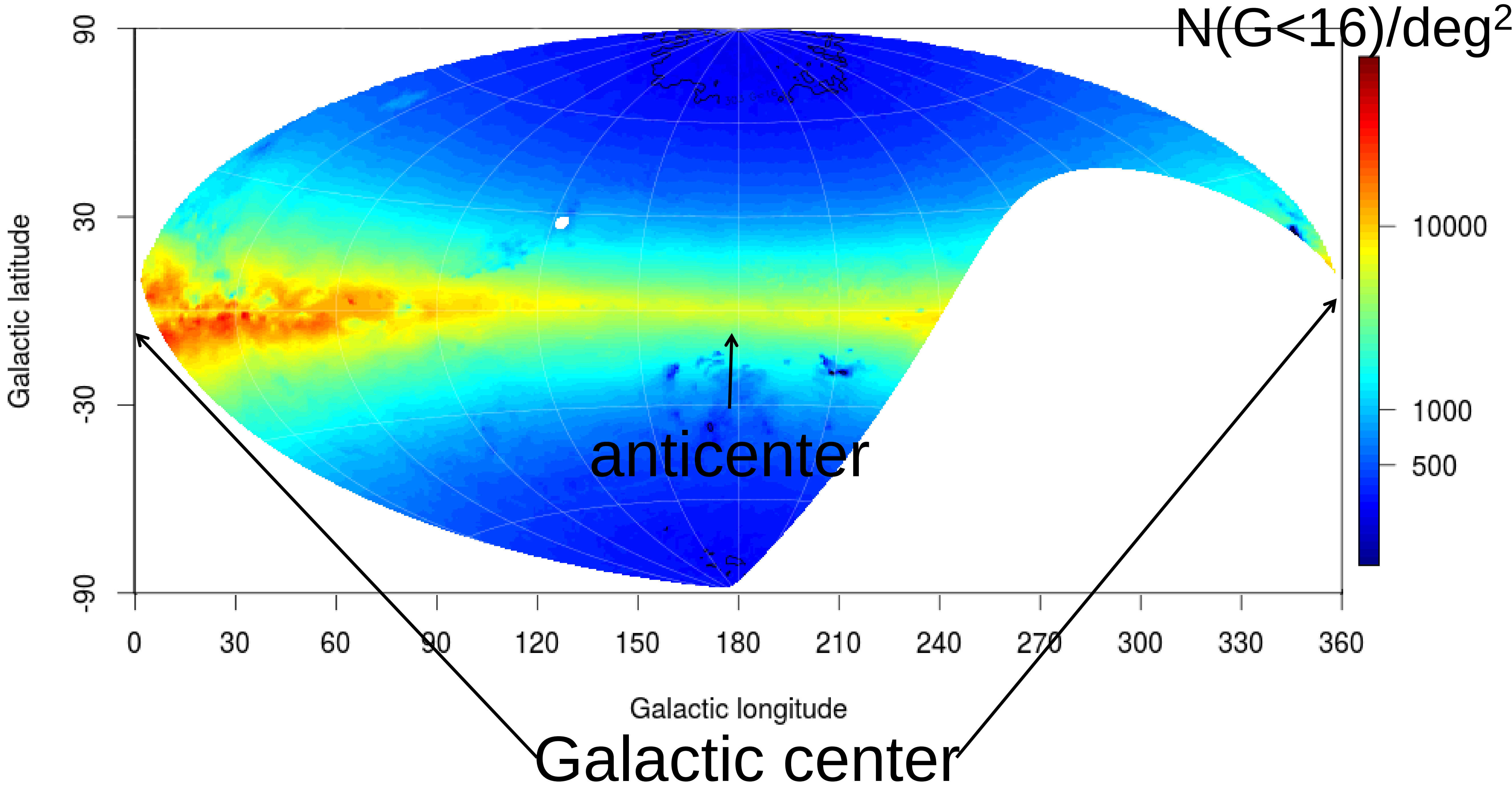
Gaia’s reach: 1bilion stars V<20



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

WEAVE: a northern



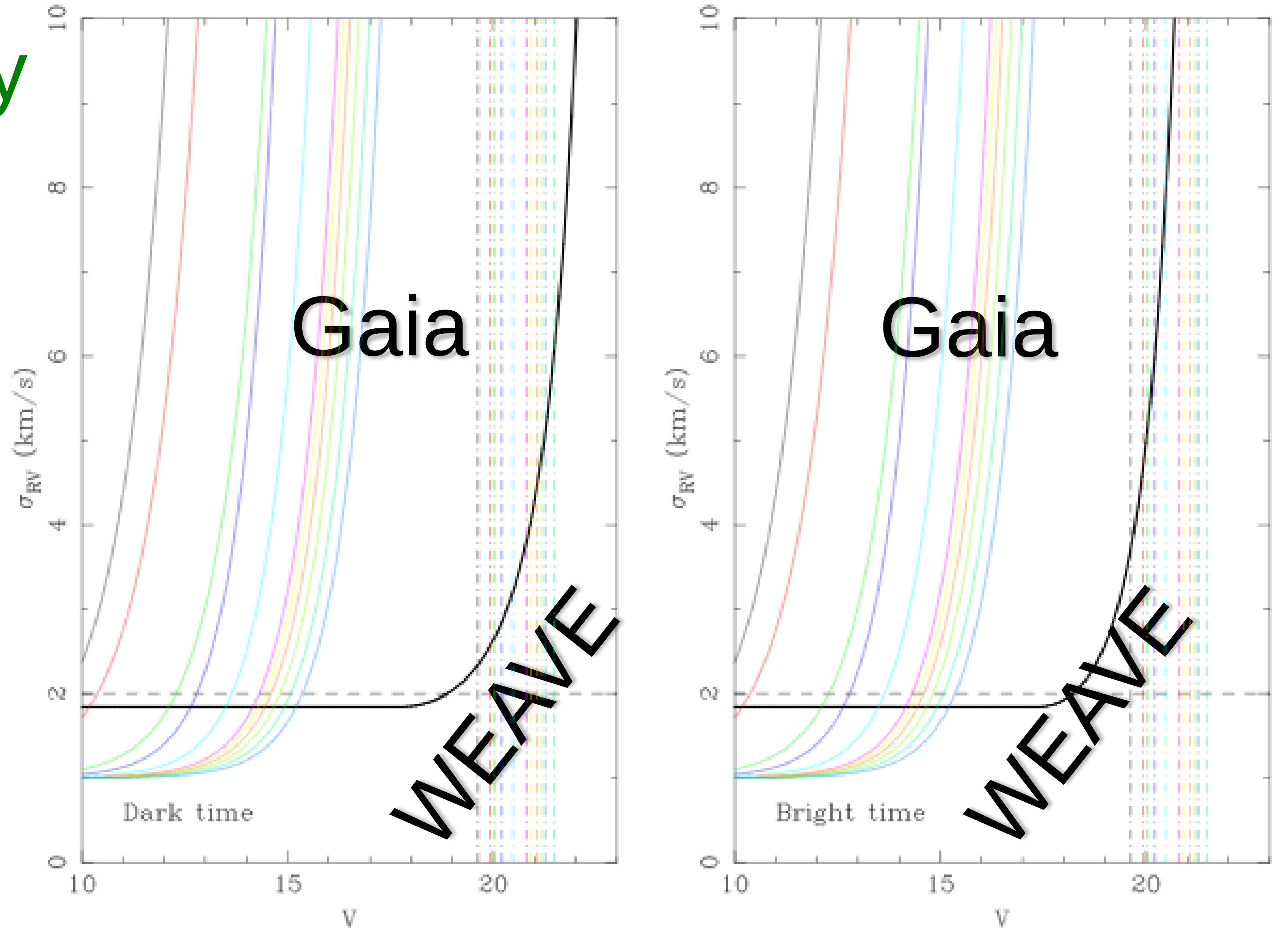
WEAVE is the only HR Xwide field Xmultiplex optical facility in the north !

WEAVE LR surveys

Two main LR survey areas:

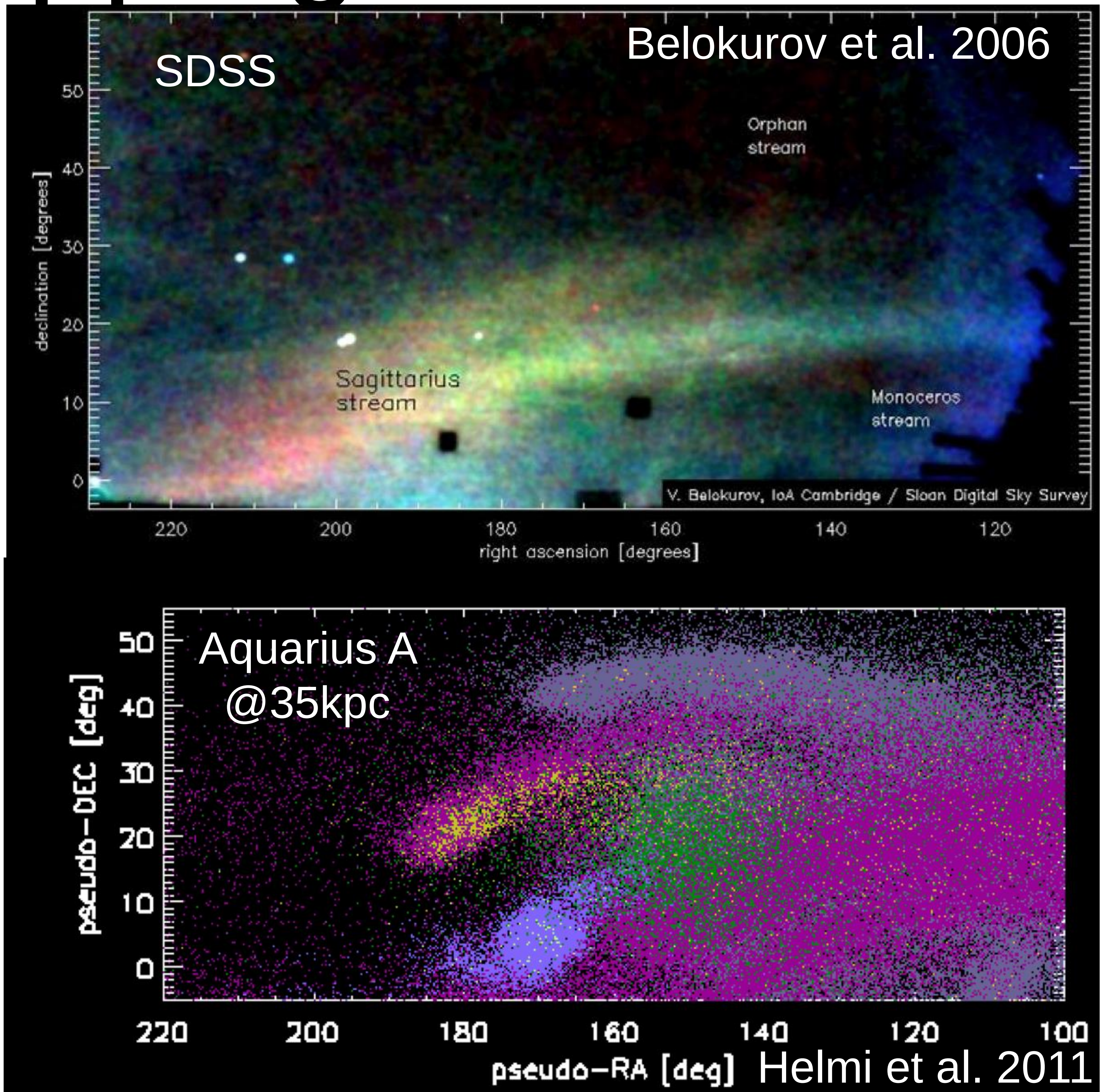
1. A high latitude survey mapping the assembly of the stellar halo
2. A experiment to constrain the disc potential (spiral arms, bar, …)

talk by B. Famaey

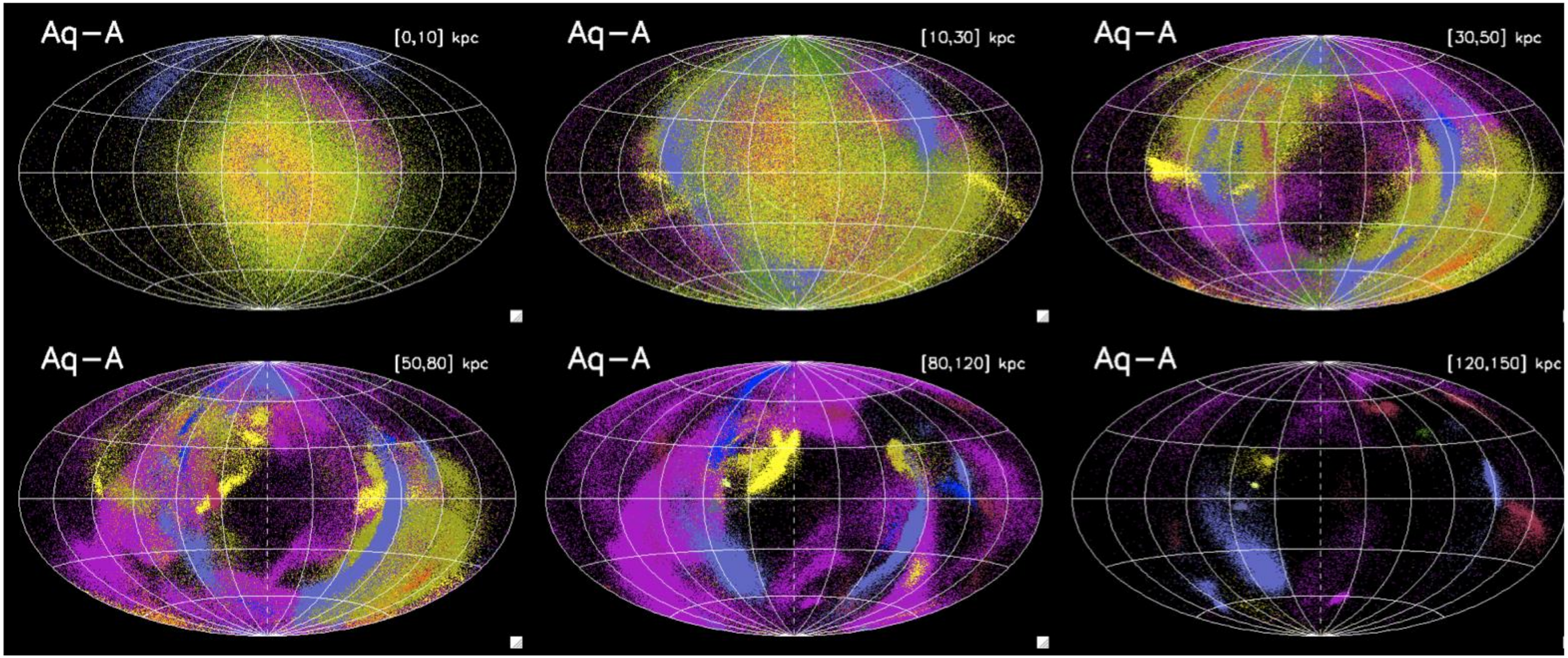


WEAVE can measure Vr to $\sigma(v_r)<3$ km/s at V=20 in 1hr (dark time) or V=19 (bright time), i.e. *closely matching the Gaia astrometric and photometric limits*

