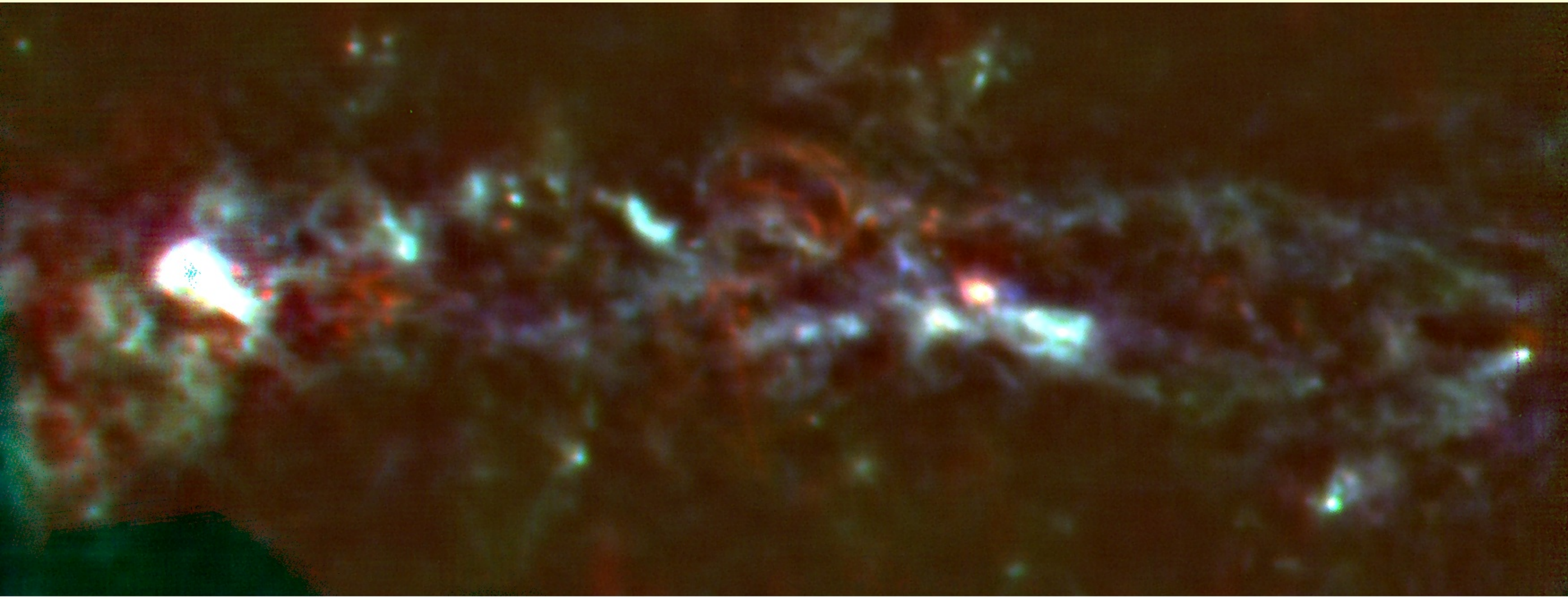
Galactic Center Science with a Next Generation Far-IR Telescope

