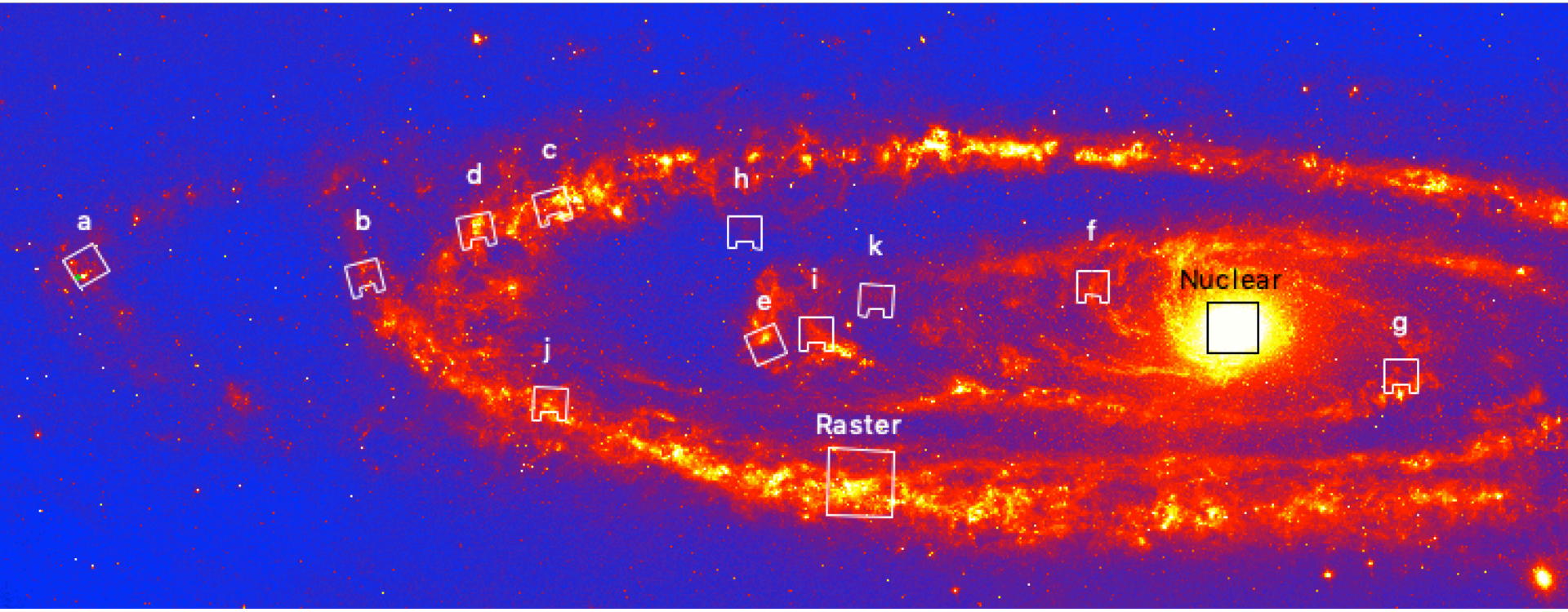
JCMT CO(3-2) Mapping of the disk and Circumnuclear Region of M31



Zongnan Li (Nanjing University)

Collaborators: Zhiyuan Li, Yu Gao (PMO), Matthew Smith (Cardiff University)

