SDSS-IV
&
SPIDERS

SPectroscopic IDentification of EROSITA Sources

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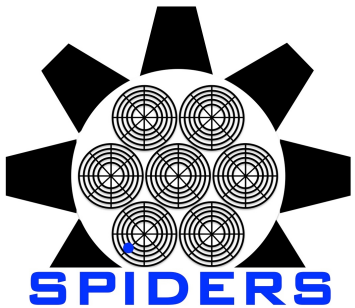
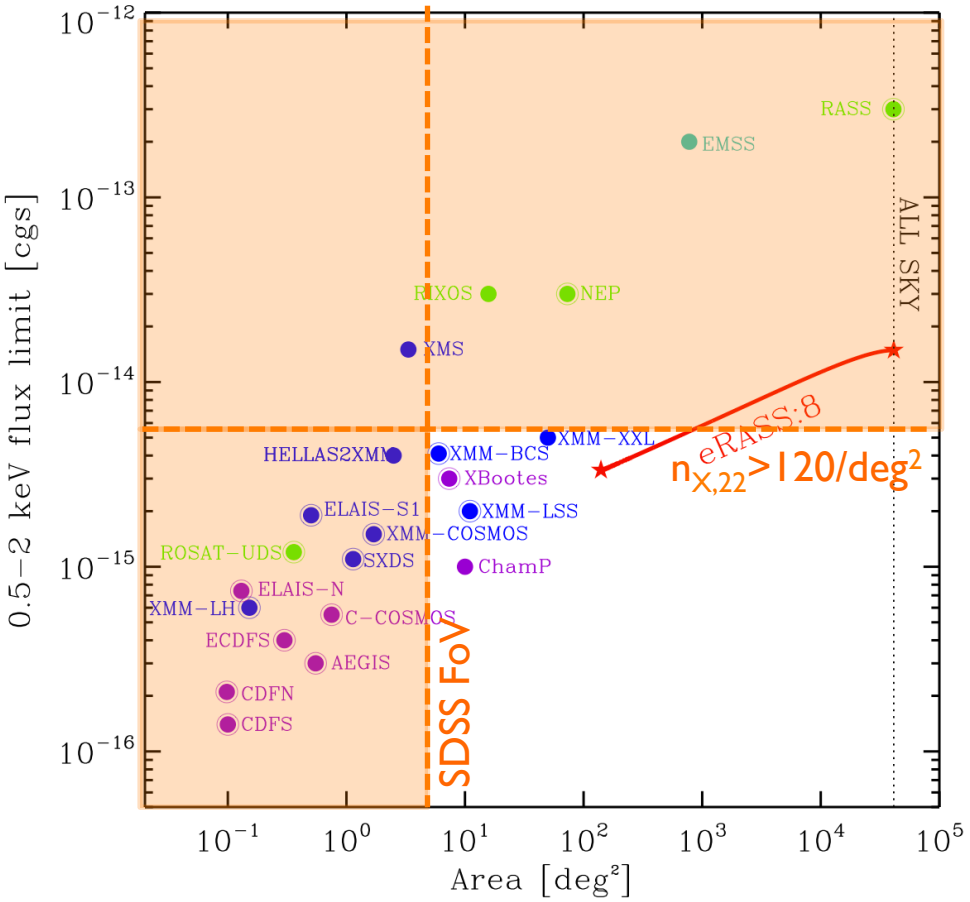
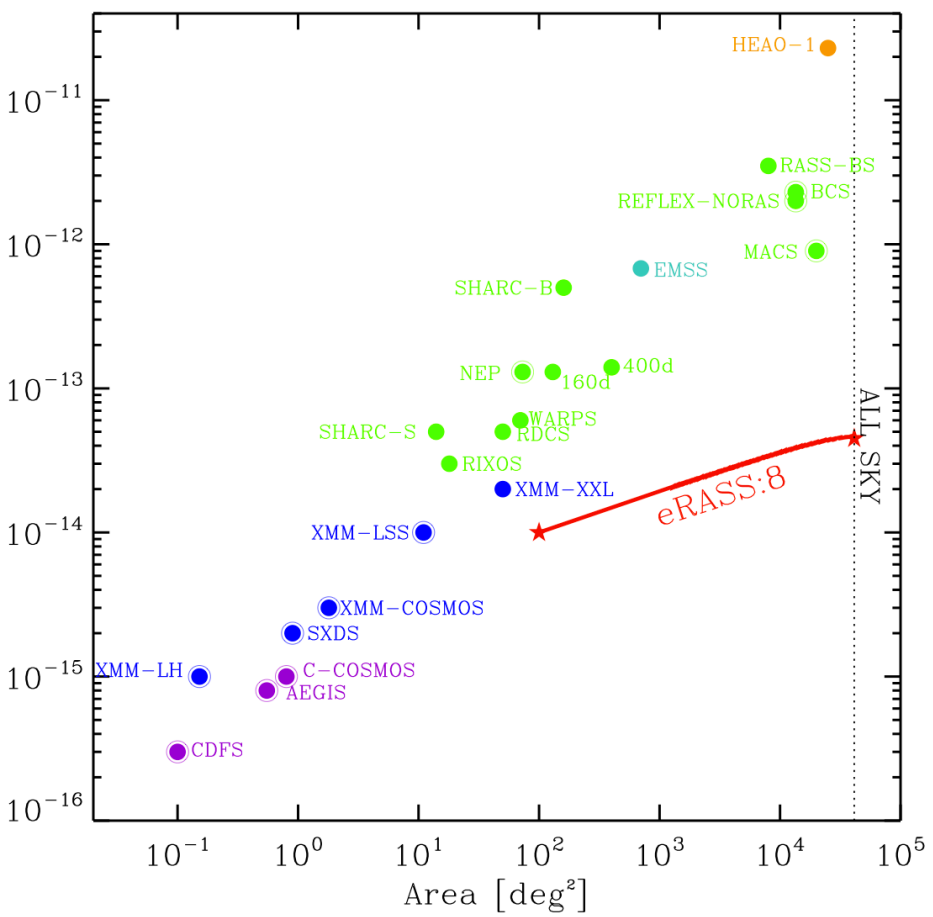
N. Clerc, T. Dwelly, A. Georgakakis, M.-L. Menzel, K. Nandra (co-PI), J. Ridl, M. Salvato & the SPIDERS team



eROSITA surveys in context



All sky: 10^{-14} (0.5-2 keV)
2×10^{-13} (2-10 keV) [erg/cm^2/s]

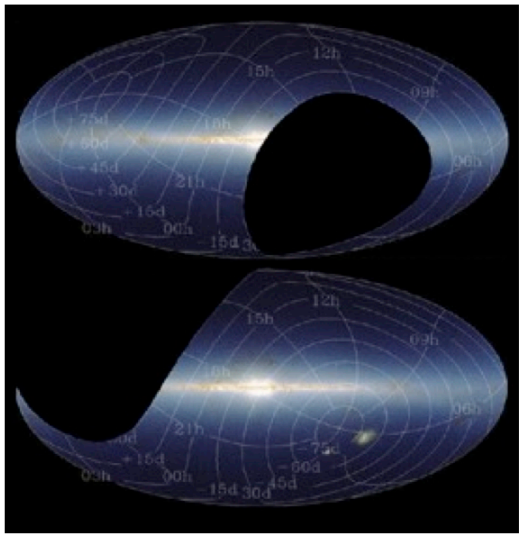


All sky: 3.4 x 10^{-14} (0.5-2 keV)

Merloni et al. 2012

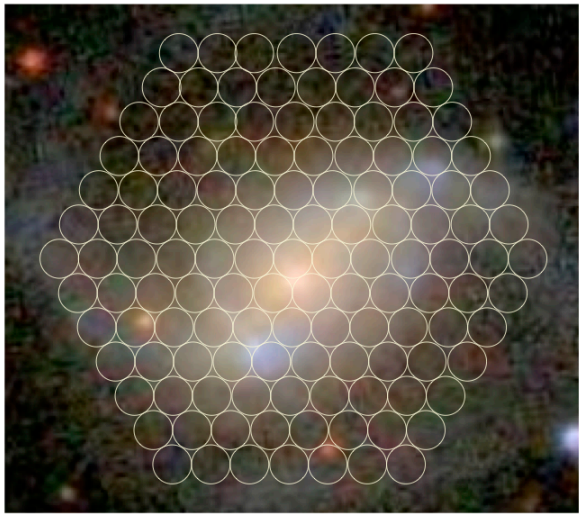
SDSS-IV surveys (2014 through 2020)

APOGEE-2



Maps hundreds of thousands of individual stars in the Milky Way.

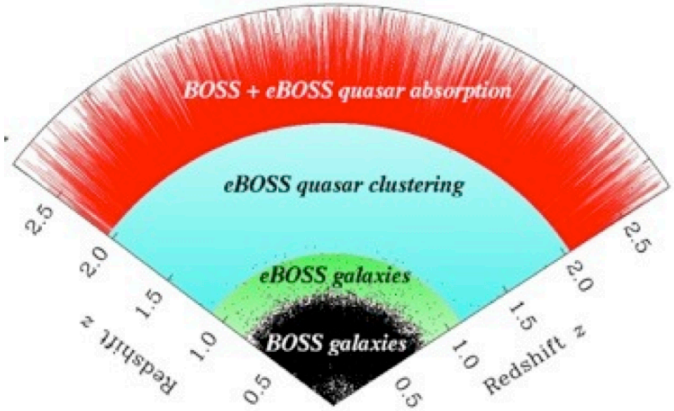
MaNGA



Maps 10,000 nearby galaxies.

galaxy evolution & dark matter

eBOSS, TDSS, SPIDERS



Maps the Universe of galaxies and quasars. Especially quasars.

dark energy & cosmology

Fund-raising

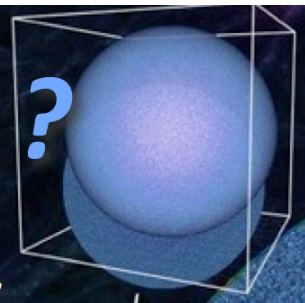
- Full six-year survey budget is approximately ~ $58M
- Reached a milestone in May, funding a four-year survey (with no second spectrograph).
- Around $27M in institutional commitments already, with $7M more in advanced drafts.
- Sloan Foundation has awarded $10M (first large increment released after May milestone)
- Additional Sloan Foundation grant proposal for the second spectrograph just submitted; to be decided by November.
- DOE proposal pending
- NSF Mid-Scale Innovation Program proposal *not* currently selected for funding.
- Success with DOE would help secure fifth year.
- Next major goal is final year.

