



**INAFA OAS
BOLOGNA**



xmm-newton



Smithsonian Astrophysical Observatory

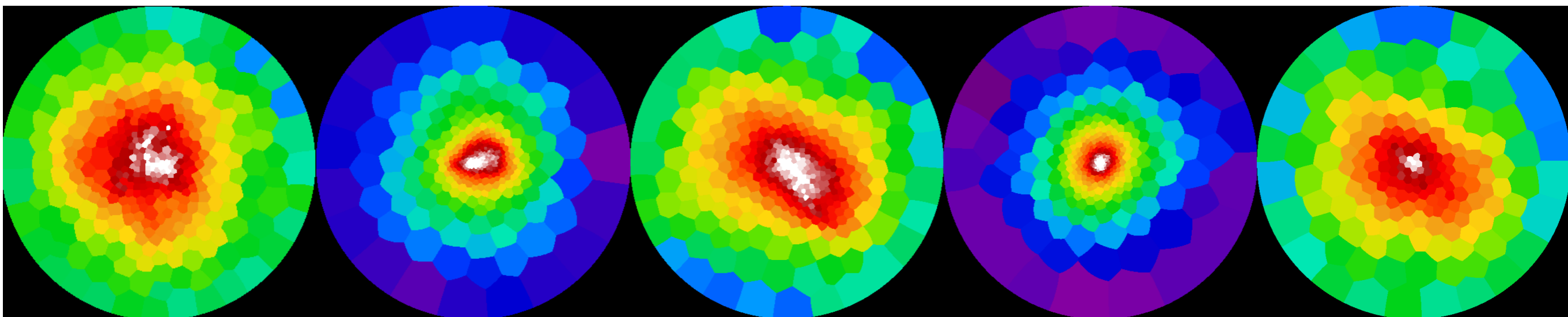
2D thermodynamic maps **dynamical state, scatter, and systematics**

L. Lovisari & S. Ettori

contributions by: **H. Bourdin, D. Eckert, F. De Luca, P. Mazzotta, M. Rossetti, F. Gastaldello, et al.**

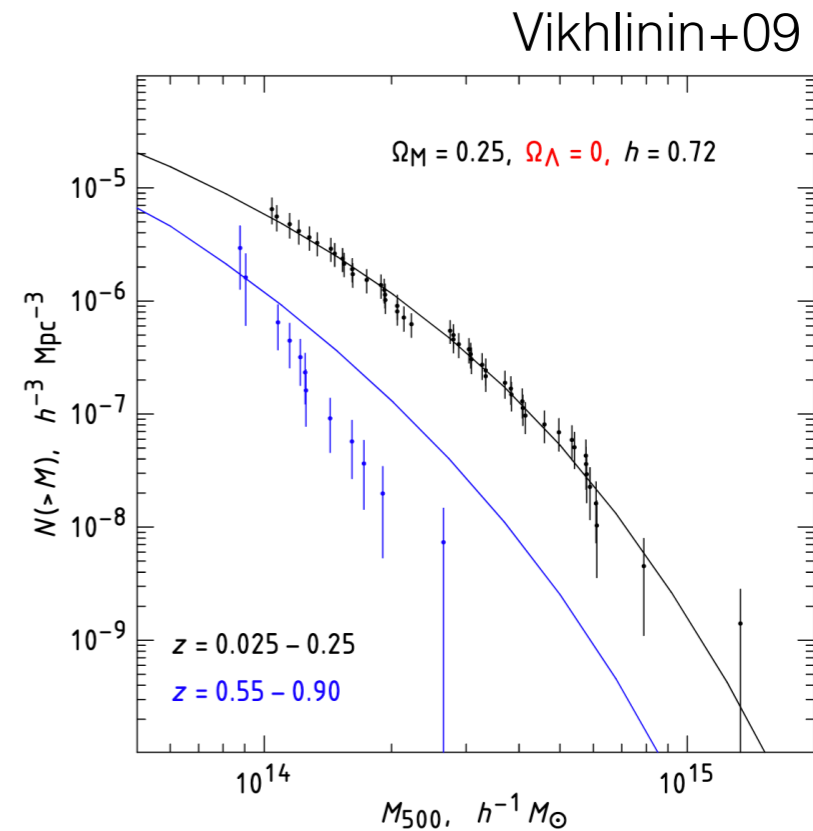
Observing the millimeter Universe with the NIKA2 camera

30/06/2021



Motivation

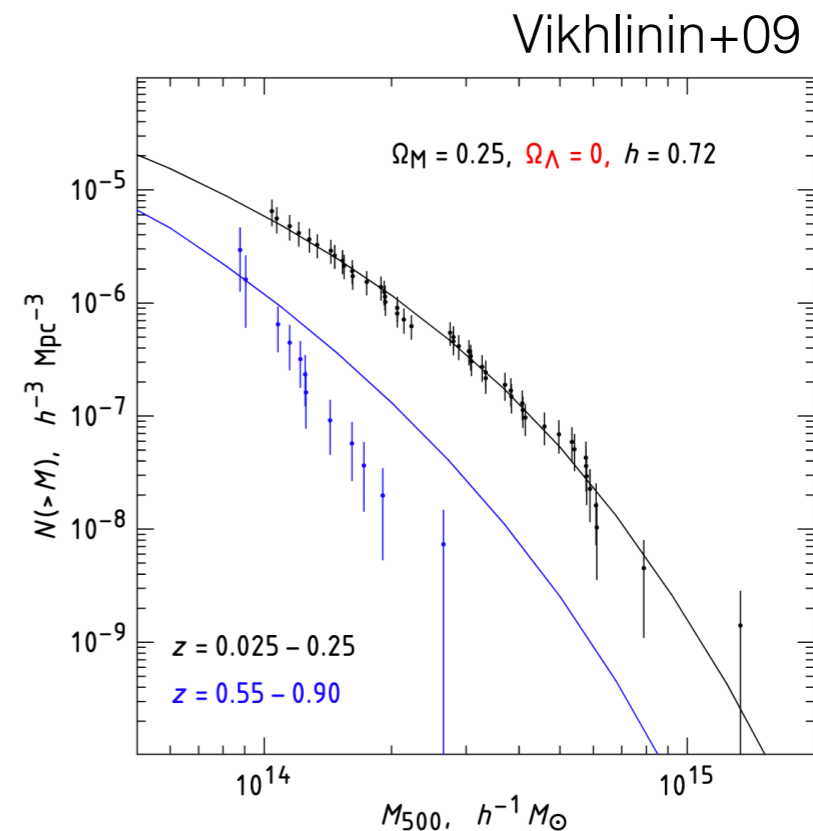
One of the key ingredients to use cluster number counting to constrain the cosmological parameters is a robust total cluster mass estimate.



the accuracy of X-ray cluster mass estimates is limited by physical processes in the ICM and projection effects

Motivation

One of the key ingredients to use cluster number counting to constrain the cosmological parameters is a robust total cluster mass estimate.



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Relate th HE mass bias to the dynamical state



Remove (any) dynamical state dependence of the bias

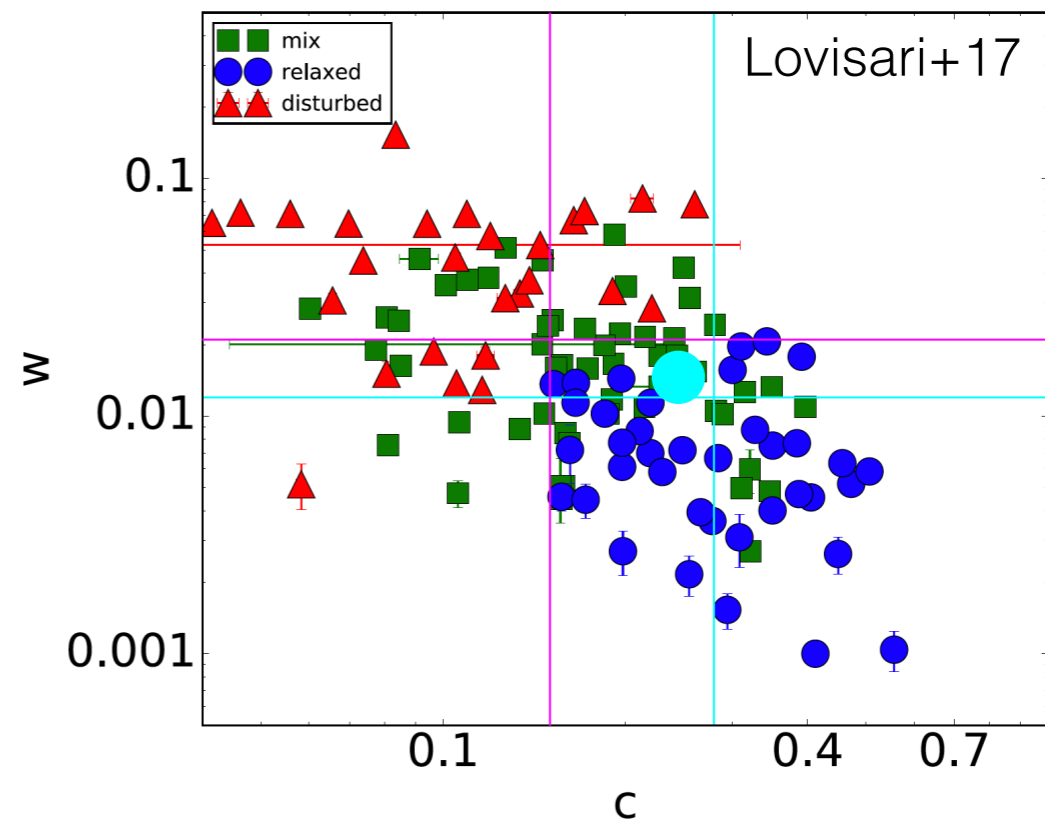
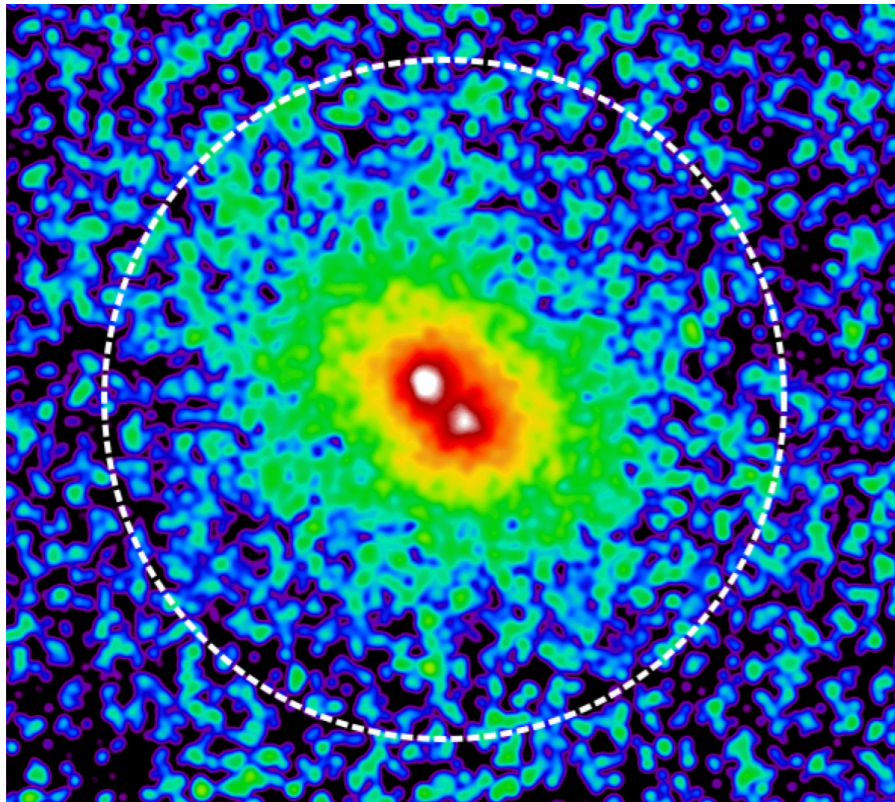
Dynamical state

Morphological parameters are very powerful (and cheap) tools to identify very relaxed and very disturbed systems (see next talk by Giulia)

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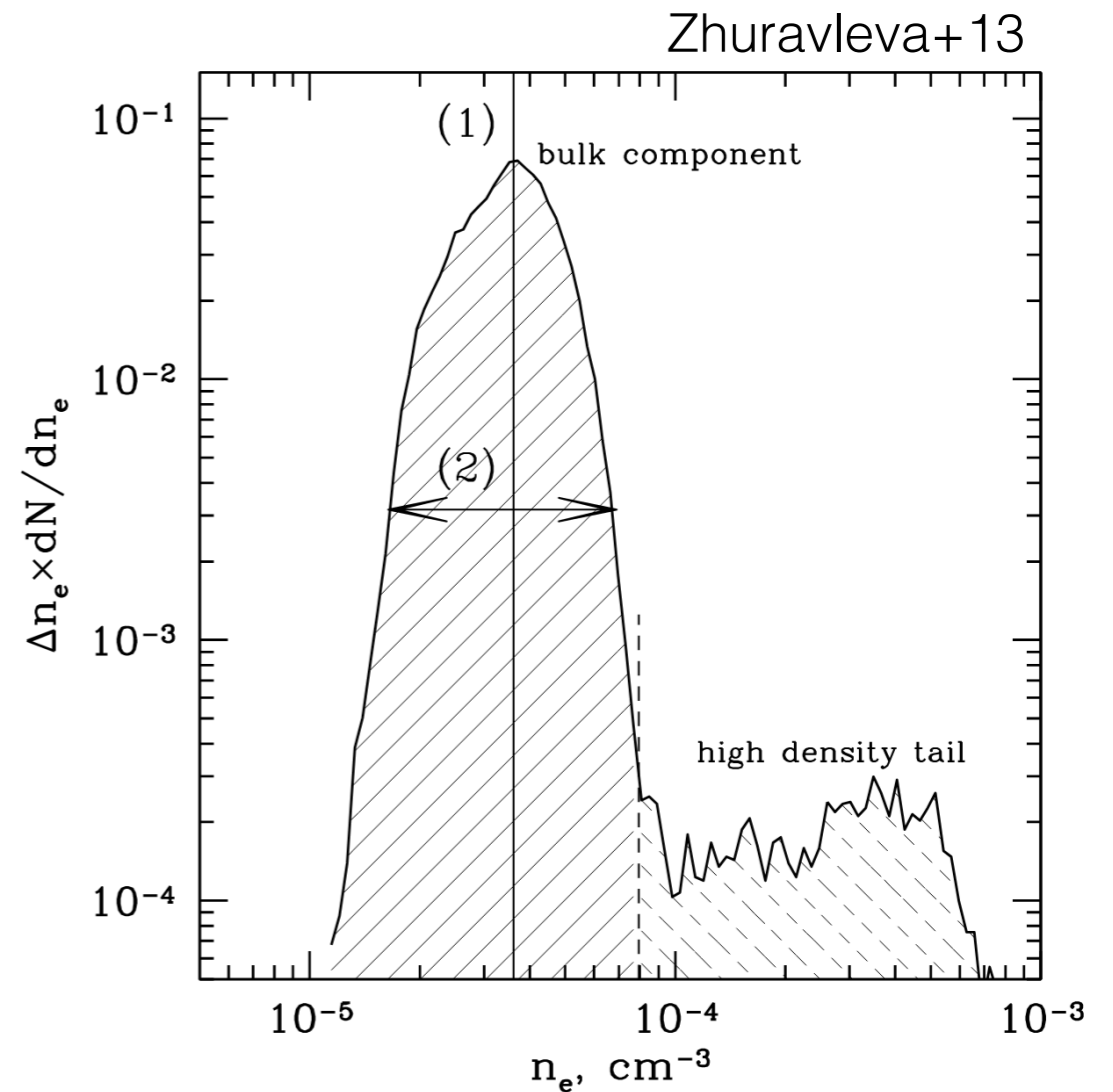
G036.72+14.92



Because of projection effects they are not a flawless indicator of the dynamical state of the cluster

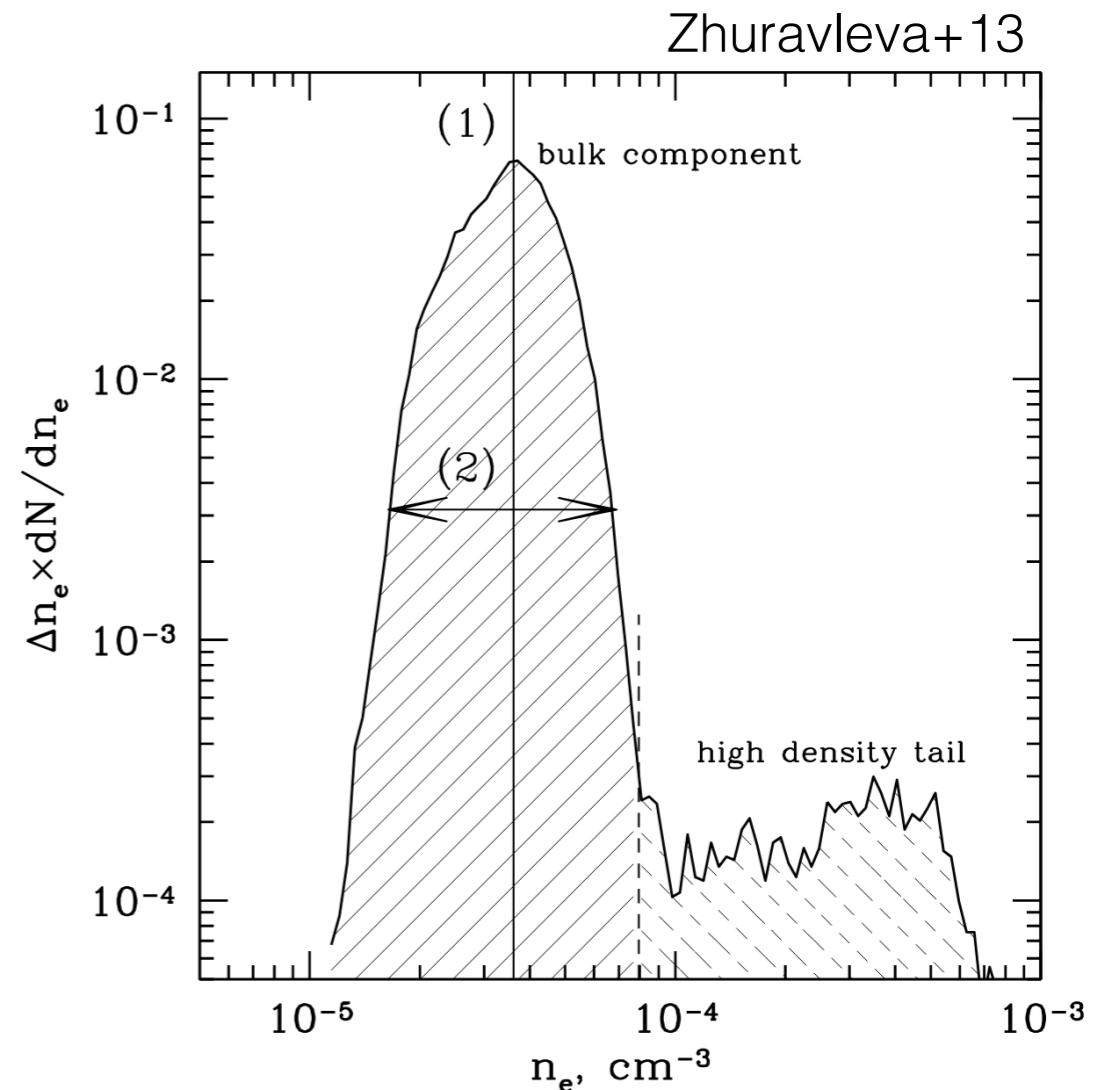
M_{tot} & ICM inhomogeneities

the presence of temperature and density inhomogeneities can cause biases in the determination of the azimuthal profiles (key inputs in the mass estimate from X-ray analysis), and so on the X-ray measured mass distribution.



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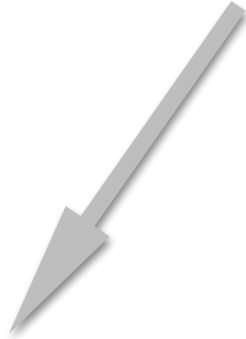


Can we remove the kT inhomogeneities and improve the cluster mass estimate?

