Synthetic observations of cosmological simulations of galaxy clusters

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Need for synthetic observations?

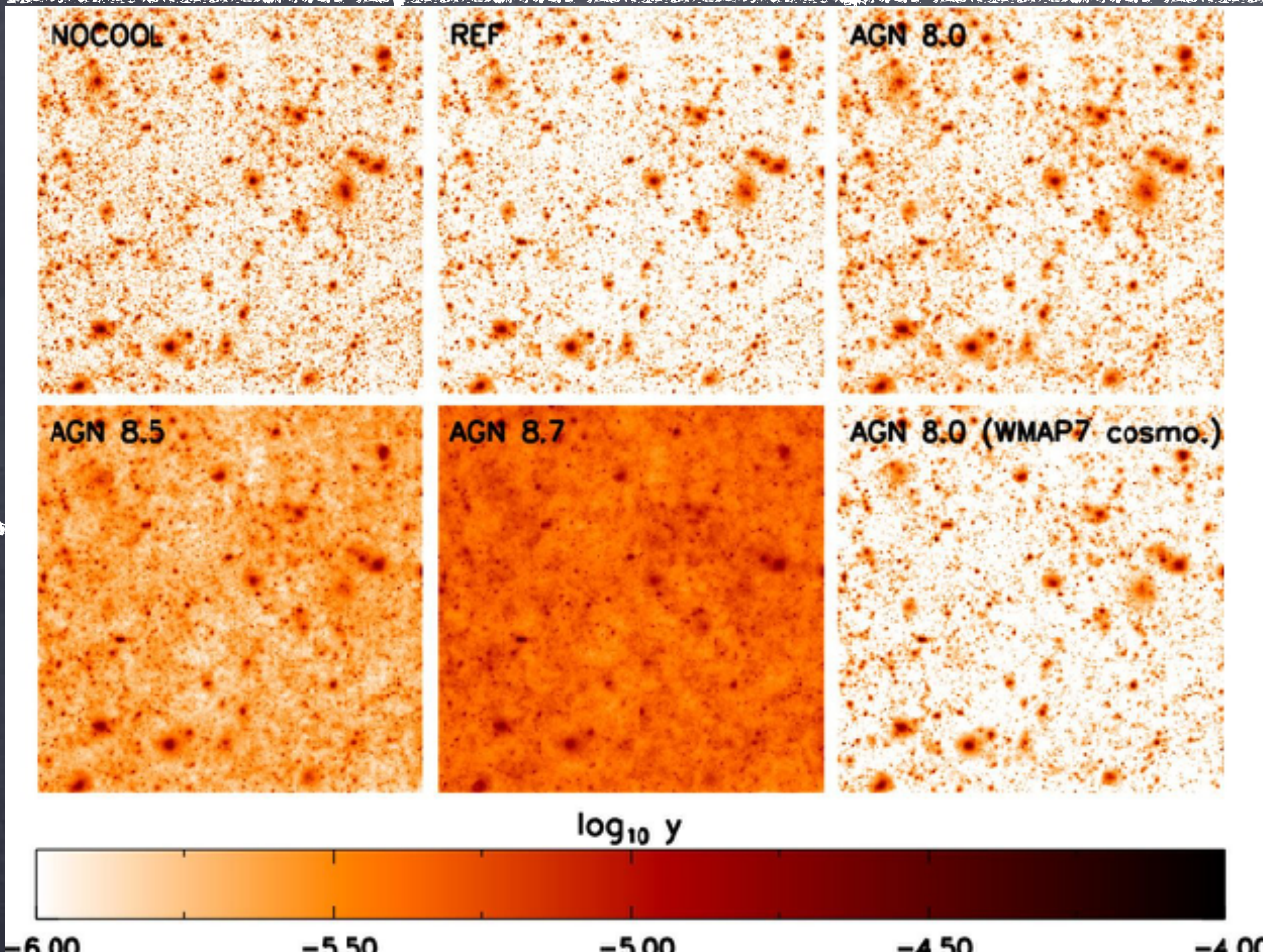
- Increased size and depth of surveys allowed for transition into the era of 'precision cosmology' where systematic errors are starting to dominate over the statistical ones.

