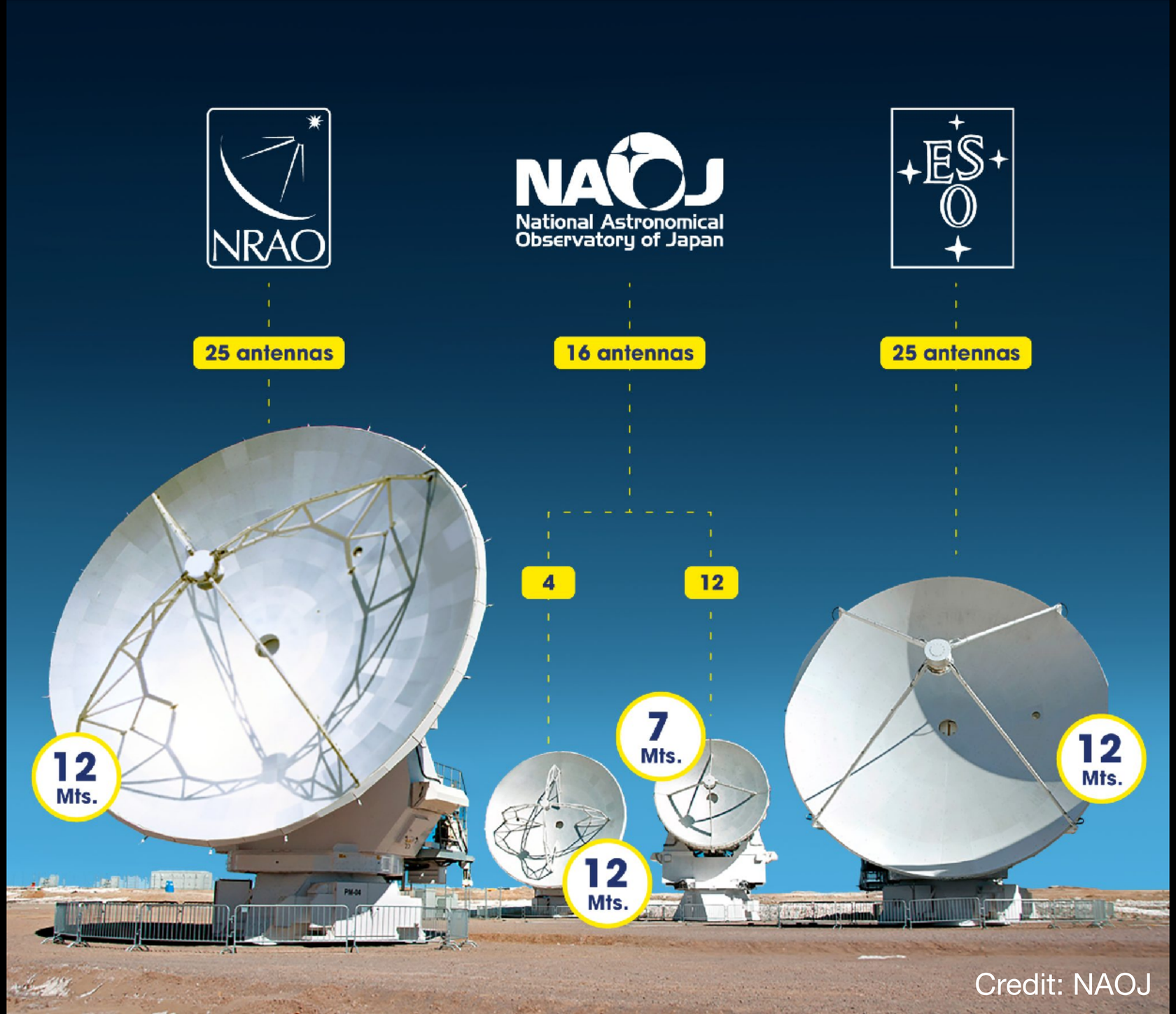
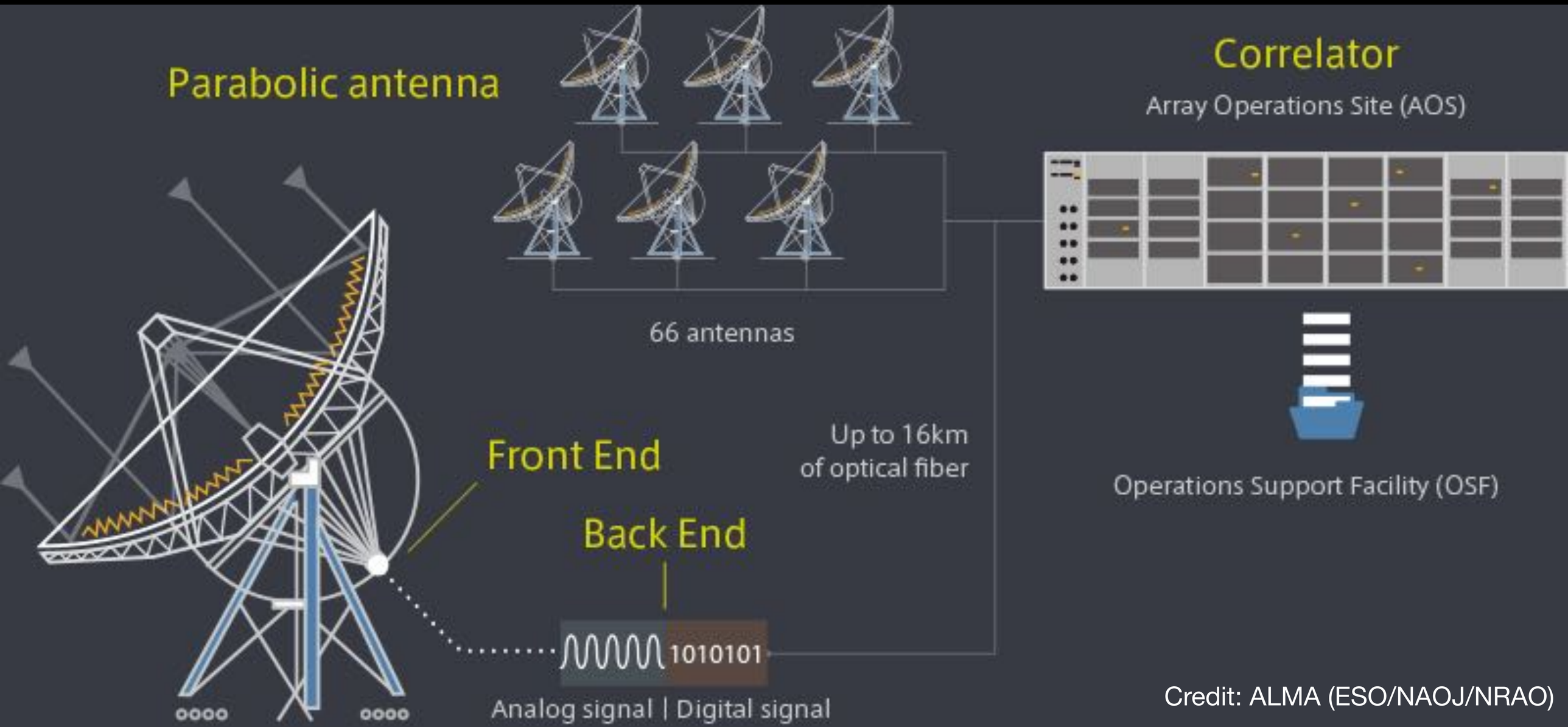

Credit: A. Duro/ESO
ALMA
and the GALACTIC CENTER
Alyssa Bulatek '20 (she/her)
UF Astronomy
April 29, 2024
PHYS 440

The Atacama Large Millimeter/submillimeter Array

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


NRAO
NAOJ
National Astronomical Observatory of Japan
ESO
25 antennas
16 antennas
25 antennas
4
12
12 Mts.
7 Mts.
12 Mts.
12 Mts.
Credit: NAOJ

ALMA Signal Path



Credit: ALMA (ESO/NAOJ/NRAO)

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	ASIAA (Taiwan) / NAOJ (Japan)	HEMT	2021
2	2.6–4.5	47	67 – 116	OSO (Sweden) / NOVA (Netherlands) / INAF (Italy) / NAOJ (Japan)	HEMT	2023
3	2.6–3.6	60	84 – 116	HIA (Canada)	SIS	2009
4	1.8–2.4	82	125 – 163	NAOJ (Japan)	SIS	2013
5	1.4–1.8	105	163 – 211	OSO (Sweden) / NOVA (Netherlands)	SIS	2016
6	1.1–1.4	136	211 – 275	NRAO (US)	SIS	2009
7	0.8–1.1	219	275 – 373	IRAM (France)	SIS	2009
8	0.6–0.8	292	385 – 500	NAOJ (Japan)	SIS	2013
9	0.4–0.5	261	602 – 720	NOVA (Netherlands)	SIS	2011
10	0.3–0.4	344	787 – 950	NAOJ (Japan)	SIS	2012

My advisor (Adam Ginsburg) @ ALMA

The ALMA Site

Credit: ALMA (ESO/NAOJ/NRAO)

Operations Support Facility

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 :'-)

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.

