Searching for cool molecular gas via CO 1-0 in star-forming galaxies at high-redshift

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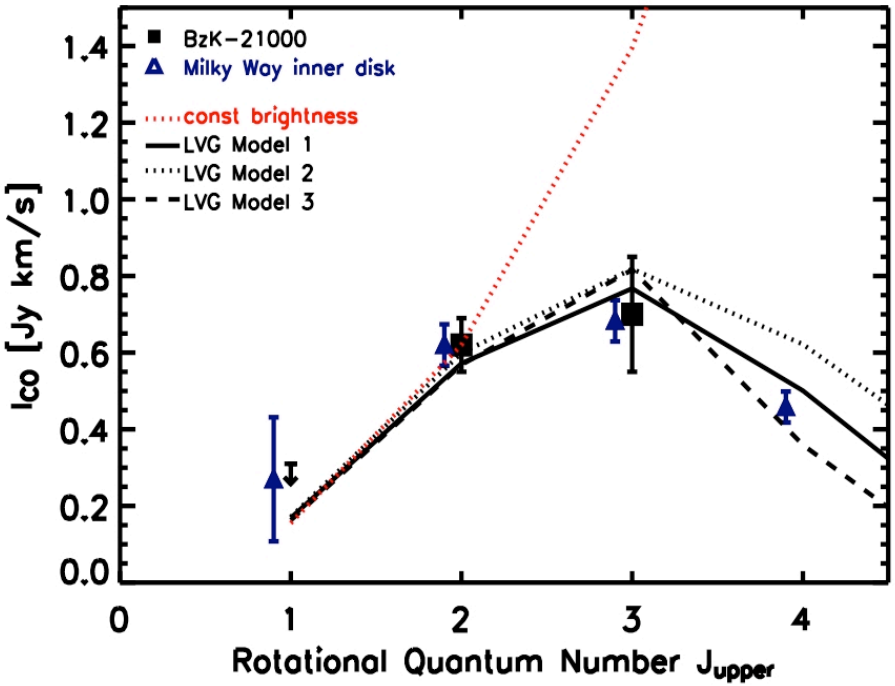
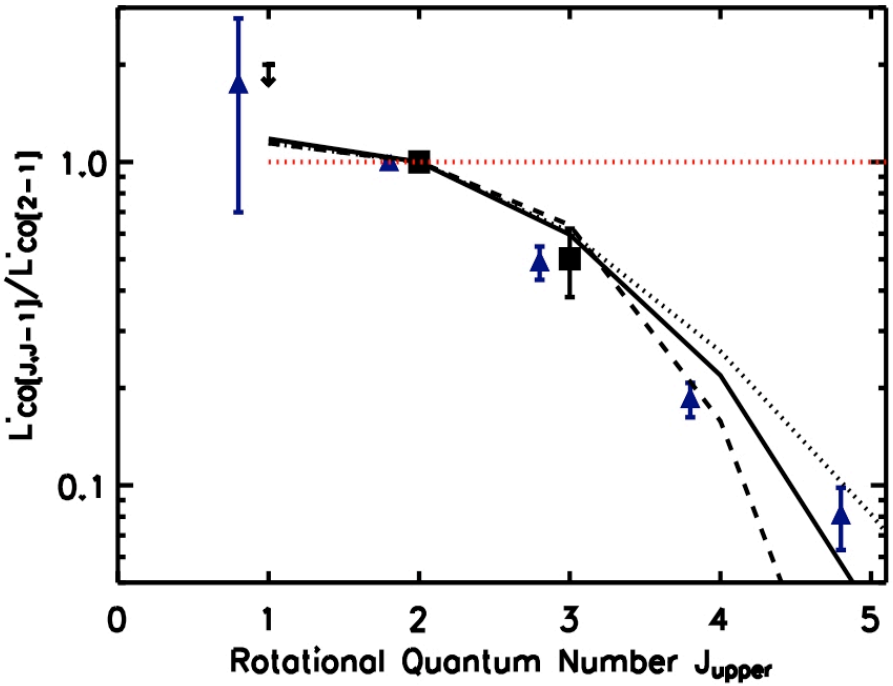
Multi-transition CO detections