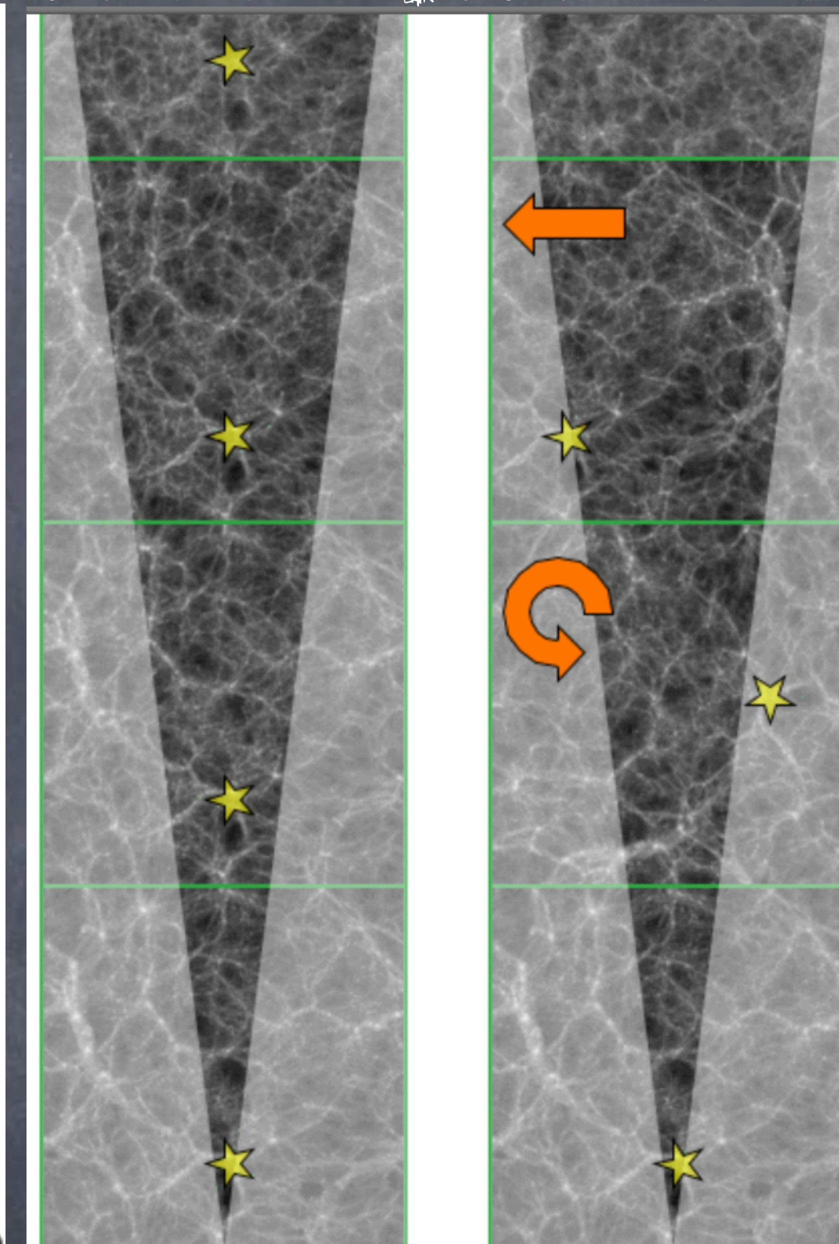
- Limiting systematics now comes from our incomplete knowledge of cluster physics, especially of its baryonic aspects, and of non-linear structure formation.

- Further progress requires the development of increasingly realistic theoretical models and the confrontation of synthetic surveys generated using these models with observational data sets.