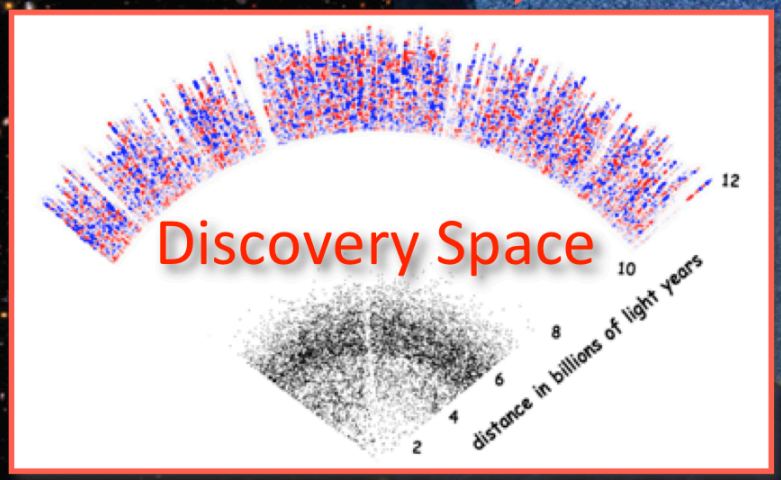
Detailed information was reported to the Advisory Council in May 2014; consult your institution's AC rep or myself for specific questions.

Why eBOSS ?

Understanding our Cosmological world model:

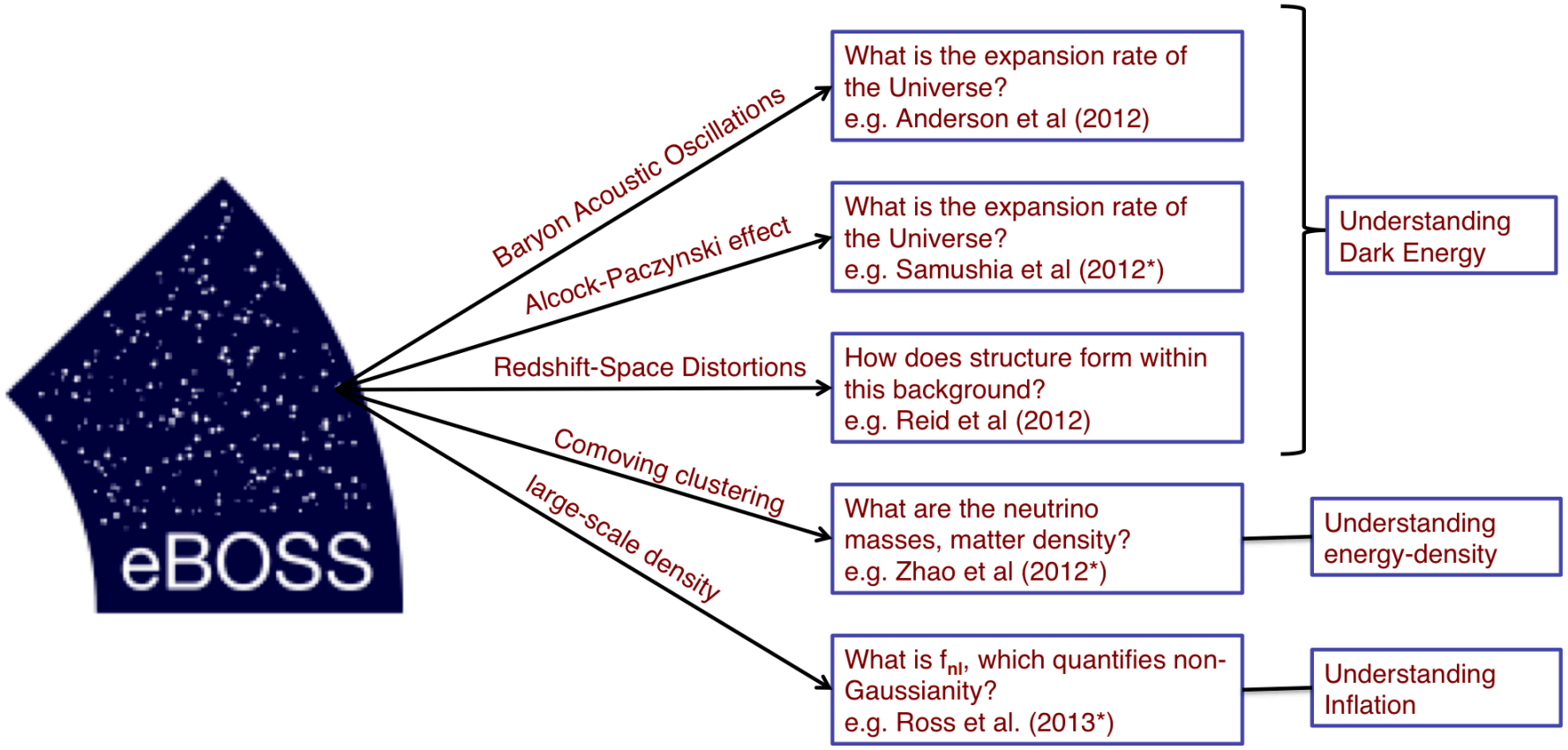
- *Are we leaving in a Lambda-CDM Universe?*
- *What is Dark Energy?*
- *Do we understand Gravitation on Large Scales? link with DM?*
- *Neutrino Masses?*
- *Non-Gaussianities and inflationary models?*





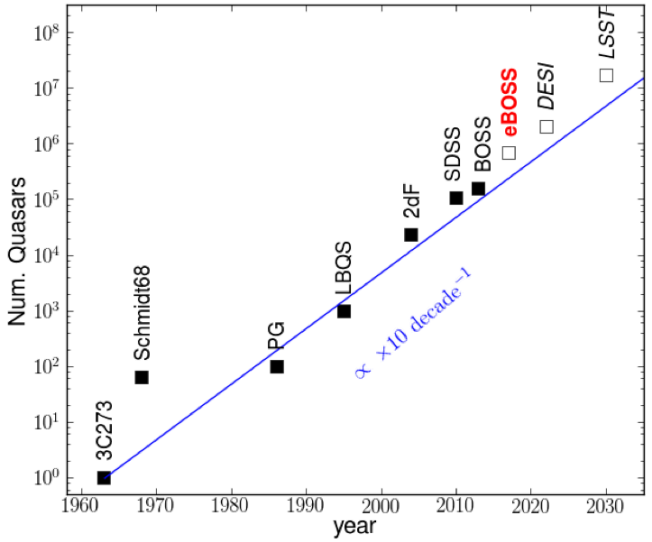
eBOSS

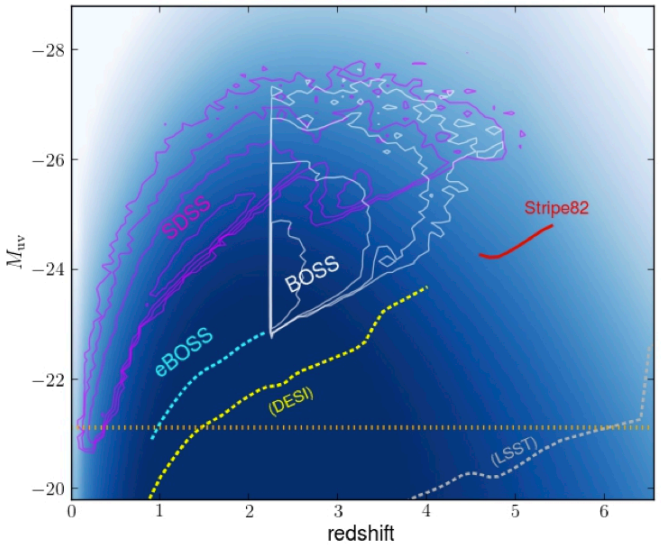
Science Driver = Cosmology



2nd Science Driver = Quasars

- Quasar luminosity function
  - extend DR7 measurements to fainter quasars
- Luminosity dependence of bias and HOD
  - auto-correlation of quasars
  - cross-correlation with galaxy samples
- Rich data set of quasar spectra
  - BH virial mass estimates
  - Composite spectra
- Synergistic surveys: TDSS & SPIDERS



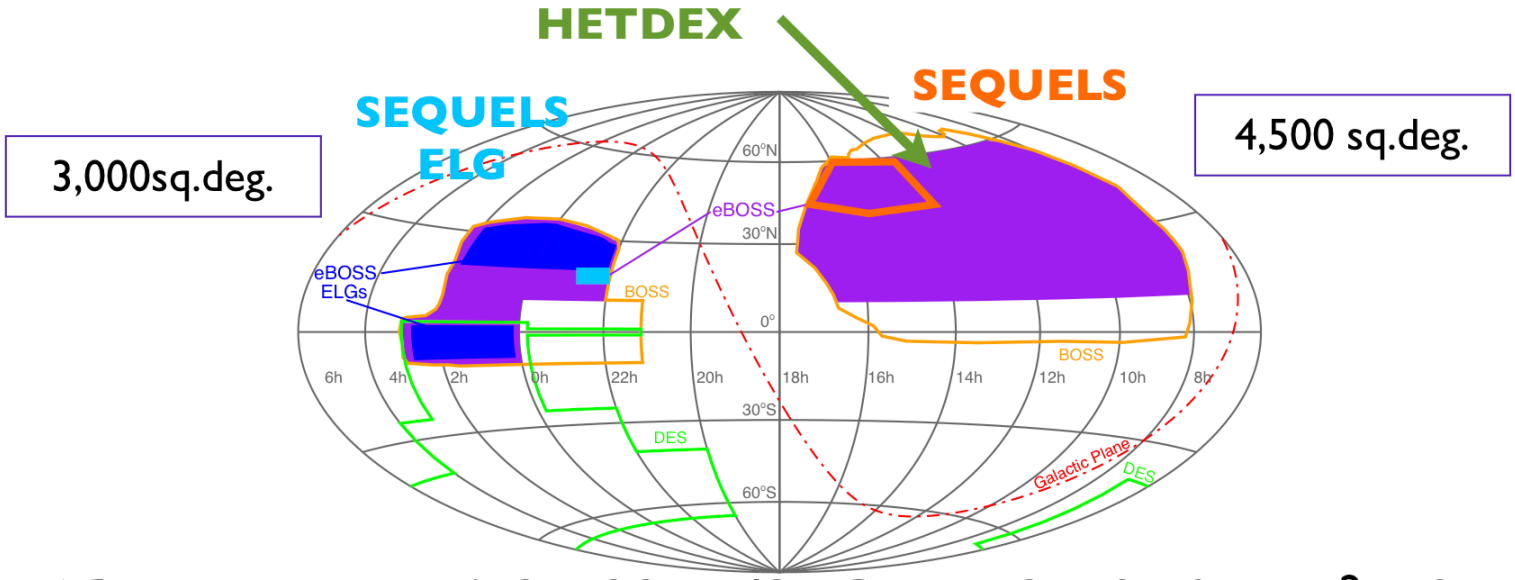


BAO cosmology forecast

	Redshift range	N_{gal}	BAO measurement
LRG	z>0.6	350k	0.9%
ELG	0.6<z<1.0	190k	2.0%
QSO	0.9<z<2.2	510k	1.8%
QSO Ly-alpha	2.15<z<3.5	50k	1.1%