GENERAL INFORMATION

ALMA Cycle 11 will start in October 2024 and will span 12 months. The JAO anticipates having 4,900 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

25 April 2024
Proposal submission deadline

August 2024
Results communicated to PIs

2024

2025

21 March 2024
Release of the ALMA Cycle 11 Call for Proposals and Observing Tool, and opening of the archive for proposal submission

1 October 2024
Start of Cycle 11 observations, spanning 12 months

30 September 2025
End of Cycle 11

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 7 mm 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 IRSO/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 12-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.

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

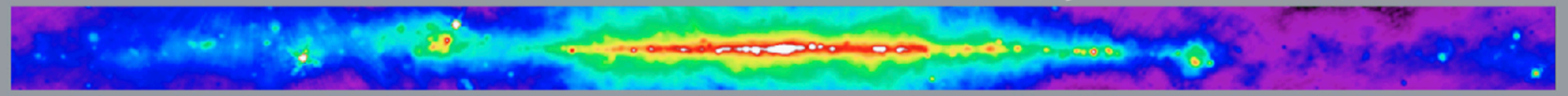
Break for questions about ALMA?

Defining some acronyms

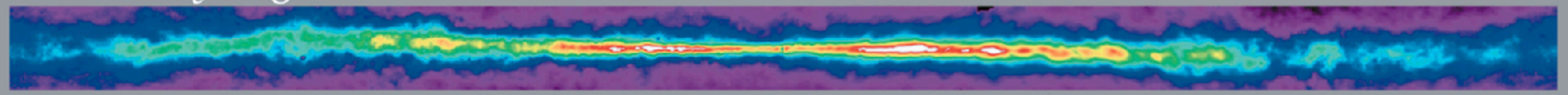
- **Star formation** = SF
- **Galactic Center** = GC: the inner part of the Milky Way
- **Central Molecular Zone** = CMZ: molecular material within $R_{Gal} \approx$ X00 pc

Multiwavelength Milky Way

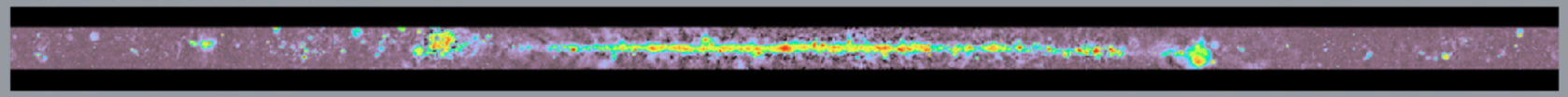
Radio Continuum — 408 MHz Bonn, Jodrell Banks, & Parkes



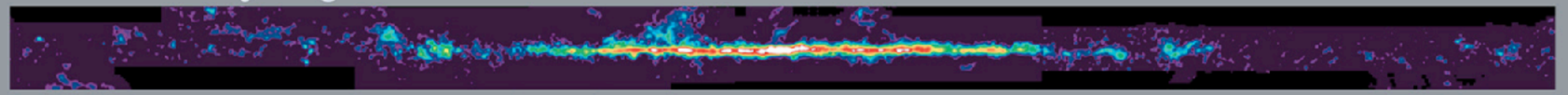
Atomic Hydrogen — 21 cm Leiden-Dwingeloo, Maryland-Parkes



Radio Continuum — 2.4-2.7 GHz Bonn & Parkes



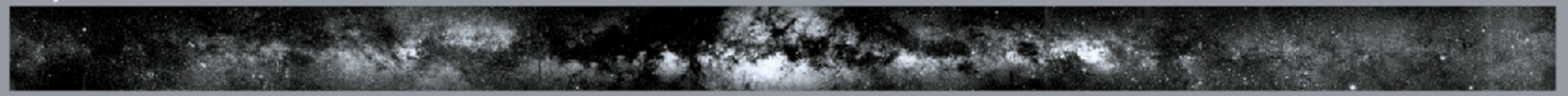
Molecular Hydrogen — 115 GHz Columbia-GISS