Examples of synthetic surveys

McCarthy et al. 2014





Blaizot et al. 2005

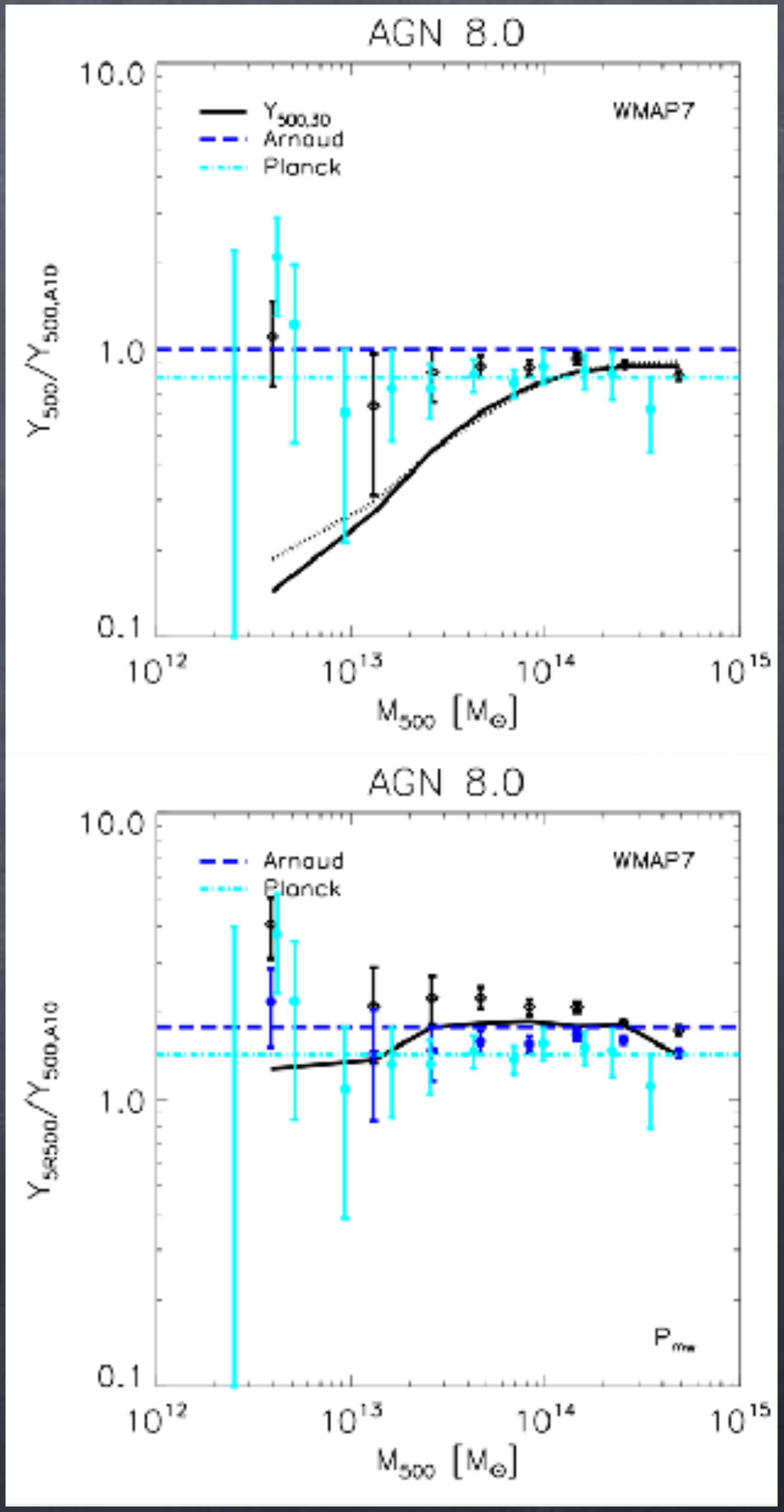
Developed light cone software using a method derived from the ones used by Blaizot et al. 2005 and Kitzbichler & White 2007. Except that it is applied to gas, star, BH and DM particles as well as groups and galaxies.

Applications of synthetic surveys

- Impact of baryonic physics and cosmology on the thermal Sunyaev-Zel'dovich power spectrum and comparison to the Planck results (McCarthy et al. 2014; see also Battaglia et al. 2012)

- Impact of baryonic physics and cosmology on the thermal Sunyaev-Zel'dovich-gravitational lensing cross-correlation and comparison to the detection of van Waerbeke et al. (Hojjati et al. 2014; see also Battaglia et al. 2014)

- Testing the Planck Sunyaev-Zel'dovich measurements of the hot gas content of dark matter haloes (Le Brun et al. 2015; see also Greco et al. 2015)



