Galaxy groups and clusters in the NEXUS survey

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+X-CLASS and NEXUS

Galaxy Cluster France workshop
27 November 2026 - Meudon

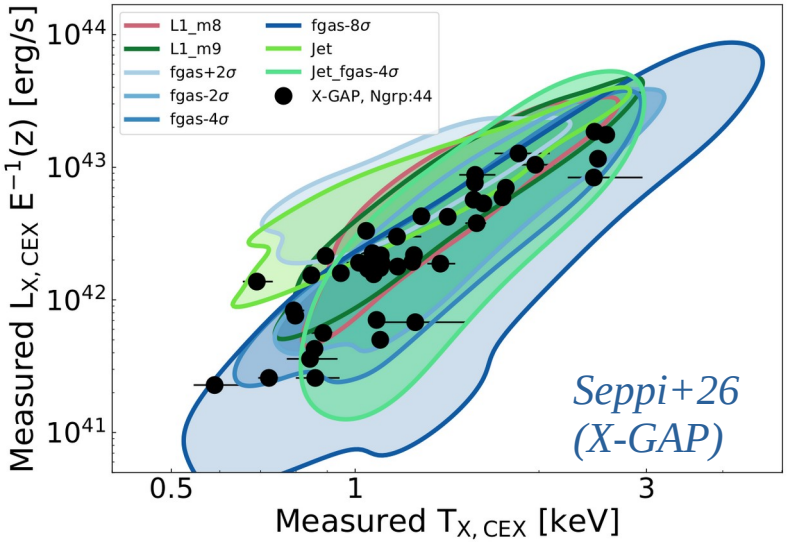
Groups and low-mass clusters

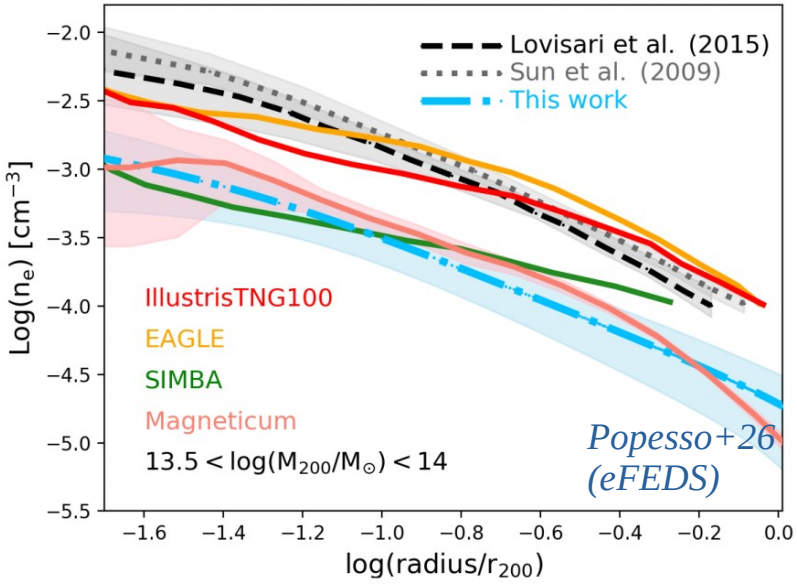
- **Typical masses 10^{13}-10^{14} M_{sol}**

- Regime between clusters and galaxies
- Most common environment of galaxies
- *Low-z:* what remains of structure formation
- *High-z:* building blocks for massive objects

- **Feedback by AGN is key shaping process**

- Potential well is shallower than in clusters, more susceptible to non-gravitational feedback
- Hot gas keeps imprint of these processes
- Understanding feedback for cosmology (e.g. shear PS)
- Studies still not fully agree on the amount and effects of feedback (simulations and observations)





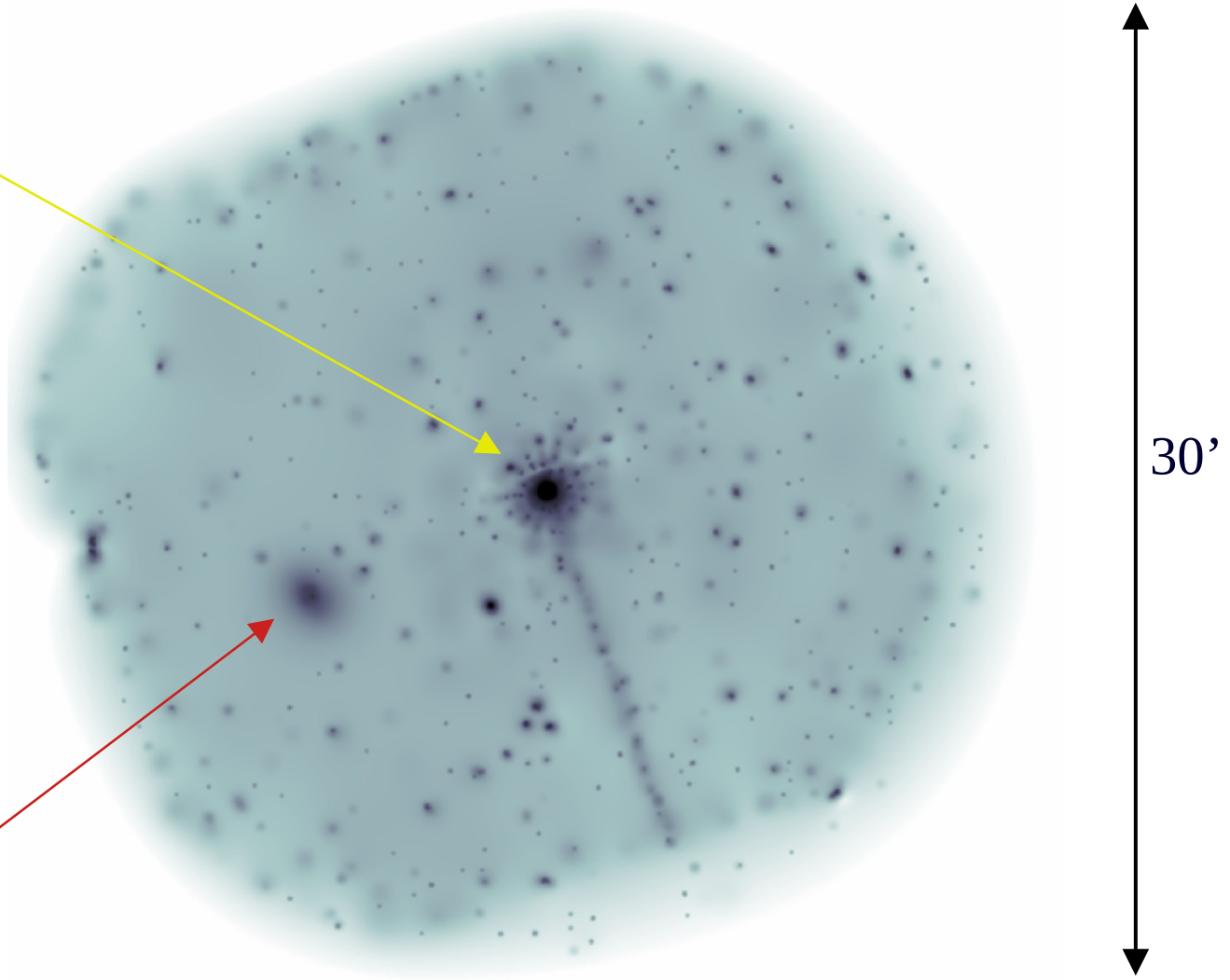
Searching for low-mass ICM systems

- X-ray are most promising at low redshift
  - S-Z at higher redshifts, however mostly unresolved
  - Alternatively *stack* optical/WL clusters (loses individual information)
- Examples of current X-ray based surveys/samples:
  - AXES-2RMS (Khalil+25), X-GAP (Eckert+25, Seppi+26)
  - eFEDS/eRASS surveys (Bahar+24)
  - XMM-XXL, Fornax (Pierre+16)
  - X-CLASS (Moysan+26)

Launching NEXUS

- XMM-Newton is the most sensitive soft X-ray observatory with excellent imaging capabilities
- It is accumulating data since 25+ years in thousands of fields (“pointings”) each of size ~full moon
- Perfectly suited for the discovery of low-mass and high-z clusters (e.g. XXL project)
- We have built expertise on analyzing and building cluster catalogs from this kind of data

What’s in a XMM-Newton pointing?



