

4MOST Science & Performance C. Chiappini

- Design Reference Surveys (DRSs)
- What is in our current DRS Mocks
- Simulation Results



Design Reference Surveys*

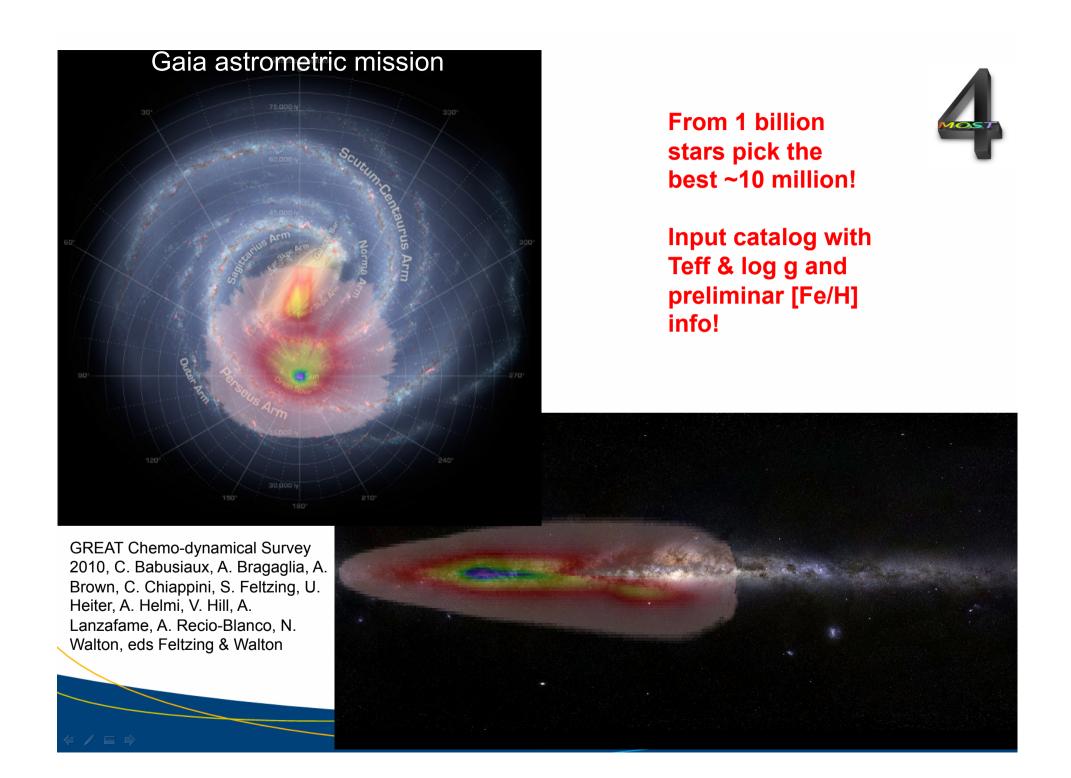


Doing Science in parallel!

- Science being designed for GOAL > 20 Million Objects
- Science Coordinator: C. Chiappini (deputy A. Schwope):

4MOST SWP represented at this meeting by names in red

- ➤ Halo A. Helmi; M. Irwin (LR), N. Christlieb (HR) (Korn & Ludwig)
- Disk+Bulge − A. Koch; I. Minchev (LR), E. Caffau (HR)
- ➤ AGN A. Merloni
- ➤ Galaxy Clusters H. Boehringer
- Redshift Survey & BAO Science F. Kitaura
 - * Purpose of the DRSs: science cases that constrain the design the most. We have made use of Galaxia model (Sharma et al. 2011 + Sharma priv. comm.)





Gaia + spectroscopic follow-up to achieve its full potential

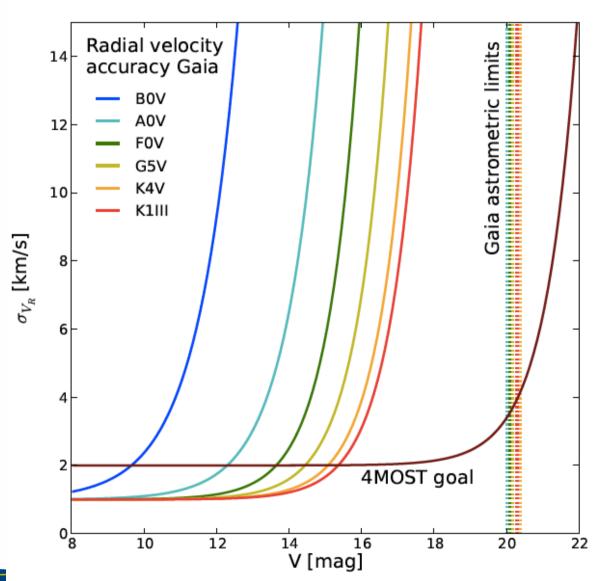


Gaia Launch 2013:

- •parallaxes and proper motions for ~1 billion stars to m_G <20 mag
- •spectra for radial velocities m_G<~15 mag

Gaia + 4MOST ~2019:

- Radial velocities 14< V <20
- Detailed Chemical Abundances ~14 < V < 16





Halo LR ~ 5000



Goal: to retrieve the history and dynamical evolution of our Galaxy by determining the mass, density, shape and substructure of the MW dark matter halo + the chemodynamical properties of its stars.

- ➤ Survey of ~10,000 deg² that will measure the radial velocities of halo stars (mostly K-giants) with a precision of 1-2 km/s as well as their metallicity distribution to 0.2 dex ([Fe/H]).
- FoM that requires a high completeness level *per field*, implying a high fraction of RGB stars with S/N > 10 at r = 19 for a survey of 10000 deg².

