Title: Chemical enrichment patterns as a tool to identify feedback processes in the CGM

Speakers: Suyash Kumar

Collection/Series: Cosmic Ecosystems

Subject: Cosmology

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Abstract:

The CGM is sensitive to various baryonic flows (e.g. stellar winds, supernovae, etc.) occurring on different timescales. Chemical abundance patterns in circumgalactic clouds provide a unique timing clock for constraining the dominant source of feedback regulating galaxy growth. In this talk, I will discuss how we leverage multiwavelength quasar spectra from surveys like the Cosmic Ultraviolet Baryon Survey (CUBS) to constrain the gas ionization state and elemental abundances of cool/warm-hot CGM absorbers. We find relatively cool (~1-5e4 K), diffuse (~0.001-0.01 cm^-3) photoionized gas clumps exhibiting a variety of chemical enrichment patterns. Several absorbers show an enhancement in non-alpha elements (e.g. carbon, nitrogen) reflecting metal production by secondary nucleosynthetic pathways. We also find chemically mature, metal-poor absorbers, showing evidence of mixing between pre-enriched gas and pristine inflows. These results demonstrate the value of using elemental abundances to understand which feedback processes are most critical in shaping the cosmic baryon cycle.

Tracing CGM Feedback Through Chemical Enrichment Patterns

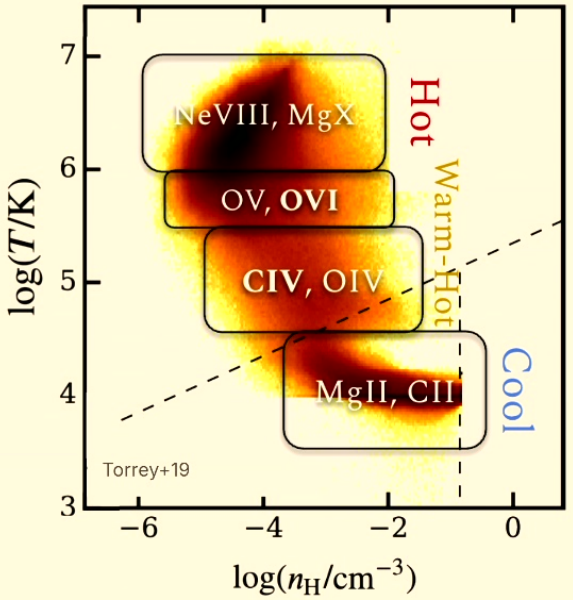
Suyash Kumar (UChicago)

Hsiao-Wen Chen (UChicago), Gwen Rudie (Carnegie Obs.), Zhijie Qu (Tsinghua U.), Sean Johnson (UMich), Nishant Mishra (UMich), Fakhri Zahedy (UNT), the CUBS team

Probing the multiphase CGM with ionic tracers

The CGM spans a large dynamic range in gas densities and temperatures traced by different ionization stages

The hot phase is probed in emission with X-ray, while the cooler phases are probed using absorption in the UV



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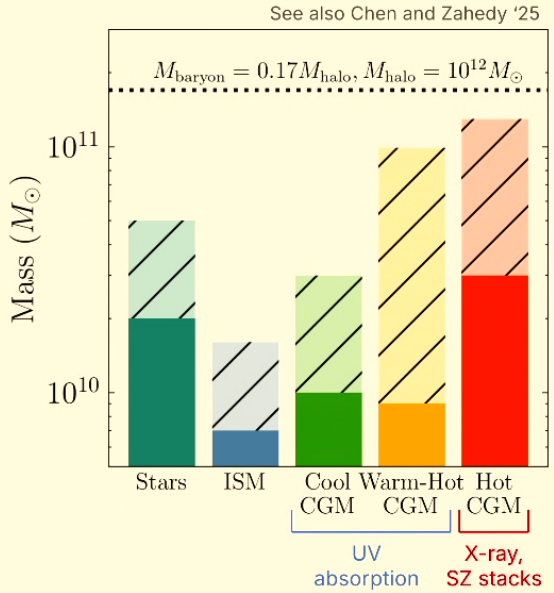
Mass census of diffuse gas in galaxy halos