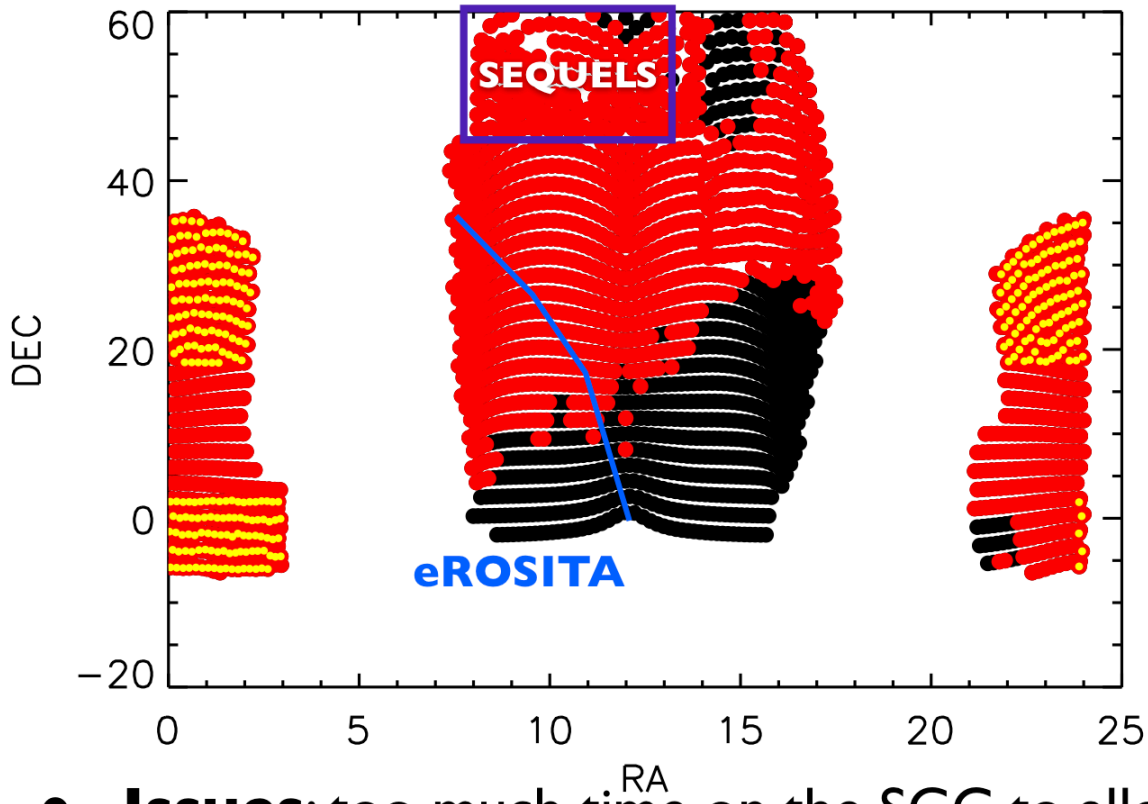
- eBOSS will observe multiple samples, covering a wide redshift range
- Decrease risk, enhance science return
- BAO DETF FoM increase by a factor of ~2.2 from BOSS to eBOSS (Assume Planck CMB measurements, 5% H_0 constraint)

How? - Survey Planing



- *'Commissioning'*: SDSS-III/SEQUELS ~250 deg^2 of LRG and Quasars (Jan-Jul 2014)
- 7500 deg^2 of LRGs and Quasars (Sept 2014- July 2020)
- 1500 deg^2 of ELGs (Sept 2015- Jan 2017)
- including TDSS and SPIDERS sub-project.

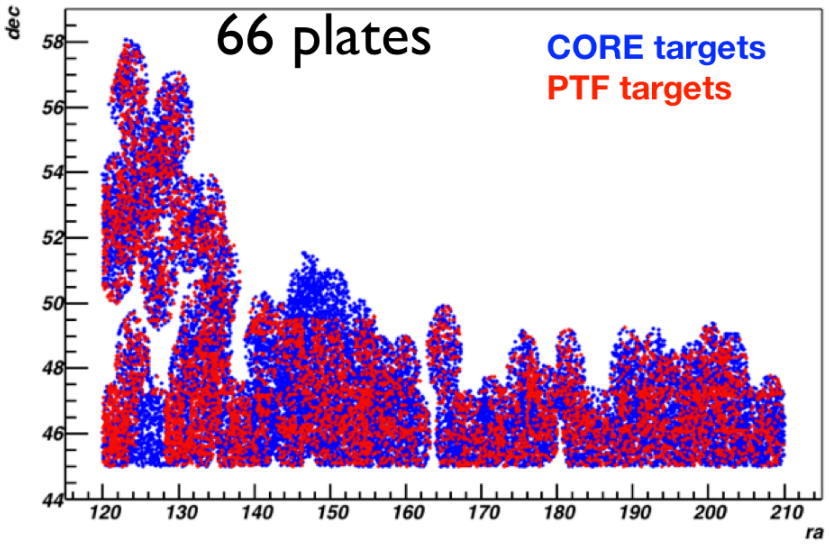
Footprint and Survey Design

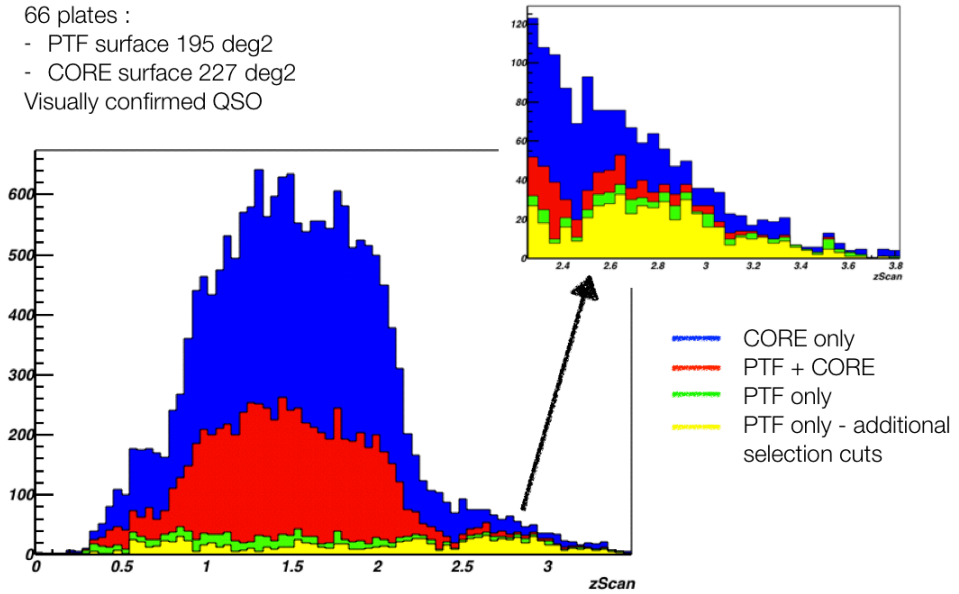


- Red: QSO/LRG/TDSS/ SPIDERS
- Yellow: ELG/TDSS targets over part of the SGC
- ELG: Sept 2015- Jan17
- eROSITA data available from 2017

- **Issues**: too much time on the SGC to allow reaching the 7500 deg^{-2} of LRG+QSO
- From year-5, hard to fill the Galactic transit
- Should we reconsider and adjust the time split?