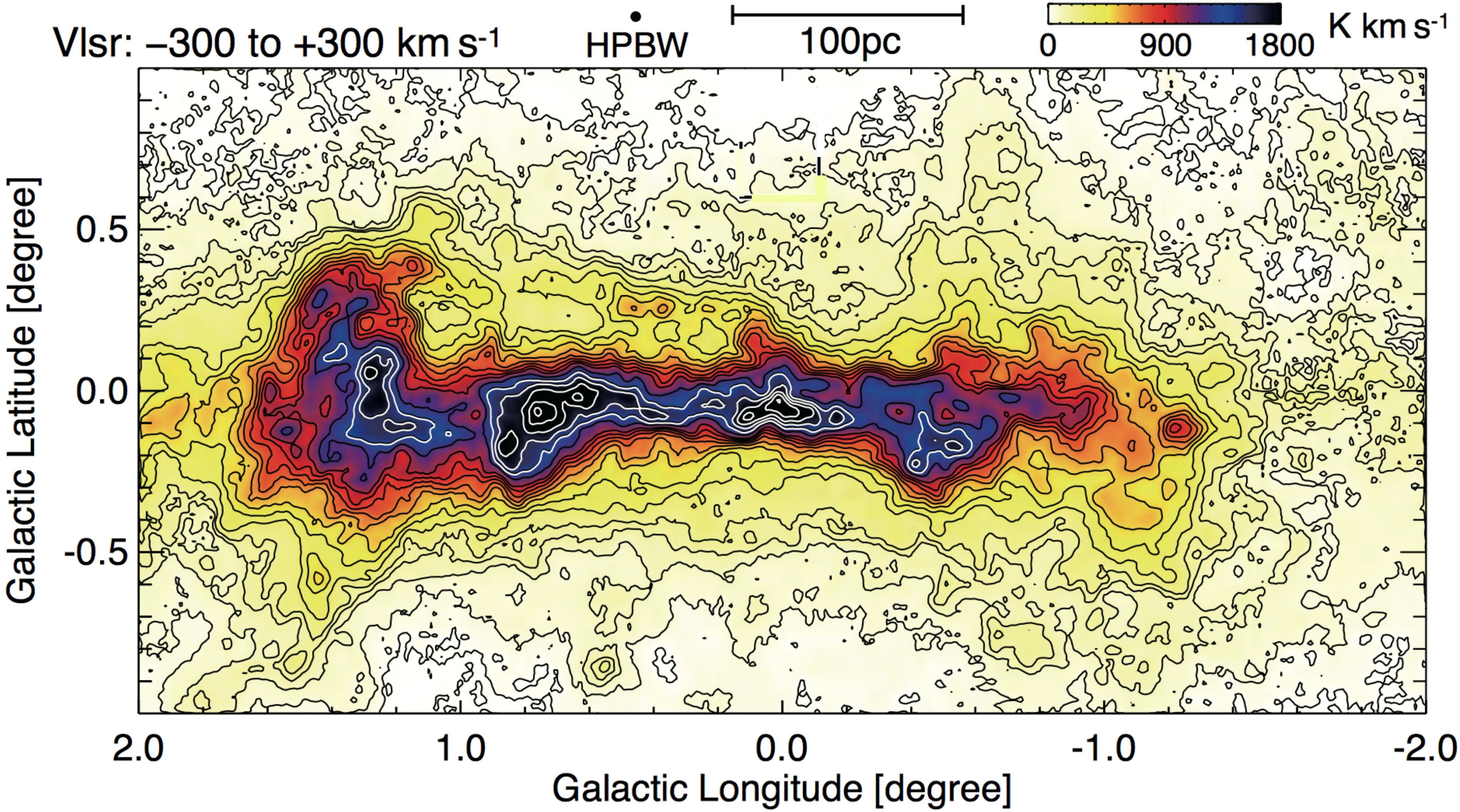
Mark Morris (UCLA)



2mm (GISMO) in red + submm : Staguhn, MM +

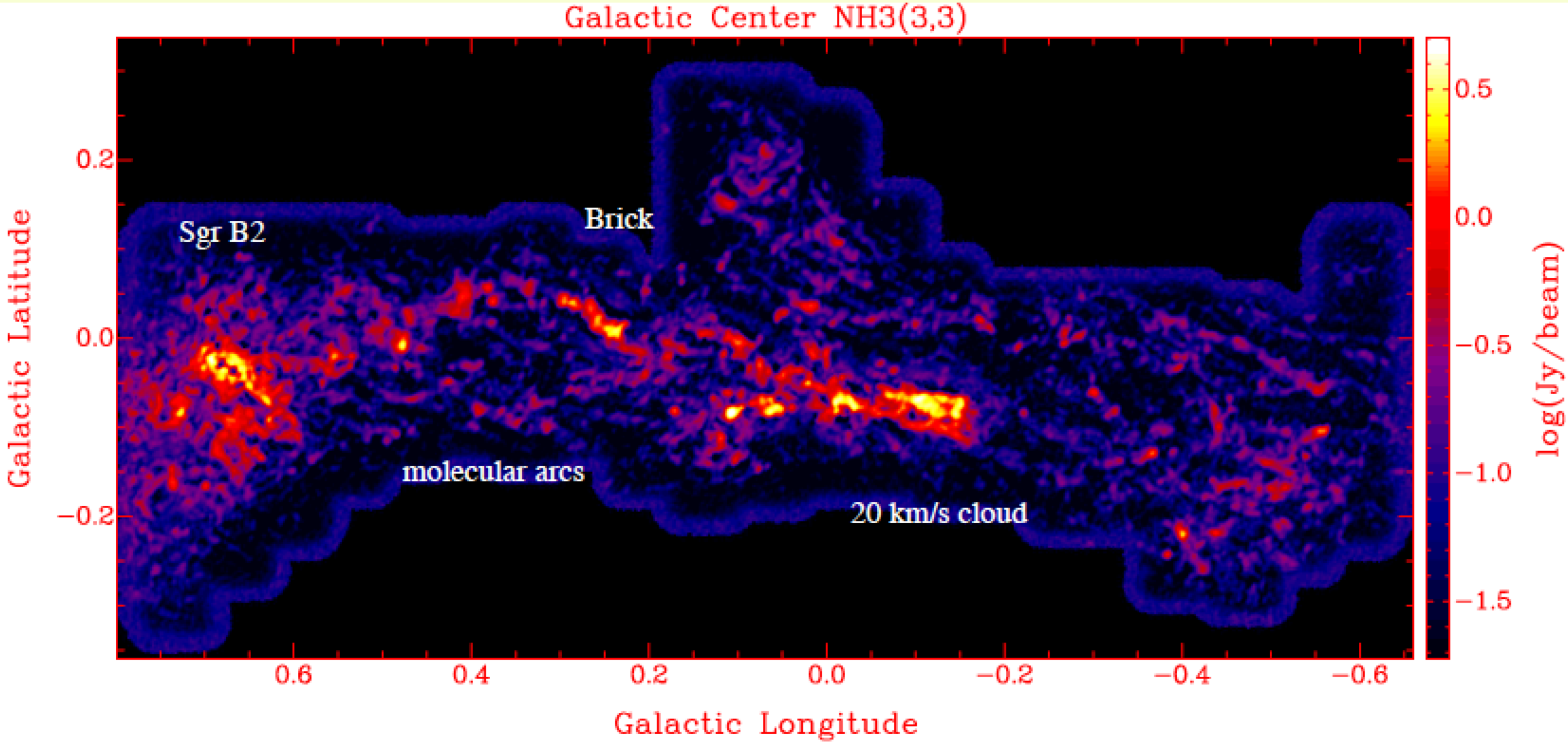
The setting – The Central Molecular Zone (CMZ)

