

Credit: A. Duro/ESO

# ALMA

and the **GALACTIC CENTER**

Alyssa Bulatek '20 (she/her)  
UF Astronomy

April 29, 2024  
**PHYS 440**

# The Atacama Large Millimeter/submillimeter Array



Credit: A. Marinkovic/X-Cam/ALMA (ESO/NAOJ/NRAO)



25 antennas



16 antennas

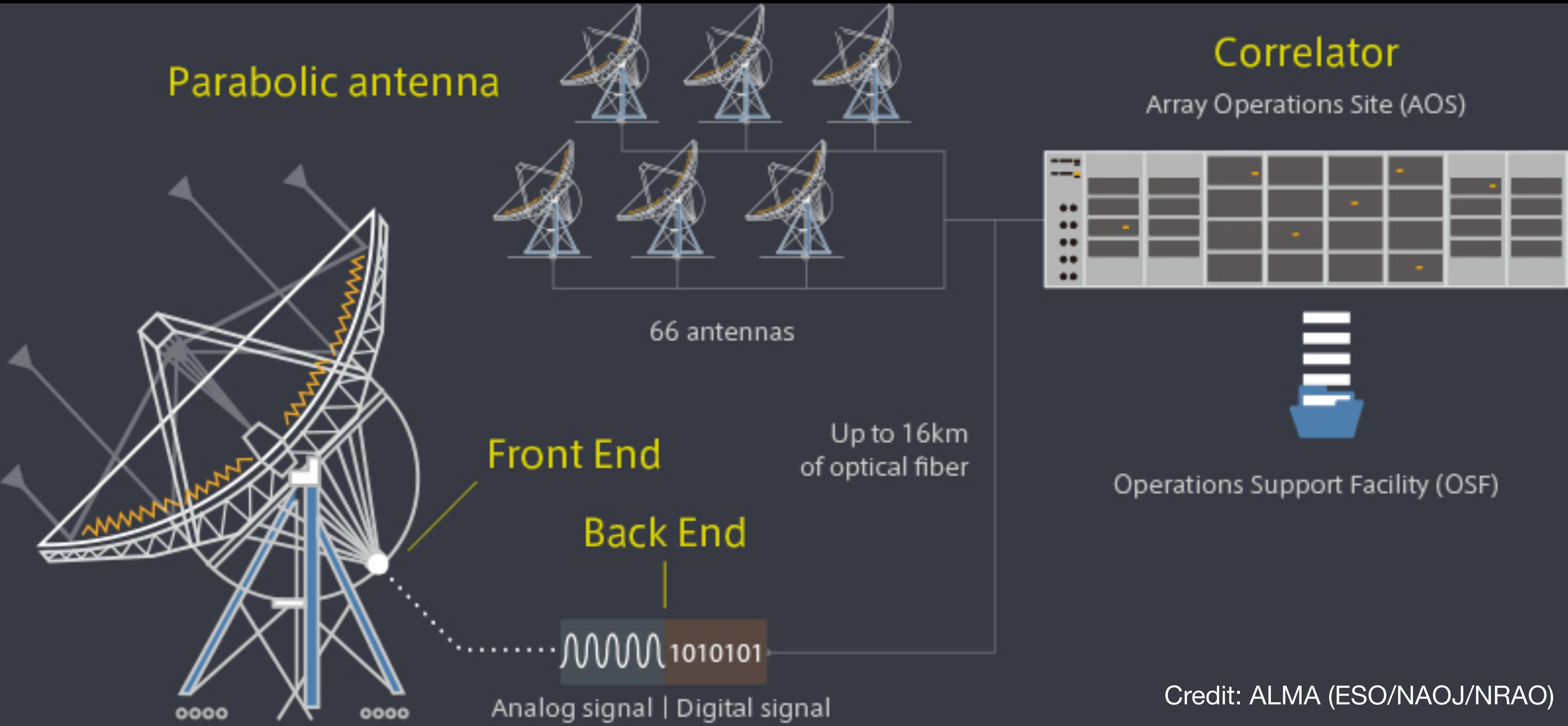


25 antennas



Credit: NAOJ

# ALMA Signal Path



# ALMA Receiver Bands

ALMA Band	Wavelength coverage (mm)	Noise Temperature (K) Specification	Frequency (GHz)	Produced by	Receiver Technology	First light
1	6–8.6	32	35 – 50	<a href="#">ASIAA</a> (Taiwan) / <a href="#">NAOJ</a> (Japan)	HEMT	2021
2	2.6–4.5	47	67 – 116	<a href="#">OSO</a> (Sweden) / <a href="#">NOVA</a> (Netherlands) / <a href="#">INAF</a> (Italy) / <a href="#">NAOJ</a> (Japan)	HEMT	2023
3	2.6–3.6	60	84 – 116	<a href="#">HIA</a> (Canada)	SIS	2009
4	1.8–2.4	82	125 – 163	<a href="#">NAOJ</a> (Japan)	SIS	2013
5	1.4–1.8	105	163 – 211	<a href="#">OSO</a> (Sweden) / <a href="#">NOVA</a> (Netherlands)	SIS	2016
6	1.1–1.4	136	211 – 275	<a href="#">NRAO</a> (US)	SIS	2009
7	0.8–1.1	219	275 – 373	<a href="#">IRAM</a> (France)	SIS	2009
8	0.6–0.8	292	385 – 500	<a href="#">NAOJ</a> (Japan)	SIS	2013
9	0.4–0.5	261	602 – 720	<a href="#">NOVA</a> (Netherlands)	SIS	2011
10	0.3–0.4	344	787 – 950	<a href="#">NAOJ</a> (Japan)	SIS	2012

My advisor (Adam Ginsburg) @ ALMA





Credit: ALMA (ESO/NAOJ/NRAO)



# Operations Support Facility

Credit: NAOJ

## ALMA CYCLE II

The Joint ALMA Observatory (JAO) will start Cycle 11 observations in October 2024. A Call for Proposals with detailed information on Cycle 11 was issued on March 21 and the deadline for proposal submission is April 25, 2024, at 15:00 UT.

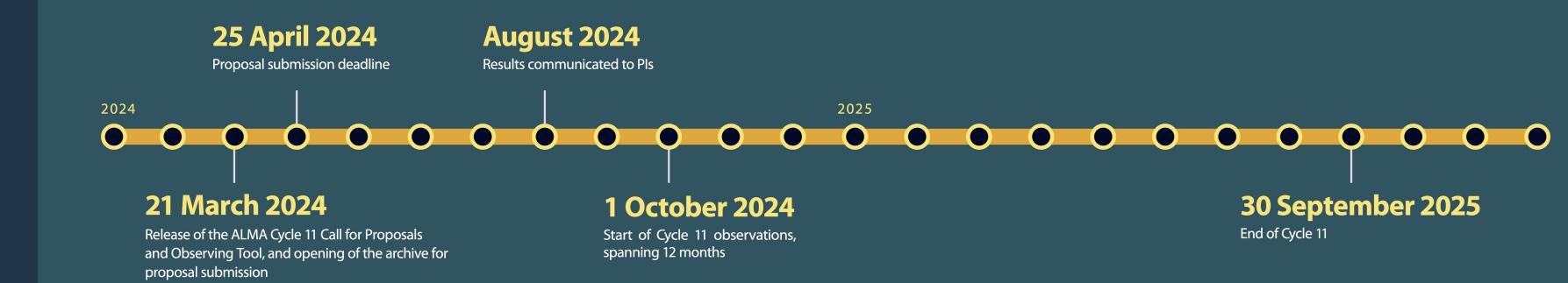
# ALMA Proposal Process

- 10% of observing time allocated to Chile
- 90% for partners accd. to financial support (North America, Europe, East Asia)
- "Open Skies" time: any affiliation
- Annual call for proposals (Cycle 11: April 25)
  - Distributed peer review process helps prevent bias
- Astronomers don't usually visit to take data
- Calibrated data products delivered to users, so no need to hand-flag data :-)

### GENERAL INFORMATION

ALMA Cycle 11 will start in October 2024 and will span 12 months. The JAO anticipates having 4,300 hours for approved science observations on the 12-m Array and 4,300 hours on the Atacama Compact Array (ACA), also known as the Morita Array. Antenna configurations C-1 to C-10 (with maximum baselines between 0.16 and 16.2 km) will be offered during this cycle. Observations that are particularly encouraged include: ACA, especially in the Local Sidereal Time (LST) range of 20h to 10h; High frequency (Bands 8, 9, and 10) in any configuration; Low frequency (Bands 1, 3, and 4) at long baselines (C-7, C-8, C-9, and C-10).

### KEY DATES



### PROPOSAL TYPES

- The proposal types in Cycle 11 will be the same as in Cycle 10. Principal Investigators submitting a proposal to ALMA for Very Long Baseline Interferometry (VLBI) observations in ALMA bands 1 or 3 made in concert with the Global mm-VLBI Array (GMVA) at 7mm and 3 mm must also have submitted a proposal to the GMVA network by 31 January 2024.
- In the main 12-m Array, antenna configurations C-1 to C-10, with maximum baselines between 0.16 and 16.2 km, will be offered.
- Large Program proposals can be submitted for a subset of observing modes (see the Call for Proposals for more details).
- Joint Proposals can be submitted including requests at ESO/VLT, NRAO/VLA and JWST.

### TECHNICAL CAPABILITIES

The anticipated Cycle 11 capabilities are:

#### Number of antennas

- At least 43 antennas will be available from the 12-m Array.
- At least ten 7-m antennas (for short baselines) and three 12-m antennas (for single-dish maps) will be available in the ACA.

#### Receiver bands

- Receiver Bands 1, 3, 4, 5, 6, 7, 8, 9 and 10 (wavelengths of about 7, 3.1, 2.1, 1.6, 1.3, 0.87, 0.74, 0.44 and 0.35 mm, respectively).

#### 12-m Array Configurations

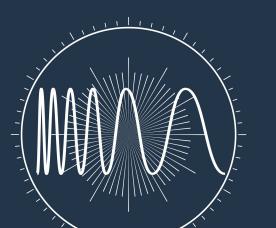
- Maximum baselines for the antenna configurations will vary from 0.16 km to 16.2 km.

The following technical capabilities will be available this Cycle for the first time:

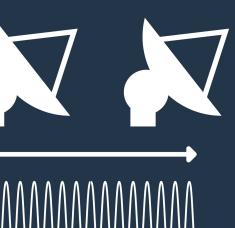
- Full polarization in Band 1 on the 12-m Array. The polarization accuracy and capability will be the same as in Bands 3–7.
- Band 1 on the 7-m Array for Stokes I only (no Stokes Q/U/V).
- High-frequency and long-baseline observations with Band 9 in C-10 configuration, and Band 10 in configurations of C-9 and C-10.
- 4x4-bit spectral mode on the 7-m Array (dual polarization). The 4x4 mode is available for the 7-m Array and allows spectral setups that are fully compatible with those of the 12-m Array.
- Also, there are no longer time caps except for the 50 hour limit on Phased Array, the LP caps, and DDT caps.