Mapping the stellar halo



Mapping the stellar halo



- Aquarius simulations (Helmi et al. 2011): most merger traces found D [10-30]kpc.
- # of streams increases towards the galactic centre (Gomez et al. 2013)
- Chemo-dynamical information for streams fundamental in the inner halo to identify accretions and characterize their

Galactic halo survey goals & means

1. Fraction of accretion/in-situ formation ? (LR&HR)
2. Total mass of the MW >100kpc; potential shape and lumpiness (LR)
3. Hunting and following-up metal-poor stars (LR&HR)

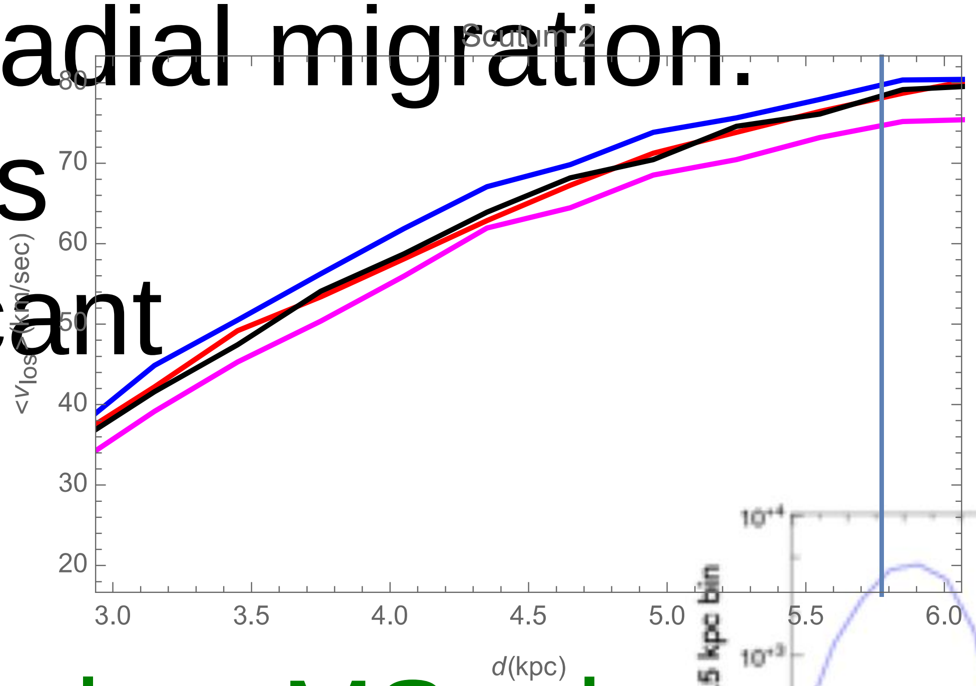
- Known streams follow-up (incl. dSph) LR
- « blind » halo survey LR (MSTO + giants)
- « blind » halo survey HR of giants

- ~1.5 10^6 stars over ~9000deg^2 selected SDSS + PanStars + Gaia-DR2(2017)+

Disc dynamics survey: goals & means

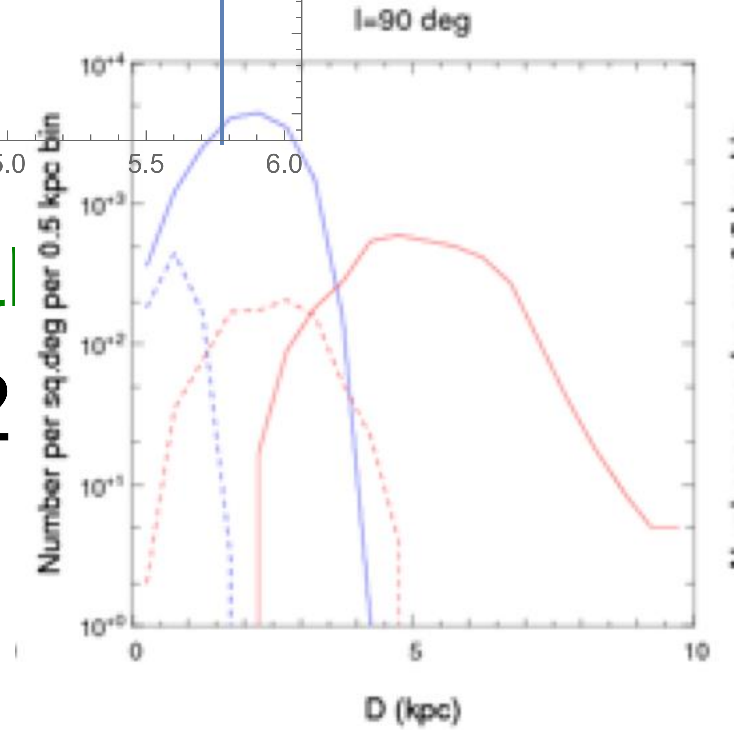
Discriminate fundamental aspects of galactic dynamics in the MW: moving groups, velocity elipsoid accross the disc ➔ probe the axisymetric potential + non-axisymetric terms (bar, spiral arms). Implications for radial migration.

- Need Vr to a few km/s
- Reach across significant disc fraction



- LR in 100 well chosen los; MS+gia
- Several 10^6 stars selected Gaia-DR2

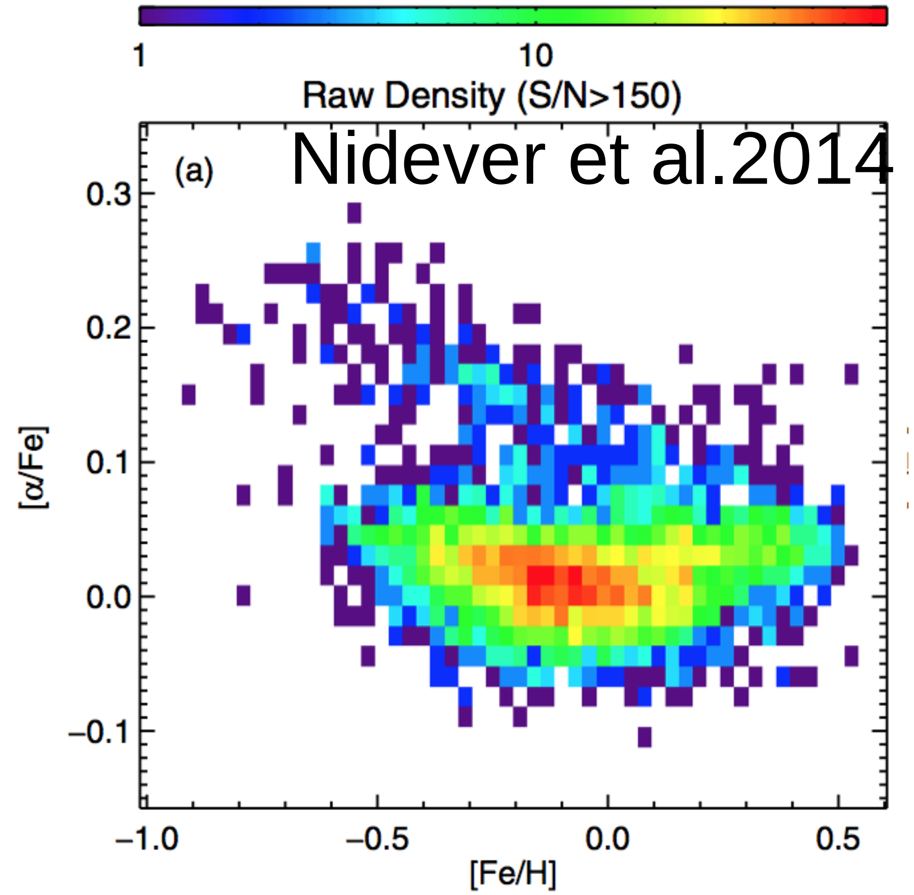
+ gal plane phot surveys

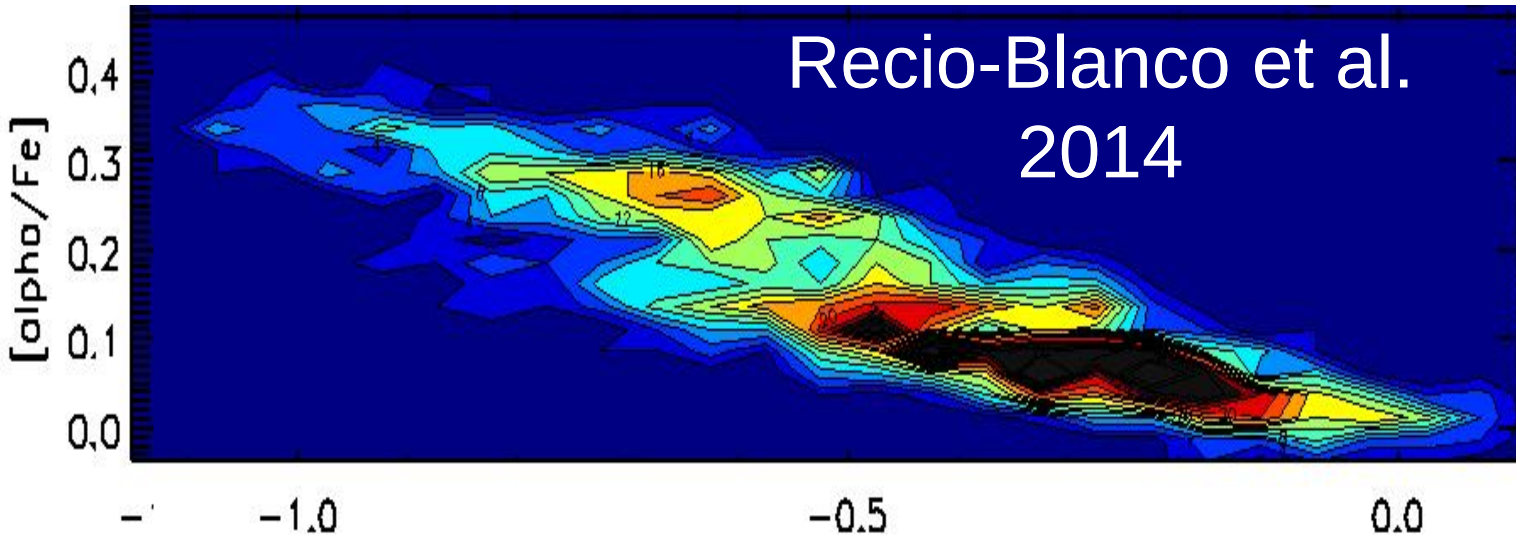


WEAVE HR surveys

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

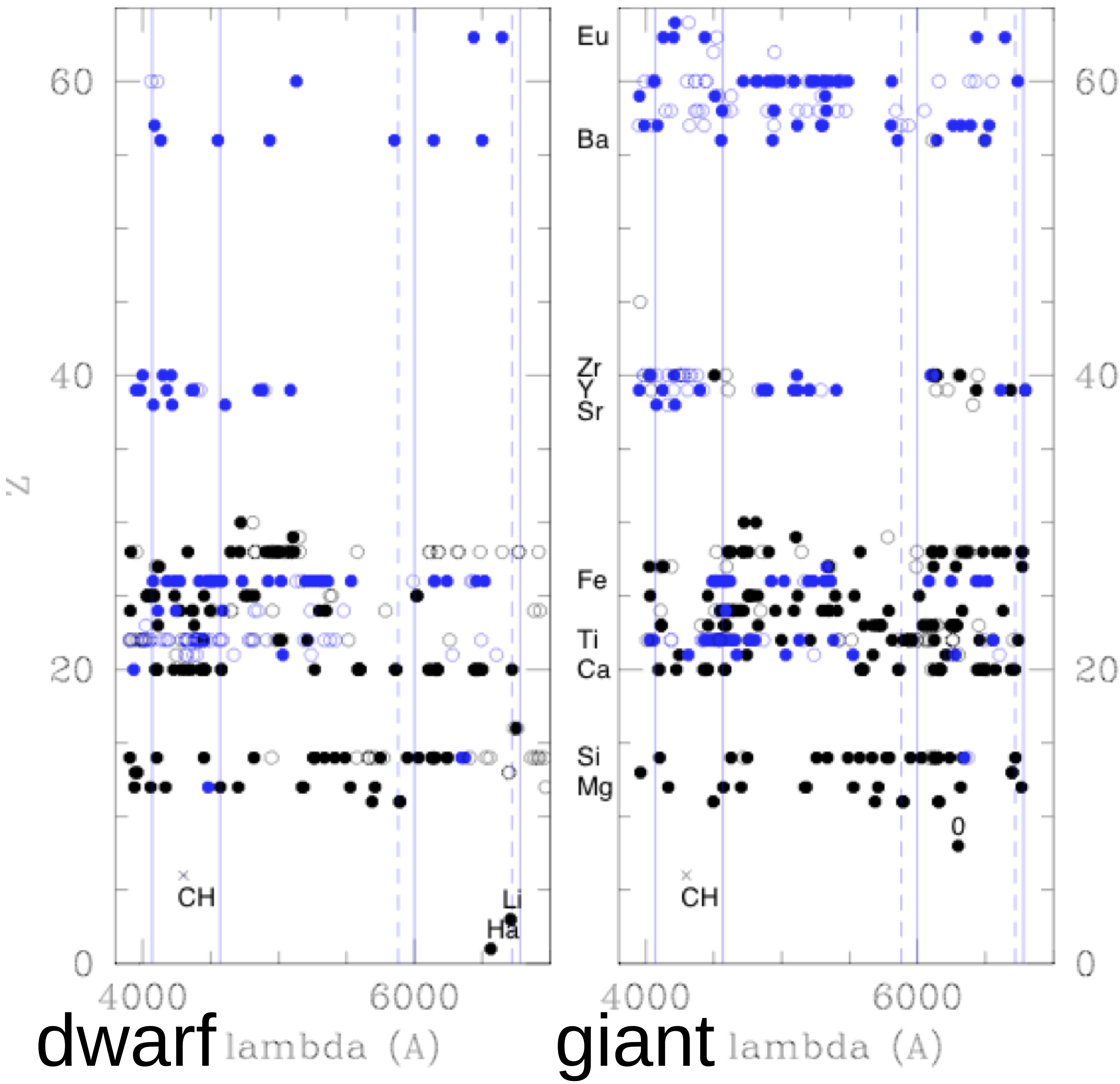
1. A high latitude survey searching for streams in the stellar halo
2. A intermediate latitude survey mapping the thick away from the solar vicinity





