Explore Extended X-ray Emission around Galaxies at $0.05<z<0.1$ with eRASS1 Data

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Motivation

Studying the distribution and characteristics of gas around galaxies (circum-galactic medium, CGM) is important to understand the evolution of central galaxies. The majority of the gas that is virialized with temperature larger than 10^6K, produce X-ray emission. With eROSITA and its full sky survey, we can study the hot gas with large galaxy sample and get the relatively unbiased result of the properties of CGM, and its relation to the properties of central galaxies, like stellar mass or star formation rate.

In this work, we stack galaxies to get better statistics to detect the X-ray emission from hot gas. We find the projection effect of background galaxies is too strong, properly modelling it is necessary to interpret the observation result correctly.

Data

eROSITA data: We use the data products (version 020) from the first scan of eROSITA (eRASS1), including event files, exposure maps and preliminary source catalogs of AGN and galaxy cluster. The average exposure time of eRASS1 is about 250s. After masking the sky area with $N_H > 10^{21} cm^{-2}$, $E(B-V) > 0.1$ and sky area near bright local extended sources, the clean area we studied is about 9340 square degree.

Galaxy sample: We use the DESI Legacy Imaging Surveys DR9 catalog and the corresponding SED fitting results of photometric redshift (z_p) and stellar mass(M_*) [1][2]. To ensure the completeness of the galaxy sample, we select galaxies with $0.05<z_p<0.1$ and $10^{10} M_\odot < M_* < 10^{11.5} M_\odot$ (see the second plot at top right panel). We remove satellite galaxies and only keep central galaxies in our sample. The galaxies are divided into red and blue populations according to its color (see the first plot at top right panel). Finally, we have about 156k red galaxies and 44k blue galaxies.

Stacking method

We refer to the stacking method of Comparat et al. (2022), extract event cubes around galaxy, bright point source, random point to get the X-ray emission around galaxy, empirical point spread function (PSF), background intensity respectively. We mask point sources and extended sources in the event cubes with the source extent radius from srcTOOL and correct the masking area when we calculate the X-ray surface brightness. We stack the red sequence and blue cloud in different stellar mass bins respectively to get the projected X-ray emission morphology and profile.

References

[1] https://www.legacysurvey.org/dr9/
[2] Zou, H., Gao, J., Zhou, X., Kong, X. (2019). Photometric Redshifts and Stellar Masses for Galaxies from the DESI Legacy Imaging Surveys. The Astrophysical Journal Supplement Series, 242(1), 8.
[3] Comparat, J., Truong, N., Merloni, A., et al. 2022, arXiv:2201.05169

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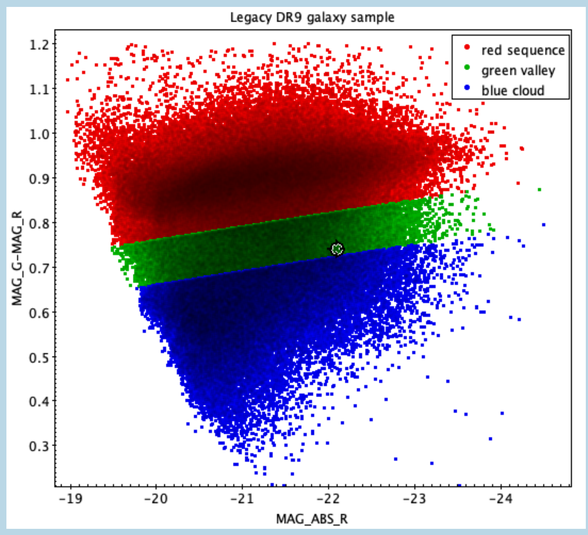
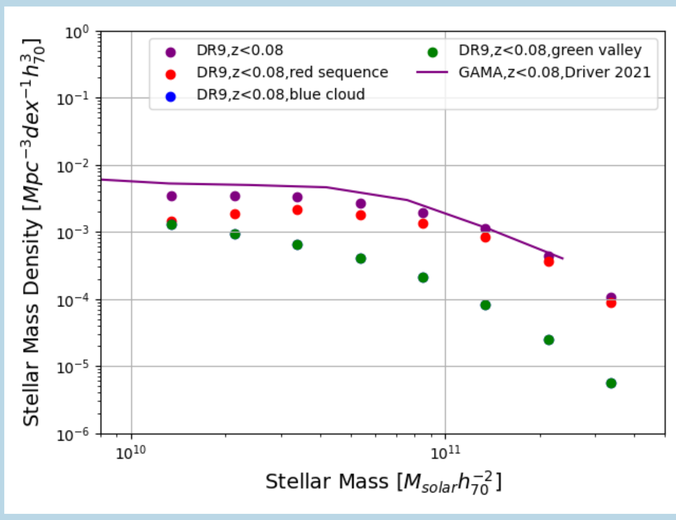
Galaxy sample