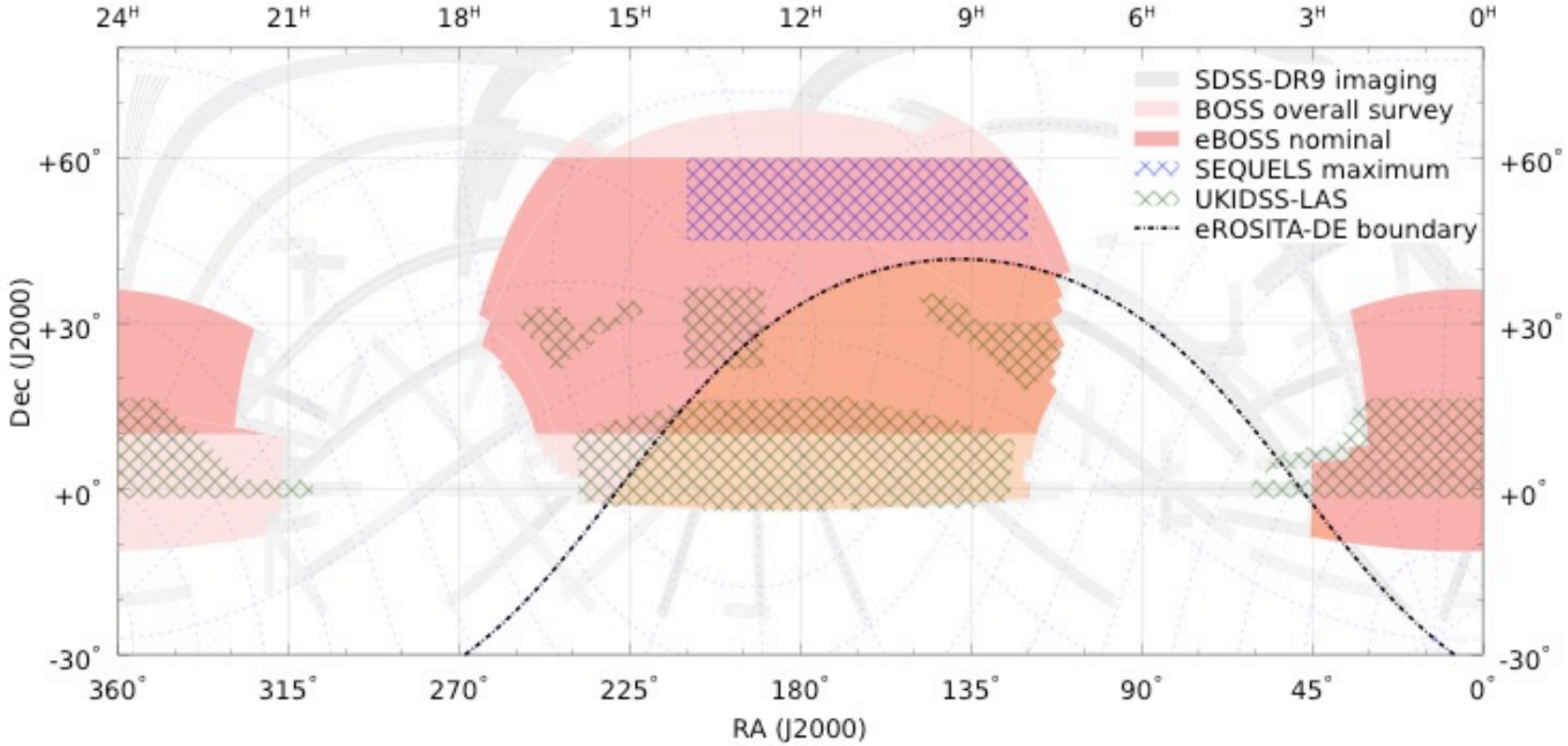
TS Quasars - Validation with SEQUELS



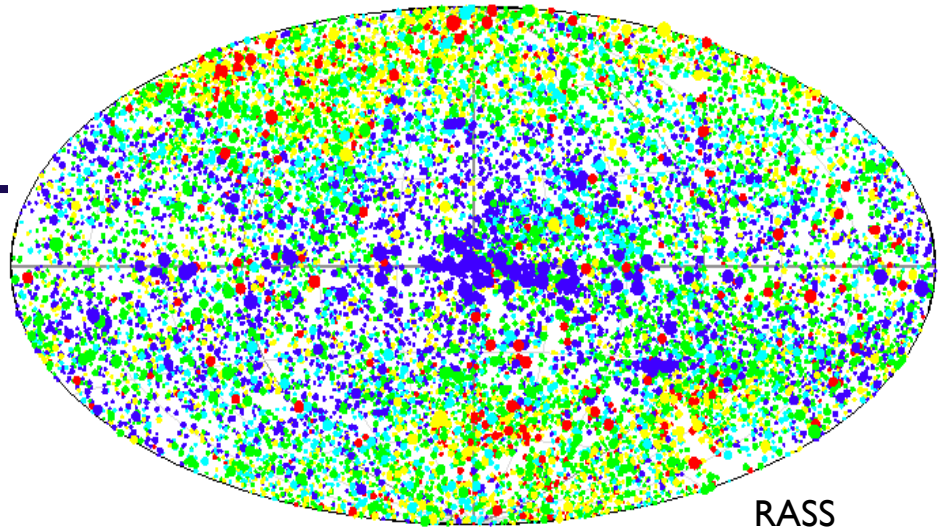


- **SEQUELS targeting show that QSO target selection complies with SRD**
  - 86 deg^{-2} QSO core target => 60 deg^{-2} with 0.9<z<2.15 and 5.4 deg^{-2} with z>2.15
  - 20 deg^{-2} QSO Ly-a target => at least 6.5 deg^{-2} with z>2.15
- **Homogeneity of QSO core targets:** (less than 15% variation)
  - NGC: 97% of the area SGC: 77% of the area

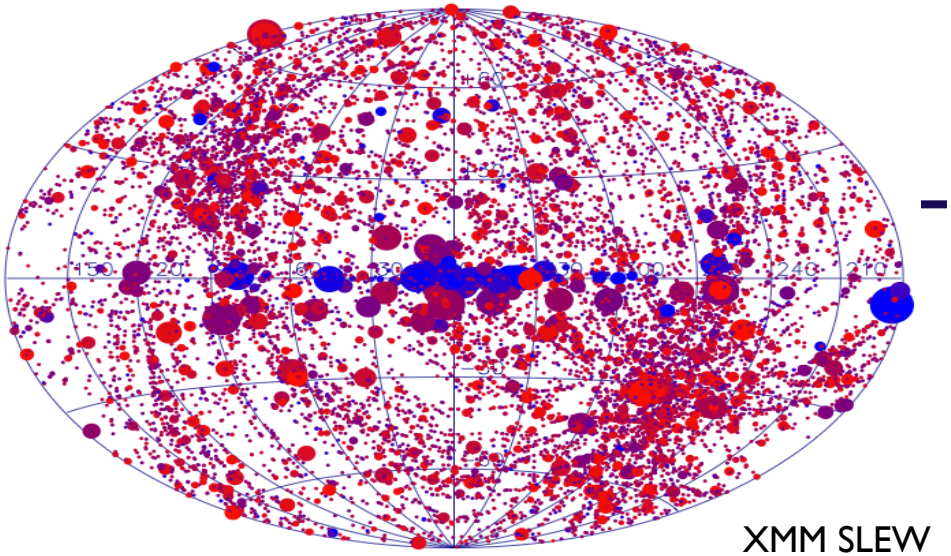
SPIDERS



Early (eRASS:1-4) spectroscopic follow-up over most of the eROSITA_DE/eBOSS overlap region (2000-3000 deg^2)
+ complete follow-up of RASS AGN and clusters
TIME CRITICAL: eRASS catalogs between Q1/2017 & Q4/2018



RASS



XMM SLEW

SPIDERS Tier-0

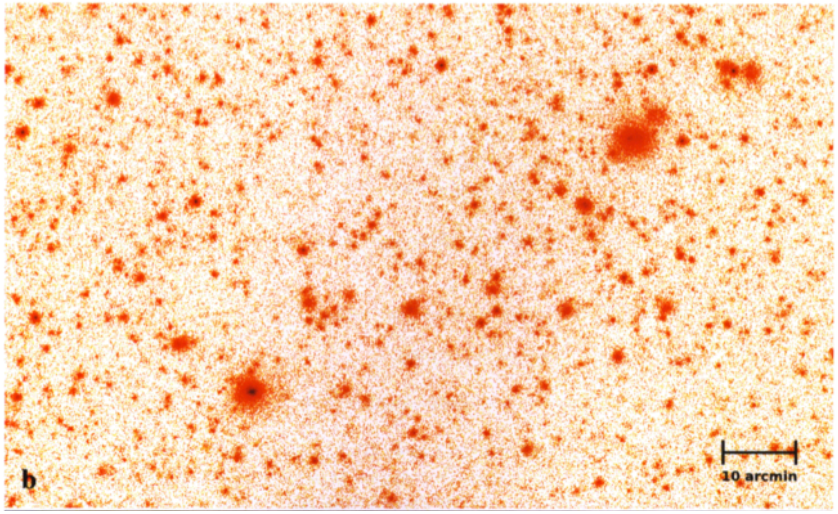
Selected from RASS and XMM-Newton

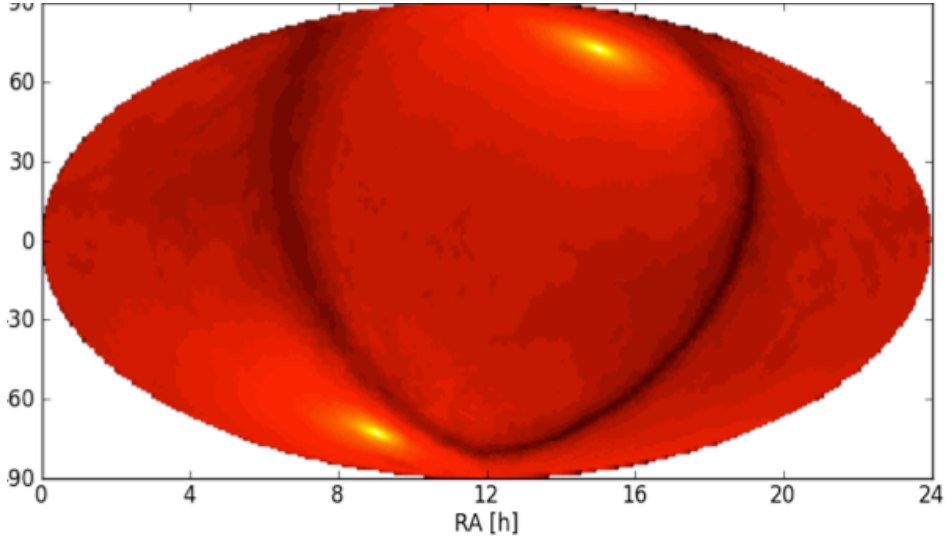
Available from start of eBOSS

Table 1: SPIDERS Tier 0. Sources' selection criteria and target densities.

X-ray class	Selection	Optical Imaging	# of sources [deg^{-2}]	SPIDERS targets [deg^{-2}]	Area [deg^2]
Point-like	RASS+AllWISE	SDSS DR12	3	0.7	
	XMMSL	SDSS DR12	0.2	0.1	
Extended	RASS + RedMapper	SDSS DR12	(0.6)**	4.3	
	XMM	SDSS DR12	(0.03)**	0.2	
Total				5.3	5250

**Number of individual clusters detected per deg^2.





SPIDERS Tier-1+2

X-ray sources from SRG/eROSITA All Sky Survey

Targets available for 2nd half of eBOSS

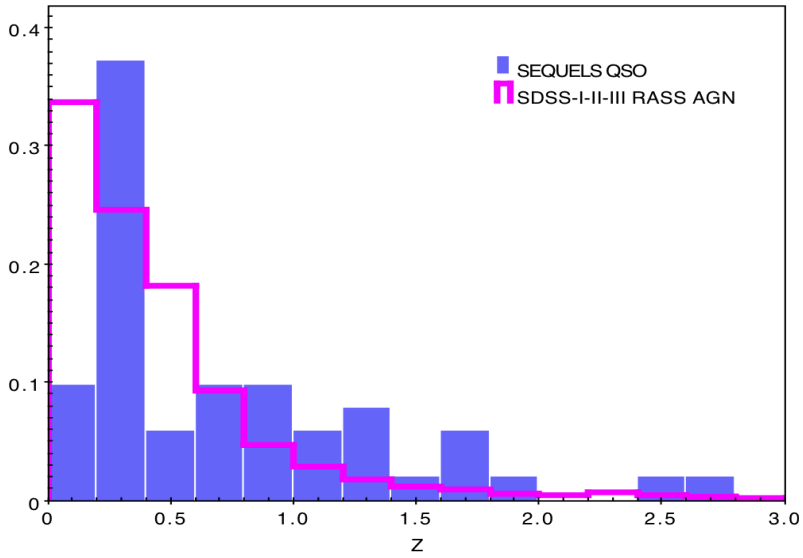
Table 3: SPIDERS Tier 2. Sources' selection criteria and target densities.

X-ray class	Selection	Optical Imaging	# of sources [deg^{-2}]	SPIDERS targets [deg^{-2}]	Area [deg^2]
Point-like	eRASS:4*	SDSS DR12	28	17	
Extended	eRASS:4*	SDSS DR12	(1.5)**	10	
Total				27	1500

*The expected flux limits for eRASS:4 are: 1.8×10^{-14} ergs/s/cm^2 for point-like sources, and $\approx 5\times10^{-14}$ for extended sources. **Number of individual clusters detected per deg^2.

