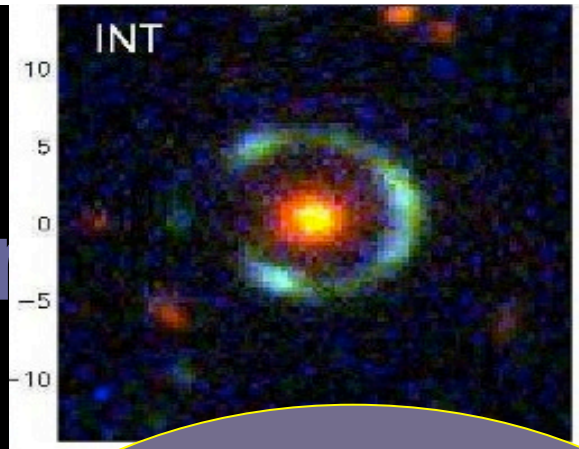
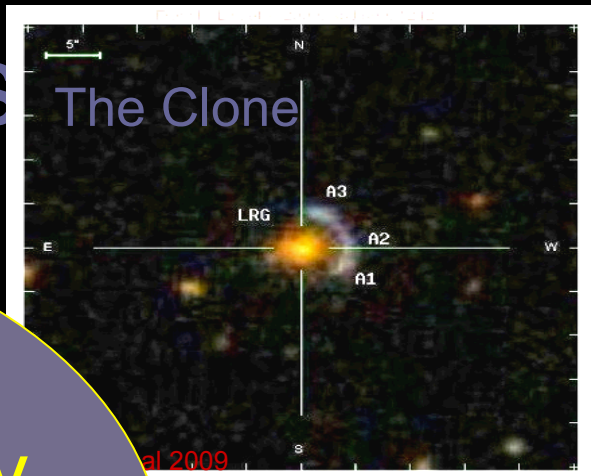




Herschel Extremely Lensed Line Observations (HELLO)

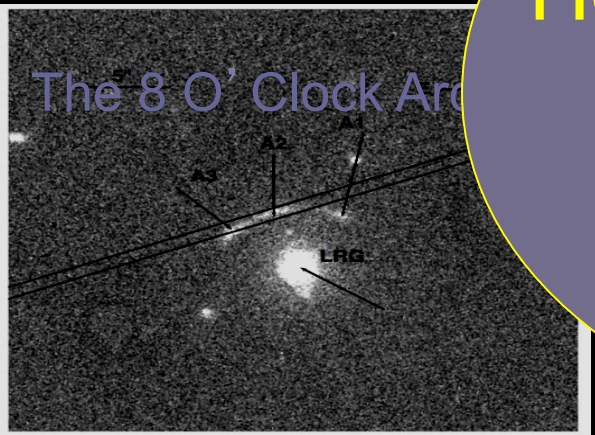


FIG. 2.— NIRI H-band image of the 8 o'clock arc, made from combining the acquisition images. The three components as defined by Allam et al. (2007) are labeled, and we show the position, orientation and width (0.72″) of our slit, which covered components A2 and A3. Also indicated is the luminous red galaxy (LRG) at z = 0.38 responsible for the lensing of the 8 o'clock arc.

Finkelstein et al 2009, ApJ 700, 376

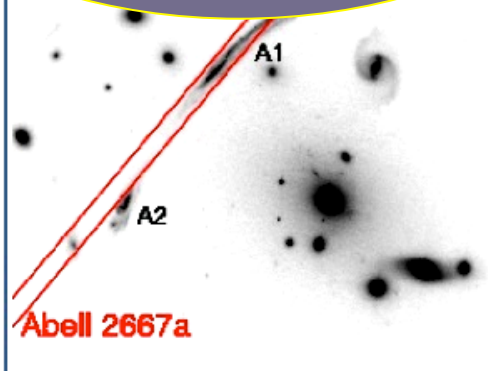


Figure 1. (Left) A true-colour image of the core of A 2218 composed from the *HST* F450W (blue), *HST*
The 850-μm submm image from SCUBA is overlayed as white contours at flux densities of 2.5, 3.3,

[CII] observations of galaxies of ordinary luminosities at the peak of cosmic star-formation epoch.

Motivation:

Why [CII] line?

Why High redshift of z~2

Why Blue galaxies…

[CII]

- **Powerful**
  - 0.1-1% of FIR luminosity in *a majority of the galaxies.*
  - Typically 1000-4000 times the brightest CO line.
- **Puzzling**
  - Where is it coming from -CNM, WIM?
  - What drives the variations in [CII]
- **Practical**
  - no extinction (for most galaxies)
  - Great tool for studying high redshift (z>6) galaxies with ALMA

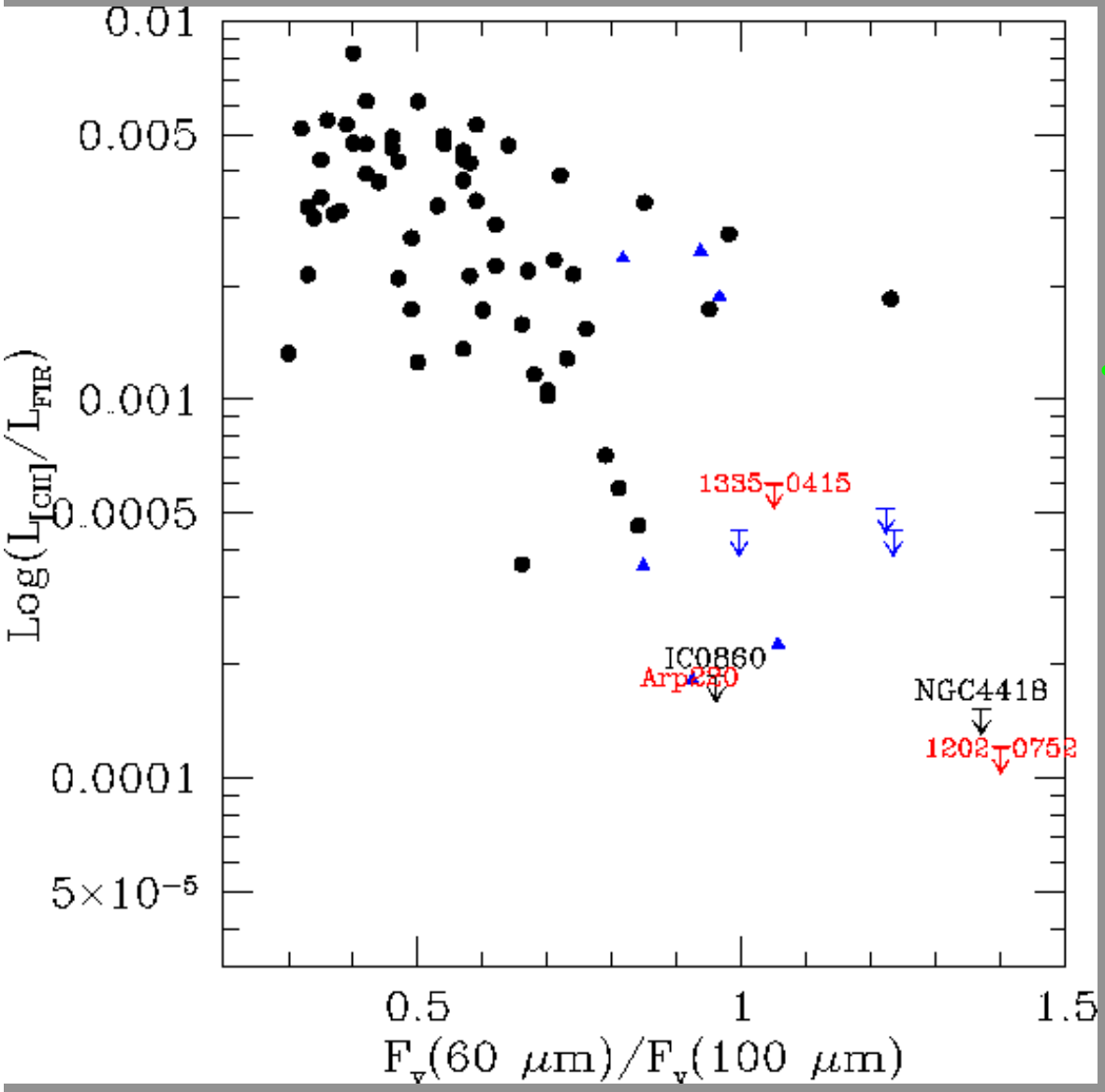
Why high redshift ?

- Z ~2 is the peak of cosmic star-formation
  - What is special about that epoch?
  - Probe the physics of the ISM
  - Complement the CO studies (e.g. Daddi et al. Genzel et al. 2010)

- ALMA will probe [CII] at even higher redshifts.