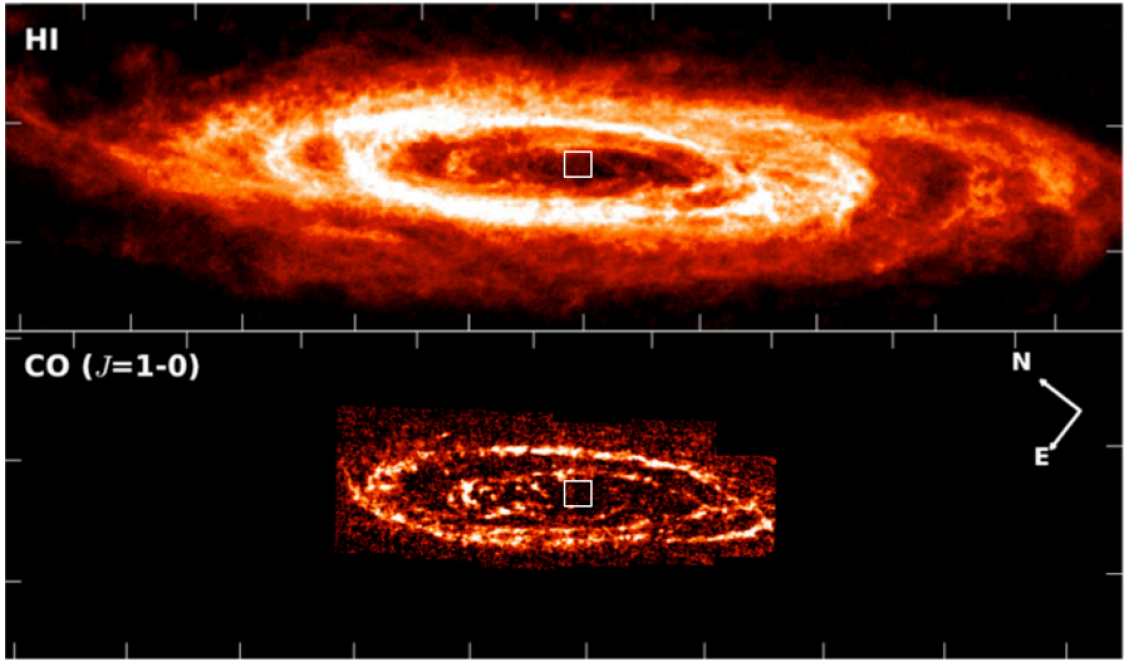
EAO future meeting

2019.5.22

CO(3-2) mapping of circumnuclear region

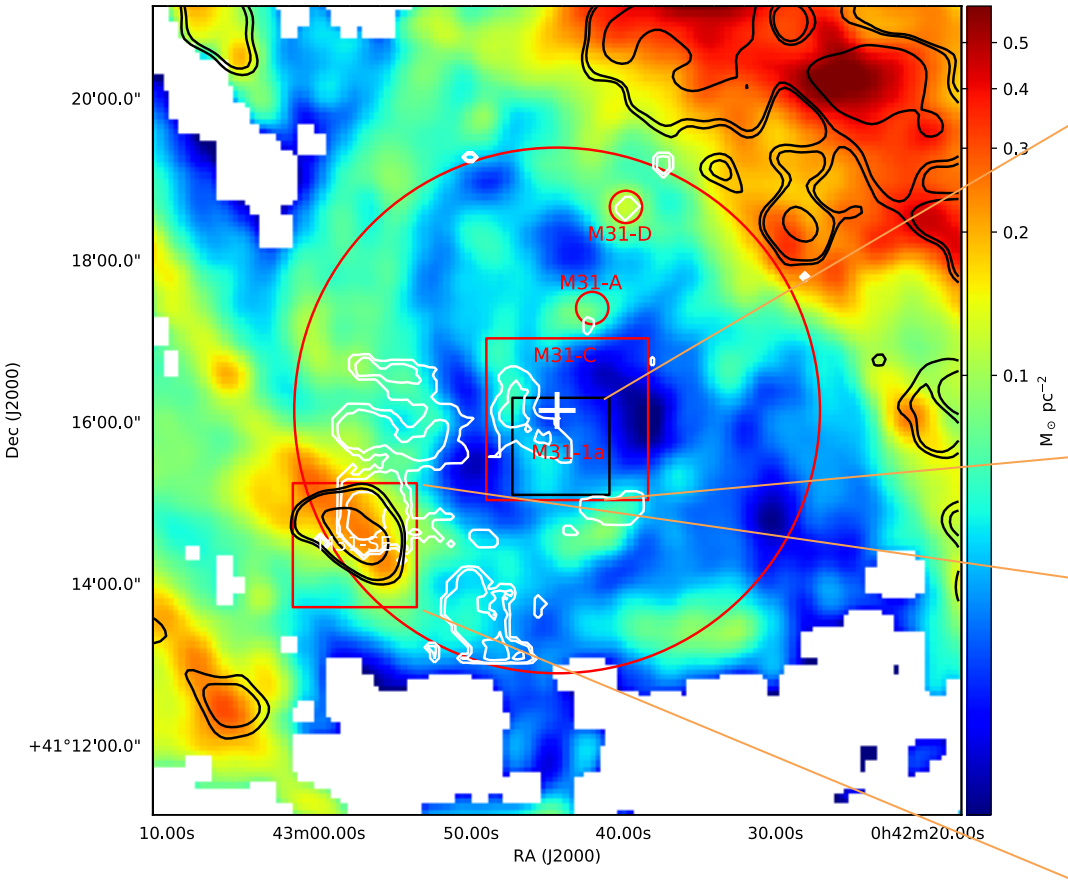
PI: Zhiyuan Li

- M31: distance: 780 kpc, i.e. 1’’≈ 4 pc, nearest large spiral, hosts an extremely quiescent SMBH, with little AGN activity and star formation in the central region (~0.4 solar mass/yr). It has a much larger bulge and less obvious spiral arms, with most of the star formation occurring in a 10 kpc ring.

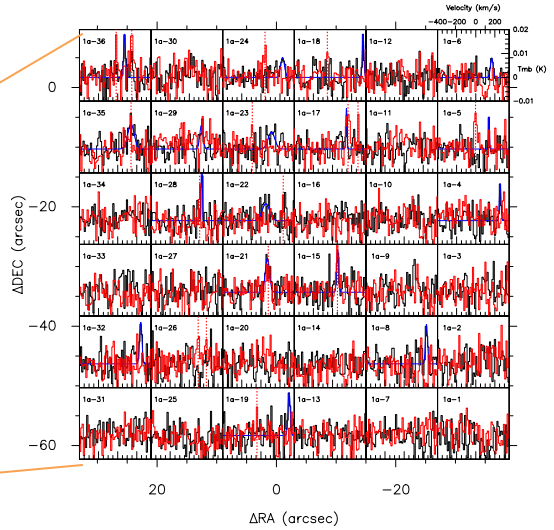


- Previous surveys show limited neutral gas detections in the circumnuclear region. (e.g. Braun 2009, Nieten 2006)

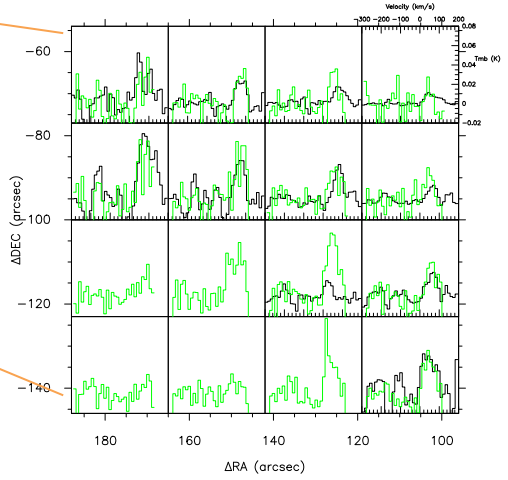
CO morphology and line ratio



CO(3-2)/CO(2-1)~0.8



CO(3-2)/CO(1-0)~0.9



Color map: dust mass surface density.
White contour: CO(3-2). Black contour: CO(1-0).