- H. Dannerbauer et al. (2009):
  - CO 3-2 detection of one galaxy: BzK-21000
  - VLA CO 1-0 :
    - Tentative 3σ 'detection' for the combined CO emission of two BzK galaxies





The need for CO 1-0

- Direct measurement of the molecular gas mass.
- Not obvious high-J (J>2) trace the bulk of molecular gas in these galaxies. Gas mass estimates based on CO 3-2 underestimated.
- Low-J CO traces colder, diffuse gas while high-J CO trace dense, warm gas.
- CO 1-0 could be more extended than high-J CO as in SMGs (Ivison et al. 2011)

Very Large Array (VLA)

Robert C. Bird Green Bank telescope (GBT)

CO 1-0 line emission with the GBT and "old" VLA

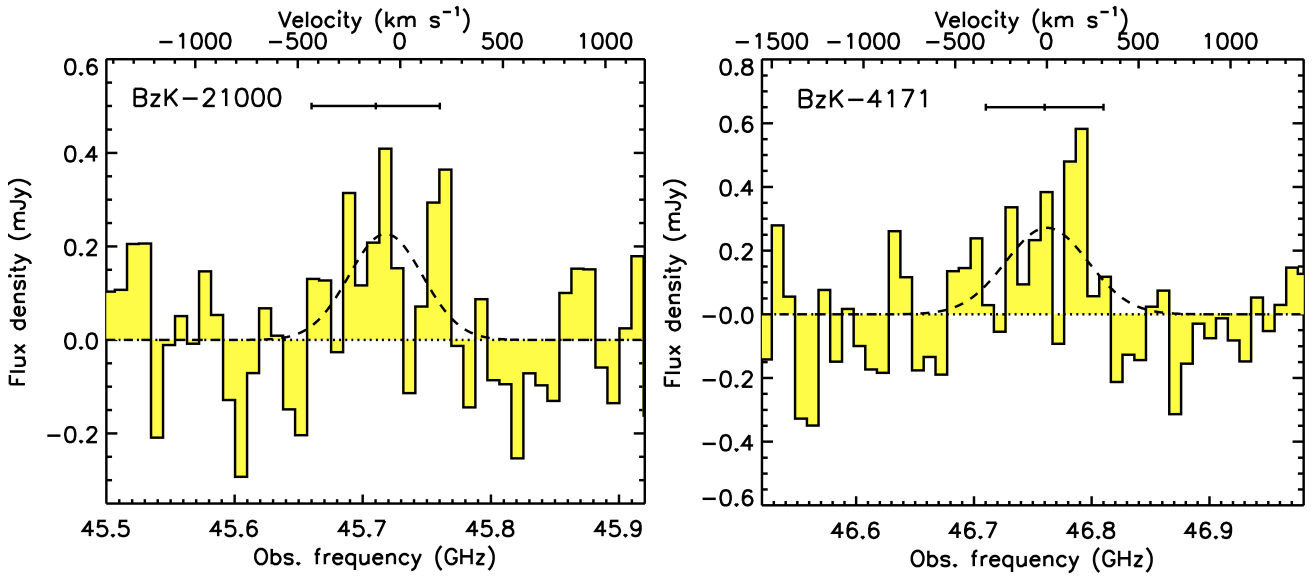
GBT observations:

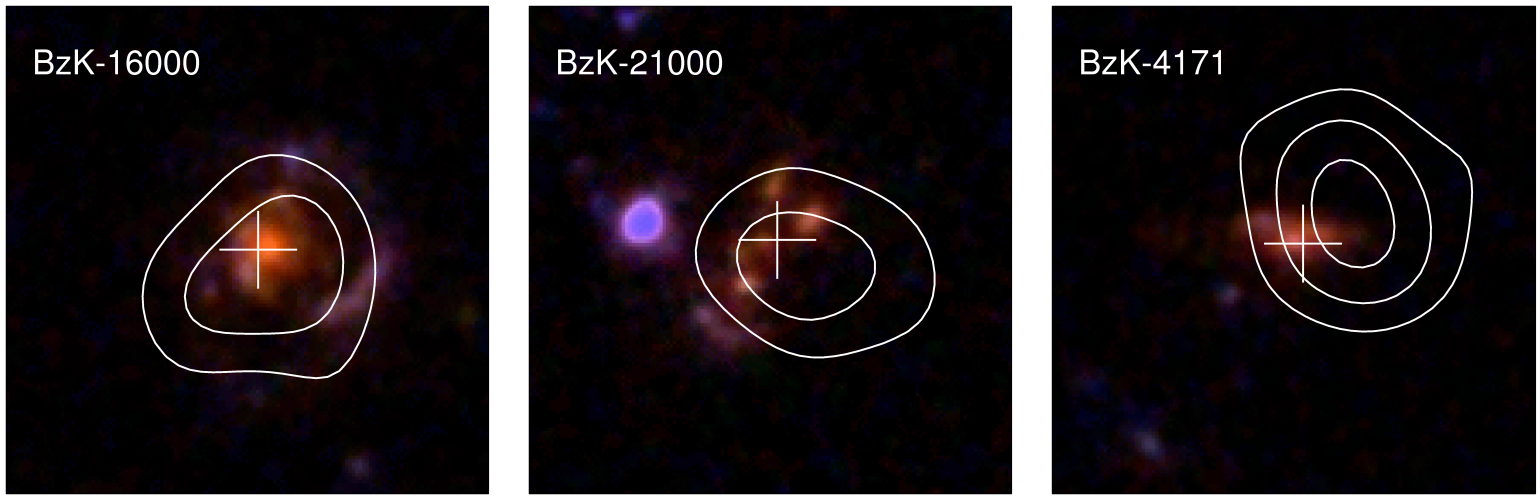
~3σ detections

VLA observations:

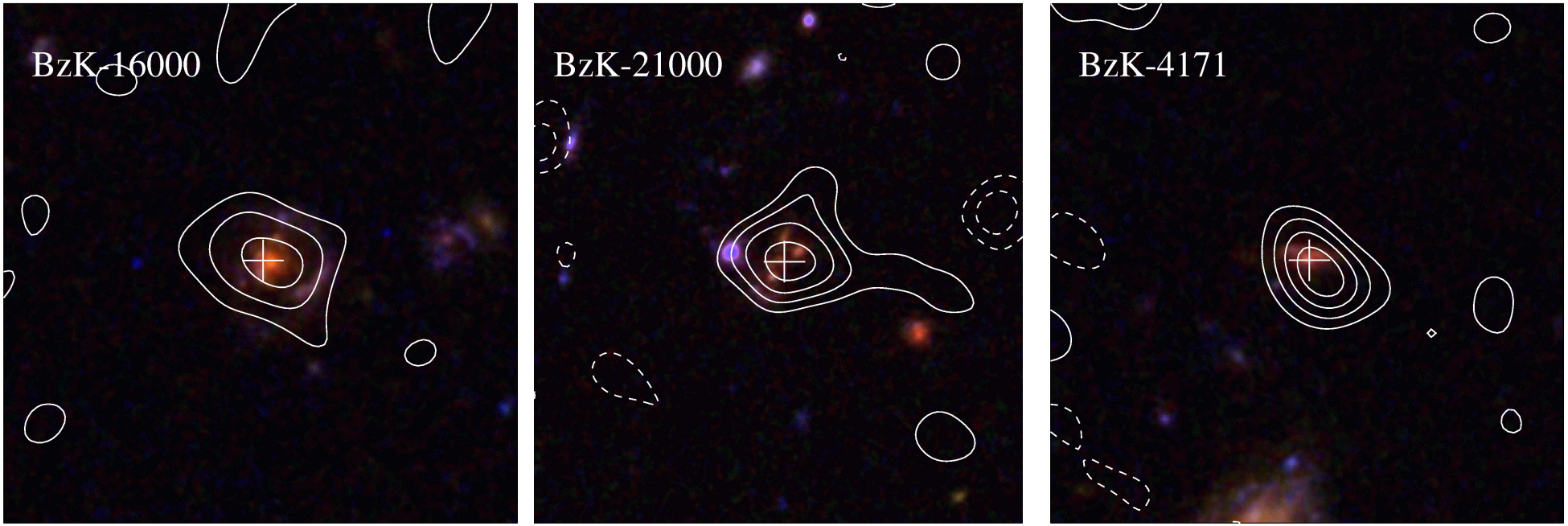
Confirmation –

~4σ detections





New EVLA higher-sensitivity CO 1-0 maps



Merged VLA + EVLA data. CO 1-0 flux density maps.

CO SED: low-excitation of the molecular gas

- **Confirmation:** gas less excited than in other massive galaxies at high-z: SMGs, QSOs
- Excitation ladder similar to that of local disk galaxies (at least up to J=3).