- Why optically selected galaxies (one submm)
  - In numbers (at least) the faint blue galaxies constitute the bulk of star-formation
  - In total star-formation they make up 30-80% of SF
- Why lensed:
  - Magnification makes it possible to get a relatively unbiased sample.
  - possible to observe these galaxies.
  - possible to probe ~100 pc range.

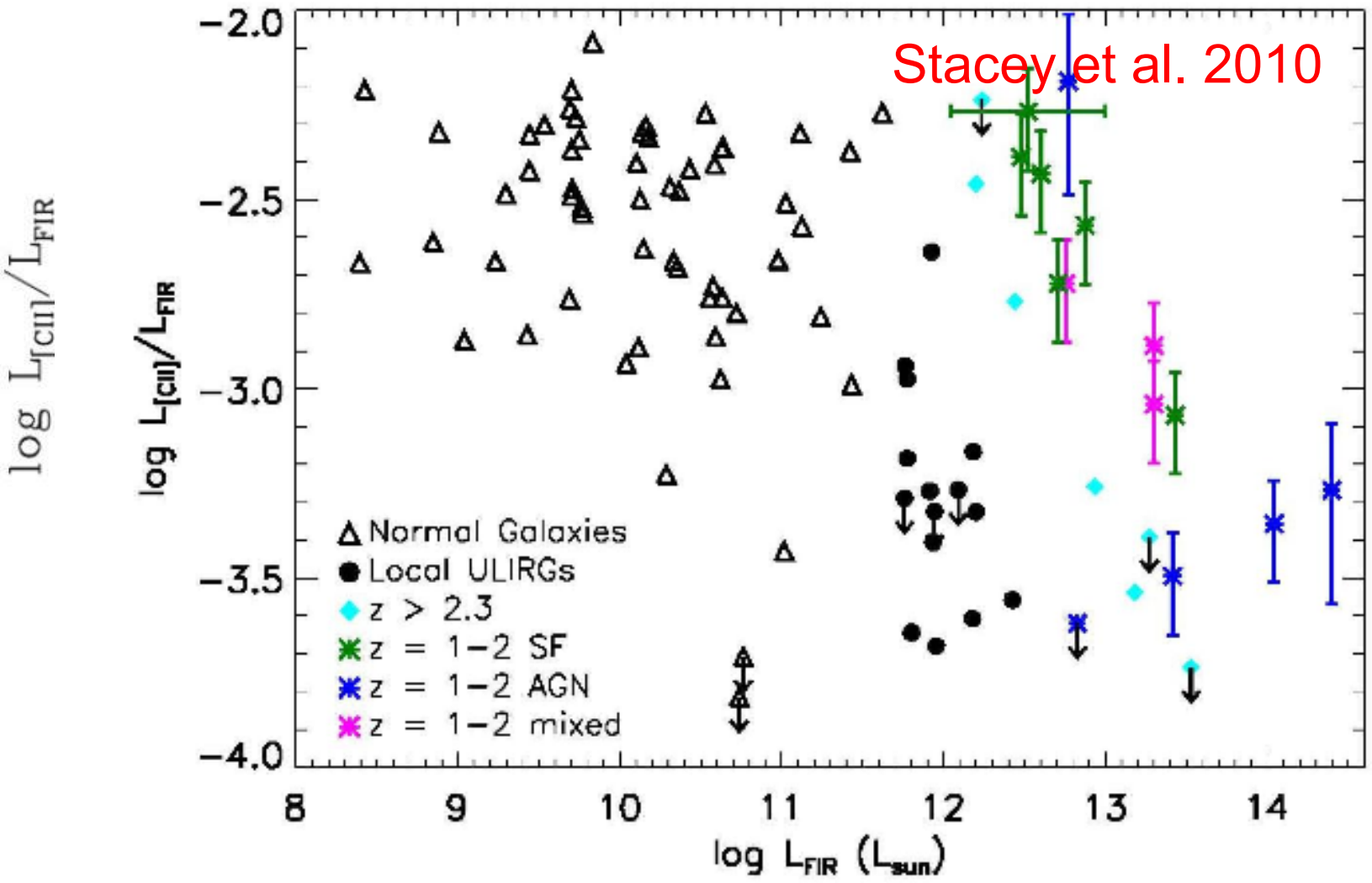
How does [CII] vary in galaxies?



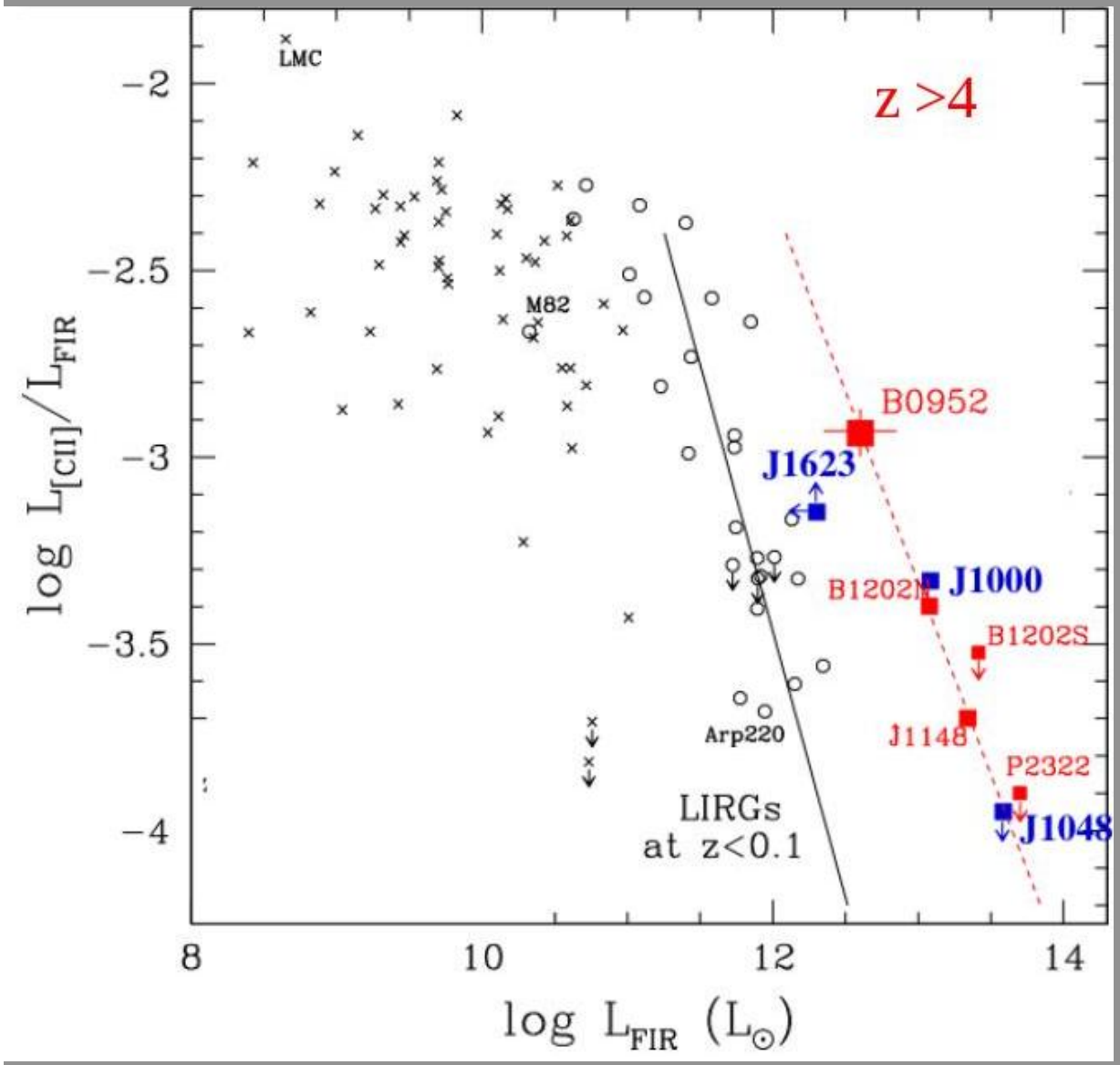
a.k.a. who killed the [CII] line?