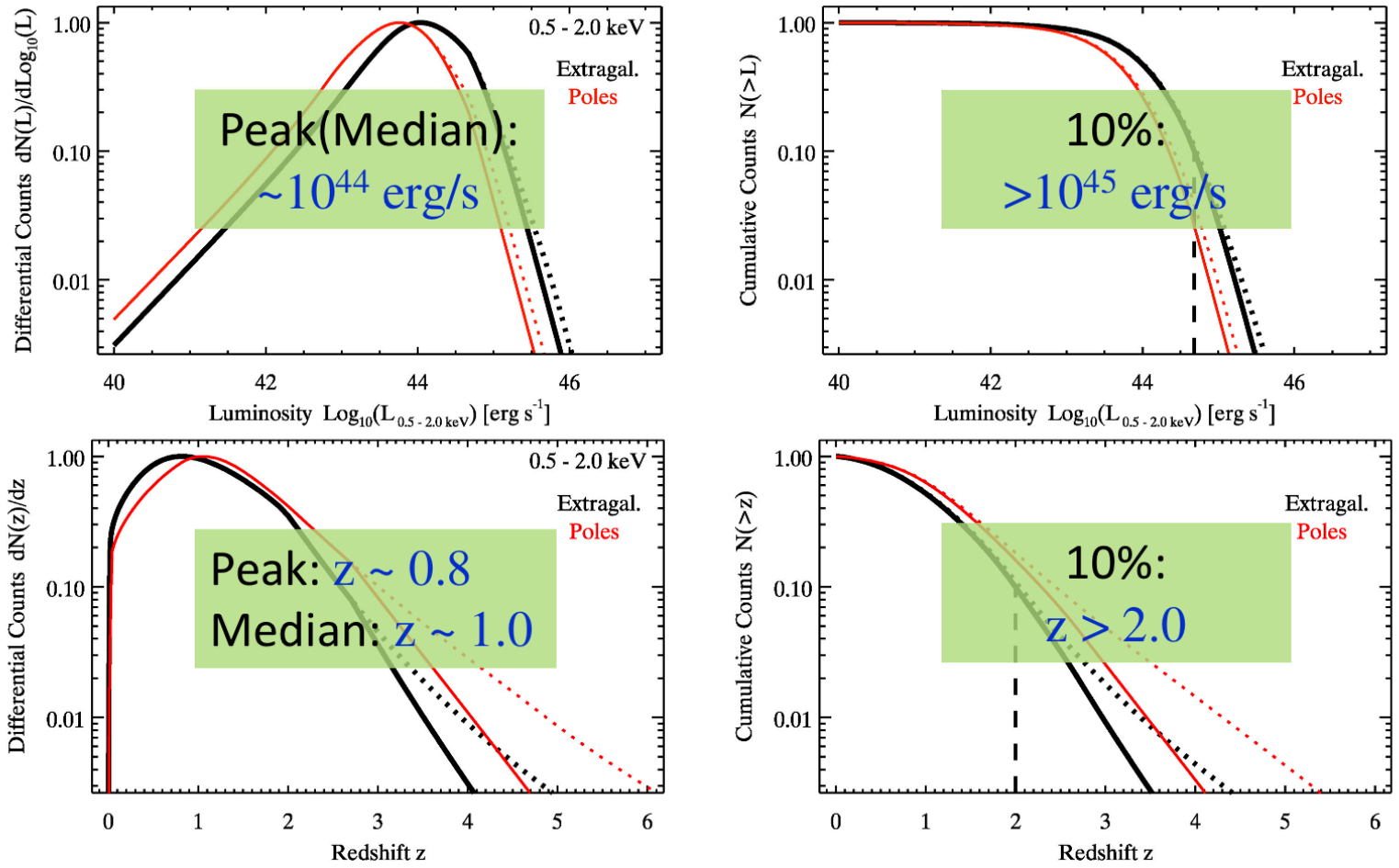
Summary, Tier 0 AGN

- Candidate X-ray sources primarily from RASS
  - Plus 0.2/deg^2 sources from XMM Slew Survey
- 2-step Bayesian association method (Salvato+ in prep)
  - Priors in WISE W1 and W2 derived from secure identifications of bright XMM sources
  - Associations are >90% reliable

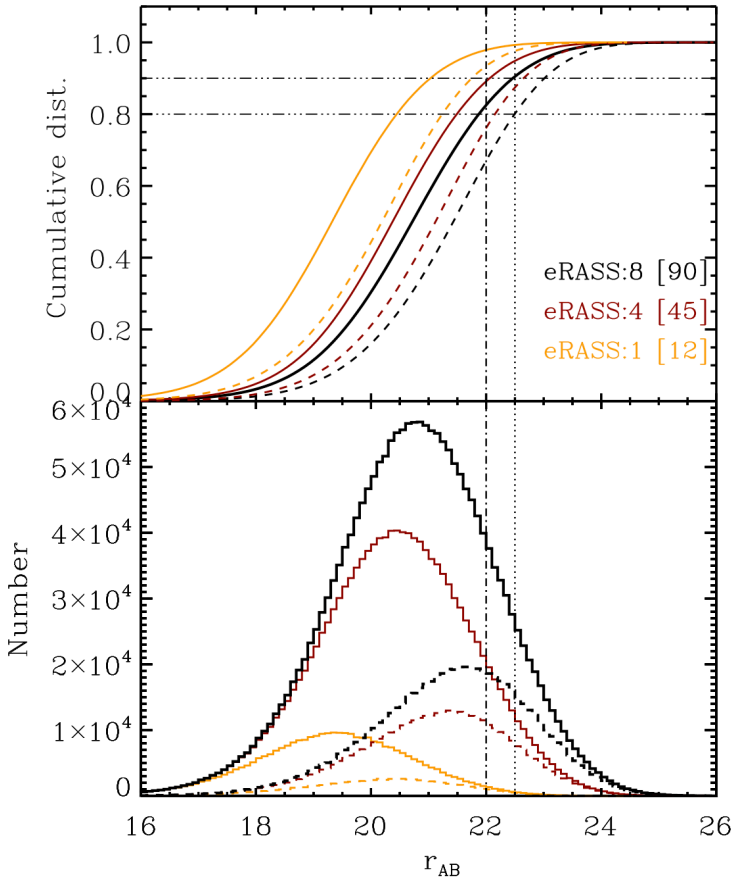


A legacy sample of 3M AGN

Kolodzig et al. 2012



eROSITA AGN followup



Expectation based on AGN XLF model of observed 0.5-2 keV counts

ERASS 2 **2.8E-14 erg/sec/cm^2, 17 < r < 22**

[#]	all AGN	XDQSO	
total	101	29	0.29
fibers	69	22	0.32
	0.68	0.76	

[deg^{-2}]	all AGN	XDQSO	SPIDERS
total	14	4	10

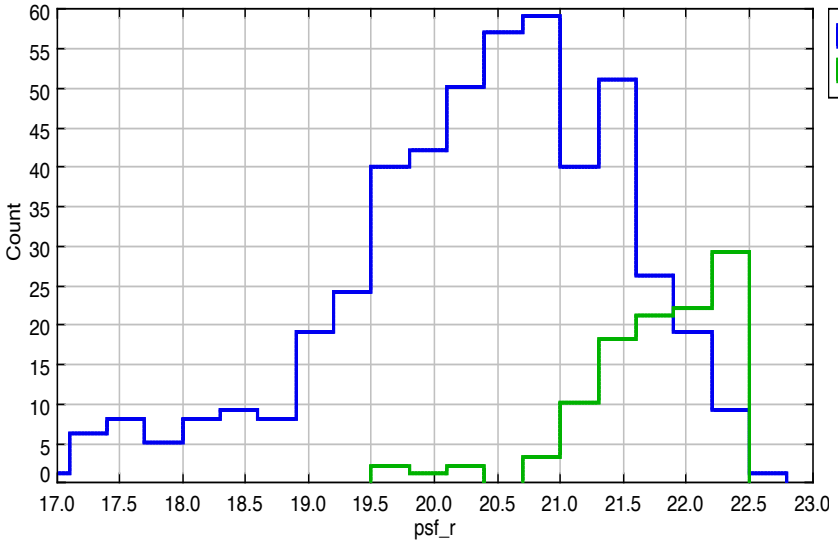
ERASS 4 **1.8E-14 erg/sec/cm^2, 17 < r < 22**

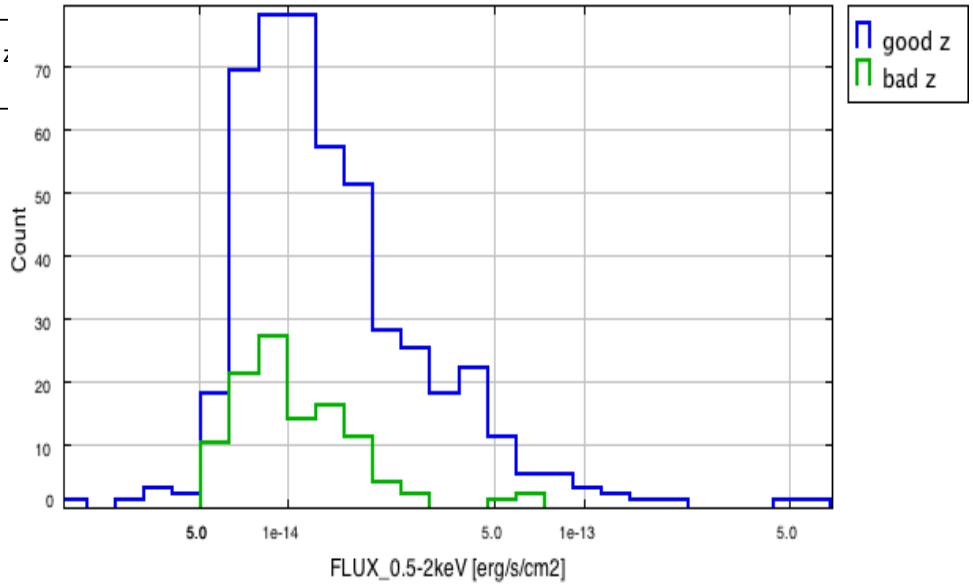
[#]	all AGN	XDQSO	
total	199	78	0.39
fibers	126	48	0.38
	0.63	0.62	

[deg^{-2}]	all AGN	XDQSO	SPIDERS
total	28	11	17

Results of BOSS ancillary survey in XMM-LSS

Redshift success (BOSS)