More details A. Korn talk



Halo HR ~ 20000



Goal: characterize the metallicity distribution function at low metallicities by increasing the number of objects known below [Fe/H] ~ -2.5 dex by a factor of 10; perform chemical tagging to identify substructures (streams etc.) associated with past merger events

- ➤ Observing all metal-poor giant stars brighter than V ~ 16, over 10000 deg² which will lead to a sample of 100,000 halo stars with HR spectra -> 100 times larger than any sample available to date.
- FoM that requires a minimum 50% of the total number of targets, with the specified quality per target.

Individual abundances of various species accessible in the 4MOST wavelength range at high resolution.



AIP

	[380; 45	0] nm domain	[580; 680] nm	
Parameter	Element	# lines	Element	# lines
		(dwarf/giant)	(dwarf/giant)	
$T_{ m eff}$	FeI	73/70	FeI	96/107
			$H\alpha$	1
$\log g$	Fe II	12/7	FeII	8/2
[\alpha/Fe]	Cai	8/8	Cai	14/14
	Mg I	2/1	MgI	1/2
	SiI	3/2	SiI	13/12
	Τiι	13/19	Tiı	8/27
	Ti II	10/26	TiII	0/1
[X/Fe]			LiI	1
	Naı	1/0	Nai	4/3
	A11	2/1	Alı	1/2
	ScI	1/0	ScI	1/1
	Sc II	3/4	ScII	2/6
	Vı	7/7	VI	9/27
	VII	1/1	VII	0/0
	CrI	6/4	CrI	1/2
	Cr II	1/1	CrII	0/0
	Mn I	19/13	MnI	2/3
	Mn II	0/1	MnI	0/3
	CoI	9/11	CoI	0/11
	NiI	3/3	NiI	18/19
	SrII	1/1	SrII	0/0
	YΠ	3/1	YII	1/1
	ZrII	2/2	ZrII	0/0
	BaII	1/1	BaII	2/2
	LaII	1/6	Laii	0/4
	NdII	2/5	NdII	1/0
	EuII	1/1	EuII	1/1
	CH	G-band		
	CN	X-A band		



More details A. Korn talk

(E. Caffau/N. Christlieb SWG)



Disk LR ~ 5000



- Goal: Gaia proper motions and parallaxes + 4MOST radial velocities & metallicities
- •Kinematical and chemical substructures -> map the position-metallicity-velocity space throught the disk
- •Velocity field for an unprecedentedly large disk area -> quantify the bar and spiral structure dynamical parameters
- Extended Solar vicinity: To study the changes of structure in velocity space of spatially localized samples (the U-V plane): we require σ(distance) < 200 pc and accuracy in U, V, W of ~2-5 km/s -> obtain accurate radial velocities for F/G dwarfs with 14 < V < 16.5 (d < 2kpc) Requirement: millions of targets!
- ➤ Extended disk sample: a) dynamical sample (SNR~10 but large number of targets) + b) chemo-dynamical sample (SNR >~30 but smaller number of targets) using giants and dwarfs as tracers Requirement: millions of targets!

More details I. Minchev's talk





> FoM 8.6 x 10⁶ targets (2.6 ESN + ~5.5 disk + 0.5 bulge)

- ➤ We **must** understand *secular processes combined with accretion/merger & can only calibrate them from million-star surveys (modified from Bland-Hawthorn)*
- ▶ Obtaining individual abundances from low-resolution spectra by taking advantage of the combination of R ~ 5000 (similar to RAVE) and a very large spectral range (as in SDSS/SEGUE).
 See Boeche's talk



Disk HR ~ 20000



Goal: Disk chemo-dynamics (Fe, α- and neutron-capture elements): trace abundance gradients with different chemical elements as well as gradients in the abundance ratios. Ages for brighter stars.

>~14 < V < 16; criterion is complementary to other high-resolution surveys such as HERMES (V< 14) and also complements the Gaia's chemical information that will be available only for V < 12 - 13;

➤ Giants and dwarfs to cover large bins of (R, Z) in the Galaxy -> obtain [X/Fe] vs [Fe/H]; X = alphas, iron peak, n-capture elements ...

FoM: HR disk – N_{min} ~ 1M, N_{goal} ~1.5M on disk
 + High latitude sample ~0.5-1M (interface thick/halo)
 With quality requirements

More details I. Minchev's talk



Bulge LR & HR



➤ Bulge sample: probe a large number of giants, in particular targeting the red-clump region in the HR-diagram. Search for multi-components & signatures of First Stars.

4MOST can deliver large bulge samples. Currently larger one is the ARGOS (Freeman & Collab.) sample (~28 000 objects) and FLAMES samples (Hill et al. 2011, Uttenthaler et al. 2012)

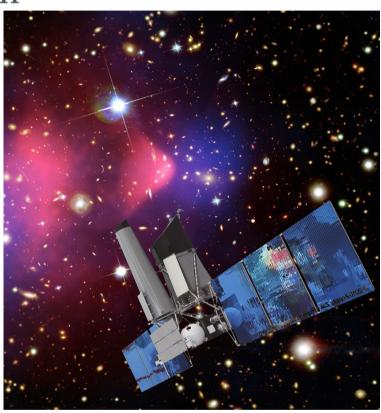
- LR: Find the most metal-poor stars in the Bulge new candidates with APOGEE & ARGOS, but many more expected with 4MOST and APOGEE-South (AS3)
 -> 300 000 true bulge stars (~700 000 surveyed)
- HR: Full chemical analysis + 8m follow-up First Stars abundance pattern?
 n-capture elements is key (Chiappini et al. Nature 2011)

-> 120 000 min (goal 170 000)



eRosita Follow - up





- AGNs
- Cluster of Galaxies
- MW Compact objects



Cluster of Galaxies



Goal: 4MOST will provide redshifts for most of the eROSITA detected clusters and improve the cosmological constraints from the survey by about an order of magnitude compared to having only photometric redshifts.

- ≥ 2 3 Million possible target galaxies will be available in the survey area. We expect to reach our goals already with a fraction of targeted galaxies of 30 50%. targets, with the specified quality per target (the minimum fiber distance constraint)
- FoM: We define a positive cluster detection if we were able to identify 4 cluster members (BCG plus 3 further members) for clusters below redshift 0.9 and 1 member galaxy for clusters above z=0.9.