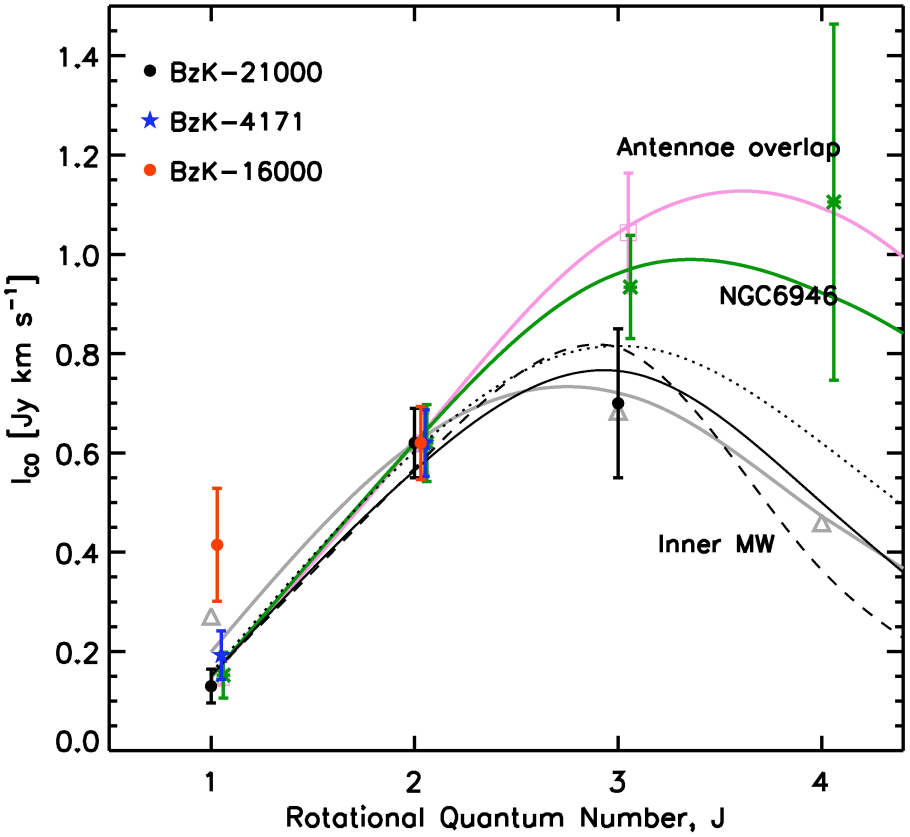


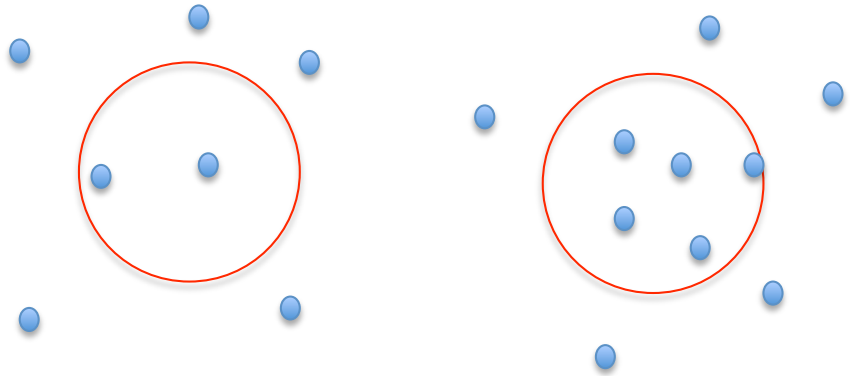
Fig. CO ladder of three BzK galaxies.
(Dannerbauer et al. 2009; Aravena et al 2010)

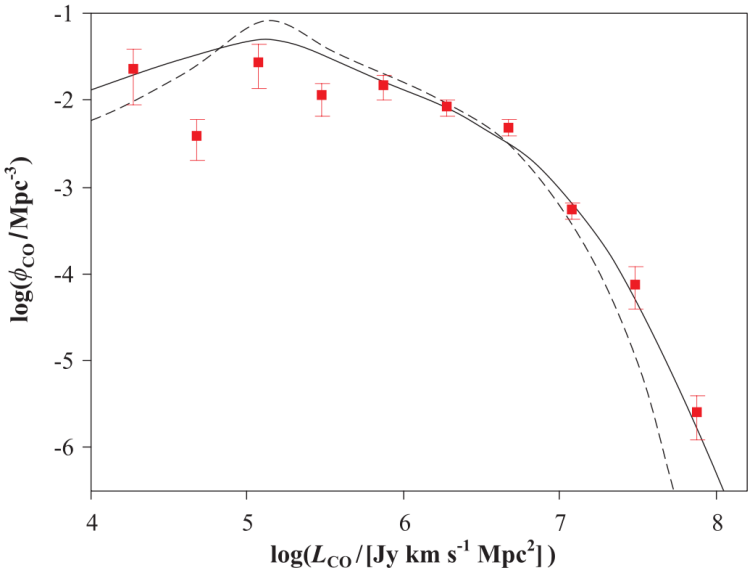
A deep search for CO line emission in a cluster of galaxies at z=1.5

Why? Ideally…

- "Bang for the buck": Efficient way to study several galaxies in one pointing
- High-mass end of the CO/H2 luminosity function at high-z, provided we have good sensitivity

