# AHEAD 2020 WP14 - Advanced tools for X-ray data analysis - task 14.8

(P. Mazzotta, H. Bourdin & F. Tombesi on behalf of task 14.8 members)

14.8.1-- Hyper-spectral fitting // Development of physical models to be fitted to high resolution spectra, including:

a) *AGN nuclear winds, both MHD and radiation driven;*

b) *AGN accretion disks;*

c) *AGN driven shocks;*

14.8.2 -- Development of algorithms and prototypes for advanced analysis of extended sources:

a) *Semi-automatic production of maps of physical quantities (e.g. temperature, abundance and/or velocity maps in the Intra-Cluster Medium);*

b) *De-noising. PSF deconvolution. Point source subtraction. Extended component separation and background noise modelling;*

c) *Prompt visualization/compression of data cubes by projecting quantities in one, two or three dimensions.*

## *14.8.1 Models for AGN nuclear winds, both MHD and radiation driven*

- People involved in this task: F. Tombesi, A. Luminari, M. Cappi, M. Dadina, F. Nicastro (need confirmation from E. Piconcelli, L. Zappacosta)
- Work under development for an Athena A&A white paper on the modelling of MHD and radiation driven disk winds. Paper led by Dadina, with several external collaborators.

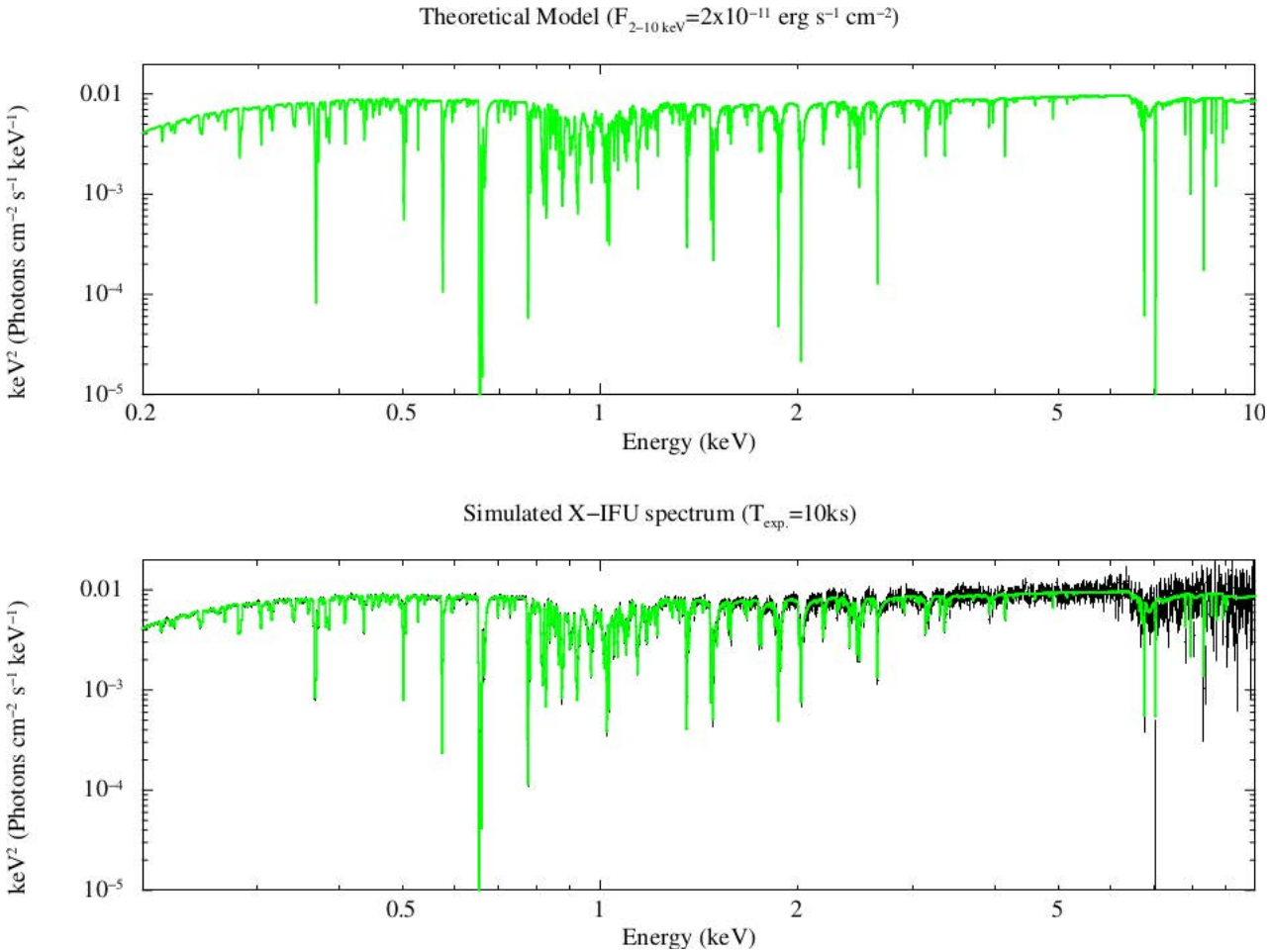
Definition of suitable MHD wind models from Fukumura et al.
Definition of suitable radiation driven wind models from Sim et al.
Comparison of XRISM and Athena simulations of MHD and radiation driven models, using PDS 456 as a case study
Definition of a larger collection of model realizations specific for very high energy resolution spectroscopy with X-ray calorimeters
Further development of the WINE emission and absorption model for the photoionization, geometry and kinematics of disk winds (Luminari et al.)