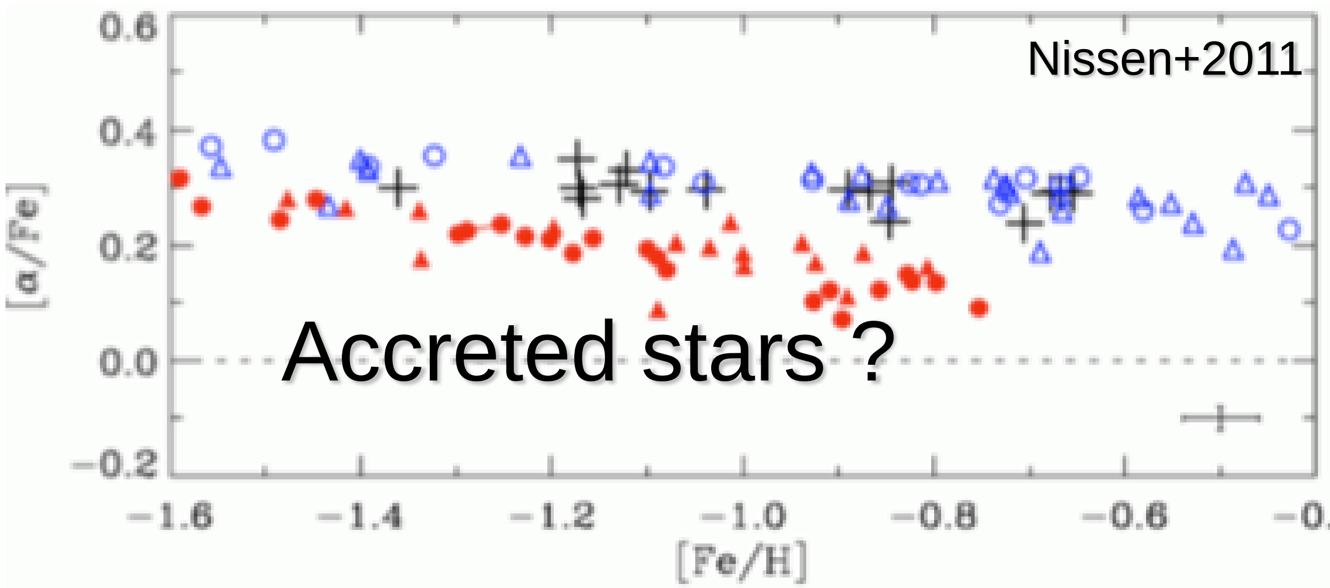
WEAVE can measure stellar parameters and individual abundances in all main nucleosynthetic channels to V=16, i.e. *closely matching the Gaia's most precise sphere (distances, ages)*

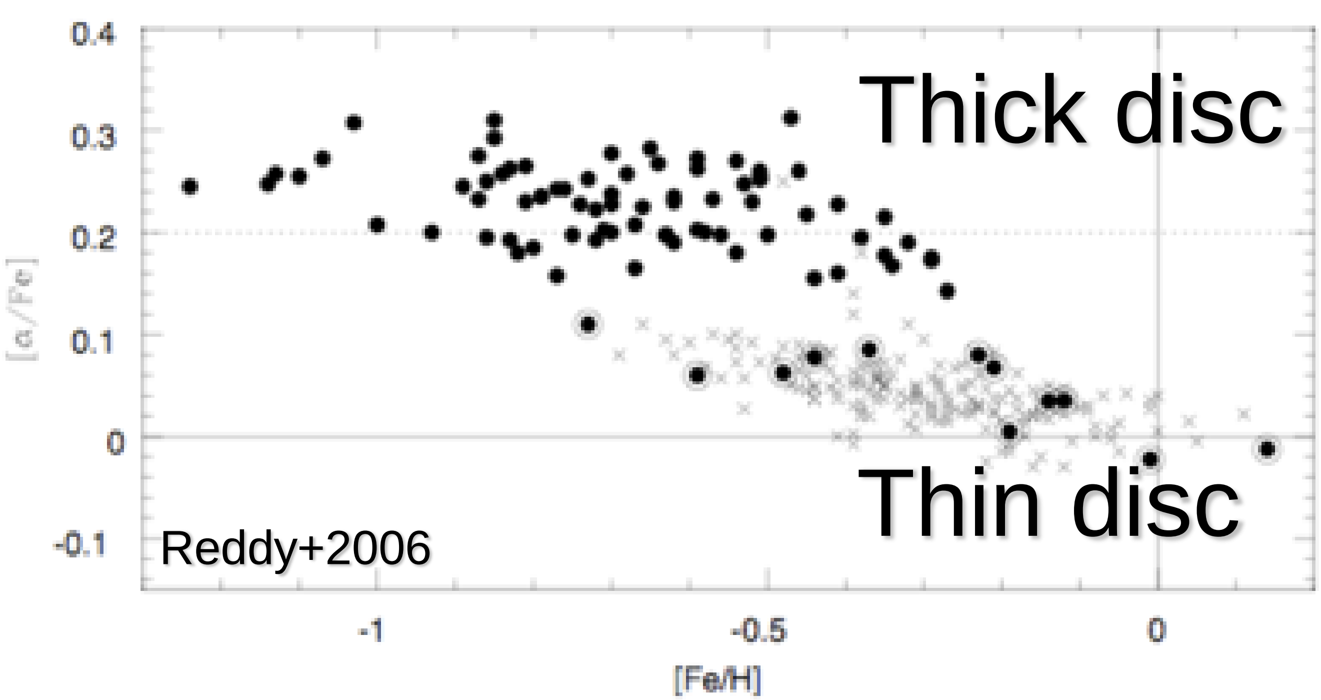
Elemental abundances



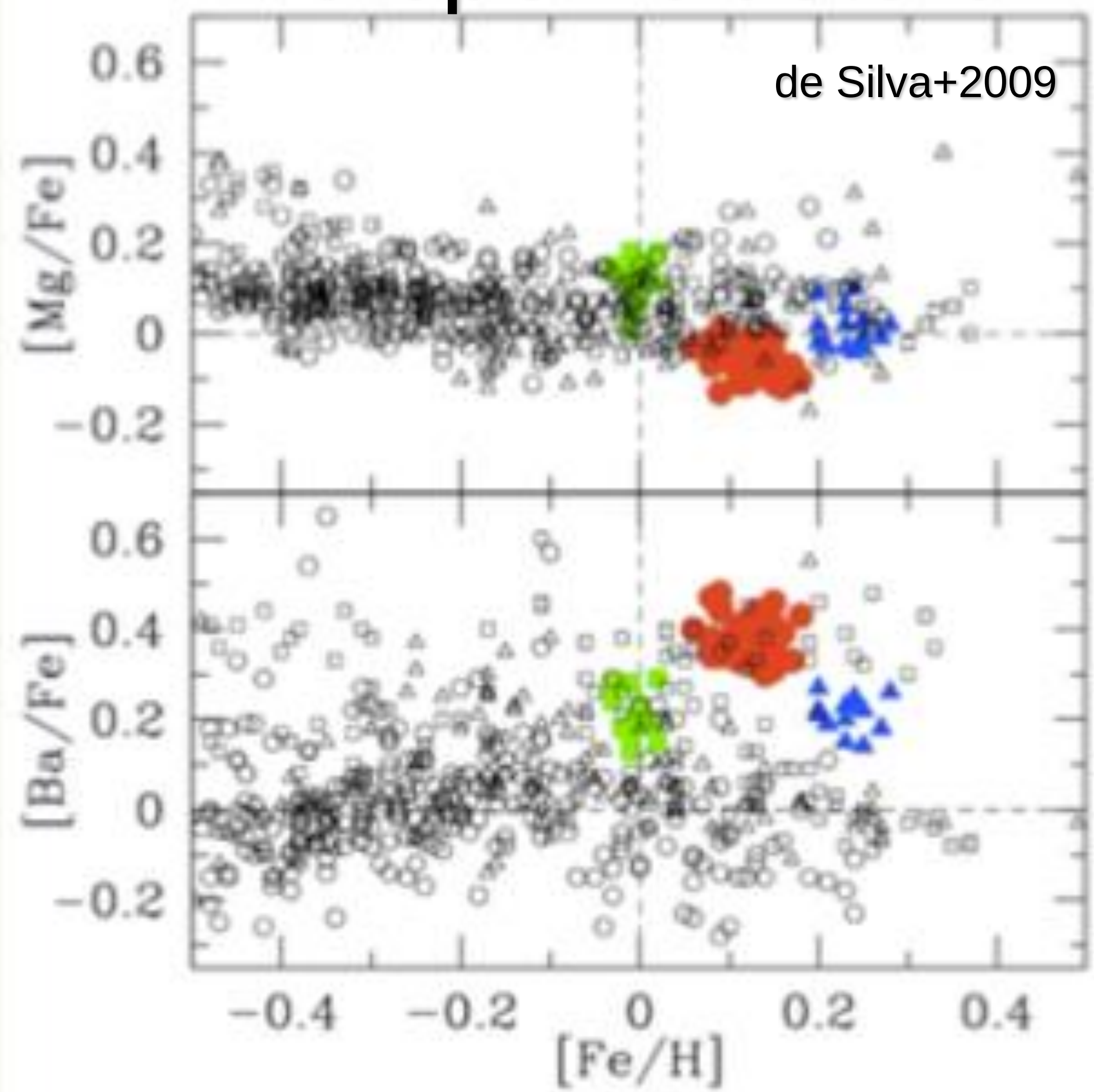
dwarf giant

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





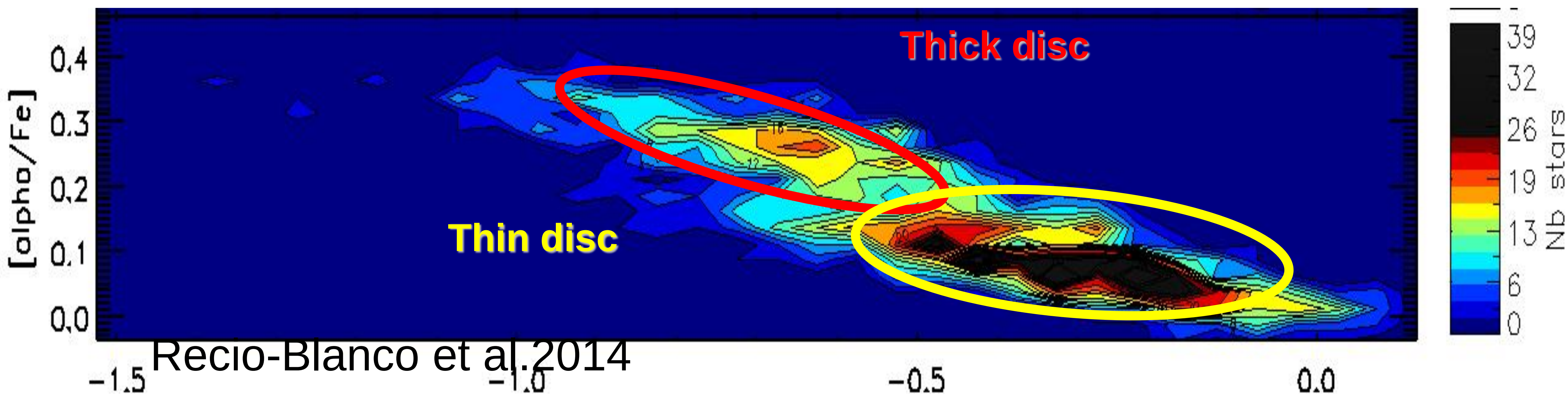
3 open clusters



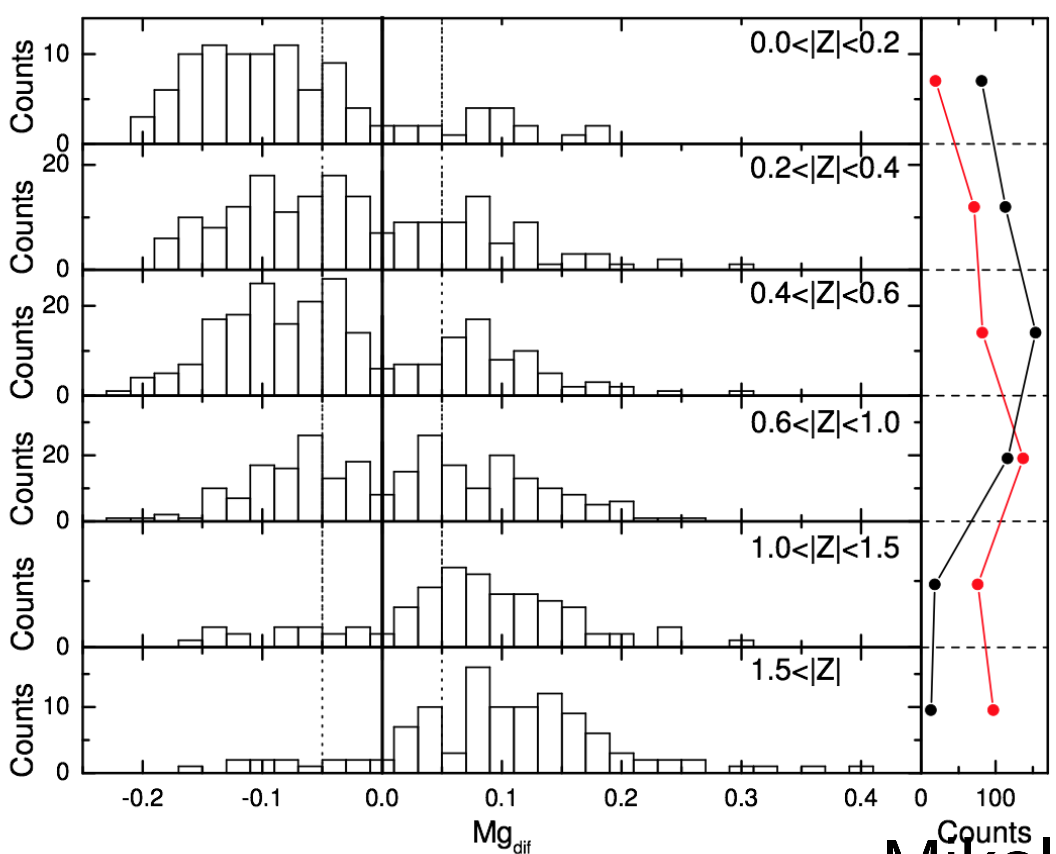
These samples deal with 100 to 1000 stars, in a volume of <100pc around the Sun, at very high SNR and resolution