Le Brun et al. 2015

Applications of synthetic surveys

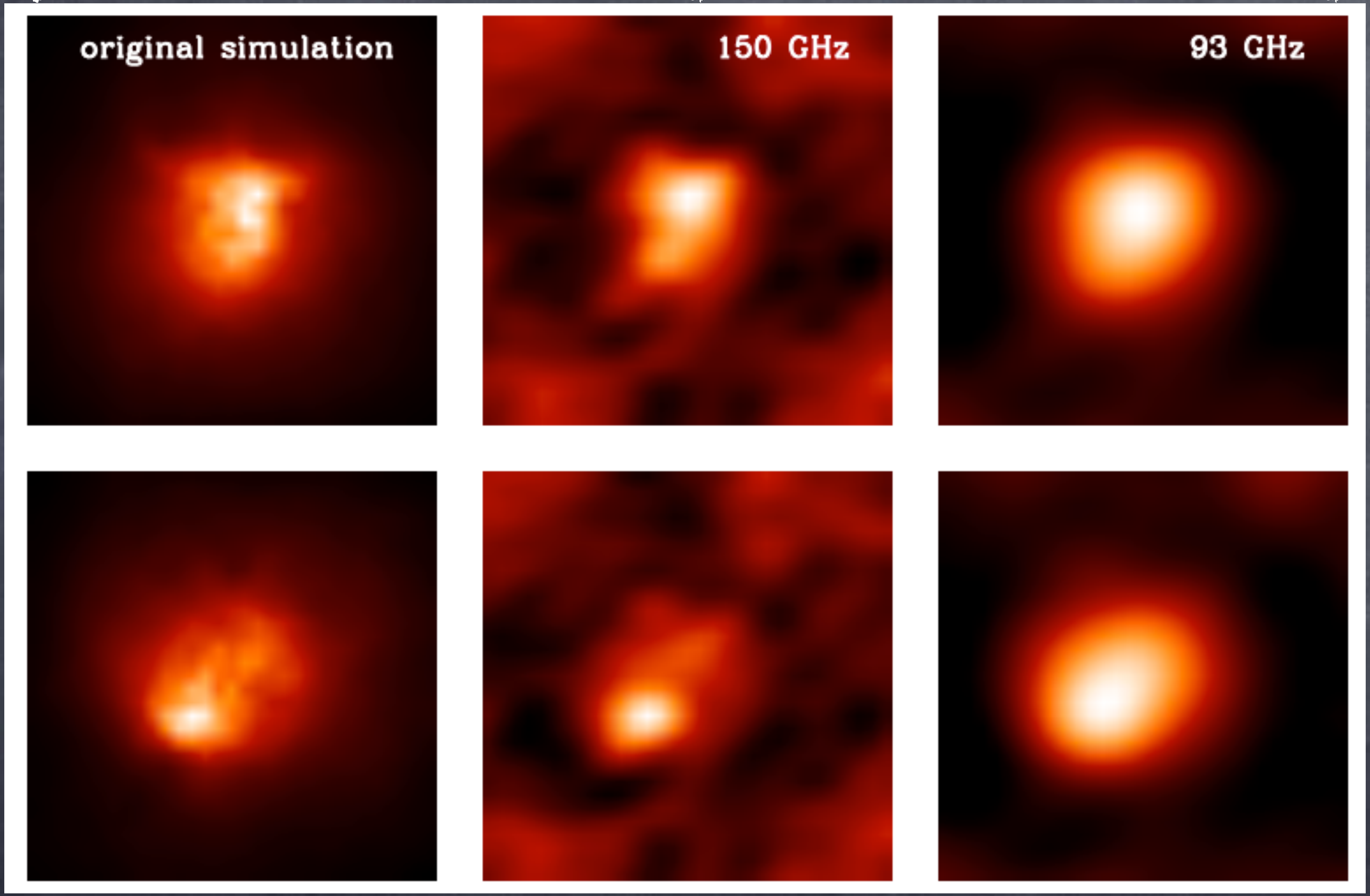
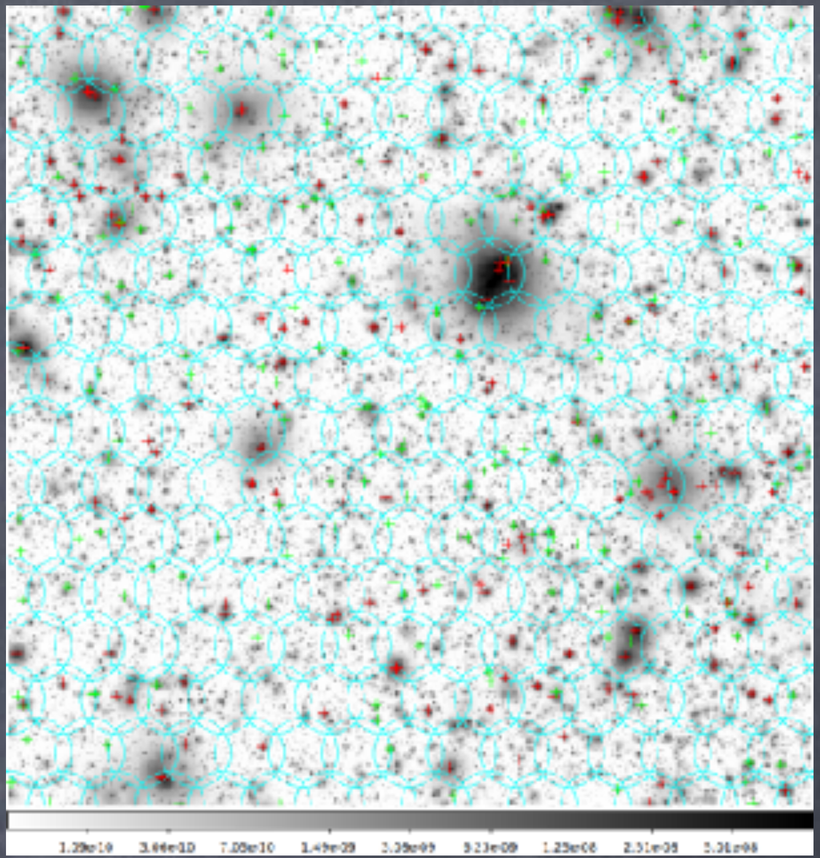