- (Malhotra et al. 1997, 2001)
  (Luhman et al. 1998, 2003)

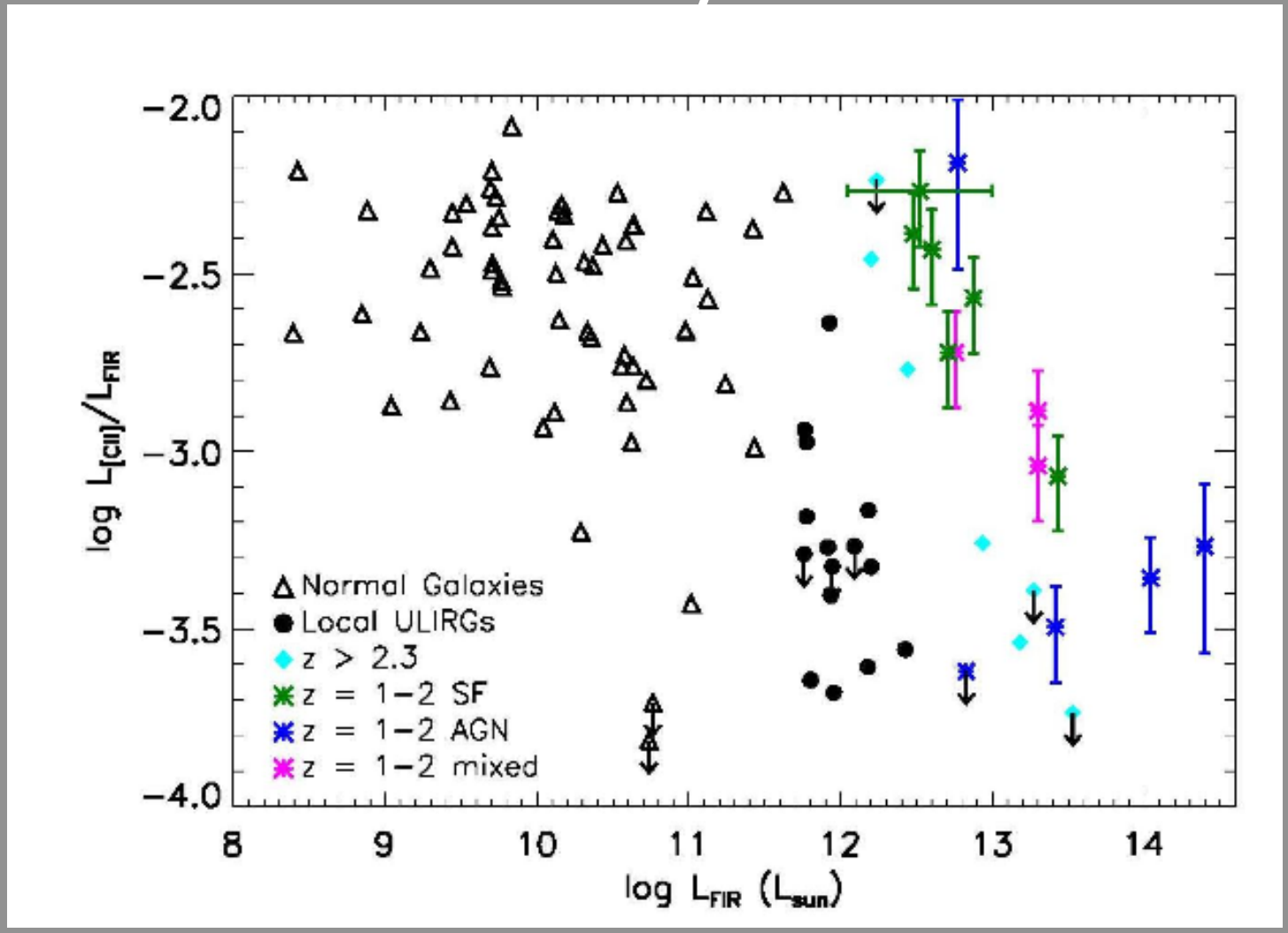
How does [CII] vary in galaxies?



Maiolino et al. 2009



Stacey et al. 2010

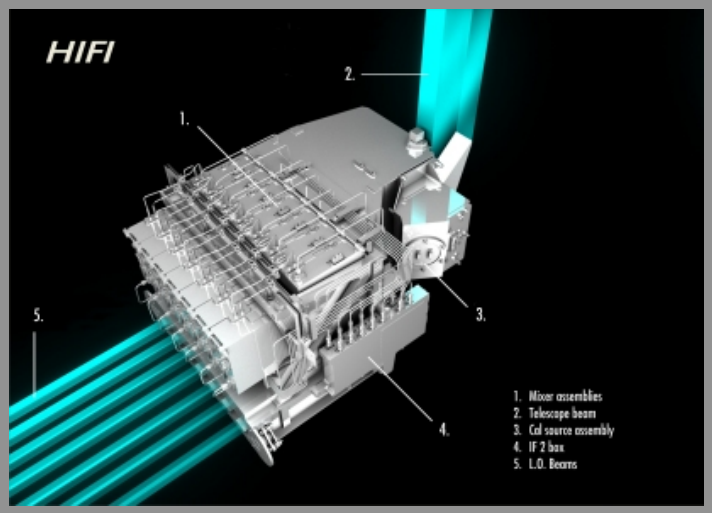


The sample:

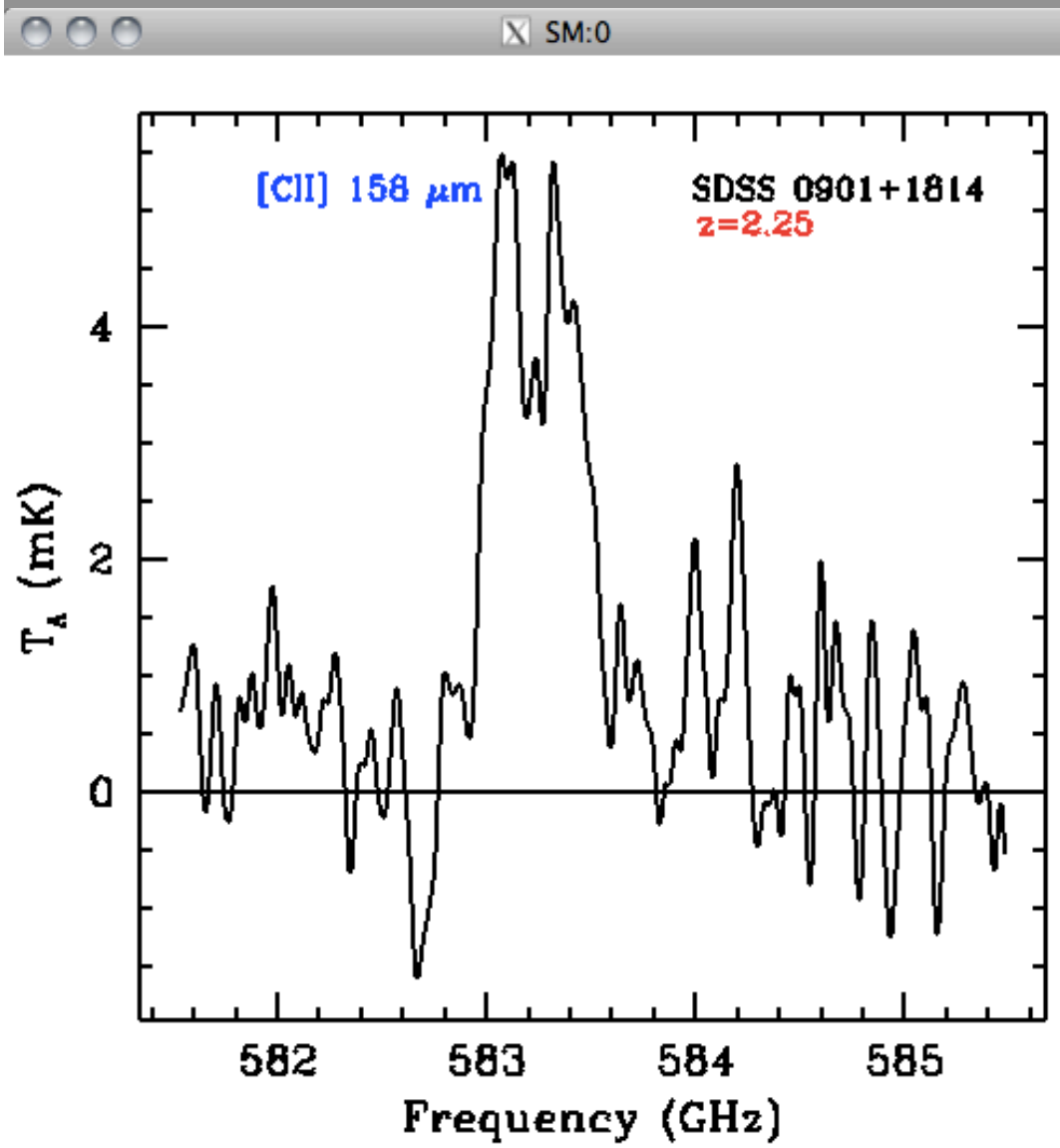
- SFR = 1.4 -- 500 Msun/Year
- Magnification 6 -- 70x
- Redshift 1 to 2.9
- Sample size of 15 : ultimately limited by the precise velocity required by HIFI bandwidth.