In a typical L* halo, stars+ISM account for <25% of the expected baryon budget – the rest is in the CGM

The hot CGM dominates in mass, but physical properties (e.g., thermodynamics, chemistry) necessary to understand the baryon cycle can only be studied in cooler phases

See also Chen and Zahedy '25



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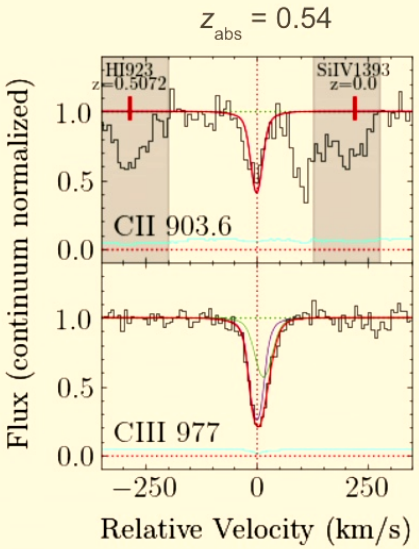
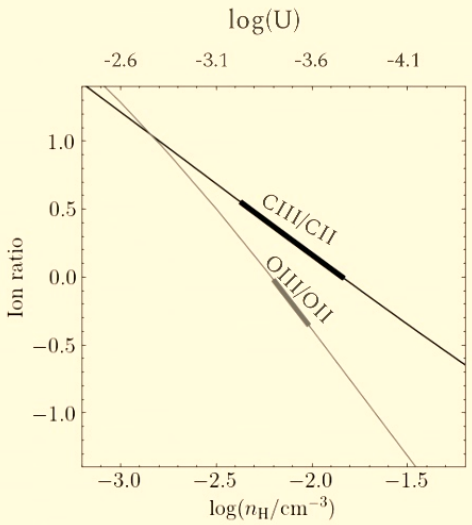
Constraining the ionization state



Kinematically aligned absorption is identified in successive ionization stages

The relative strength of ions is sensitive to the ionization parameter $U = \Phi/cn_H$

The ionization correction is necessary to derive elemental abundances



See Zahedy+19, Qu+22

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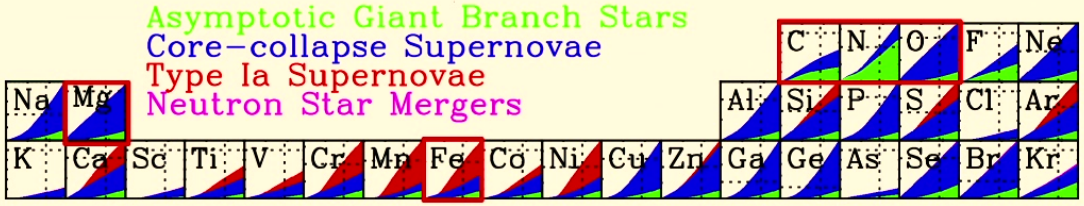
Chemical abundances as a timing clock



Kobayashi+20

α-elements (O, Mg, S, Si, etc.) are primarily produced by CCSNe on ~Myr timescales, while Fe, C, N are produced by type Ia SNe and AGB winds on >100 Myr timescales

Relative abundances [X/α] = $\log_{10}(n_X/n_\alpha)-\log_{10}(n_X/n_\alpha)_\odot$ therefore trace the relative importance of different feedback processes in enriching the CGM