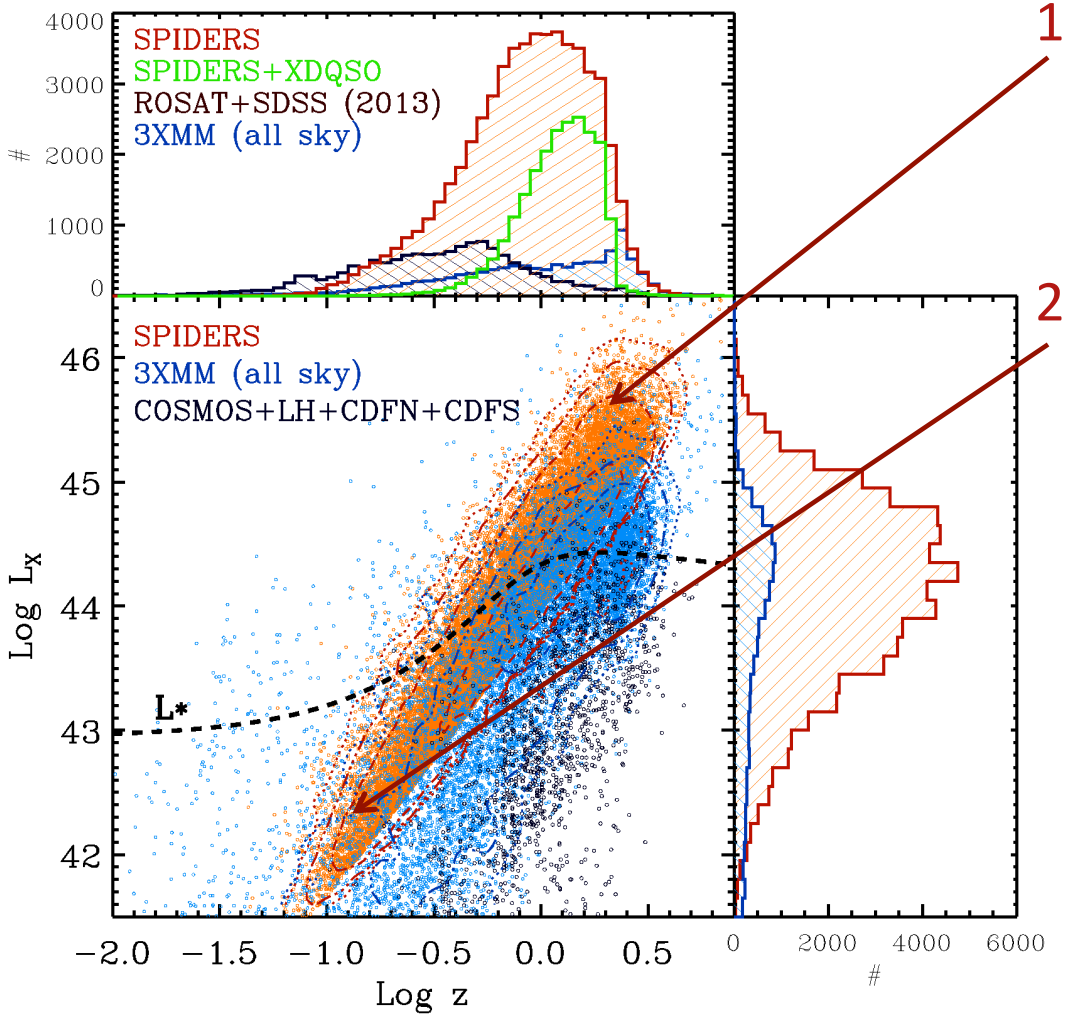
Overall success rate = 82% ➔ Completeness = 60%

At eRASS:8 limit (10^{-14}) = 87% ➔ Completeness = 69%

At eRASS:4 limit (1.8×10^{-14}) = 93% ➔ Completeness = 78%

At eRASS:2 limit (2.8×10^{-14}) = 96% ➔ Completeness = 82%

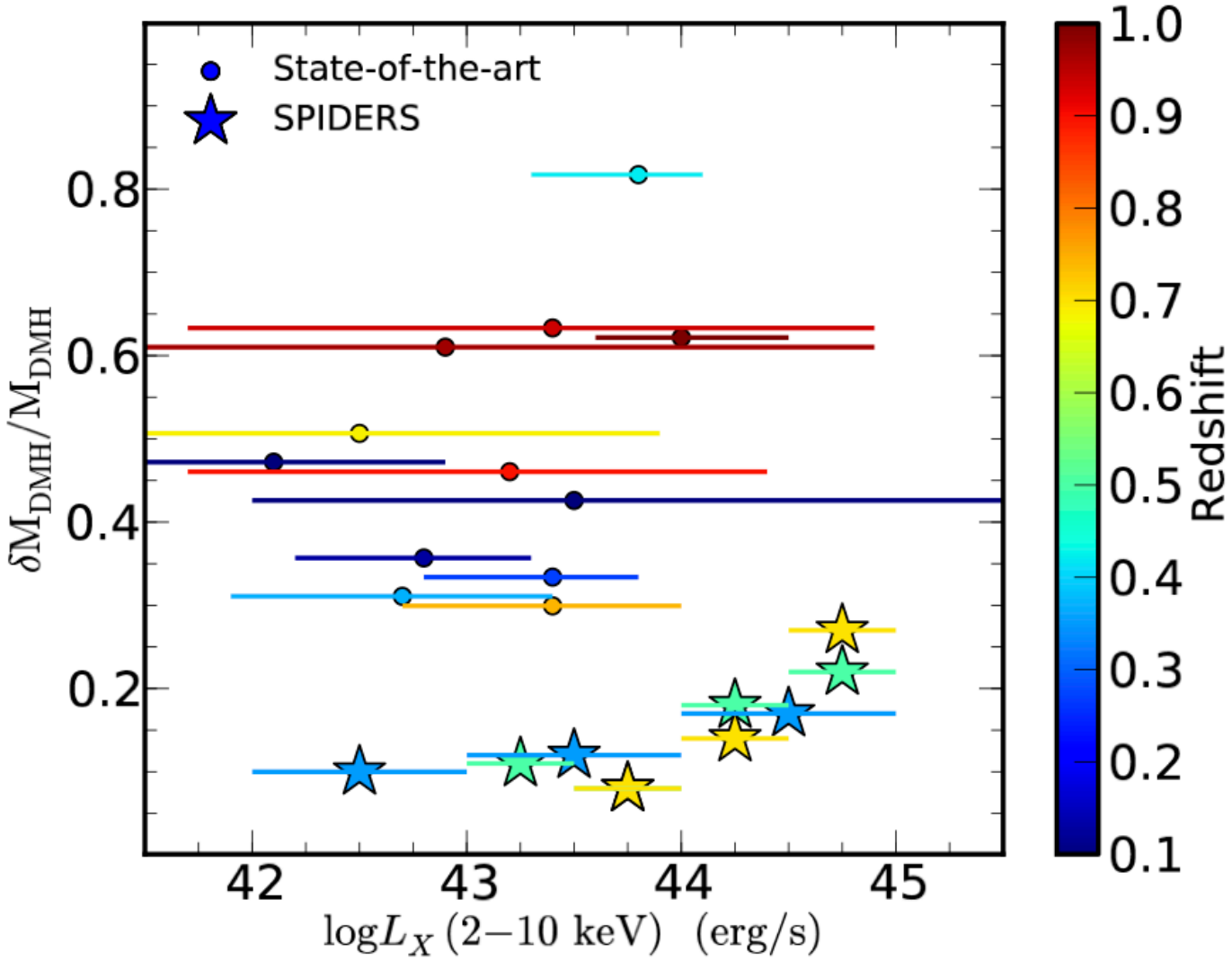
SPIDERS impact



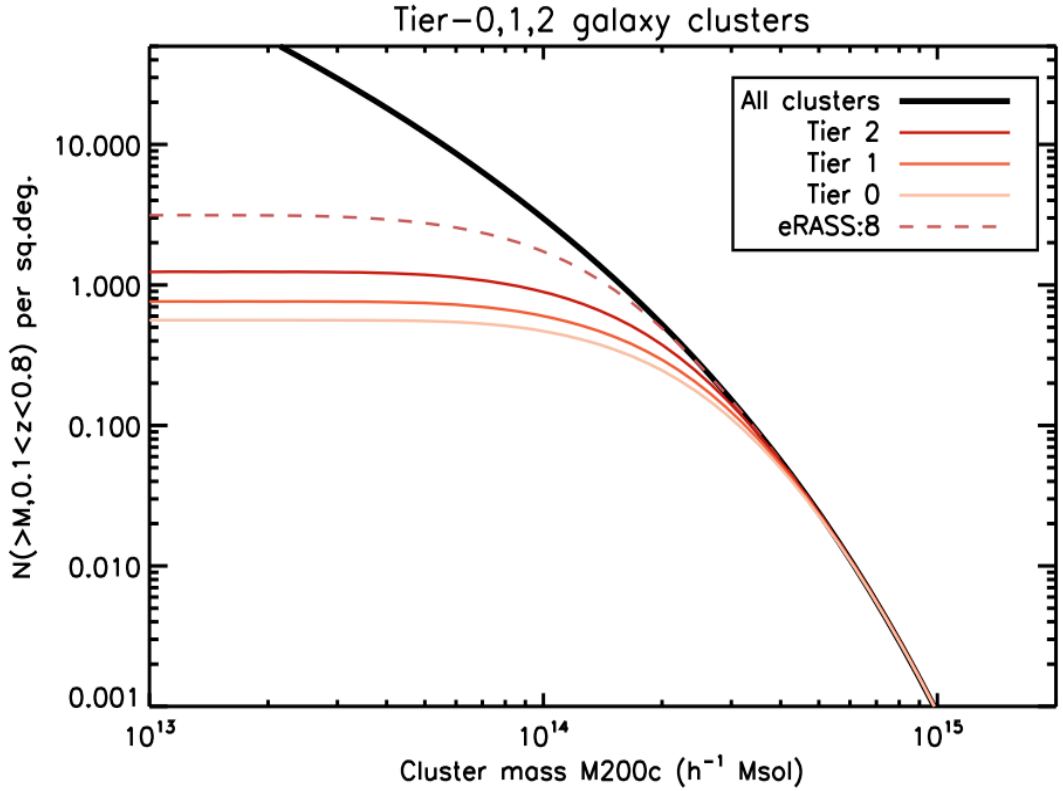
1. The most luminous AGN, tracers of large scale structure: the "quasar" mode of AGN feedback
2. Nearby LLAGN: the "kinetic (radio)" mode of AGN feedback

In both areas, SPIDERS will deliver samples ~1 order of magnitude larger than anything done before!