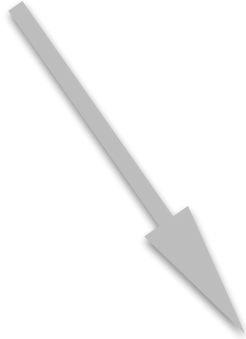
Spectral analysis

X-ray observations measure 2 key ICM observables

gas density & temperature



Density is trivial to obtain from X-ray imaging

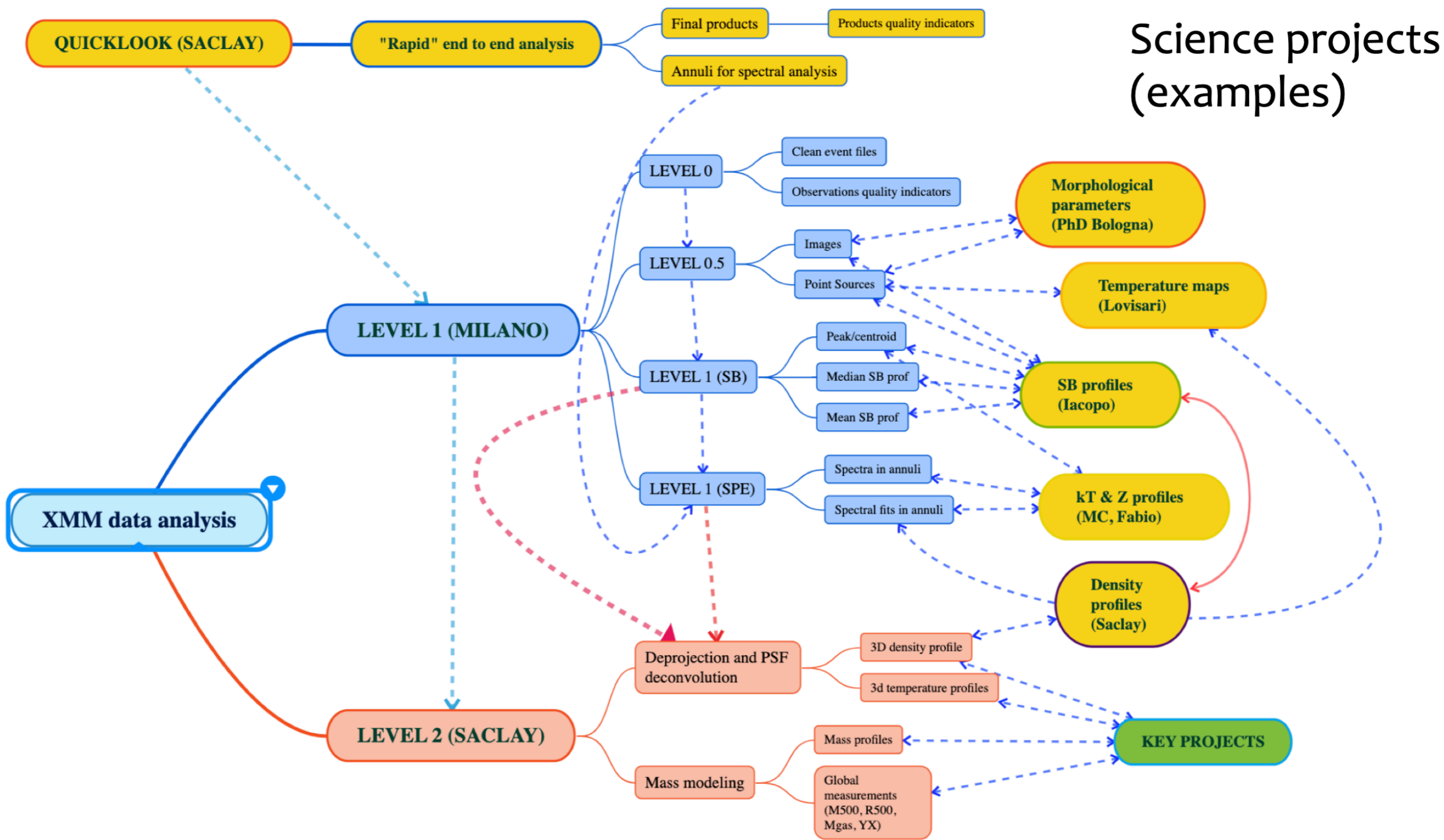


Temperature (and density) can be derived from an isothermal model fit to the spectrum.

Accurate temperatures are essential to infer cluster masses under the assumption of hydrostatic equilibrium

The temperature structure yields information on the detailed physics of shock-heated gas in merging events, the nature of cold fronts, and the role of turbulence and gas sloshing

CHEX-MATE pipeline



Science projects (examples)

CHEX-MATE strategy

There has been a large effort to identify and combine «best practices» from different X-ray groups and build a new optimized pipeline with several improvements (in particular on the bkg modeling)

Official pipeline for azimuthal profiles

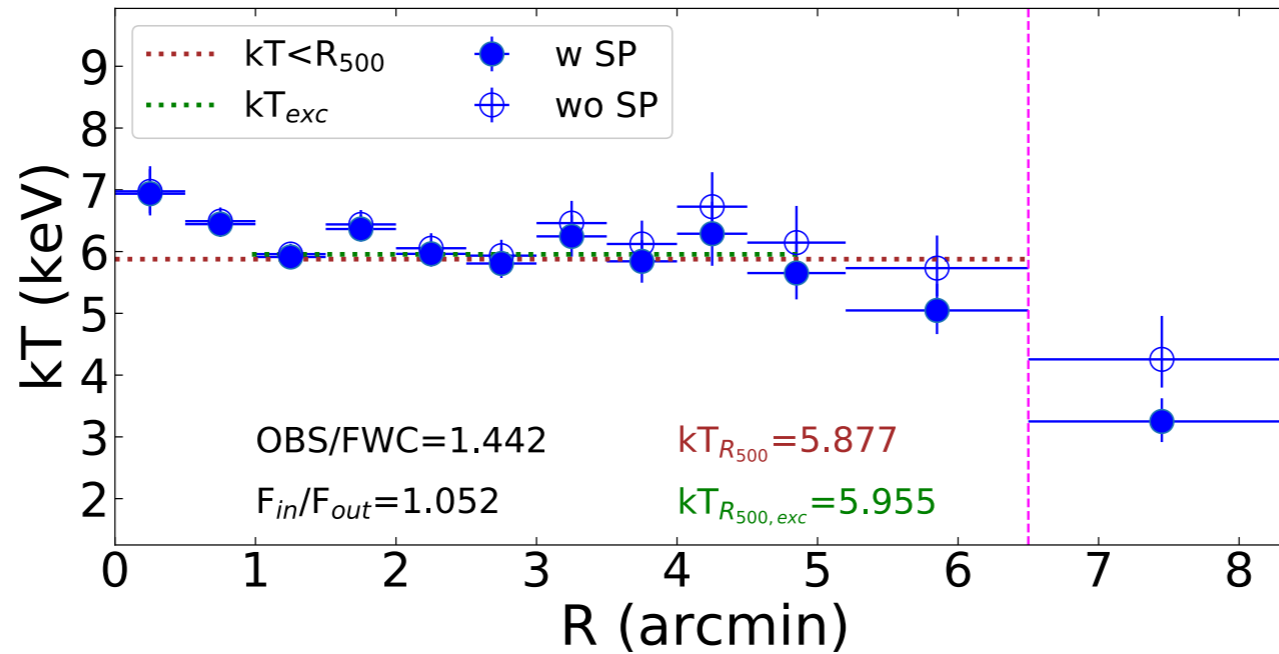
- **Radial binning**: based on X-ray SB profile and S/N criteria
- **Background Modeling**: fully predictive (include CXB+foreground, QPB, and SP modeling)
- **Fitting procedure**: Cstat (adapted to Poisson statistics) using an average ARF in the extraction regions, computed from observed counts/rates
- **Parameters setting**: Cosmology and astrophysical quantities (nH , redshift), Spectral model for absorption (phabs) and cluster (apec); Abundance table: **aspl** (Asplund+2009)

CHEX-MATE strategy

There has been a large effort to identify and combine «best practices» from optimized pipelines and the big models. I build a new pipeline in particular on

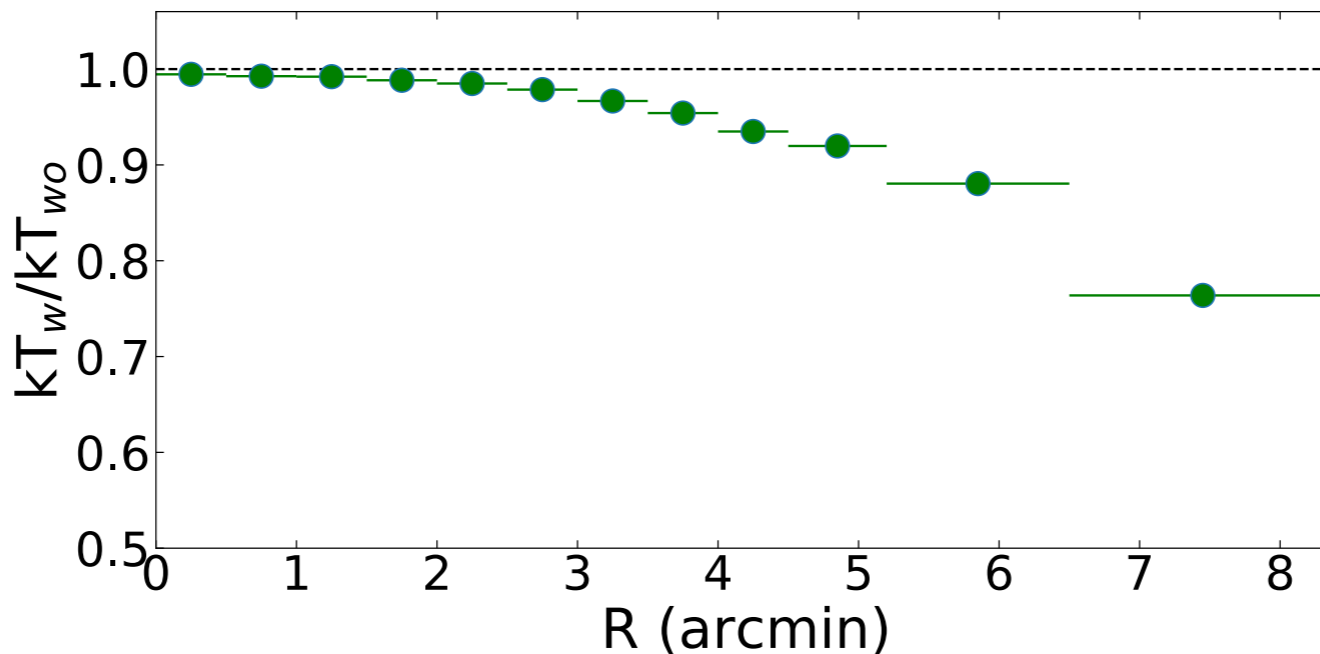
SP contribution

the big models



Official pipeline

- Radial binning
- Background subtraction (QPB, and S)
- Fitting procedure (average AR, counts/rates)
- Parameters (redshift), Sp Abundance



in particular on

criteria XB+foreground,

istics) using an from observed

al quantities (nH , and cluster (apec);

CHEX-MATE strategy

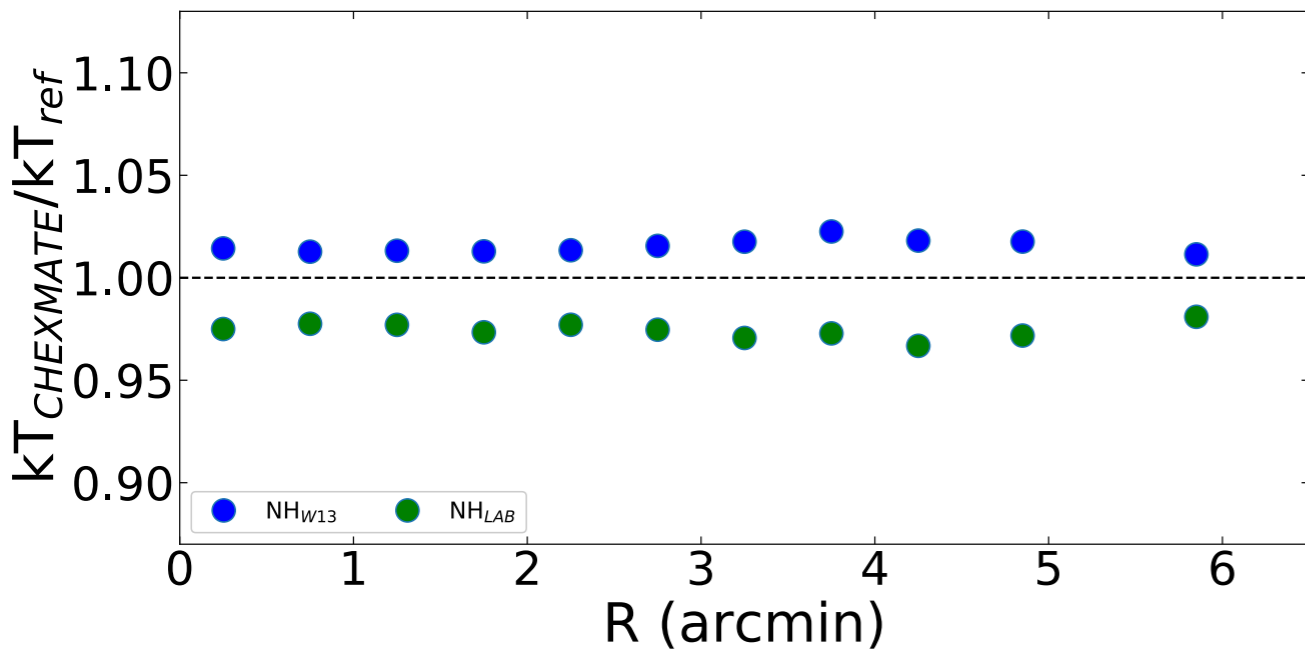
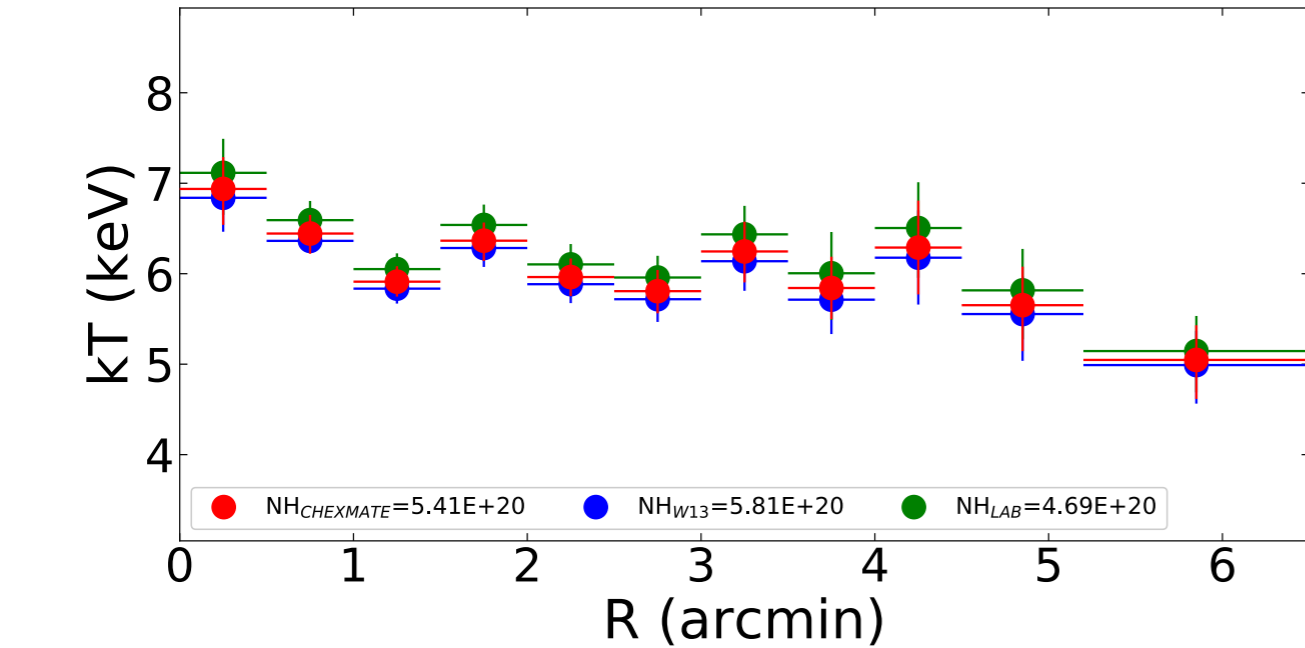
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CHEX-MATE strategy

NH effect



Abundance table: [aspl](#) (Asplund+2009)

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practise» groups and build a new
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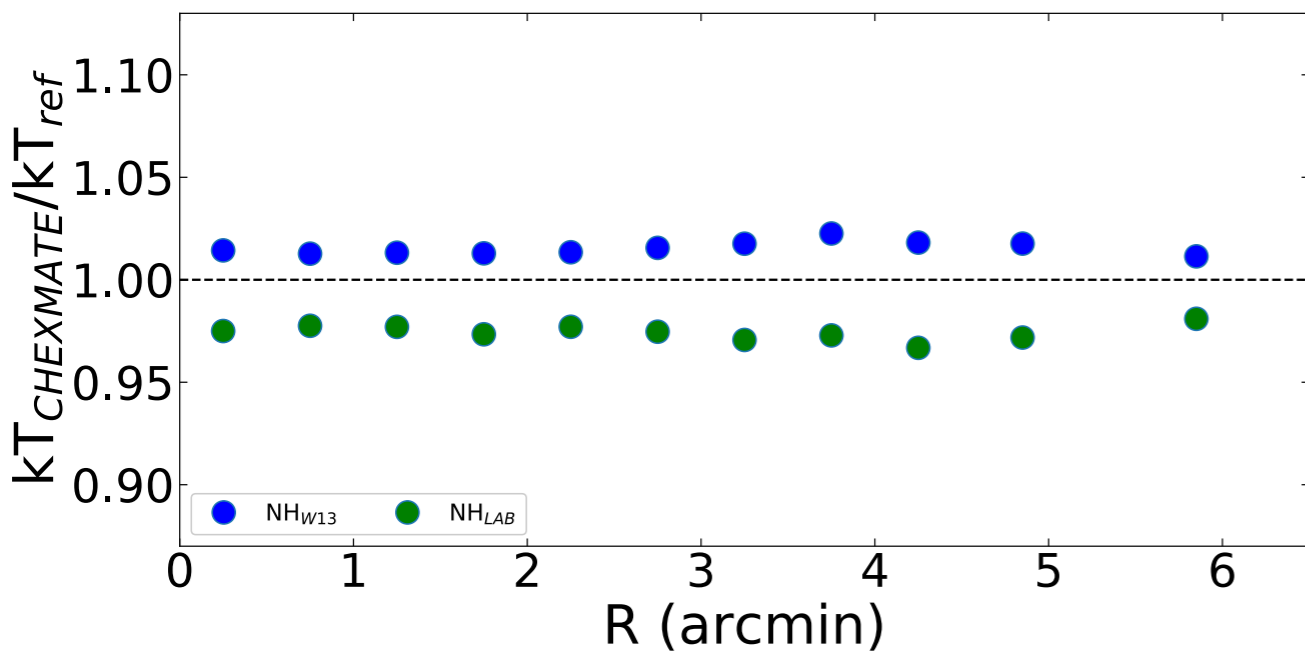
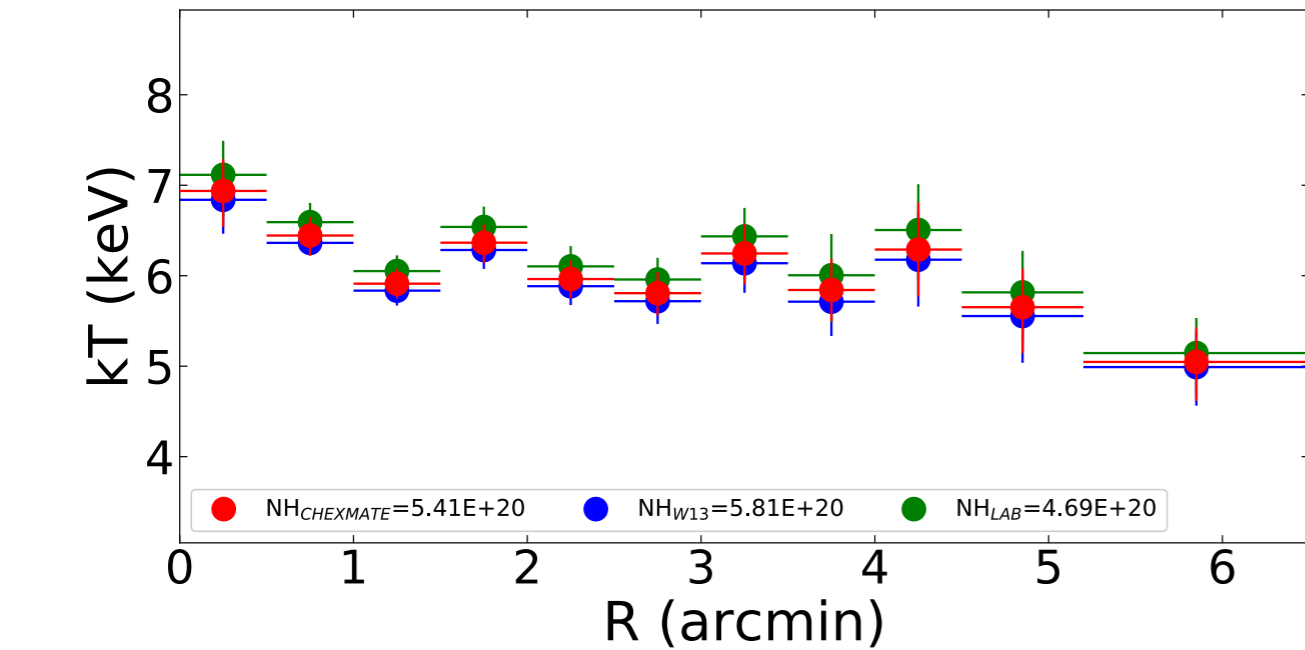
files