## *AGN accretion disks*

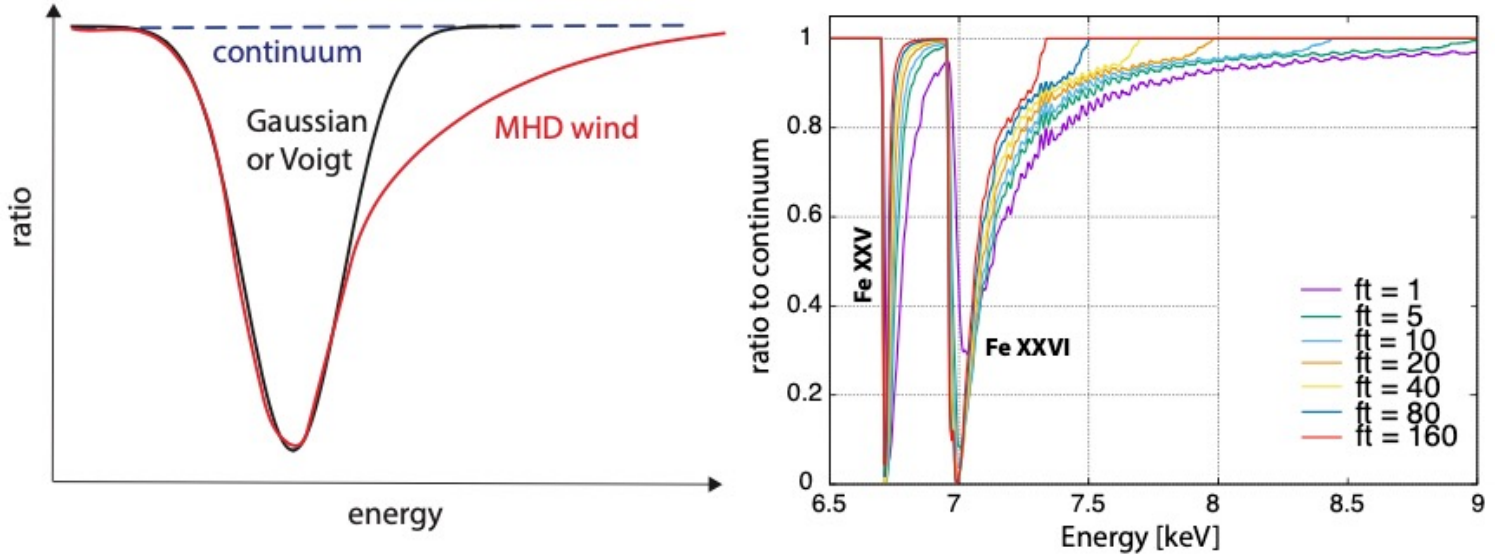
- People involved in this task: G. Matt, S. Bianchi Need input on the project.

## *AGN driven shocks*

- People involved in this task: F. Fiore et al. Need input on the project.