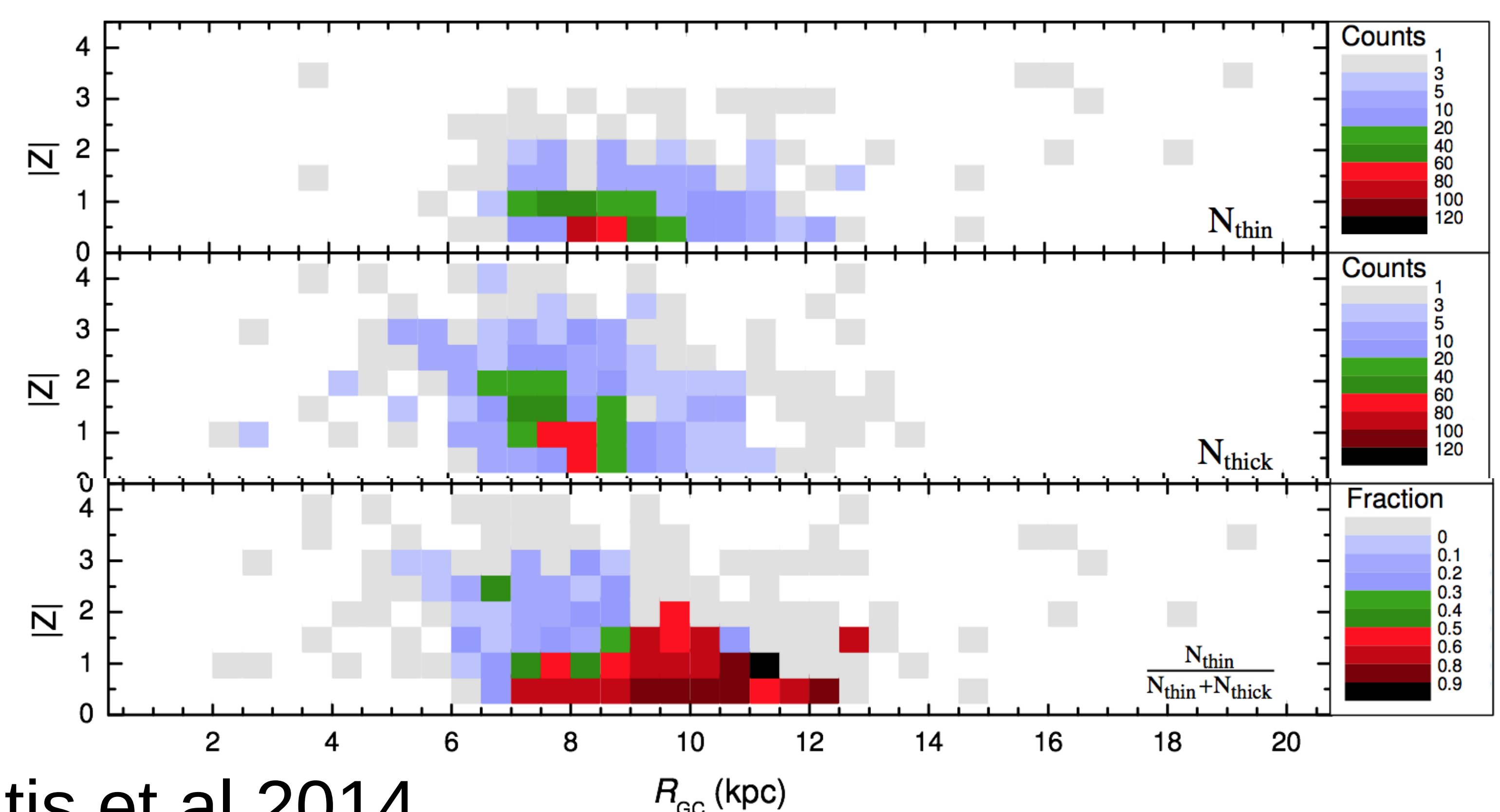
Gaia ESO experience

R=20,000, smaller λ range, lowish S/N



Recio-Blanco et al.2014





Mikolaitis et al.2014

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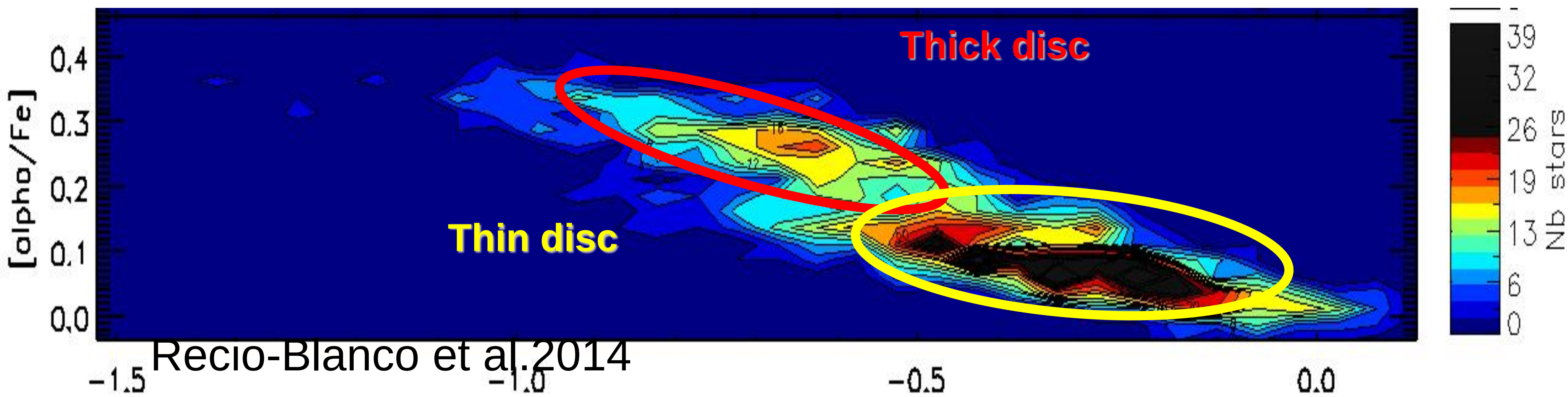
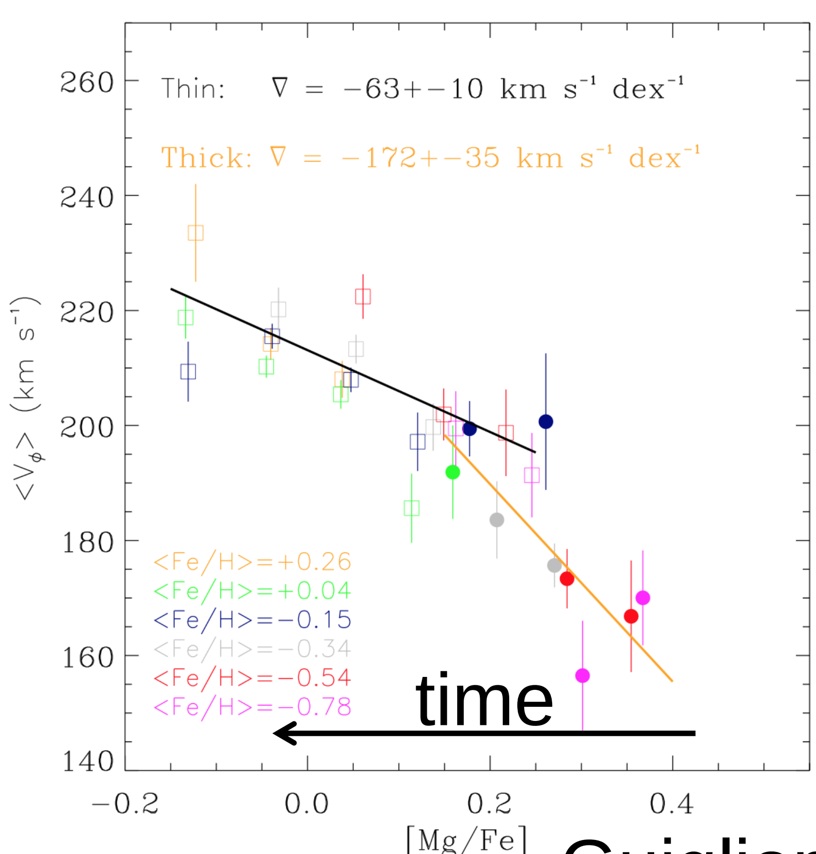
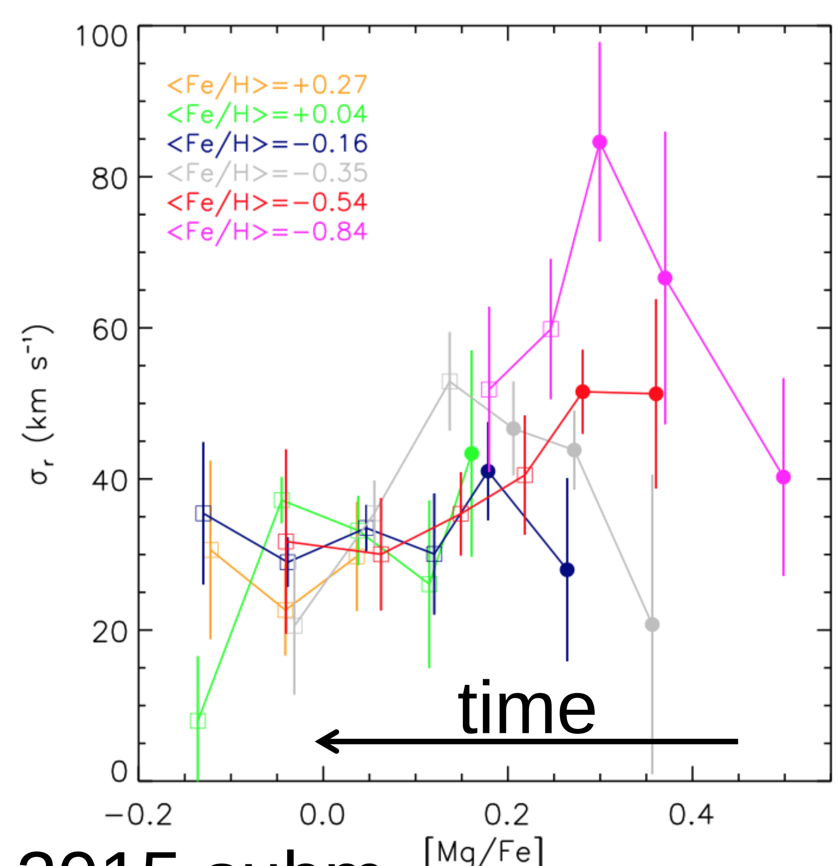


Recio-Blanco et al.2014



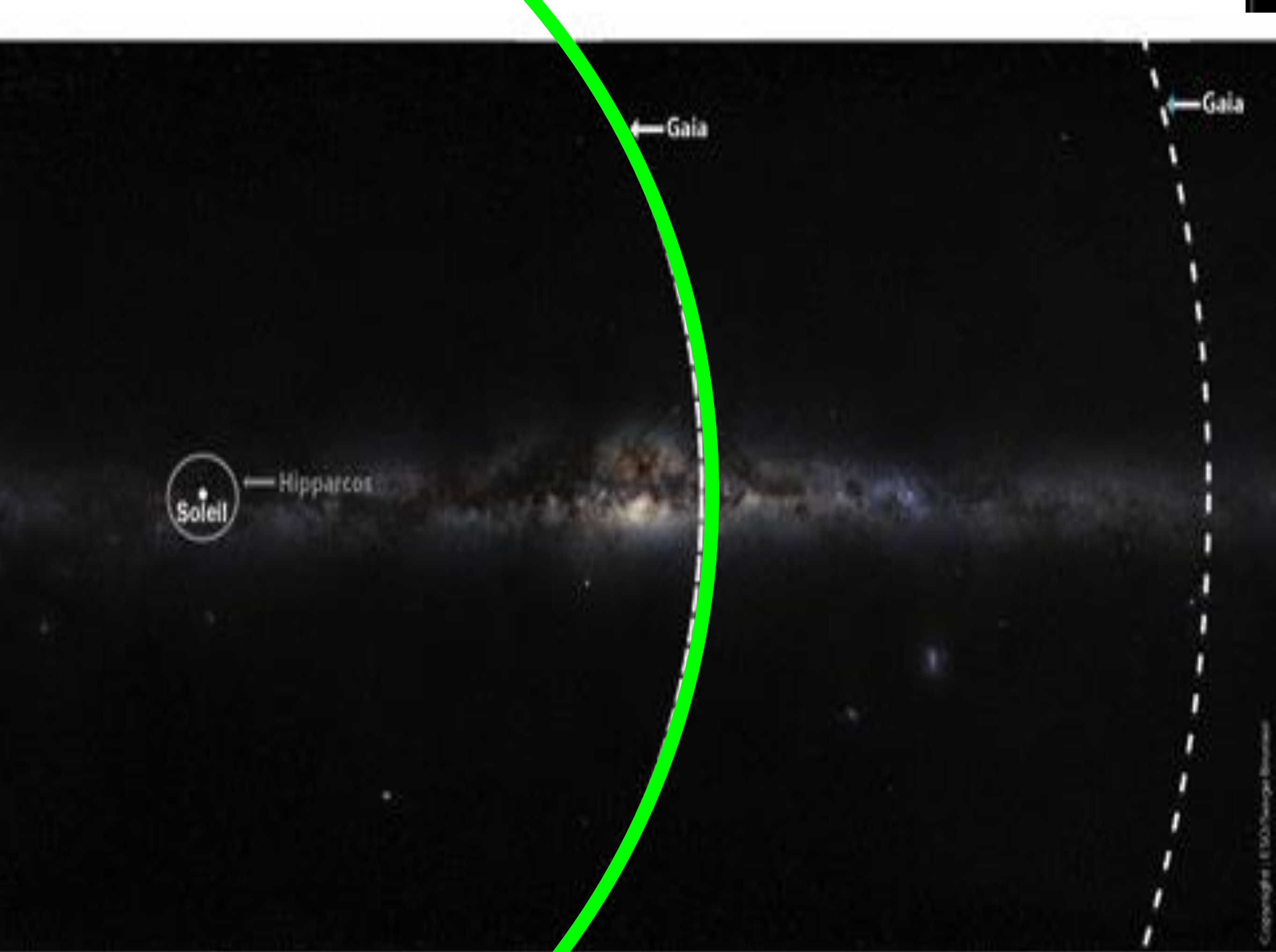


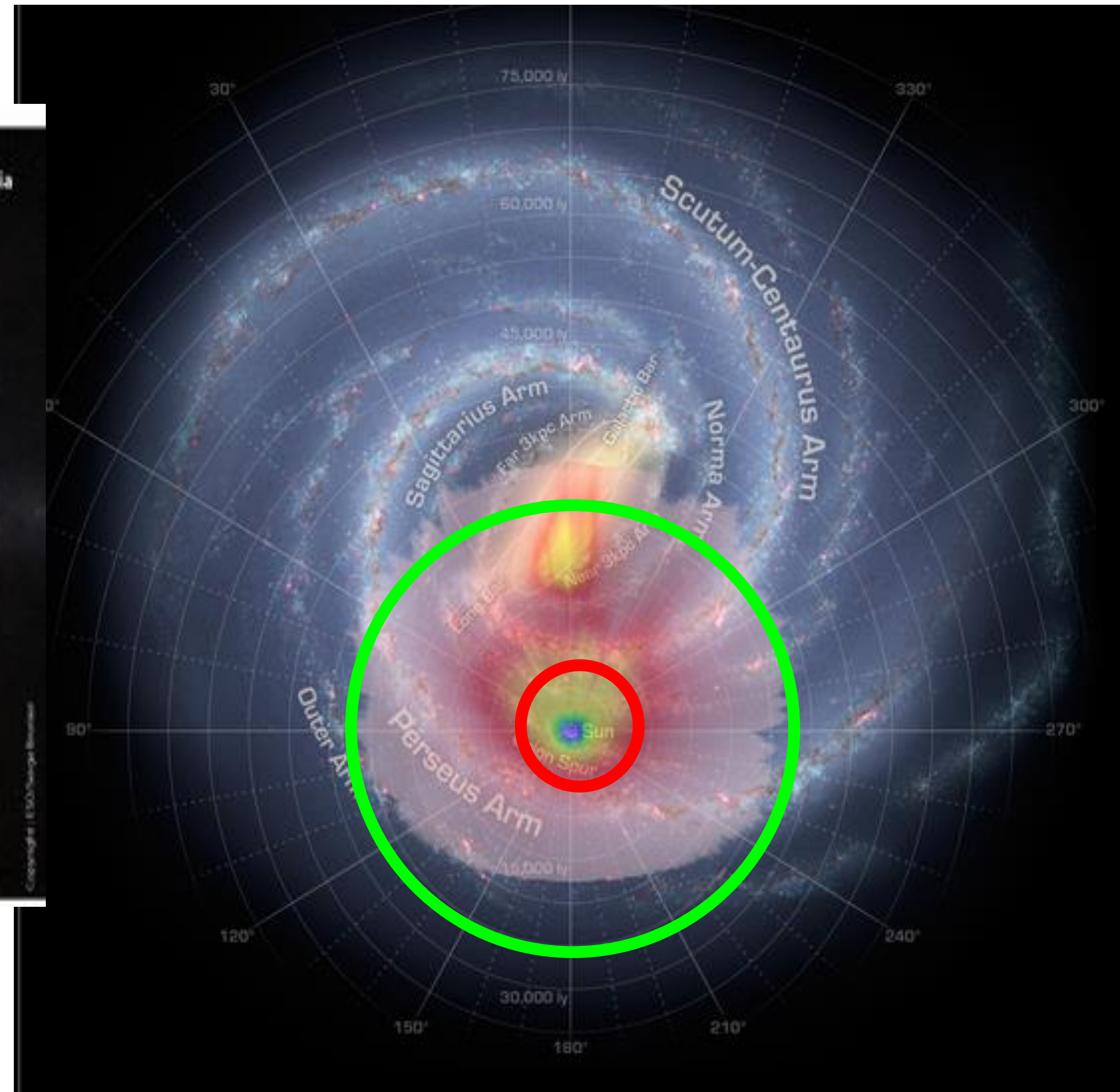
Guiglion et al.2015 subm.