Molecular gas temperature and density in the central region

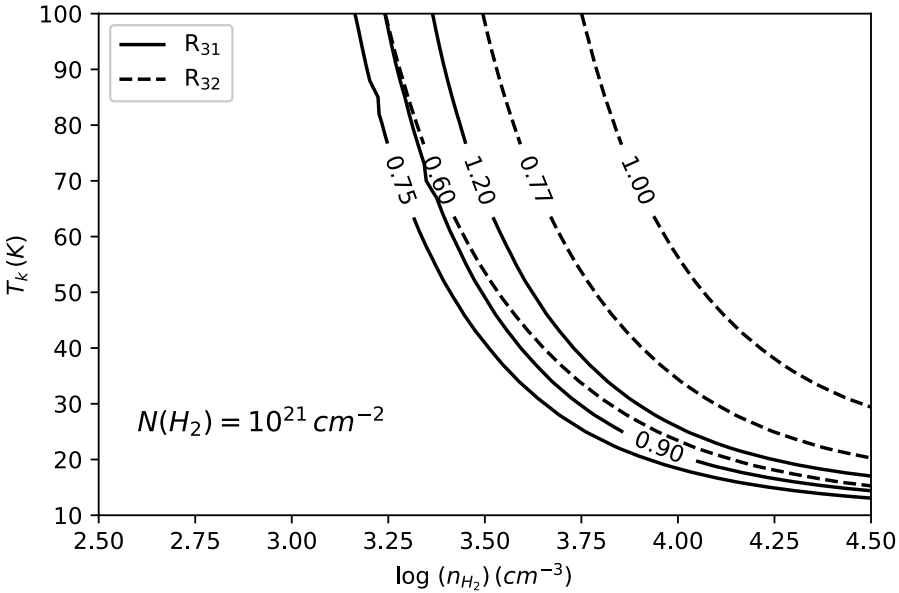
- A_v ~1, n(H_2)~ 10^3 – 10^4 cm^{-3}.
- Large velocity gradient (LVG) assumption with RADEX code:

R_{31} ~ 0.90 :

T_k > 20 K and n(H_2) > 4 x 10^3 cm^{-3} ;

R_{32} ~ 0.8 :

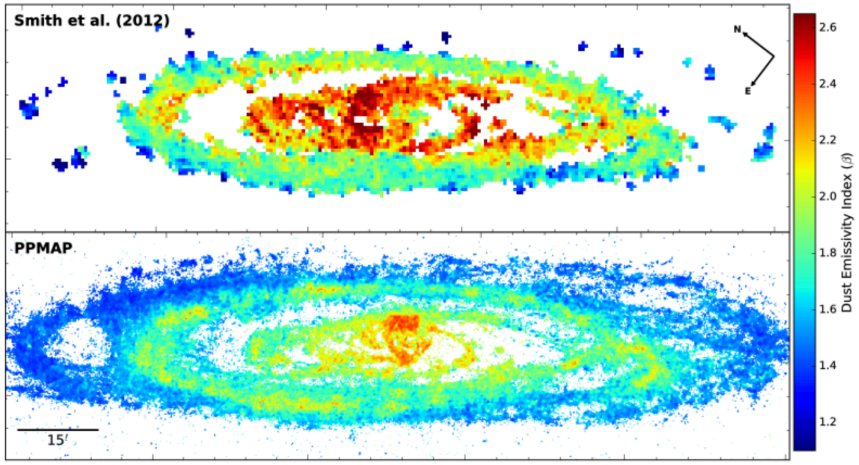
T_k > 30 K and n(H_2) > 2 x 10^3 cm^{-3}.



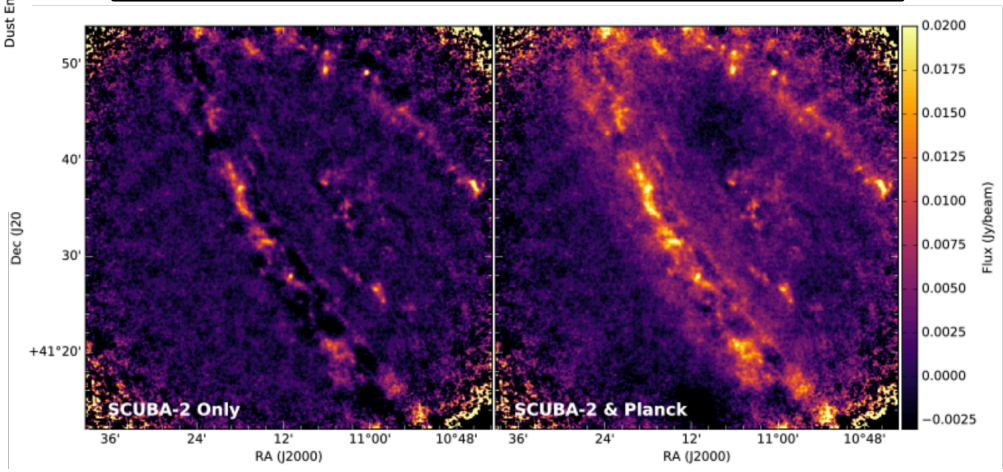
Li et al. 2019, MNRAS, 484, 964

HARP and SCUBA-2 High-Resolution Terahertz Andromeda Galaxy Survey (HASHTAG)

- JCMT large program: first ground-based submillimeter continuum survey of the Andromeda. (273.6 hr)
- SCUBA-2: 450 μm (25 pc) and 850 μm (50 pc) very cold dust survey for entire M31.



