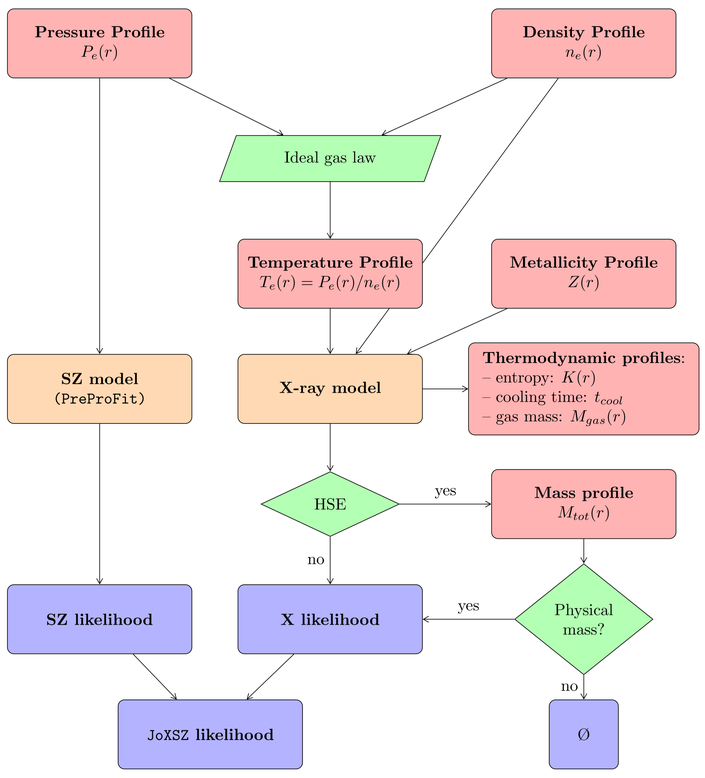
JoXSZ – Joint X-SZ pressure profile fitter for galaxy clusters

Fabio Castagna, Stefano Andreon
INAF – Osservatorio Astronomico di Brera, via Brera 28, 20121 Milano, Italy
github.com/fcastagna — fabio.castagna@inaf.it

SZ and X-ray observations both encode information about the intracluster medium. We present the first, to the best of our knowledge, publicly available code for jointly fitting the pressure profile of galaxy clusters. JoXSZ, as we named it, is build upon the SZ data fitting pipeline described in PreProFit[1] (Castagna & Andreon 2019) and the X-ray data cube fitter MBProj2, developed by Sanders et al. (2018). A special attention has been given to time-requiring operations, since a joint fit is notoriously slow.

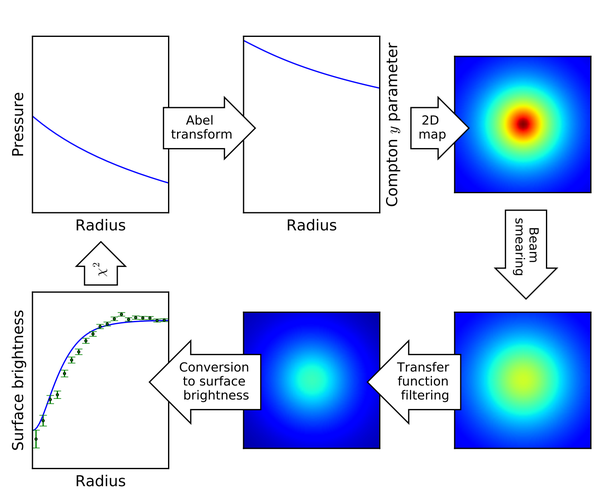
Program flow

The modeling behind JoXSZ relies on the parametrization of three quantities: the pressure profile, described by the generalized Navarro, Frenk & White (gNFW) model (Nagai et al. 2007), the electron density profile, modeled as a modified β-model (Vikhlinin et al. 2006), and the metallicity profile, which is assumed to be flat.



Flow chart. JoXSZ pipeline.

The modelization on SZ data, conducted with PreProFit, makes use of the pressure profile. PreProFit projects the three-dimensional pressure profile into a two-dimensional map using the forward Abel transform, then convolves the map with the instrumental beam and the transfer function, and finally derives the surface brightness profile, whose fit to the data is measured through the likelihood function of the model.