SB profile and S/N criteria
dictive (include CXB+foreground,
and to Poisson statistics) using an
regions, computed from observed

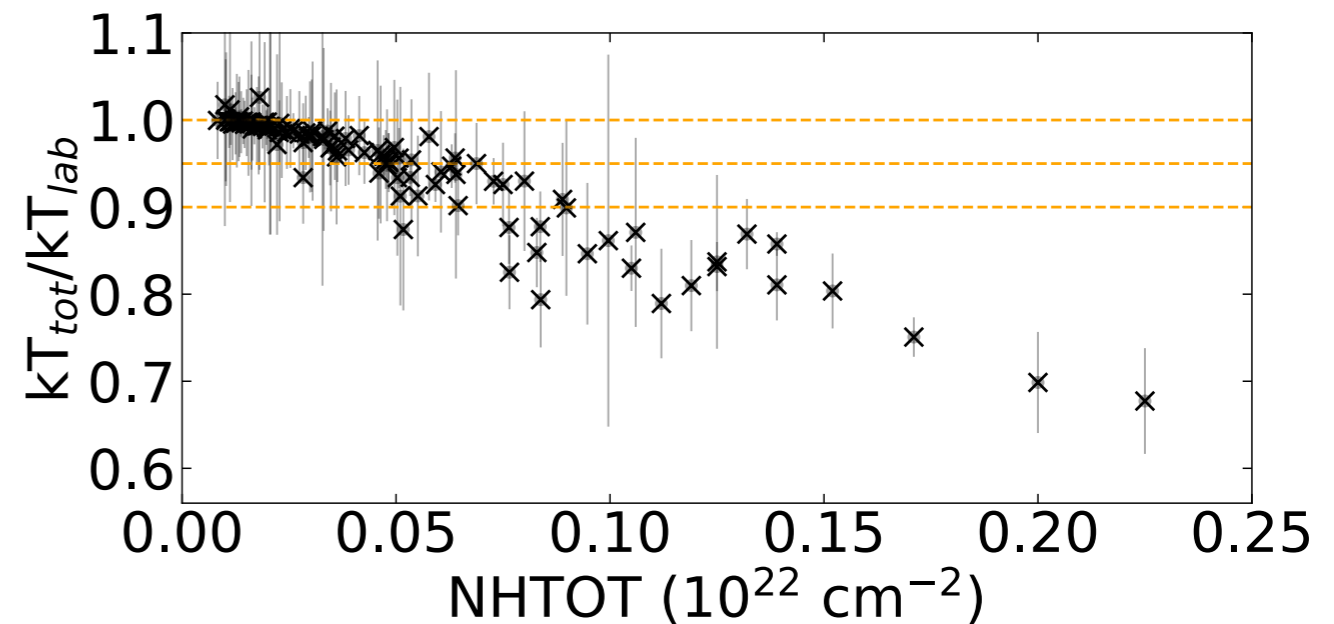
and astrophysical quantities (nH ,
absorption (phabs) and cluster (apec);

CHEX-MATE strategy

NH effect



There has been a large effort to identify and combine «best» groups and build a new improvements (in particular on



Abundance table: [aspl](#) (Asplund+2009)

2D analysis

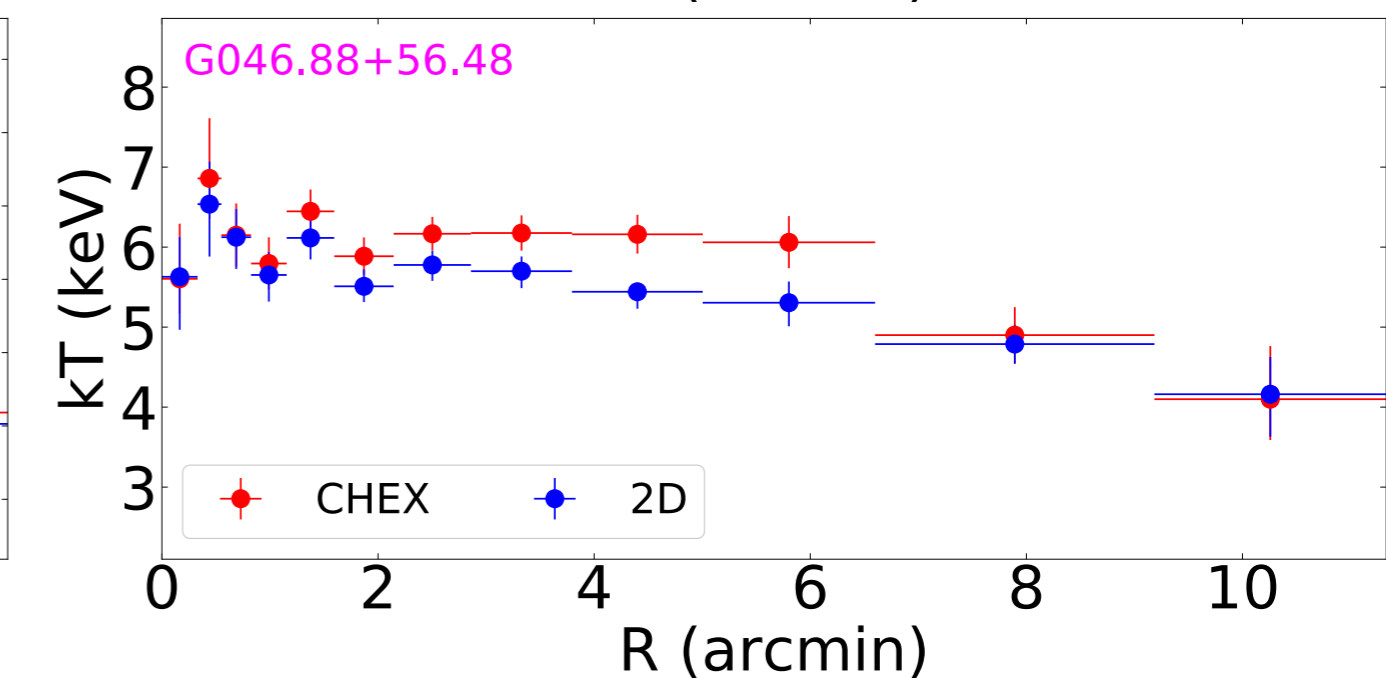
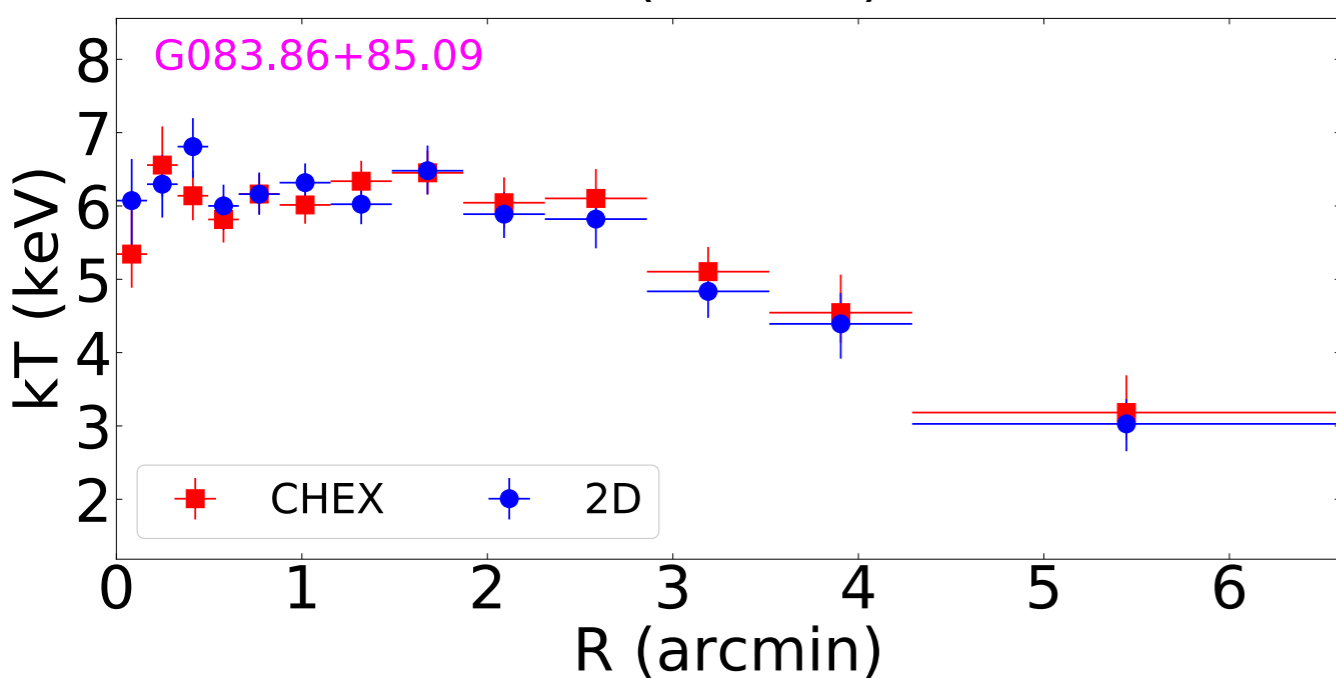
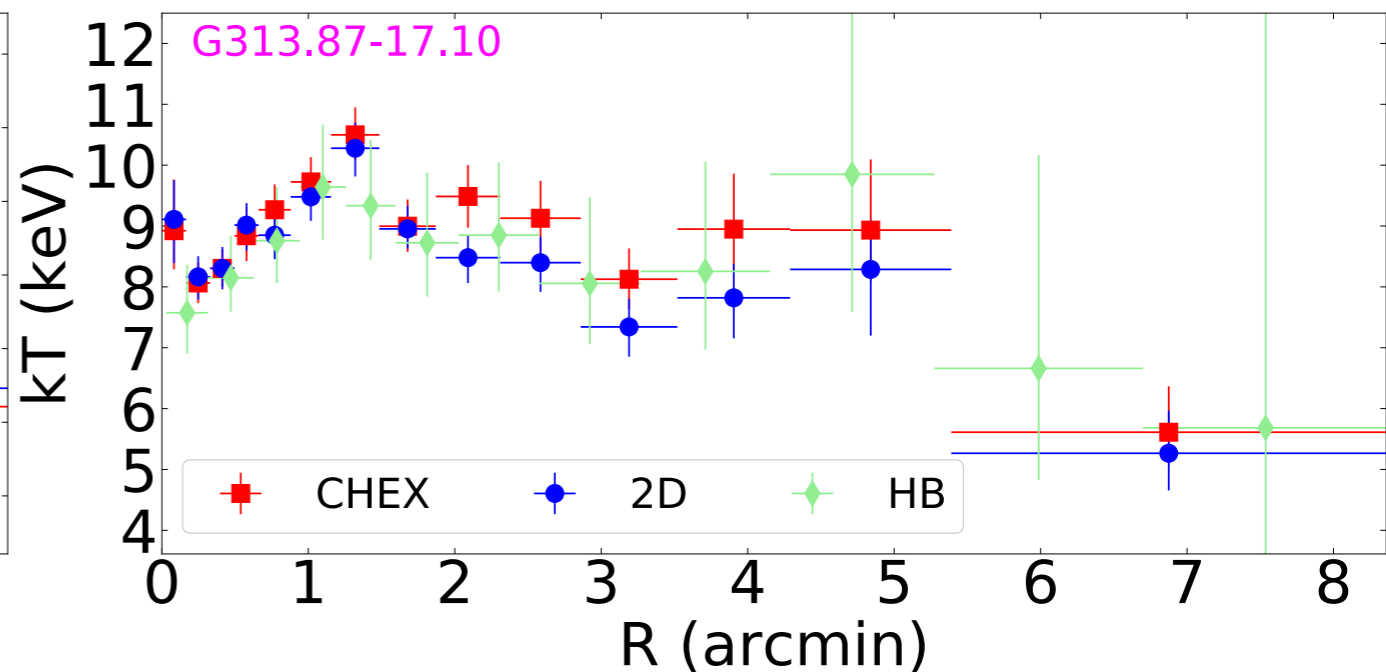
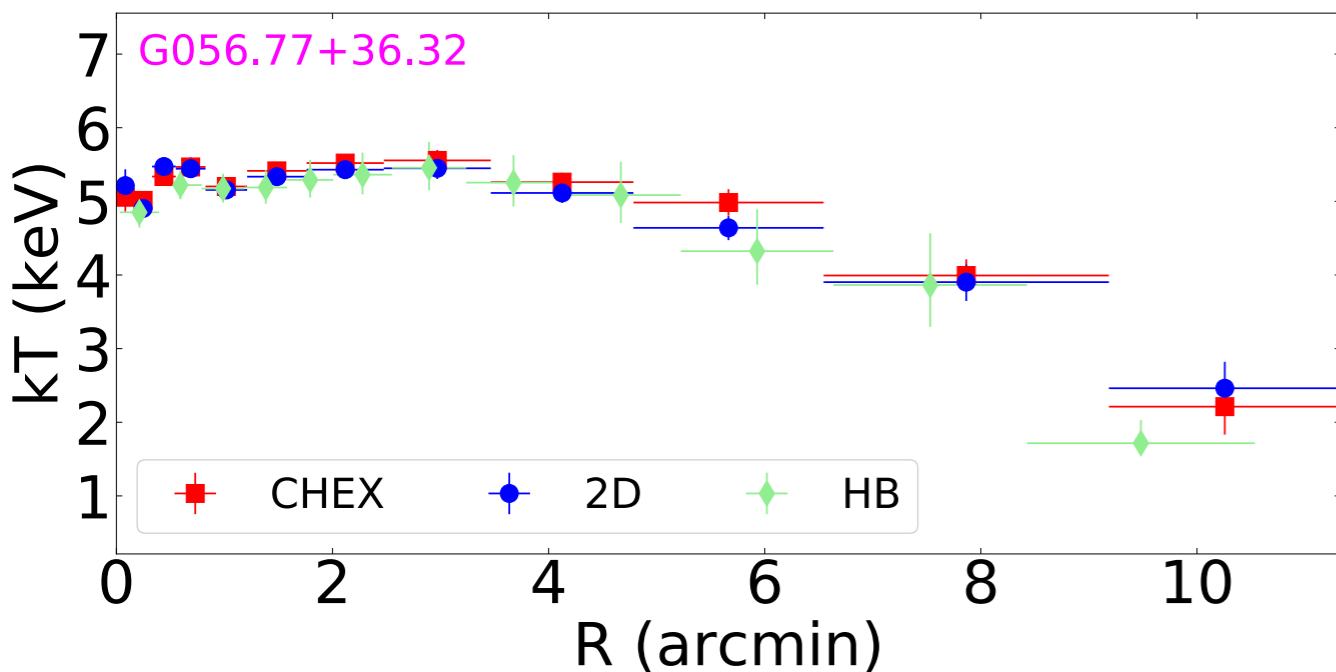
Differences from the official pipeline

- **spatial binning**: based on X-ray SB distribution and S/N criteria
- **Background Modeling**: fully modeled (CXB+foreground: joint fit with RASS, QPB: renormalized FWC, and SP: shape fixed, slope free)

Official pipeline for azimuthal profiles

- **Radial binning**: based on X-ray SB profile and S/N criteria
- **Background Modeling**: fully predictive (include CXB+foreground, QPB, and SP components)
- **Fitting procedure**: Cstat (adapted to Poisson statistics) using an average ARF in the extraction regions, computed from observed counts/rates
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kT cross-check



Independent pipelines allow us to check for bugs!
If differences remains they can be added a systematics

Sample

Currently working with a **sample of ~30 objects**

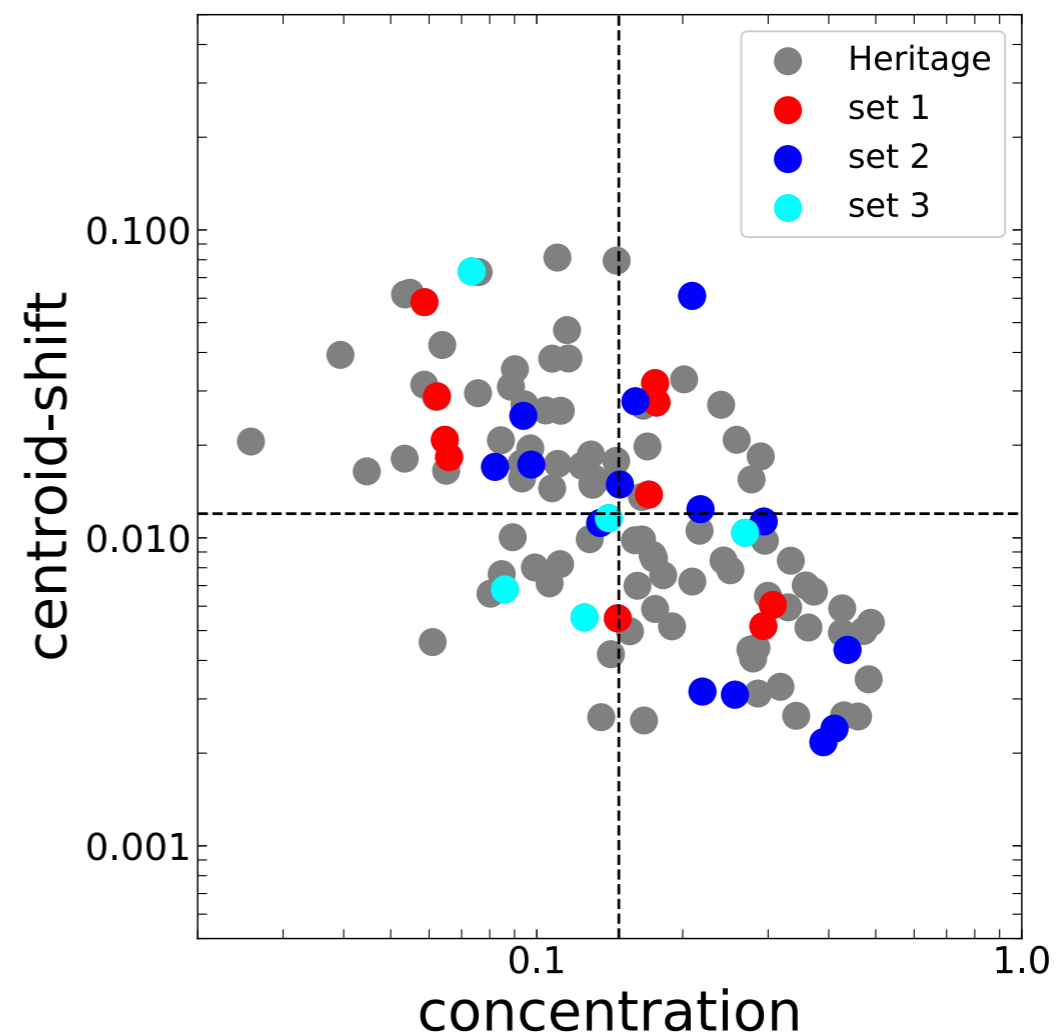
**NOT representative of the CHEX-MATE sample
in terms of M_{tot} & z**