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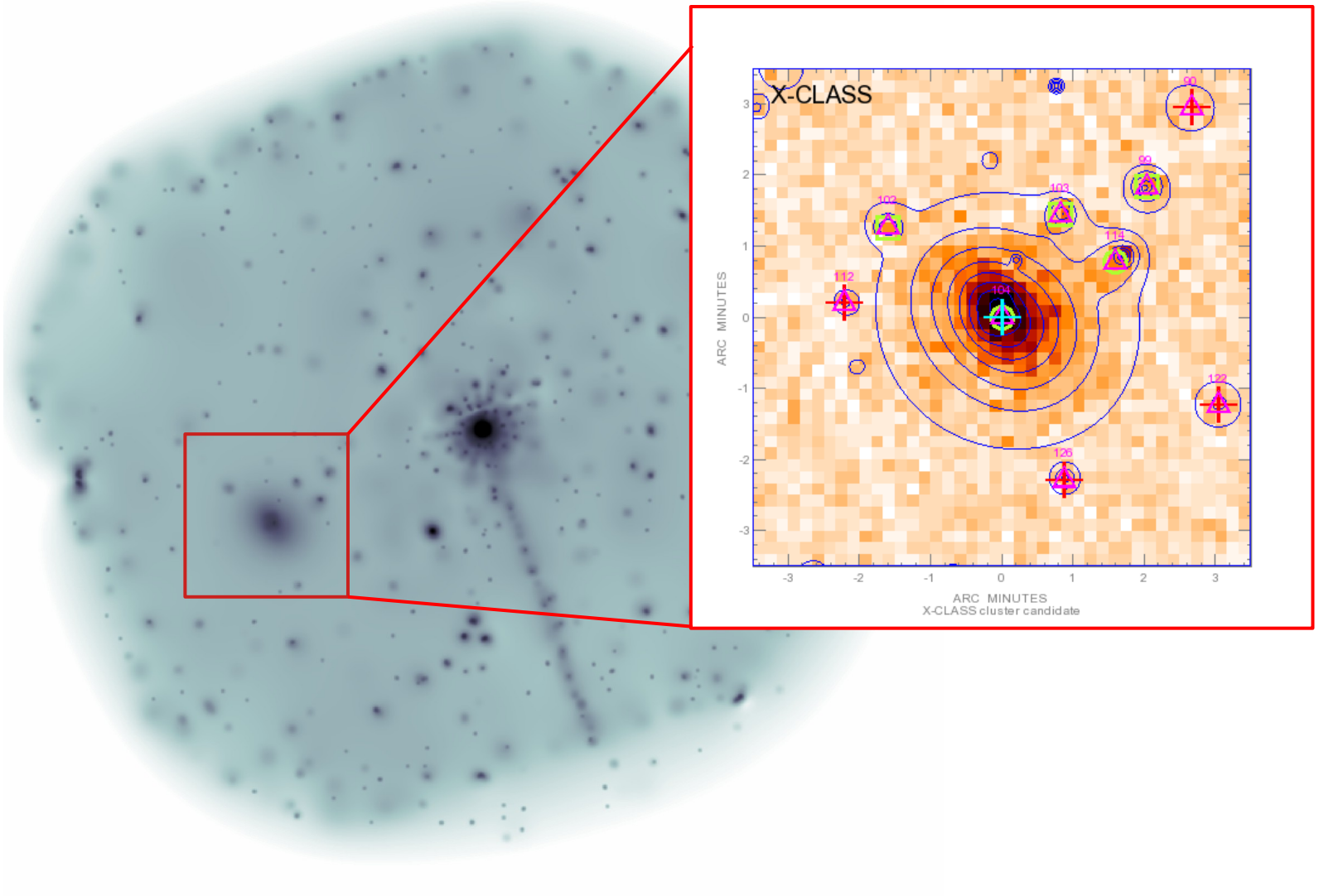