H. Boehringer's talk





Goal: Follow-up all point-like extragalactic X-ray sources (mostly AGN) detected over an area of (at least) ~13,000 deg². The Xray flux limits expected to be reached by eROSITA are well matched by the spectroscopic capabilities of a 4-meter class telescope

- ➤ Reach completeness levels higher than 90% in both soft (0.5-2 keV) and hard (2-8 keV) X-ray bands.
- >A wide wavelength coverage (380 1000 nm) will allow us to continuously map broad lines in the very wide redshift range 0< z <5, thanks to the different emission lines (Hβ, MgII and CIV) redshifted into the 4MOST observed wavelength window.
- ➤ FoM: Function of completeness in number of targets, mag bin and redshift bin

A. Merloni's talk



Galaxy Redshifts & BAO

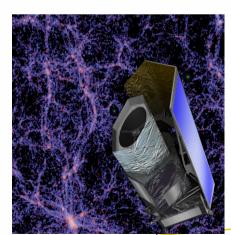


Goal: Trace a *large* number of objects at different redshifts from z=0 to about 1.5. This will permit us to study the cosmic galaxy network, perform BAO reconstructions and deepen our understanding of structure formation.

➤To perform an accurate estimation of the BAO signal we require homogeneous sky coverage . We expect about 3.8 Million BCG-like objects with M>~ 10^{13} M $_{\odot}$ in the surveyed volume. Additionally, we have also considered the counterpart of less massive tracers to fill the volume with ~7.6 Million objects.

➤ FoM: Completeness

F. Kitaura's talk



Euclid





Doing Science in Parallel

Finding best compromise between FoV, number of fibers, ratio HR/LR

Need Survey Simulator (next talk T. Dwelly)

New "systems concept":

Echidna + HR/LR = 1/3 + FoV ~ 4 deg²





Mocks & "Figures of Merit"

how to condense a whole science case in one number without avoiding over-simplifications?