PI: Matthew Smith
Observing Manager: Yu Gao
Spectroscopy data reduction lead: Zhiyaun Li

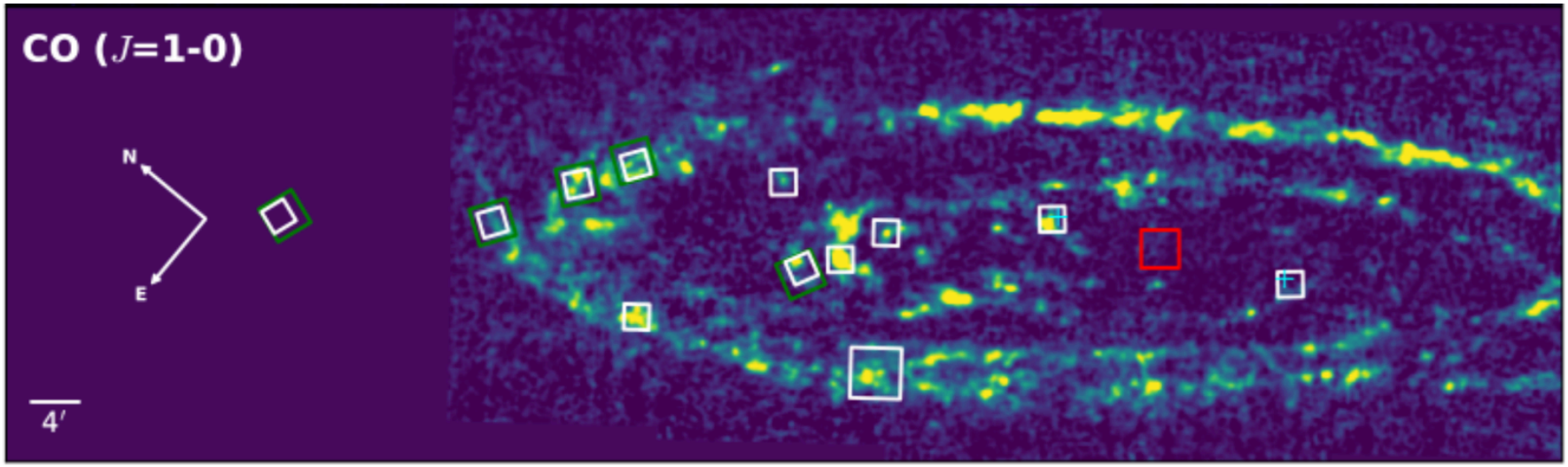


HARP CO observations

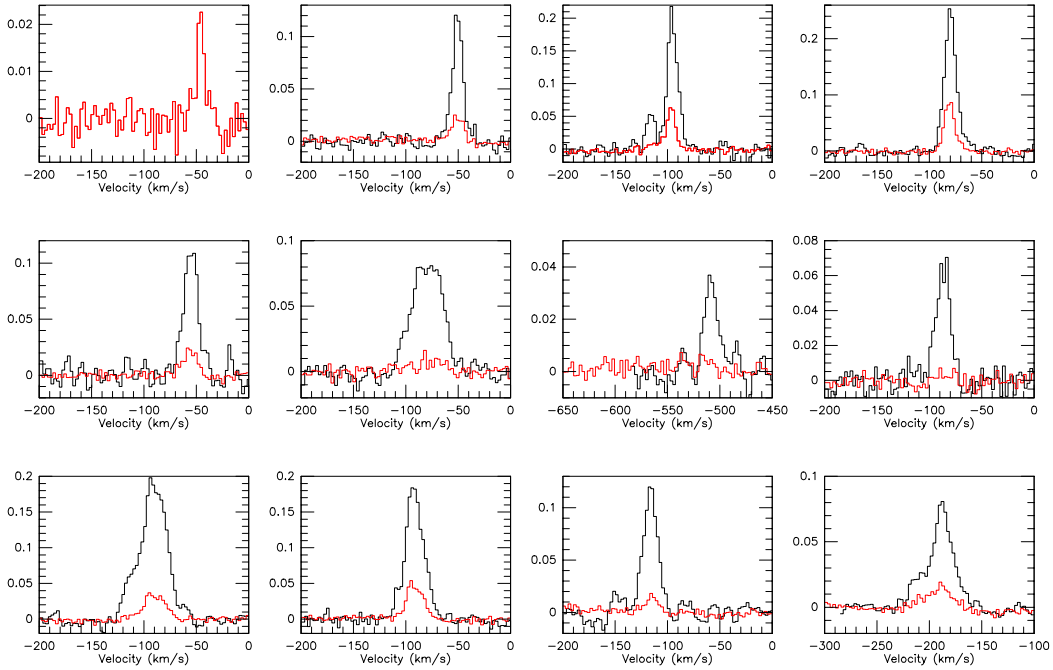
- HARP CO(3-2) observations: Eleven 2’ x 2’ jiggle fields, one 4’ x 4’ raster field (55.3 hours in total). Mean rms: 0.013 K T_A^*

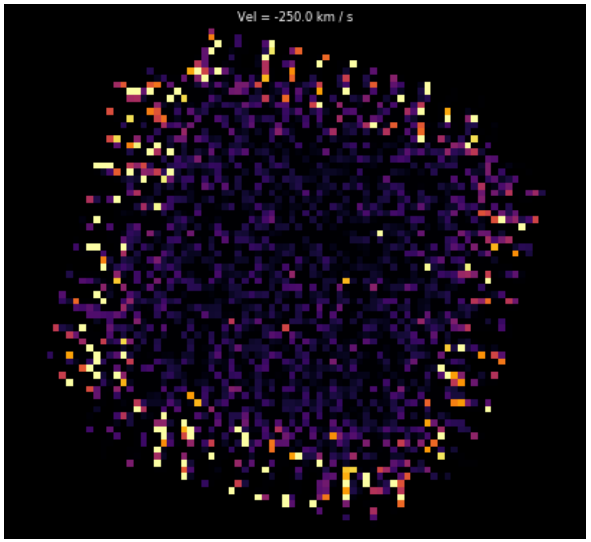
1. Five regions covered by Herschel and optical IFU spectroscopy
2. Two regions where it has been suggested that there is a component of very cold gas
3. Four in the area observed by PHAT, CARMA and the IRAM CO(1-0)/CO(2-1)

- For now: use CO line ratio to estimate the gas temperature.