the Galaxy's strongest concentration of molecular gas – 3 x 10^7 $M_\odot$



Enokiya et al. 2014; Nanten Observatory

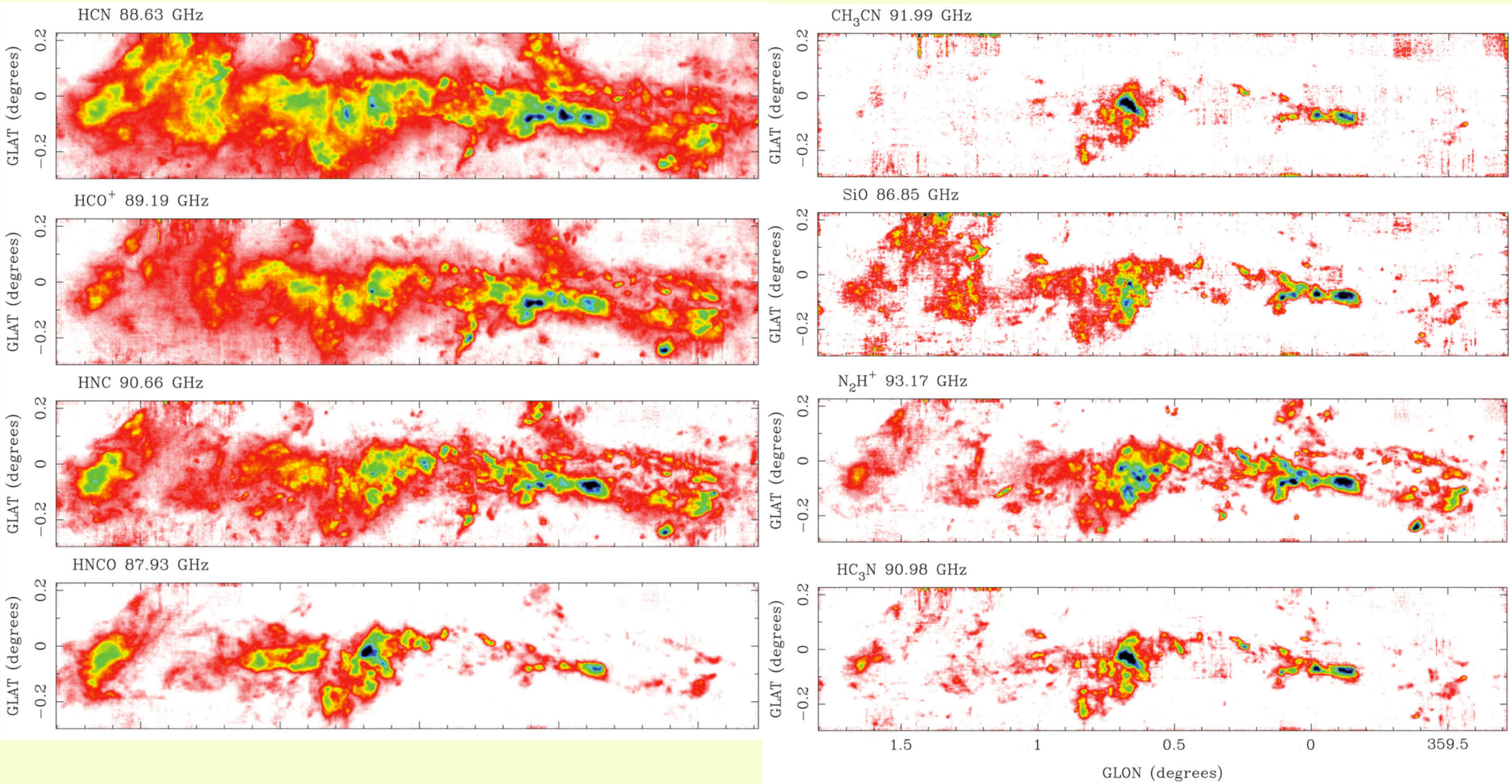
Numerous molecular surveys – past and present