Normal field **Clustered field**



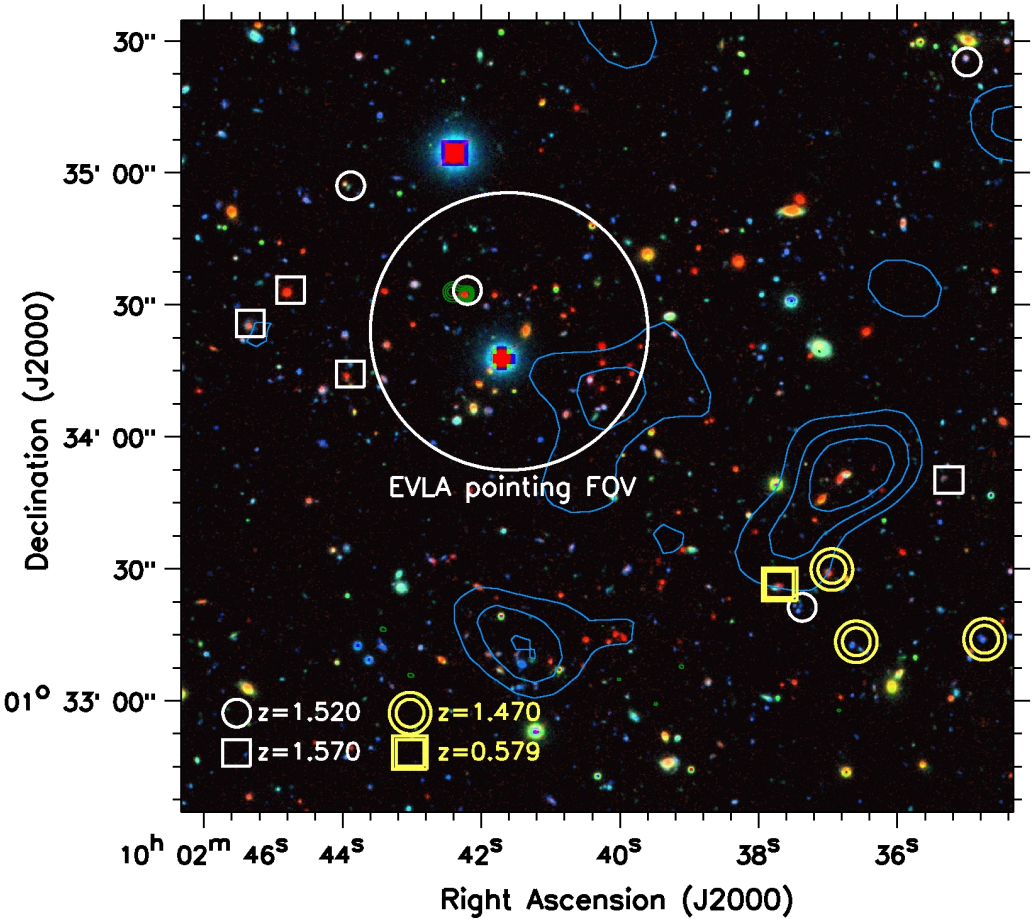


Obreschkow & Rawlings (2009)

A deep search for CO line emission in a cluster of galaxies at z=1.5

Our Target:

- X-ray tentative detection / Bright quasar in the field with radio lobes.
- Prominent overdensity at z~1.55
- Spec-z suggest filament z~1.49 and cluster center at z~1.57



RSRO project to observe CO 1-0 in cluster galaxies with 2 GHz bandwidth of the EVLA.

Redshift coverage z=1.48-1.59

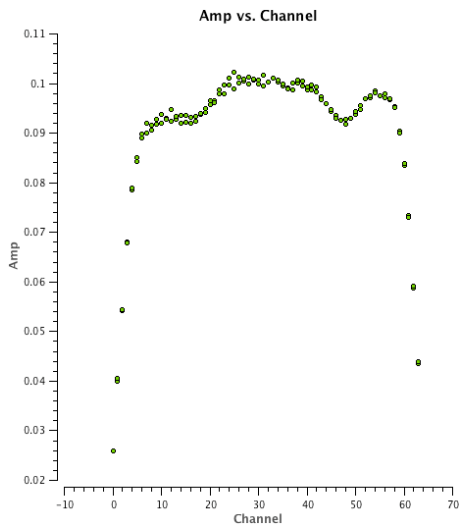
Lack of spectroscopic redshifts in the VLA pointing.