### NEW IN CYCLE II

The following technical capabilities will be available this Cycle for the first time:



Band 1 Polarization on 12-m



High-Frequencies on Long Baselines



Band 1 on 7-m

### THE PROPOSAL REVIEW PROCESS

- All proposals requesting fewer than 50 hours on the 12-m Array, and ACA stand-alone proposals requesting fewer than 150 hours on the 7-m Array will be reviewed through the distributed peer review system.

- Large Programs will be reviewed by a panel of experts.
- All Cycle 11 proposals will be reviewed through a dual-anonymous procedure.

# ALMA and Star Formation

- Optical telescopes can't see areas of star formation due to dust
  - See Milky Way dust lanes (dark)
- IR telescopes can see light from young protostars...
- ...but only mm/sub-mm telescopes can observe collapsing cores (before stellar ignition)
  - Interferometers specifically give us ang. res.

## ALMA REVEALS THE BIRTH OF PLANETS

The Young Star HL Tauri and its Protoplanetary Disk



Demonstrating the power of the Atacama Large Millimeter/submillimeter Array, this image reveals a spectacular planet-forming disk of dust and gas around the young Sun-like star HL Tauri, located 450 light-years from Earth. The superposed ellipses indicate, for comparison, the orbits of the planets in our Solar System.

Credit: ALMA (NRAO/ESO/NAOJ); NRAO/AUI/NSF, C. Brogan, B. Saxton, J. Hellerman

Credit: ALMA (NRAO/ESO/NAOJ); NRAO/AUI/NSF, C. Brogan, B. Saxton, J. Hellerman

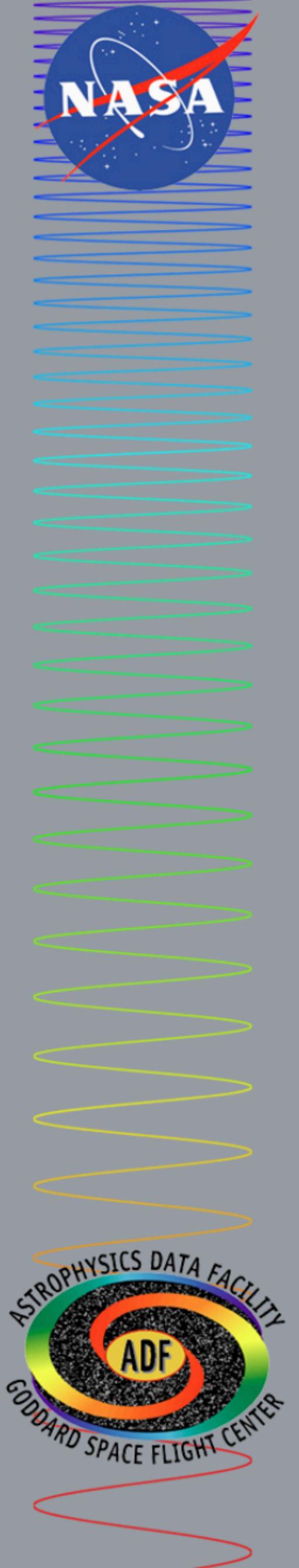
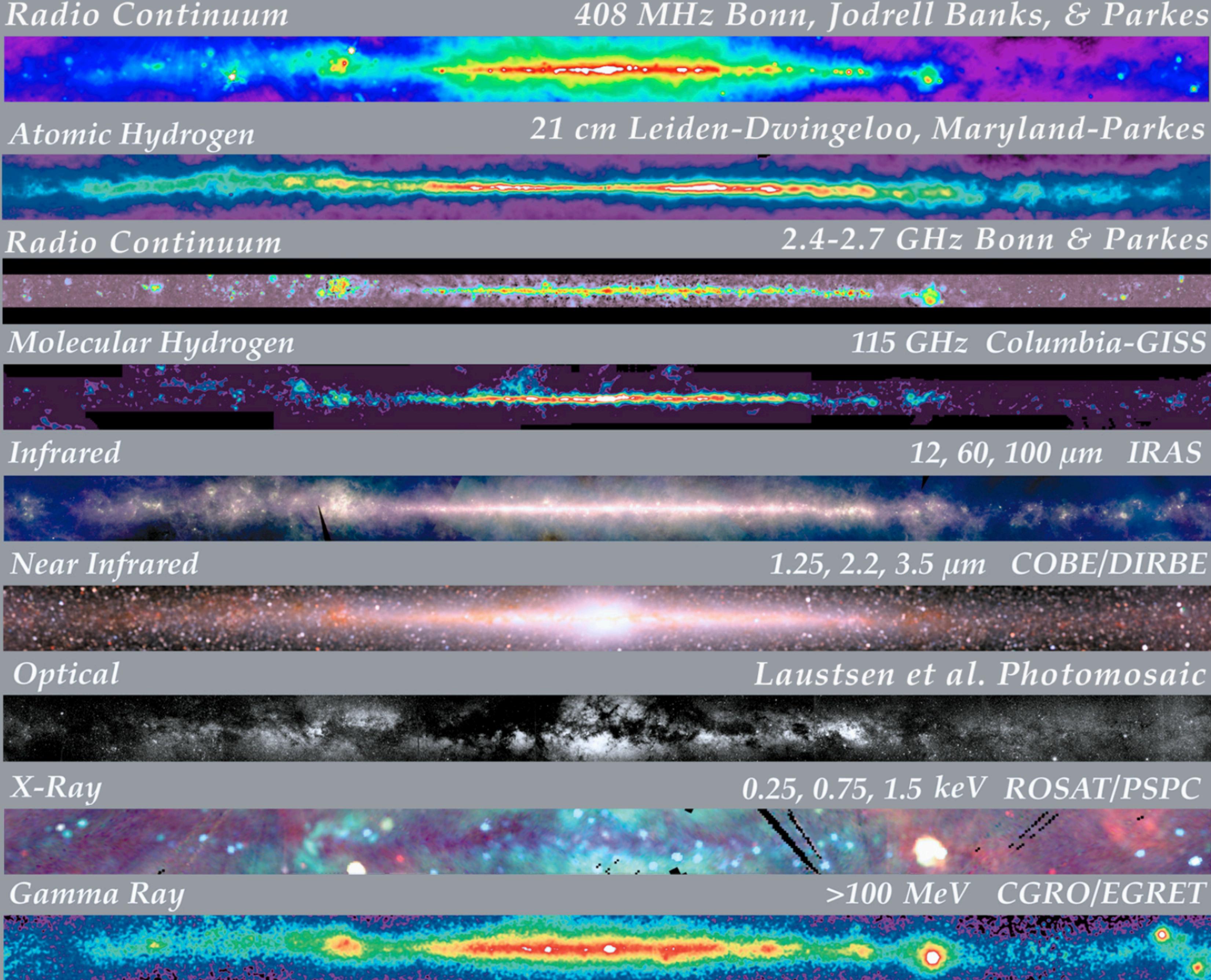
**Break for questions about ALMA?**

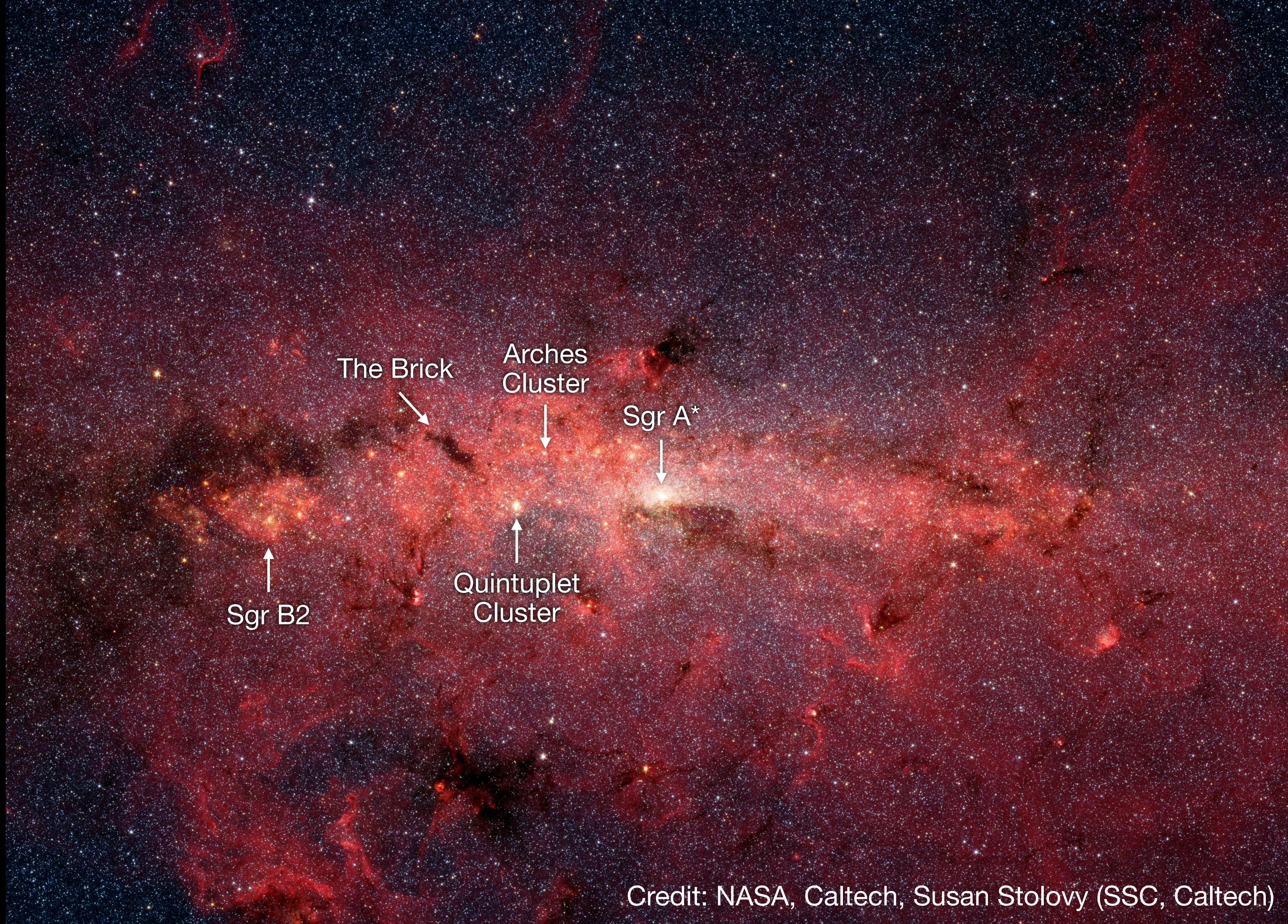
# Defining some acronyms



- **Star formation** = SF
- **Galactic Center** = GC: the inner part of the Milky Way
- **Central Molecular Zone** = CMZ: molecular material within  $R_{Gal} \approx 100$  pc