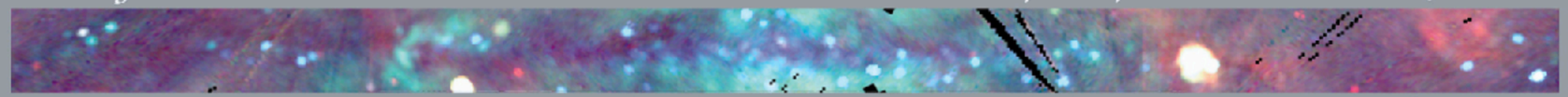
Infrared — 12, 60, 100 μm IRAS

Near Infrared — 1.25, 2.2, 3.5 μm COBE/DIRBE

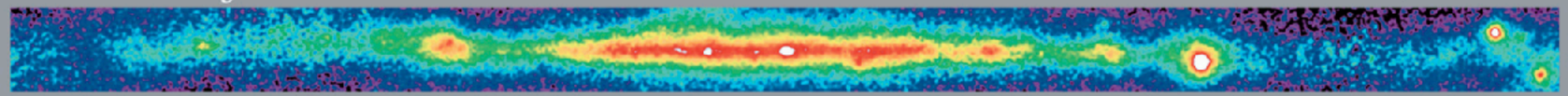
Optical — Laustsen et al. Photomosaic



X-Ray — 0.25, 0.75, 1.5 keV ROSAT/PSPC

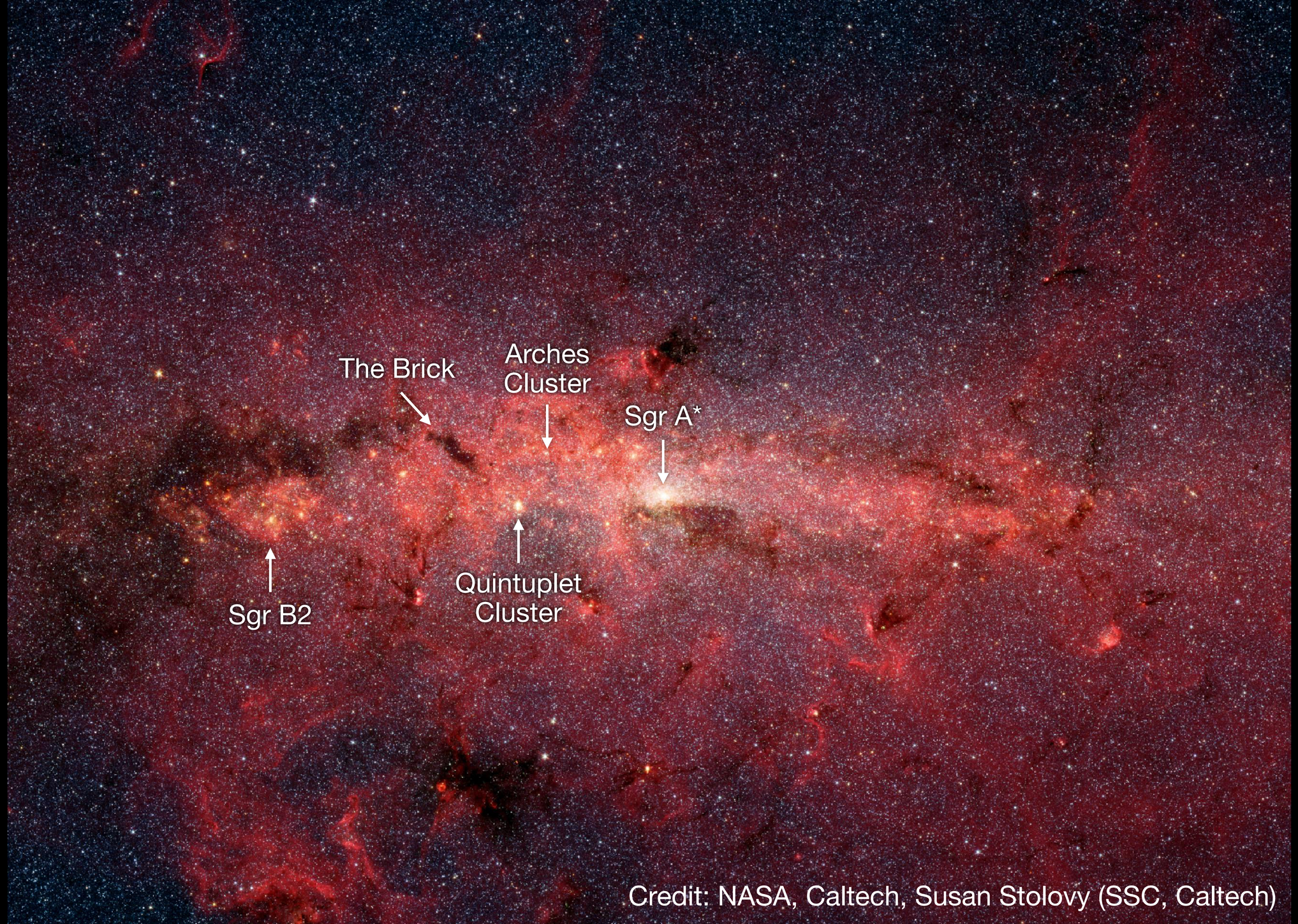


Gamma Ray — >100 MeV CGRO/EGRET

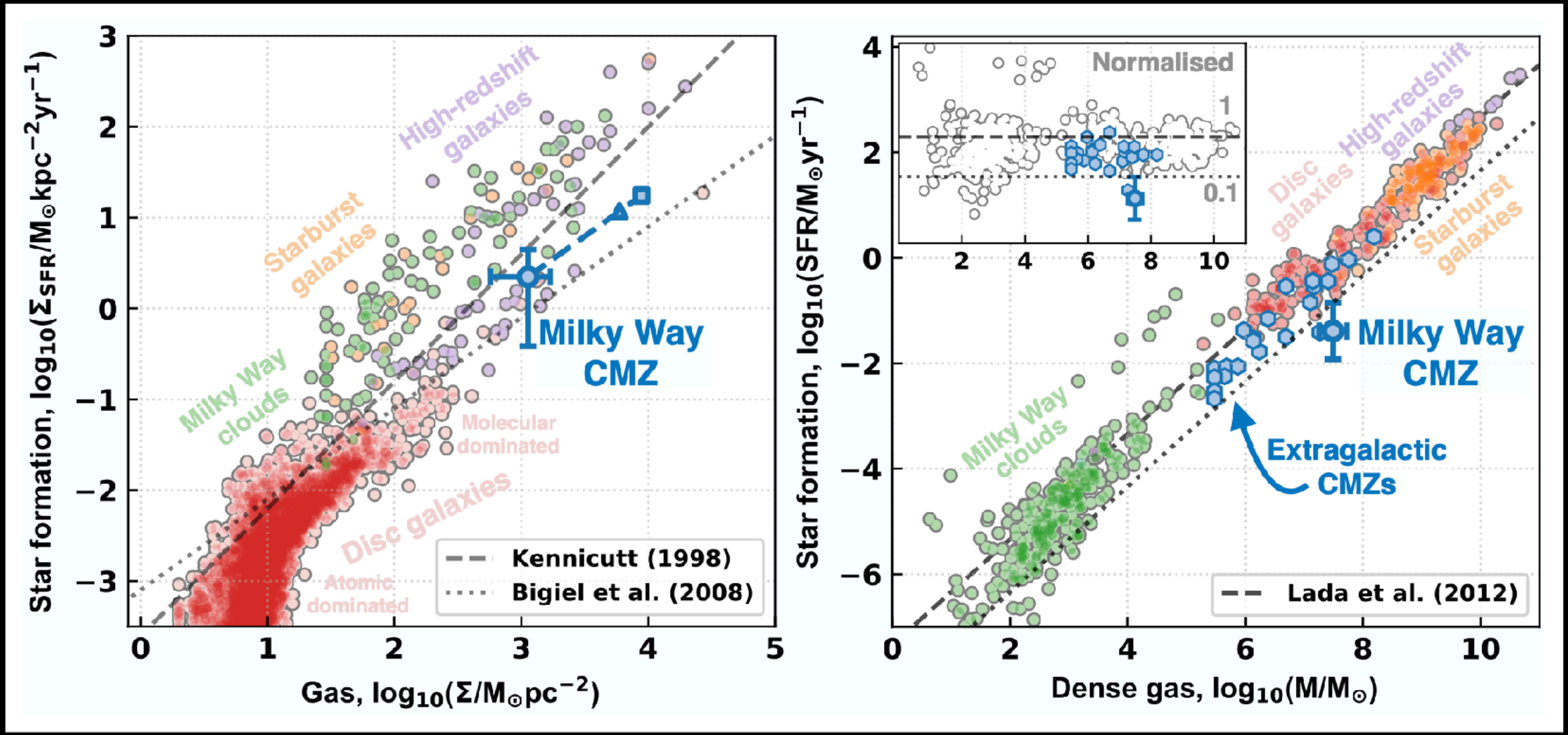


NASA

ASTROPHYSICS DATA FACILITY
ADF
GODDARD SPACE FLIGHT CENTER

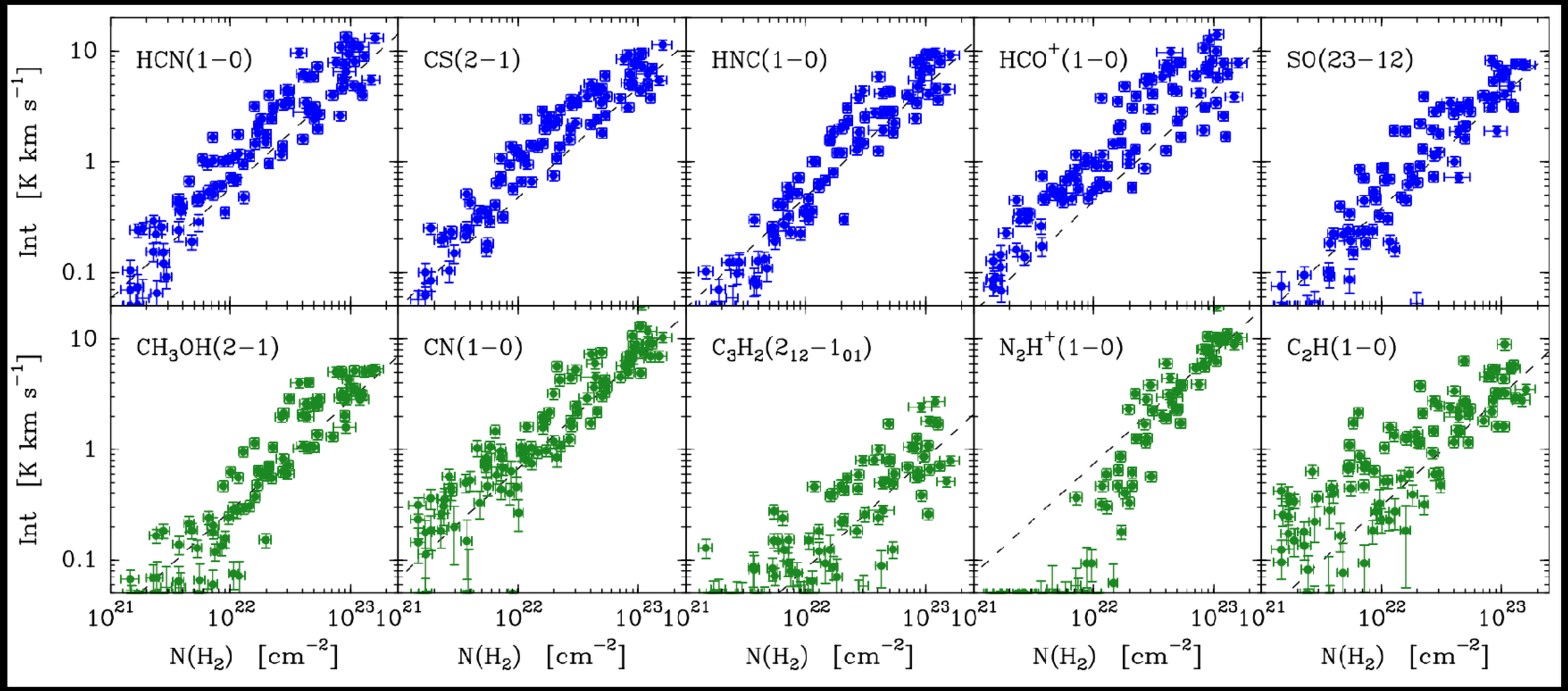

The Brick
Arches Cluster
Sgr A*
Sgr B2
Quintuplet Cluster
Credit: NASA, Caltech, Susan Stolovy (SSC, Caltech)