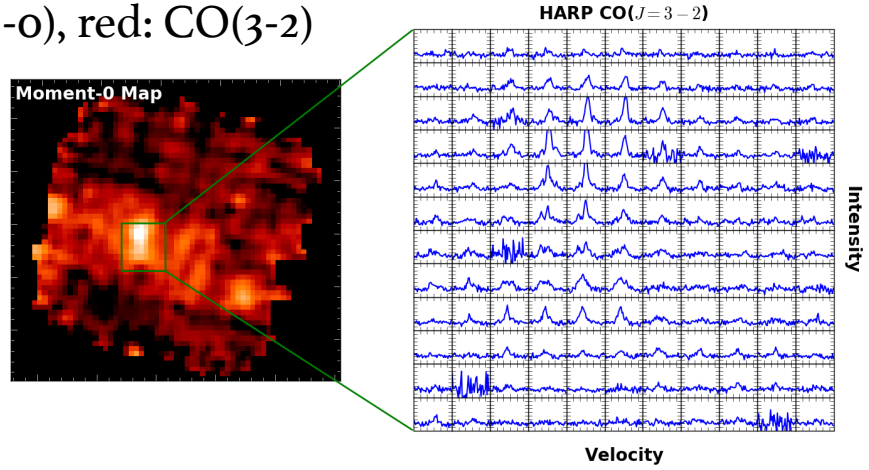


CO Spectra of the disk



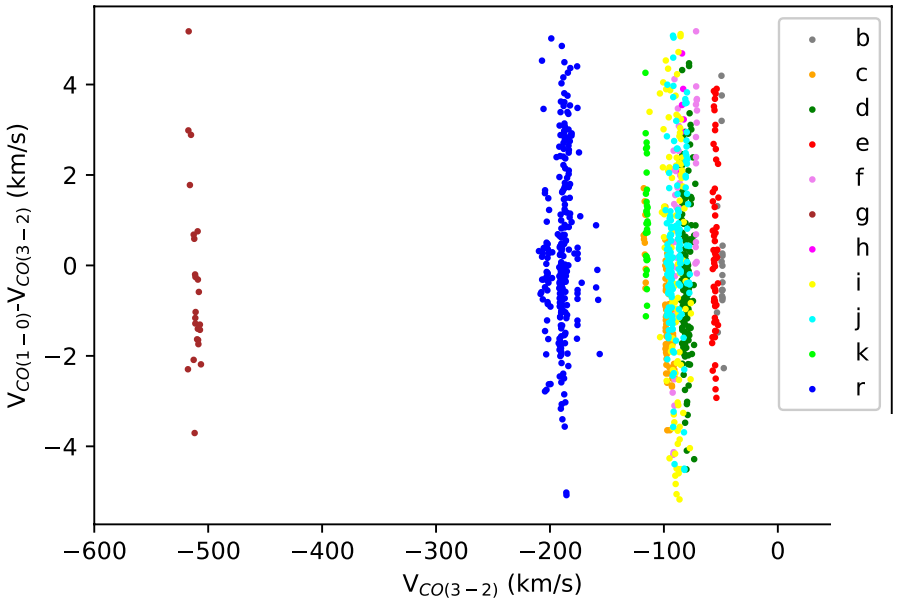


Black: CO(1-0), red: CO(3-2)