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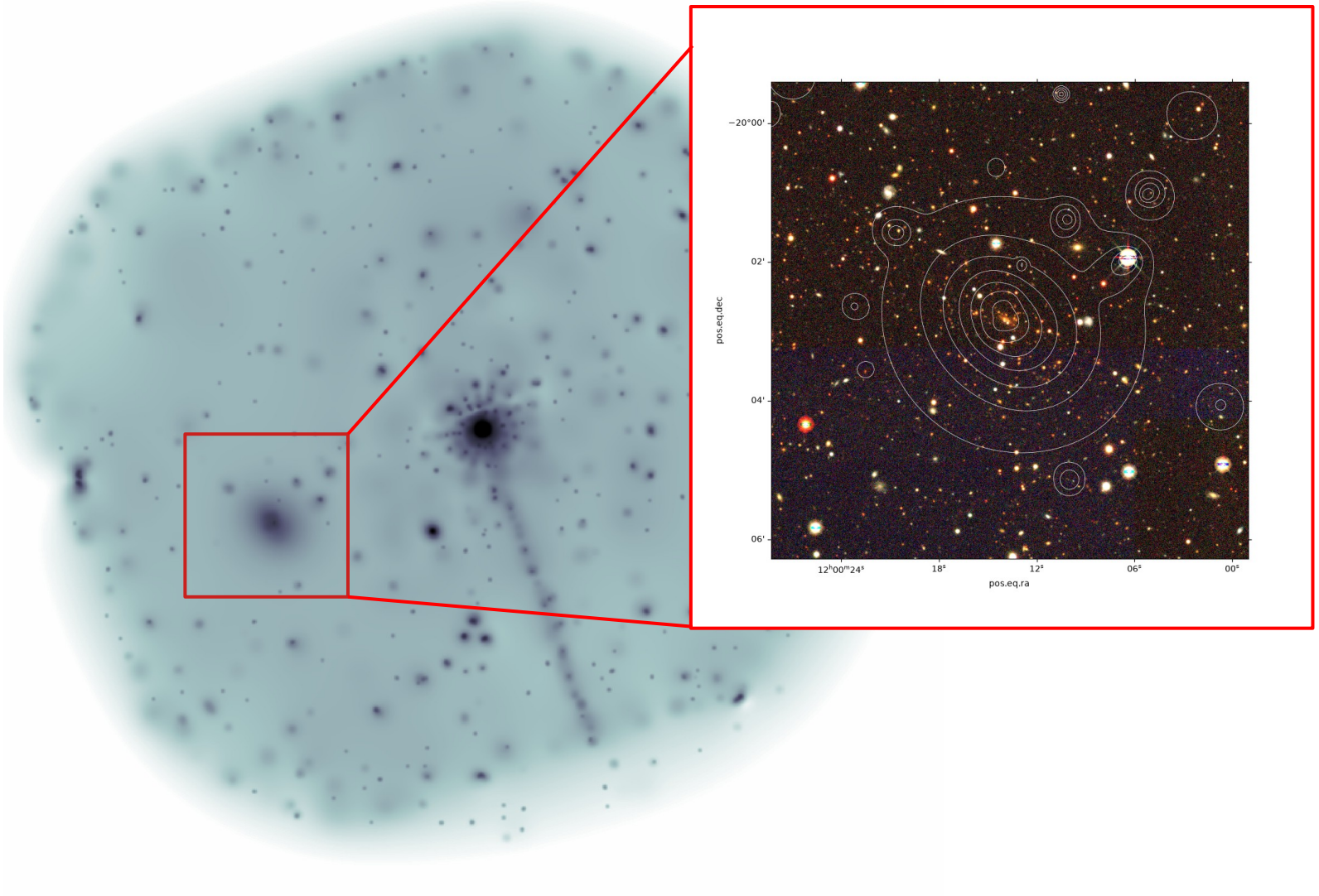
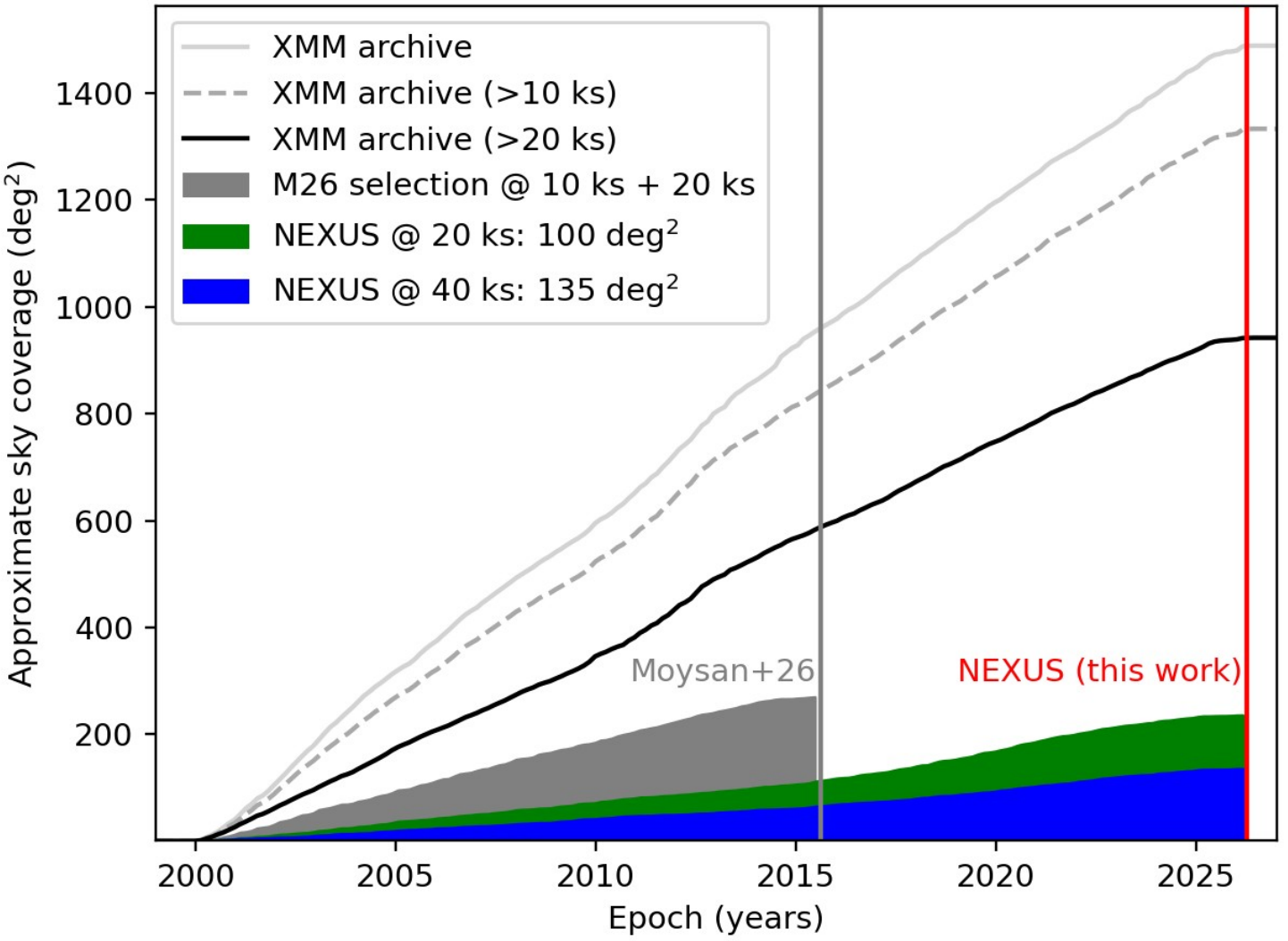