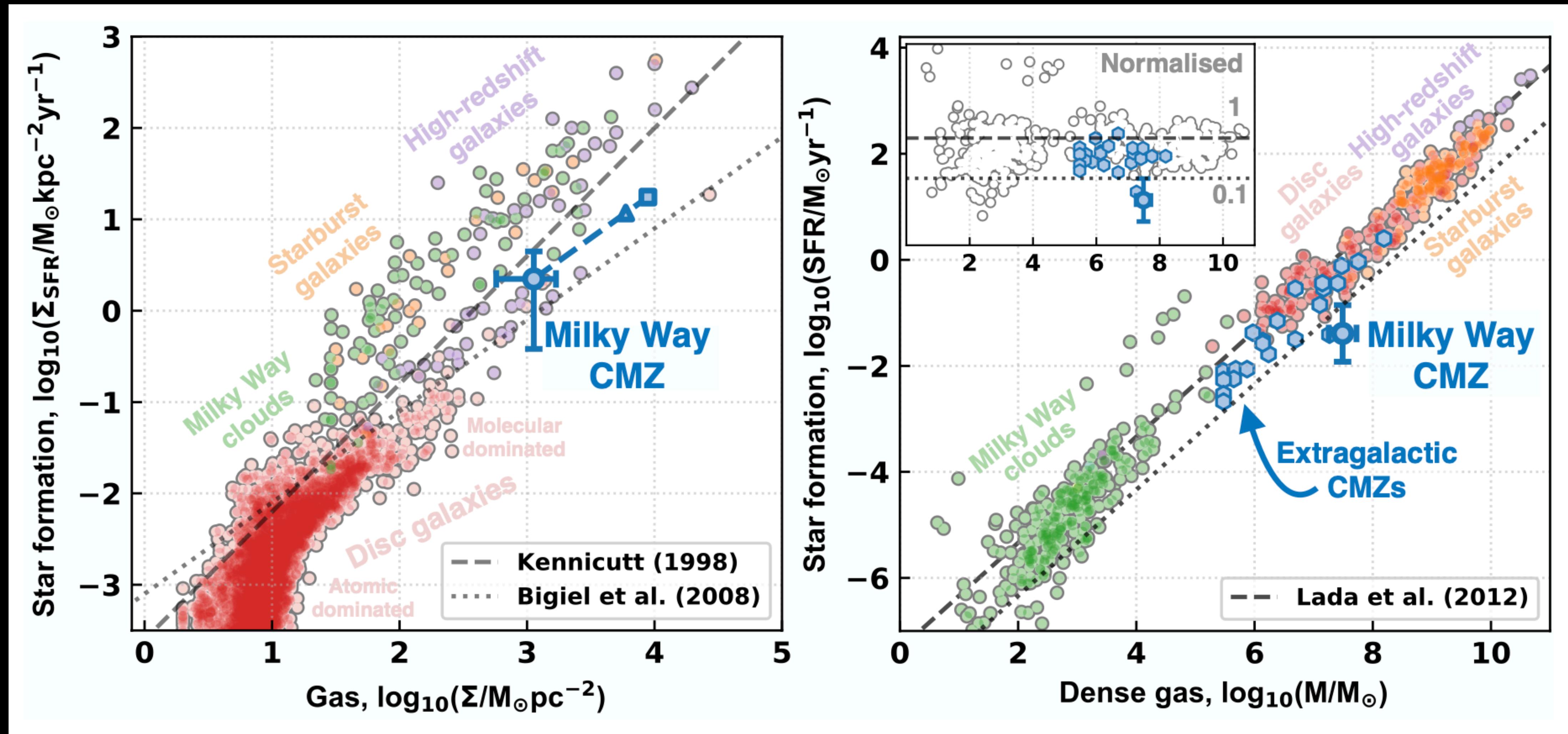
# Mult wavelength Milky Way



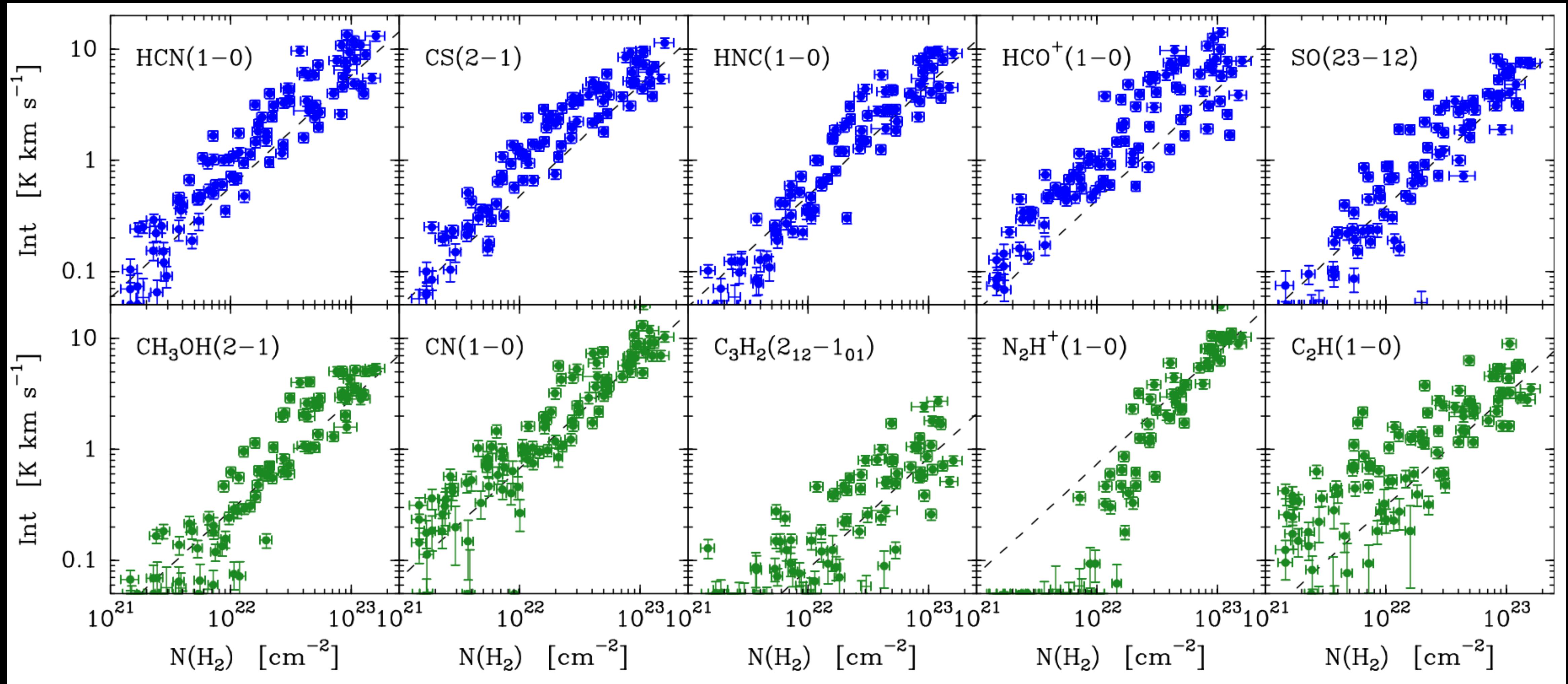


Credit: NASA, Caltech, Susan Stolovy (SSC, Caltech)