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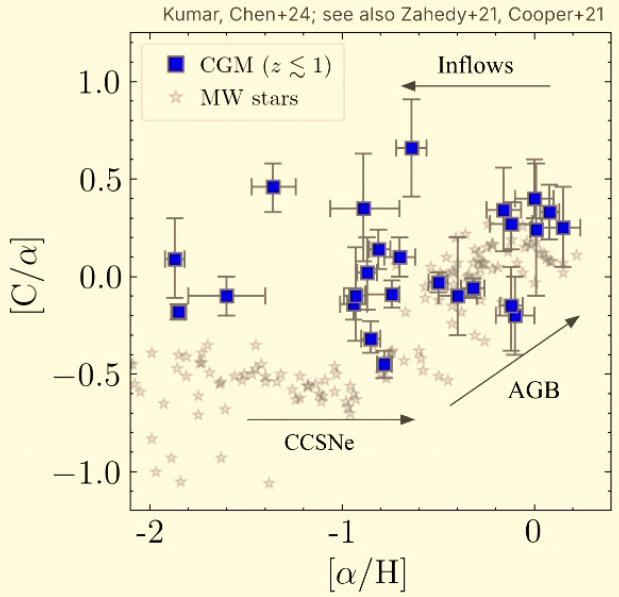
Chemical enrichment patterns in the CGM

Absorbers found to target metal-enriched, carbon-enhanced gas

CGM reflects secondary carbon enrichment driven by AGB winds following primary enrichment by CCSNe

Metal-poor enriched absorbers indicate dilution of pre-enriched gas with pristine inflows from the IGM

Kumar, Chen+24; see also Zahedy+21, Cooper+21



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6 Chemical enrichment patterns in the CGM

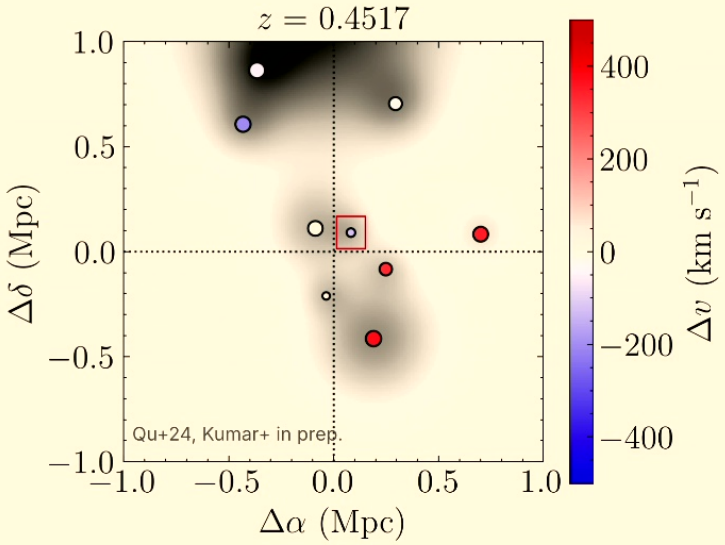
7 Future outlook

8 Backup slides

9 The impact of galaxy environments

Future outlook

- The cool+warm-hot CGM offer an opportunity to investigate chemical abundance patterns tracing feedback processes enriching the halo gas
- Deep galaxy surveys (e.g. CUBS) will help connect the CGM enrichment pattern with star-formation properties and overdense environments



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Backup slides

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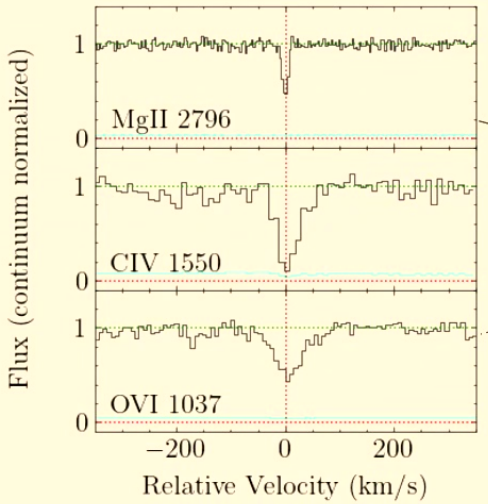
The impact of galaxy environments