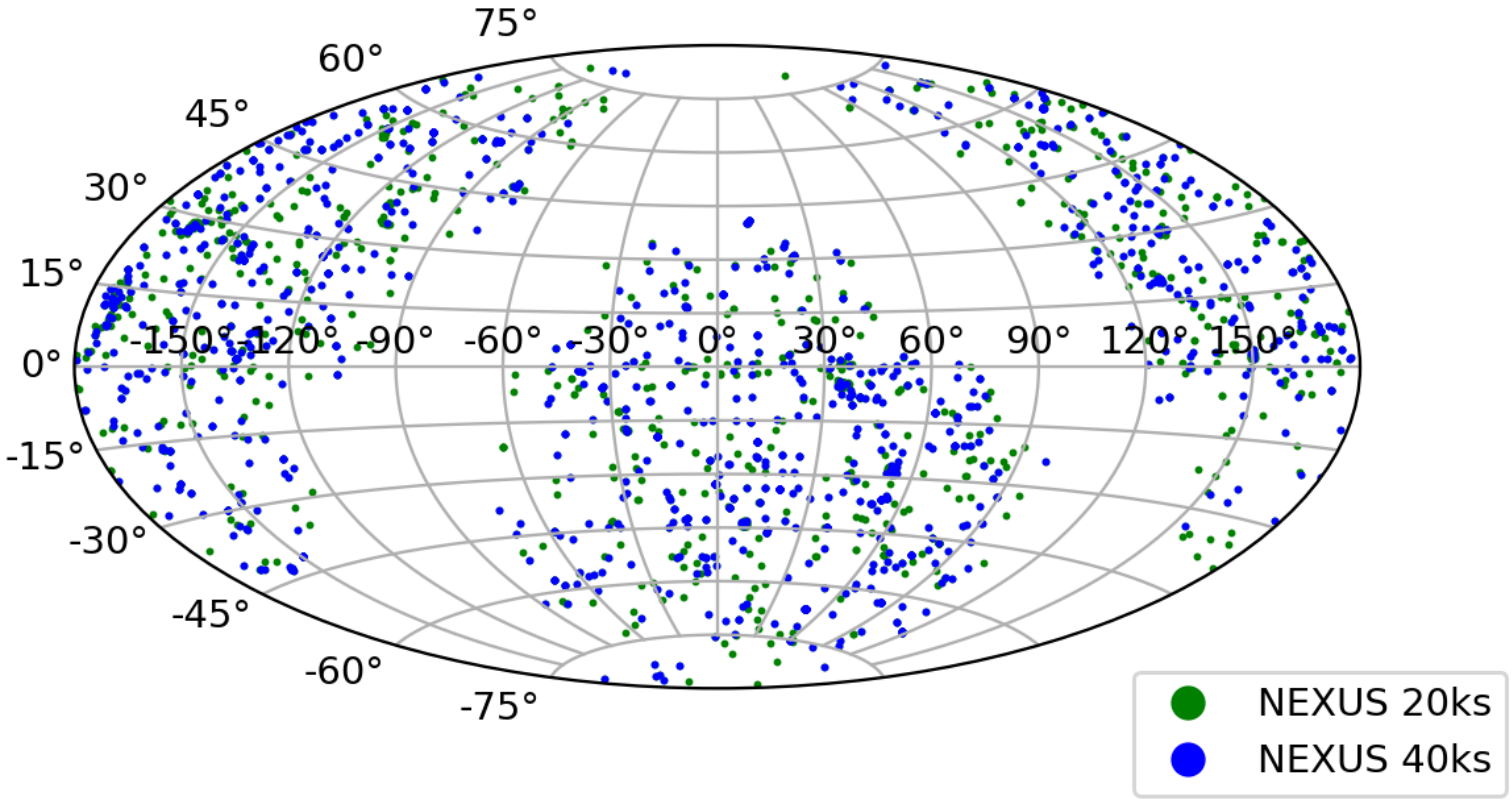
Growth of the XMM-Newton archive



NEXUS on sky: pointing selection

- **Criteria for selection ~4000 pointings:**
  - Low galactic absorption, low star density
  - Depth >20 ks

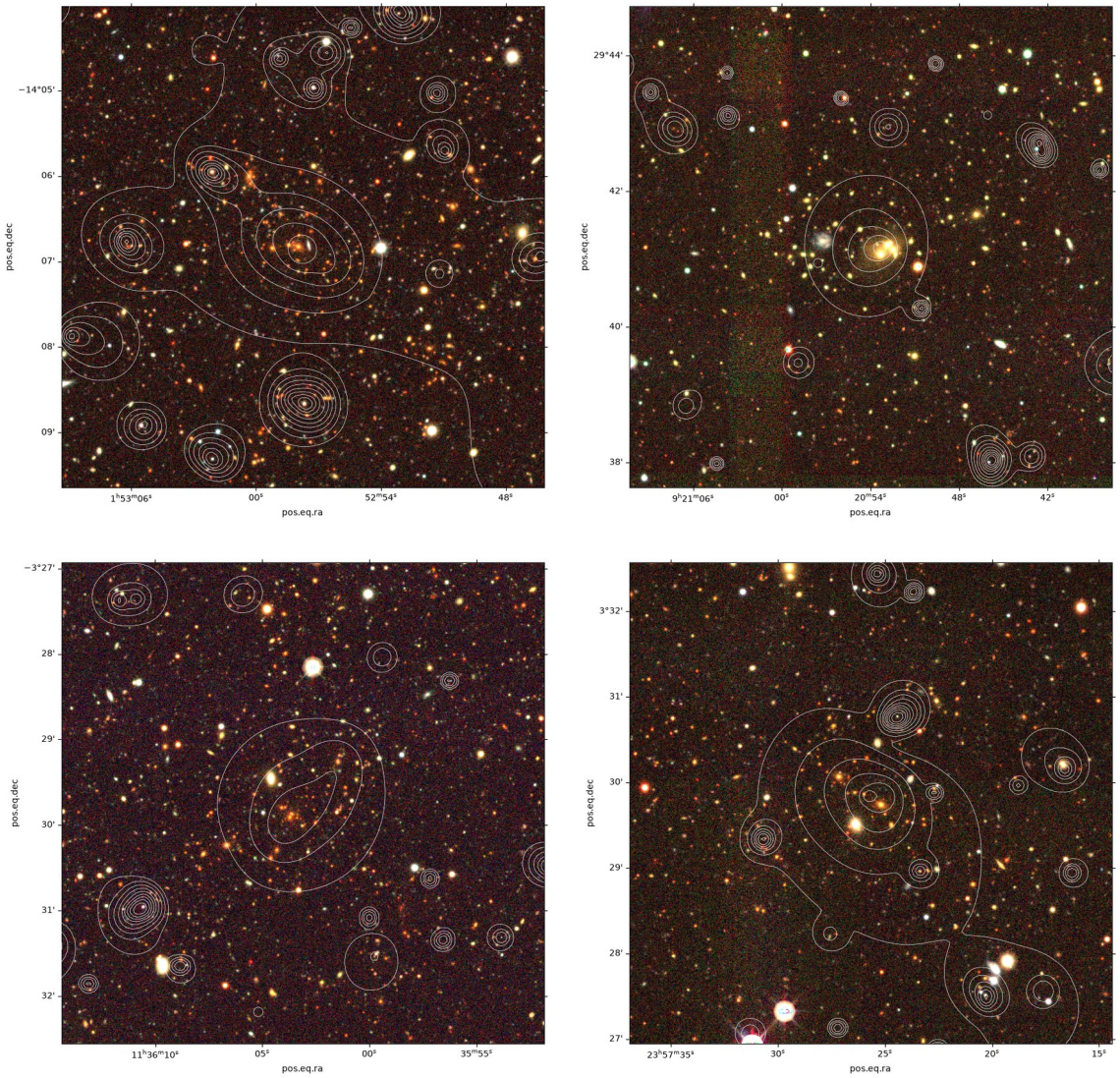
- **‘Clean rather than exhaustive’**
  - Ensure ability to derive a selection model



Previous experience: X-CLASS

- **A catalog of 1600 X-ray clusters** with XMM Newton archive and a selection function (Koulouridis+21)

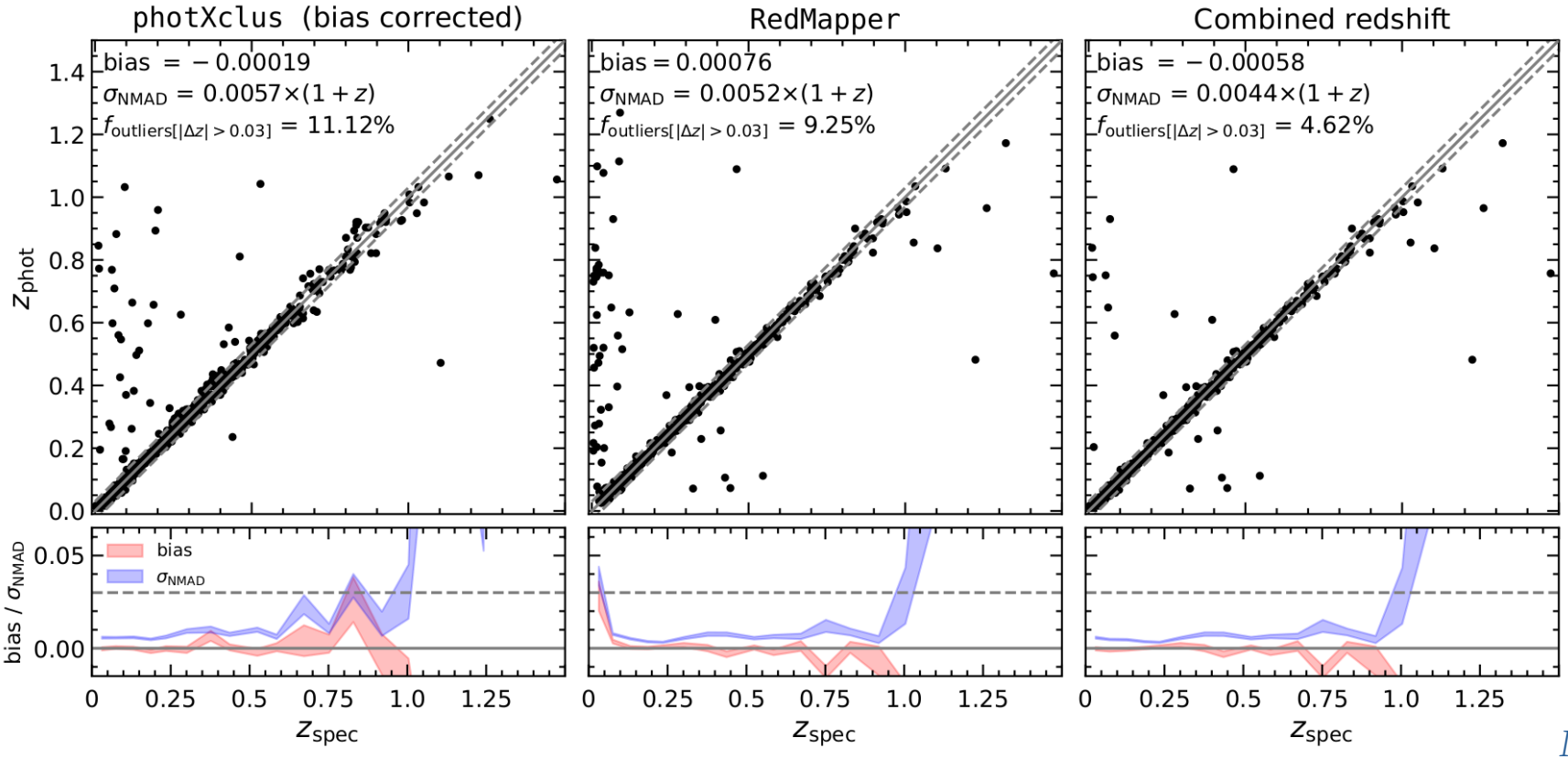
- **Redshift confirmation, analysis of subsamples** (Molham+20; Kosiba+; Moysan+26; Drigga+, Soucail+...)