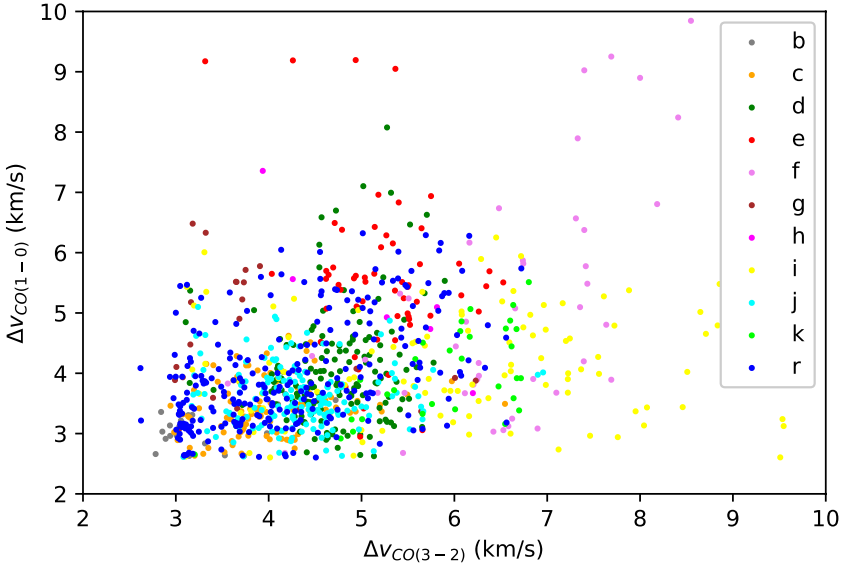
Credit: Matt Smith

Velocity distribution



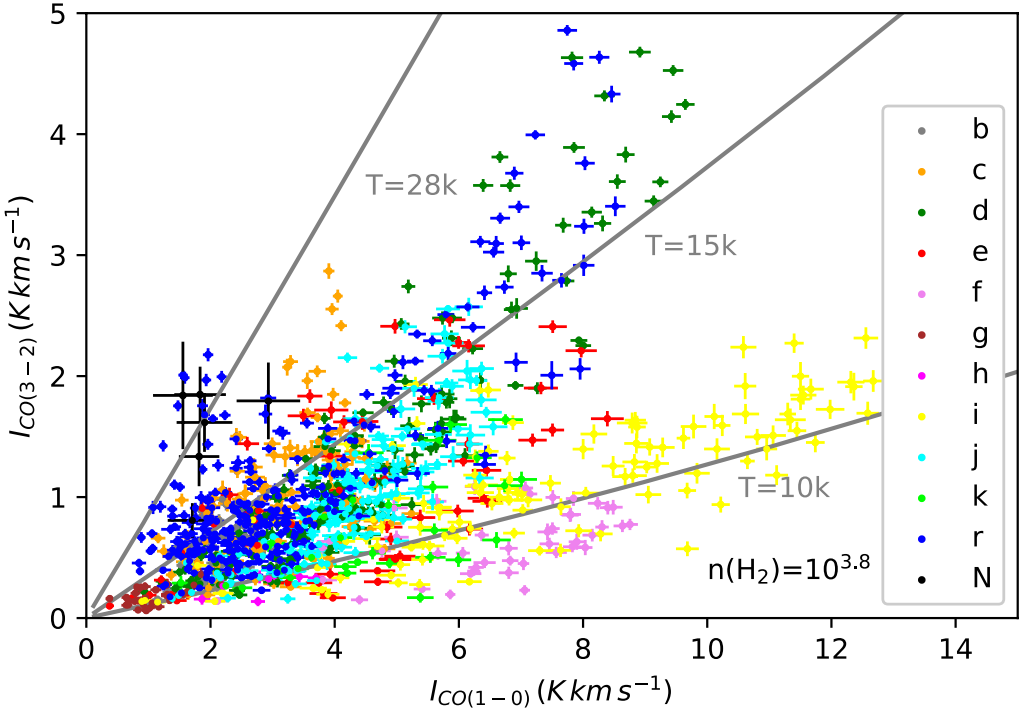
Excluded points:

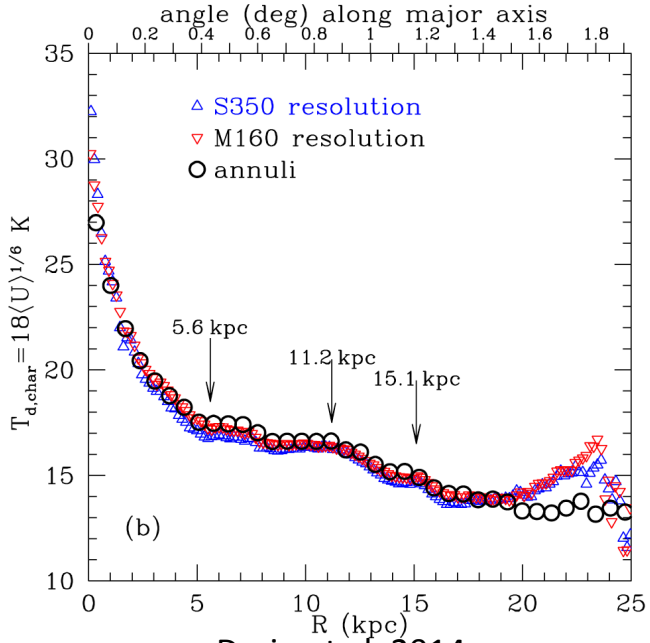
1. Central velocity difference greater than two channel widths.
2. Velocity dispersion less than the channel width.



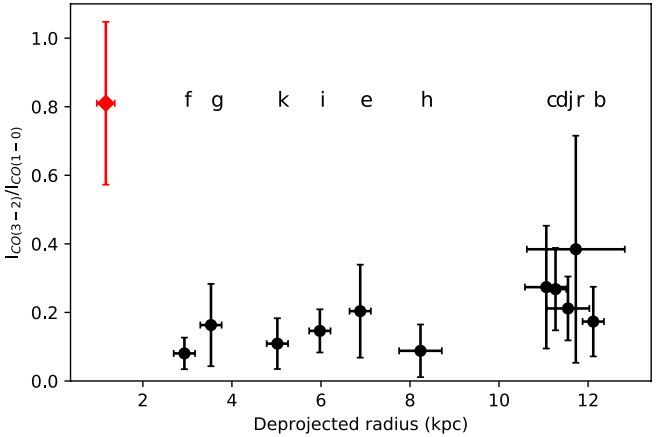
CO(3-2)/CO(1-0) ratio (R_{31})

- Nuclear region: 0.81 ± 0.24
- Mean ratio on the disk: 0.255 ± 0.005





Drain et al. 2014



Nucleus: 0.81 ± 0.24 , Disk: 0.26 ± 0.08.
Galactic center: ~0.7, Galactic disk: ~0.4
(Oka et al., 2012)