4MOST Science Diversity -> Diversity in exposure times



Mocks Overview

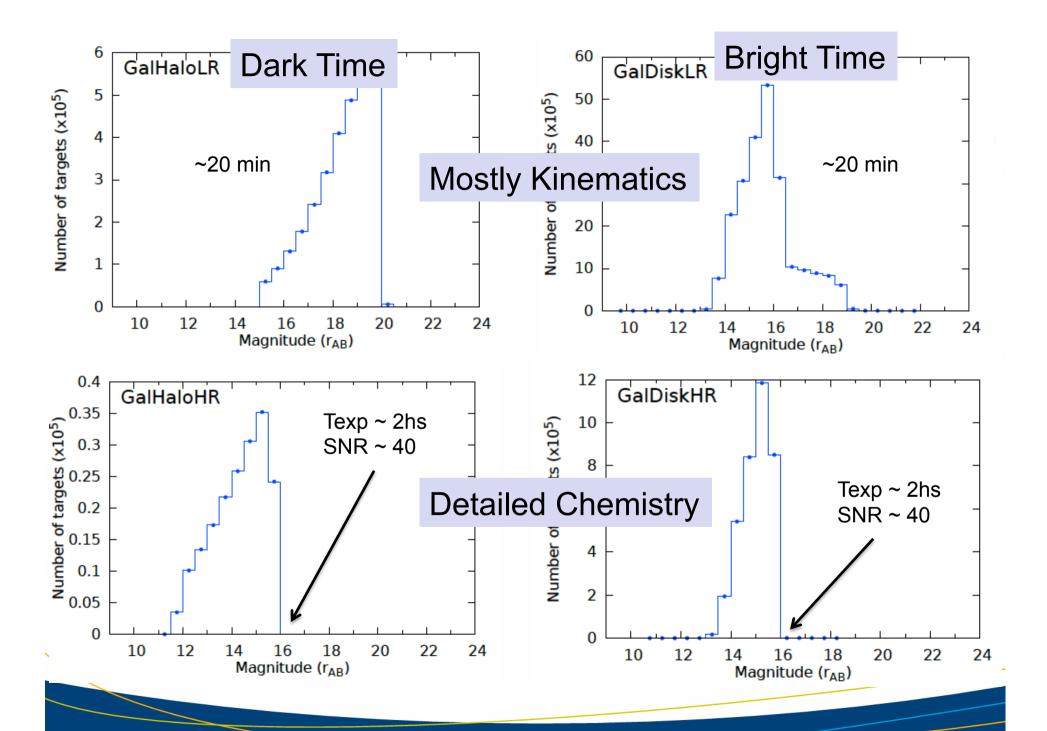


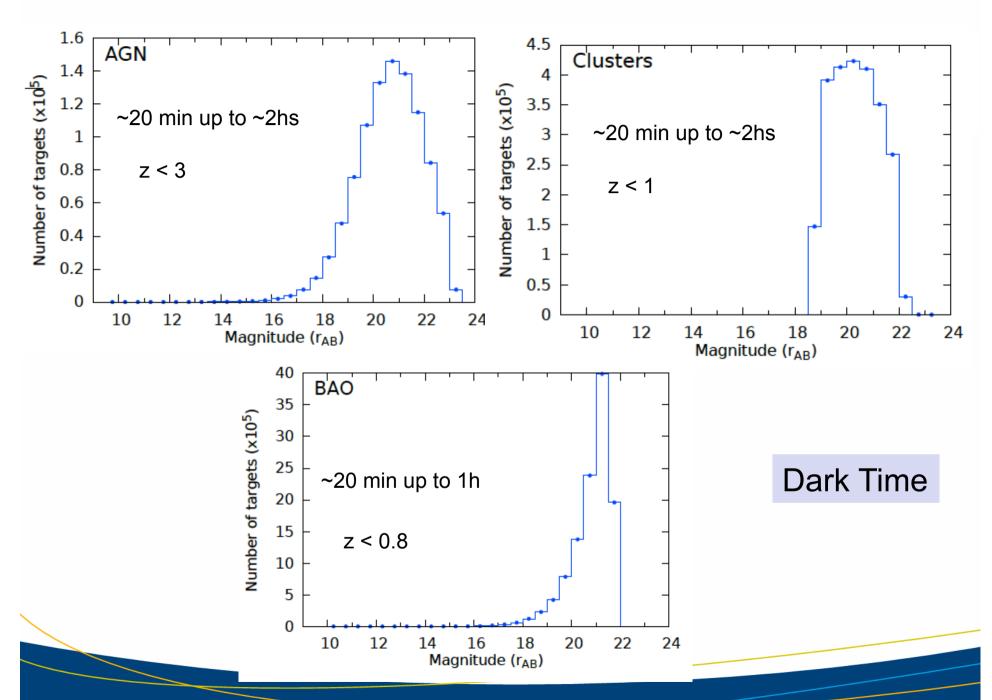
(-70 < DEC < + 20) 4FS, TB and DW, 09.03.2012

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•	DRS	area	Objects	den	sities	
•		[deg ²]	•	[deg ²]	[3 deg ²]	[4.2 deg ²]
•	AGN BAO GalHaloLR Clusters	26691 20397 18362 25177	1.187.146 11.383.002 3.065.078 2.945.325	44.5 558.1 166.9 117.0	133.4 1674.2 500.8 351.0	~190 ~2340 ~700 ~490
	GalDiskLR	26715	23.081.666	864.0	2592.0	~3630
	GalHaloHR GalDiskHR	14423 26692	182.951 2.215.660	12.7 83.0	38.1 249.0	~50 ~350
			HR (b>30)	~100	~300	~420