Gaia's reach: best distances

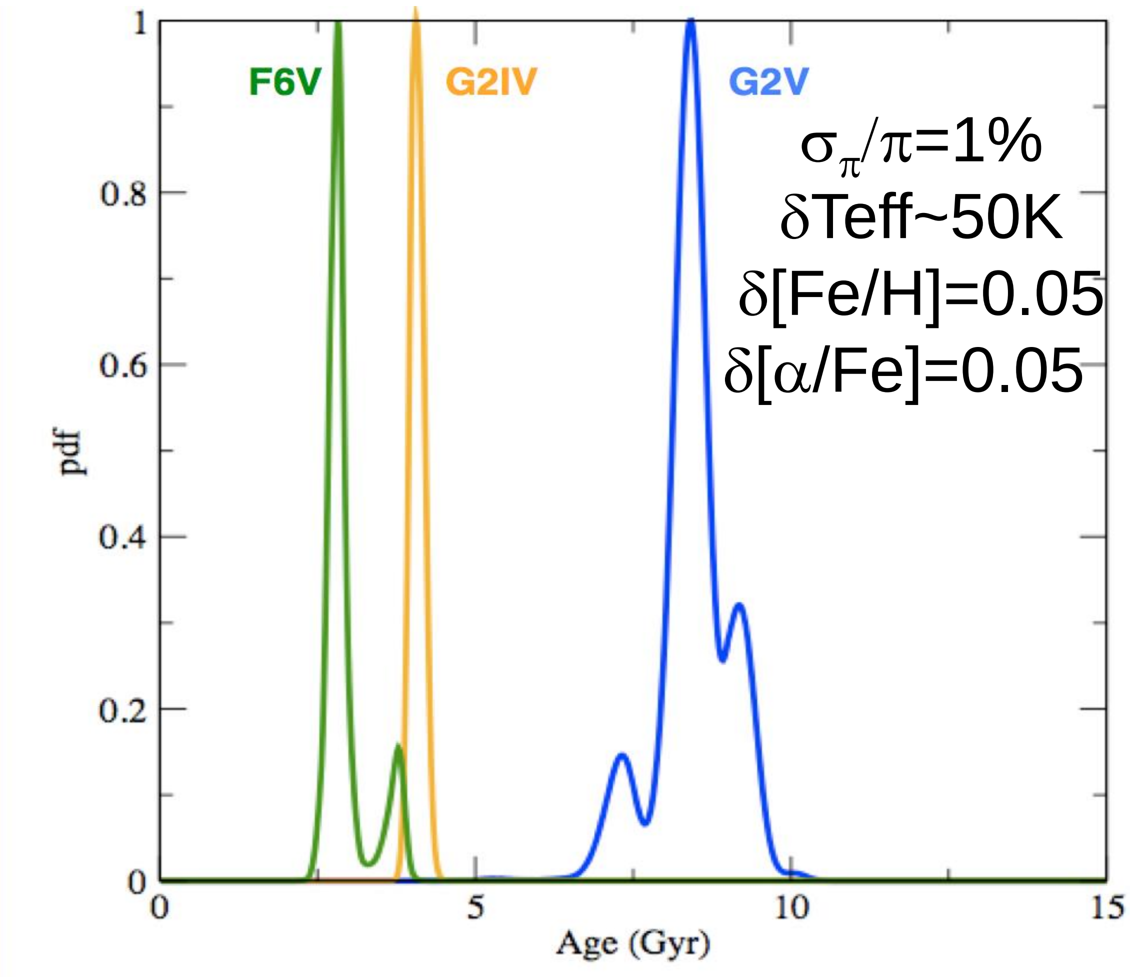
$\sigma_\pi/\pi<1\%$ (10^6*)

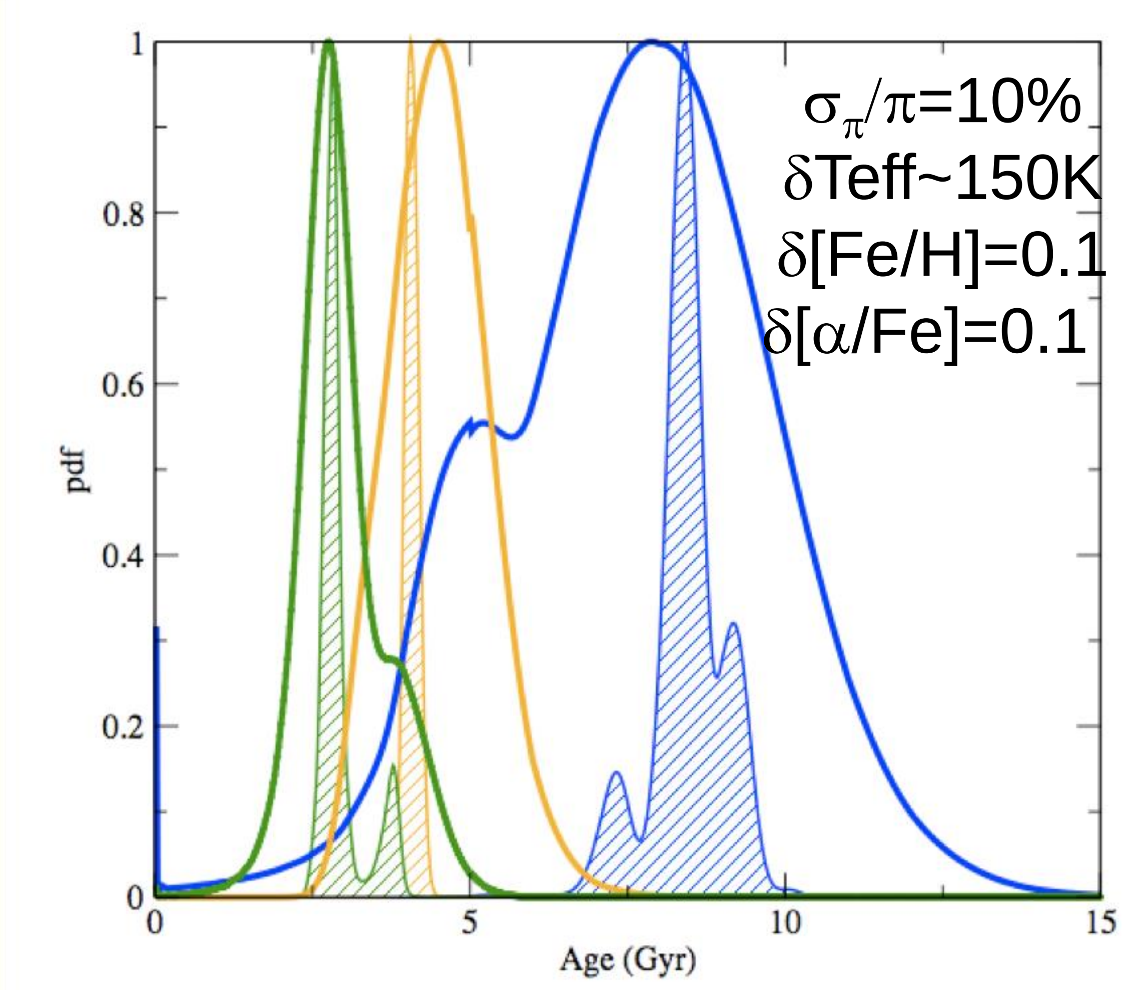
$\sigma_\pi/\pi<10\%$ (150.10^6*)





Gaia's reach: ages





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

	Gaia only					Gaia + Ground-Spectro			
Vmag	σdistance	σteff (RVS)	σteff (BPRP)	σage	σ[α/Fe]	σdistance (Gaia)	σteff (GES)	σage	σ[α/Fe] (GES)
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

1-2 kpc

3-4 kpc

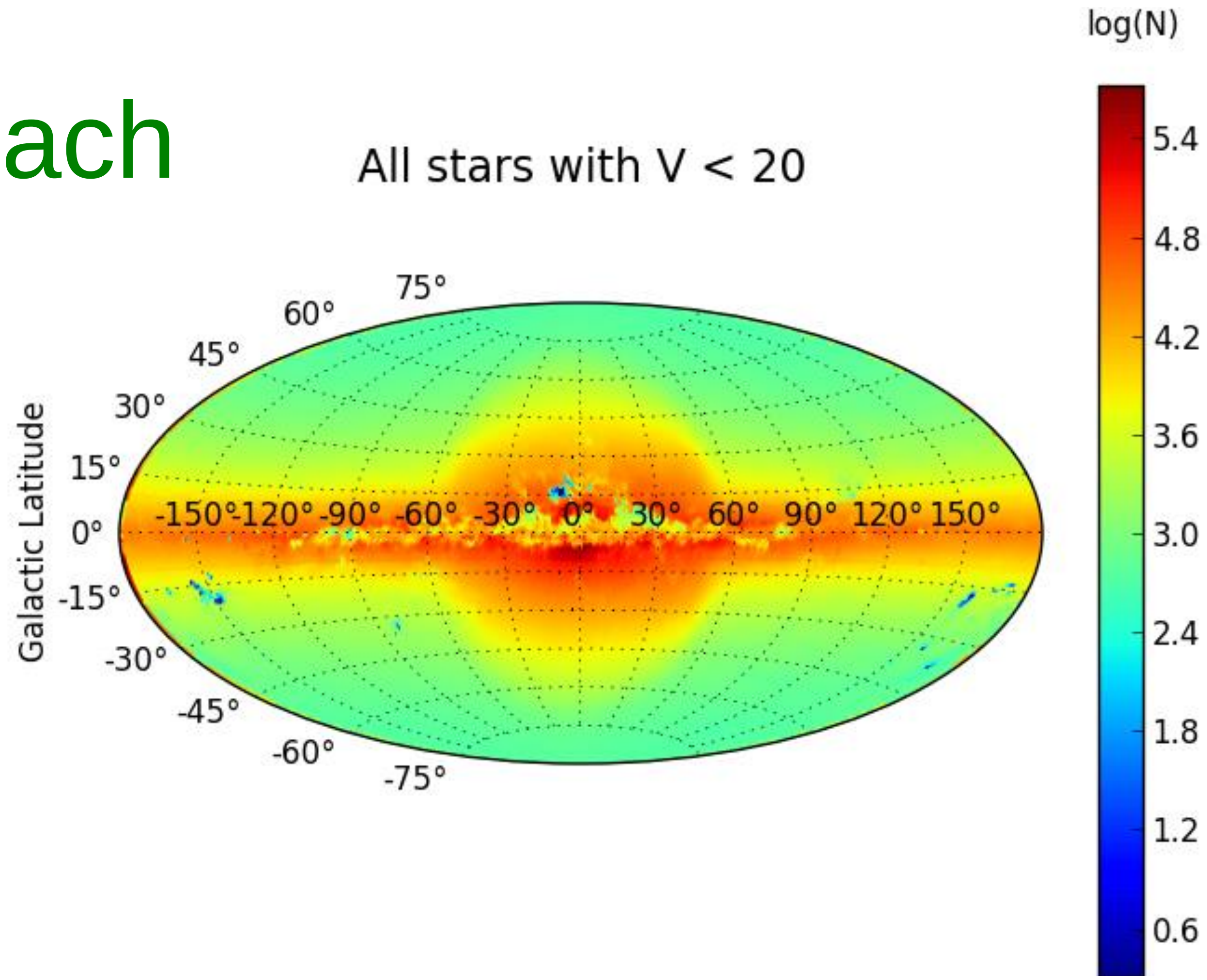
HR survey: goals & means

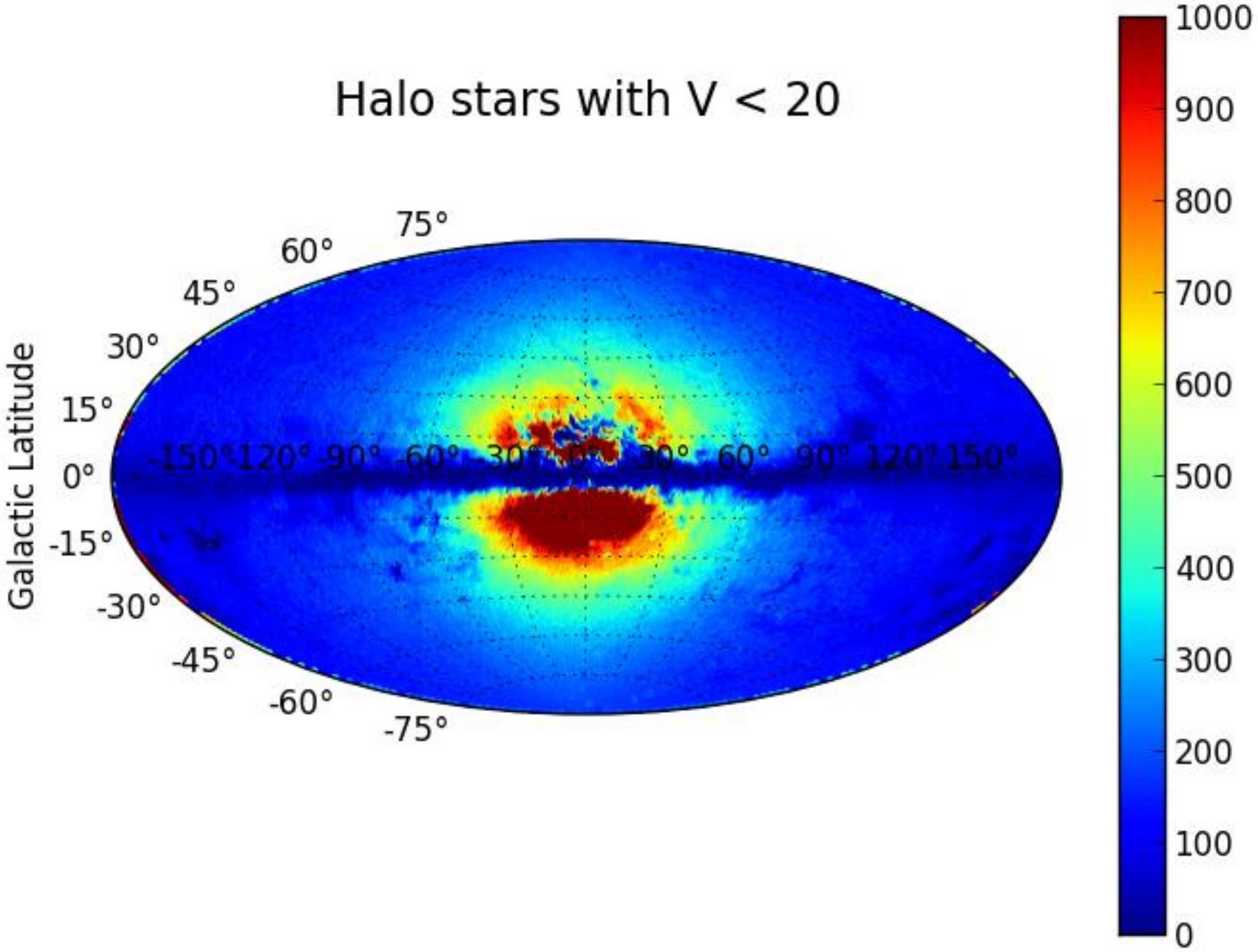
Probe the MW main populations history (mass assembly, internal evolution):