SPIDERS impact



ALL massive clusters

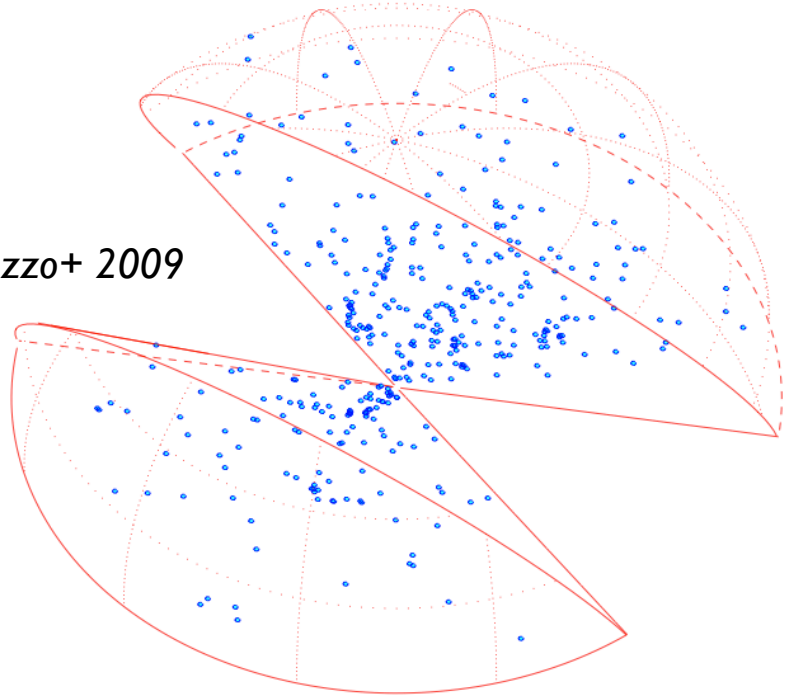


~ order of magnitude increase in size among X-ray selected clusters surveys with complete optical follow-up

- For clustering analysis we are limited by statistics!
- Expect $\Delta\sigma_8<0.01$ $\Delta w<0.04$ (SPIDERS+Planck)

Why SPIDERS

- Spec-z needed for
  - Confirmation
  - Substructure/projections
  - L_X, T_X, Y_X, M…
  - σ_v, M_{dyn}
  - 3-d LSS
- Also
  - BCG spectra → BCG activity
- Pathfinder for wide-area MOS cluster (and LSS) surveys (4MOST, WEAVE, DESI)



Guzzo+ 2009

- ξ(r,z) & P(k ; M, z)

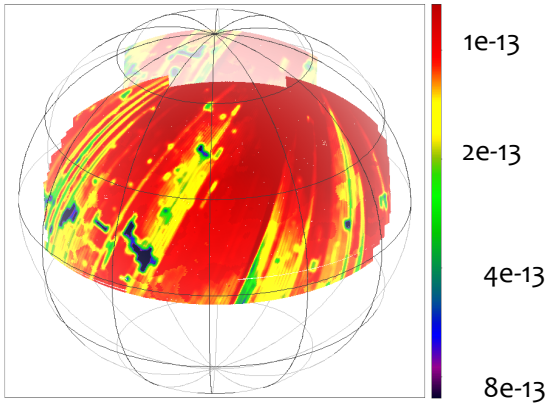
Using clusters as highly-biased tracers

RASS clusters in SPIDERS/SEQUELS

(N. Clerc, A. Merloni, A. Finoguenov, J. Ridl, the SDSS

Pre-eRosita: CODEX (RASS+RedMapper)

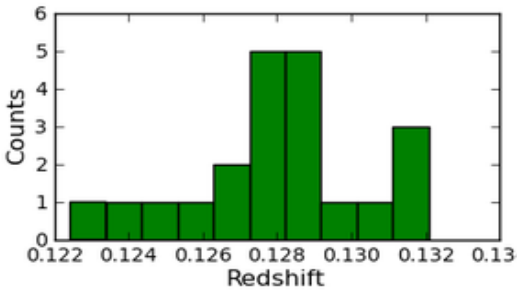
RASS-faint sensitivity ergs/s/cm²



SDSS ugriz+RedMapper

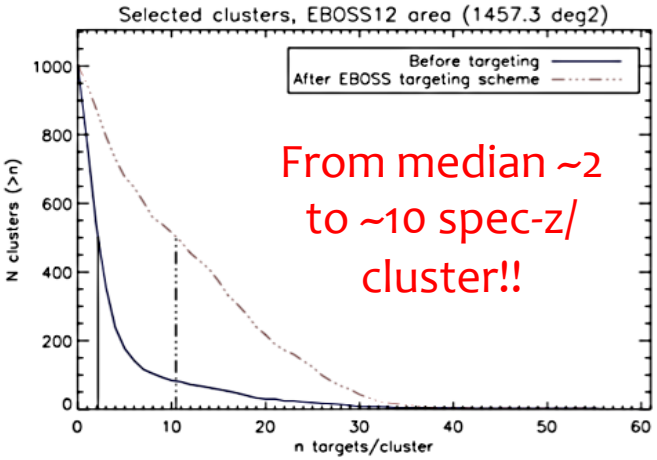
Goal: secure spectroscopic confirmation of 75% CODEX clusters (~4,000) + statistical velocity dispersion for massive subsamples

- 0.1<z<0.6
- 0.7/deg² (richness>10)
- Median mass ~4.10^{14} M_{sol}
- Optimized selection of targets
  - 17<*i*(2")<21.2
  - Red-sequence prioritization
  - Cluster richness penalty



SDSS-III/SEQUELS

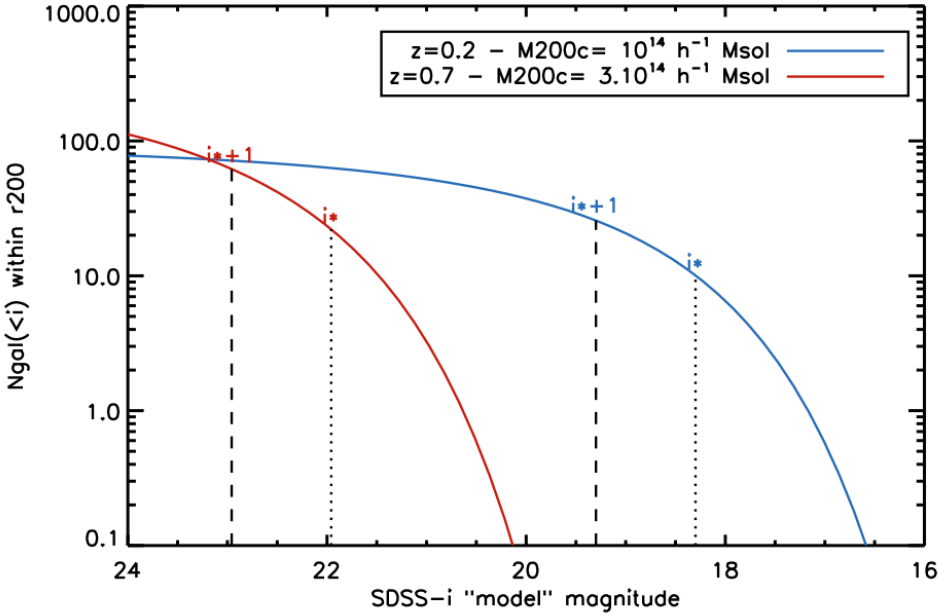
351 clusters targeted!



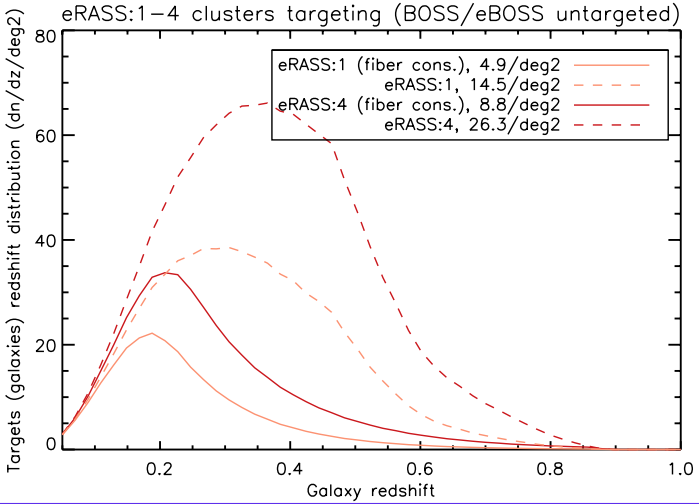
From median ~2 to ~10 spec-z/ cluster!!

eROSITA clusters

- Confirmation
  - Best: > 10 similar *z*
  - Average: 3 similar *z*
  - Extreme case: 1 *z* (BCG) +photo-z



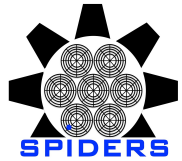
- Velocity dispersions
  - ~10 members: scatter and bias (understood with simulations)
  - Stacking in M (or Lx/z) → accurate scaling relations
- Completeness
  - X-ray selection well-handled
  - Sampling ok if unrelated to X-ray properties



e BOSS Data Release Plan

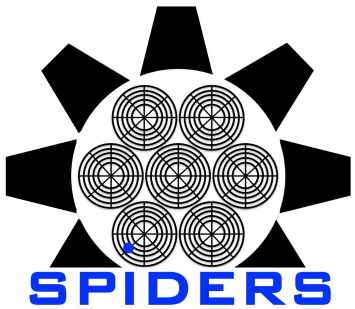
- **July 2016 (DR13): eBOSS DR1**:
  - LRG+QSO targeting catalogues
  - SEQUELS- designed plates (~500 deg^2 of LRG+QSO) - possibly more
- **July 2017 (DR14): eBOSS DR2**:
  - ~2,500 deg^2 of LRG+QSO; first Cosmology papers
- **July 2018 (DR15): eBOSS DR3**: ~3,000 deg^2 of LRG+QSO and 1500 sq degrees of ELGs; second Cosmology papers
- **July 2019 (DR16):** no eBOSS Data Release
- **Dec 2020 (DR17): eBOSS DR4**: ~7,500 deg^2 of LRG+QSOs and 1500 sq degrees of ELGs; third Cosmology papers

Collaboration policy



- SDSS-IV membership does not imply eROSITA membership/ unfettered data access
- MoU between eR_DE and SDSS-IV approved
- In general, both SDSS-IV and eROSITA_DE consortium rules will be respected
- Basic X-ray information (DL1) on SPIDERS targets will be made public to the whole SDSS-IV collaboration (e.g. X-ray position, positional uncertainty, flux). DL1 products (redshift, etc.) will be available to eROSITA_DE (on eROSITA sources)
- DL1 projects free to be pursued by SDSS-IV members but notification to eROSITA_DE required and authorship offered
- Use of higher level ROSITA data (DL2) requires approval from eROSITA_DE (working group)