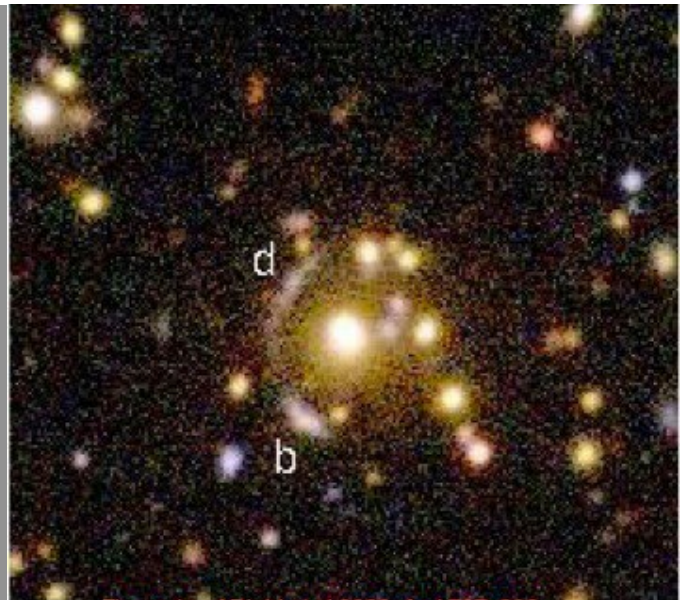
Observing Strategy:

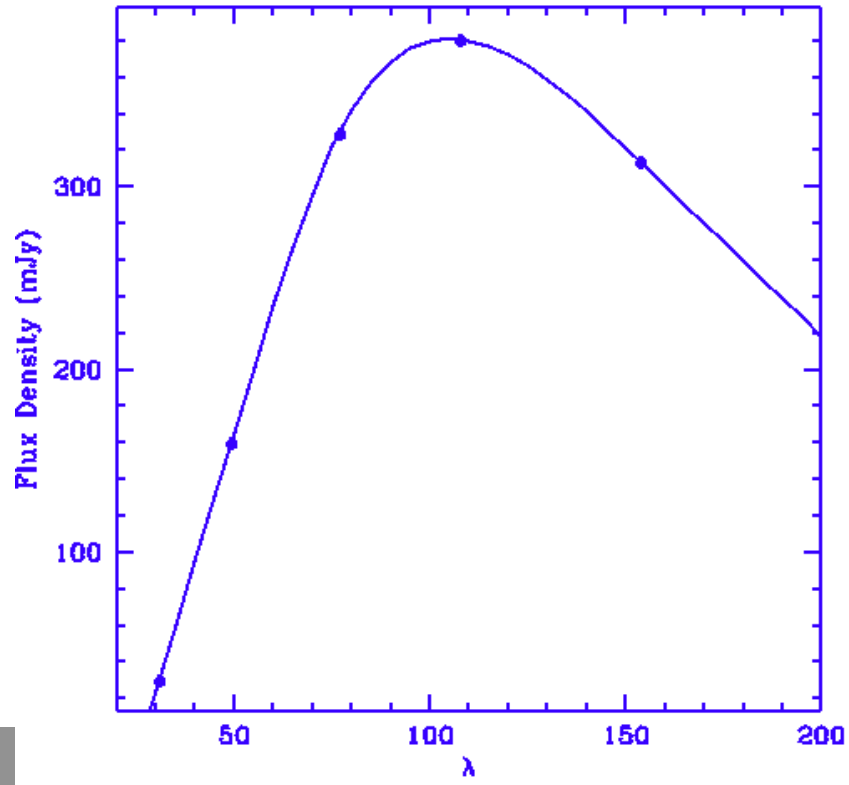
- [CII] line from 321 to 619 microns with HIFI.
- [OI] 63 microns with PACS (for 5 sources)
- Imaging 100 microns-500 microns with PACS +SPIRE (some from archive observations, PI: Lutz, Egami.)



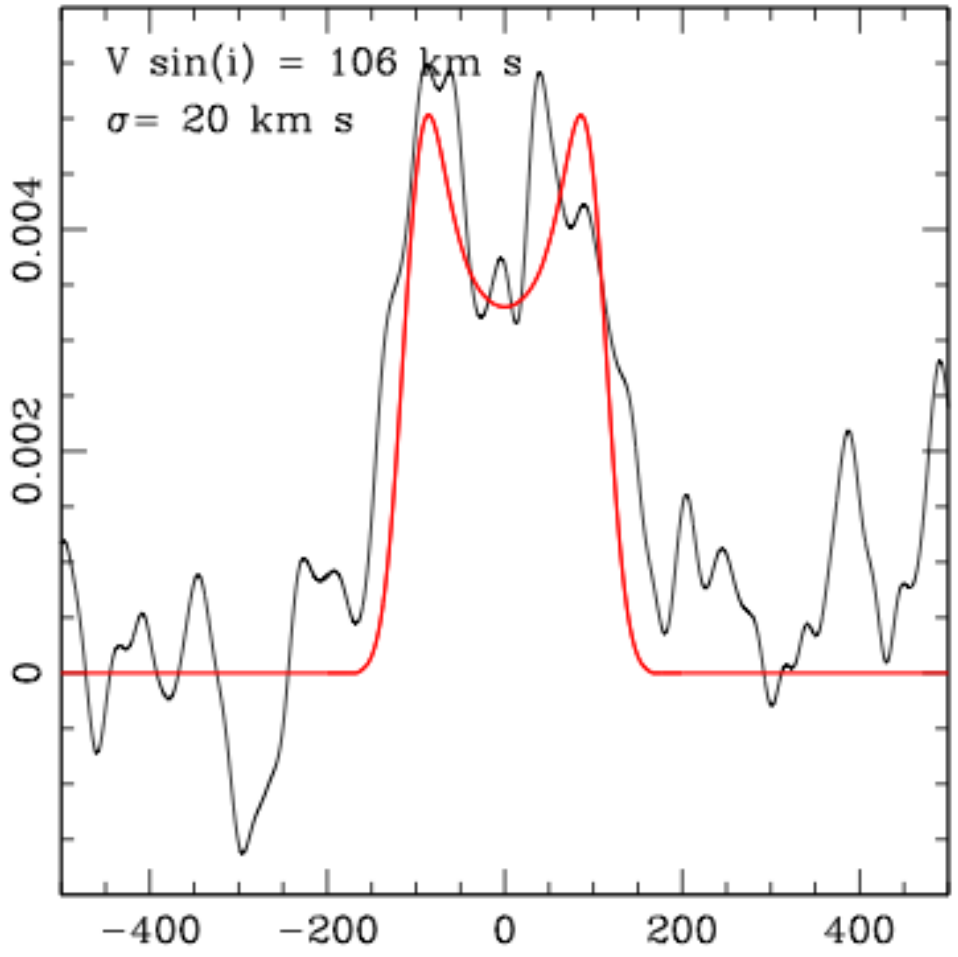
SDSS 0901+1814







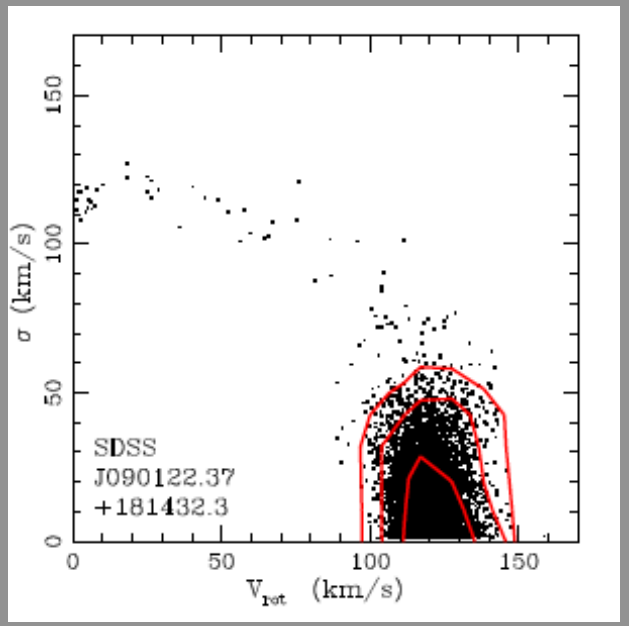
SDSS 090122.37+181432.3
- A rotation dominated galaxy?