Redshift assignment in X-CLASS

- **Combining 2 algorithms exploiting Legacy Surveys DR9 & DR10**
  - PhotXClus: photo-z based (*Florian Sarron*)
  - RedMapper: red-sequence based

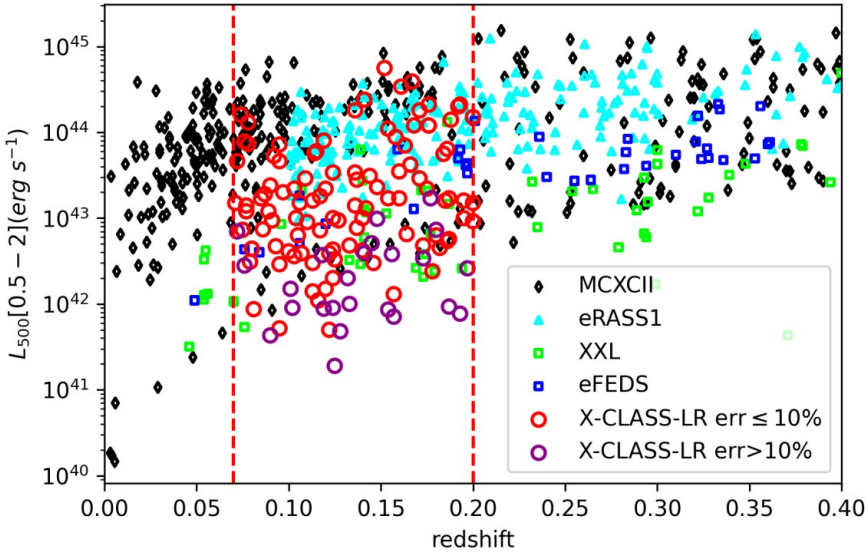
- **Quality flags** for each cluster photo-z