No room for back of the envelope calculations









Key point: Survey Strategy matters*

Dwelly's talk

*Results Round 5b + Round 5



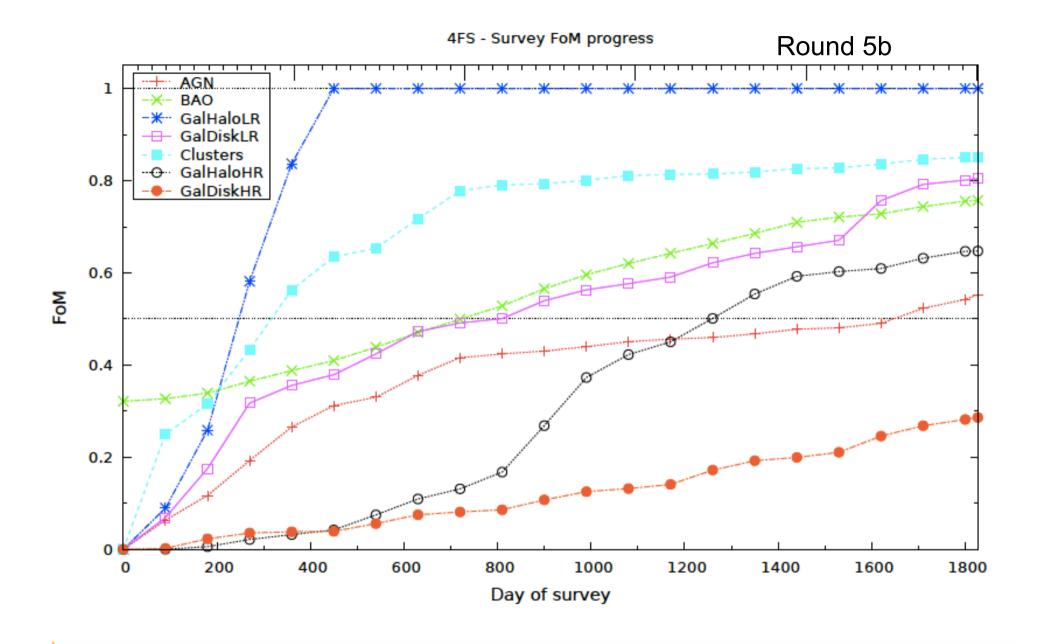


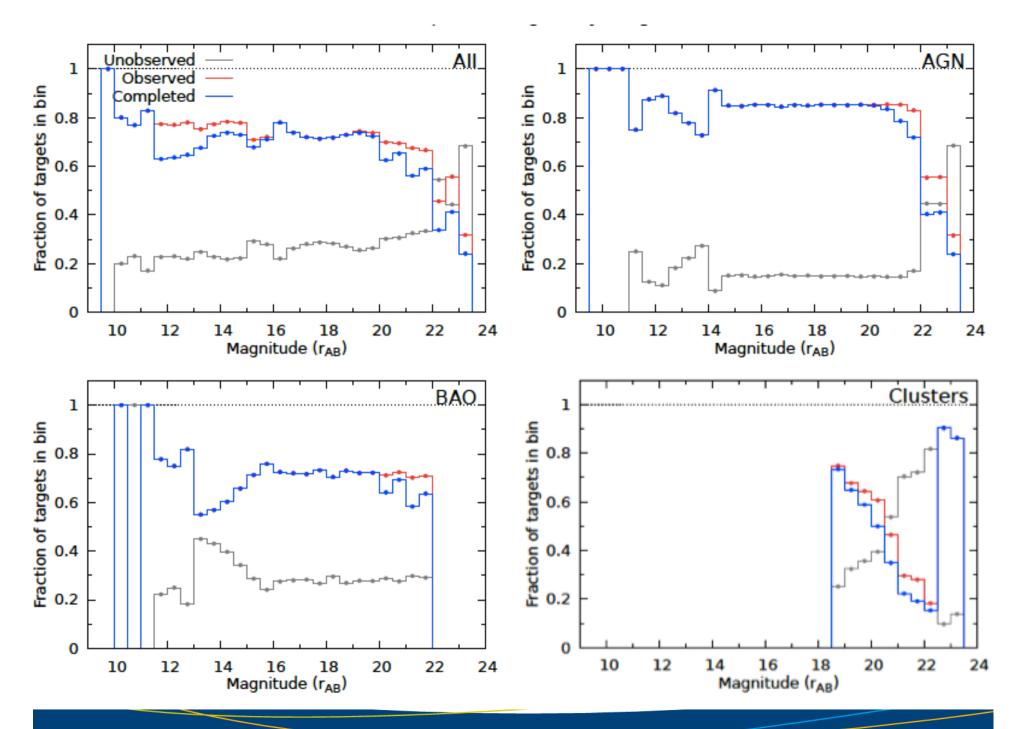
Round 5b*

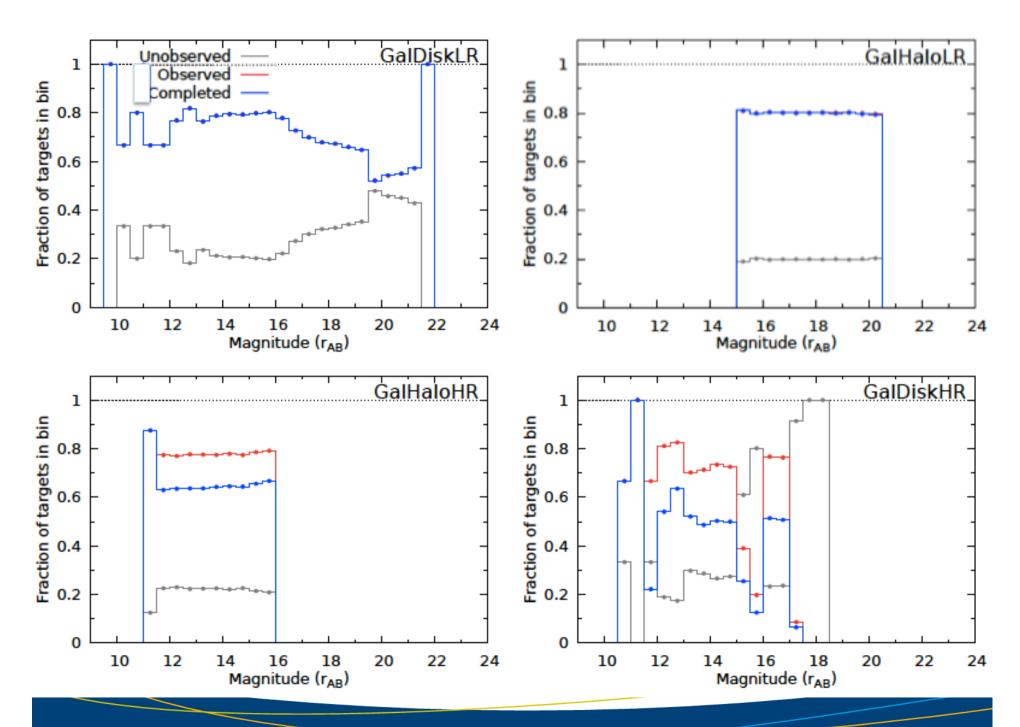
Loss due to sky reduction

Case	Nobs	Nsucc	Fsucc	Ffail	Nobs,red	Nsucc,red
AGN LR	775986	729310	0.94	0.06	0.9	0.9
BAO LR	8110110	7322074	0.9	0.1	0.85	0.9
Halo LR	2458023	2455358	1	0	0.85	0.85
Disk LR	17881260	17879892	1	0	0.99	0.99
Clusters LR	1270737	1092176	0.86	0.14	0.91	0.92
Halo HR	141622	117630	0.83	0.17	0.9	0.99
Disk HR	1789817	1204565	0.67	0.33	0.96	1.36
All	32427555	30801005	0.95	0.05	0.93	0.96

