PICO Collaboration Science Meeting

Science from the Probe of Inflation and Cosmic Origins (PICO)



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SZ Effects and Galaxy Formation

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Goals

- Remark: This is NOT (only) about clusters
 ⇒This is about galaxy formation and the baryons
- The SZ effect is a powerful tool to probe an elusive cosmic component
- Case for space and for space-ground synergy
 - Ground: High angular resolution
 - Space: High frequencies



The cosmic web of LSS: Illustris Simulations (http://www.illustris-project.org)

Lensing (galaxy and CMB) will probe the DM web



Galaxy surveys will probe the galaxy web



But a big piece is missing...

Only ~10% of baryons make stars!

Galaxy Formation Is shockingly inefficient:

~90% of baryons are elsewhere

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90% of the Baryons are here!

This



is really ...

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That:



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The Imperatives

You cannot understand galaxy formation and evolution without understanding:

- 1. Where most of the baryons are
- 2. Why they don't make stars

Questions

- The CGM/IGM and its relation to the cosmic web and galaxy properties
- What keeps it from making stars: feedback
- How it supplies fresh fuel for star formation

Galaxy Formation

The rise and fall of cosmic star formation activity

Produces stellar mass that we call galaxies

But leaves 90% of baryons behind



Madau & Dickinson (2014)

The Challenge

Understanding Galaxy Formation

Understand Feedback & the CGM/IGM

Observe the CGM/IGM

low density, diffuse gas Difficult to observe

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A New Probe

Understanding Galaxy Formation

Understand Feedback & the CGM/IGM

Observe the CGM/IGM

Sunyaev-Zeldovich Effect (thermal & kinetic SZ)

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Planck tSZ Measurement



tSZ Effect and the CGM



Probing Galaxy Formation



Verdier et al. (2015)

Battaglia et al. (2017)

Measure CGM and star formation rate out to high redshifts Constrain feedback efficiency to % level

European CMB, Florence, 9/2017



kSZ Effect and the CGM/IGM



PICO & Galaxy Formation

- The thermal SZ effect directly probes the thermal energy of the CGM
- The kinetic SZ effect probes the quantity of CGM
- CMB halo lensing measures dark matter host halo mass (see talk by A. van Engelen)
- Study CGM versus mass and redshift and by galaxy type & properties

All out to peak of cosmic SFR

PICO Thermal SZ Sensitivity



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PICO SZ Dust Contamination



S4 Thermal SZ Sensitivity



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S4 SZ Dust Contamination



Conclusions

- SZ effects are powerful new probe of the dominant baryon phases: CGM/IGM
- Key to understanding galaxy formation
- Key systematic: dust contamination by the sources themselves
 - Need high frequencies to separate SZ and dust
- Dust emission interesting in own right
 - SFR tracer (e.g, CIB)

Case for space and space-ground synergy