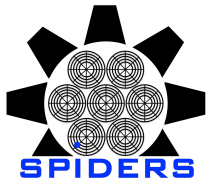
Thanks



AGN Strategy

Catalog	X-ray AGN [deg^{-2}]	Targets [deg^{-2}]	AREA [deg^2]	Date	
RASS +XMMSL	3	1	5250	Fall 2013	←Tier 0
eRASS:1	9	5	750	End 2016	
eRASS:2	14	9		Summer 2017	←Tier 1
eRASS:3	20	13	1500	End 2017	
eRASS:4	28	17		Summer 2018	←Tier 2

Clusters Strategy

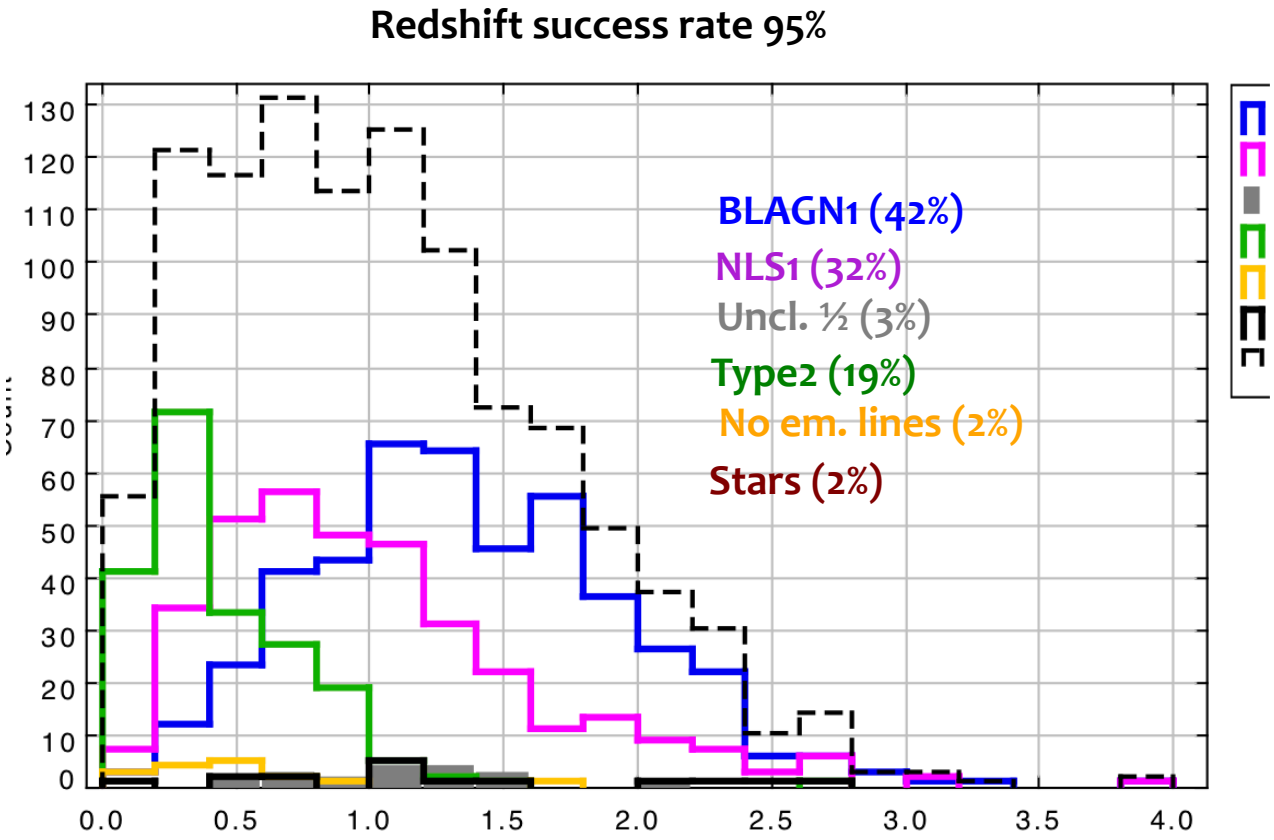


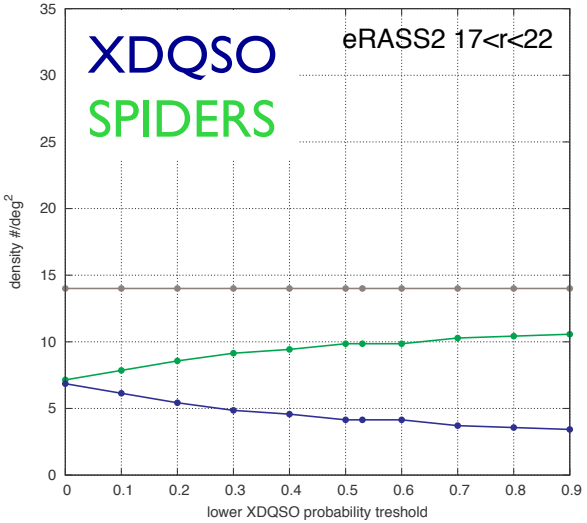
Catalog	Min. targets [deg^{-2}]	Optimal (# cluster) [deg^{-2}]	Area [deg2]	Date	
RASS/ RedMapper	-	4 (0.6)	5250	Fall 2013	←Tier 0
eRASS:1	2.6	5 (0.8)	750	End 2016	←Tier 1
eRASS:2	3.4	7 (1.0)		Summer 2017	
eRASS:3	3.9	8 (1.2)	1500	End 2017	←Tier 2
eRASS:4	4.6	10 (1.5)		Summer 2018	

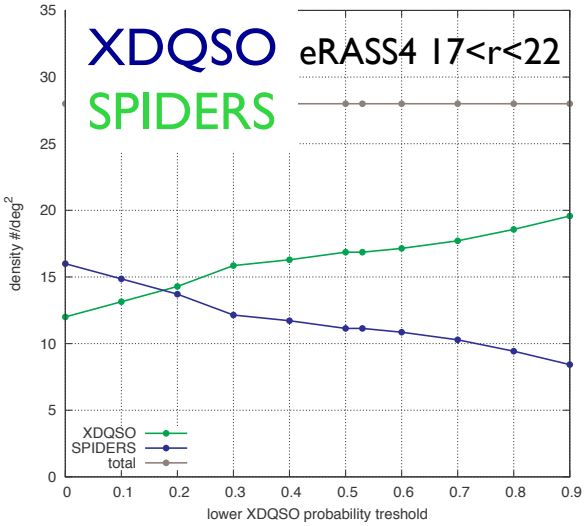
Within XMM-LSS cluster sample (non-SDSS spectro-z/photo-z)
Existing BOSS spectroscopy provides:

- ~20% with >3 spec-z agreeing with z(cluster)
- ~40% with 1 BCG spec-z agreeing with z(cluster)
- ~40% unconfirmed/ambiguous

X-ray vs. optical QSO selection



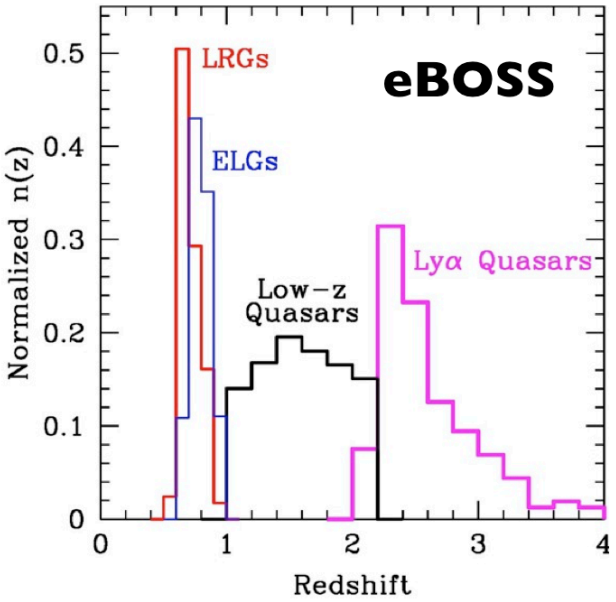


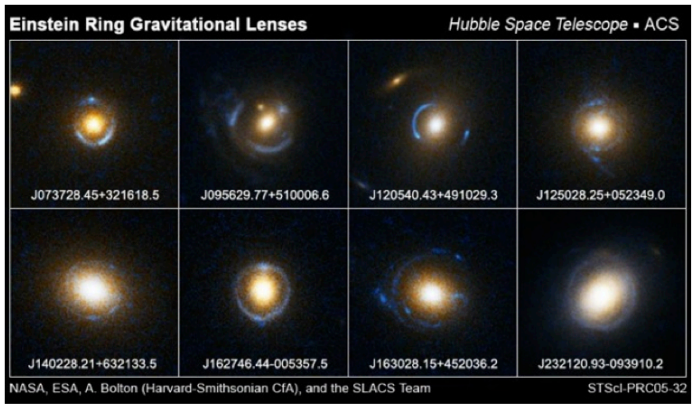


Menzel et al. in prep.

3rd Science Driver = Galaxies

- Photo-z calibration by cross-correlation
  - Important for DES, LSST
- Small-scale galaxy clustering
  - Halo positions and densities of galaxies as a function of properties
- Cross-correlation with Ly-α forest
  - Gas & metal distribution around ELGs and LRGs
- Strong lensing
  - discovery of strong lens systems from spectra
- *Galaxy Clusters discovery and science (Synergy with SPIDERS)*





Check plenary presentation by Zheng Zheng tomorrow

Discovery space

	N_{eq} [deg^{-2}]	F_{eq}	F_{deep} (m)	F_{wide}	A_{wide} [deg^2]
Radio [1.4 GHz]	~1200	~100 μJy	10 μJy	2.5 mJy	30,000 [NVSS]
IR color	~200-1000	50-100 μJy	1-5 μJy	0.1 mJy	41,251 [WISE]
Opt. QSO color	~150	4 μJy (r~22.4)	~20 nJy (r~28)	4 μJy (r~22.4)	~10,000 (SDSS)
X-ray 0.5-2 keV	**~20,000**	5×10^{-18} cgs	10^{-17} cgs	3×10^{-13} cgs	41,251 (ROSAT)
X-ray 2-10 keV	>10,000	~10^{-18} cgs	4×10^{-17} cgs	~10^{-12} cgs	~15,000 (XMMSL)
X-ray 10-200 keV	>0.03	?	?	1.3×10^{-11} cgs	41,251 (Swift)