*(6 x 20 min, reduced sky, no dither), 1600 LR, 800 HR, FoV ~4 deg²





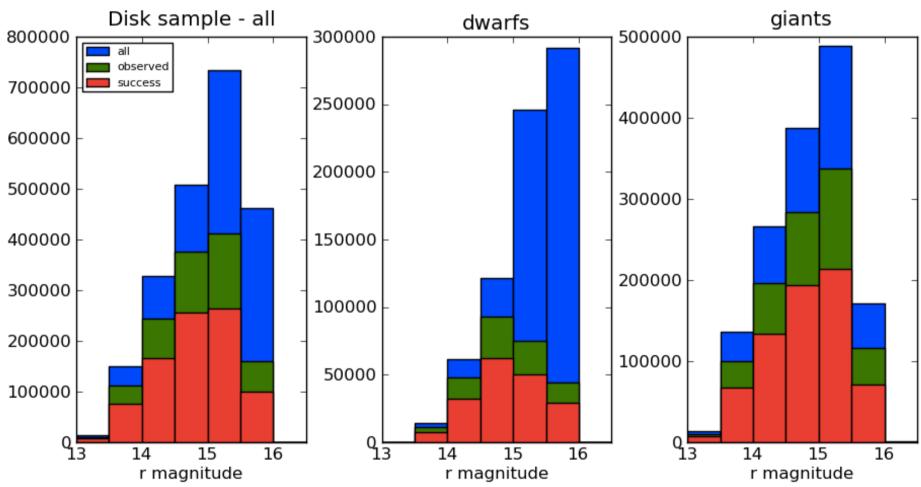




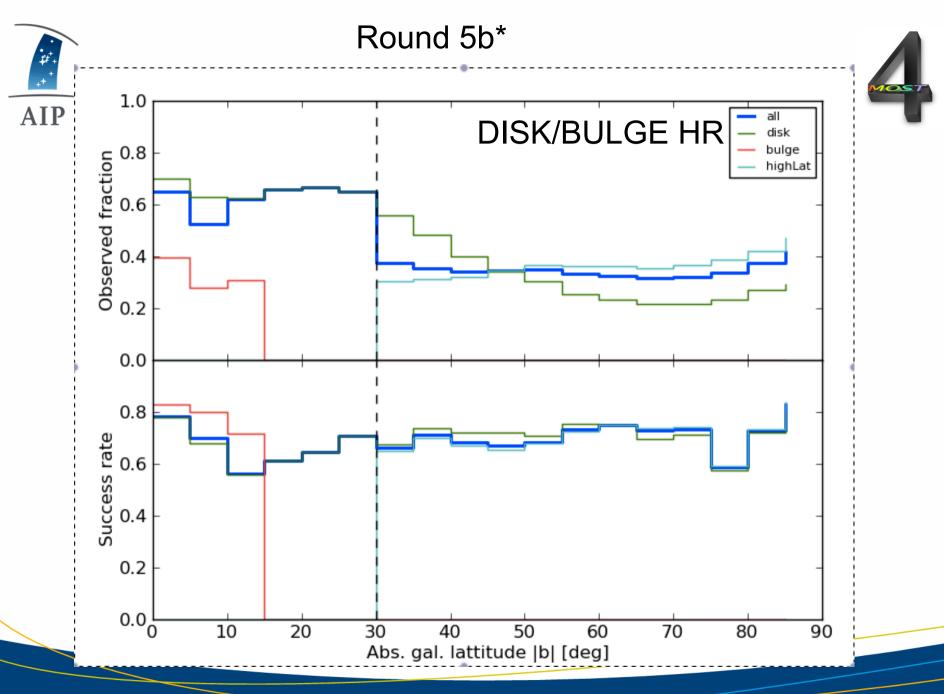
DISK HR

Round 5b*





(figure by T. Piffl- AIP)





Overview Round 5 - Clusters



Clusters	Z_bin	N_clust_obs	N_clus_succ
	0.0 - 0.2	28 938	27 620
	0.2 - 0.4	27 014	25 925
	0.4 - 0.6	11 872	11 245
	0.6 - 0.8	4 035	3 733
	0.8 - 1.0	1 306	1 109
	1.0 – 1.2	359	319
Total			69 951

N_gal_succes = 1M



AGN



AGN	Zbin	Obs	Succ	Magbin	Obs	Succ
	0	511 003	409 850	16-17	5 706	5147
	1	369 694	293 135	17-18	22 061	19 950
	2	78 043	62 886	18-19	74 764	67 843
	3	6 389	4 902	19-20	183 016	165 810
	4	586	528	20-21	279 033	252 216
				21-22	253 510	213 968
				22-23	138 187	43 240

 $Ntot_obs = 750 \ 291 - FoM_t = 0.6$



Diversity of science cases





Diversity of exposure times



Strong requirements on:

- > Keeping overheads to a minimum (CCDs readout & fiber positioning)
 - ➤ Repositioning fibers each 20min while reading CCDs
 - > Throughput



But also opens opportunity for many other science cases (sub-catalogs of ~1000 – 10 000 Targets



What will 4MOST do that others cannot?



- All hemisphere coverage (with WEAVE, full sky)
- Permanent on telescope (enables time domain spectroscopy)
- Largest Gaia follow-up machine (> 10 Million Targets in LR and 2 Million in HR) -> only way to really understand secular processes in disk formation & map the chemo-dynamics of MW components
- Southern Location: Best Bulge & Inner-disk & LMC/SMC follow-ups
- Possibility to build large galaxy redshift catalog > 10 Million!





All this work done in 14 months!