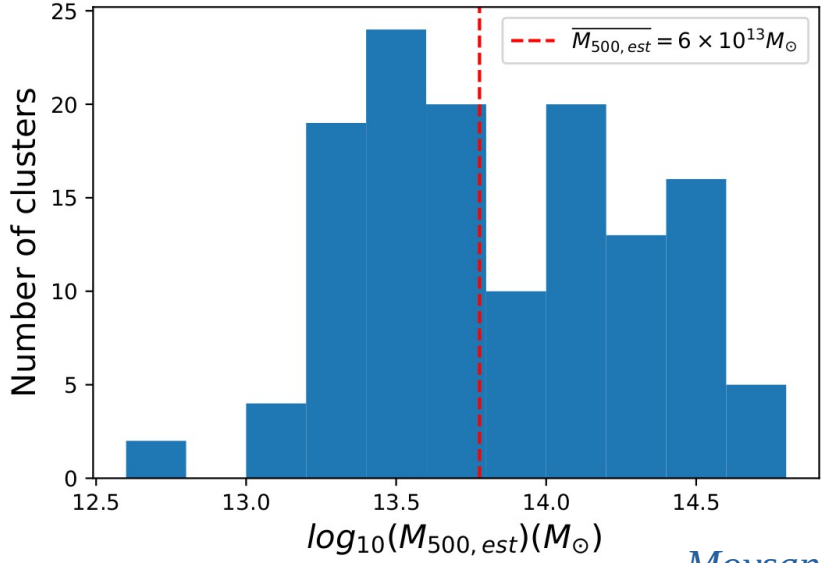


Moysan+26

The X-CLASS ‘low-z’ sample

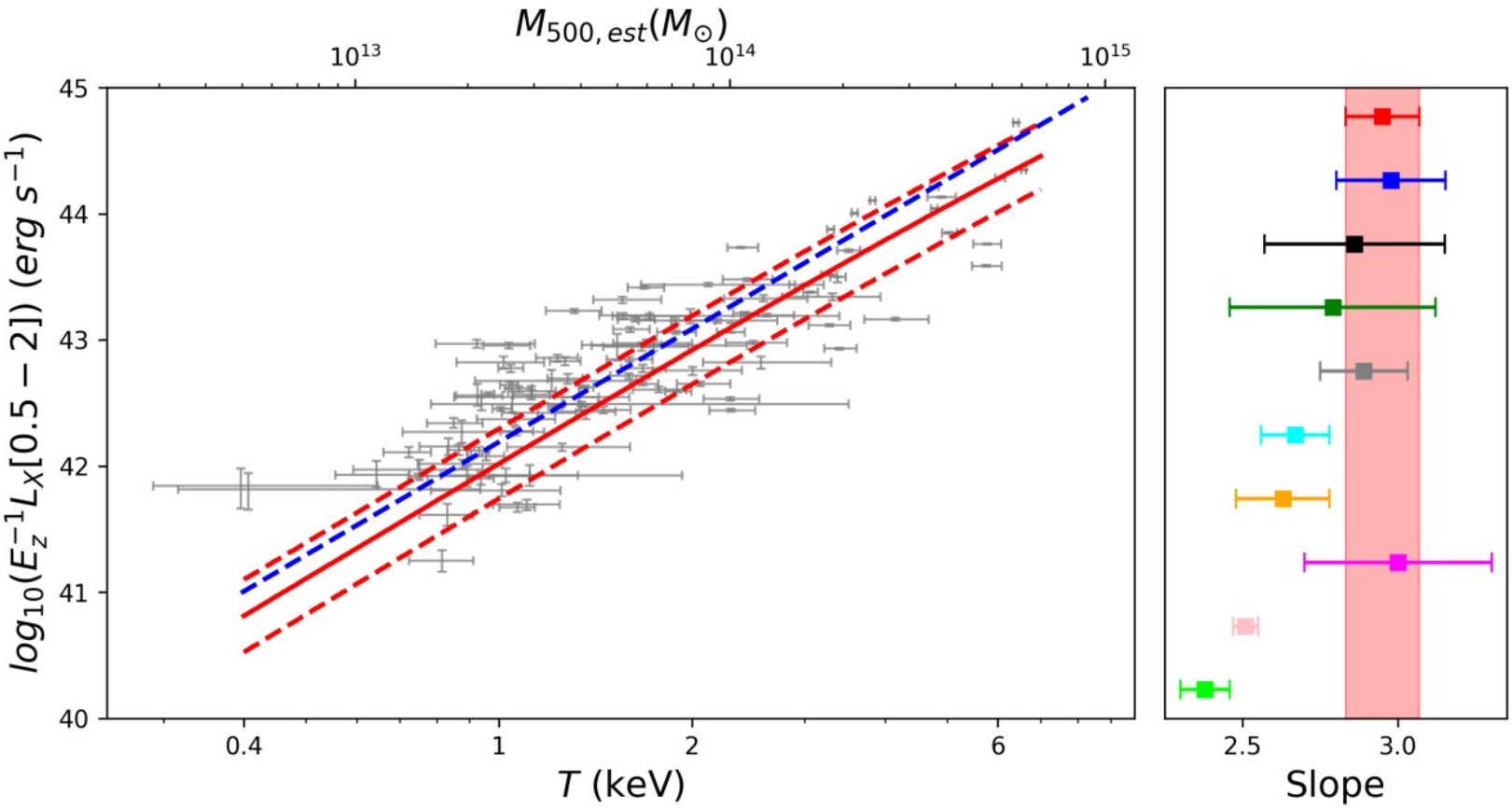
- A subsample of X-CLASS **155 clusters** with 0.07<z<0.2
- **Complete in redshift** [northern hemisphere only]
  - Selection function is entirely under control
- Characterization of ICM quantities: gas temperature, luminosity, M_{gas}.
- Estimate of M_{500} from temperature-mass relation