Block diagram. Program flow representation of PreProFit.

The modelization on X-ray data, conducted with an up-dated version of MBProj2, takes into account the metallicity profile, the density profile and the temperature profile, which is derived from the ideal gas law. JoXSZ fits surface brightness profiles in multiple X-ray energy bands and allows to compute thermodynamic profiles such as entropy, cooling time, gass mass profile. Optionally, under the assumption of hydrostatic equilibrium, the total mass profile can be obtained adopting a positive prior on mass at all radii.

Execution time

- SZ data modeling: 94% (Abel transform: 33%; 2D image interpolation: 18%; beam smearing: 24%; transfer function filtering: 23%; other: 2%)
- X-ray data modeling: 6%

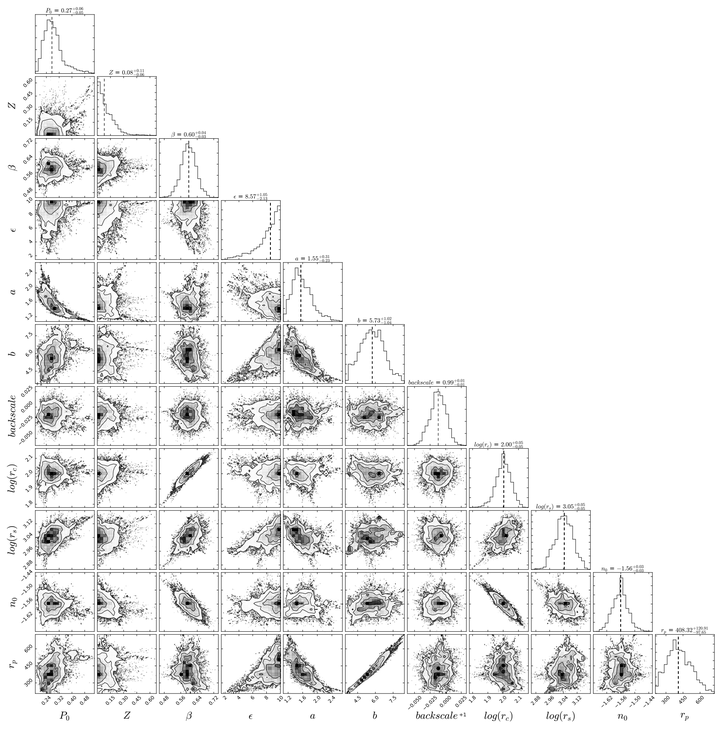
Application to CL J1226.9+3332 ($z = 0.89$)

We present an application of the program to the high-redshift cluster of galaxies CL J1226.9+3332. SZ data come from the publicly available NIKA data release[2], X-ray data come from the *Chandra* archive.

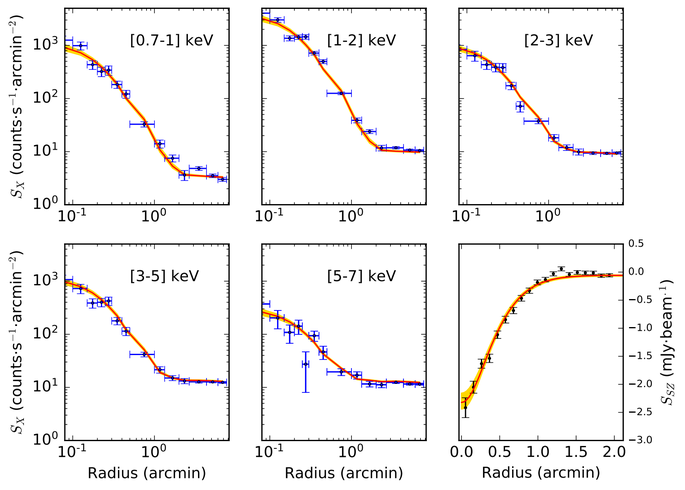
	Fitted	Fixed
Pressure	P_0, r_p, a, b	c
Density	n_0, r_c, β, r_s, ϵ	α, γ
Metallicity	Z	-

JoXSZ **parameters.** Free parameters and fixed parameters for our example. In general, users are free to choose which one to fit.