Galactic Center star formation



Henshaw+2023

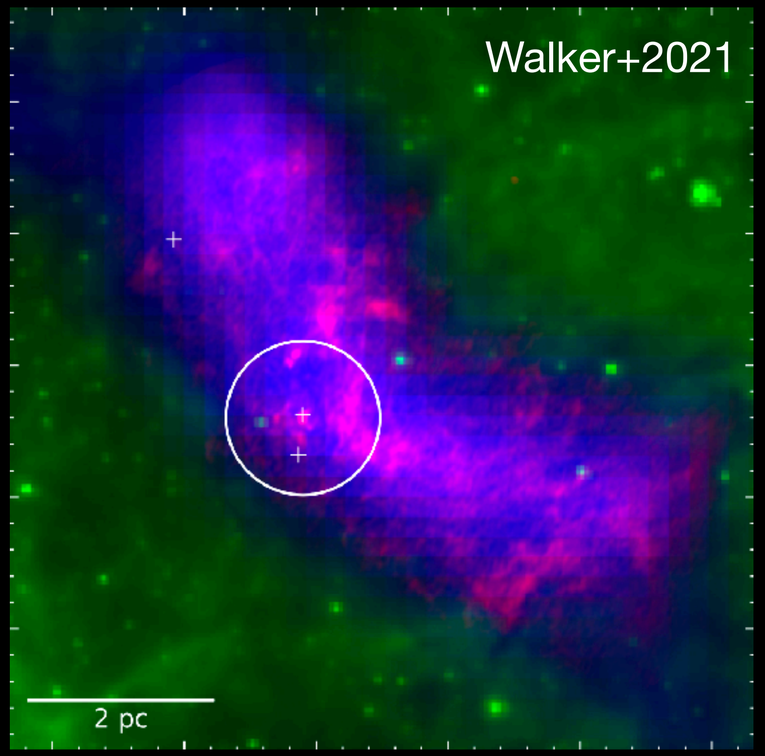
Galactic Center star formation



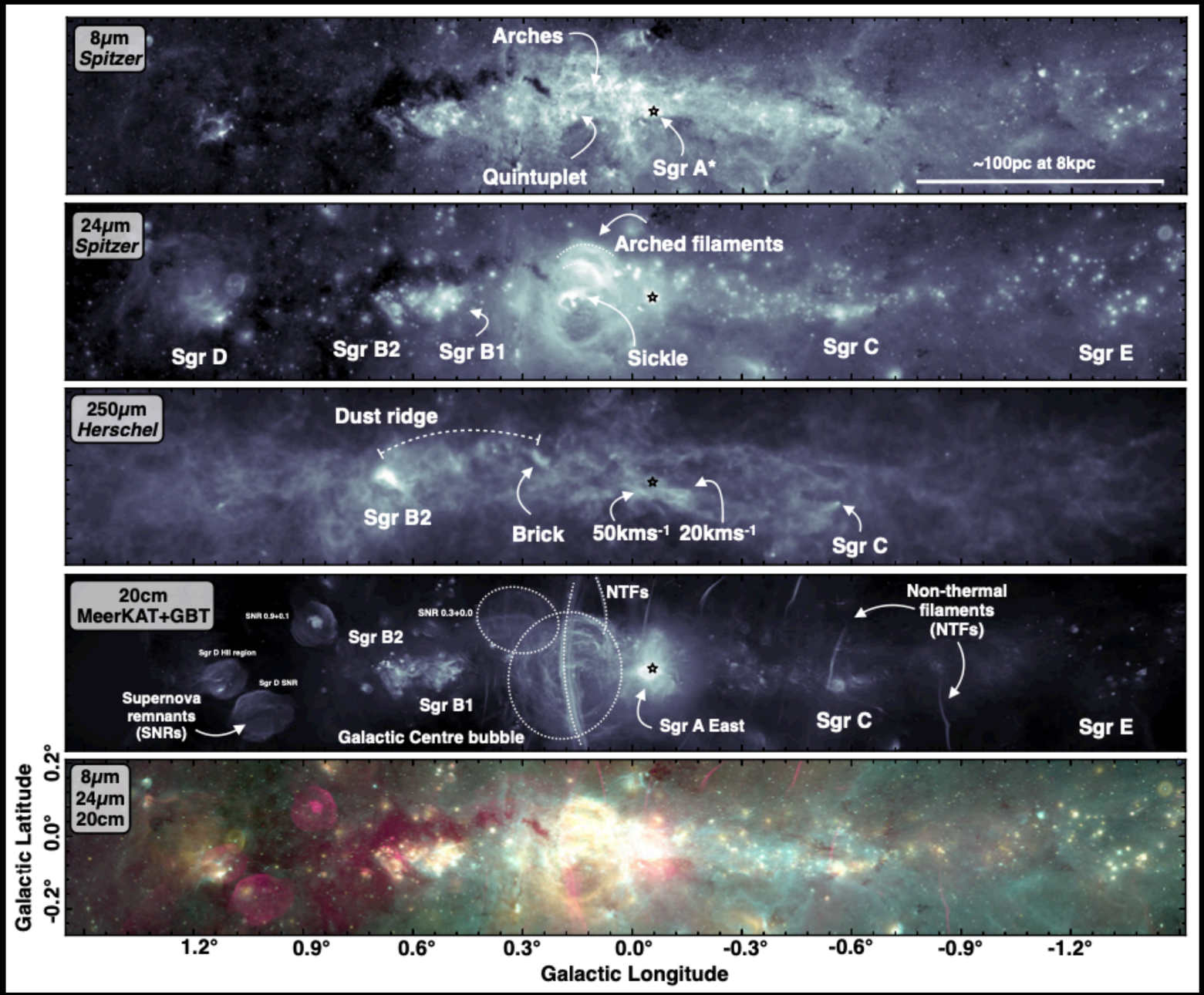
Tafalla+2021

G0.253+0.016

The Brick



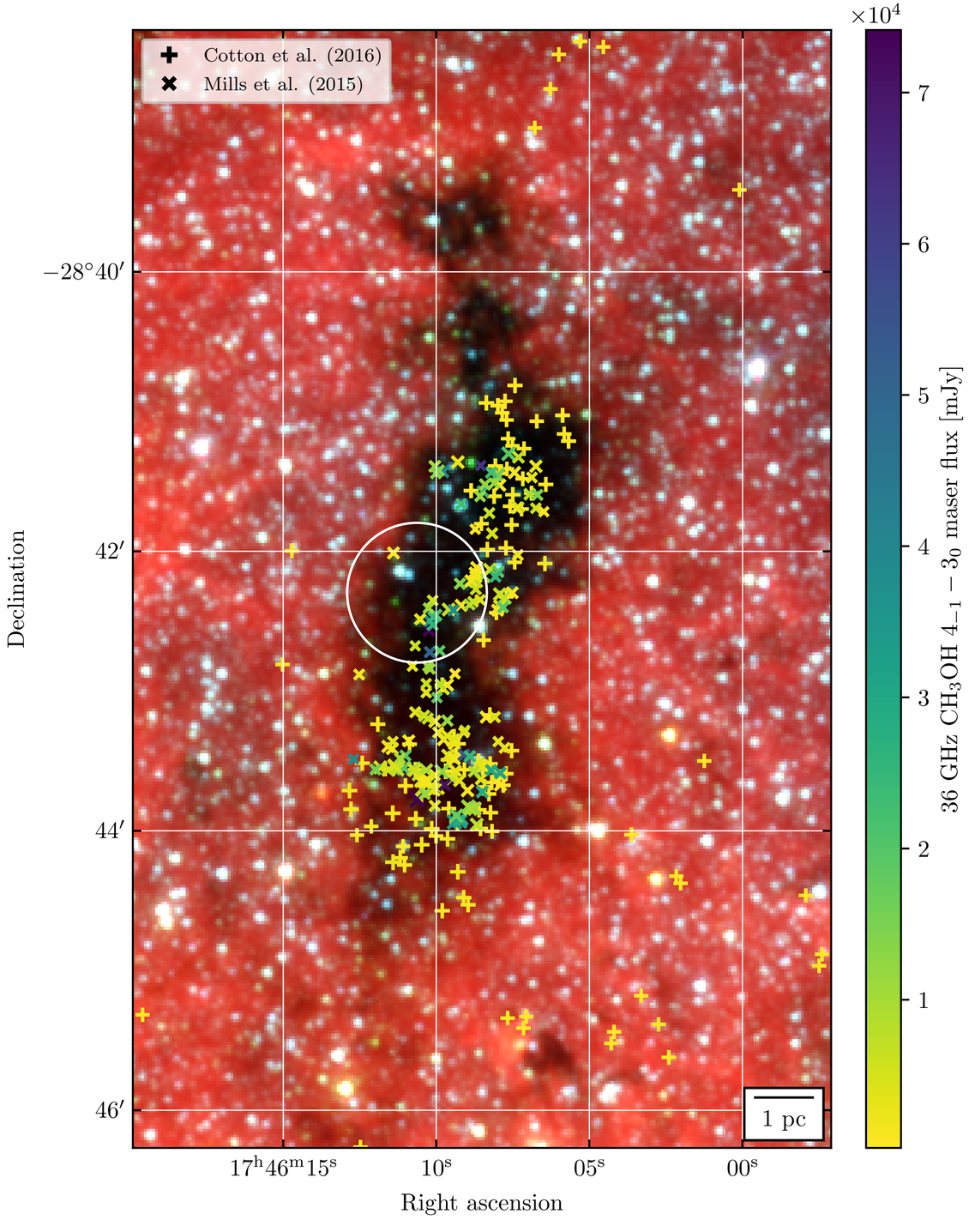
red: ALMA 3mm dust continuum
green: *Spitzer* 8 μm emission
blue: *Herschel* dust column density