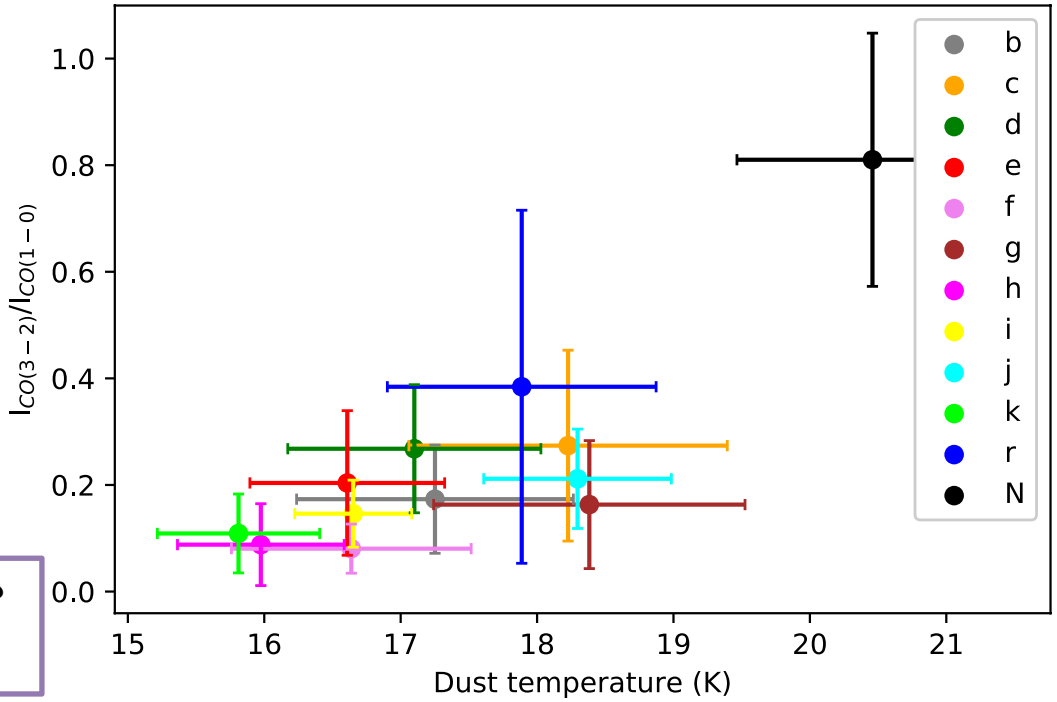
T_{dust} vs. R_{31}

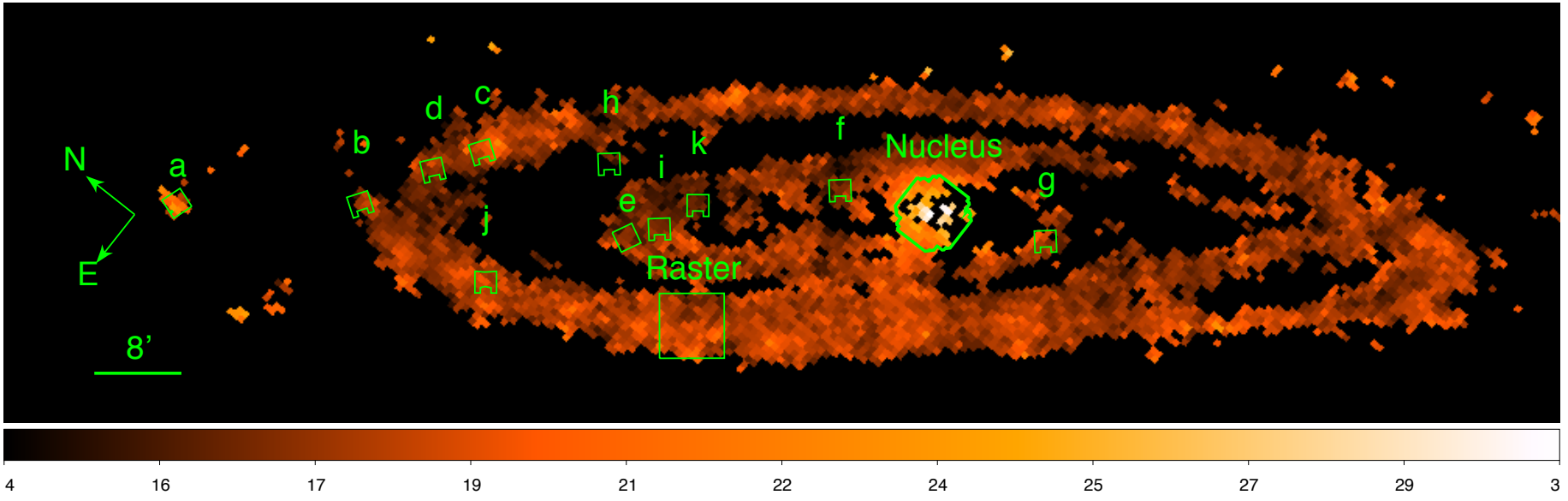
- Spearman's rank correlation coefficient:

0.69 for all points, p-value: 0.014

0.59 for the disk, p-value: 0.056

Want a high-resolution image? Check out Matt's talk!