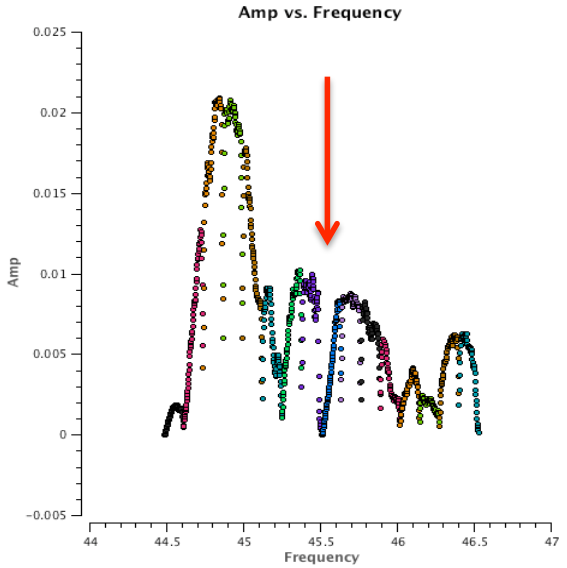
Searching for “blind” detections in a CO data-cube? (without z-spec)

1: Select optical sources in the respective redshift range (phot-z) and compute CO spectra or limits on those positions.

2: Search for significant CO detections (>4σ) in the data-cube using an algorithm (AIPS SERCH). If not “very” significant (<6-10σ), see which of them coincide with optical counterparts and have consistent redshift (phot-z) range.

Some technical issues (EVLA):



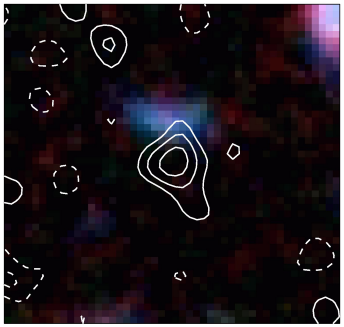


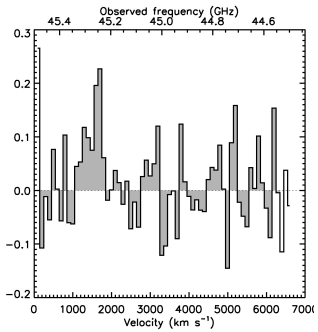
Possible candidates with opt. counterparts:

- Well detected in CO 1-0
- photo-z : z=1.4-1.8
- distance < 1.0” from optical source

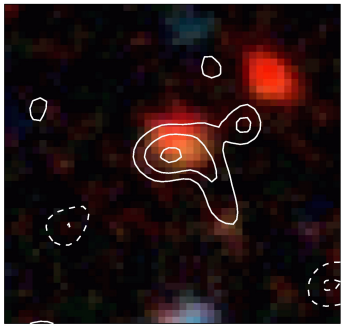
Preliminary results

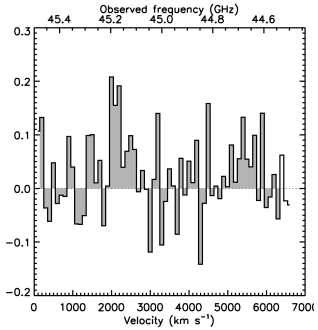
ID 8/1
Dist=1.0
Zp=1.62
M_{stars}~$6x10^9 M_\odot$



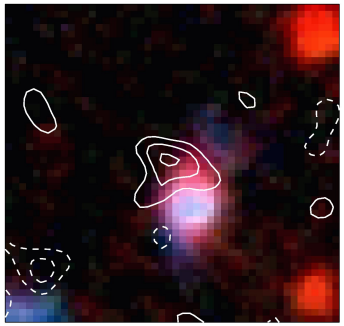


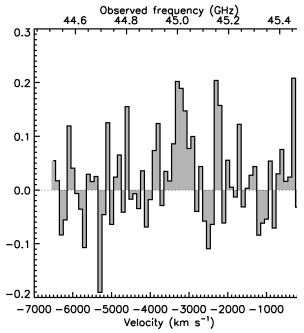
ID 11/1
Dist=0.69
Zp=1.46
M_{stars}~$4x10^{10} M_\odot$