Henshaw+2023

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″



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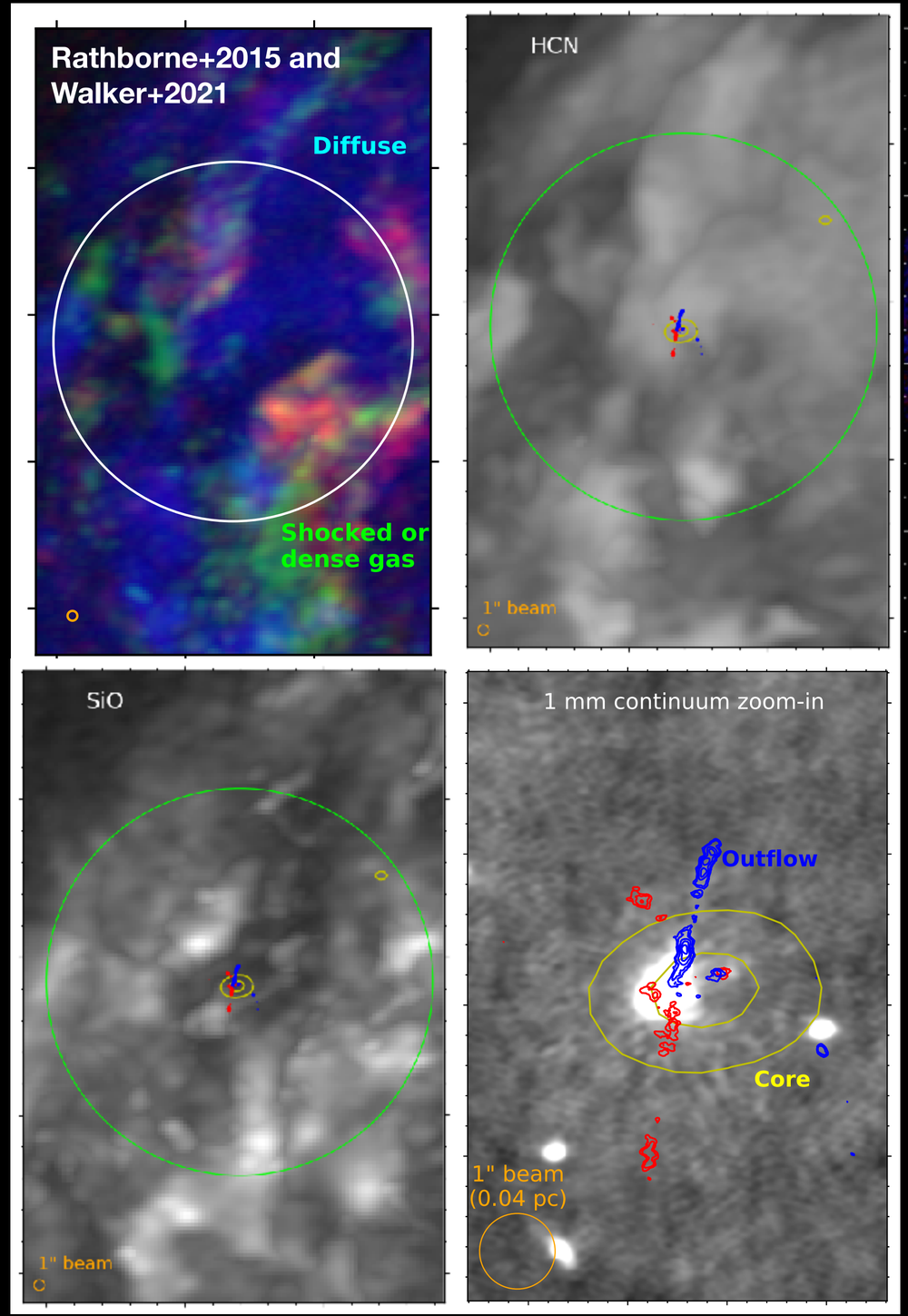
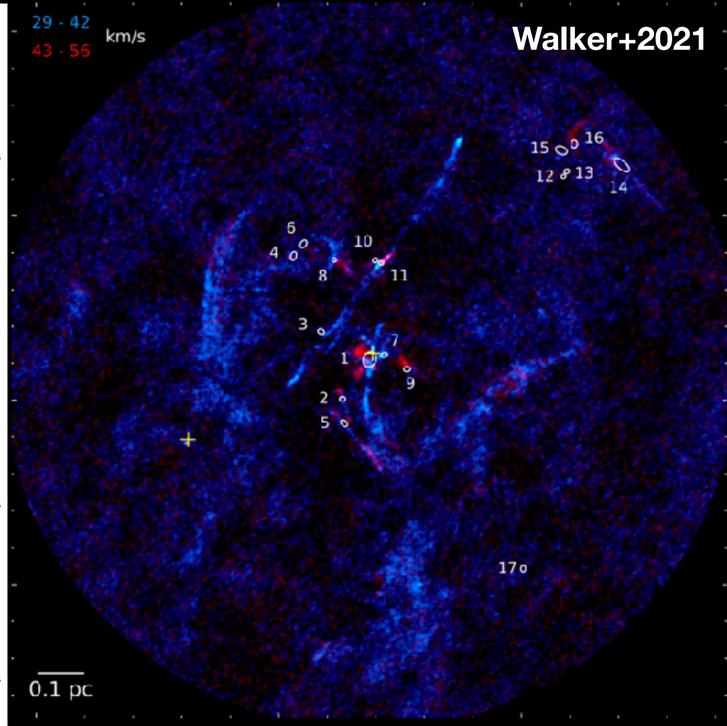
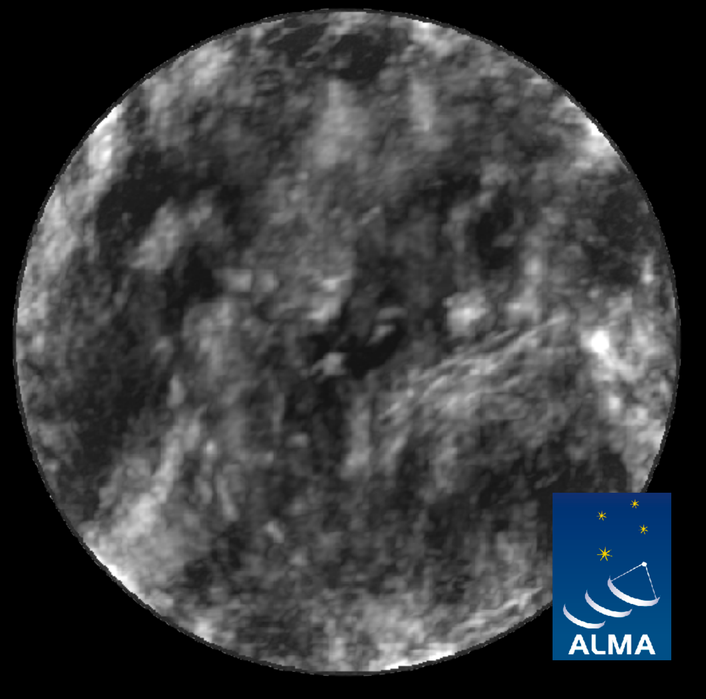