# Galactic Center star formation

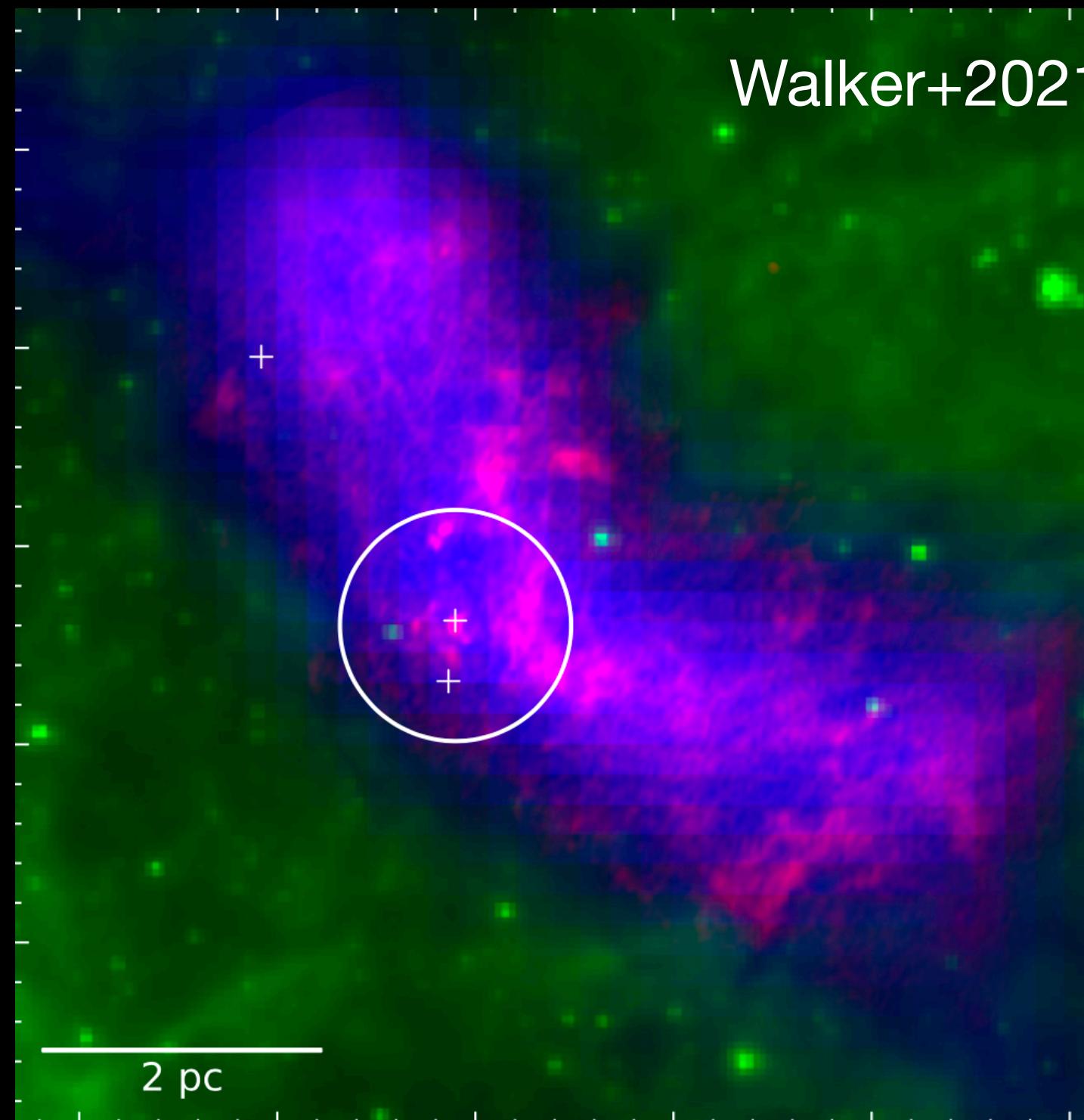


# Galactic Center star formation

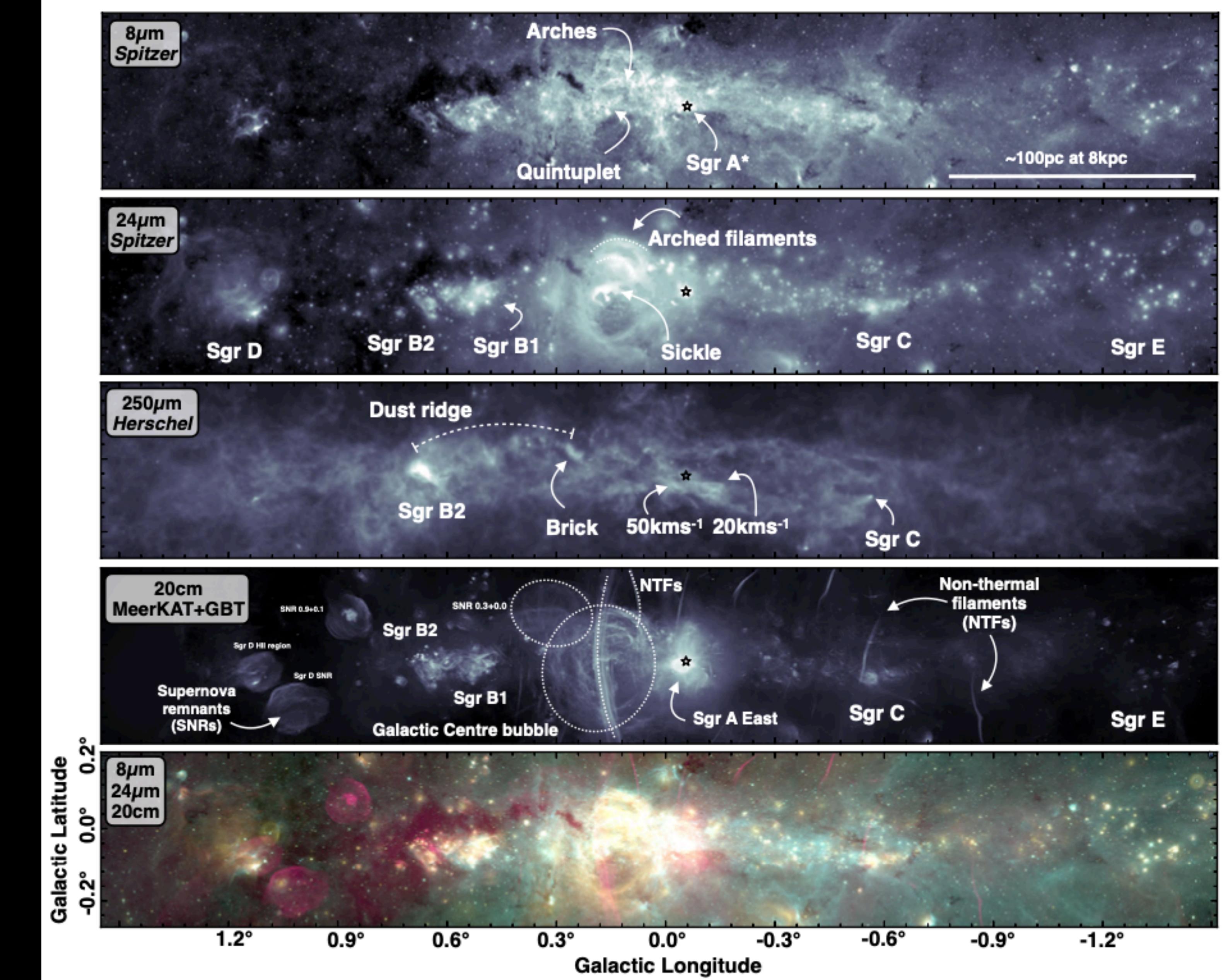


# G0.253+0.016

## The Brick

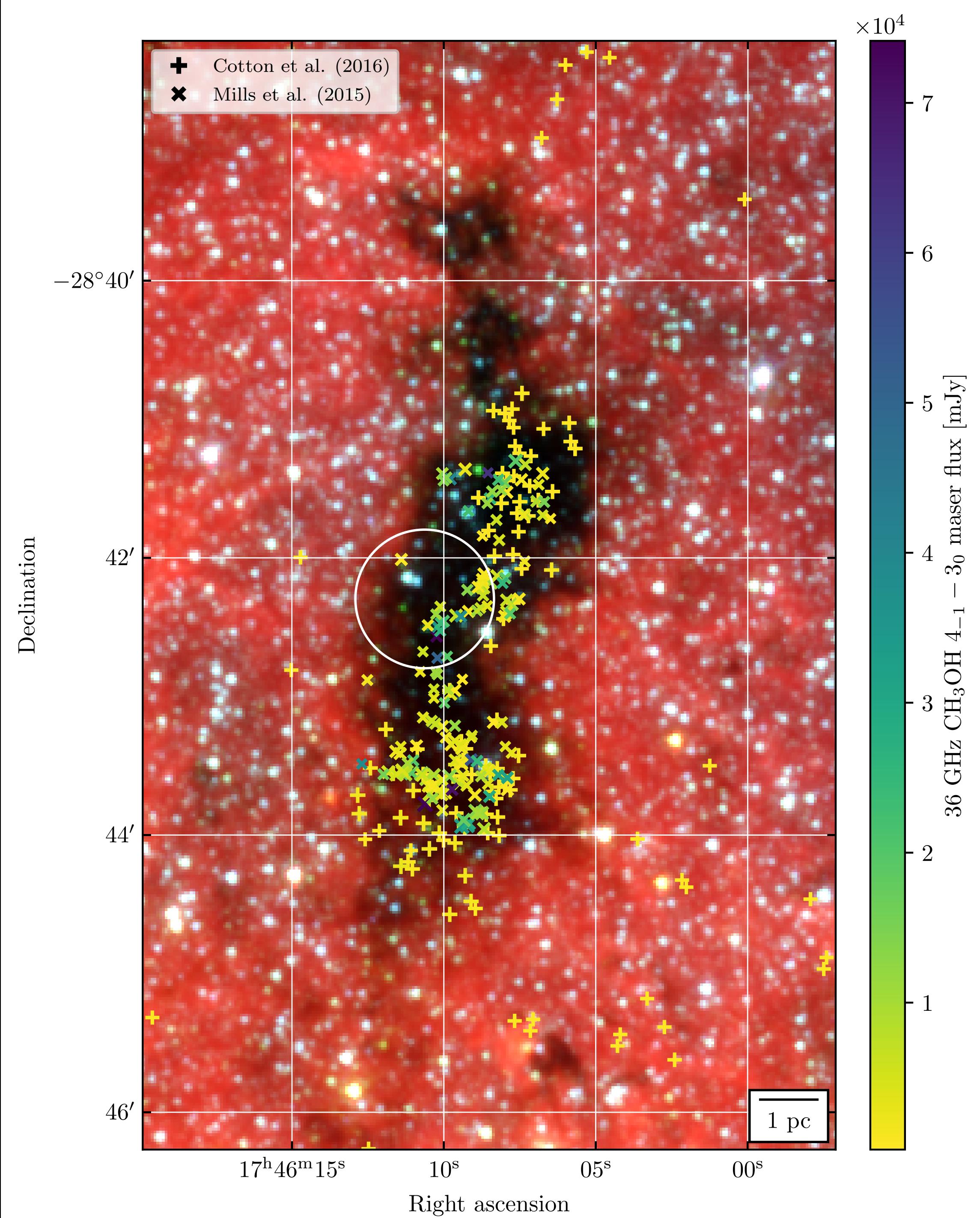


red: ALMA 3mm dust continuum  
green: *Spitzer* 8  $\mu\text{m}$  emission  
blue: *Herschel* dust column density