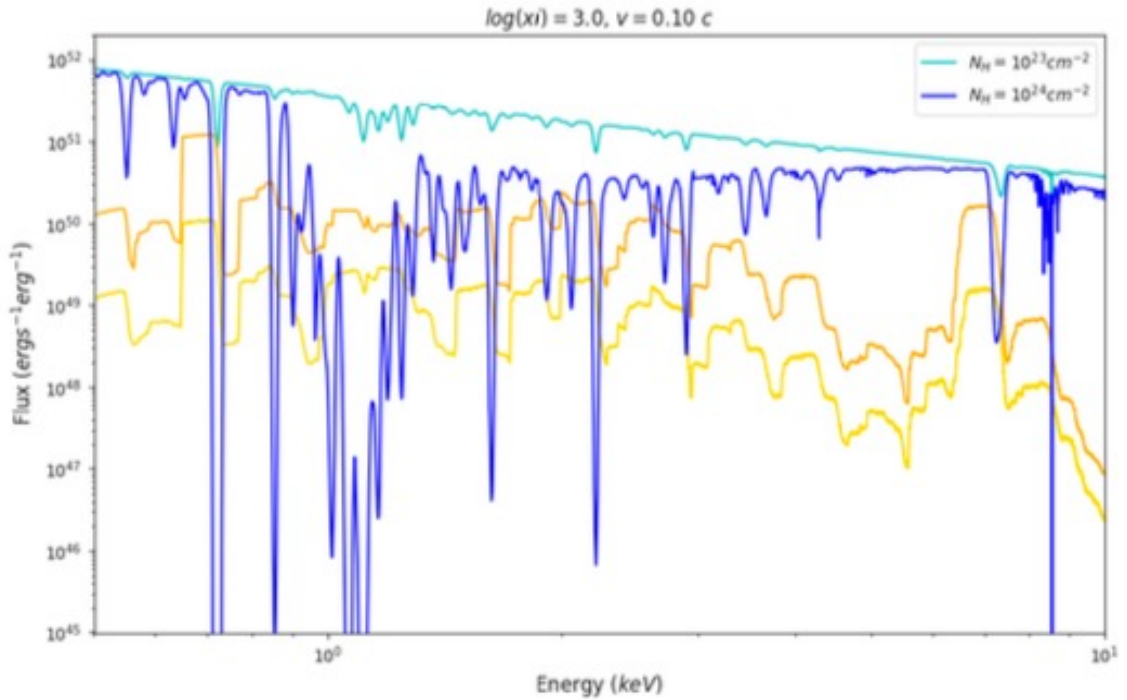



- Calculation of hyper-resolution grids of realistic black hole wind models coupled with photo-ionization calculations of ionic column densities from O to Ni
- Extensive hyper-spectral resolution simulations of XRISM/Resolve and Athena/X-IFU broad-band spectra
- Development of machine learning techniques for radiation driven models to speed-up the production of synthetic wind spectra and fitting procedures.




- Calculation and comparison between Gaussian or Voigt absorption profiles and line shapes with asymmetric blueshifts expected from magneto-hydrodynamic disk winds