Room for improvements

Room for many extra science cases

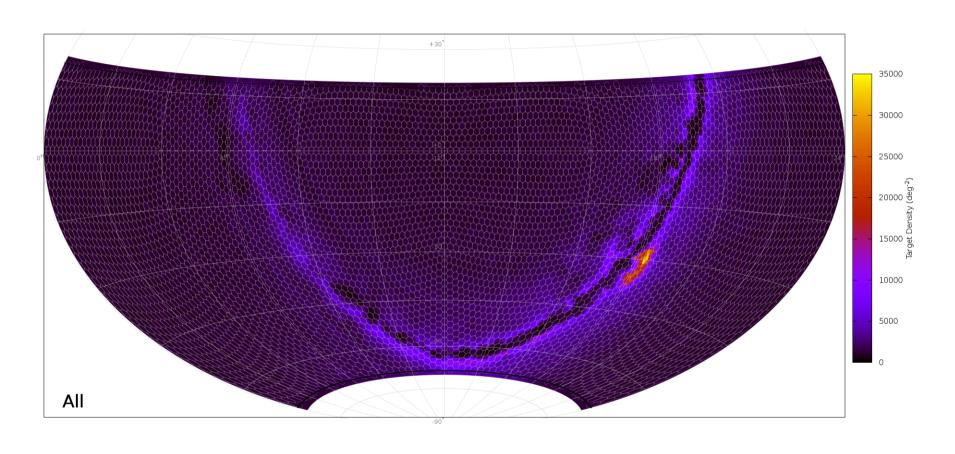


Extras



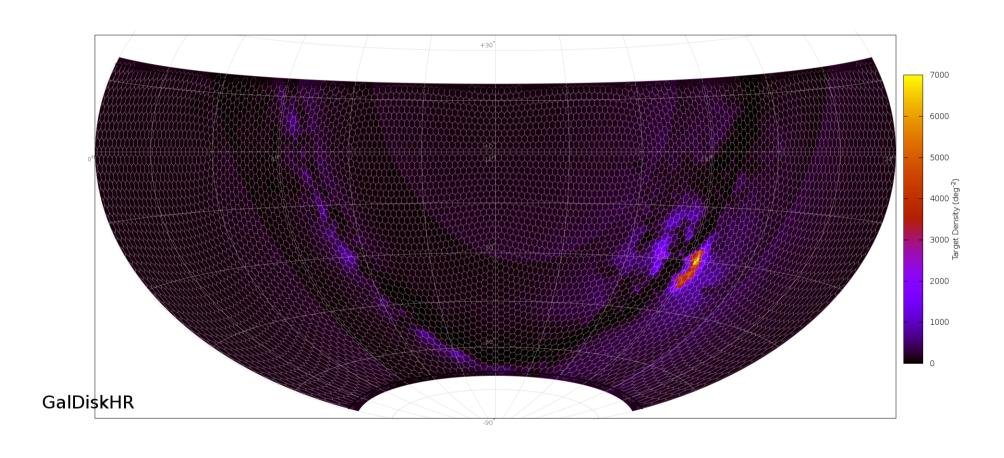








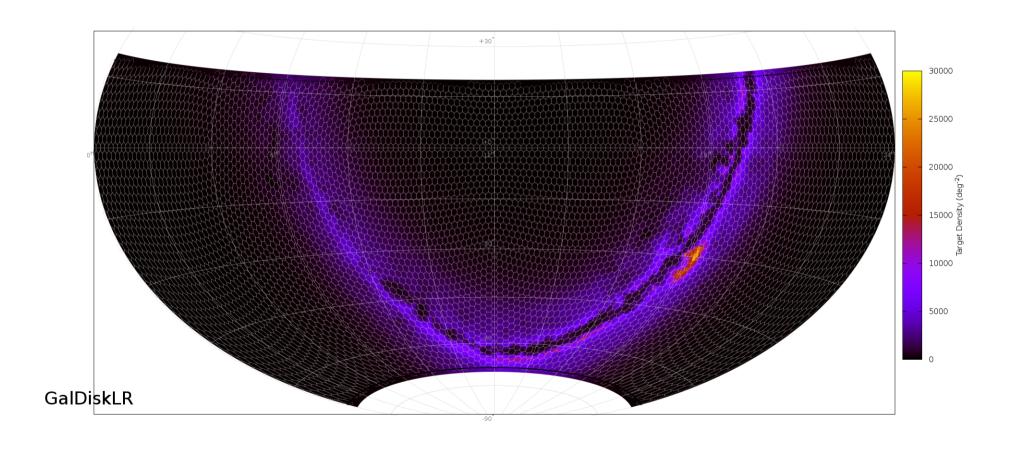








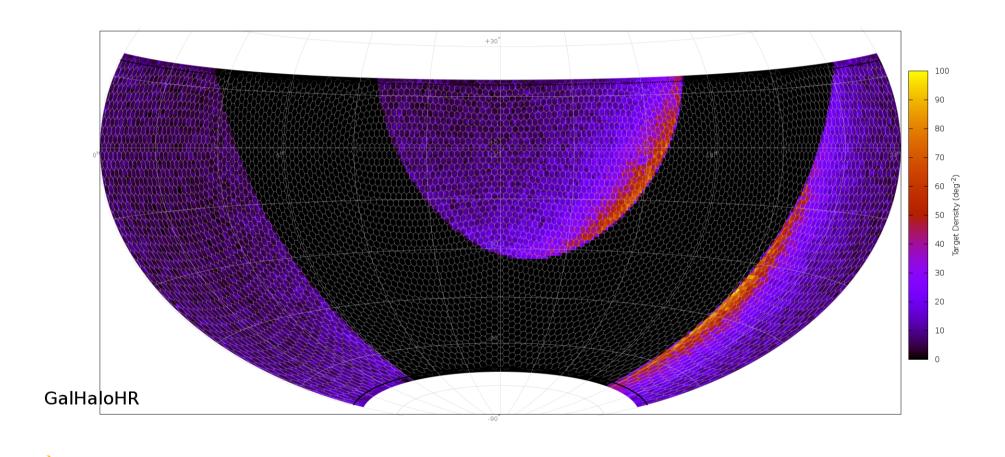








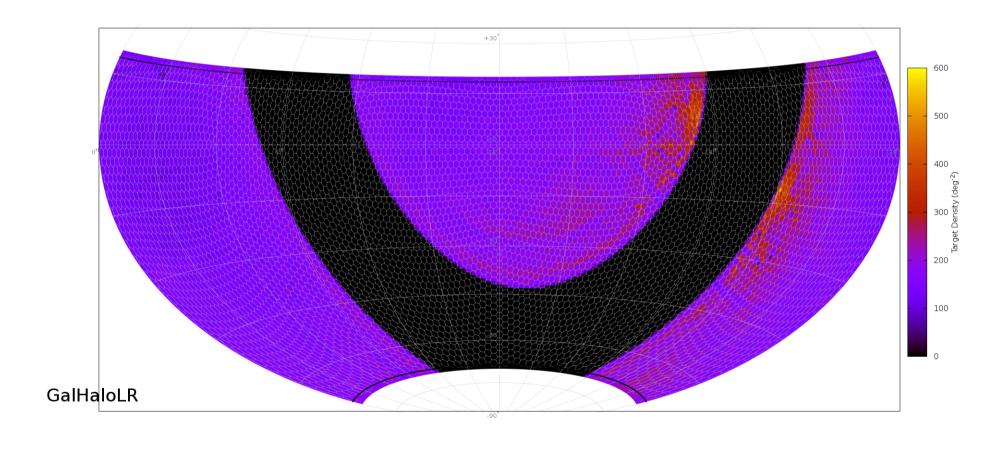








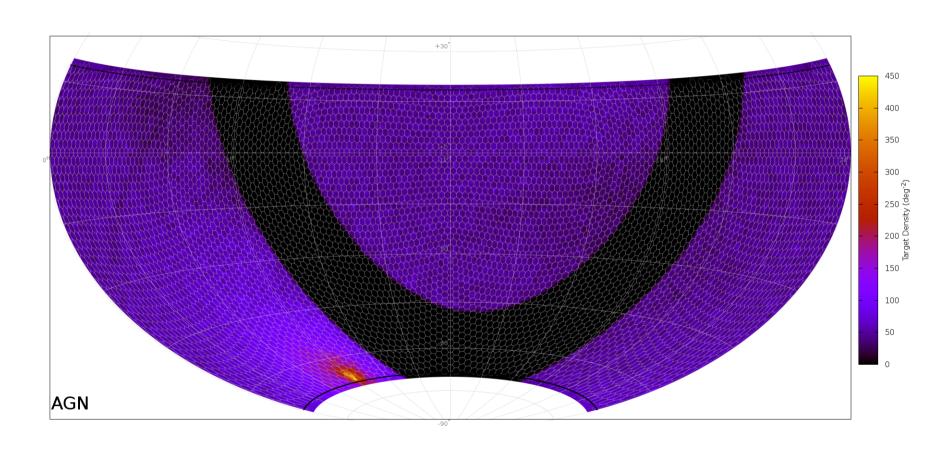






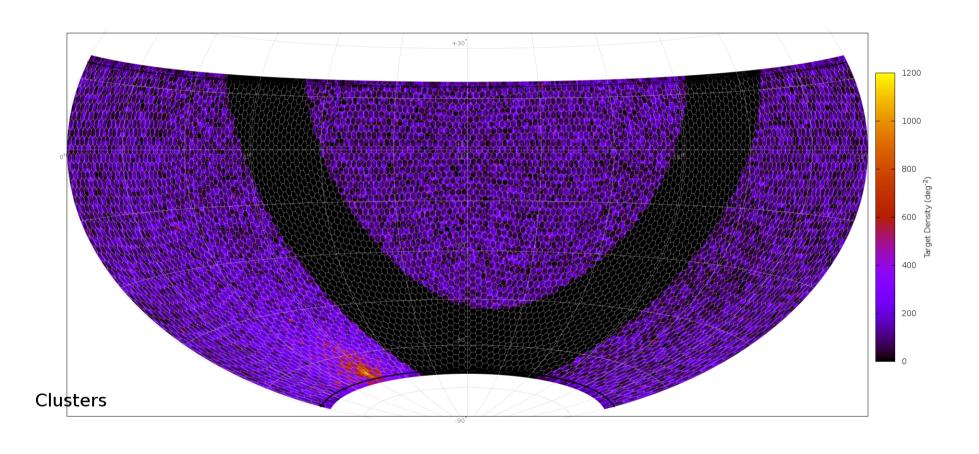










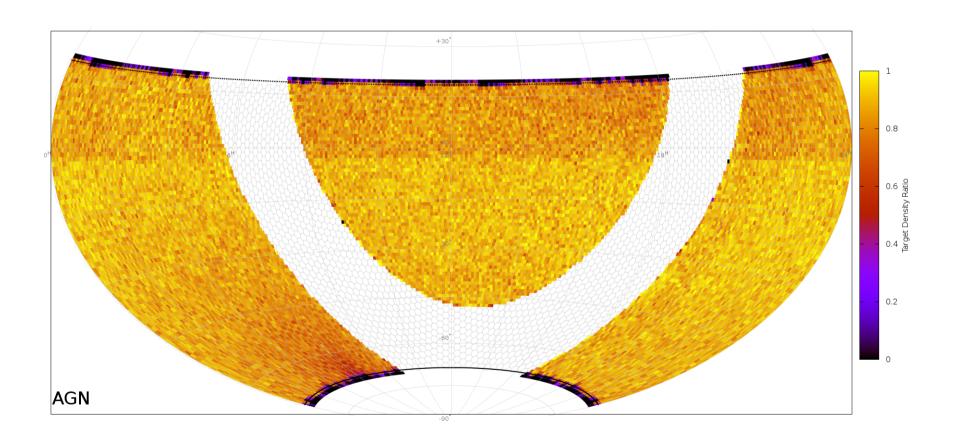


Science requirement	HR halo	HR disk/ bulge	LR halo	LR disk/ bulge	Galaxy Cluster	AGN	ВАО
Mag Range	13.5-15.5	15.5-15.5	15-20	14-18 (14-20)	17-22	16-22.5 (16-23)	16-23
Mean surface density [targets/deg²]	10-30 - with contam.	50-800	180 (x 2 if contam.)	500 - 3000	200	90- 280	1500
Total # targets (10 ⁶) Required (goal)	0.1 (0.2)	1.0 (1.5) d 0.12 (0.17)b 0.5 (1.1) hl	1.8 for 10k deg ² 3.1 for 17k deg ²	8.6 (13.8)	2 (3)	1.5	10 (15)