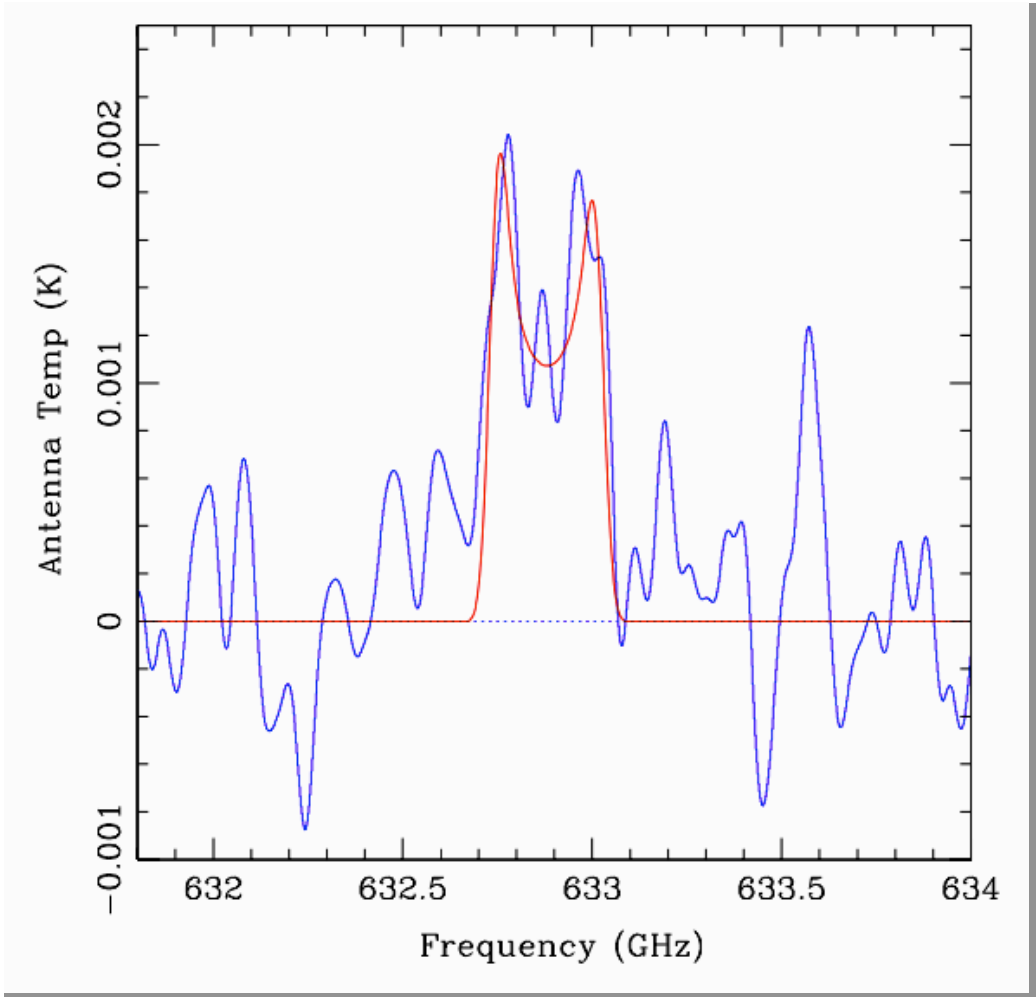


V sin(i) =120 +/- 7 km/s

σ< 23 km/s

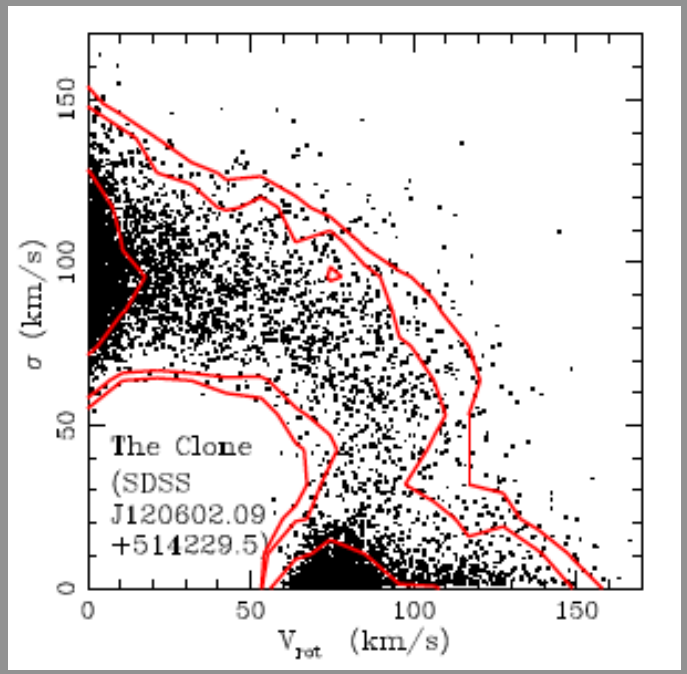
(Rhoads et al. 2013),





The Clone:

- V sin(i) = 79+/- 11 km/s
- σ<4 km/s
- Or σ=92 +/- 20 km/s



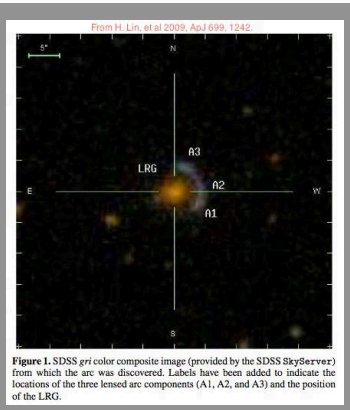
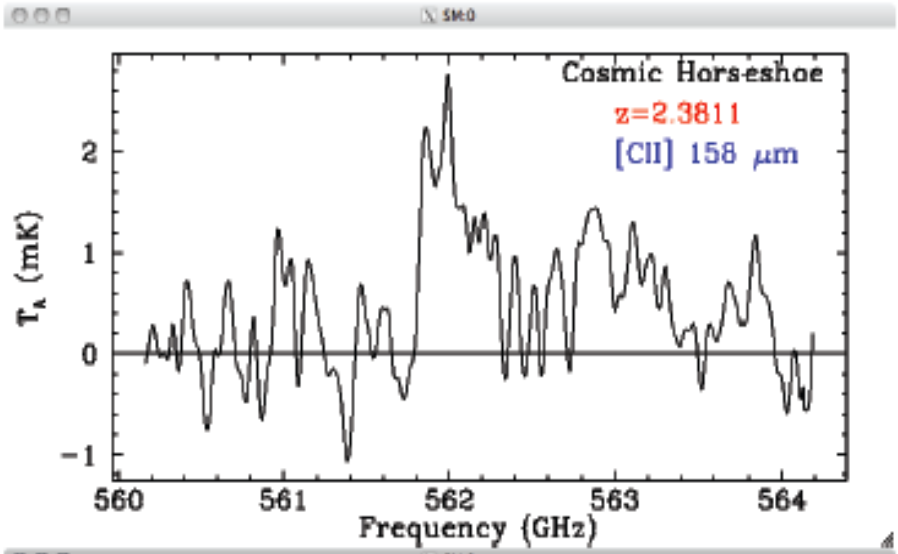
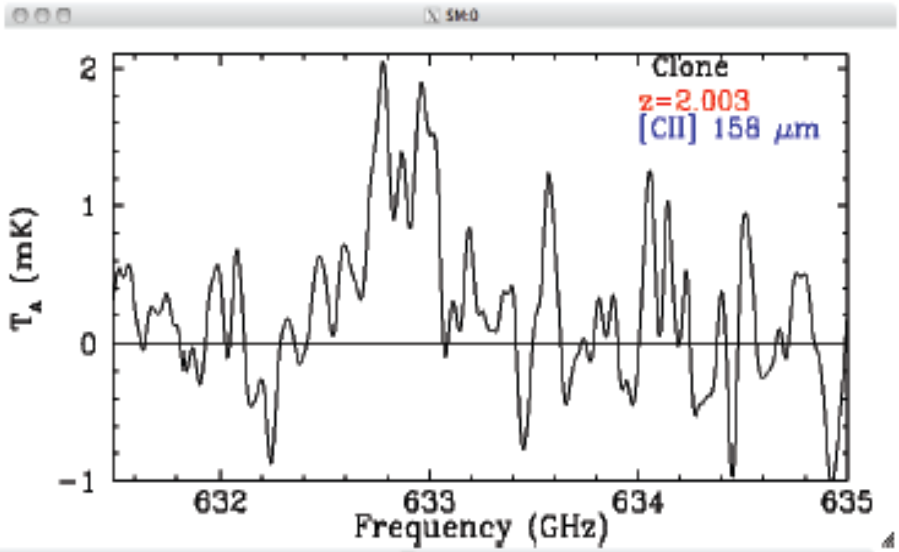
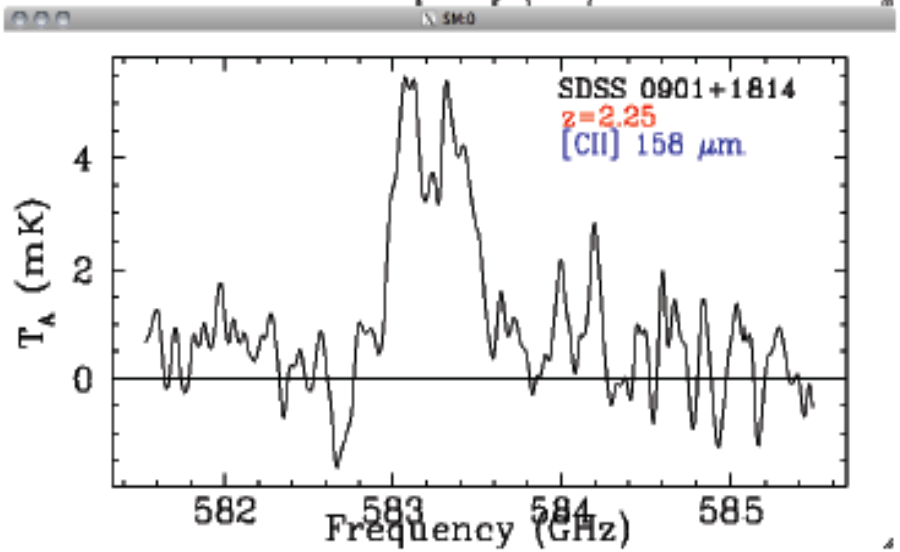
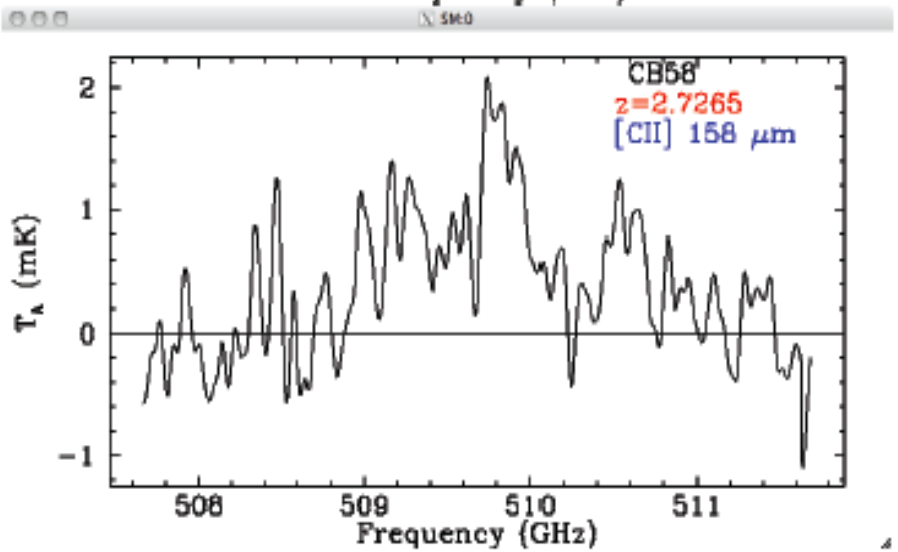


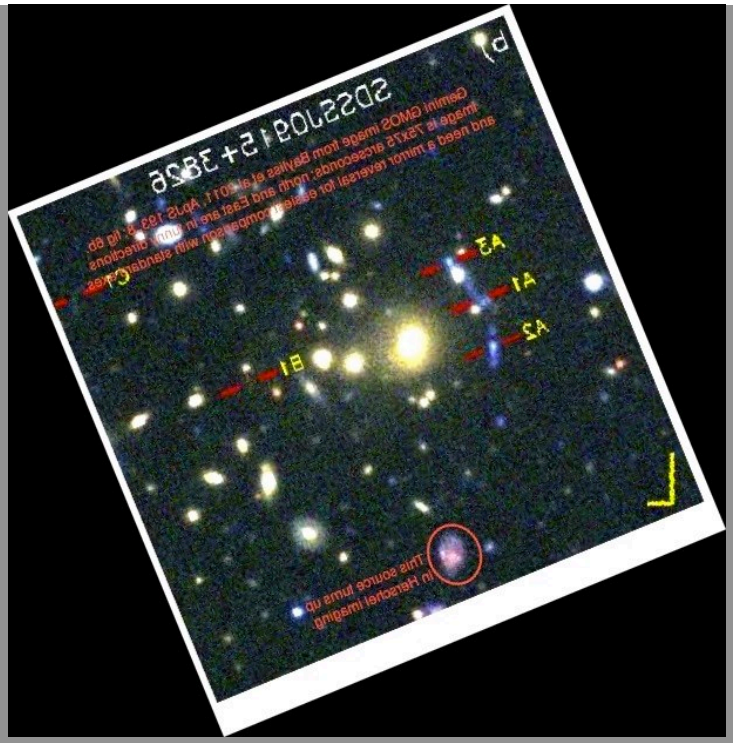
Figure 1. SDSS *gri* color composite image (provided by the SDSS SkyServer) from which the arc was discovered. Labels have been added to indicate the locations of the three lensed arc components (A1, A2, and A3) and the position of the LRG.

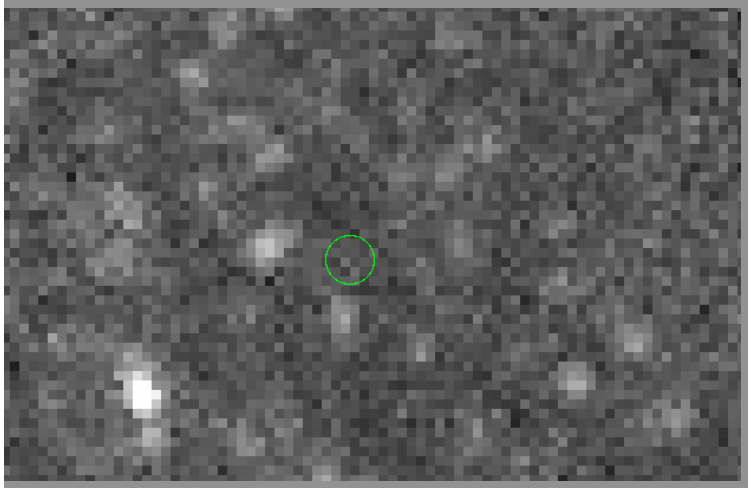

Cosmic Horseshoe
z=2.3811
[CII] 158 μm
T_A (mK)
Frequency (GHz)


Clone
z=2.003
[CII] 158 μm
T_A (mK)
Frequency (GHz)


SDSS 0901+1814
z=2.25
[CII] 158 μm
T_A (mK)
Frequency (GHz)

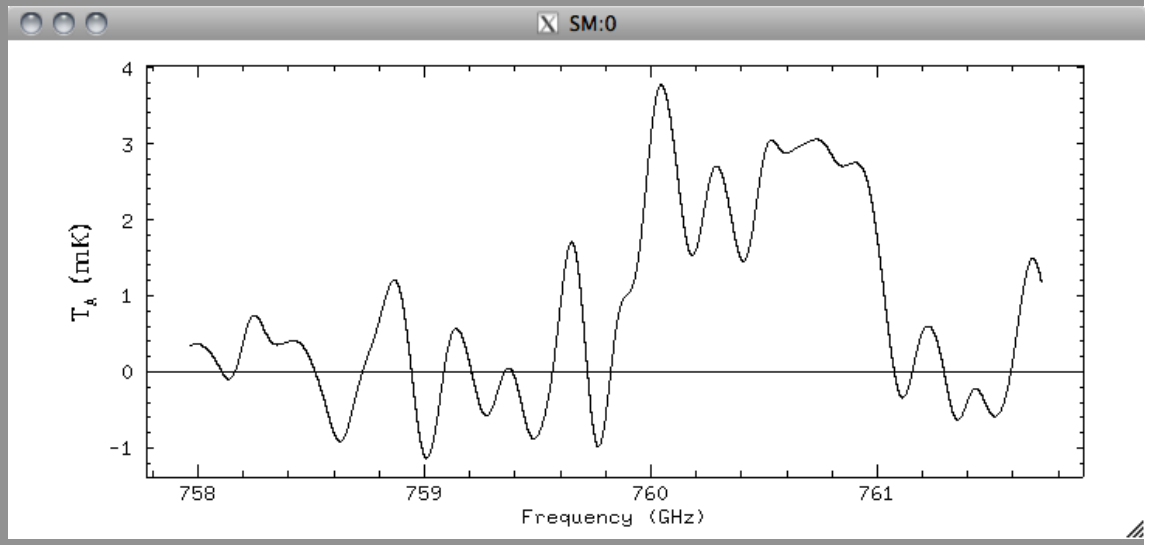

CB58
z=2.7265
[CII] 158 μm
T_A (mK)
Frequency (GHz)