We only tried to cover a broad range of morphologies

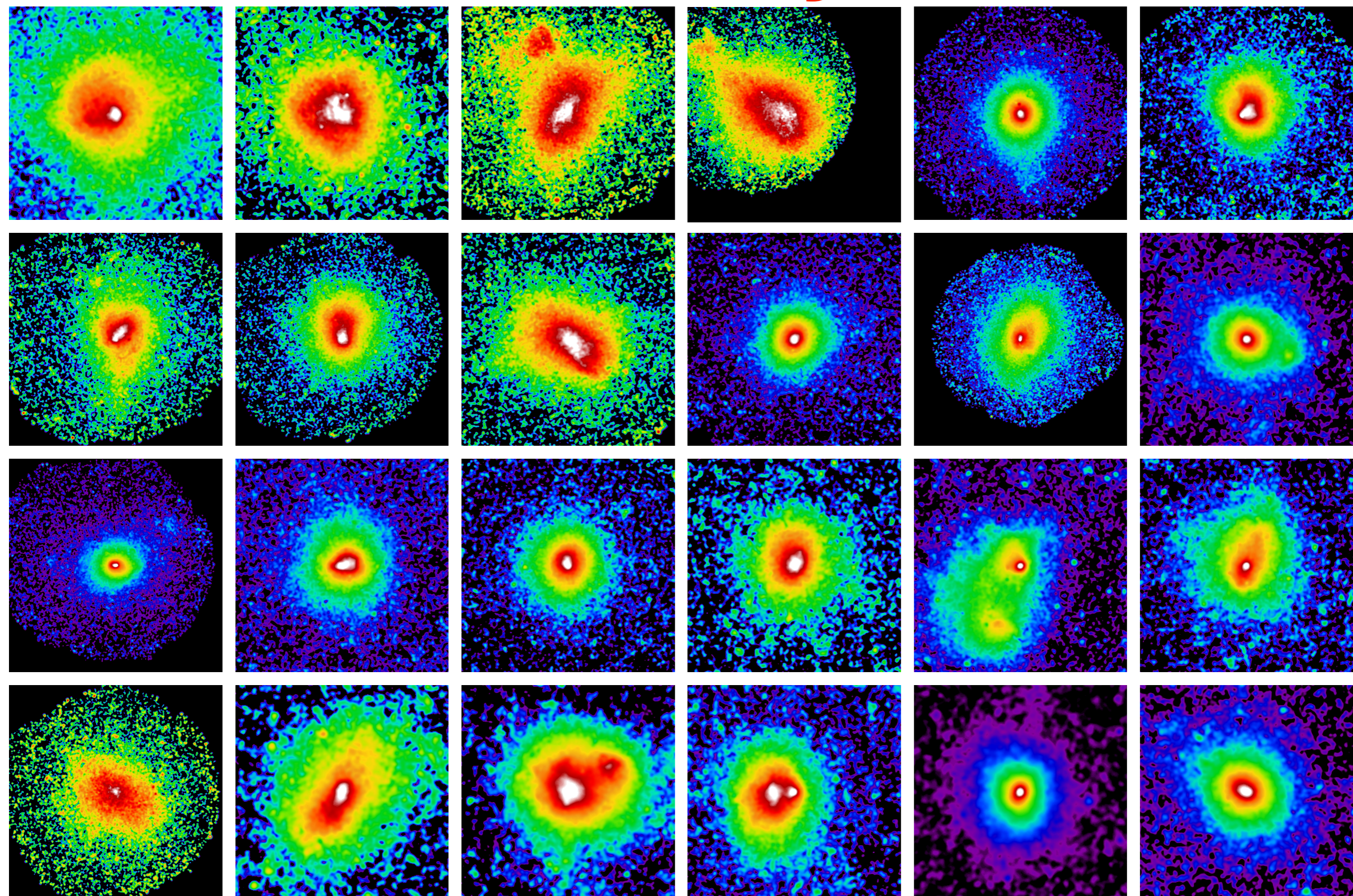
set 1 - comparison w HB
(mostly low- z systems)

set 2 - similar to set 1
(but slightly higher- z)

set 3 - high z objects
($z \gtrsim 0.3$)



Gallery



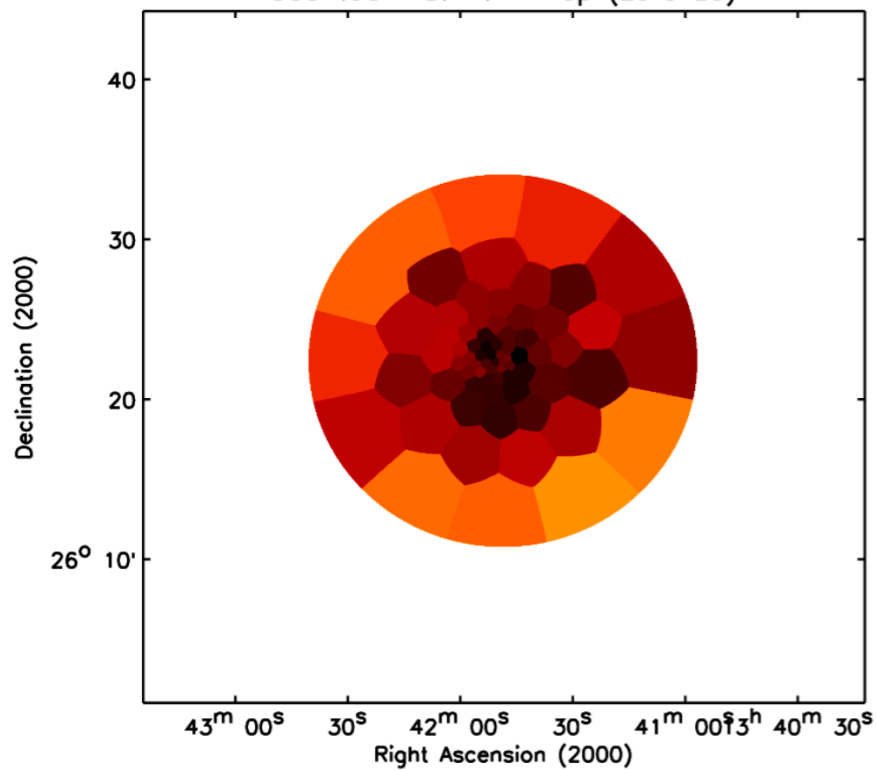
2D maps

WVT binning: a spatially adaptive 2-dimensional binning algorithm, designed to bin sparse X-ray data. The algorithm uses Weighted Voronoi Tessellations (WVT) to produce a very compact binning structure with a constant S/N per bin.
Diehl+06

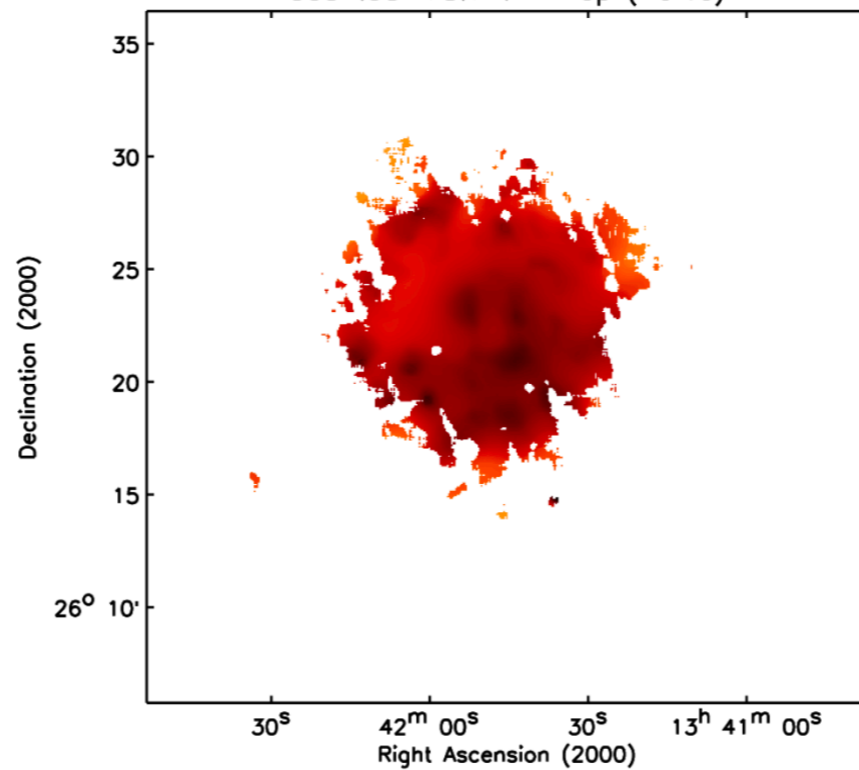
Wavelets: wavelet analysis using the wavelet coefficients to couple a multi-scale spectroscopic analysis with a structure detection scheme
Bourdin+04,+08

Comparison with HB: maps

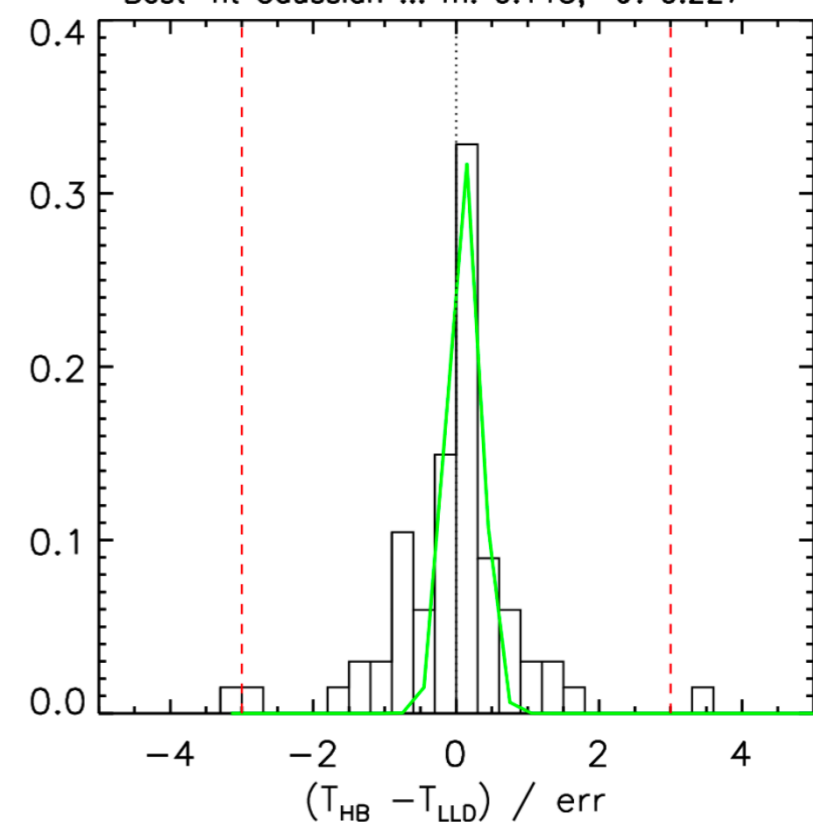
G031.93+78.71: T map (Lorenzo)



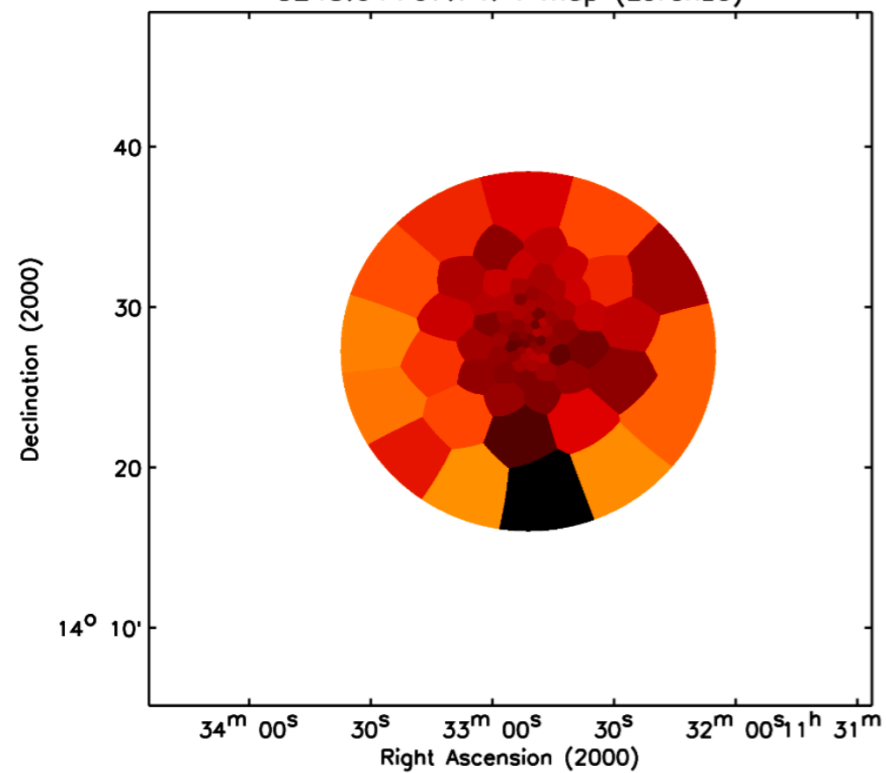
G031.93+78.71: T map (Herve)



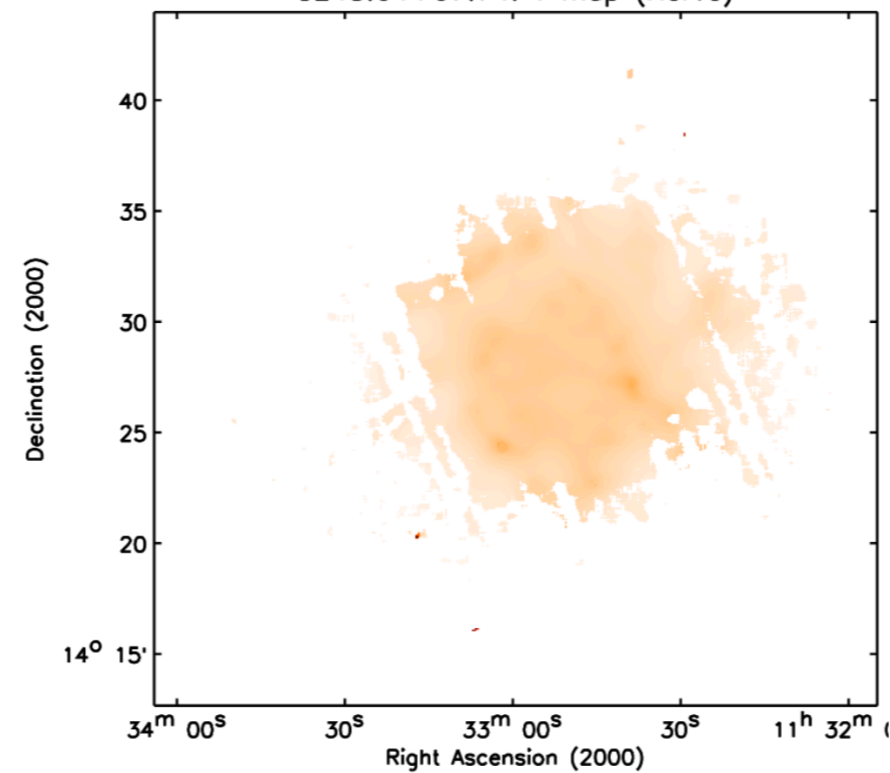
Best-fit Gaussian ... m: 0.113; σ : 0.227



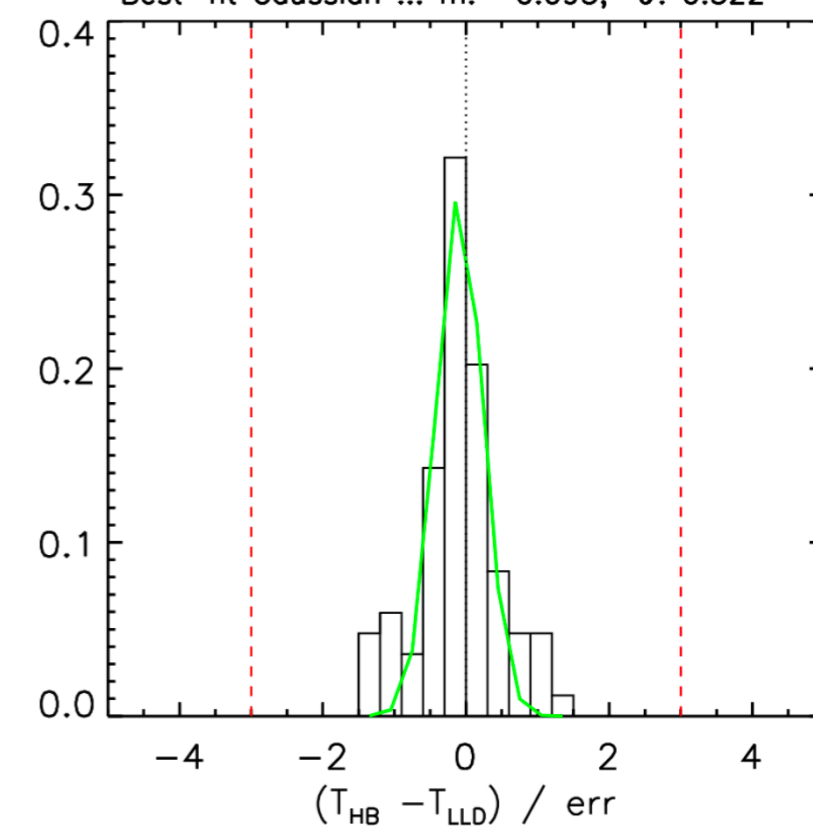
G243.64+67.74: T map (Lorenzo)



G243.64+67.74: T map (Herve)