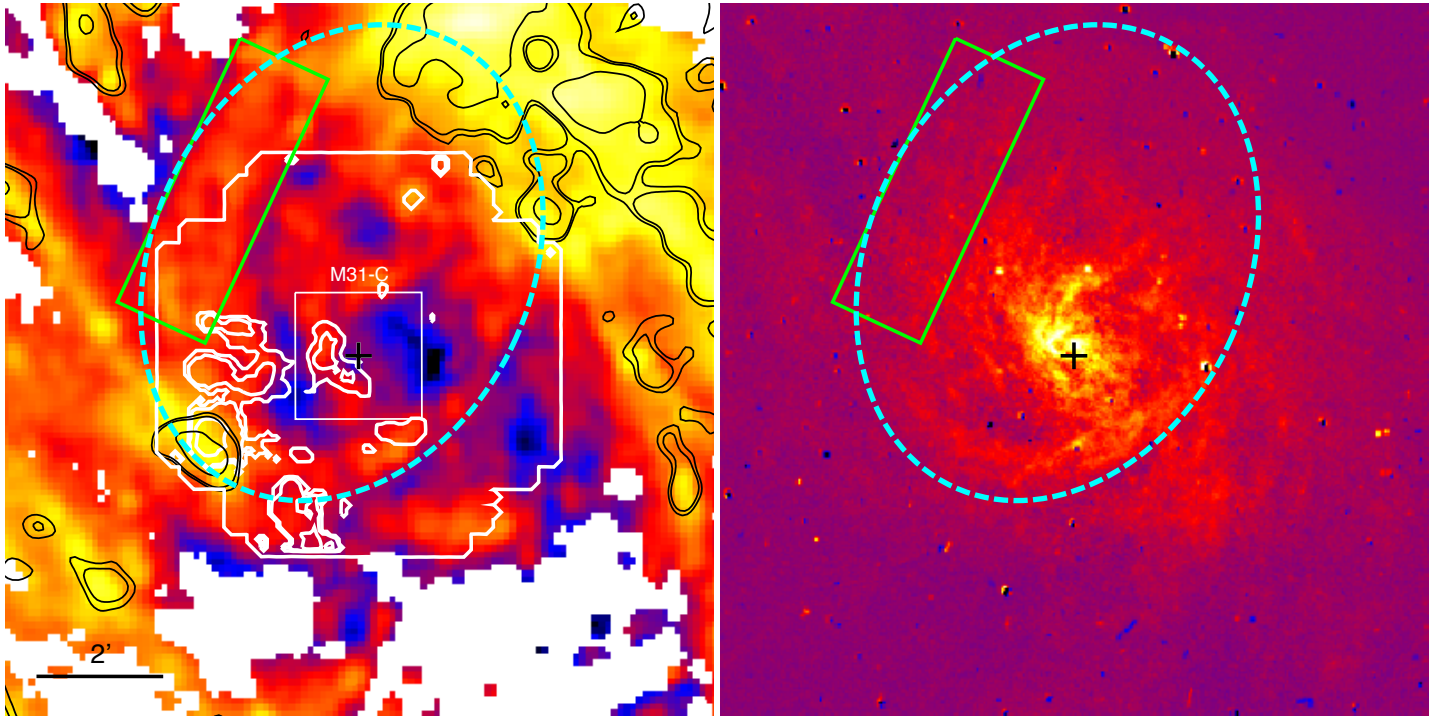
What's next

- CO contamination to dust continuum
- $L_{CO(3\text{-}2)} - L_{FIR}$ correlation
- Investigating individual GMCs
- $L_{CO(3\text{-}2)}$ correlation with SFR, stellar mass, etc.
- X_{CO} conversion factor, CO dark gas fraction
- Gas-to-dust ratio …

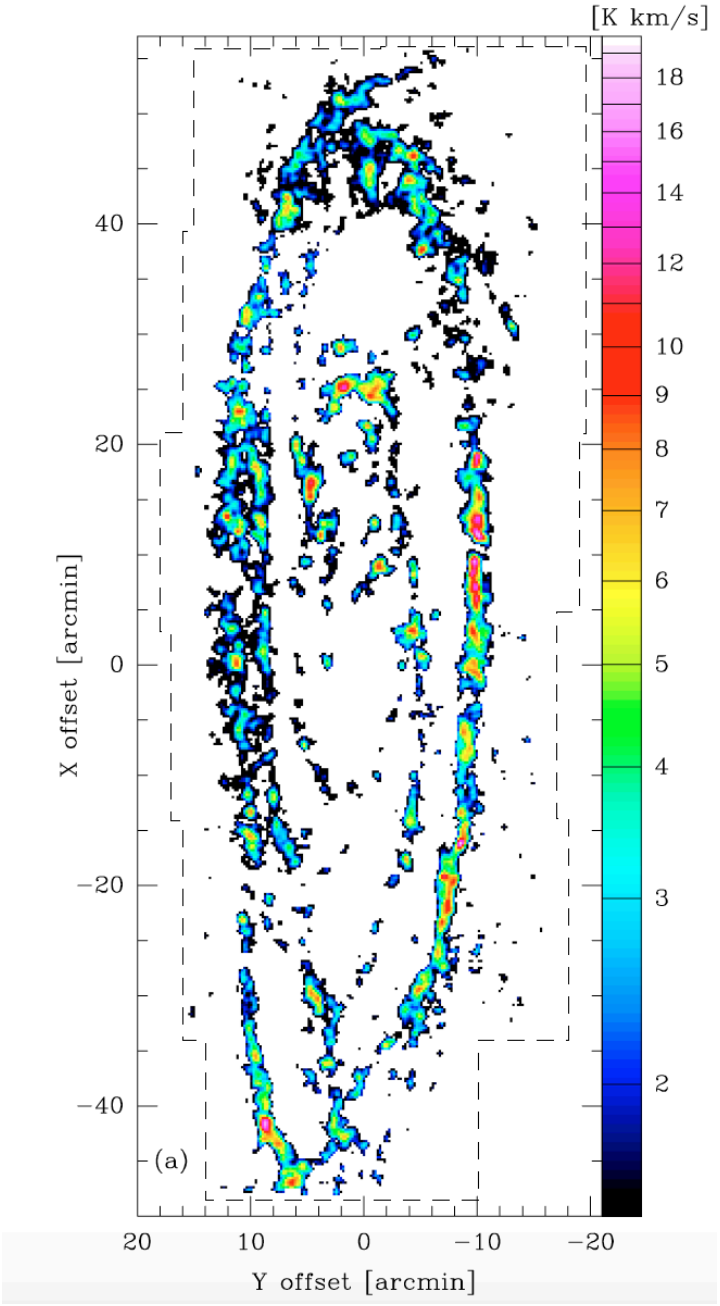
New Proposals: Follow-up CO mapping of the nuclear region

- Help reveal the origin of the nuclear spiral.
- Complementary of HASHTAG CO observations.

The IRAM 30m proposal has been accepted!



Left: dust surface density map (Groves 2012). Right: Hα map. Dashed ellipse marks the nuclear ring.



Nieten et al. 2006

The future

- To achieve a sensitivity of 0.013 K T_A^* at 2.6 km/s resolution and cover the CO(1-0) survey region (2° × 0.5°), CO(3-2) mapping of M31 requires more than **2000 hours!!**
- A 12 × 12 pixel receiver could enable a more reasonable time (~ 200 hours).

Thank you!