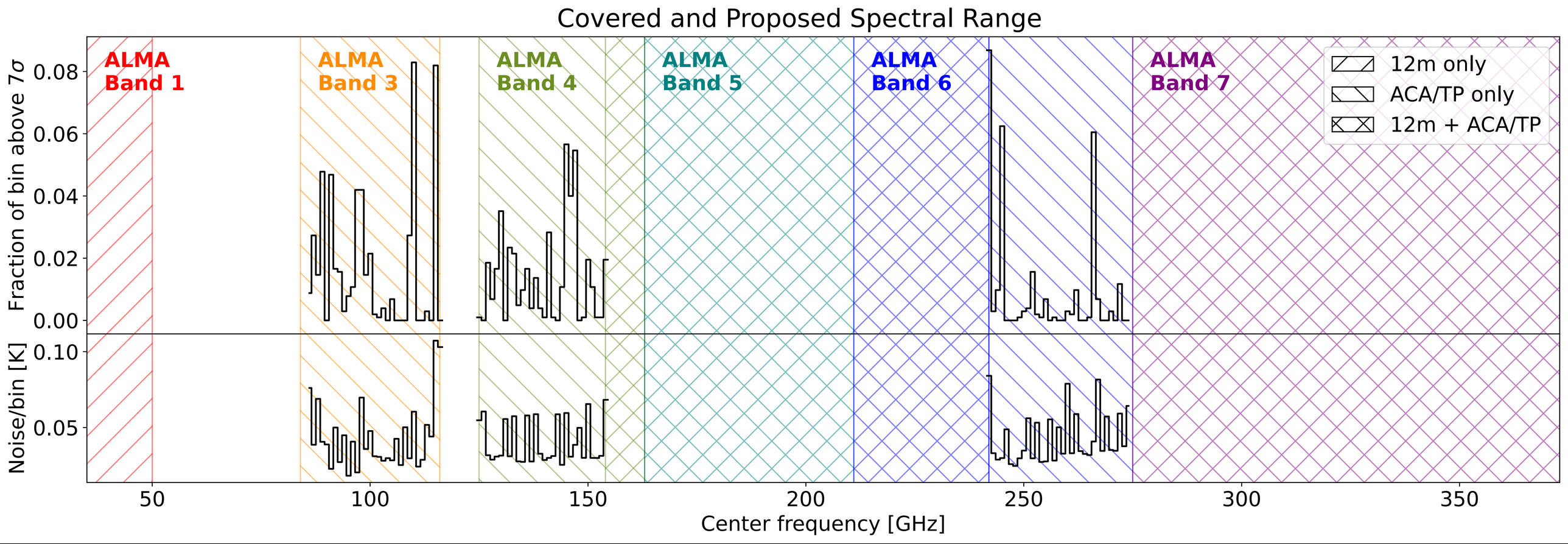




ALMA Cycle 11 Proposal

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

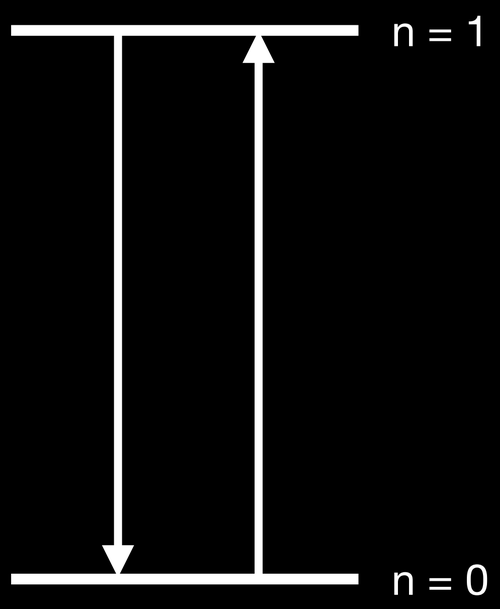
- See more lines of more molecules in missing bandwidth
- Cover larger angular scales with ACA/TP



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

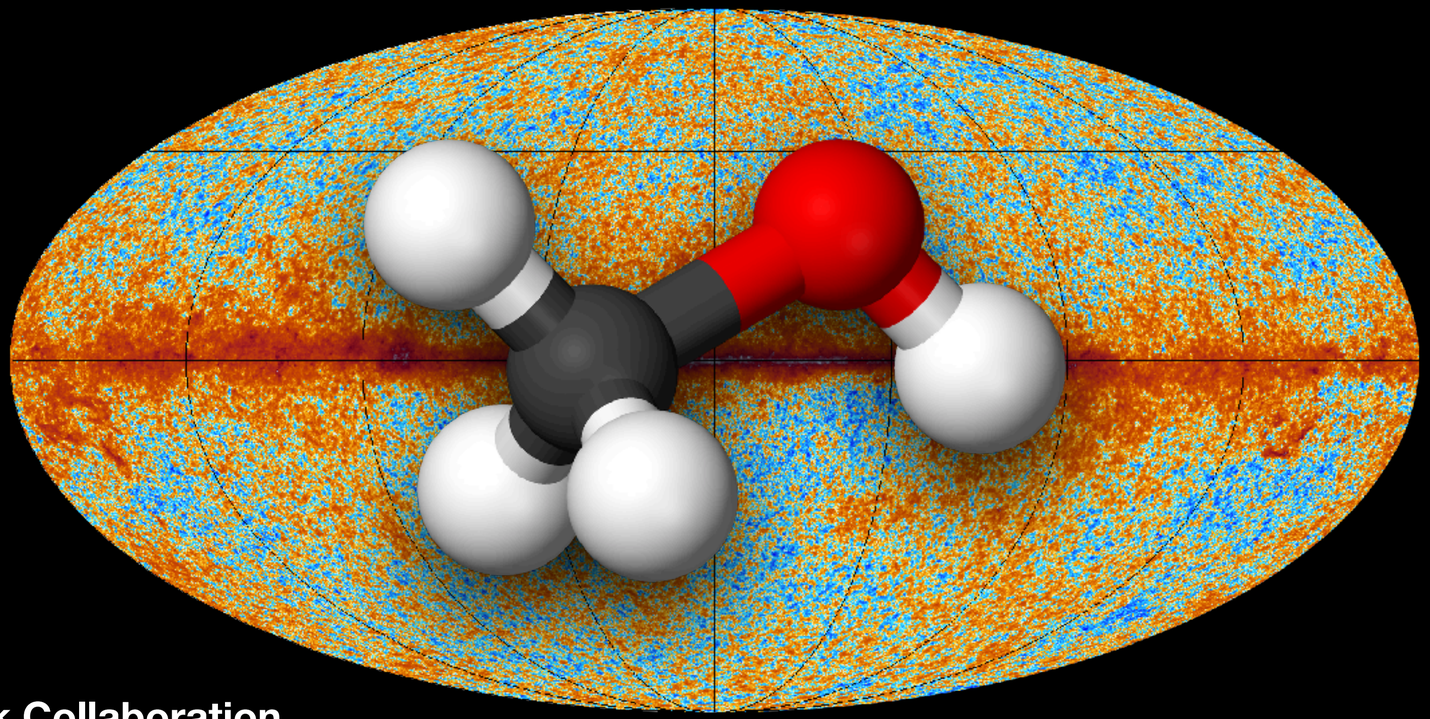


$$\frac{N_u g_l}{N_l g_u} = \exp\left(\frac{-\Delta E}{k_B T_{ex}}\right)$$

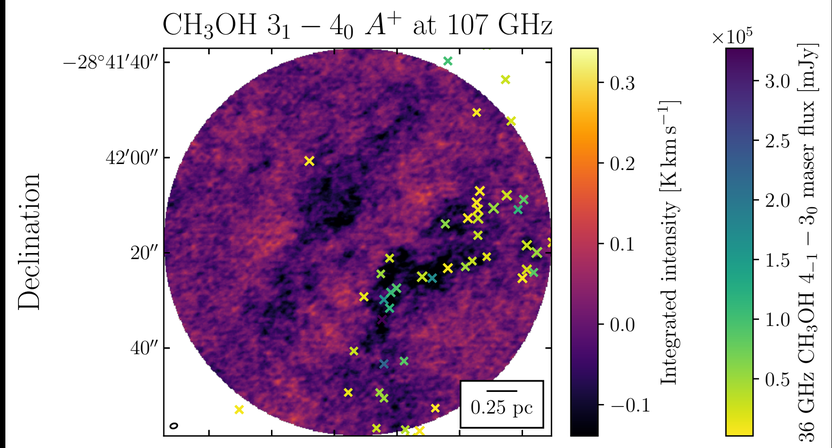
Methanol Dasar in The Brick

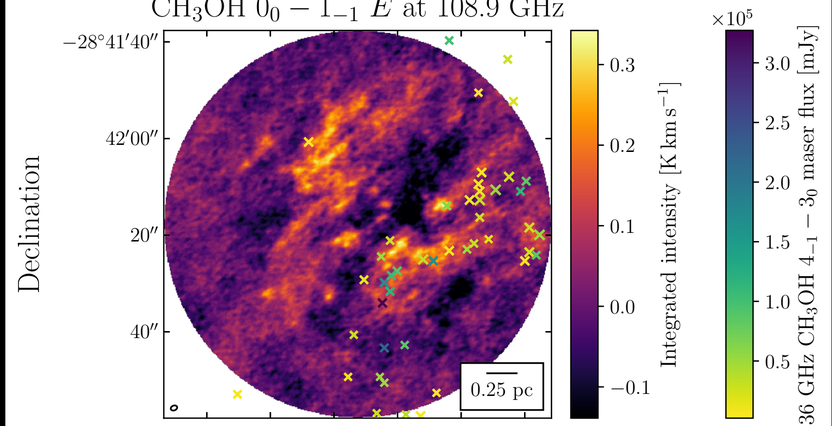
Bulatek et al. 2023, ApJ, 956, 2

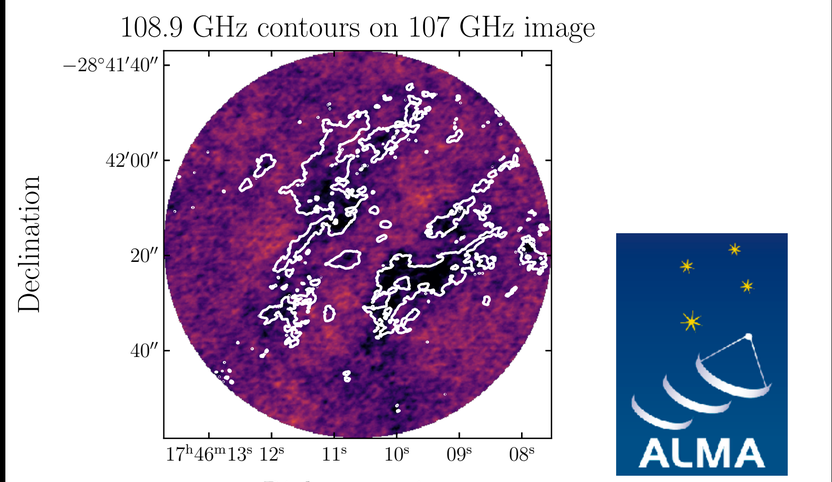
- If the pump gets T_{ex} cold enough, the molecule could even absorb the CMB!