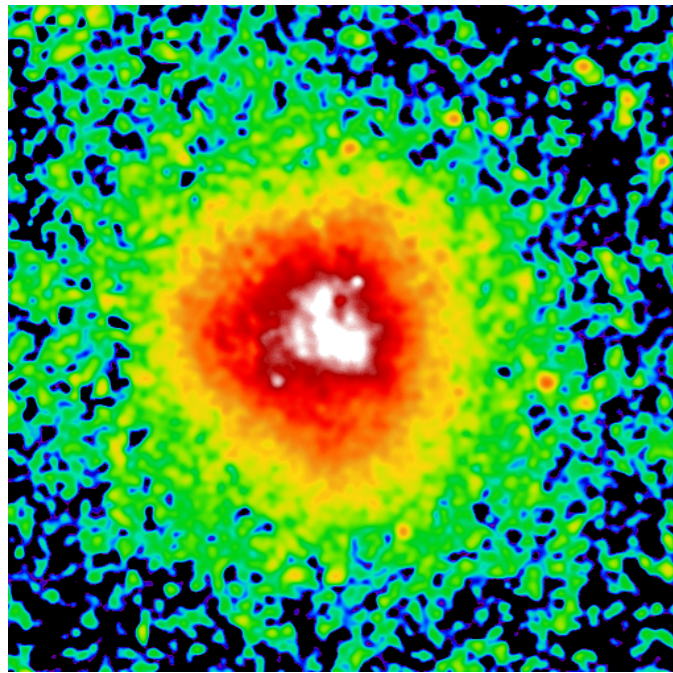


Best-fit Gaussian ... m: -0.093; σ : 0.322

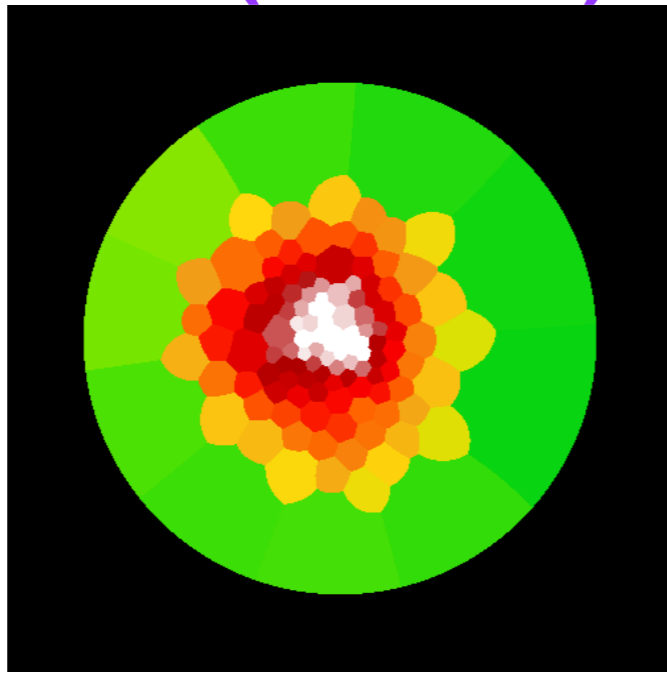


Pipeline output

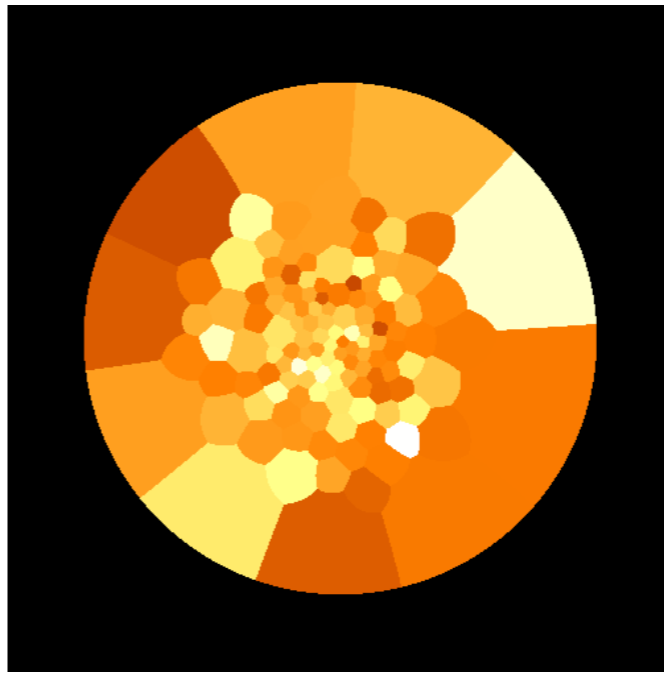
0.3-7 keV



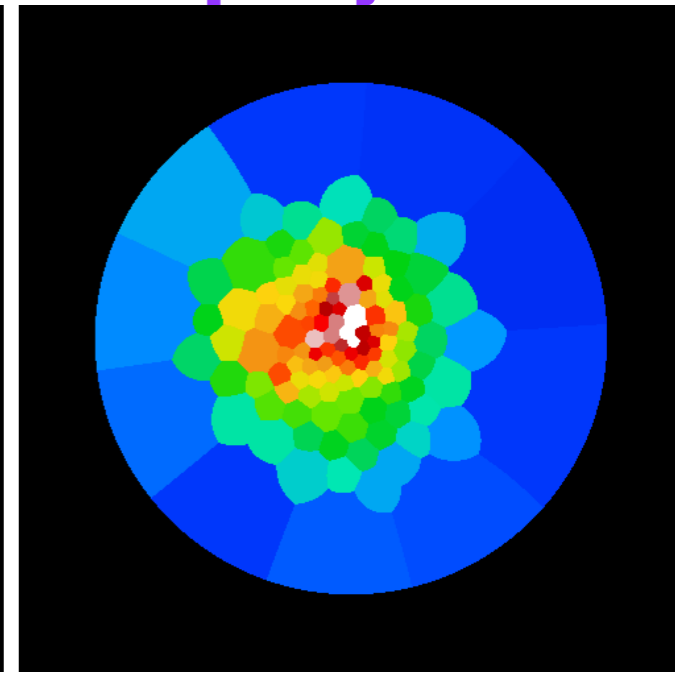
SB (S/N=30)



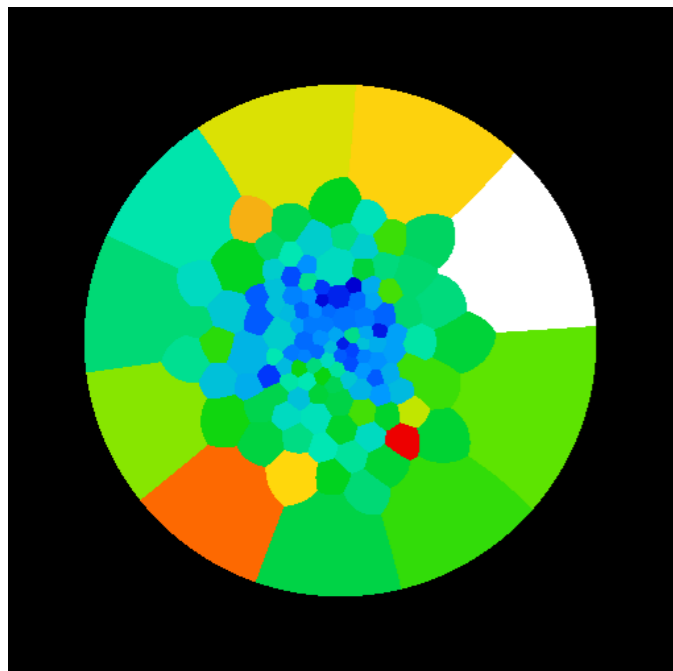
kT



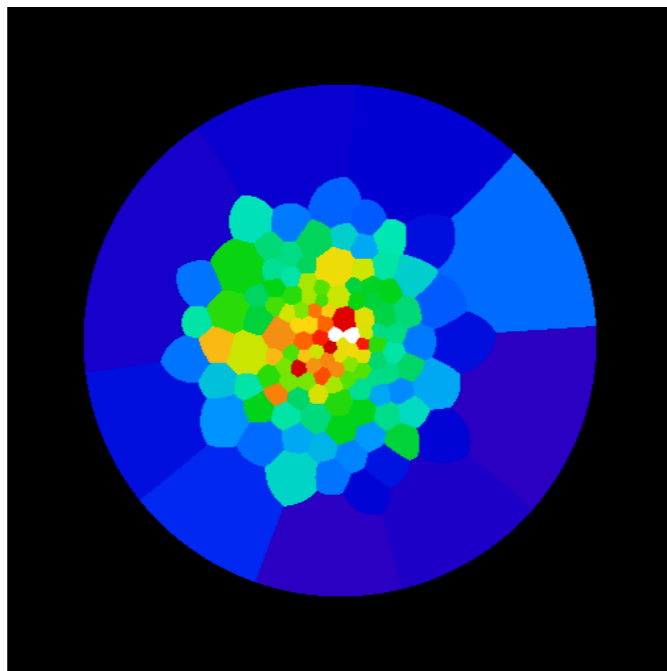
proj n_e



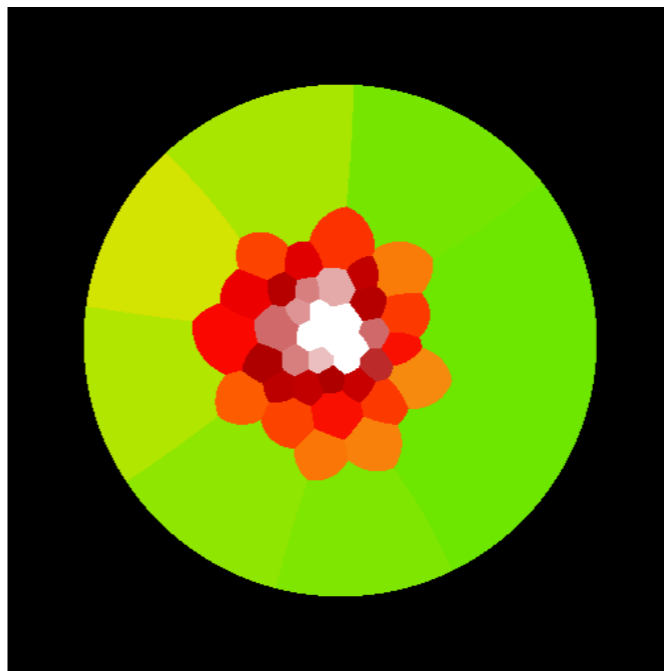
Entropy



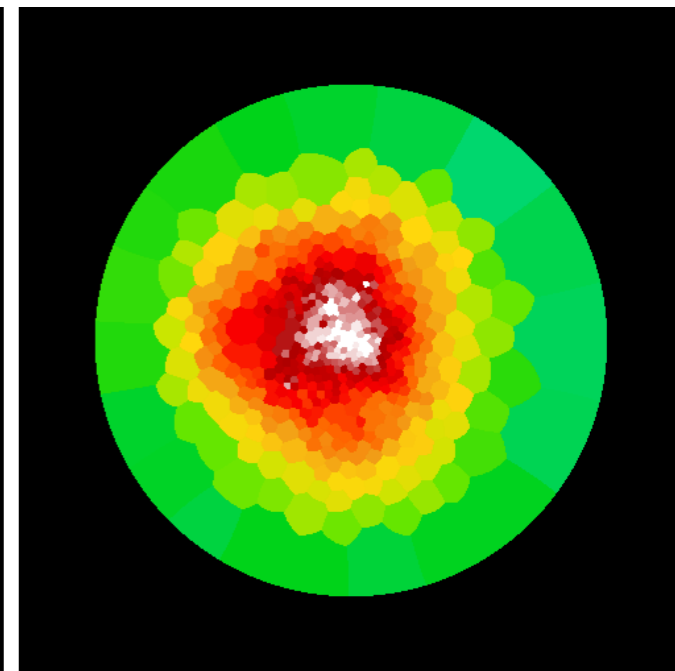
Pressure



SB (S/N=50)

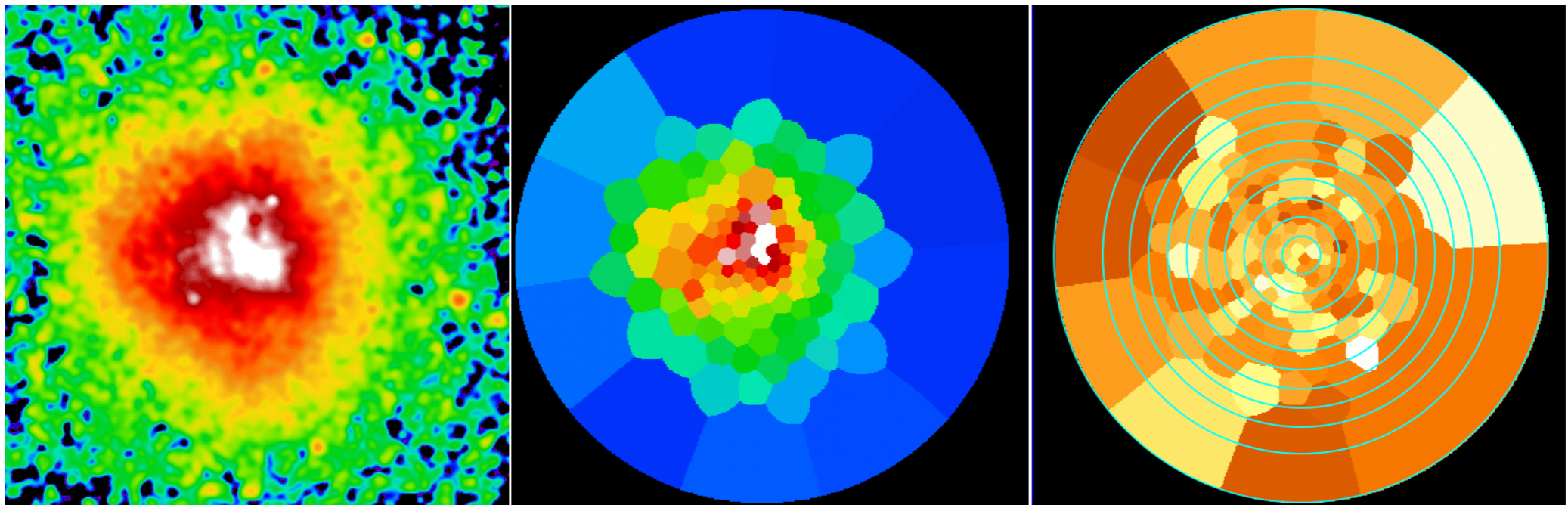
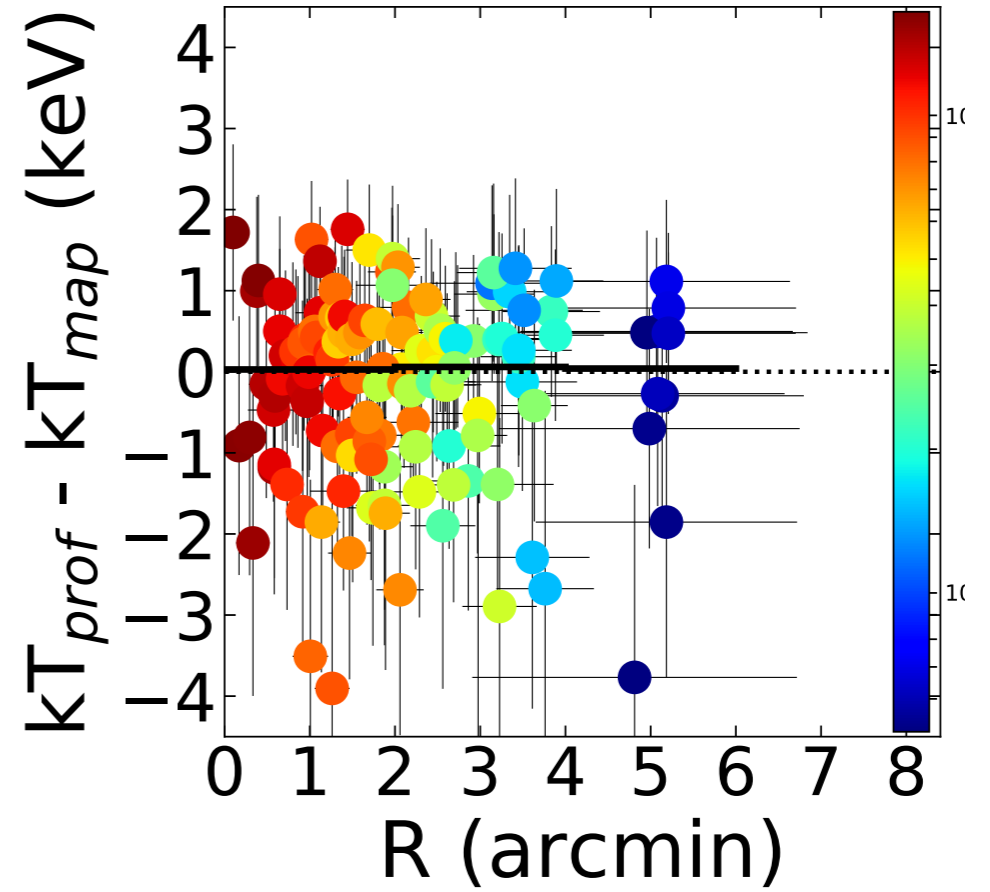
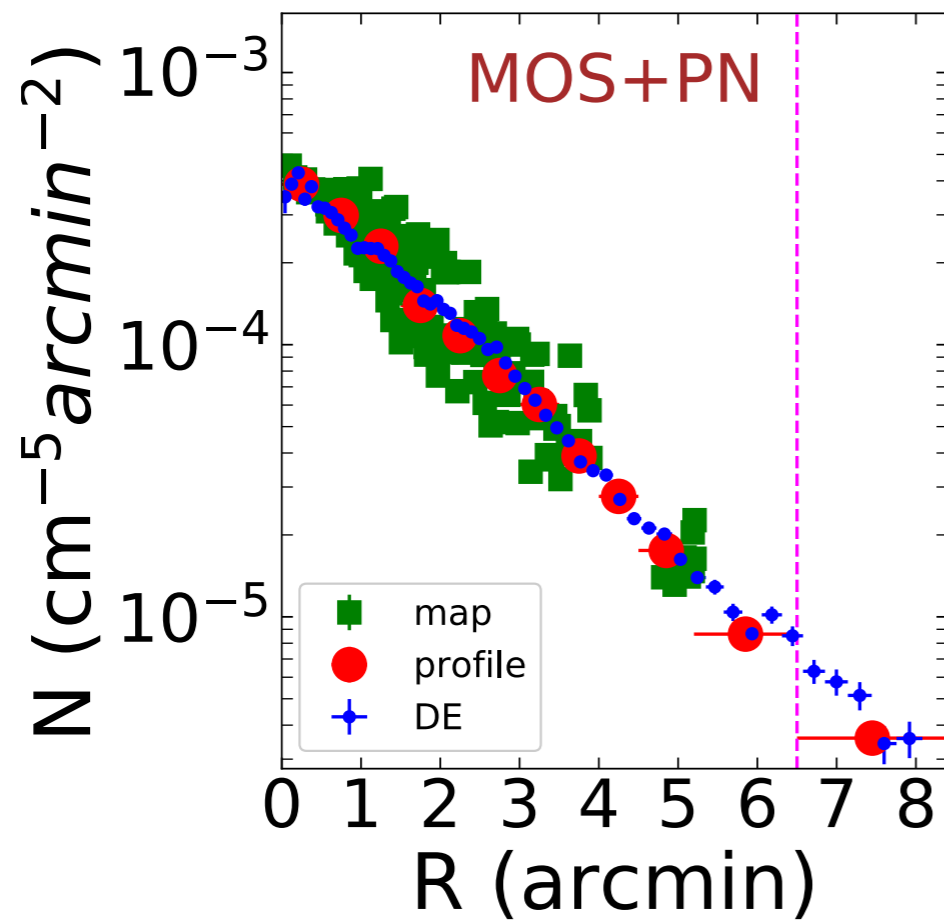


SB (S/N=15)