Total area of sky required (goal) [deg ²]	>10 000	15 000 (20 000)	10 000 (17 000)	16 000 (26 000)	15 000 (20 000)	13 000 (15 000)	10 000 (15 000)
Sky density [targets/deg ²]	18 [90%]	50-100 [90-30%]	160 [90%]	50-1000	100 (200) [>90%]	80-250 [>90%]	1000 [>50%]
Survey area (I, b) [-70 <dec +20]<="" <="" td=""><td> b > 30</td><td>All sky</td><td> b > 20</td><td>All sky</td><td> b > 15</td><td> b > 20 (b > 15)</td><td> b > 25</td></dec>	b > 30	All sky	b > 20	All sky	b > 15	b > 20 (b > 15)	b > 25
Wavelength range	395-456.5 587-673	395-456.5 587-673	390-450 480-550 835-885	390-670 845-880	420-950 (390-1000	400-950 (390-1000)	420-950 (390-10 ³)
Resolution	> 18 000	> 18 000	5000 (7000)	5000 (7000)	500 (>3000) @500nm	3000 (5000) @ 400-950	3000
S/N per Angstrom	150 [V=16]	140 [V=16]	10 [r=19]	10 [V >18] 30 [V <18]	4 (5) [r=20.5]	5 [r=21.5]	10 [r=20.5]



Round 5b 6 x 20 min all b







Round 5b 6 x 20 min all b