Planck Collaboration accessed via IRSA





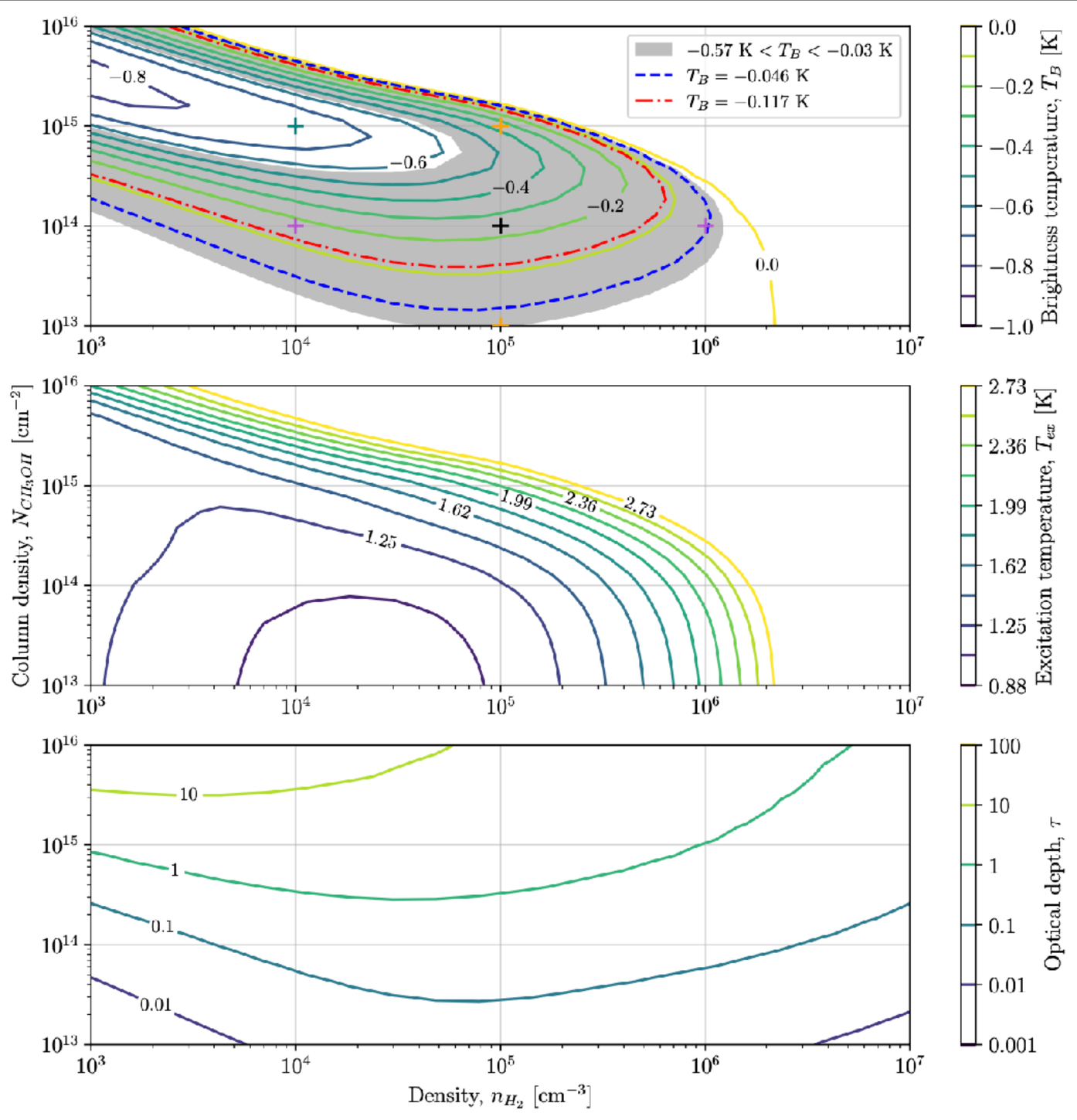


ALMA

Methanol Dasar in The Brick

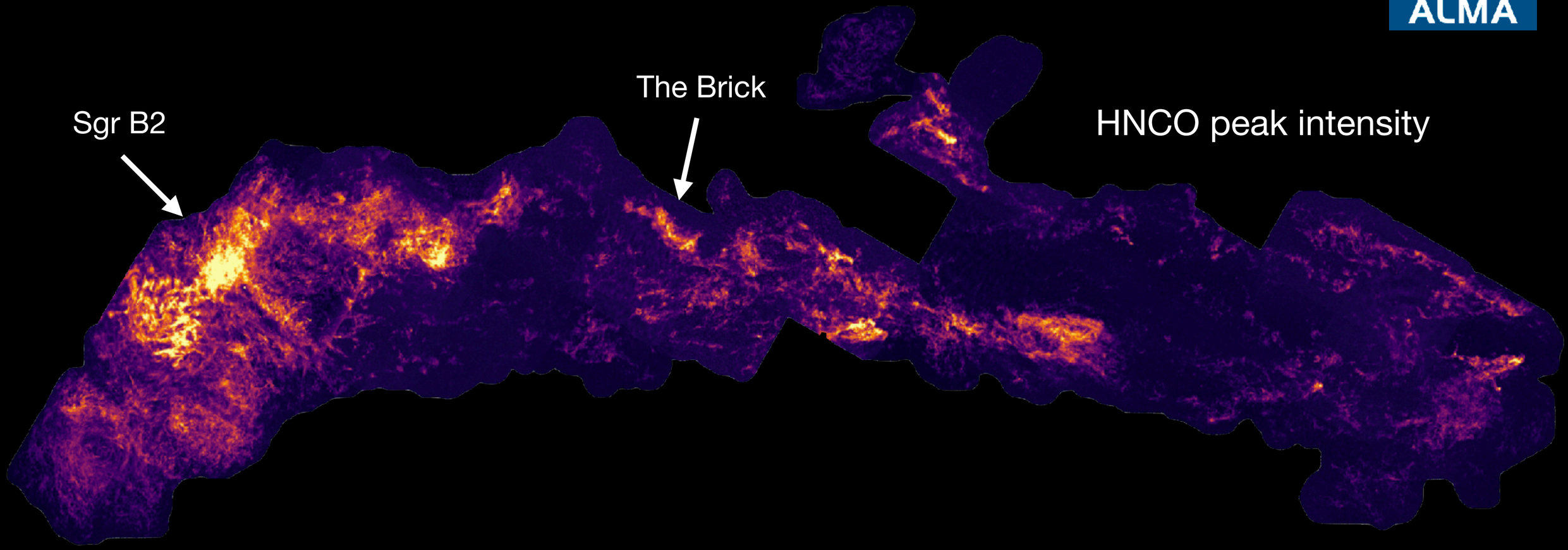
Bulatek et al. 2023, ApJ, 956, 2

- 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

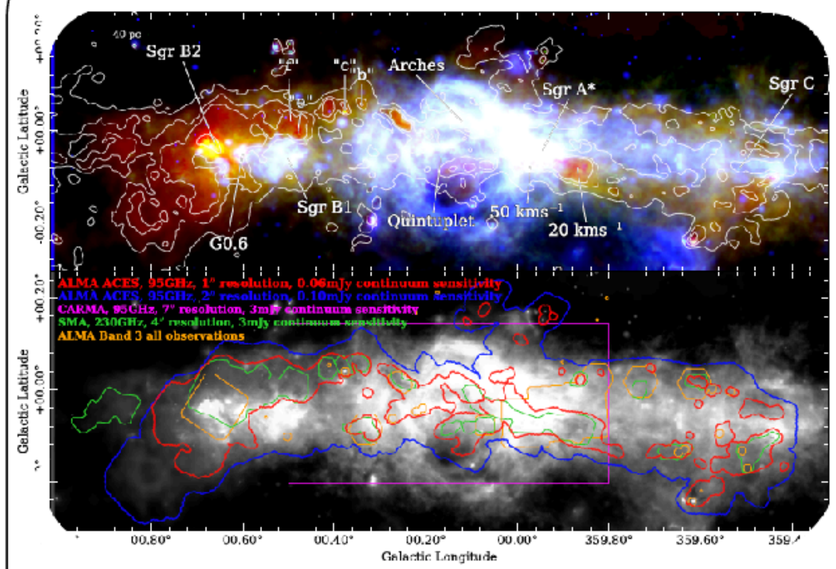
ACES



Mosaic made by Dan Walker

ACES

ALMA CMZ