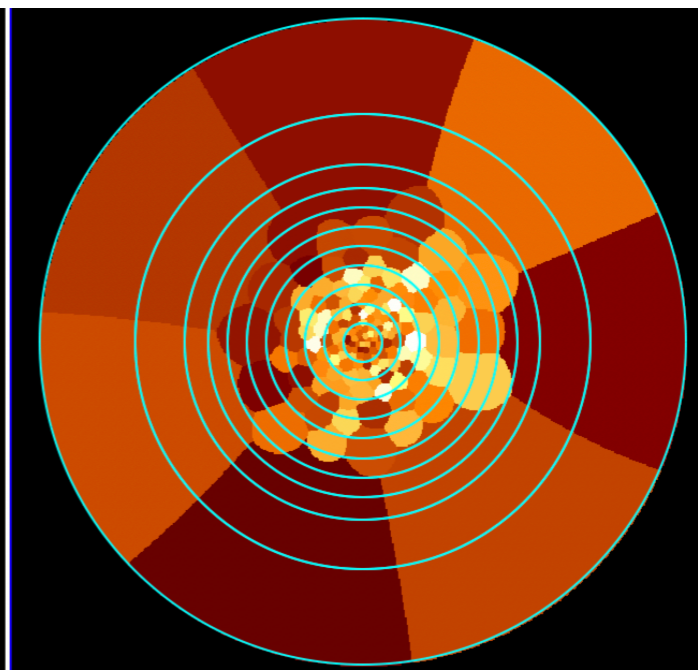
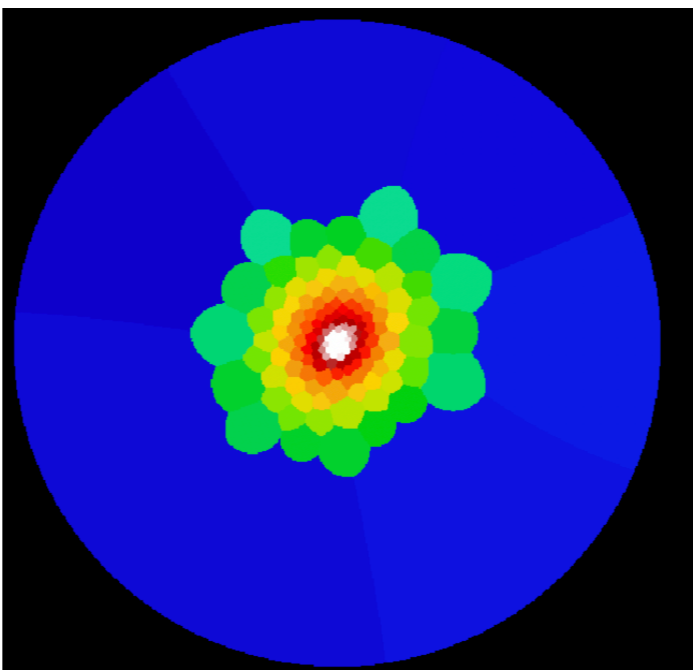
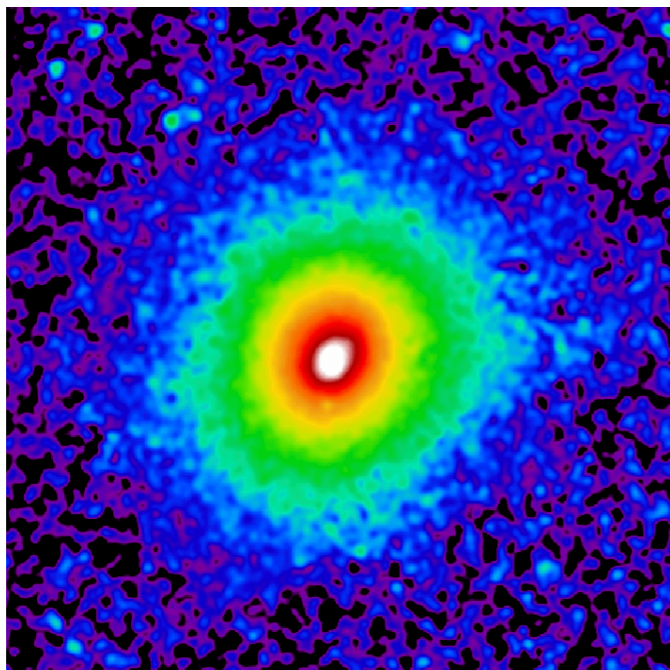
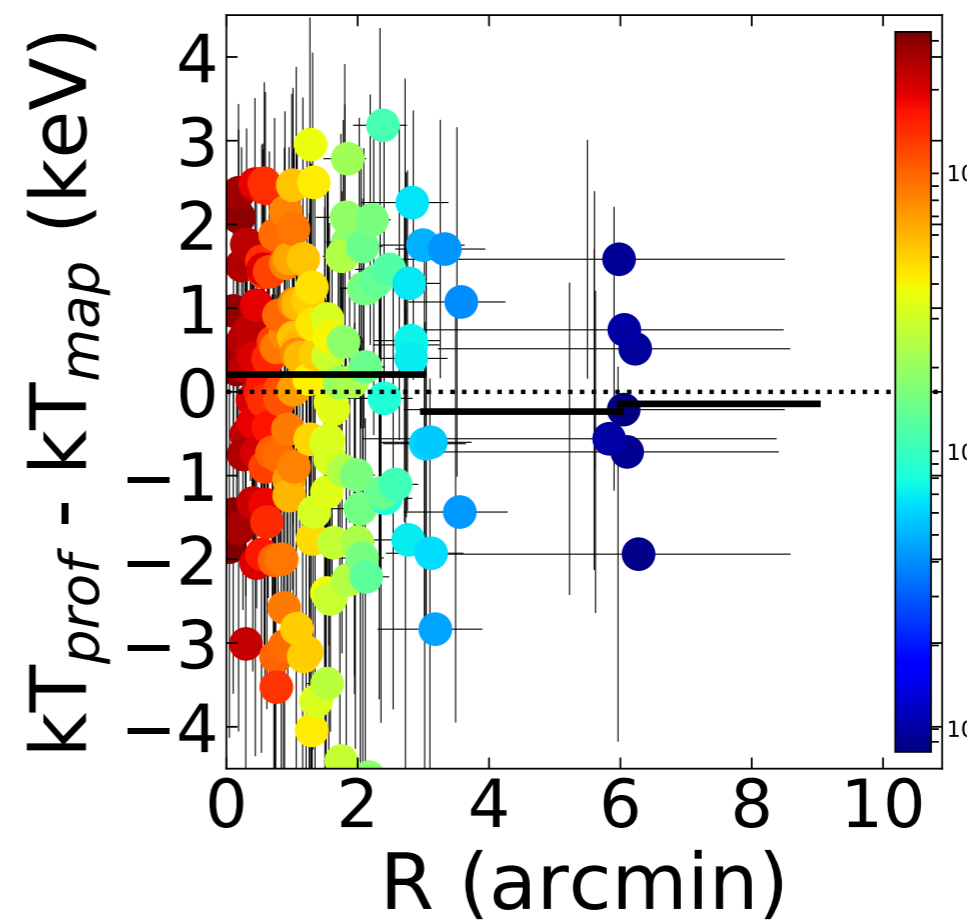
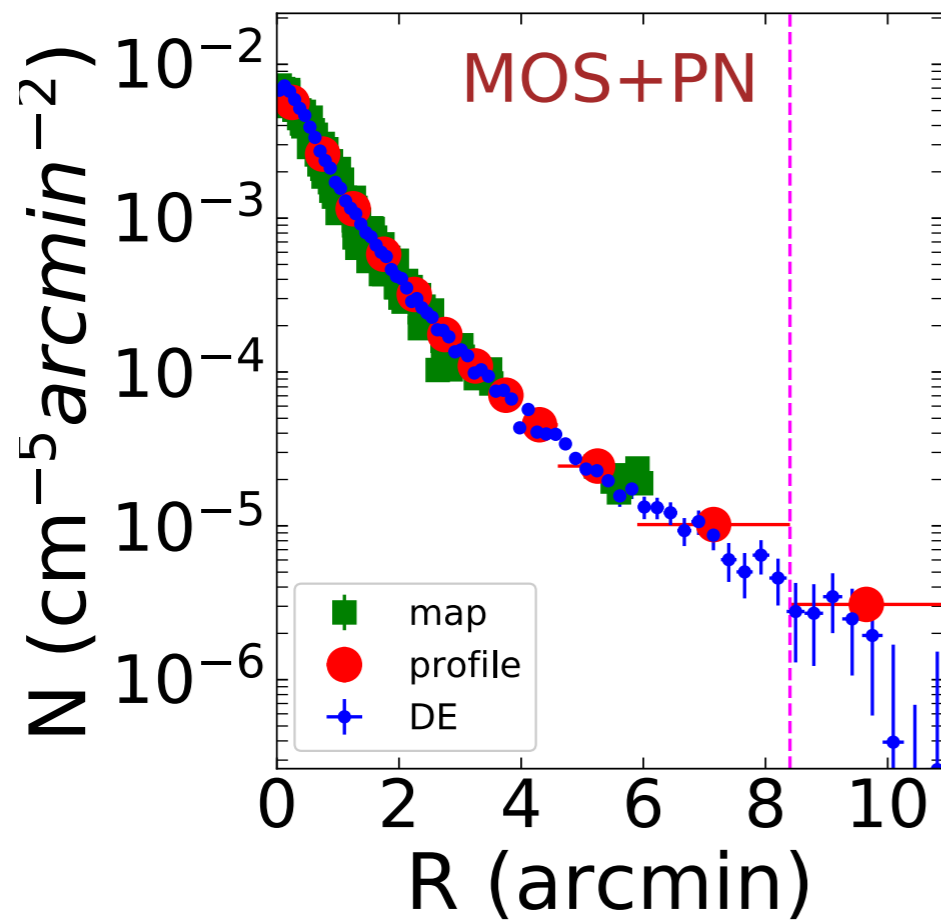


+ a Nr of other maps (currently not used) and all the profiles

G041.45+29.10: map vs profile

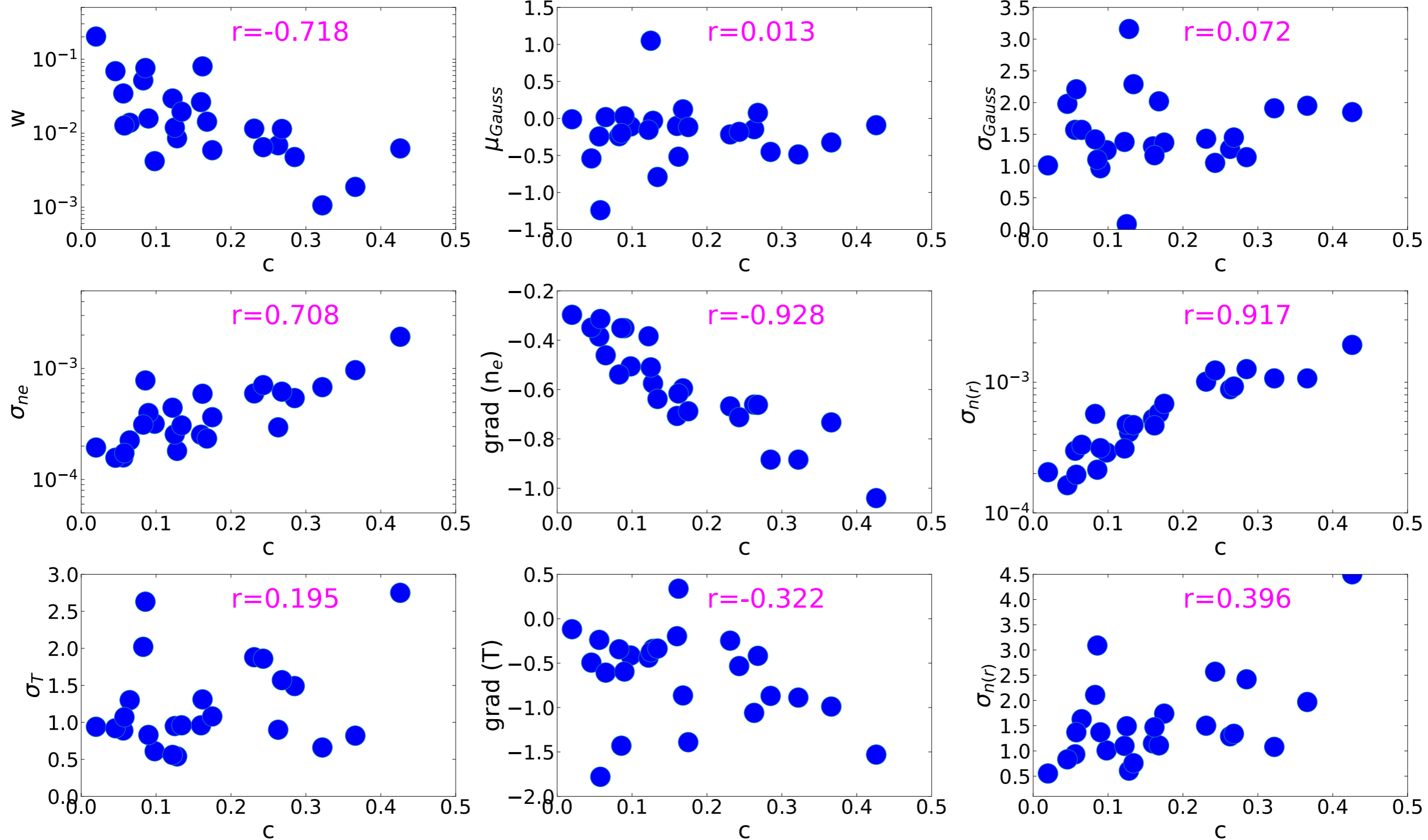


G313.87-17.10: map vs profile



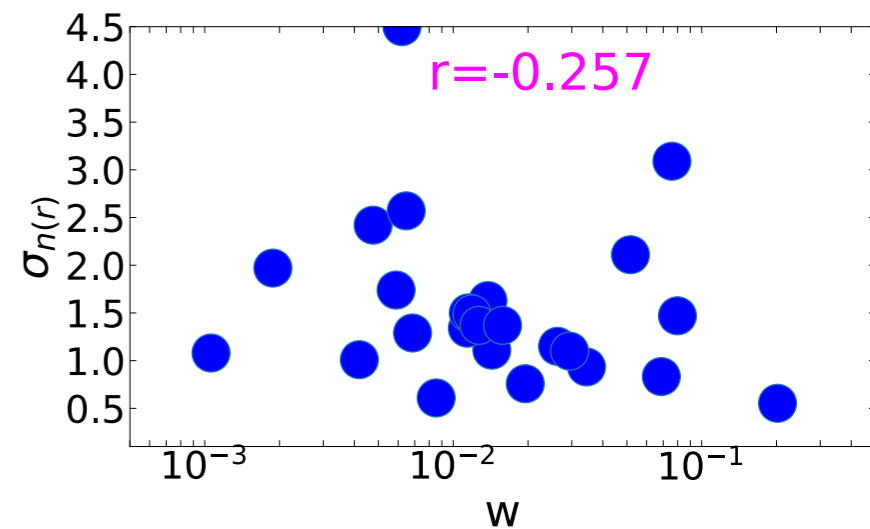
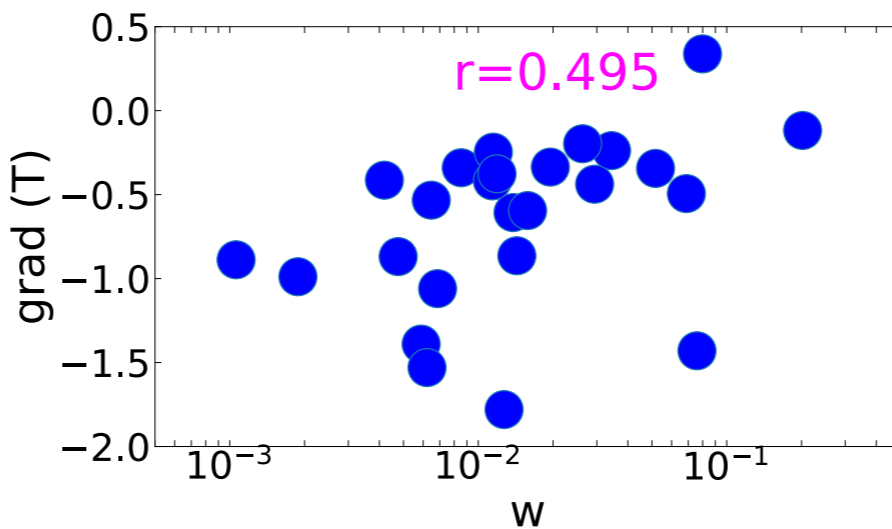
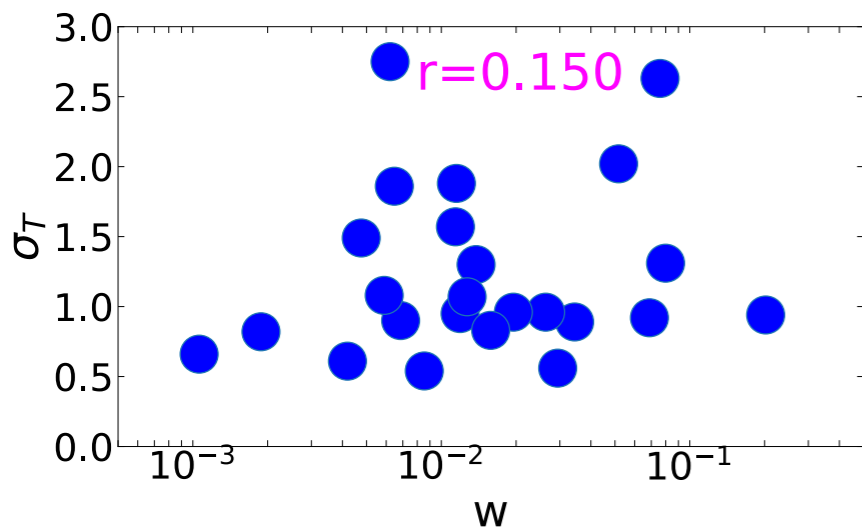
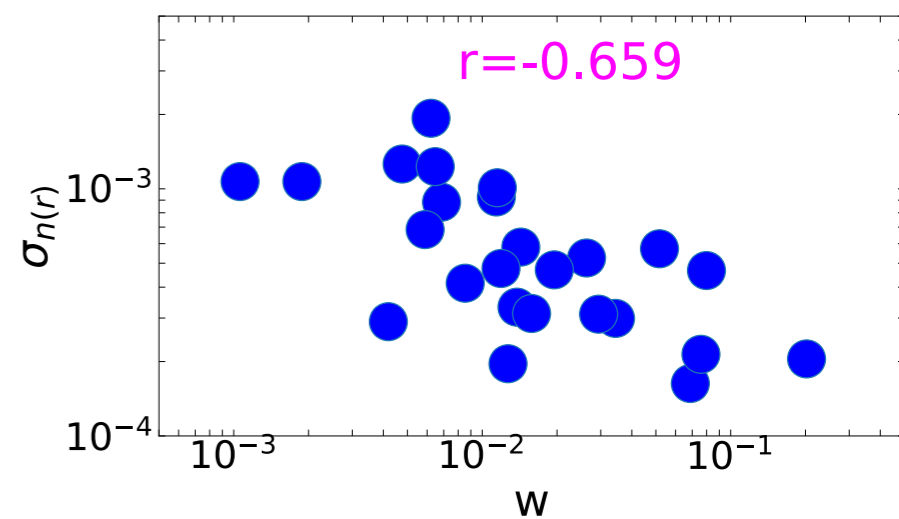
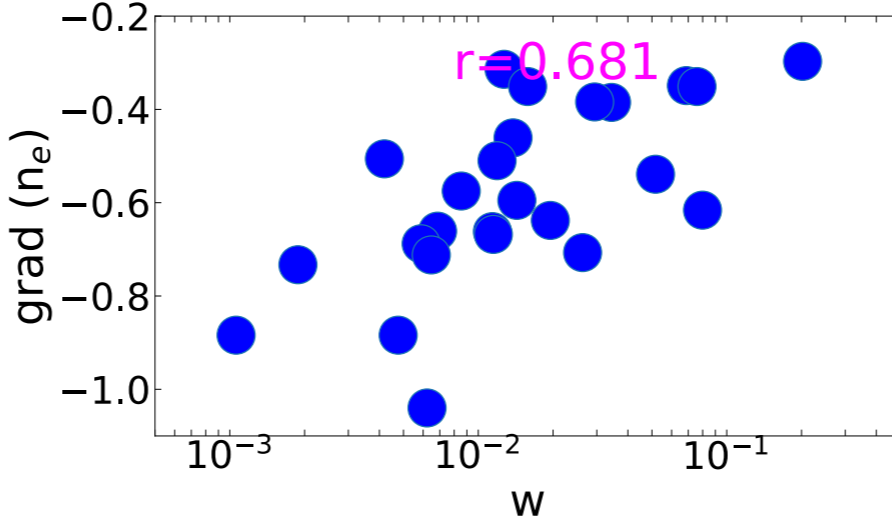
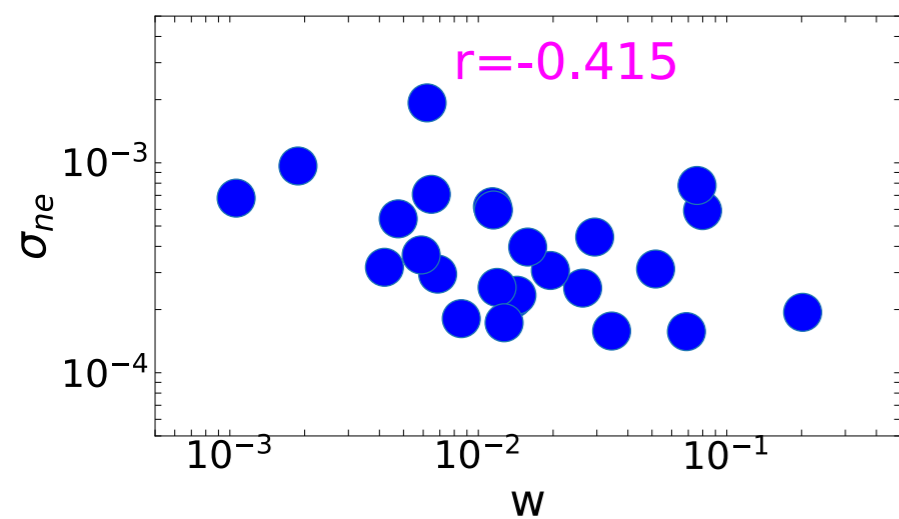
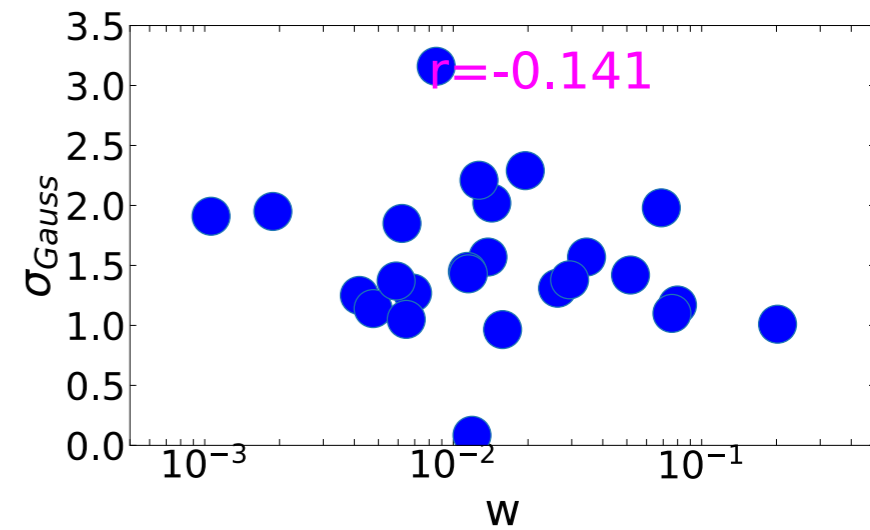
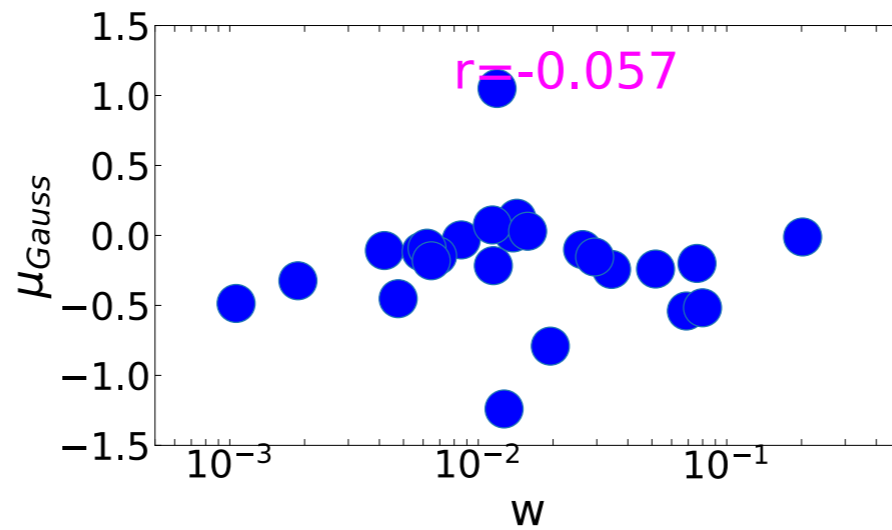
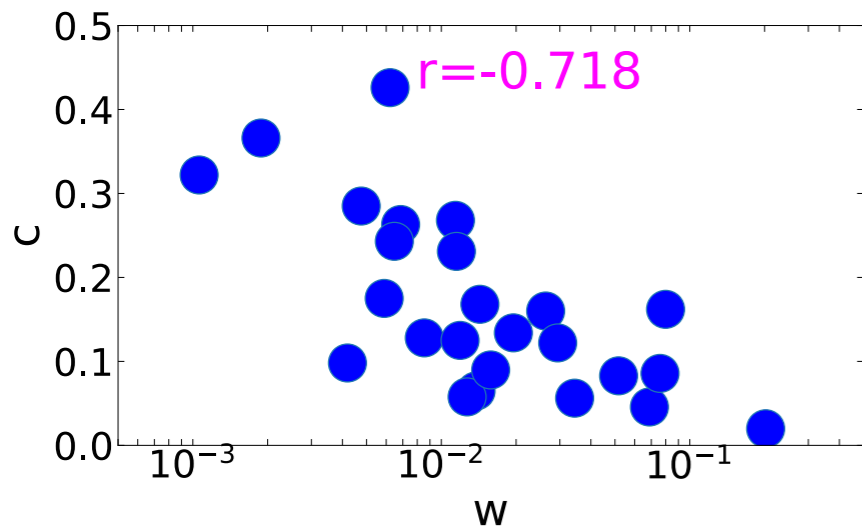
Dynamical state

