DISCOVERY OF WARM-HOT CGM AROUND A STARBURST $L_\star$ GALAXY

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INTRODUCTION

Circumgalactic medium (CGM): The multi-phase gaseous medium around the disk of spiral galaxies, extended upto the virial radius of the galaxies. "Fuel tank, waste dump and recycling center"[1] of galaxies all at the same time, playing a key role in galaxy evolution.

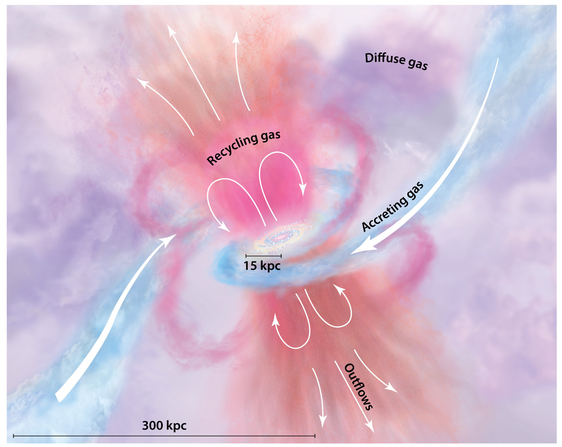

Figure 1: An artist's impression of CGM[1]

- A possible solution to the missing-baryons and missing-metals problem
- Mass measurements of cold and cool (T$< 10^4$ to $\sim 10^{4-5}$K) gas are highly uncertain due to assumptions in metallicity and ionization corrections. **Warm (T$\sim 10^{5-6}$K) and hot (T$> 10^6$K) phases are the right places to hit on**
- The diffuse soft X-ray emission from warm-hot phase is probed using O VII (0.567 keV) and O VIII lines (0.659 keV)
- Very few luminous spirals and ellipticals have their halos detected in warm-hot phase
- Independent constraints on temperature, density, metallicity profiles are rare
- Dependence of warm-hot baryons on stellar or halo mass, and SFR are NOT known yet

OBJECTIVE & METHODS

Objective:

1. Detect and characterize the circumgalactic medium of **NGC 3221**, a late-type star-forming (SFR ~ 9.92 $M_\odot yr^{-1}$) $L_\star$ galaxy
2. Model the CGM to estimate the mass and the spatial extent. Relate that to the galactic properties like sSFR, $M_\star$, R_{vir} etc.

Methods: Simultaneously fit the *Suzaku* spectra of the galaxy-field and an off-field $\sim 2^o$ away as a composite of LB & SWCX, GH, CXB and the **actual signal** to obtain the emission integral of CGM within different $r_\perp$

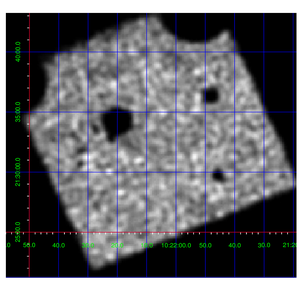

Figure 2: Smoothed Image of galaxy-field, removing point source + 20 kpc around galaxy

RESULT-I: O I CONTAMINATION IN *Suzaku* DATA

The off-field spectrum observed in November, 2014 shows a significant excess around 0.5 keV unless the O I fluorescent line contamination is taken into account, leading to a very poor fit and poorly constrained parameter values. It confirms the importance of considering O I line contamination in post-2011 data ([2]), now with a more robust spectral modeling.

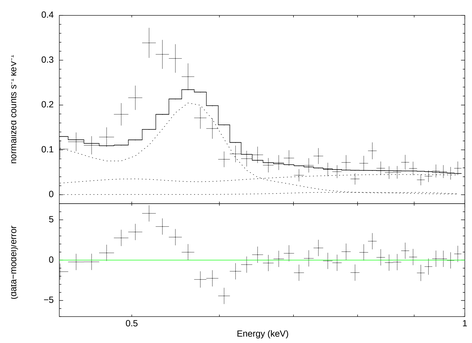

Figure 3: Off-field spectrum without O I line

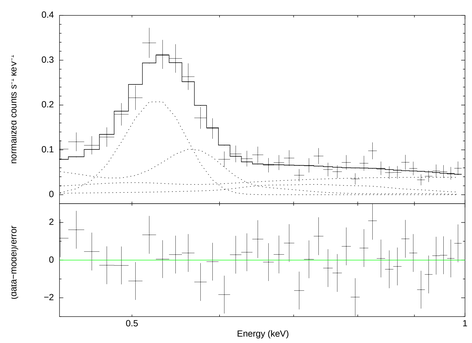

Figure 4: Off-field spectrum including O I line

RESULT- II: AN EXTENDED CGM DETECTED BEYOND 20 kpc!

We have detected warm-hot CGM outside 20 kpc region of NGC 3221, at $\sim 3\sigma$ confidence upto 100 kpc and at $\sim 2\sigma$ confidence in the whole FOV, covering ~200 kpc region around NGC 3221.

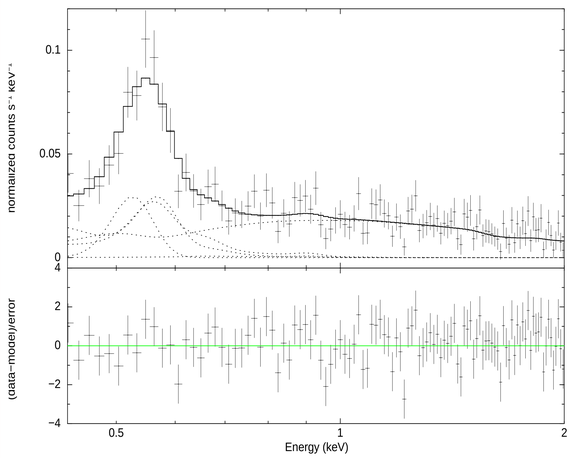

Figure 5: Spectrum within 100 kpc of NGC3221

- Comparable contribution from the local bubble (LB), O I line and the CGM of NGC 3221 makes the detection challenging
- The off-field plays the role of reference. Due to similar temperature and functional form of the LB and the CGM of NGC 3221, a separate fitting of the galaxy-field does not yield any confident detection
- **Temperature:** $1.66^{+0.49}_{-0.37} \times 10^6$ K within 100 kpc; $1.74^{+0.61}_{-0.18} \times 10^6$ K within 200 kpc ($T_{GH} \sim$ (1.8-2.4)$\times 10^6$ K [3])
- **Emission measure:** $7.40^{+2.60}_{-2.89} \times 10^{-6}$ cm^{-6}kpc at 100 kpc (assuming Z = $Z_\odot$, constant density) [$EM_{GH} \sim 3.0 \pm 0.6 \times 10^{-6}$ cm^{-6}kpc ([4])]

n$\sim 1.8^{+0.3}_{-0.4} \times 10^{-4} cm^{-3}$ **(assuming** $n_p \sim n_e$**, R**$_{halo}$**= 150 kpc). Mass**$\sim 5.68^{+0.92}_{-1.25} \times 10^{10} M_\odot$

CONCLUSION & FUTURE PLAN

Conclusion:

- Discovered hot CGM around a $L_\star$ starburst galaxy upto $\sim$ 150 kpc
- Confirmed that the detected diffuse gas is NOT an extra-planar emission, therefore residing in the halo
- Verified that the warm-hot phase of CGM is almost isothermal
- Estimated density and mass assuming a homogeneous sphere

Future plan:

- Obtain emission measure at different distances from the galaxy's center
- Test β-model and NFW density profile

REFERENCES

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[4] Gupta A.; Mathur S. et al. *ApJ*, 756(1):L8, 2012.

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