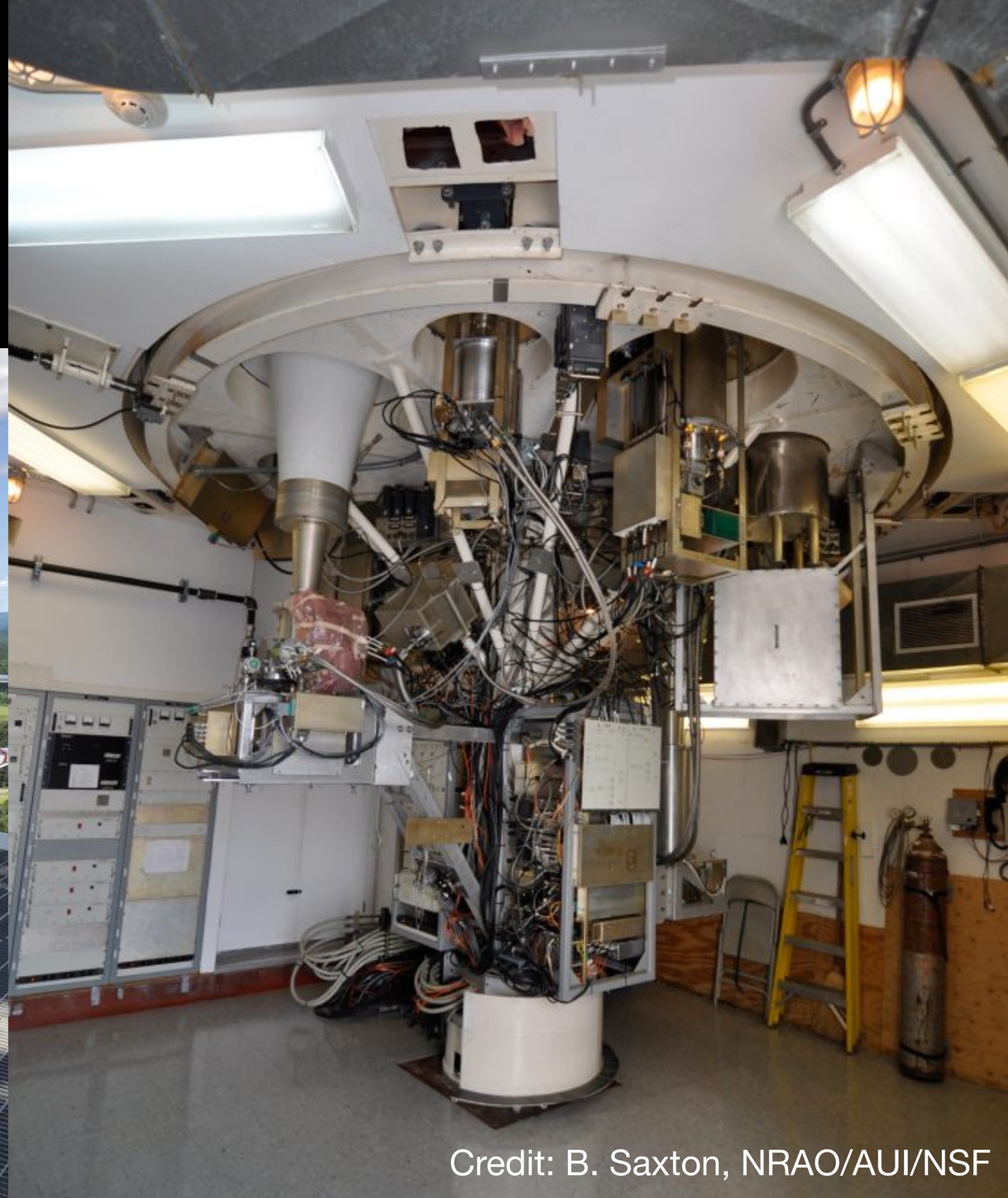
Exploration Survey

10

10

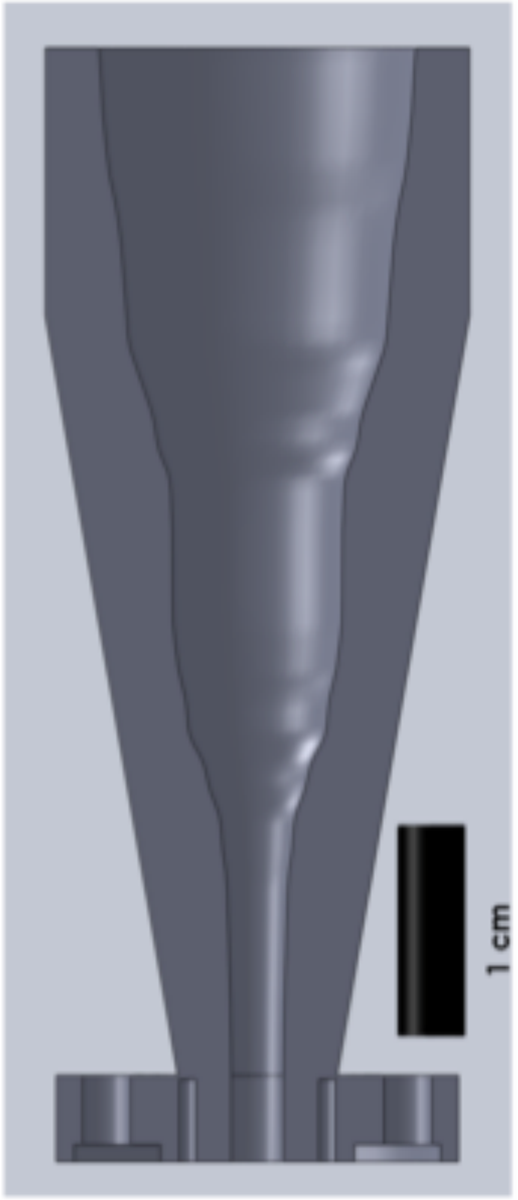
Green Bank Telescope

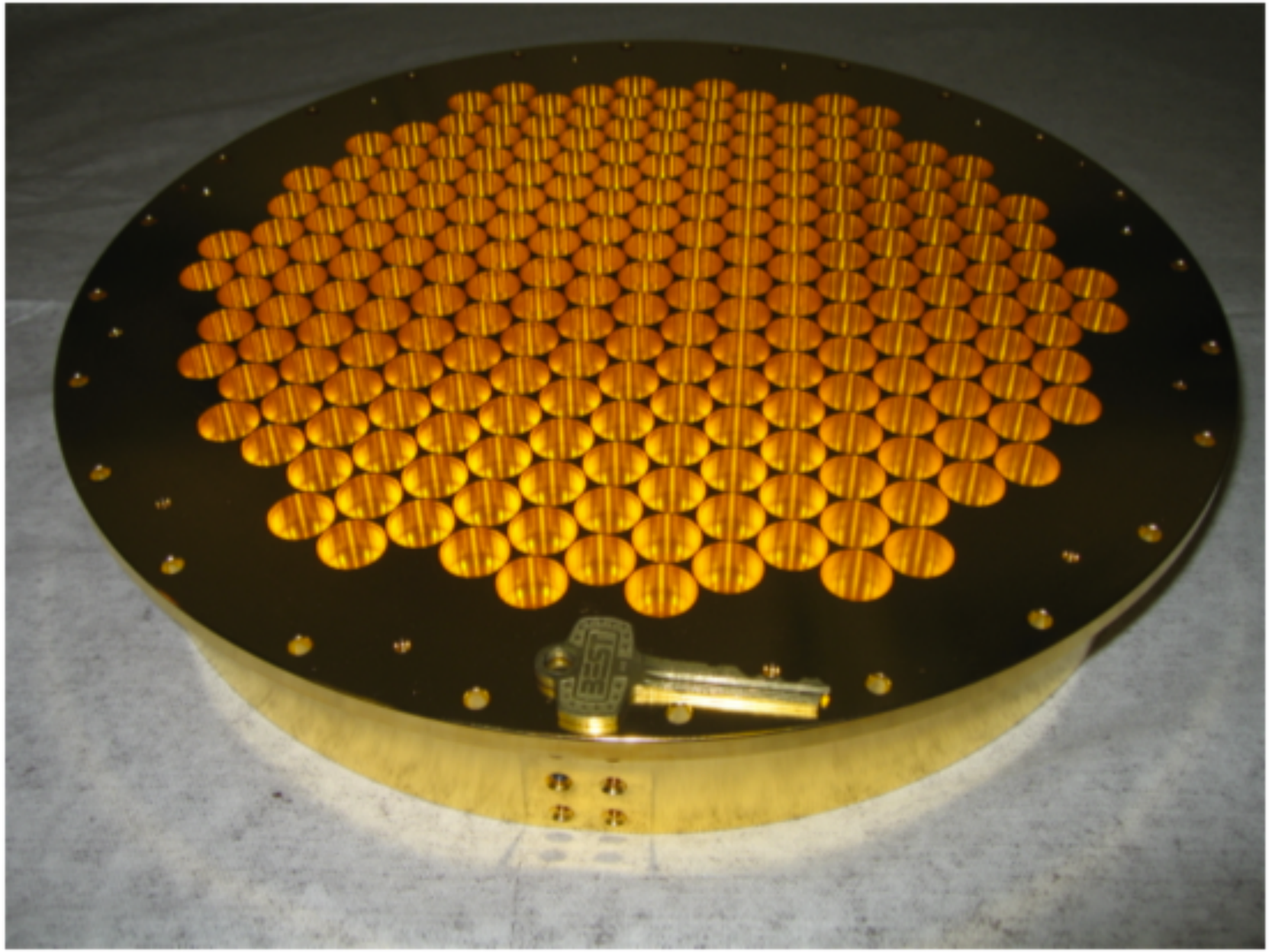
Receiver turret



Credit: B. Saxton, NRAO/AUI/NSF

MUSTANG-2





Credit: GBT documentation

Thank you!

BLS

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