concentration



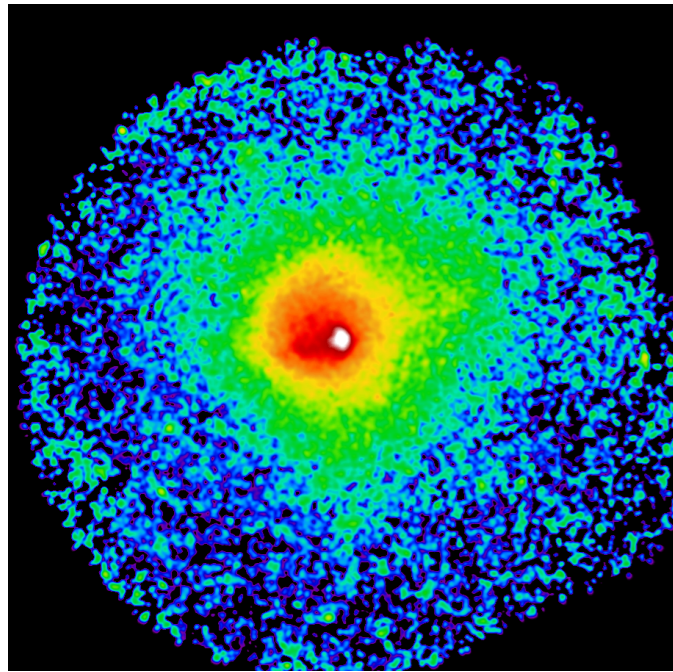
Dynamical state

centroid-shift

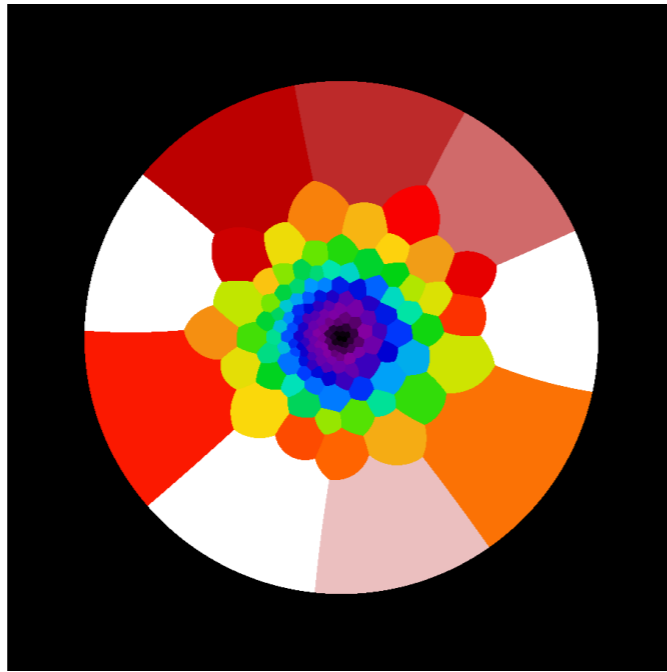


Masking the regions

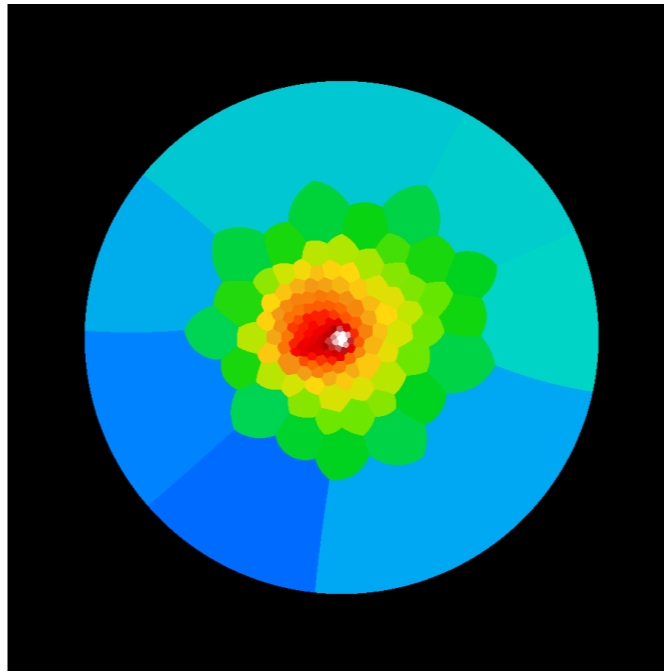
Image



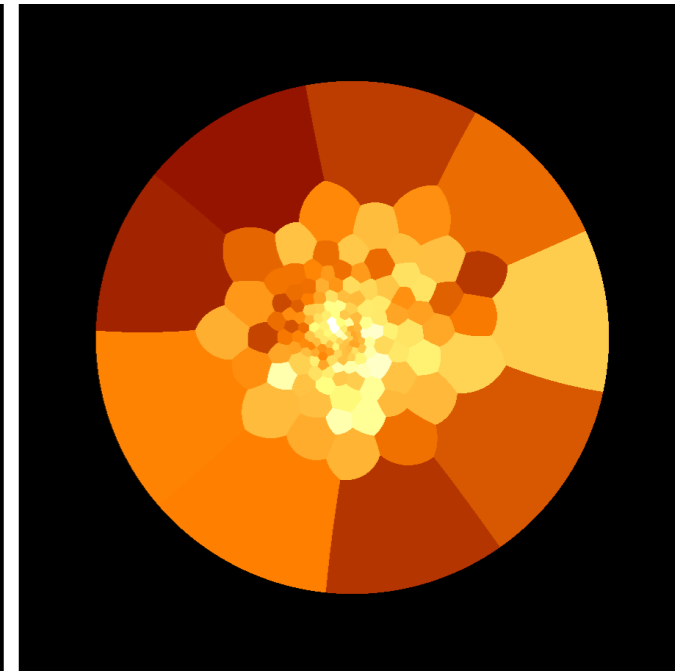
binning



SB

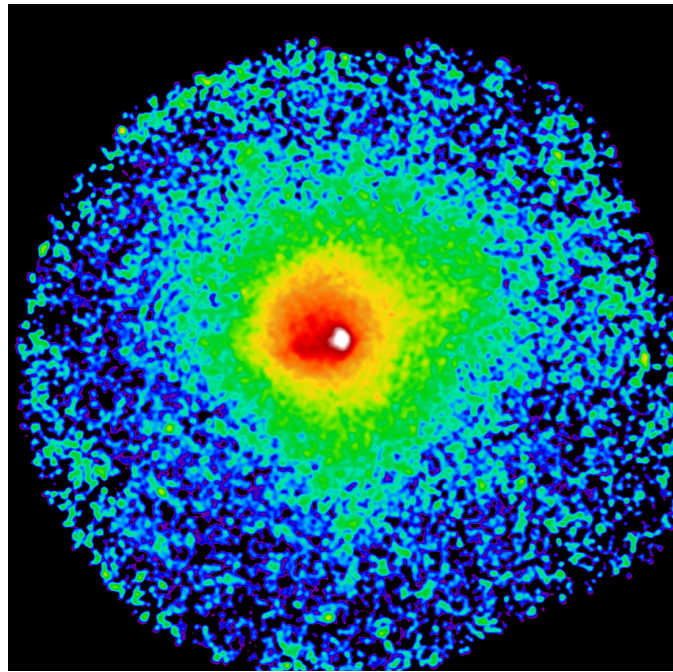


kT

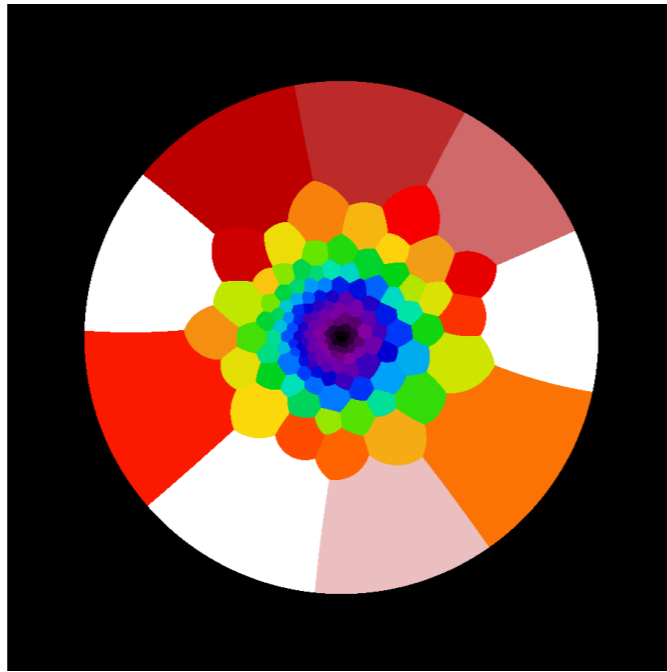


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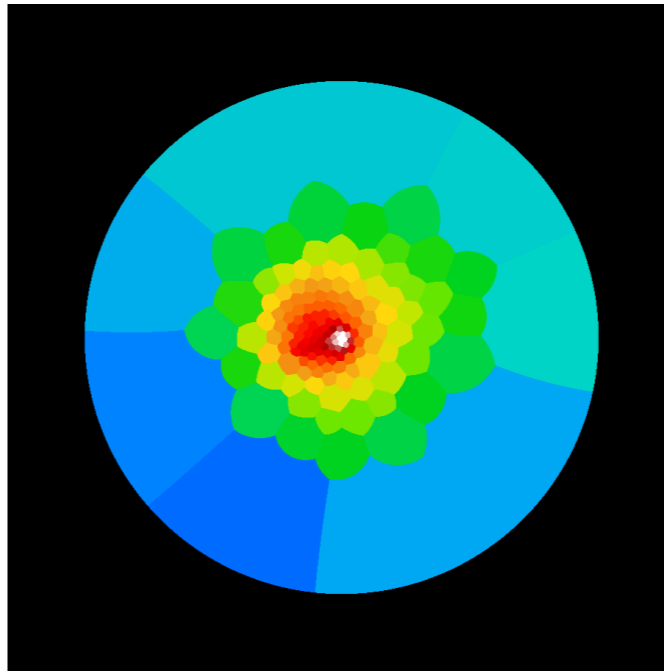
Image



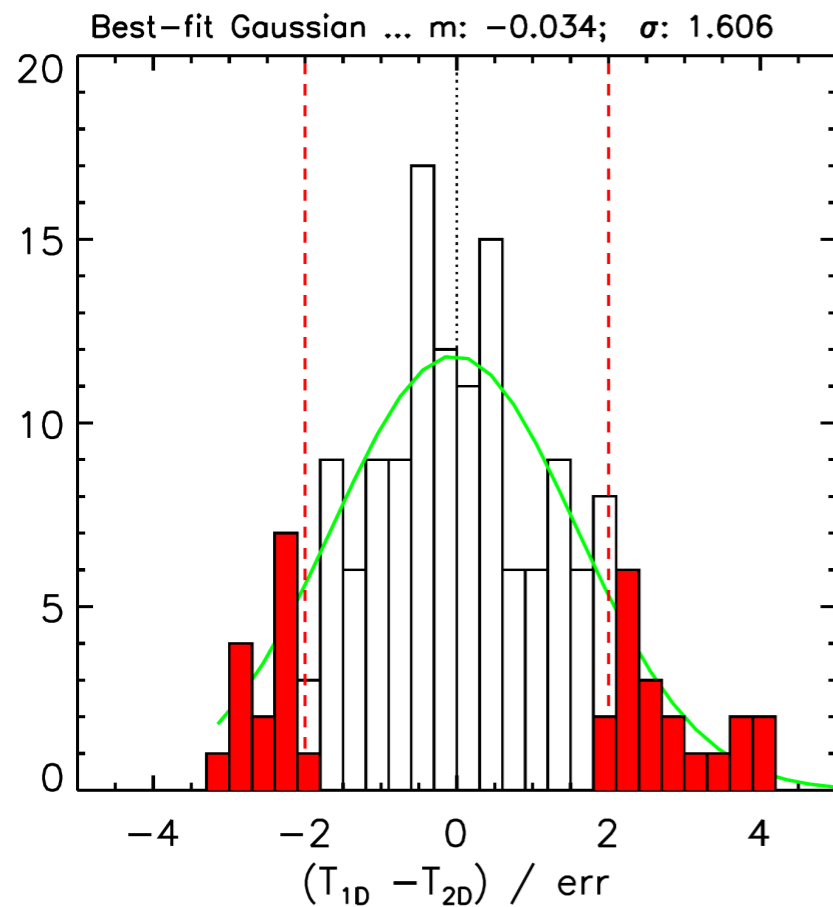
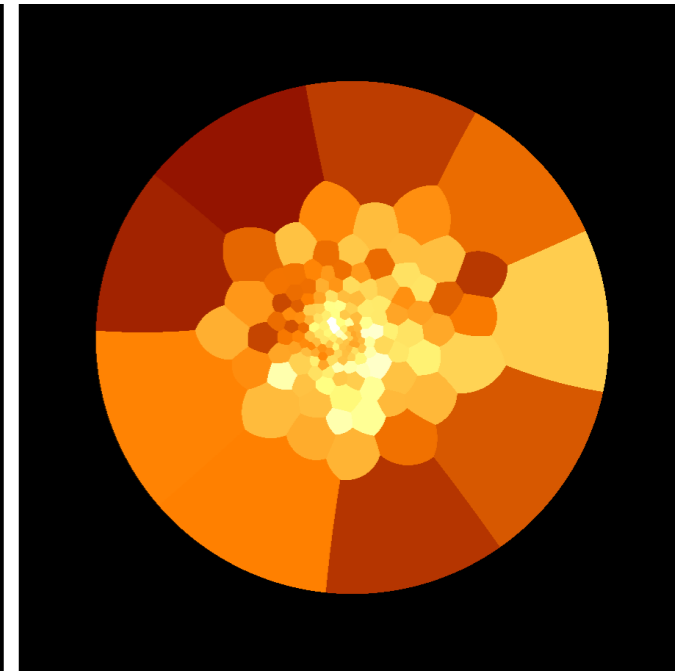
binning