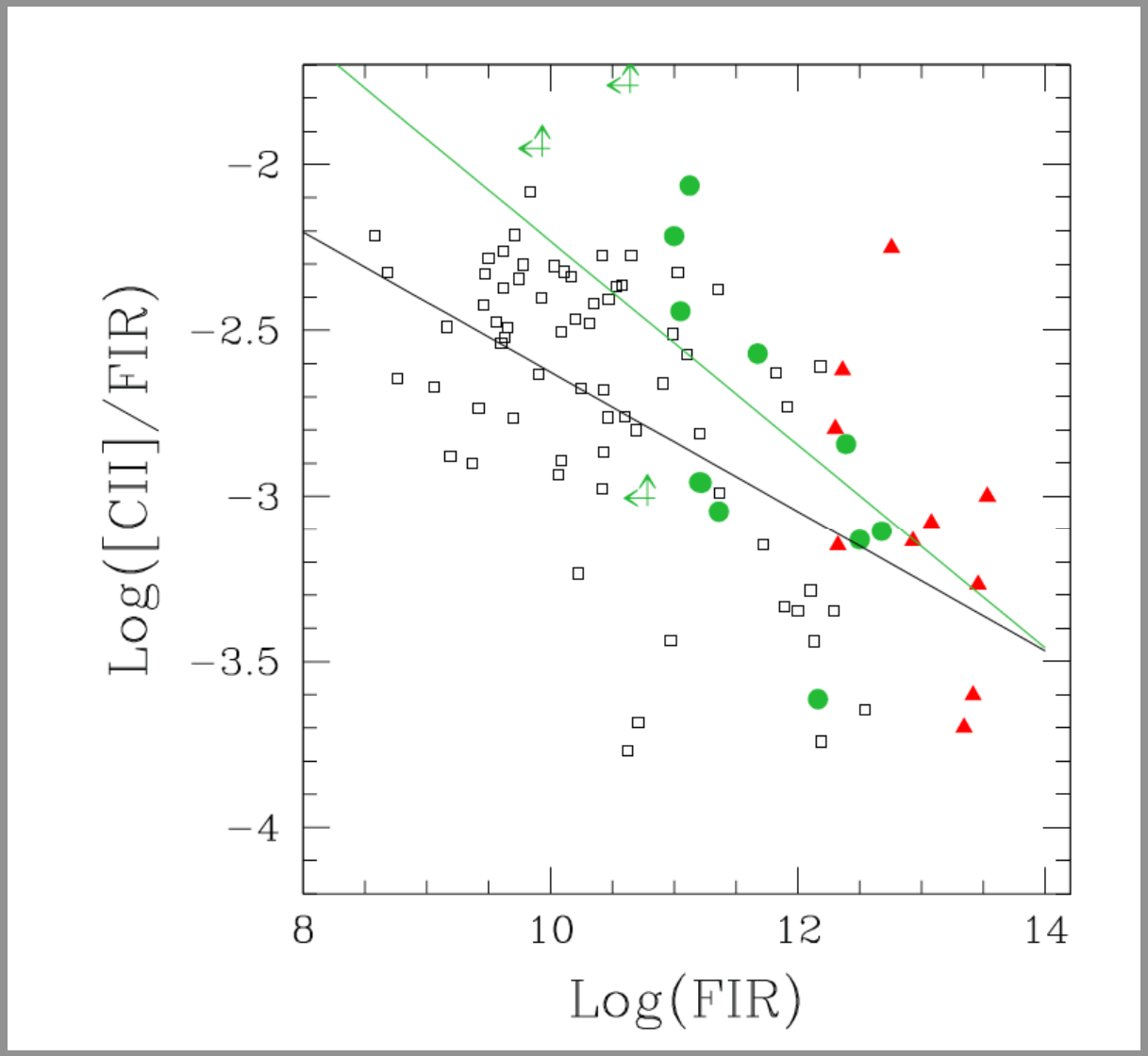


SDSS0915+3826

C+ detected, but no continuum
at 250, 350 and 500 microns.
[CII]/FIR > 2%(3sigma)
at z=1.5



Malhotra et al. 2013.