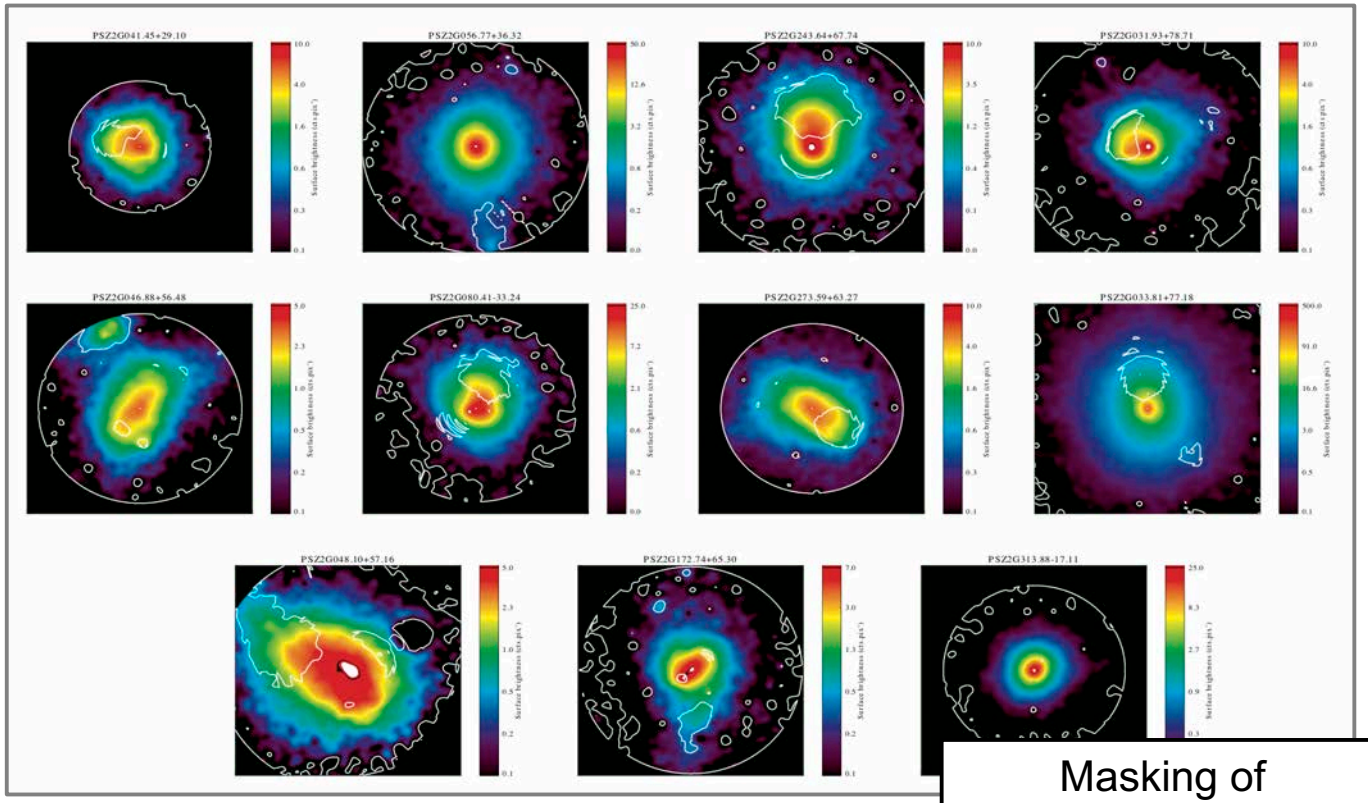
- Comparison of extensive XRISM/Resolve and Athena/X-IFU simulations of spectral lines from radiation and magneto-hydrodynamic winds




- We explored the calculation of realistic P-Cygni emission and absorption profiles from physically motivated accretion disk wind models for extended ranges of ionic species (WINE code)
- Extensive mock hyper-resolution spectra for XRISM/Resolve and Athena/X-IFU to estimate the instrumental detection capabilities

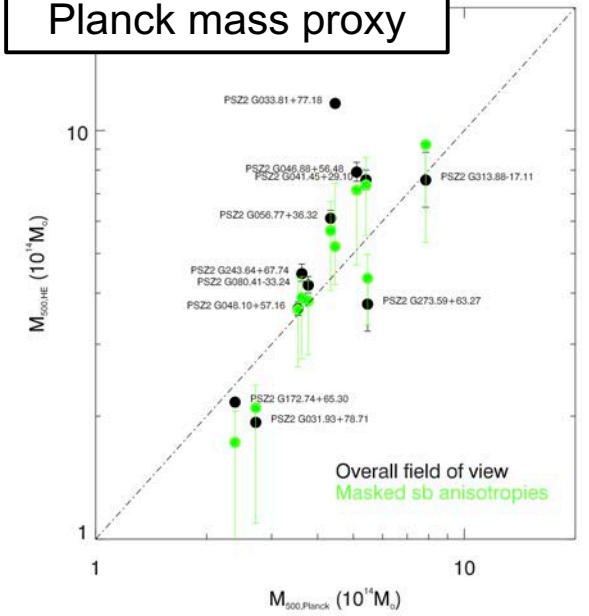
# X-ray images, denoising, Detection of features

XMM Heritage follow-up of Planck SZ catalogue of clusters
pilot sample (L. Lovisari, S. Ettori)