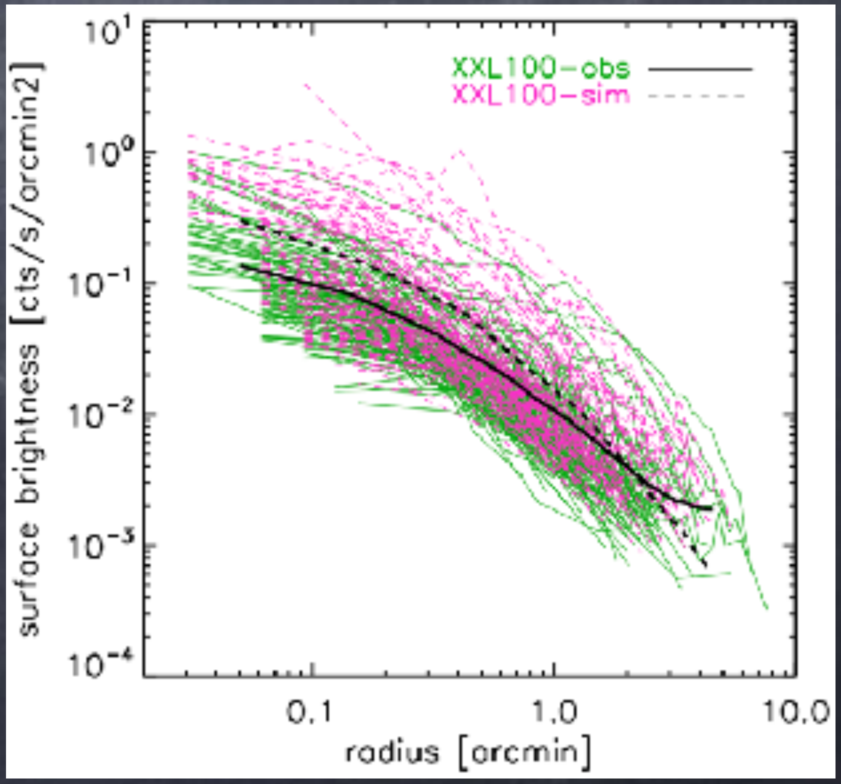
Figure courtesy of R. Gobat

Synthetic ALMA SZ observations of the Gobat et al. 2011 cluster for preparing and proposing the observations presented in Gobat et al. 2019.