# The Brick Line Survey

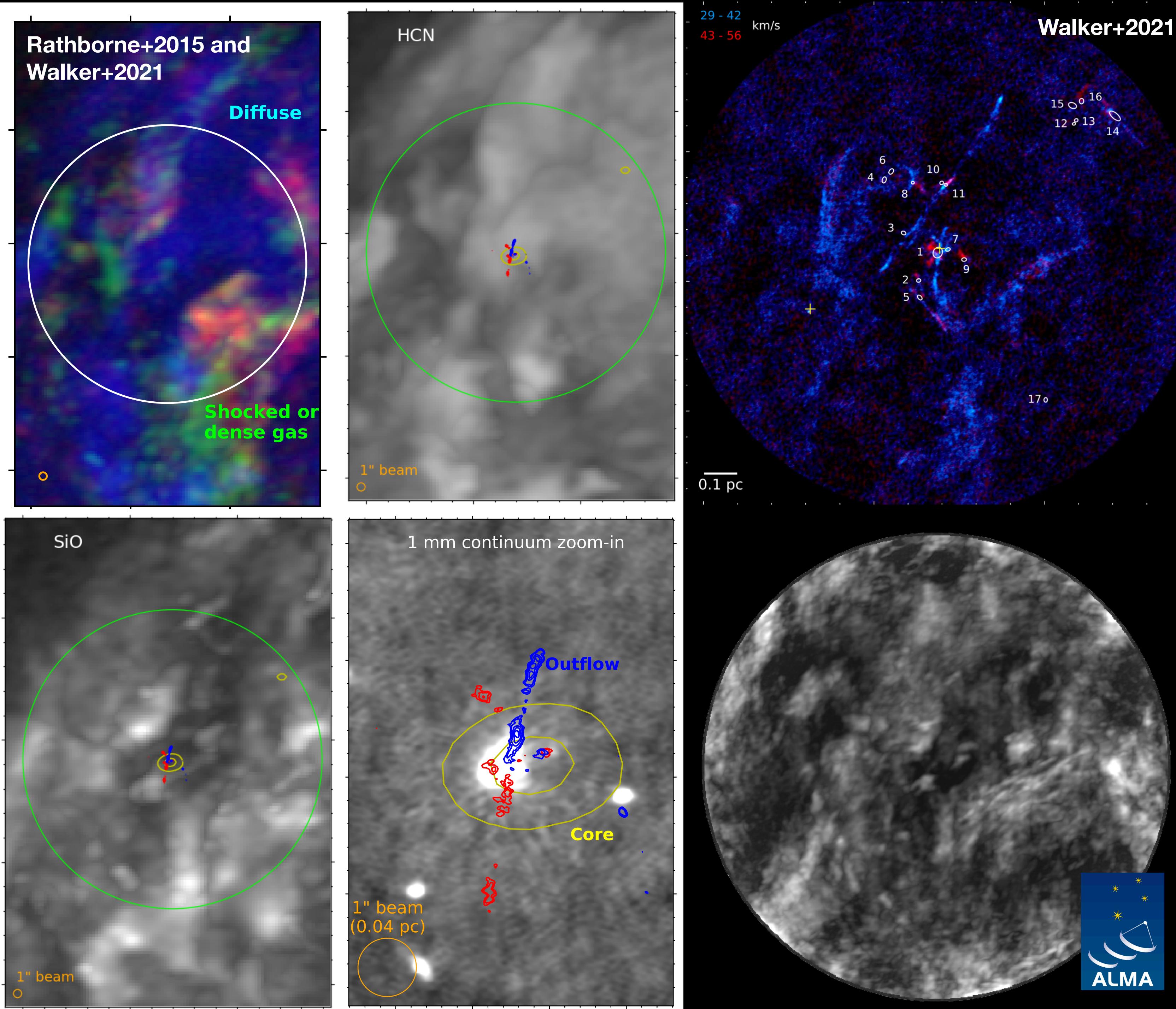
- Which spectral lines trace what physical processes in the Galactic Center?
- ALMA Bands 3, 4, 6
- 1'' angular res.,  
~0.25 K sensitivity  
in 1 km/s channel
- LAS = 5'' – 10''



BLS

# The Brick Line Survey

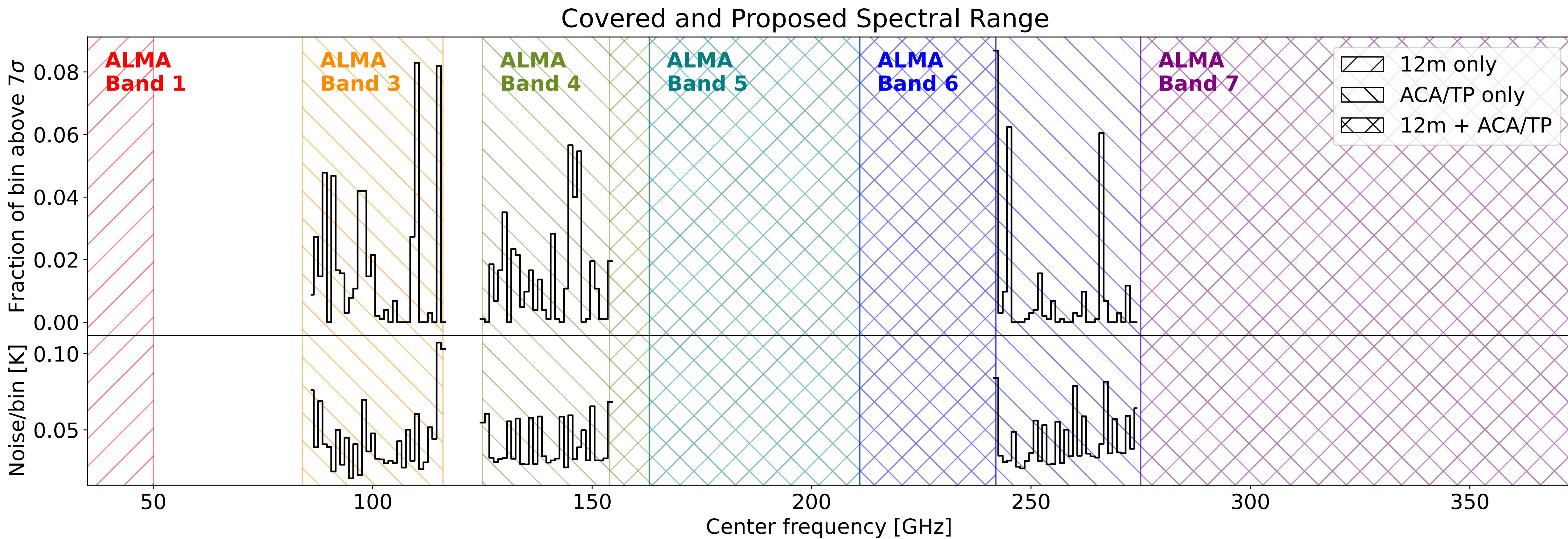
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# ALMA Cycle 11 Proposal

- Subm. in ALMA Cycles 8, 8S, 9, 10, 11

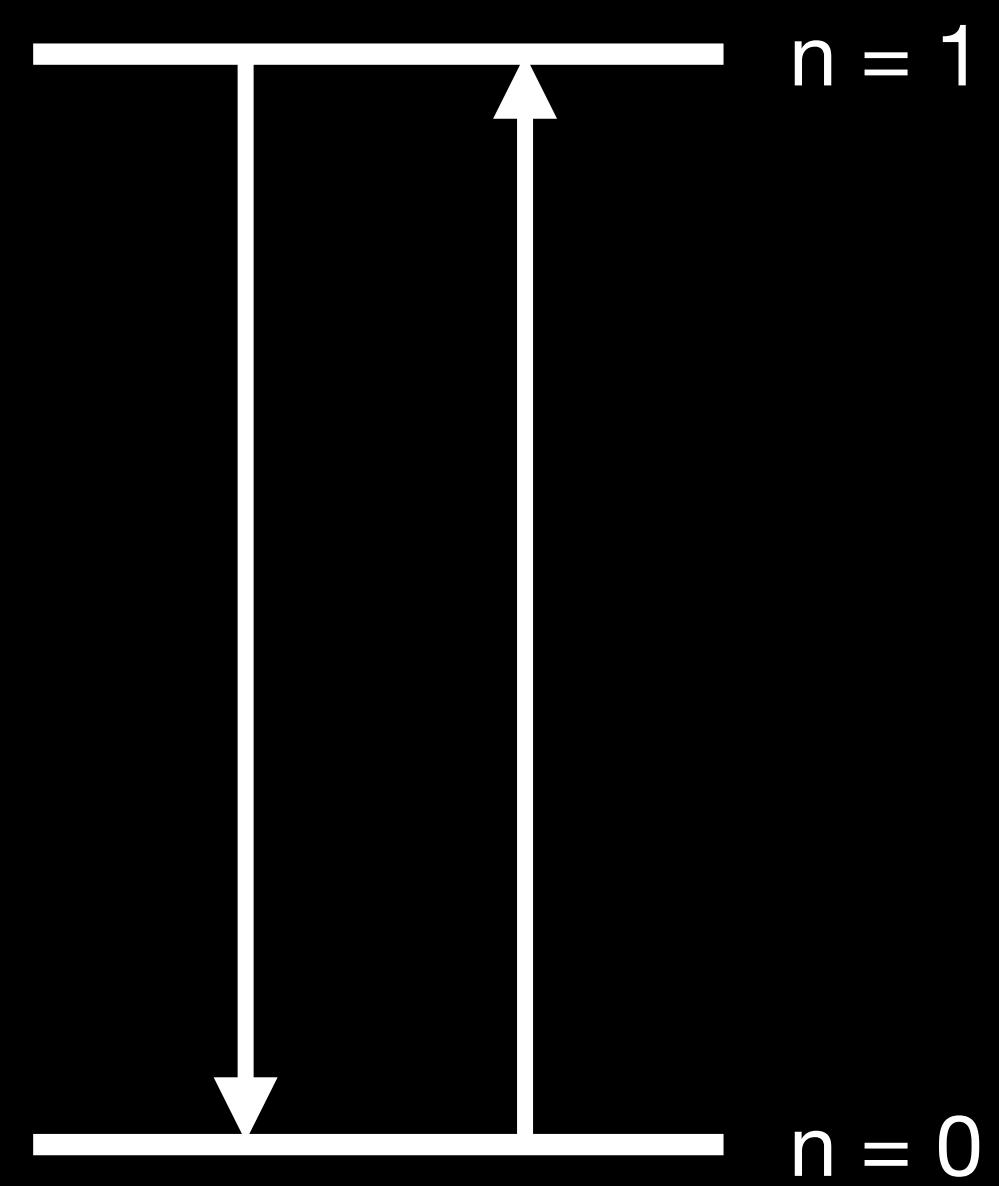
- See more lines of more molecules in missing bandwidth
- Cover larger angular scales with ACA/TP



# Methanol Dasar in The Brick

Bulatek et al. 2023, ApJ, 956, 2

- MASER = Microwave Amplification by Stimulated Emission of Radiation
  - Population inversion: excess population of molecules in upper energy state
  - A photon knocks a molecule out of the upper state
  - Needs source of coherent amplification
- DASAR = Dark "Amplification" by "Stimulated" Absorption of Radiation
  - Pump drives molecules into lower energy state, that then absorb photons