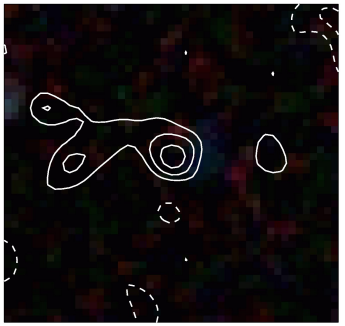


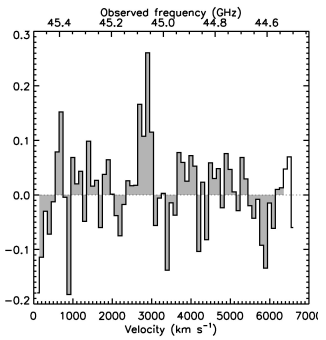


ID 11/2
Dist=1.0
Zp-1.41
M_{stars}~$4x10^{10} M_\odot$

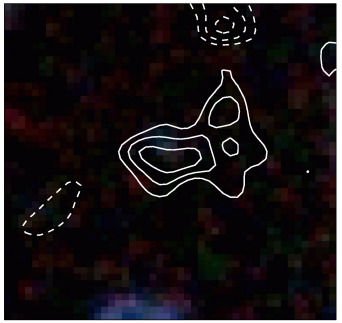


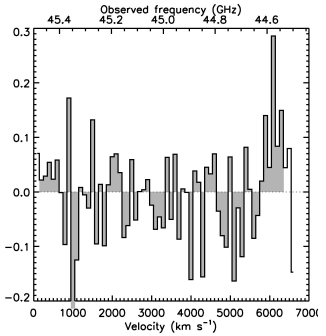




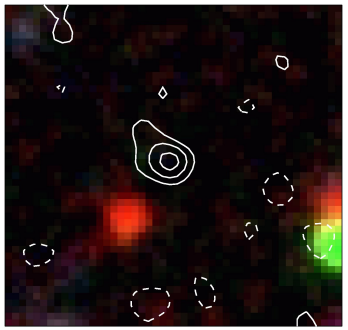


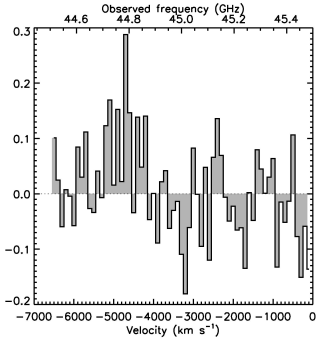
ID 12/1
Dist=0.65
Zp=1.68
M_{stars}~$3x10^9 M_\odot$



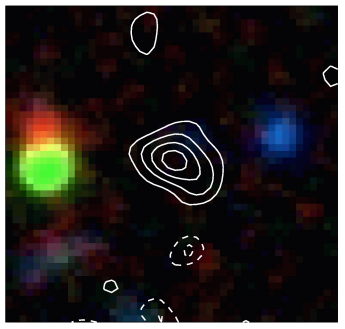


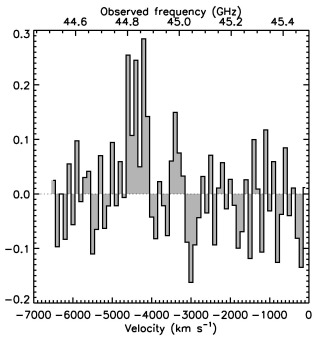
ID 23/1
Dist=0.47”
Zp=1.7
M_{stars}~$4x10^9 M_\odot$





ID 05/2
Dist=0.66”
Z_p=2.2
M_{stars}~$4x10^9 M_\odot$





ID 07/2
Dist=0.58”
M_{stars}~$1x10^9 M_\odot$

Summary

- CO 1-0 directly traces the bulk of molecular gas in galaxies

- Observations of CO 1-0 show that gas is subthermally excited at CO 3-2, thus it is not obvious to use high-J CO to measure M(H_2)

- We performed a deep search of molecular gas in a massive cluster of galaxies at z=1.5

- Search is hard given the lack of spectroscopic redshifts

- Preliminary results show CO peaks at the position of optical sources, which have compatible photo-z.

- Interestingly, a few of such sources have low stellar masses