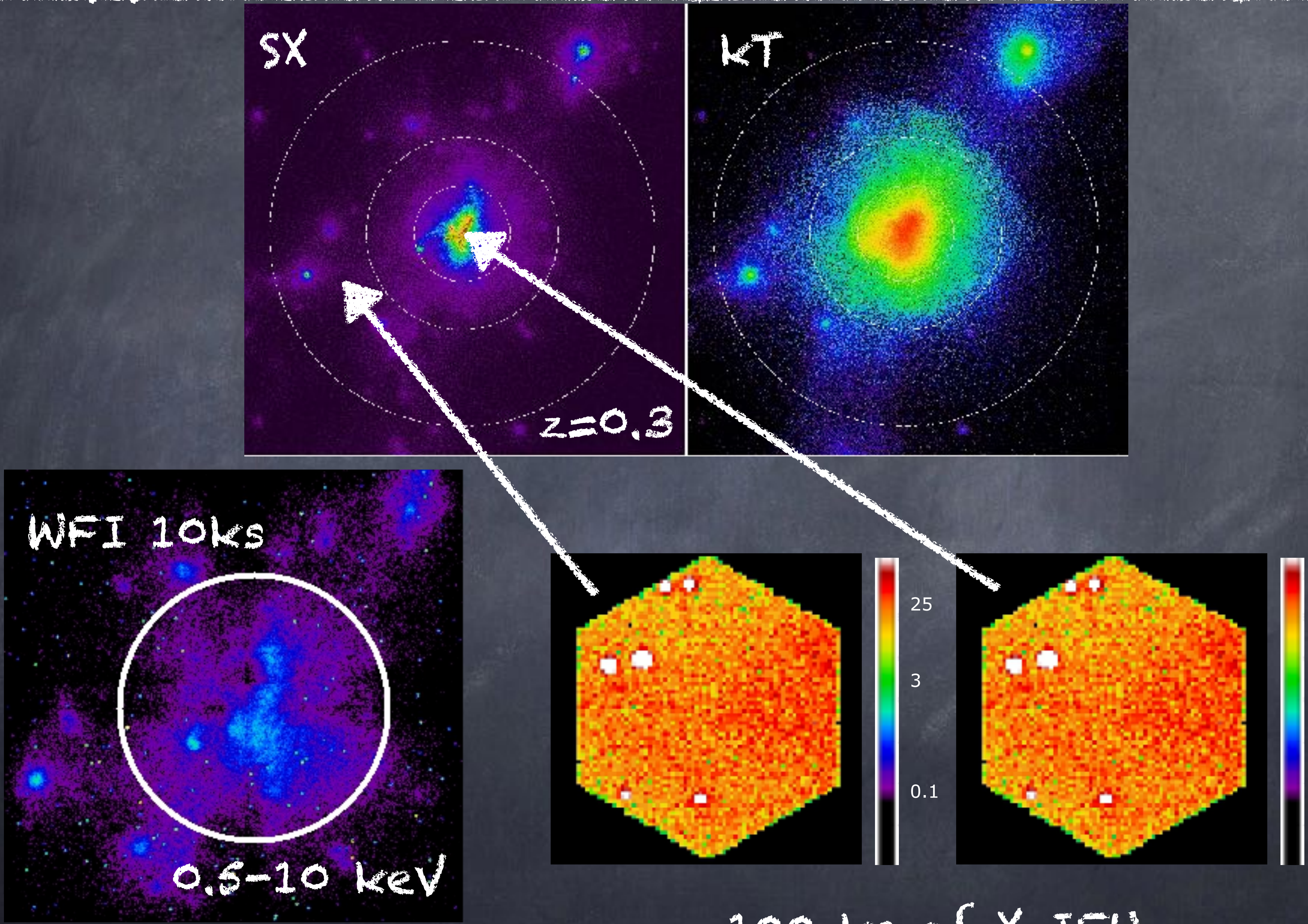
Applications of synthetic surveys

- Selection function of cluster surveys
- Comparison of physical properties of observed and simulated clusters selected by the same pipeline
- Predictions for future missions/surveys





Applications of synthetic surveys



100 ks of X-IFU

Figures courtesy of I. Baralucci

Applications of synthetic surveys

- Exploration of the role of non-thermal velocity amplitude in characterizing cluster state and relation between observed X-ray properties (Biffi et al. 2014)
- (Understanding of) HSE bias (e.g. Rasia et al. 2012, Avestruz et al. 2014, Le Brun et al. 2014, 2017, Nelson et al. 2014, Henson et al. 2017, Pearce et al. 2020, Barnes et al. 2020)
- Tests of morphological and dynamical indicators (e.g. Chon et al. 2016, Cialone et al. 2018)
- Many many others

Some (publicly) available tools

- PHOX (X-ray photon simulator; Biffi et al. 2012) is now implemented (ZuHone et al. 2016) in the yt (yt-project.org) simulation post-processing python package. This package also contains many other synthetic observations tools e.g. for SZ.
- MOCK-X (multi-wavelength synthetic observations generator; Barnes et al. 2020)

Conclusions

- Galaxy groups and clusters can be powerful astrophysical laboratories and cosmological probes.
- Limiting systematics in the era of 'precision cosmology' now comes from our incomplete knowledge of cluster physics, especially of its baryonic aspects, and of non-linear structure formation.
- Further progress requires the development of increasingly realistic theoretical models and the confrontation of synthetic surveys generated using these models with observational data sets.