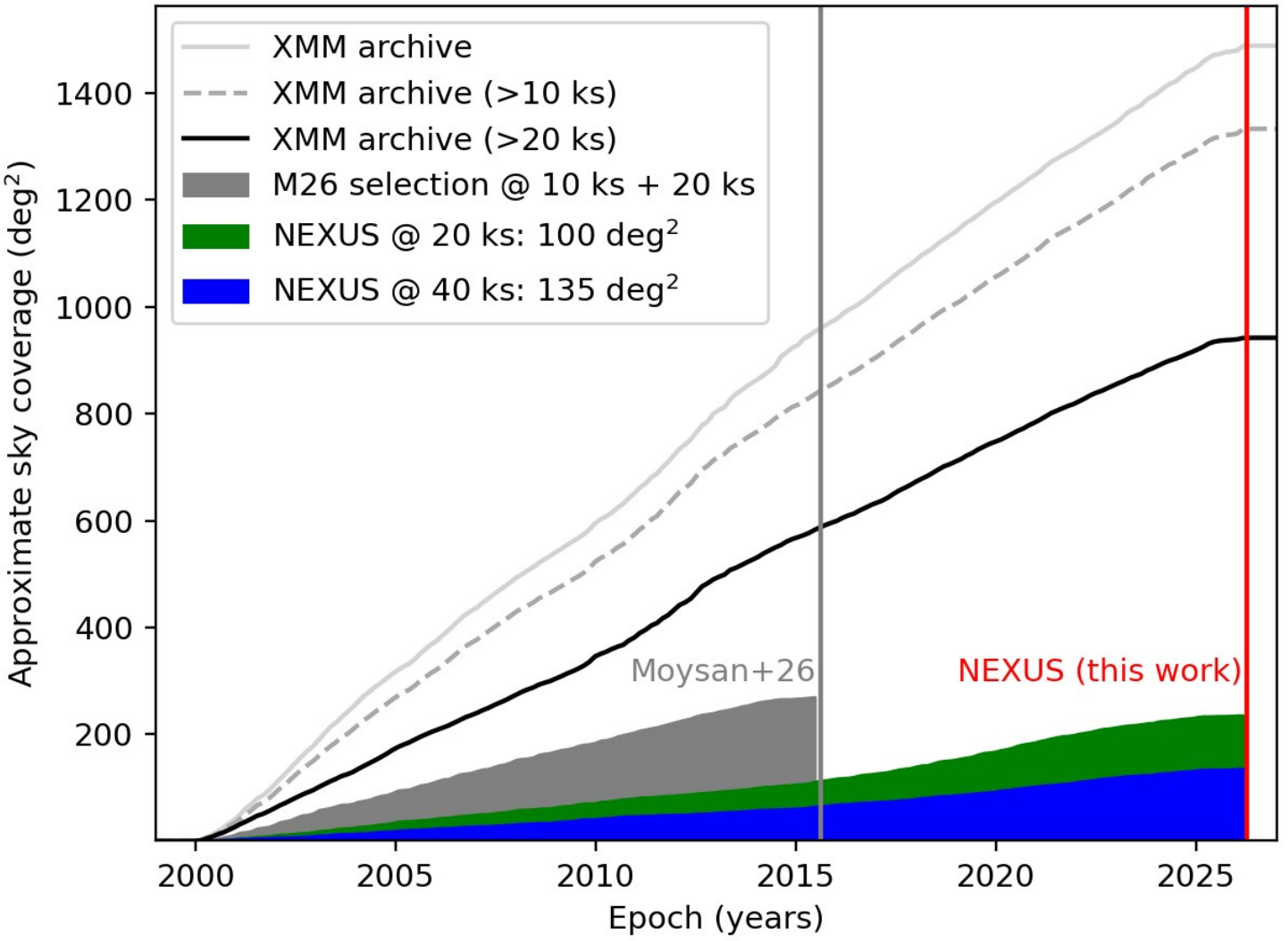
Moysan+26

L_X-T_X relation in the X-CLASS low-z



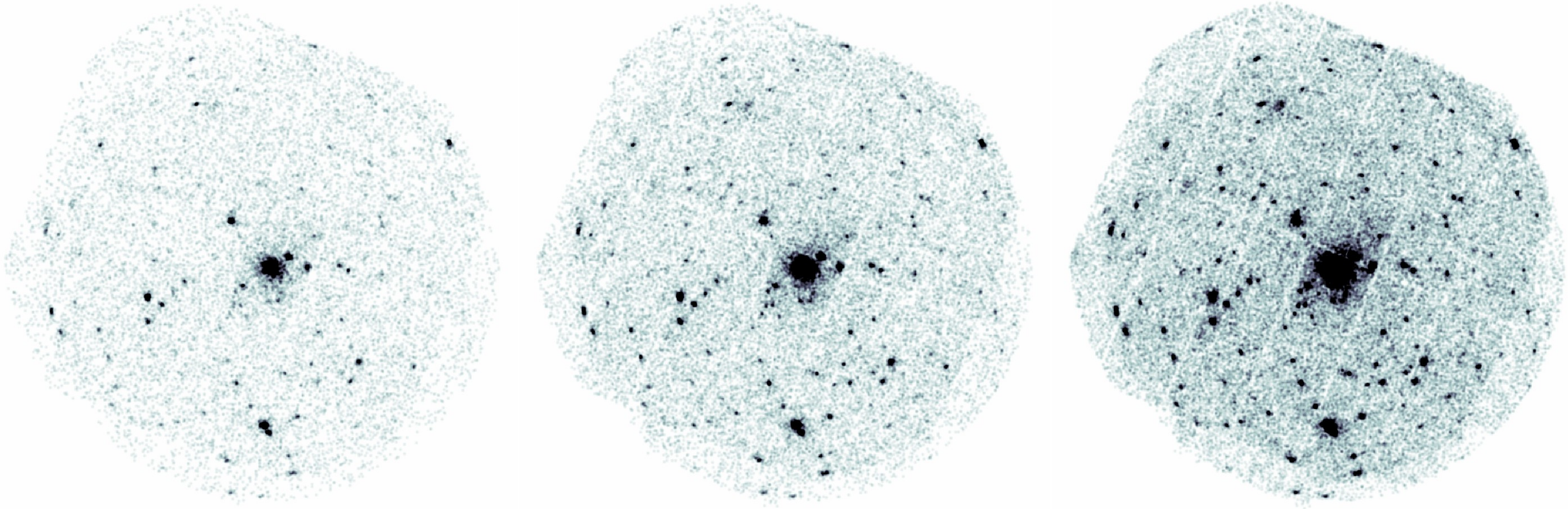
Moysan+26

NEXUS is **2x as deep** as X-CLASS



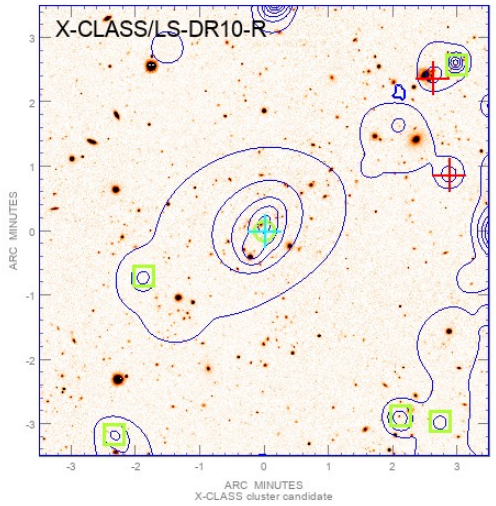
Illustrating 2x depth

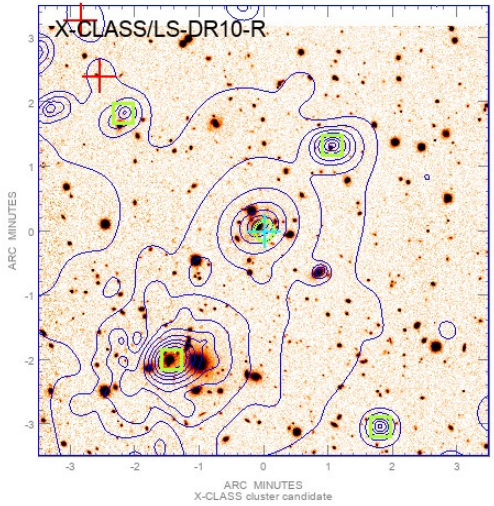
- X-ray observations are time-stamped = photon-counting detectors
- Cut all observations to 20ks and 40ks exactly → **selection function control**

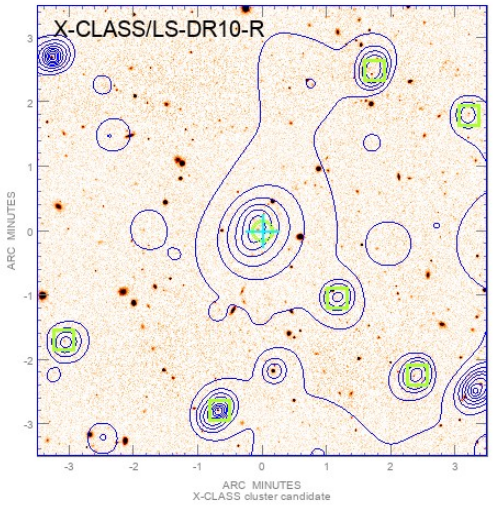


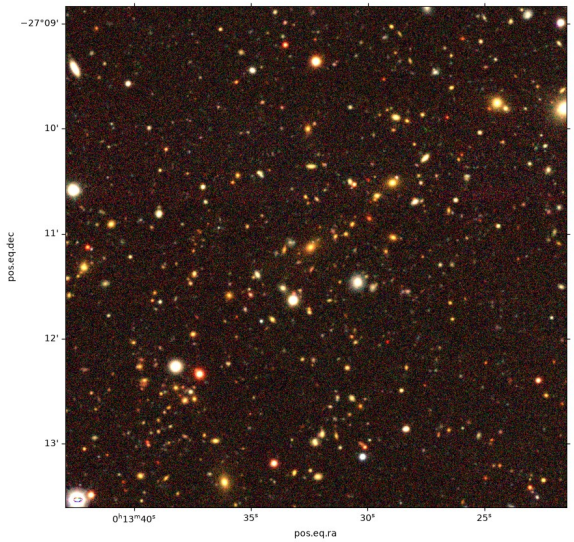
	10 ks	20 ks	40 ks
X-CLASS	130 deg^2	140 deg^2	ø
NEXUS	ø	100 deg^2	135 deg^2