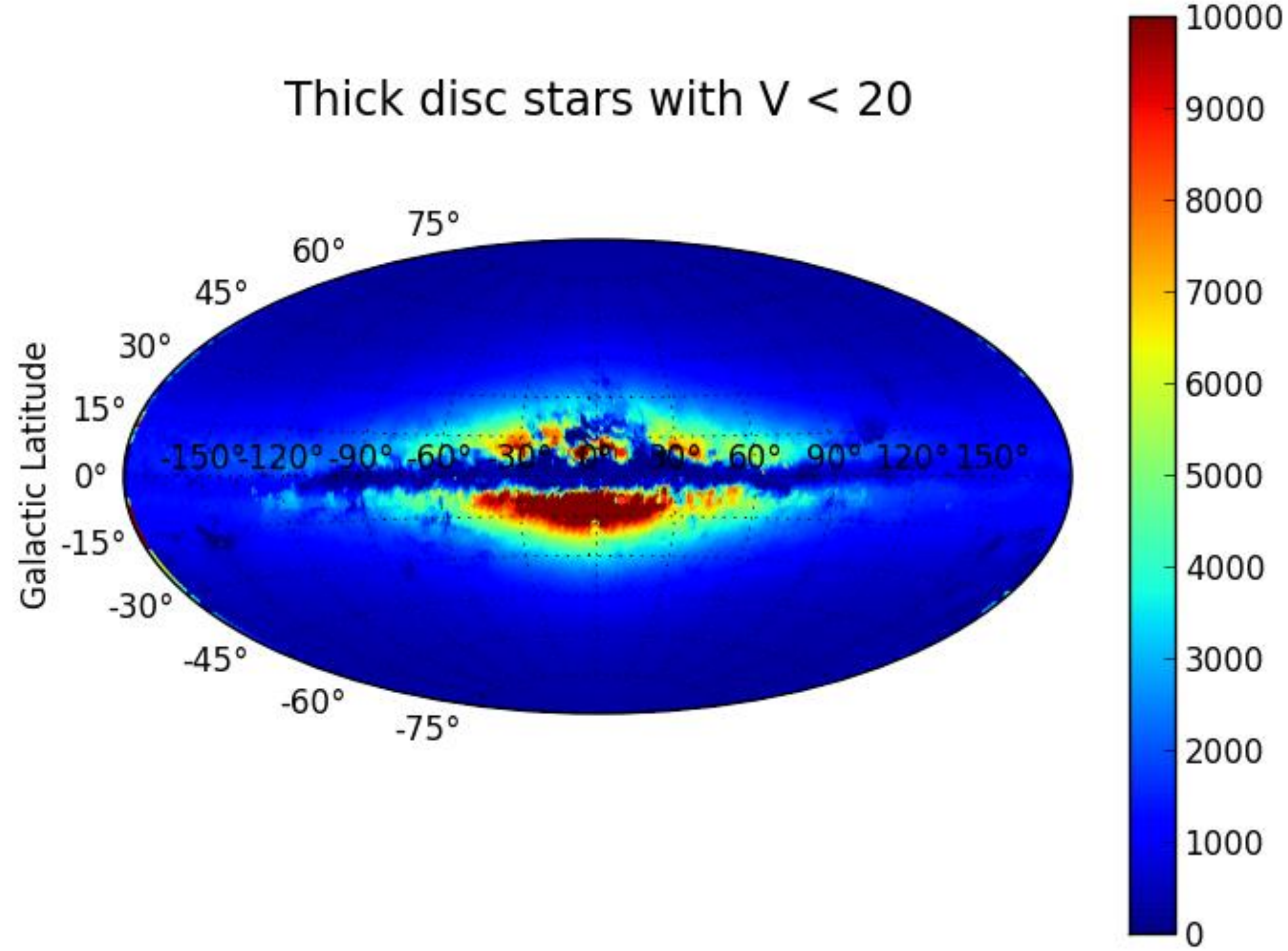
1. Chemical labelling of thin/thick disc and halo away from the Solar neighbourhood; emphasis on the outer disc
2. Complement Gaia in its extended « age-sphere » (D<3kpc)
3. Field/open cluster synergies

- 12<V<16 survey at intermediate |b|, with special emphasis on old MSTO
- « blind » halo survey HR of giants (V<16-18)
- 25 old open clusters across the disc (+25 young)
- ~0.5 10^6 stars selected Gaia-DR2(2017) (+SDSS