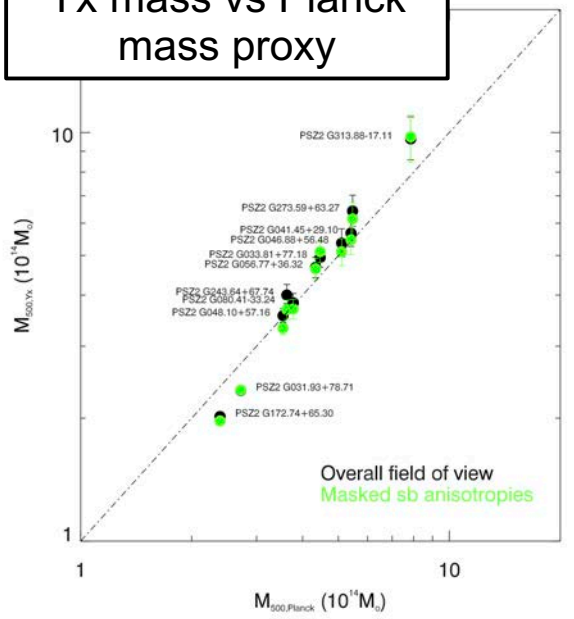



Masking of azimuthal surface brightness extrema

X-ray HE mass vs Planck mass proxy



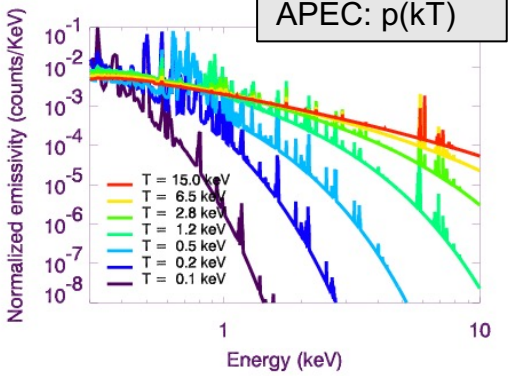

Yx mass vs Planck mass proxy



- We developed a spectral-imaging algorithm dedicated to galaxy clusters studies, that proposes to project the spatial variations of the projected Intra-cluster Medium (ICM) temperatures toward sparse representations. This has been achieved via a coupling between wavelet or curvelet analyses with an appropriate a weighting scheme of the temperature likelihoods.
- We tested this technique on a Chandra observation of the Abell 3667 cold front, where curvelet analyses allowed us to localise and trace the leading edge of this front, both on surface brightness and projected temperature maps. This allow us to evidence projected asphericities that might correspond to the growing of Kelvin-Helmholtz instabilities on the spheroidal interface. By comparing our signal with the expected signature of such instabilities on mock observations of hydro N-body simulated cold fronts, we could infer that the intrinsic width of the velocity interfaces does not exceed a few kiloparsecs. X-ray observations performed with the next generation X-ray telescopes should be needed to fully explore the microphysics of the ICM at play across and along such narrow layers.

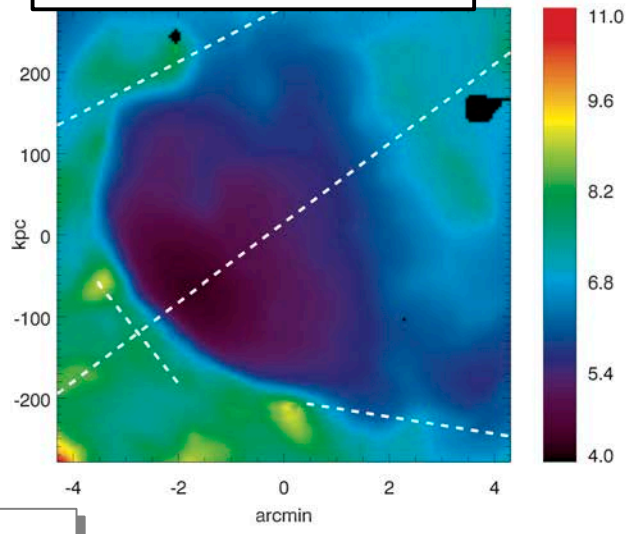
# Spectral-imaging

APEC: p(kT)