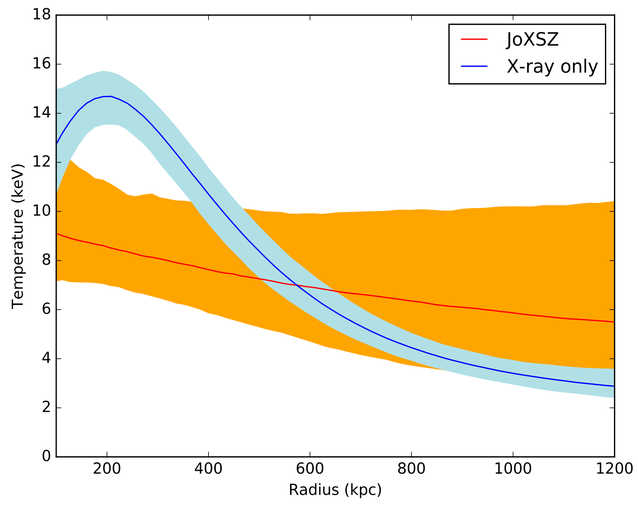
We report the main plots automatically produced by JoXSZ.



Cornerplot. Joint and marginal posterior distributions.

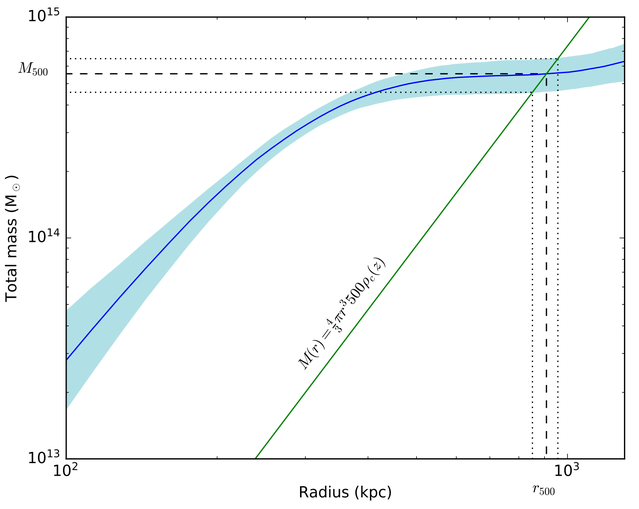


X-ray and SZ surface brightness profiles. Red lines: best-fitting profile. Yellow shaded areas: 95% CI. Blue points: X-ray data. Black points: SZ data. The X-ray profiles flat off to the background value.



Comparison of CL J1226.9+3332 temperature profiles. Our median profile is plotted in blue (95% CI shaded); the red curve shows the median profile for an analysis based on X-ray data only (95% CI in orange).

Compared to an X-ray only analysis, the addition of SZ data allows the reduction of temperature errors by a factor of 2 to 7.



Mass profile and overdensity radius derivation. Red line: median mass profile derived assuming hydrostatic equilibrium (95% CI shaded). $r_{500} = 908^{+49}_{-57}$ kpc. $M_{500} = 5.54^{+0.94}_{-0.97} \times 10^{14}$ M$_\odot$.

The median mass profile is obtained under the HSE assumption. The overdensity radius r_{500} and his mass M_{500} are derived simultaneously.

Conclusions

JoXSZ allows users to estimate the pressure profile of galaxy clusters through flexible and efficient modelization. The upcoming release of the program will supply a wide community of users with the first publicly available tool of this kind.

Acknowledgements

F.C. acknowledges financial support from the ADASS POC, from the agreement ASI-INAF n.2017-14-H.0, and PRIN MIUR 2015 Cosmology and Fundamental Physics: Illuminating the Dark Universe with Euclid.

References

Castagna, F. & Andreon, S. 2019, A&A, (in press)

Nagai, D., Kravtsov, A. V., & Vikhlinin, A. 2007, ApJ, 668, 1

Sanders, J. S., Fabian, A. C., Russell, H. R., & Walker, S. A. 2018, MNRAS, 474, 1065

Vikhlinin, A., Kravtsov, A., Forman, W., et al. 2006, ApJ, 640, 691

[1] https://github.com/fcastagna/preprofit
[2] http://lpsc.in2p3.fr/NIKA2LPSZ/nika2sz.release.php