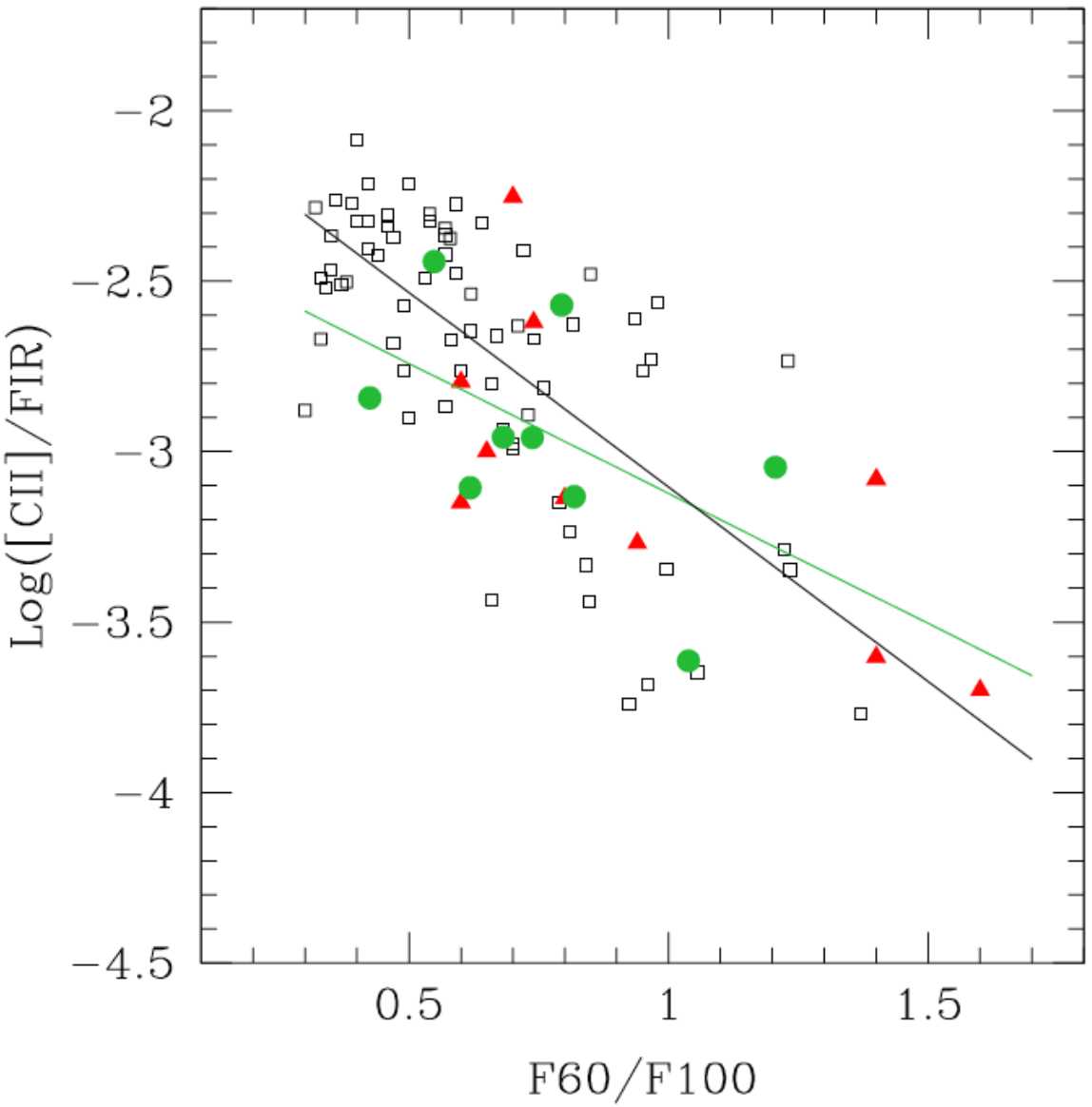


Black: z=0

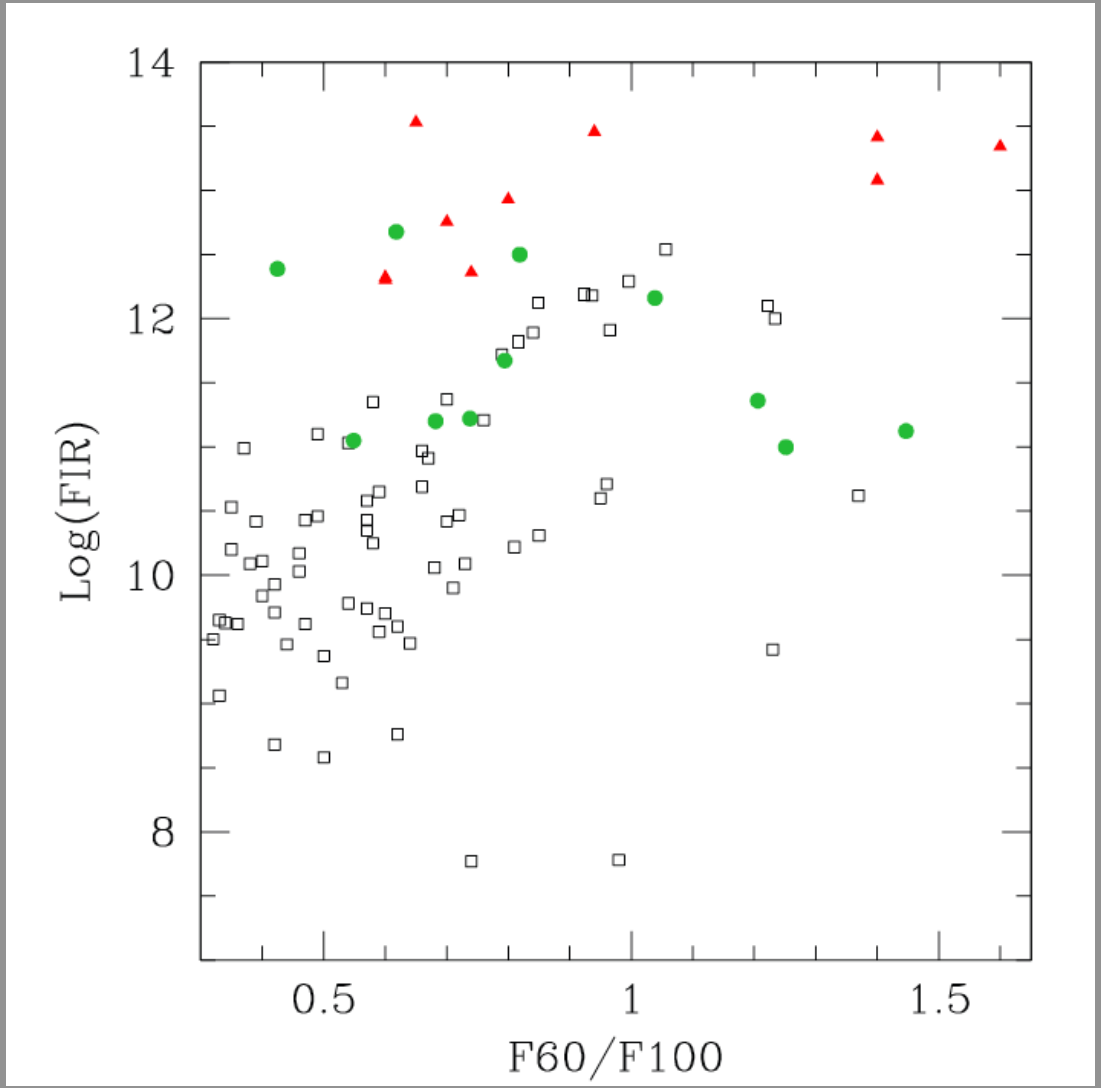
Red z >= 4

Green z~2 (HELLO)

Malhotra et al. 2013



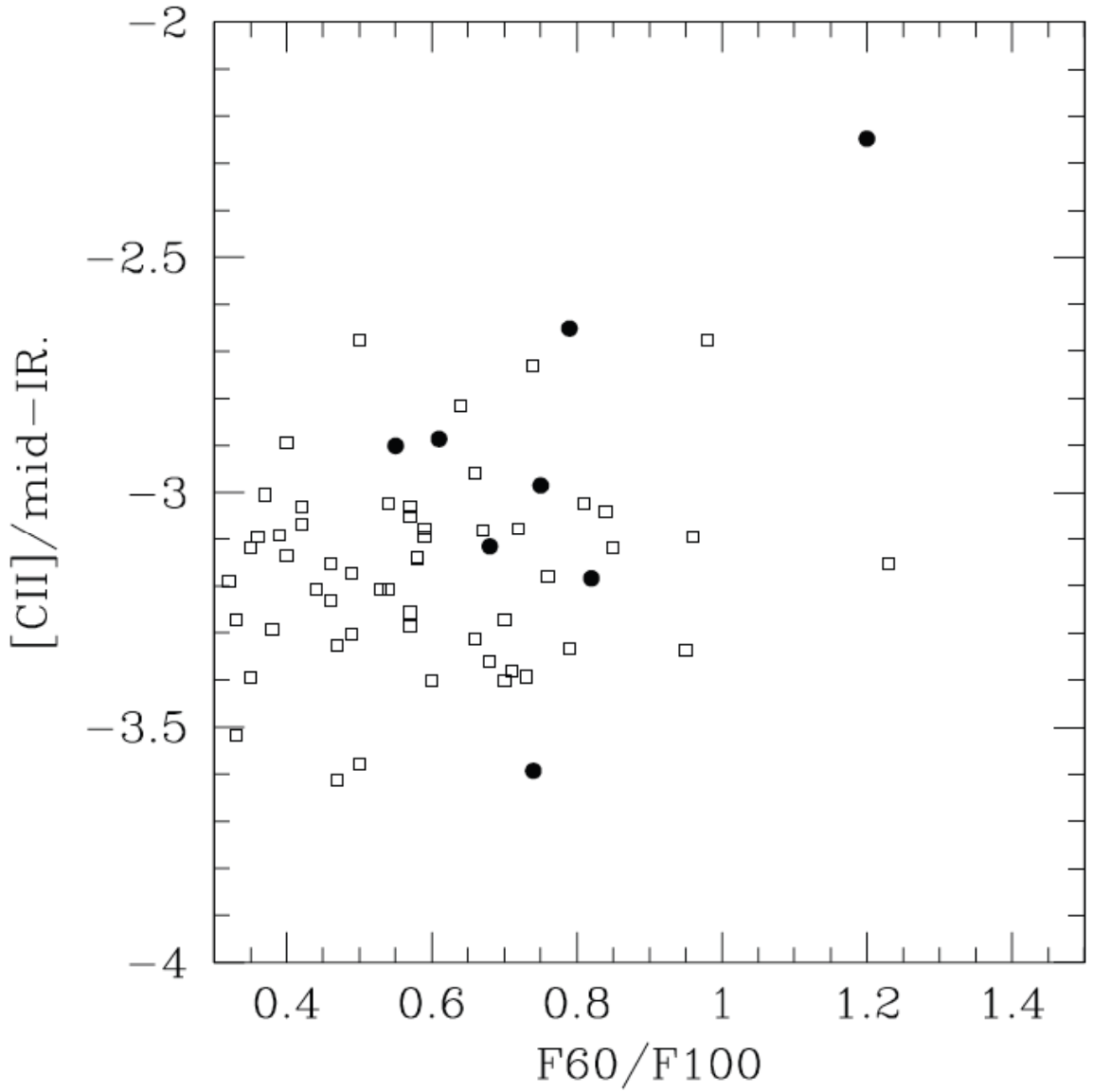
High redshift sources ARE different:



High redshift sources ARE different:

- high luminosity, but cooler galaxies:
- bigger starbursts at high redshifts (e.g. Rujopakarn et al. 2011)

Scaling with mid-IR (Helou et al. 2000)



What do we learn from this?

- FIR color (or dust temperature) NOT Luminosity is the most relevant variable to determine [CII]/FIR.
- At high redshifts we have cool but luminous galaxies. These galaxies are NOT deficient in [CII].
- Rotation dominated and dispersion dominated galaxies exist in our sample.
- Galaxies with small SFRs (< 10 M_sun) have normal [CII]/FIR, therefore one CAN scale [CII] to SFR.
- If you don't observe, you will not see.

HELLO (Herschel Extremely Lensed Line Observations)

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Chris Carilli, NRAO

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