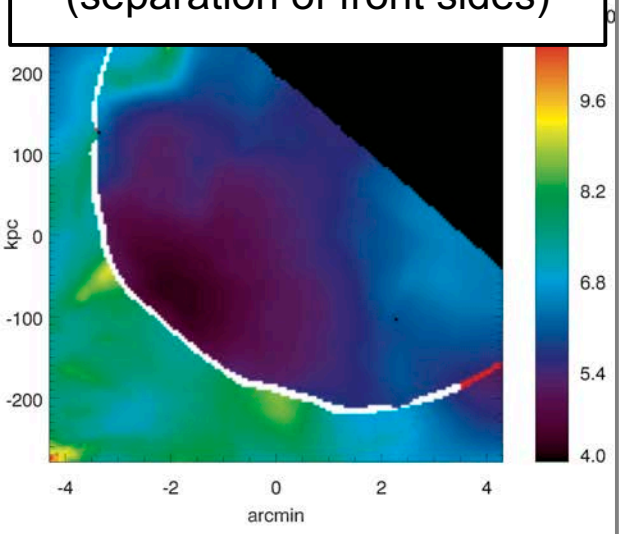



$$\widehat{kT} = arg\,max_{kT} \sum_{i=1}^{I_n} w_i \log p(e_i, kT)$$

Curvelet denoising (Chandra ACIS-I)

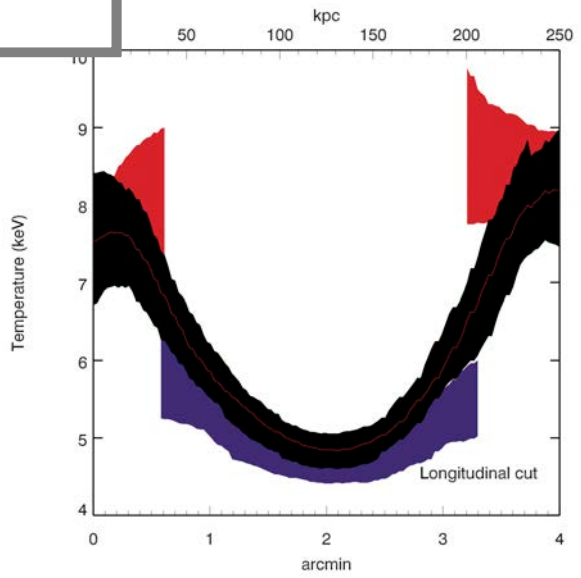


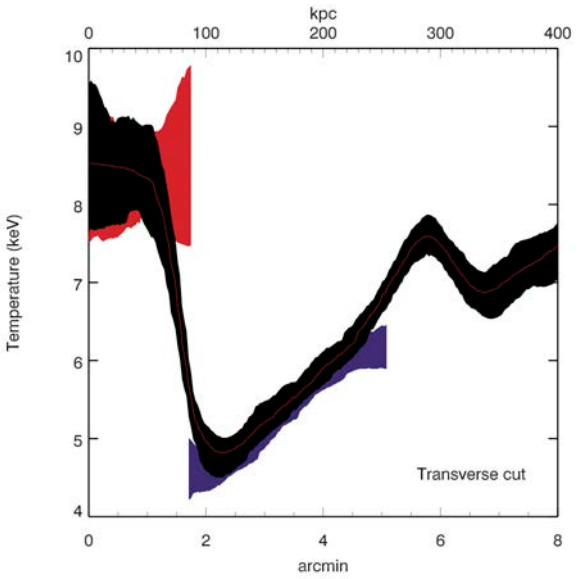

Curvelet denoising + surface brightness prior (separation of front sides)




Abell 3667 cold front

(Projected spectroscopic temperature)



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Possible developments

Alternative, complementary strategies:
– other kernel-weighting than wavelet/curvelets?
– *PSF deconvolution for imaging and spectral-imaging;*
– statistics of detected features (e.g. power spectra);
– *non-parametric spectral-imaging;*

Imaging:
– Athena WFI simulations:
Accreting material around clusters
(bridges, filaments);

Spectral-imaging:
– *Athena WFI-XIFU, maps of spectroscopic quantities (element abundances, bulk motions);*
– *Other targets than ICM?*

Data-stacking:
– *tool to test and improve (XMM) sky+instrumental background models;*
– *other self-similar objects than clusters*
*(e.g. galaxies and/or AGN coronae);*