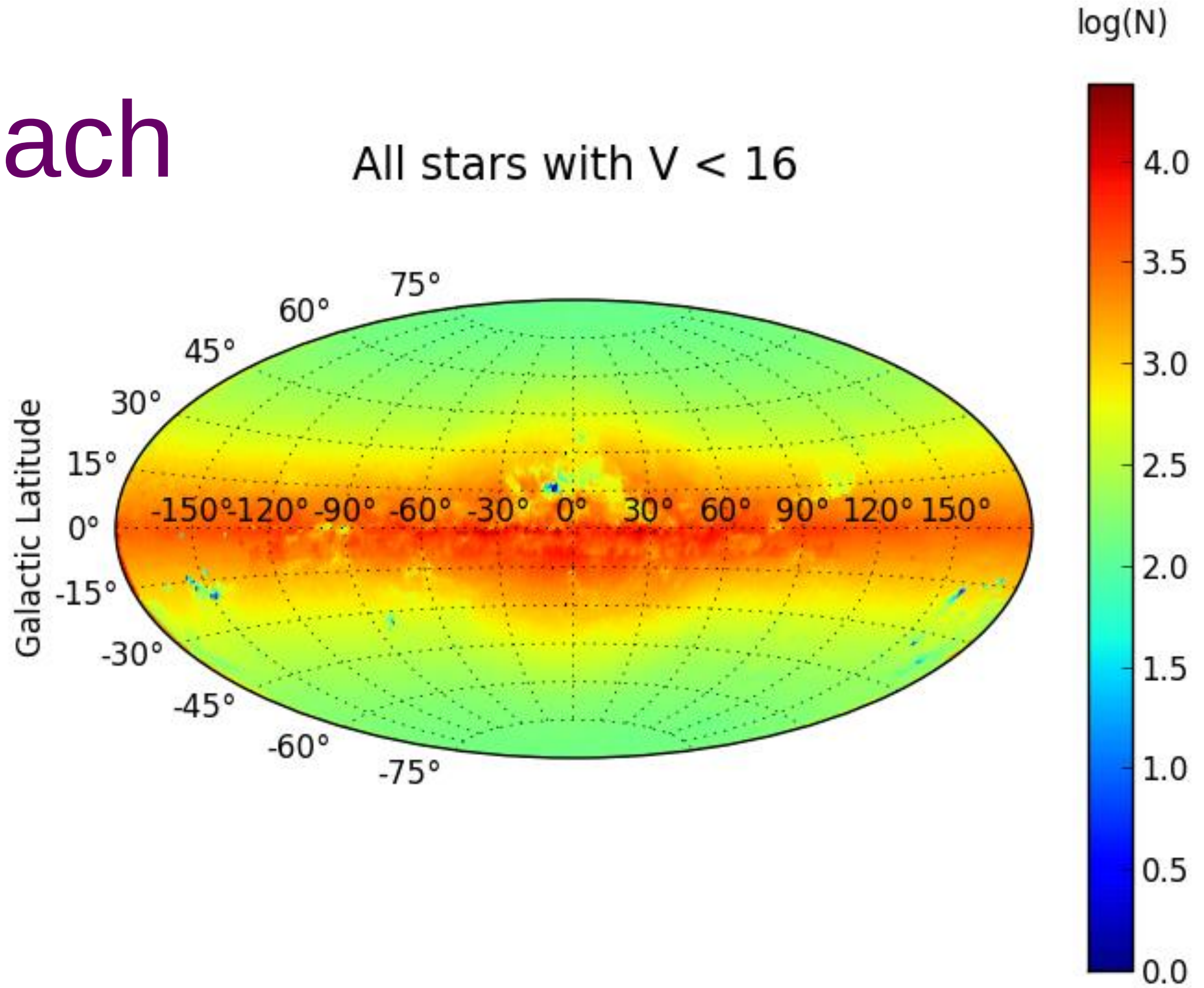
WEAVE LR reach

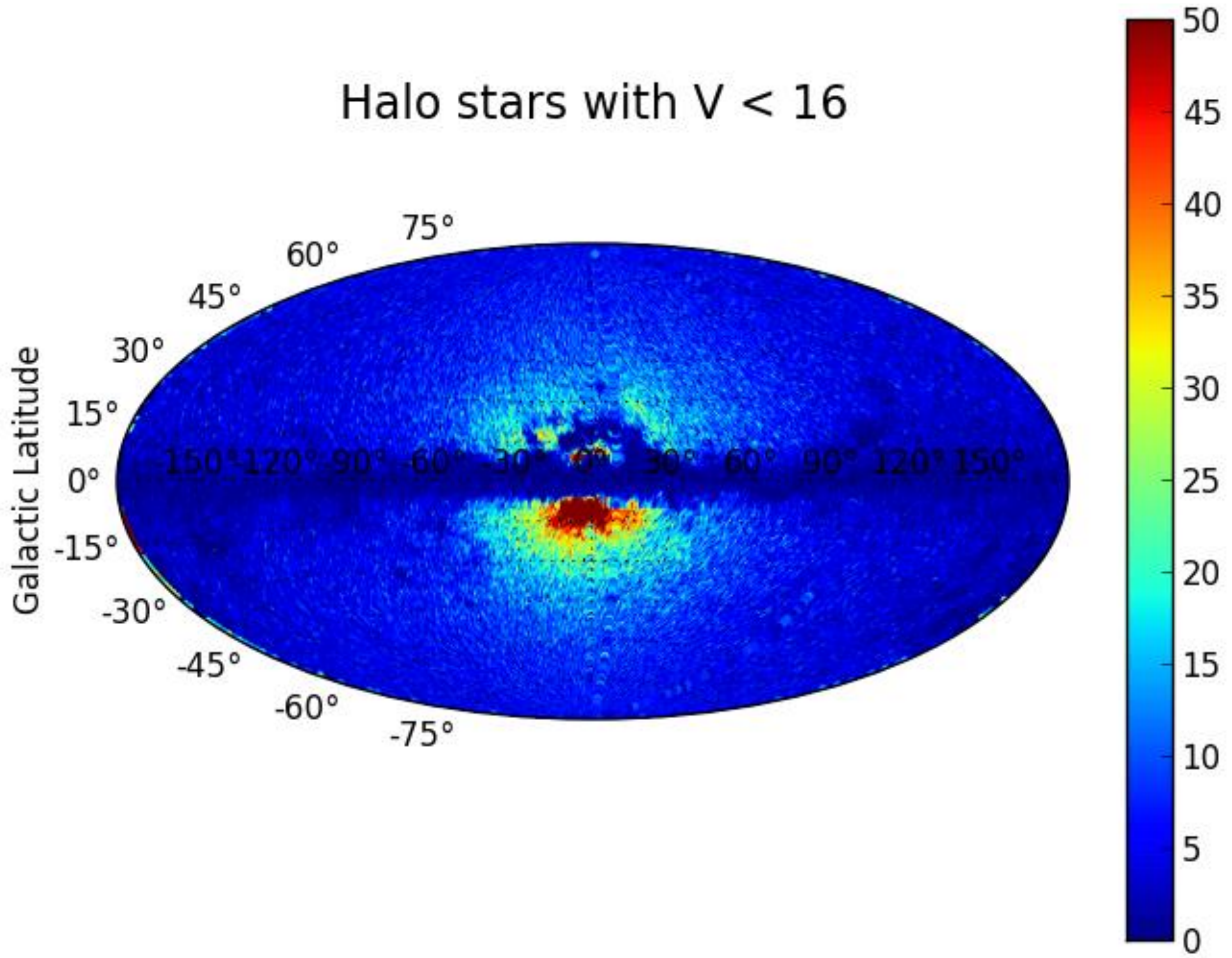


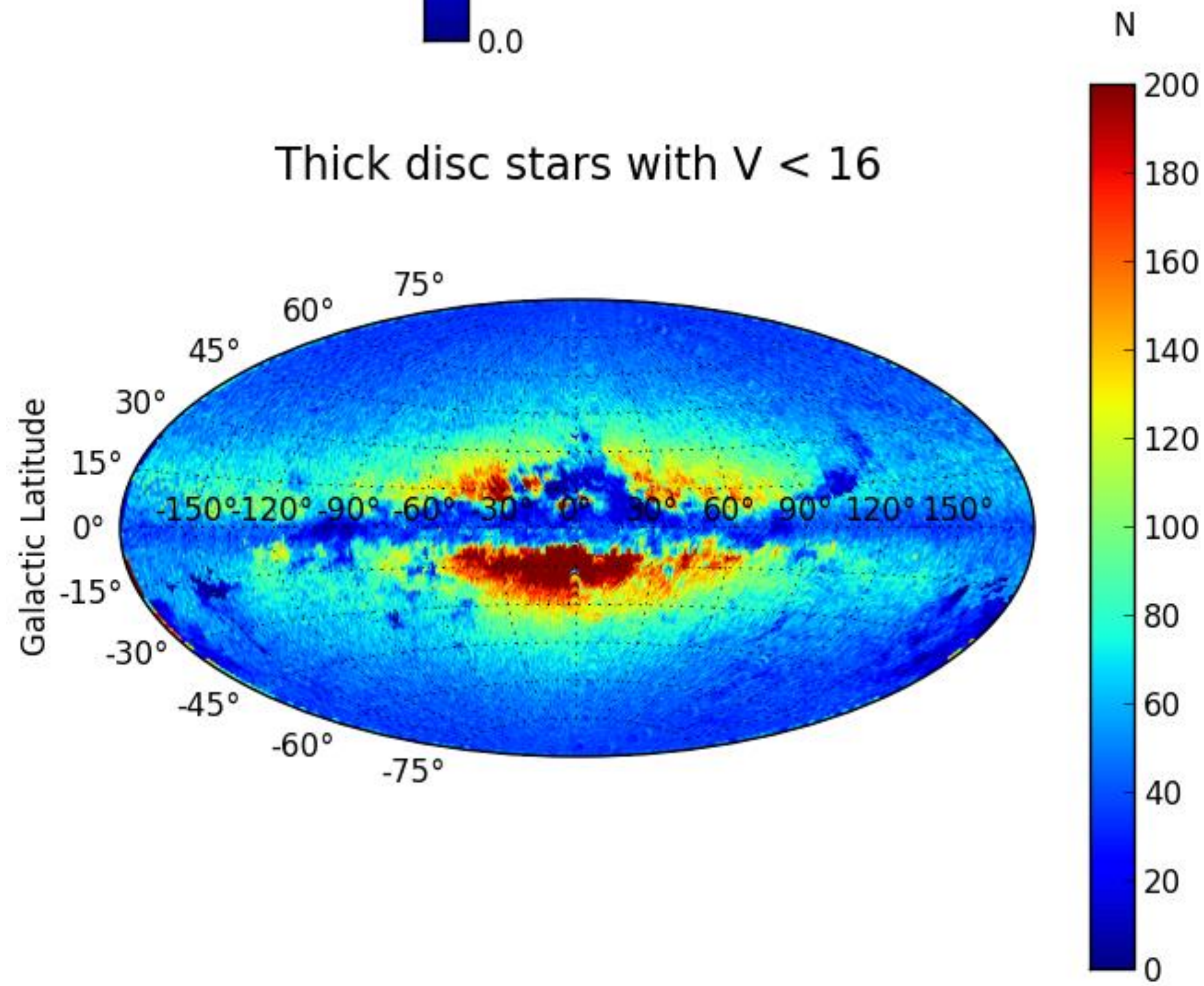




WEAVE LR reach

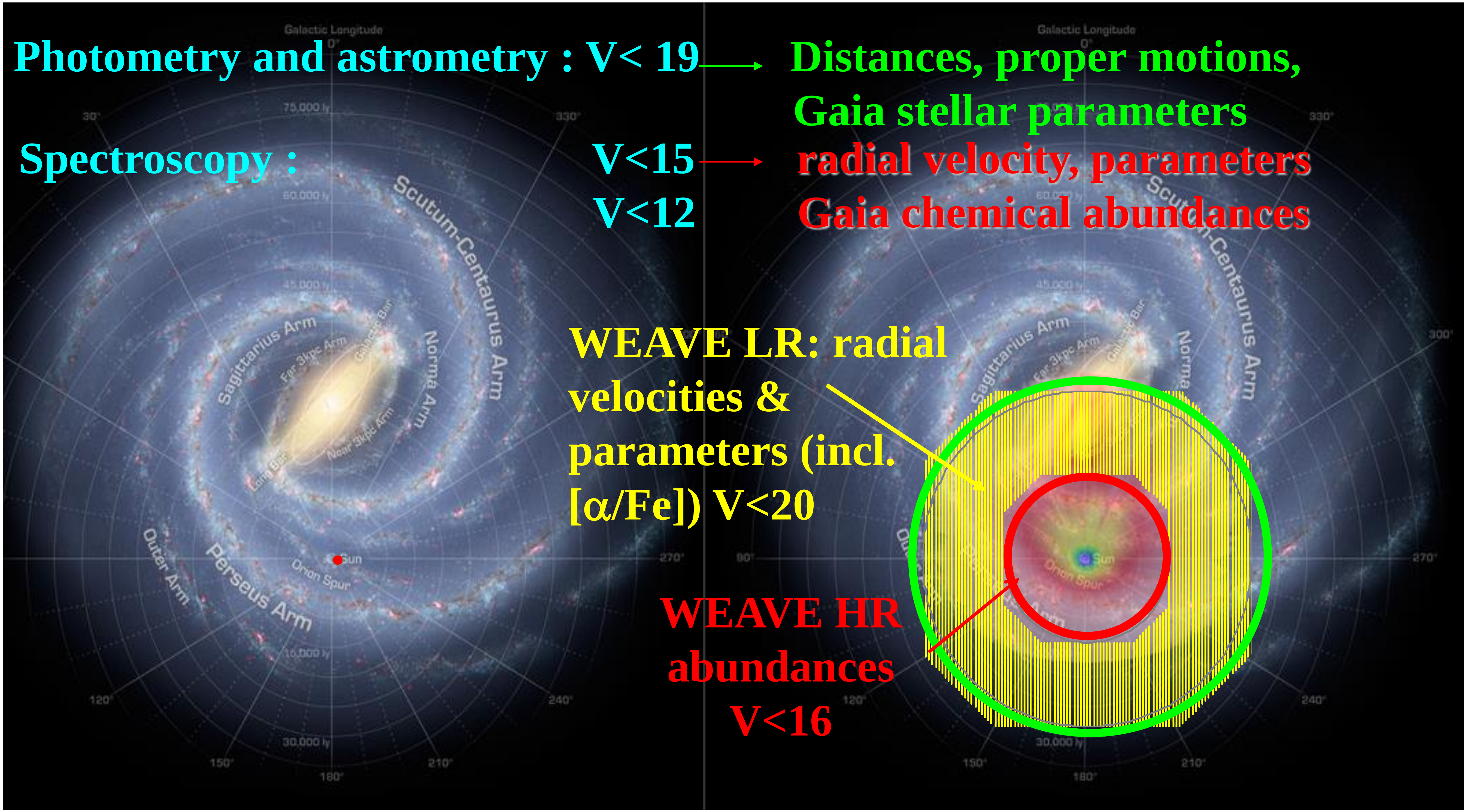






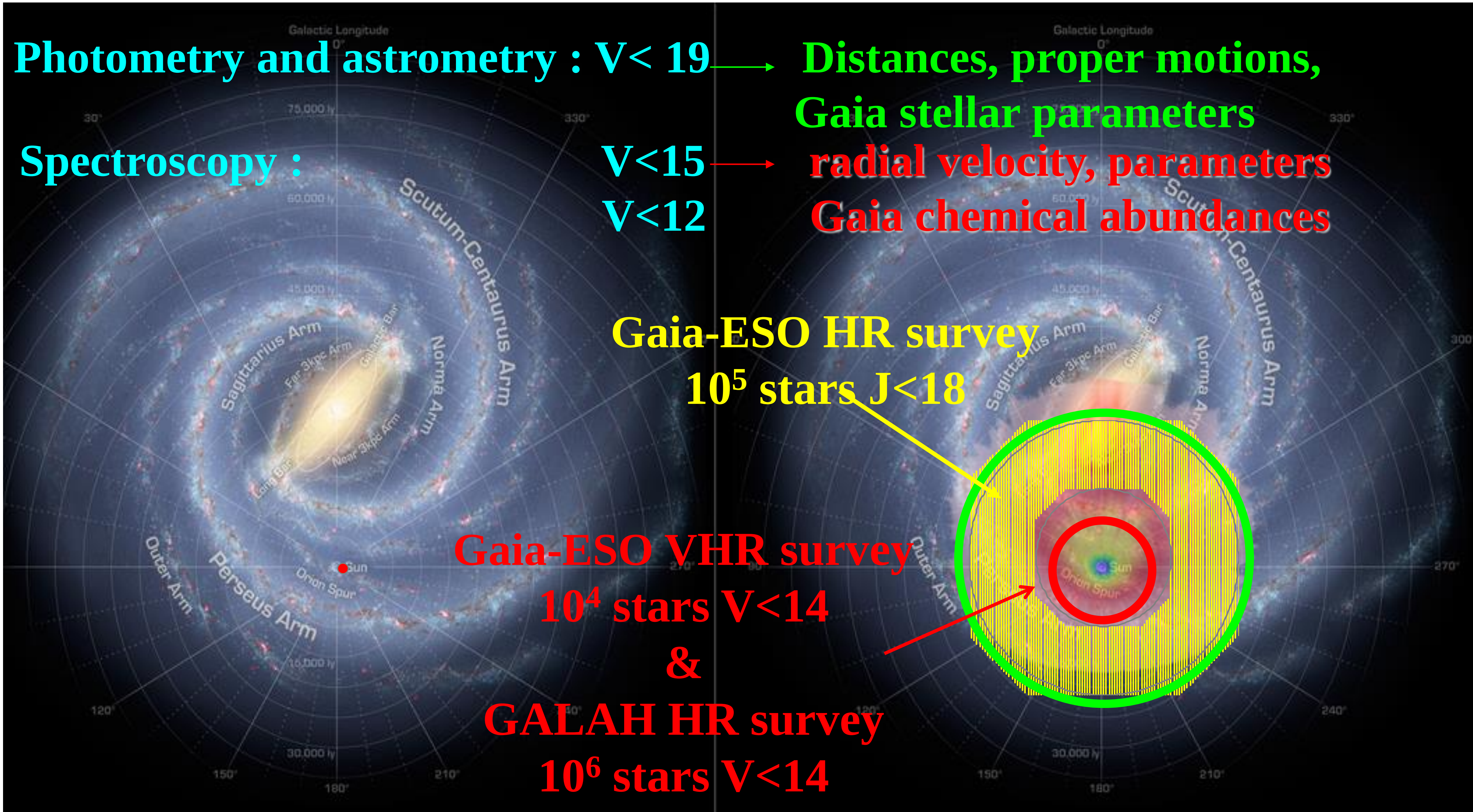
WEAVE @ WHT (4m)

HR survey of 6.10^5 stars V<16 + LR survey of 6.10^6 stars V<20



Gaia-ESO Survey & GALAH

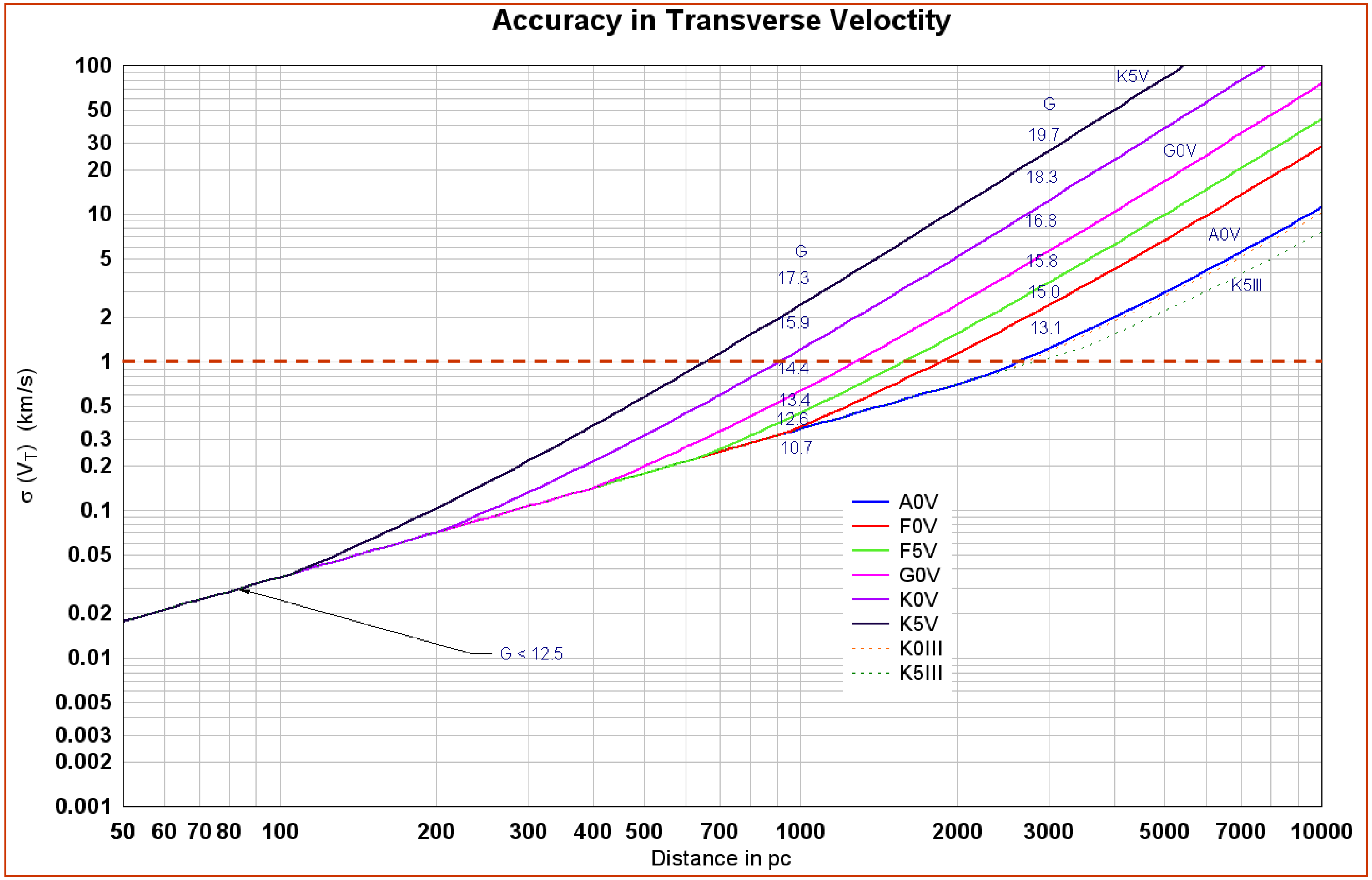
+ WEAVE is the only HR very wide field facility for the North !