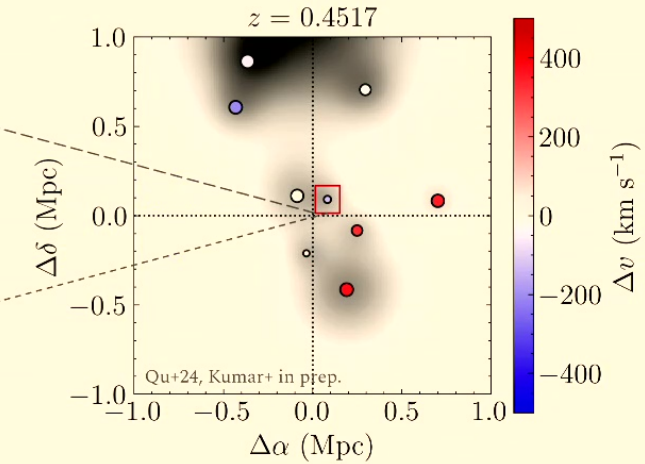
HST Cycle 25 and 31, Co-PIs: Chen, Johnson, and Rudie

Refer Nishant Mishra's talk

Multiphase gas uncovered near group environment

Understand chemical enrichment across different galaxy types





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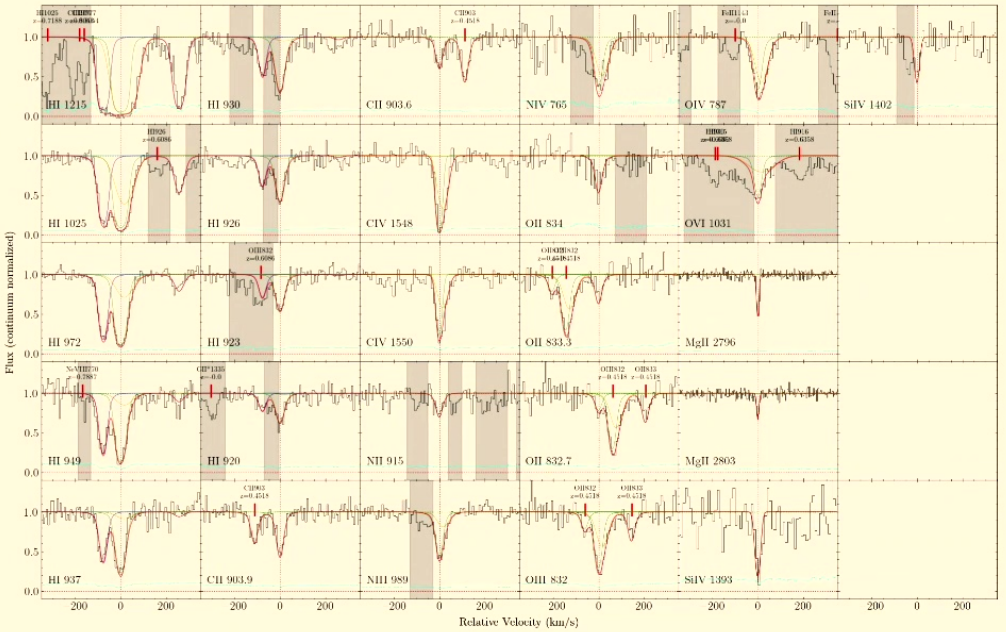
Voigt profile fitting

Invoke minimum number of components to explain metal ions

Have associated H I component for each metal component

Have ionic column densities and line widths (and uncertainties) for each component



10

15 total slides

Cloudy modeling

Fit photoionization equilibrium (PIE) models for each kinematic component

May require two phase models to explain a wide range of observed ionization stages

Possible to determine relative abundances for each phase