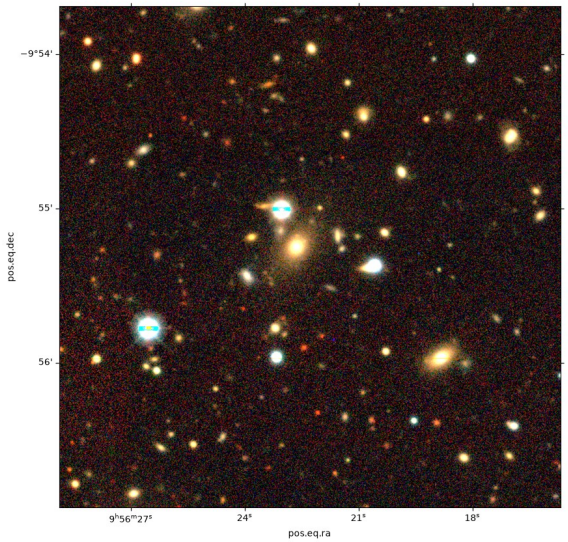
Some output from NEXUS 40ks test run

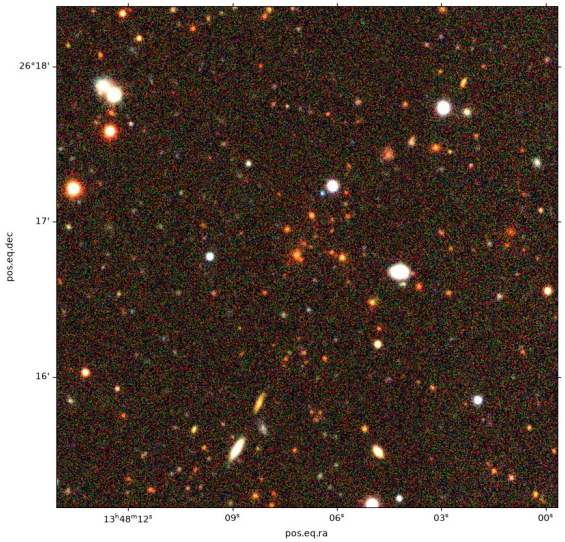






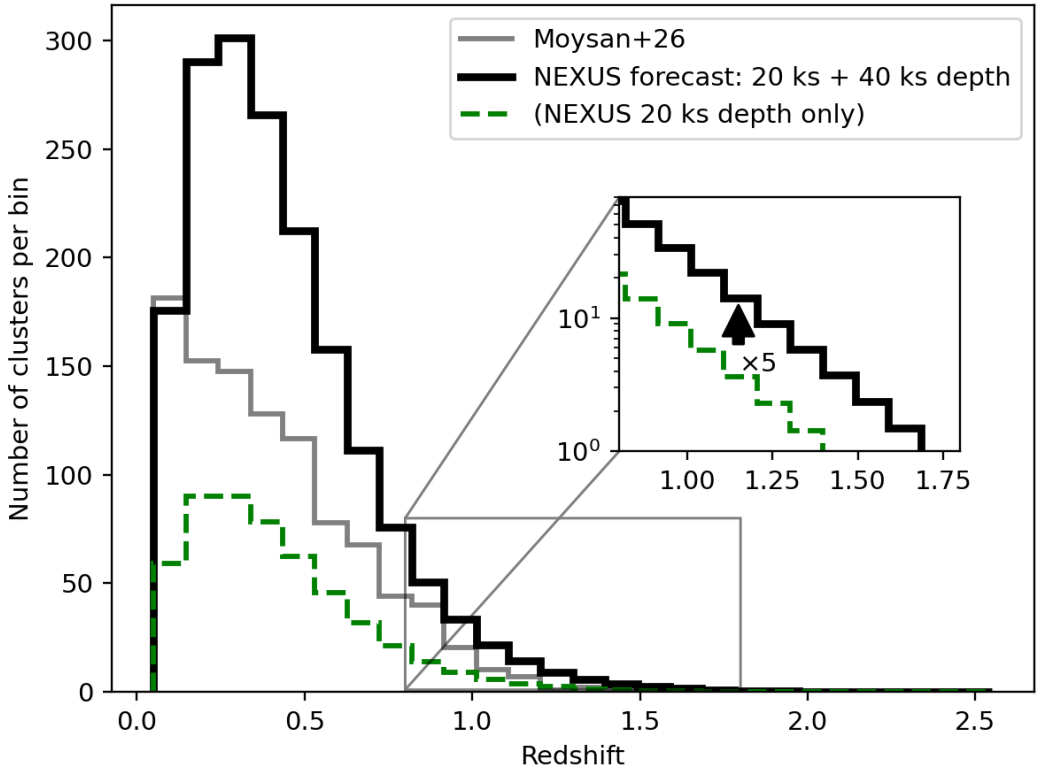






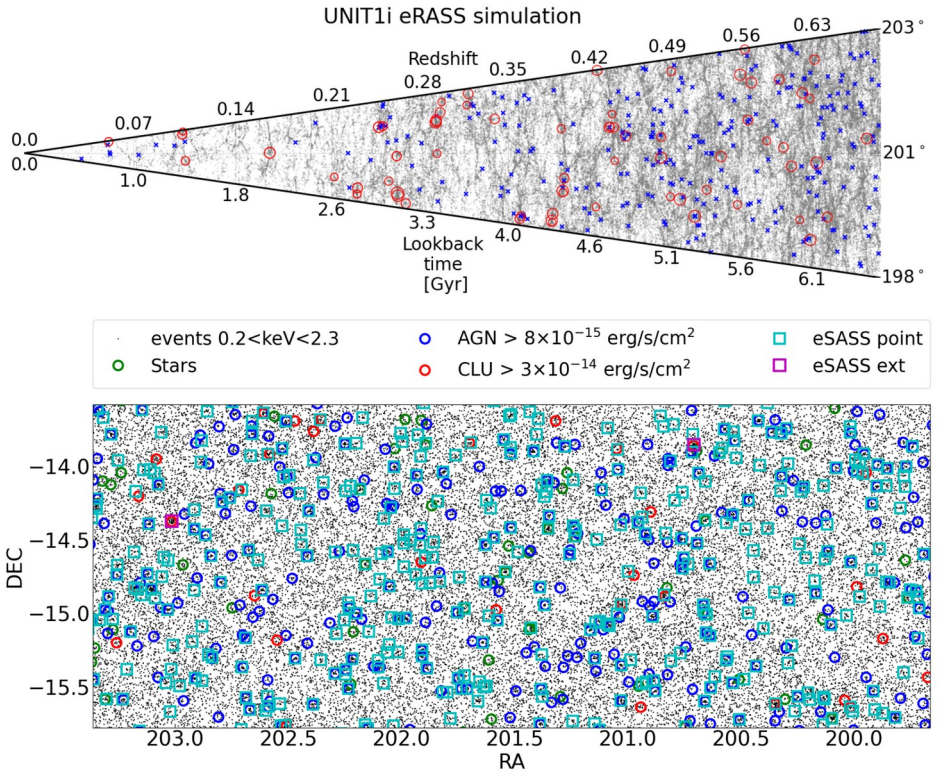
NEXUS depth: low-mass and high-z

- **Requirement:** ability to monitor selection function
- **Trim** exposures **20ks** and **40ks**
  - NEXUS = 2 surveys in 1
- 40ks brings x5 improvement in number counts at high-redshift
- Forecast makes simplifying assumptions on selection function, need refinement



Selection function: plans

- **Use simulations of the extragalactic X-ray sky with realistic inputs**
  - This is already existing as an eROSITA project: J. Comparat
- Produce simulated XMM-Newton images and post-process with source detection pipeline
- Train/emulate with ML to build a selection model
- Construct similar models with Flamingo Hydro simulation



Seppi, Comparat, et al. (2022)

Catalog production: next steps

XMM archive analysis	*Started in 2026*	I. Valtchanov, D. Coia (ESAC)
Photo-z association (Legacy Surveys) + cleaning	*S1 2027*	G. Soucail, N. Clerc, J. Comparat (IRAP, LPSC)
Simulations and selection function	*S2 2027 + 2028*	J. Comparat, N. Clerc, E. Koulouridis + intern (LPSC, IRAP, NOA)
Euclid X-comparison	*2027, 2028*	R. Cabanac, S. Bhargava, G. Soucail (IRAP, Nice)

Topic	**Time scale**	**Expertise needed**
High-z confirmation	>2027	Proposals? Euclid/Roman?
Weak-lensing stacks	>2028	Lensing (large surveys)
Environment	>2028	Cosmic web reconstruction
Stellar mass content, ICL	>2027	Physics of galaxies, stellar content
ICM measurements	>2028	X-ray, ICM models, SZ
Data release	>2028	Data management
Comparison to simus	>2027	Simulation & data analysis
...	...	...

Structure of the collaboration

- Currently a draft MoU, including governance & guidelines:
  - Steering committee
  - Working groups
  - Project-based collaboration
  - Publication policy
  - Code of conduct
- Kick-off meeting planned in Spring 2027 (Toulouse)
- 2027 & 2028: all efforts on catalog production
  - Clearly a great time to step in!
  - Get used with the catalog to get most benefit for science
  - Contribute in key technical/infrastructure aspects

Conclusion

- NEXUS: new collaborative project
  - Focus: cluster/group astrophysics, baryonic feedback and structure assembly
  - ~230 deg^2 deep *XMM-Newton* archive. Methodology inherits from XMM-XXL and X-CLASS projects.
  - Thousands of clusters & groups up to z~1.5 with ICM characterization (density, temperature, profiles)
- Catalog construction starts now
  - Pipeline in place, optical association to begin soon
  - Good time to join with ideas and/or technical inputs
  - Kick-off meeting in Toulouse Spring 2027
  - *Contact: Nicolas Clerc / IRAP*

Thank you!