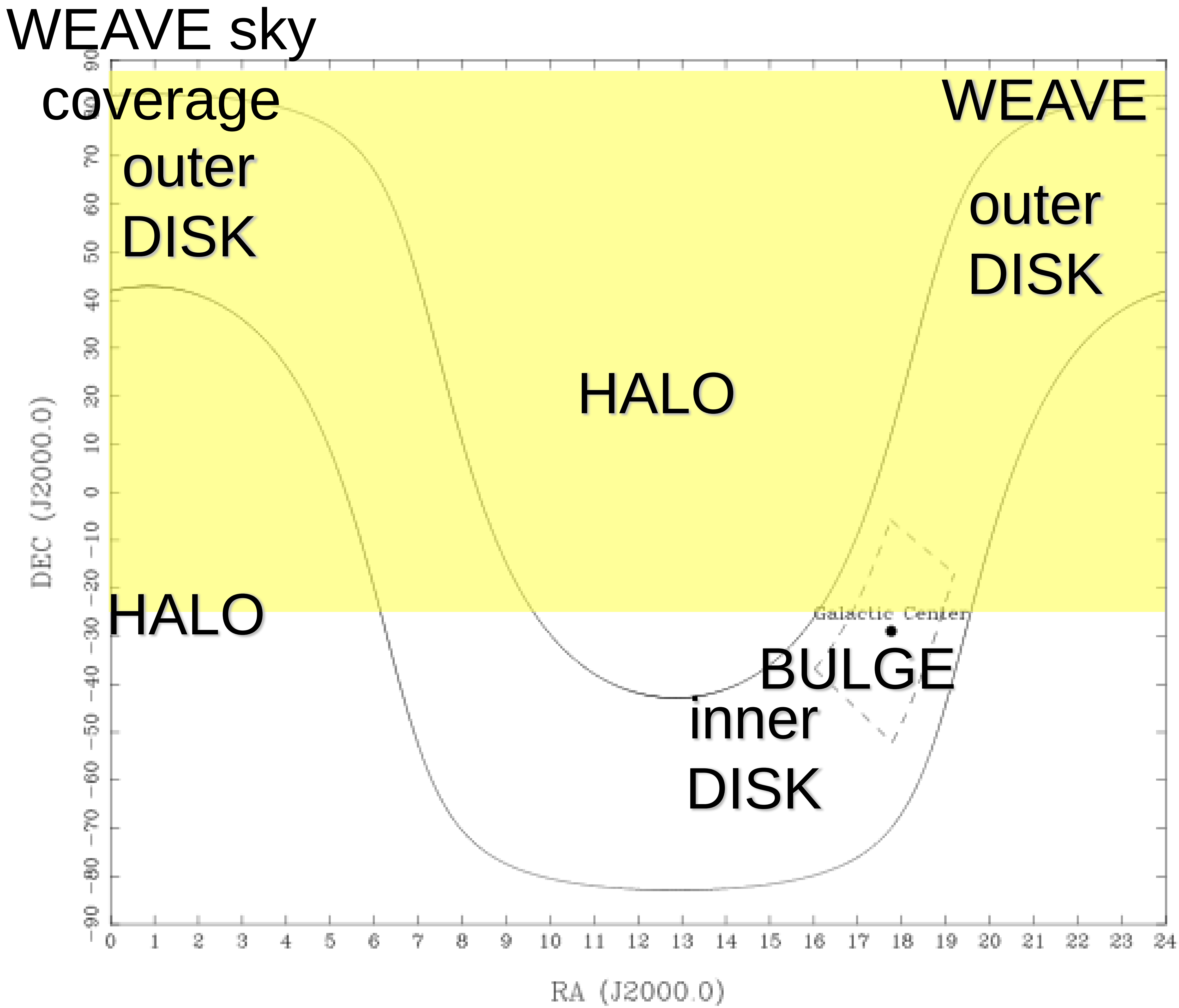
Nominal survey parameters

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…



Accuracy in Transverse Velocity
σ (V_T) (km/s)
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
Distance in pc
K5V
G
19.7
G0V
18.3
16.8
A0V
15.8
15.0
K5III
13.1
G
17.3
15.9
14.4
13.4
12.6
10.7
G < 12.5
A0V
F0V
F5V
G0V
K0V
K5V
K0III
K5III



WEAVE sky
coverage
outer
DISK
WEAVE
outer
DISK
HALO
HALO
Galactic Center
BULGE
inner
DISK
DEC (J2000.0)
RA (J2000.0)

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@WHT

Instrument consortium: UK/NL/ES/FR/IT

PI: Gavin Dalton (RAL, UK),

National CoPI: S. Trager (RUG, NL)

National CoPI: J.F. Lopez Aguerri (IAC, ES)

National CoPI: P. Bonifacio (GEPI, FR)

National CoPI: A. Vallenari (INAF-Padova, IT)

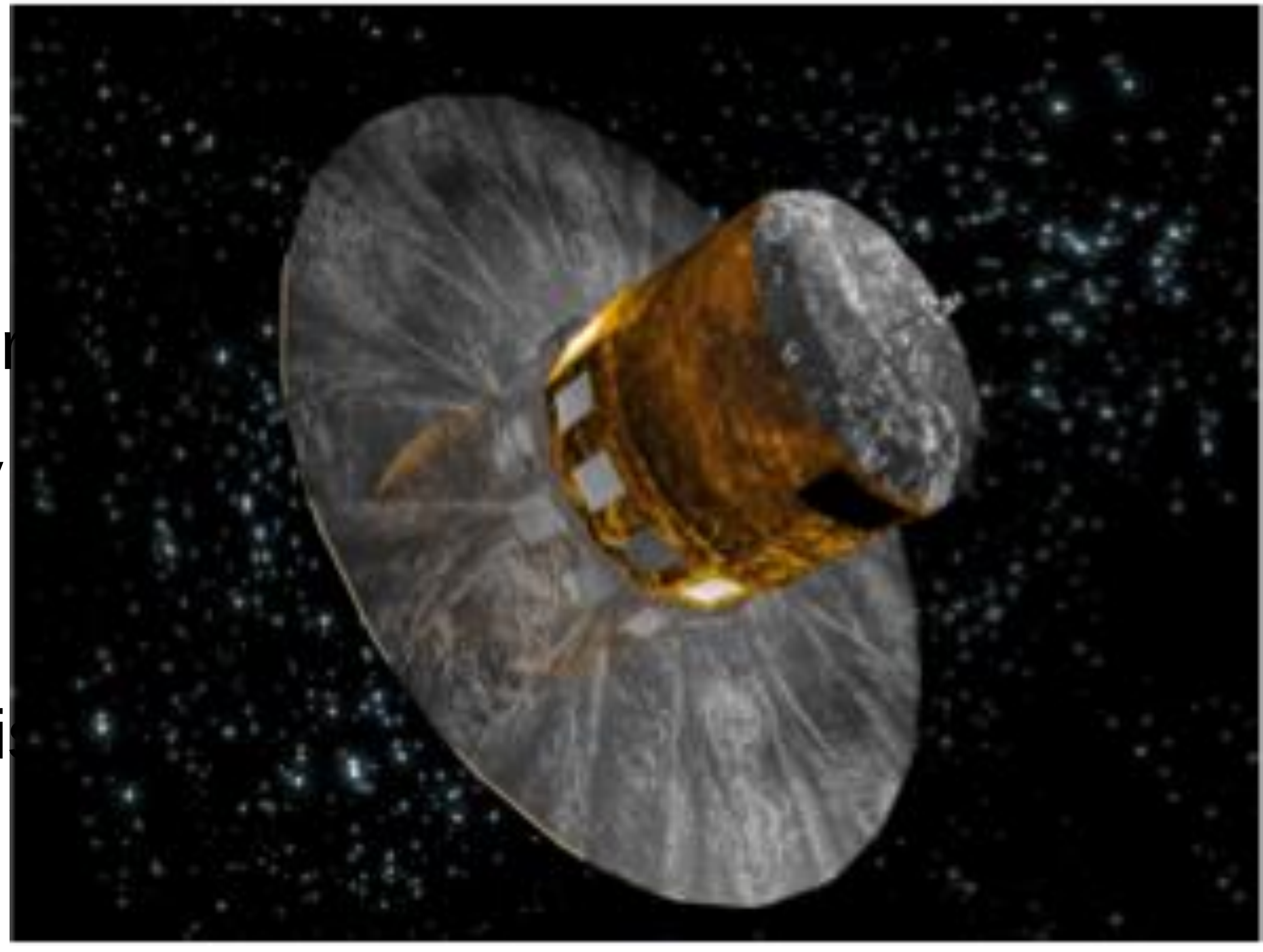
Background and progress

- Project started in 2010
- Developed from ING community meetings
- Stages:
  - Stage one: requirements capture (closed)
  - Stage two: preliminary design stage (closed)
  - Stage three: final design stage (current stage)
  - Stage four: MAIT and verification (Q1/15)
  - Stage five: closure (Q3/17)

- aiming for 1st light in 2017, surveys starting Q1/18
- Surveys 2018-2022+ at >80% of telescope time

New survey frontiers from new survey instruments

- Gaia: Astrometry at microarcsecond precision
  - The history of the Milky Way
- SKA Pathfinders:
  - LOFAR:
    - The history of star fo
    - Precision cosmology
  - Apertif:
    - HI at cosmological di



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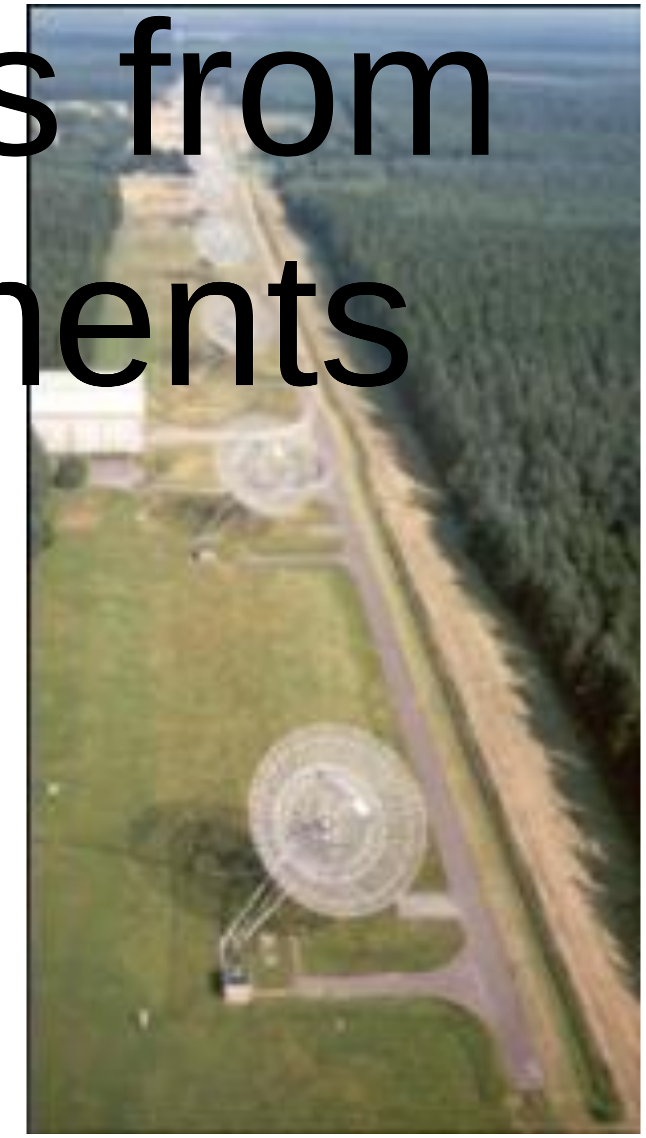

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Top level specifications

Field of view	2° diameter
Multiplex in MOS mode	1000 ±10%
Input aperture size	1.3” (goal 1.5”)
Operational wavelength range	370nm—950nm (goal 370nm—1100nm)
Spectral resolution, λ/dλ (full wavelength coverage)	5000 at band centre
Spectral resolution, λ/dλ (high resolution mode)	20000 at band centre
High resolution wavelength ranges	410—460nm & 600—678nm
Multiplex in small IFU mode	20—30
Small IFU (MIFU) field of view	7”x7” (goal 9”x9”)
MIFU spatial sampling	1.3” (MOS fibre core size)
Large IFU (LIFU) field of view	60” (goal 80”)
LIFU spatial sampling	2.6”
Overhead/1 hour observation	< 15 minutes (goal < 5 minutes)
System throughput (excluding telescope, detector and atmosphere)	>39% (blue), >23% (red) (low resolution)

WEAVE throughput

Wavelength
(nm)

More photons/object than VLT FLAMES, with 10x multiplex

Surveys: Xgal

- Galaxy clusters *(Alfonso Lopez Aguerri)*:
  - Evolution of dwarf galaxies in 50 clusters (Xray+SDSS) MOS +mIFU
  - Infall regions, in 10 superstructures (clust, groups, filaments) MOS
  - Cluster evolution z=0.2-0.5 (cluster cores) LIFU
- Galaxy evolution (z<1) *(Bianca Poggianti)*:
  - Stellar populations at intermediate redshifts (z~0.2-0.8) MOS
  - Apertif-based surveys (on hold) mIFU + IFU
- Galaxy evolution (z>1) & Cosmology *(Chris Simpson)*:
  - LOFAR follow-up of ultra deep fields. MOS
  - Possibly also a shallower wide field, piggy back on halo LR survey) –under discussion vs eBOSS/DESI etc. MOS
- Cosmology with QSOs *(Matt Pieri)*:

Complementing Gaia for Galactic Archaeology

Low resolution WEAVE survey ($\delta vr<2$ km/s) of 6-10.10^6 stars $15<V<20$

- Dynamical processes in the disc: resonances, radial migration, etc...
- Origin of the main galactic components: thick disc, thin disc, halo
- Galactic Halo: total mass, galactic potential, clumpiness (sub-structures, ...) and the dominant process for halo assembly

High resolution WEAVE survey (R~20,000) of 5.10^5 stars $12<V<17$ in the volume where Gaia offers the best precision (distances to <10%, ages):

- Chemical tagging/labelling : origin of the galactic discs (vertical et radial properties, chemodynamical properties, and their variation with time through precise age determinations)
- Halo substructures identified in chemical, link to globular cluster formation, halo-thick disc and halo-bulge transitions.
- Open clusters

Gaia follow-up surveys:

	log(N)	Area (deg^2)	R	Depth
Halo	6	1000	5000	V≤20
Disks	6.7	300	5000	V≤20
Chemical labeling	4.7 (disk) 5.7 (halo)	2000	20000	V≤17
Open clusters	4.7	150	20000	V≤17

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  - Stage five: closure (Q3/17)
- aiming for 1st light in 2017, surveys starting Q1/18
- Surveys 2018-2022+ at >80% of telescope time
- Timely with Gaia launch 12/2013, DR2 mid-2016 (first PPM and parallaxes) and DR3 2017. Target selection will use DR2+

Project Schedule

Total Project Costs

System ID	Effort (mw)	Manpower (k€)	Indirect (k€)	Equipment (k€)	Consumables (k€)	T & S (k€)	Total (k€)
PFC System	385.10	636.24	10.00	3062.00	15.50	45.00	3768.74
FP System	570.35	543.74	363.84	738.06	85.60	69.82	1801.07
Fibre System	360.00	1132.82	0.00	2040.00	4.00	18.50	3195.32
Spectrograph System	1095.80	2261.18	165.04	2129.69	48.00	201.60	4805.51
OCS	623.62	1226.11	0.00	148.15	6.00	48.00	1428.26
Core Processing System	382.00	542.98	158.00	15.20	19.40	40.00	775.58
WHT Support	160.30	305.32	0.00	161.93	6.50	16.78	490.54
Advanced Processing System	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WEAVE Archive System	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Business Case	366.00	523.80	5.20	14.00	59.00	26.00	628.00
Project Management	145.00	422.50	0.00	0.00	0.00	110.00	532.50
Documentation	16.70	35.26	0.00	0.00	0.00	0.00	35.26
Project Office	103.45	169.72	0.00	2.00	165.10	7.70	344.52
System Engineering	516.36	686.26	320.62	0.00	0.00	99.80	1106.68
Health and Safety	7.00	15.80	0.00	0.00	0.00	0.00	15.80
Totals	**4731.68**	**8501.74**	**1022.70**	**8311.03**	**409.10**	**683.20**	**18927.78**