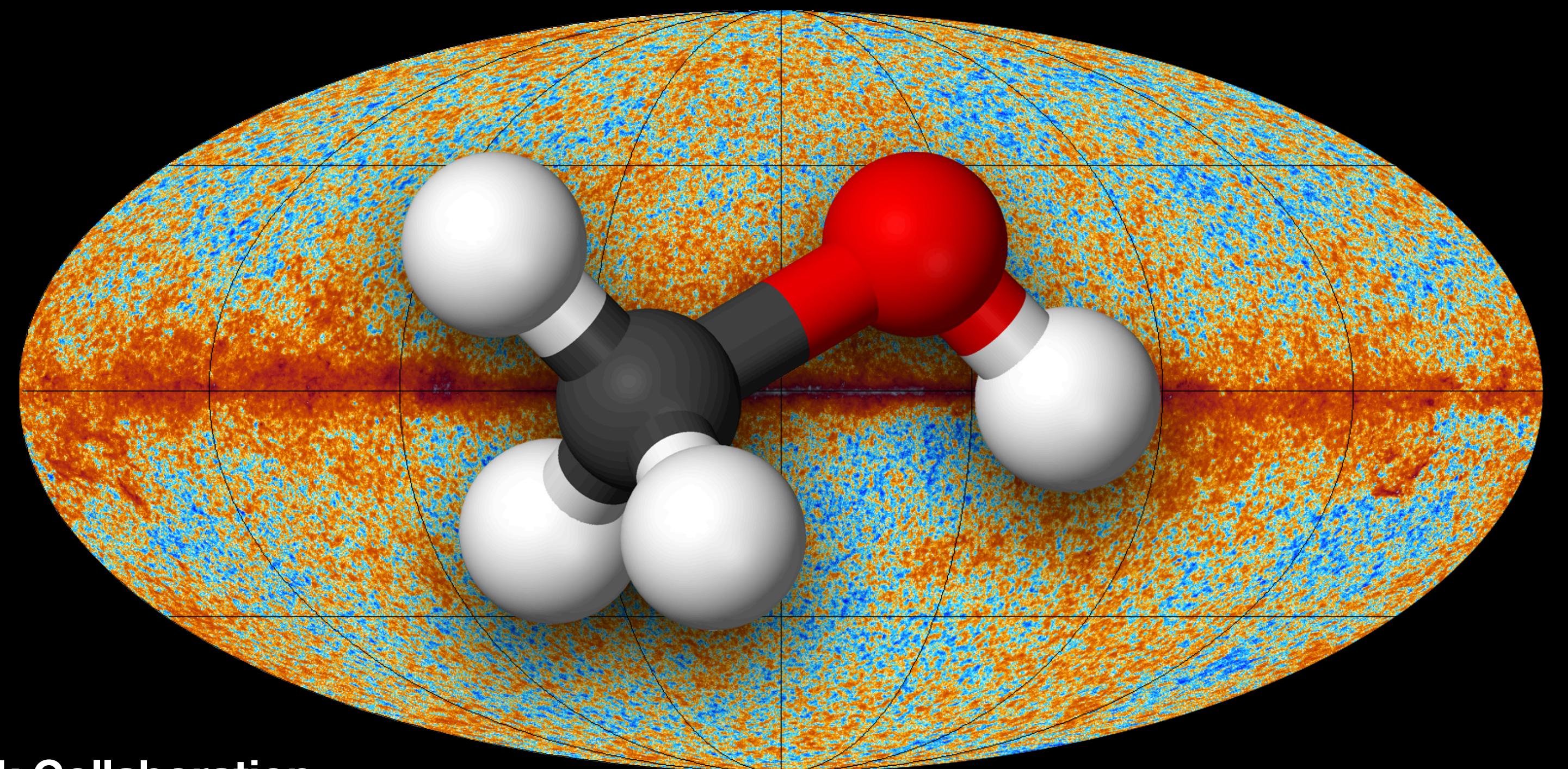


$$\frac{N_u g_l}{N_l g_u} = \exp\left(\frac{-\Delta E}{k_B T_{ex}}\right)$$

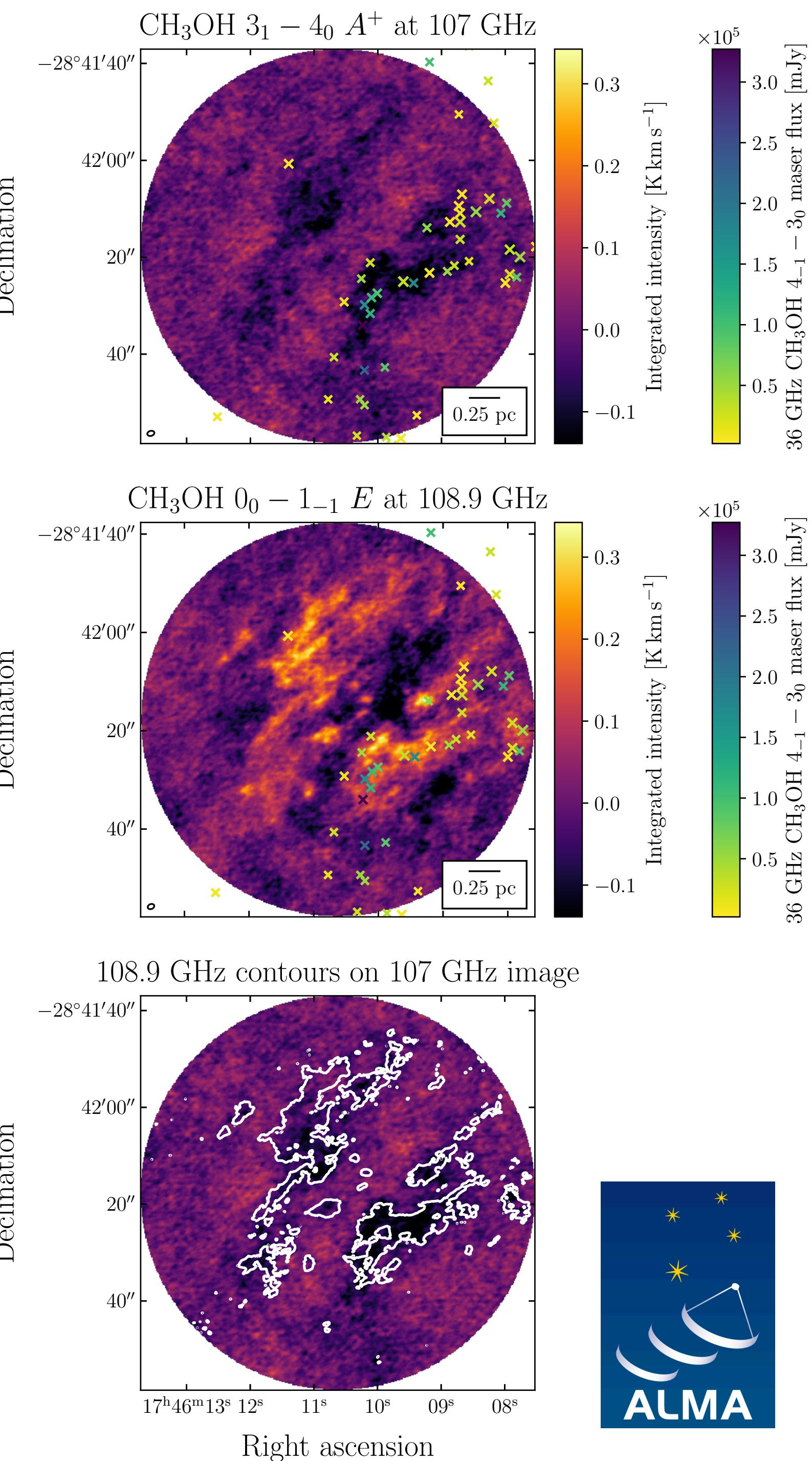
# Methanol Dasar in The Brick

Bulatek et al. 2023, ApJ, 956, 2

- If the pump gets  $T_{ex}$  cold enough, the molecule could even absorb the CMB!



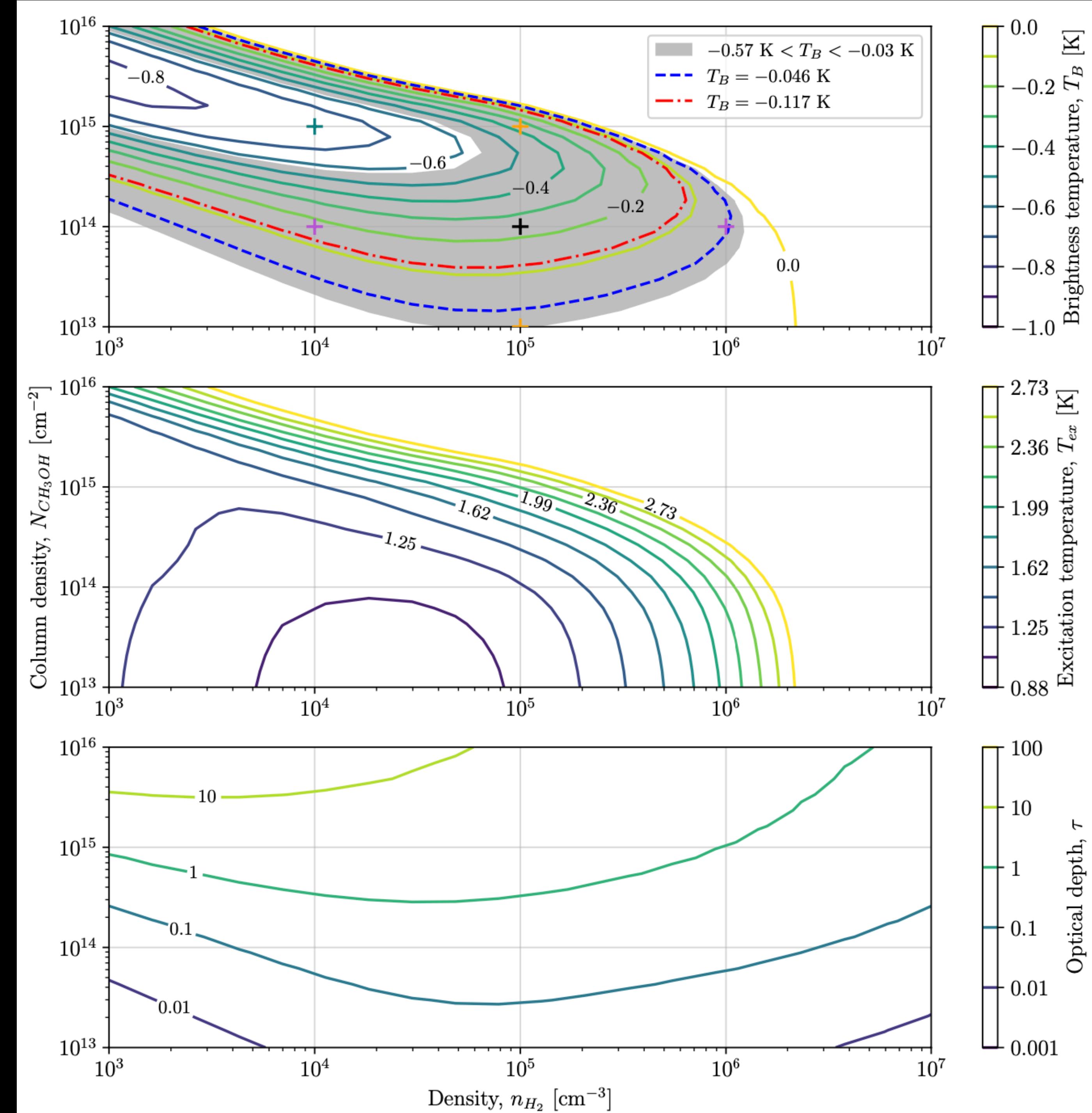
Planck Collaboration  
accessed via IRSA