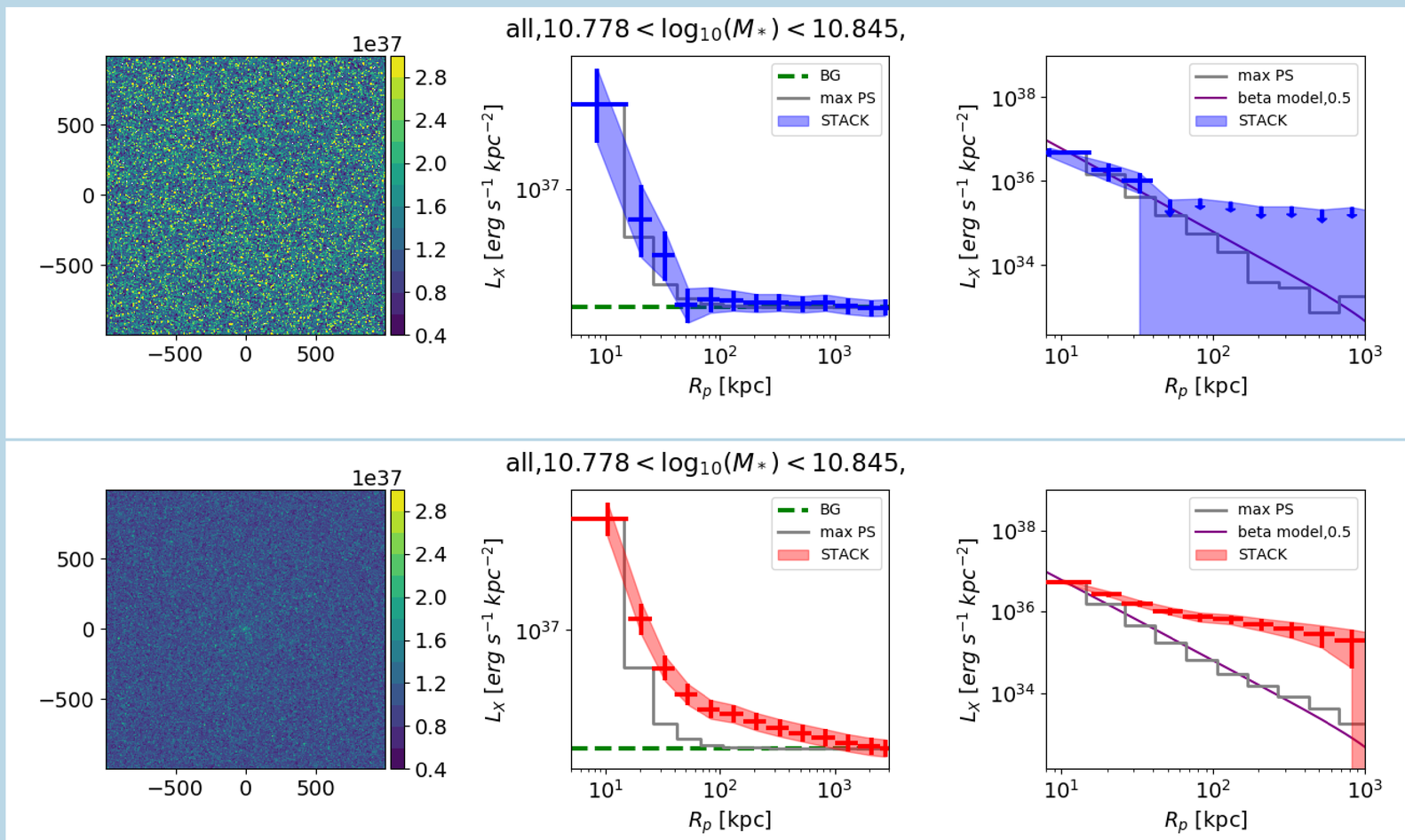


Results: extended X-ray emission

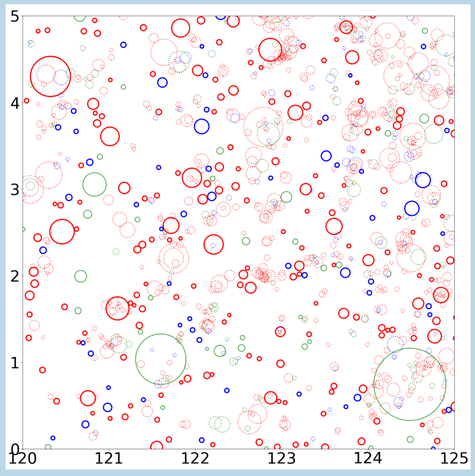
Upper and lower plots are projected X-ray surface brightness profile of blue and red galaxies in Milky-Way-like stellar mass bins. The number of stacked galaxies are 547 and 9267 respectively.

Blue galaxy: Due to the limited number of blue galaxies in this bin, we observe the X-ray halo out to 40 kpc. The emission is the sum of CGM, x-ray binary and unresolved AGN.

Red galaxy: But on the contrary, the X-ray halo of red galaxy extends out to 1 Mpc, that is further than the typical virial radius (200kpc). This means a large fraction of the X-ray emission comes from projection effect.



Quantify projection effect: "isolated" galaxy



We project the $1R_{vir}$ halo of galaxies over the sky (see the left plot for example), the colors denote the red/green/blue population of galaxies. If the halo of one galaxy has no overlap with other halos or only overlap with small halos, we define it as isolated galaxy (draw in solid circle). We stack the 1891 isolated red galaxies at the same mass bin as above stacked, the halo extends out to about 100kpc, instead of 1 Mpc.

This experiment illustrates the projection effect at stacking process and the importance of modelling it to interpret stacking result of the complete central galaxy population.