LIGHTING UP SHADOWS:
CO AND [CII] DETECTIONS OF ABSORPTION-SELECTED GALAXIES

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CGM GAS SHAPES THE GALAXY AT EVERY REDSHIFT

- Supplies the gas needed to sustain star formation.
- Ubiquitous in all simulations.
- Observationally difficult to image directly at high-z.
OBSERVING THE GAS SURROUNDING GALAXIES

HI GAS IN ABSORPTION

- HI gas will absorb light from bright background sources such as QSO.

- Strongest HI absorbers are known as damped Ly-α Systems (DLAs).

- Detailed description of the metallicity, kinematics, physical characteristics of the gas.
- Single sightline through halo enables a statistical description of the properties of the absorbing gas.
- Enrichment of the gas mimics the enrichment of galaxies.
EXCEEDINGLY DIFFICULT TO DIRECTLY DETECT THE GALAXY RESPONSIBLE FOR THE DLA

- Critical for understanding the role of HI gas in galaxy formation.
- Provide stringent constraint for current simulations modeling the HI gas around galaxies.
THE SAMPLE

FINDING OPTICAL COUNTERPARTS OF ABSORBERS IS DIFFICULT.

ANSWER: OPTICAL ➤ SUBMM

DIRECTLY DETECT THE GALAXY ASSOCIATED WITH THE ABSORBER

- 7 out of 8 absorbers at z<1 observed in CO
- 2 out of 3 absorbers observed at z~4 in [CII]
CO EMISSION OF DLA HOST GALAXIES AT Z<1

KINEMATICS OF THE ABSORPTION GAS IS INCONSISTENT WITH COMING FROM AN EXTENDED DISK
2 out of 2 host galaxies detected both in [CII] and continuum!

These are the highest - z spectroscopically confirmed host galaxies of absorbers (z=4.26 and z=3.80).

Highlights the unique ability for ALMA and [CII] as a way to detect the hosts of absorbers, where other observatories and methods have failed.
[CII] EMISSION AT Z~4

These 2 absorption-selected galaxies have:

- SFRs of 24 and 110 M⊙/yr
- TIR luminosities of ~10^{11} L⊙ and 10^{12} L⊙
- Similar properties to the more massive LBGs at similar redshifts

These are ‘normal’ galaxies at Z~4
THE [CII] EMISSION IS CONSISTENT WITH ARISING FROM A COOL DISK.
[CII] EMISSION OF DLA HOST GALAXIES AT Z~4

**HOW CAN WE EXPLAIN HI GAS THIS FAR AWAY FROM THE GALAXY?**

- Satellite galaxy?
- Outflows?
- Enriched inflow?

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HALF A DECADE OF ALMA CONFERENCE 09/22/2016 MARCEL NEELEMAN (UCSC)
SUMMARY

- Absorption-selected galaxies provide the only way to probe HI gas at high redshifts, but the association between absorbers, such as DLAs, and the host galaxy is difficult to observe.

- ALMA has proven to be exceedingly effective in detecting the host galaxies of DLAs, both in CO at low redshifts (z<1) and [CII] at high redshift (z~4).

- The two detections at z~4 are the highest known associations, and suggests that the most metal-rich absorbers have host galaxies with properties similar to massive LBGs.

- Absorption-selected galaxies therefore provide an effective way of selecting `normal' galaxies at any redshift.

FUTURE

- Increase sample size to provide a statistical description of absorption-selected galaxies. Approved Cycle 4 program: Characterizing Absorption-Selected galaxies at High-z (CASH) Survey (PI: Neeleman).