# Methanol Dasar in The Brick

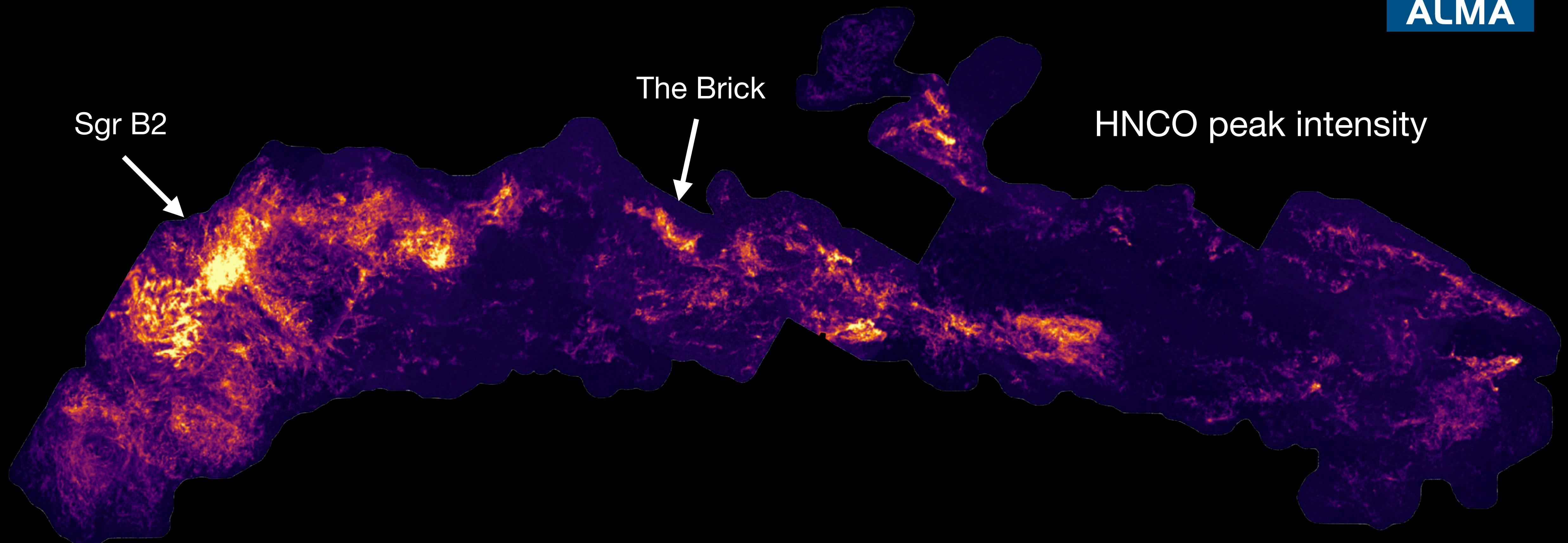
Bulatek et al. 2023, ApJ, 956, 2

- Modeled physical conditions of dasing using non-LTE modeling
- Evaluated the use of this line for detecting/measuring dasing regions in high-redshift galaxies
  - Preference for edge-on spirals
- The ngVLA will be able to observe this line (and others) in starburst galaxies up to at least  $z = 5$ 
  - Poster at *New Eyes on the Universe: SKA and ngVLA* in Vancouver, Canada (May 2023)

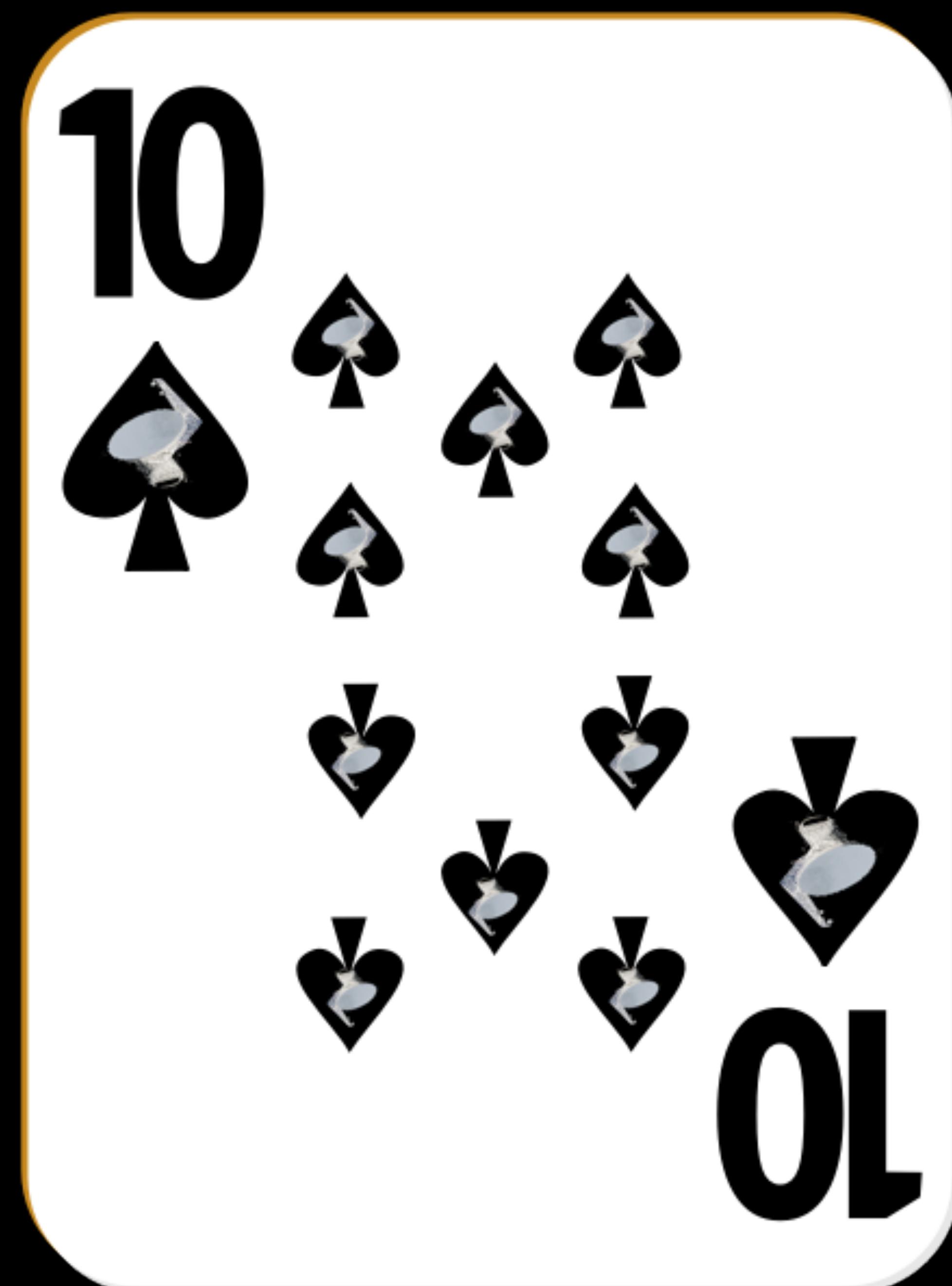
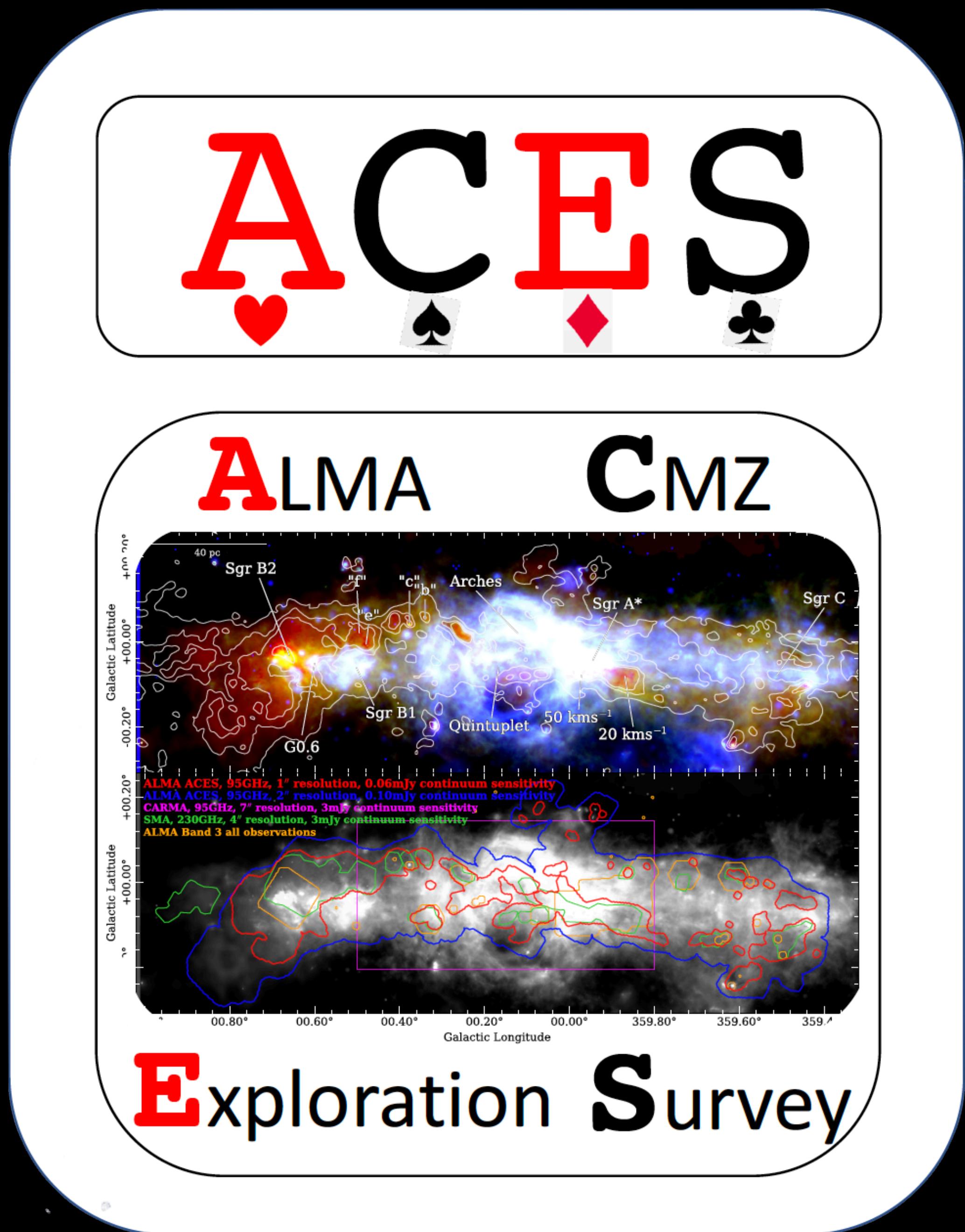