SB

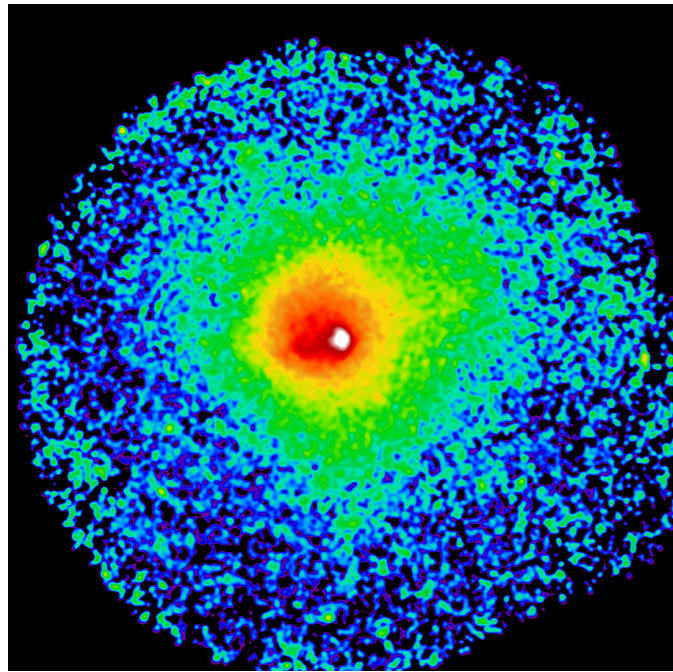


kT

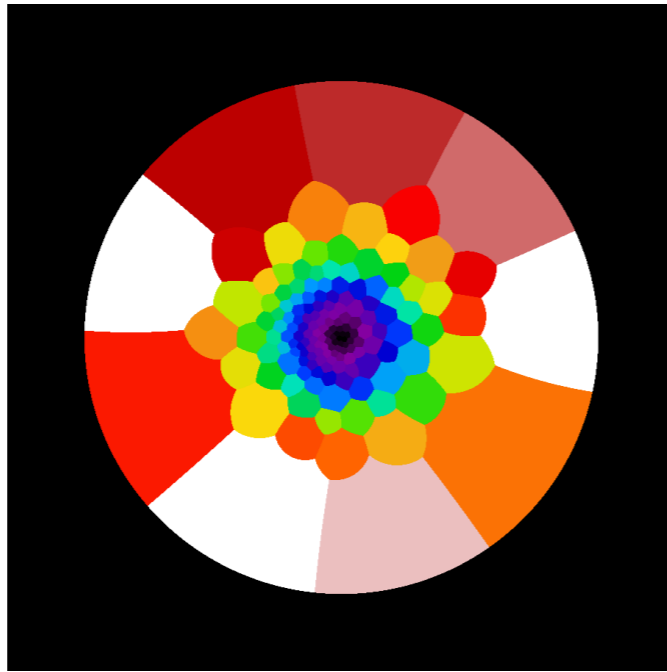


Masking the regions

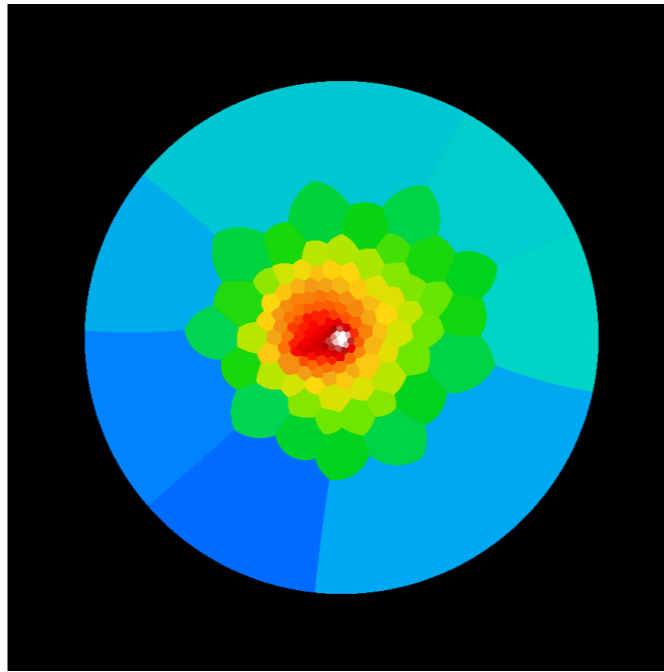
Image



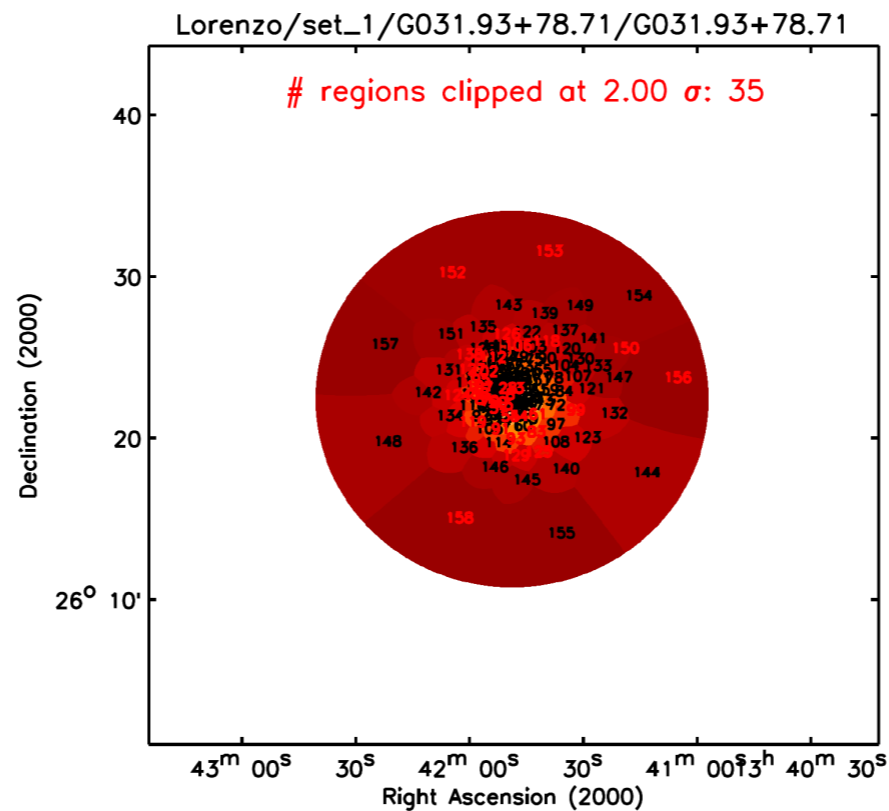
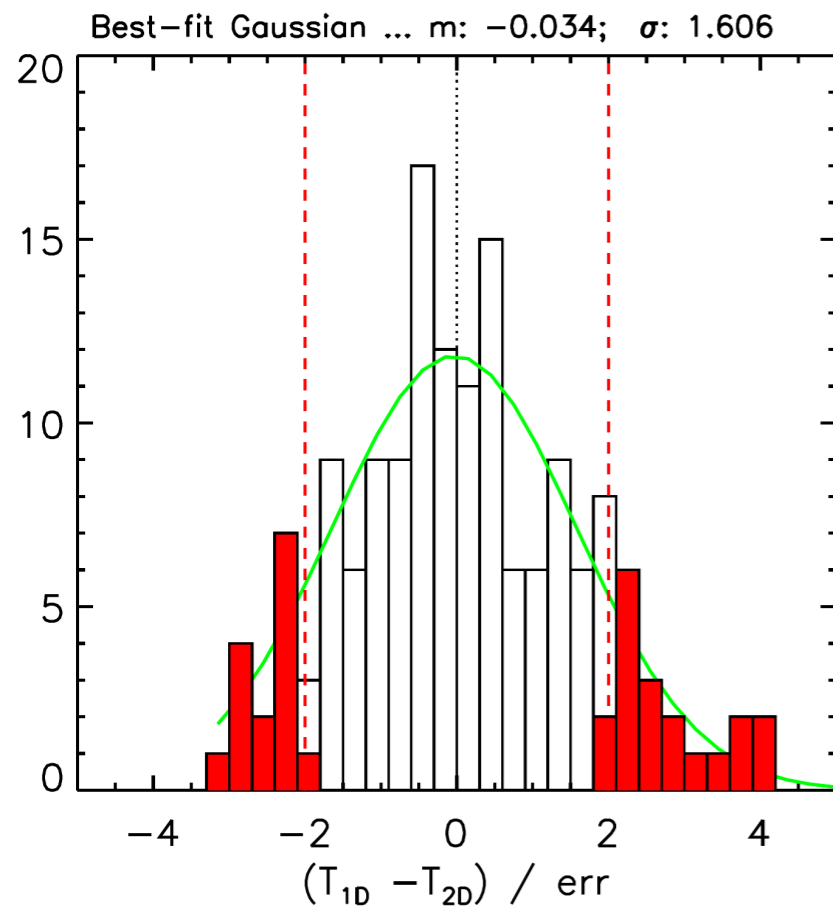
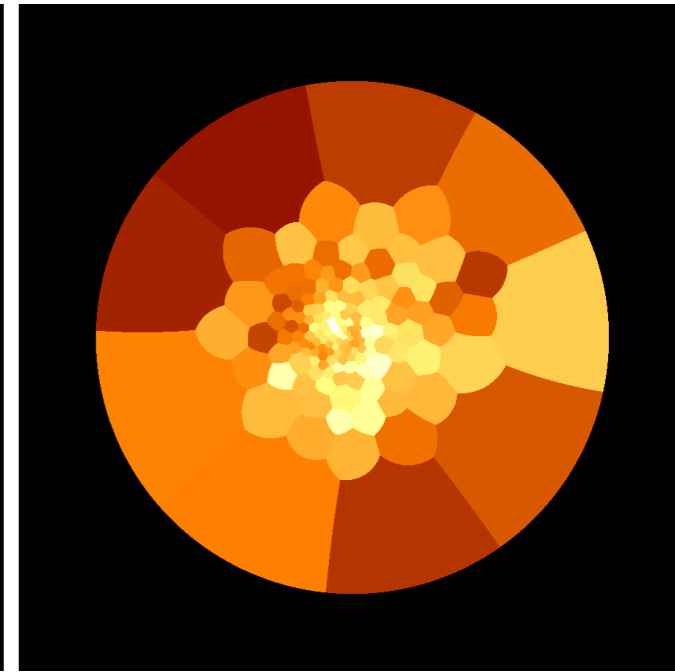
binning



SB

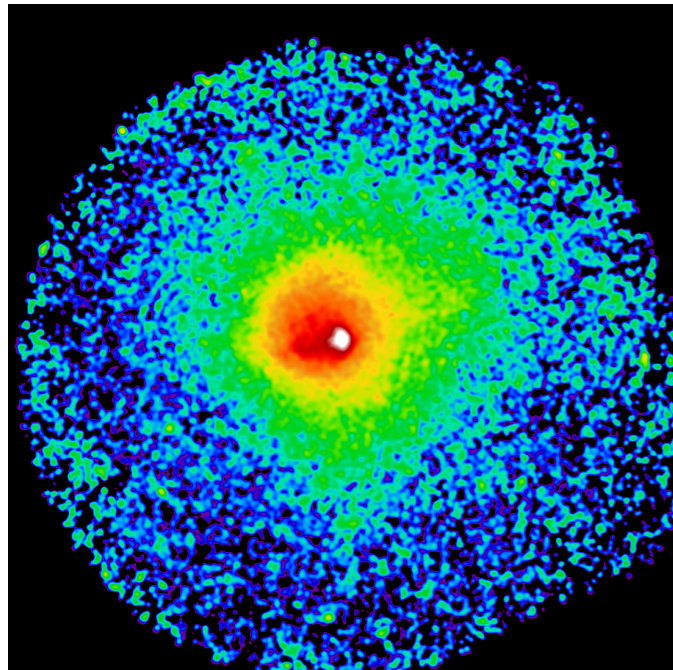


kT

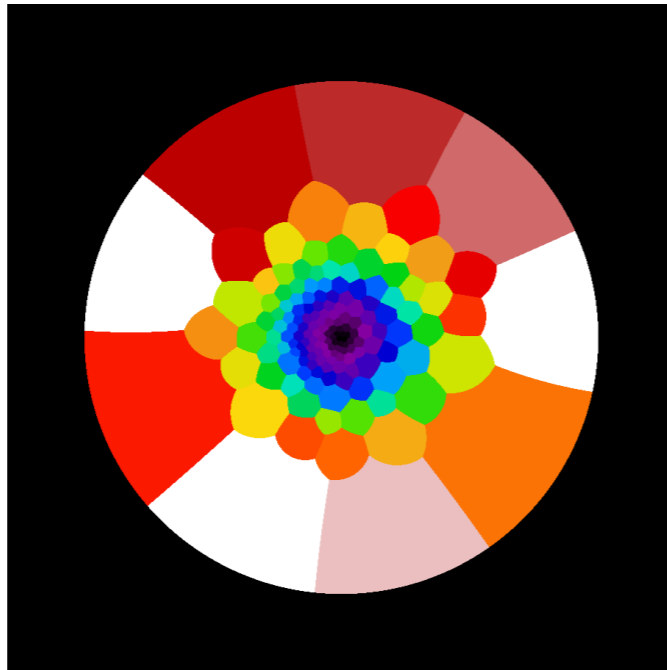


Masking the regions

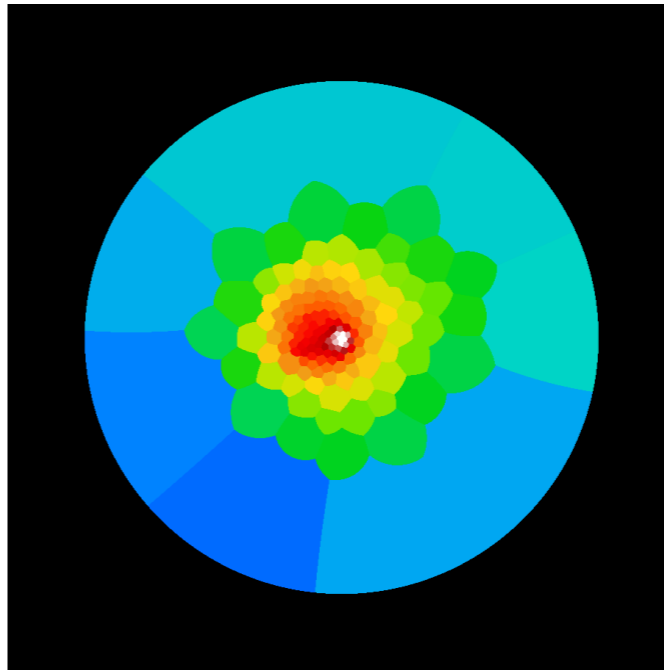
Image



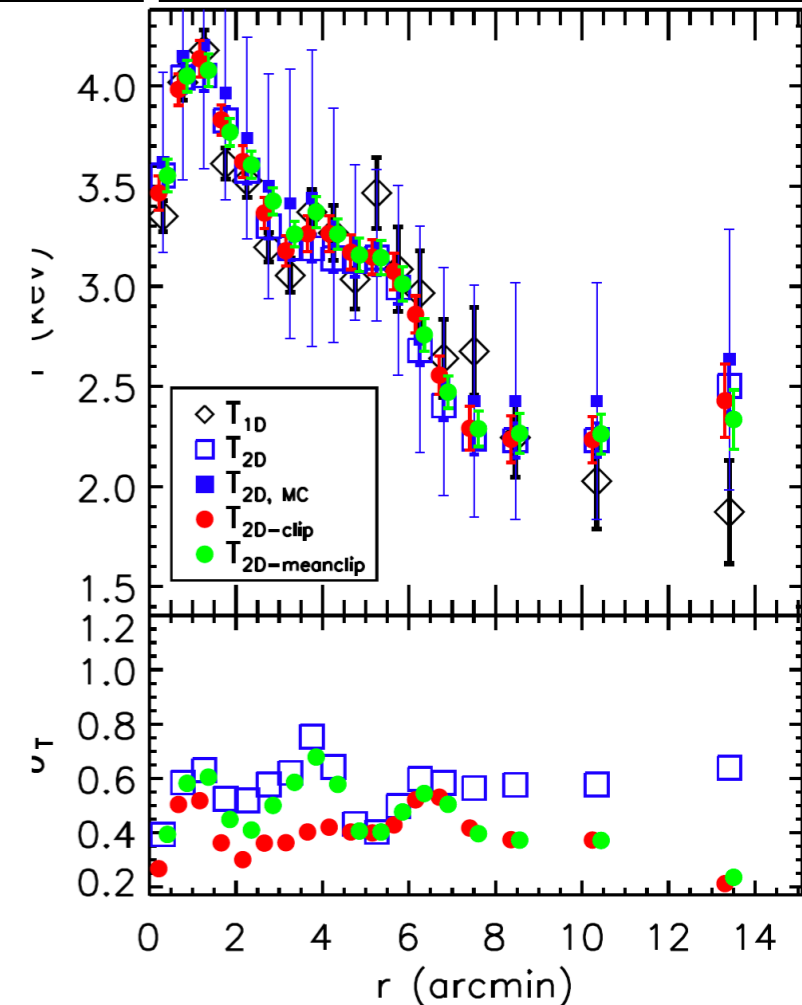
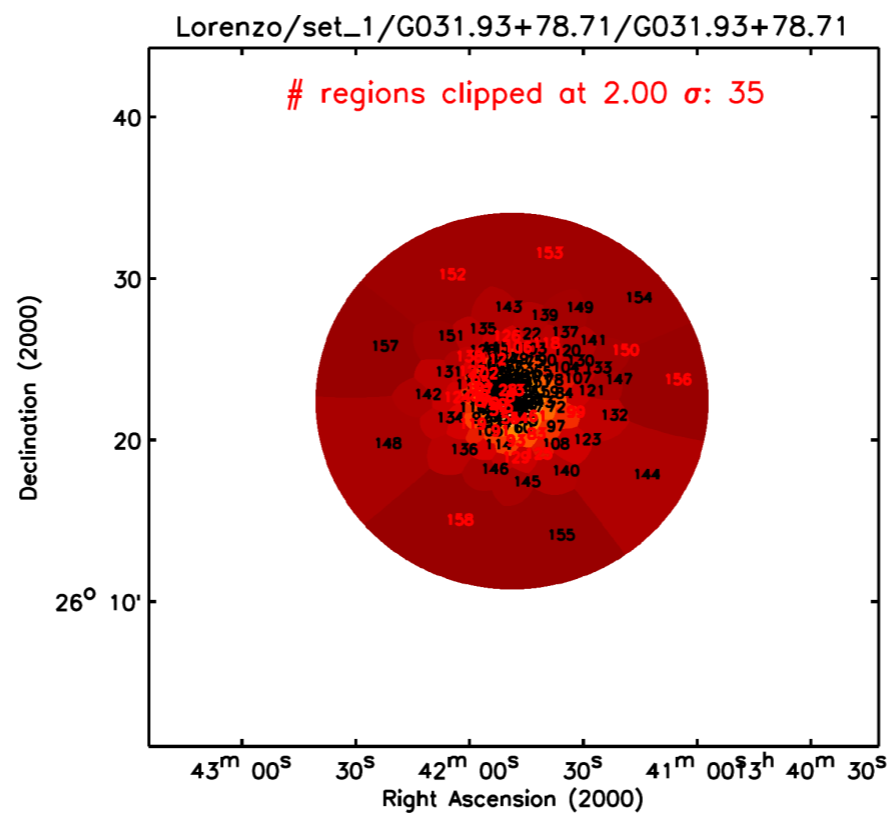
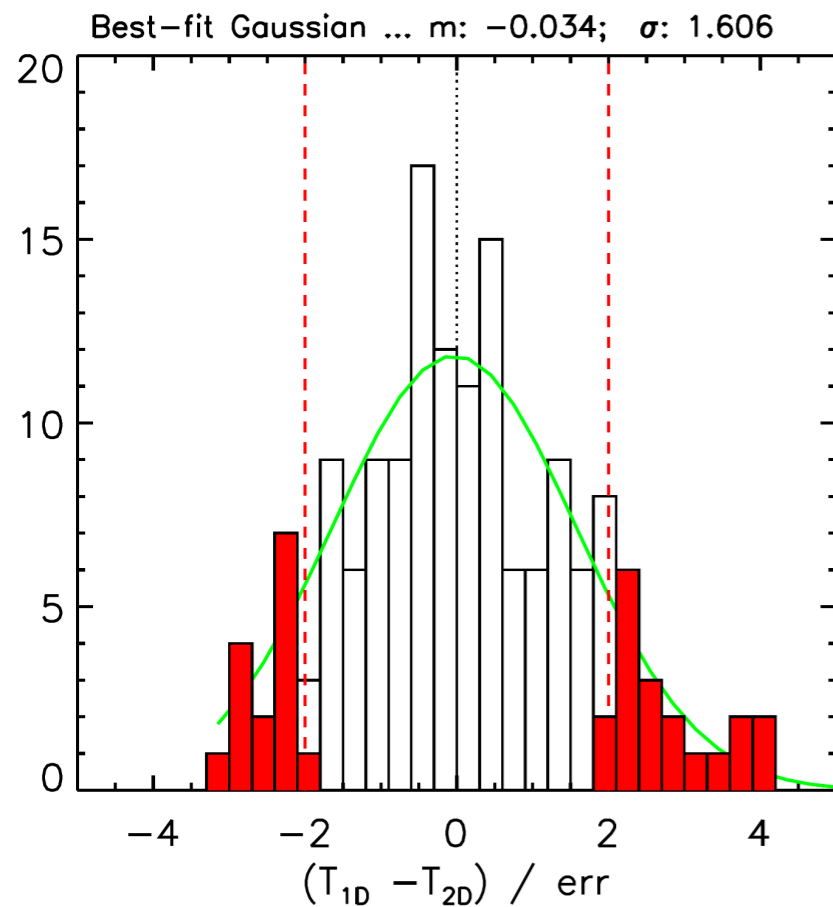
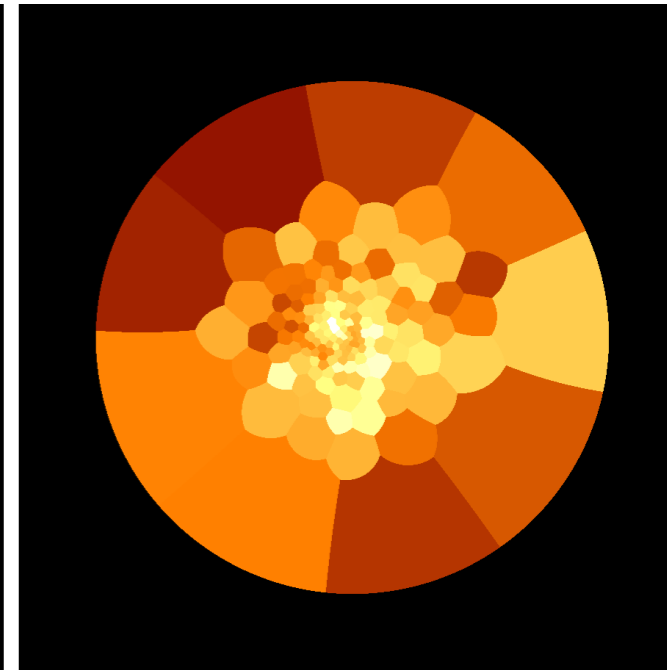
binning



SB



kT



Status

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 - ➔ **Good agreement between spectral and imaging info (e.g. n_e profile)**
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Thank you!