# The ALMA CMZ Exploration Survey

## ACES



Mosaic made by Dan Walker





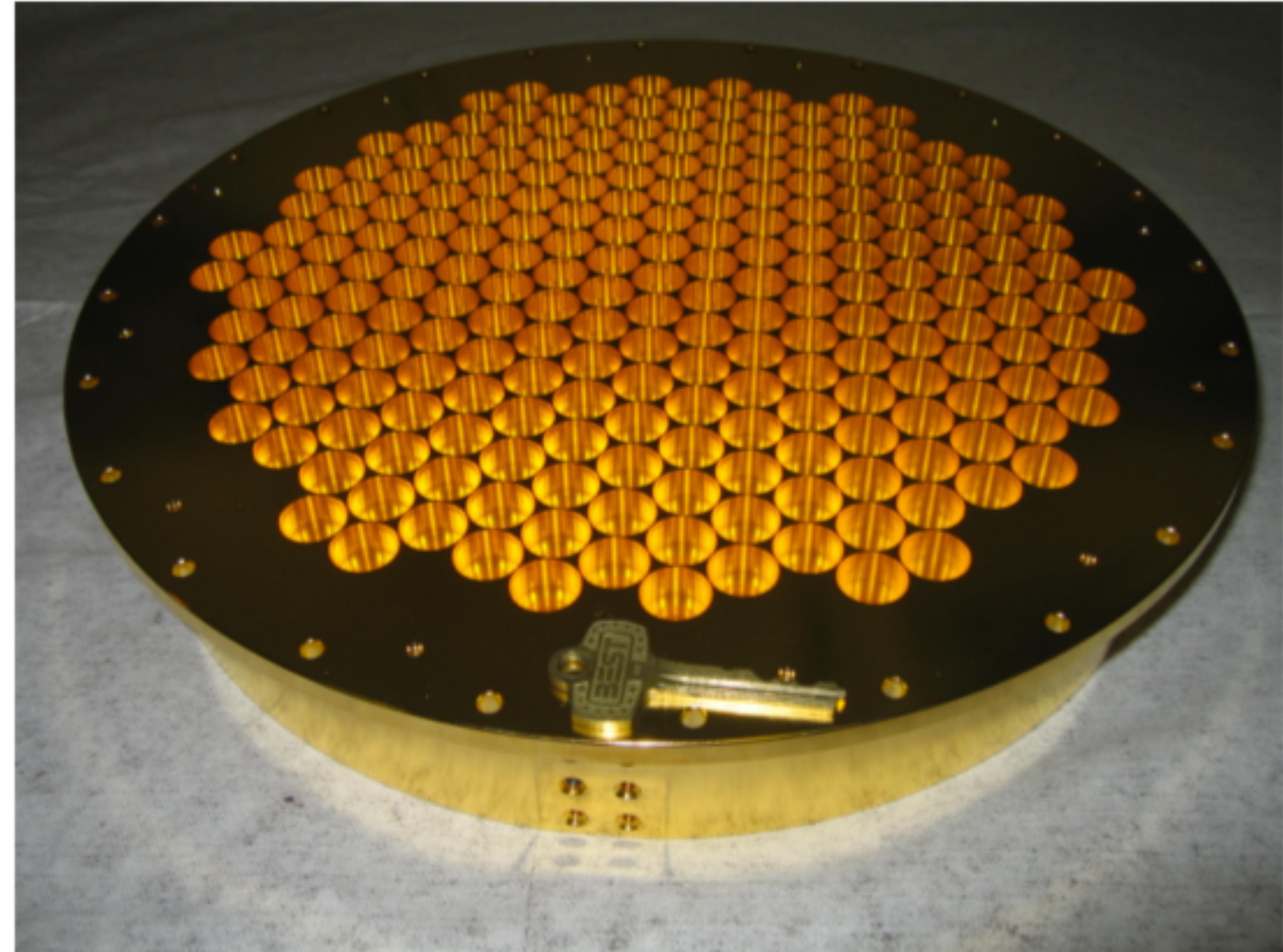
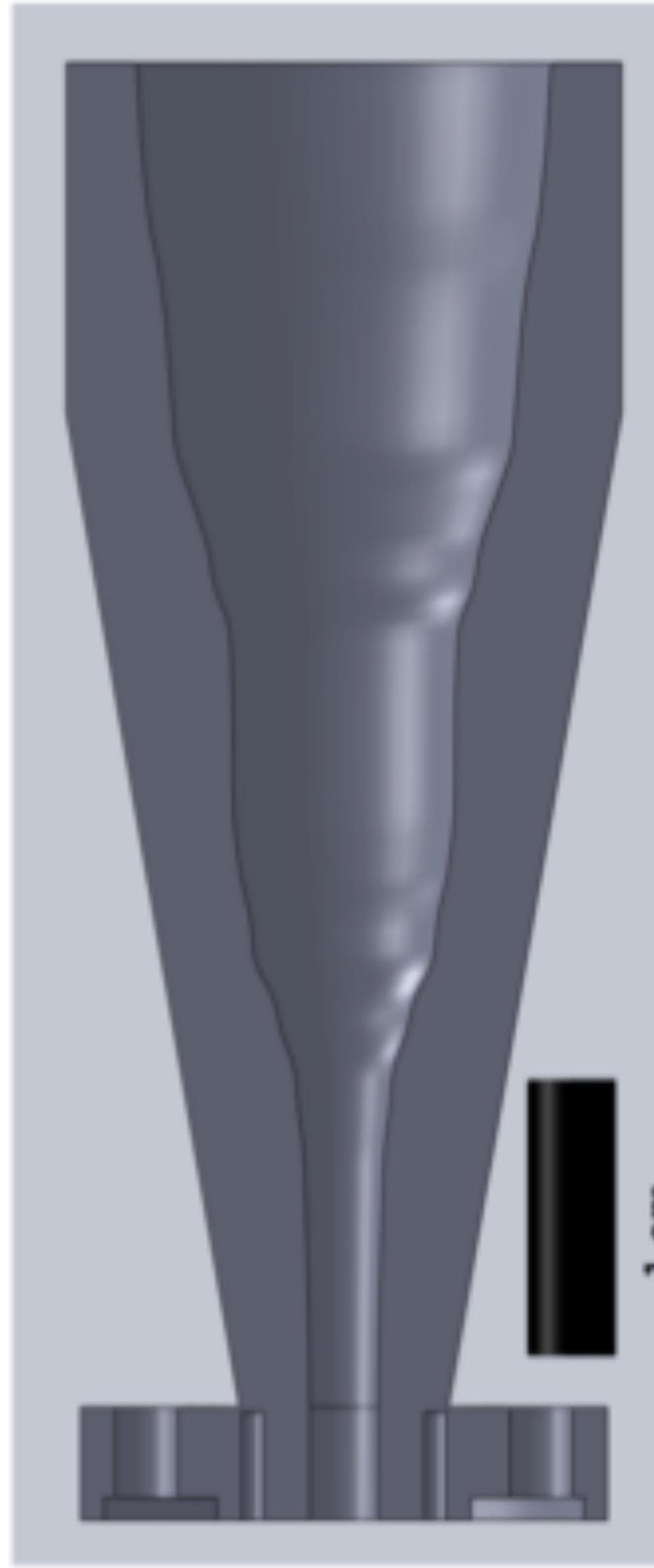
# Green Bank Telescope

## Receiver turret



Credit: B. Saxton, NRAO/AUI/NSF

# MUSTANG-2



Credit: GBT documentation

# Thank you!



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**abulatek@ufl.edu**  
**abulatek.github.io**

A vintage black and white advertisement for WLS. At the top, a banner for KQY CBS Phoenix, Arizona, proclaims "STILL AT 550". Below it, a banner for WLS Chicago says "WE'RE MOVING TO 890". Three cartoon figures are shown carrying large boxes labeled "WLS" across a frequency dial that goes from 870 to 890. The dial has a ":(h)" symbol on it. The text "WE'RE MOVING TO 890" is written in large red letters across the middle of the dial. The bottom half of the ad features a large red "WLS" logo with lightning bolts, set against a background of stars. Text at the bottom left reads "50,000 WATTS NBC AFFILIATE" and "REPRESENTED BY JOHN BLAIR & COMPANY". A small box on the right lists "The PRAIRIE FARMER STATION", "BURRIDGE D. BUTLER President", and "GLENN SNYDER Manager".

Our "sister" station in Arizona stays on 550, and that market certainly does a job in the big, buying

KQY CBS PHOENIX, ARIZONA STILL AT 550

WE'RE MOVING TO 890

WLS "Moving Day," March 29th, (we go from 870 to 890) has been amply publicized, to insure no "listener loss" to advertisers—nor missed service to listeners.

Three full page, two-color advertisements in Prairie Farmer, totaling more than 1,020,000 circulation, largely in the WLS four-state, Major Coverage Area, have impressed the new location on Mid-West farm homes—and merchants. In addition, on several pages in the March 22 issue mention was made of the new WLS frequency.

For Chicago listeners a total of eight full-column ads in the Chicago Times have told the same story. A full page back cover ad in Radio Varieties spread the news farther, and every daily and weekly newspaper in the four-state area received

a news story, written from the WLS angle, but telling the full reallocation story.

15,000 cards explaining the change were distributed to visitors to the WLS National Barn Dance and studios. We supplied servicemen with WLS tabs for push button sets, to assure the station being represented on every radio.

WLS and Prairie Farmer are using stickers on all outgoing mail. And to complete the job of getting the story to everyone, we are using every possible moment on the air to announce the new frequency and explain the reasons for the change.

So, when WLS moves up to 890, we'll have our same full-size, loyal audience moving right along with us—for they all *know* that we're moving... why we're moving... and where, too!

50,000 WATTS NBC AFFILIATE

REPRESENTED BY JOHN BLAIR & COMPANY

The PRAIRIE FARMER STATION

BURRIDGE D. BUTLER President

GLENN SNYDER Manager

CHICAGO