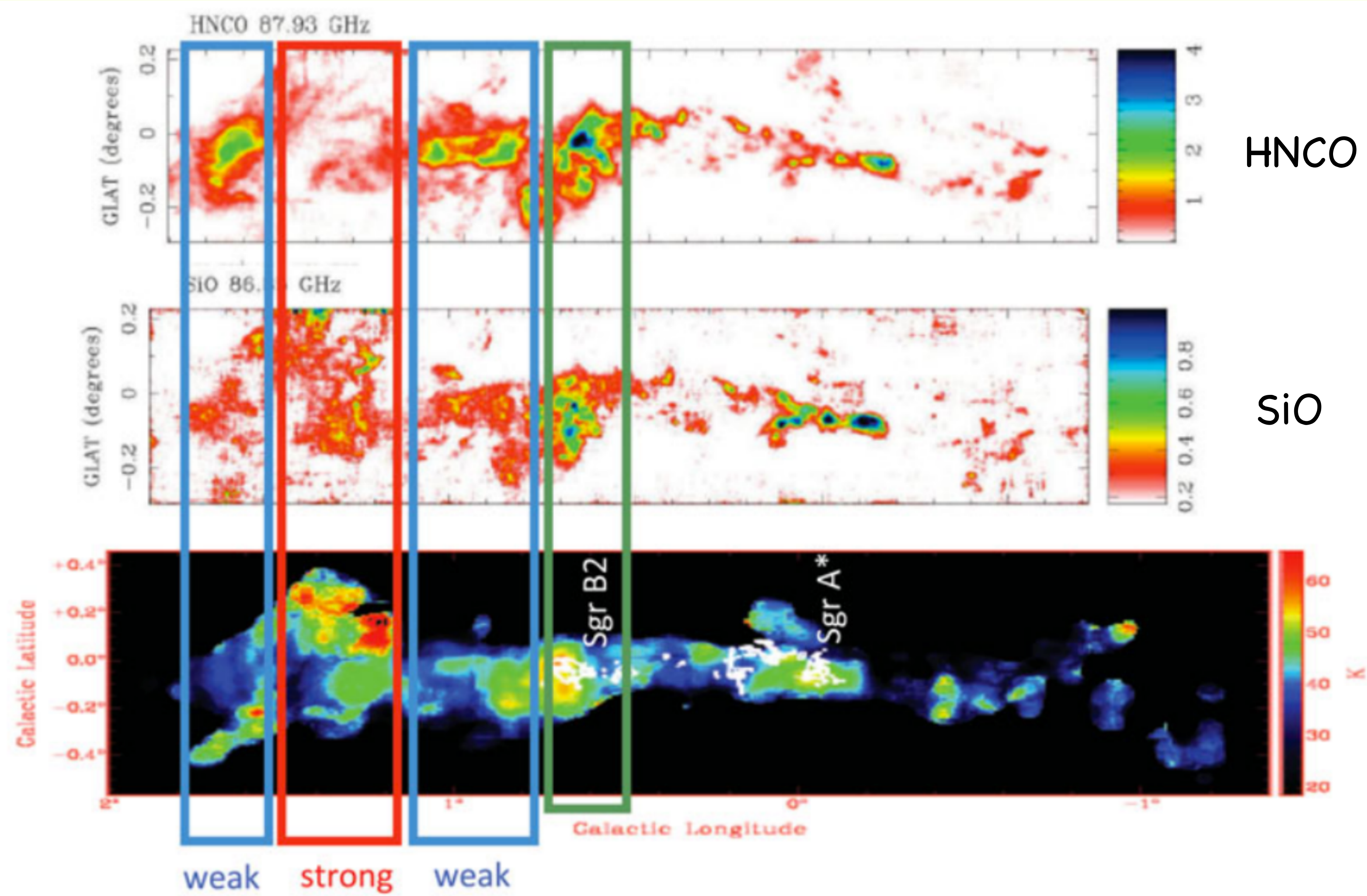
SWAG: Survey of Water* and Ammonia in the Galactic Center

PI: Jürgen Ott, with the Australian Telescope Compact Array

*masers

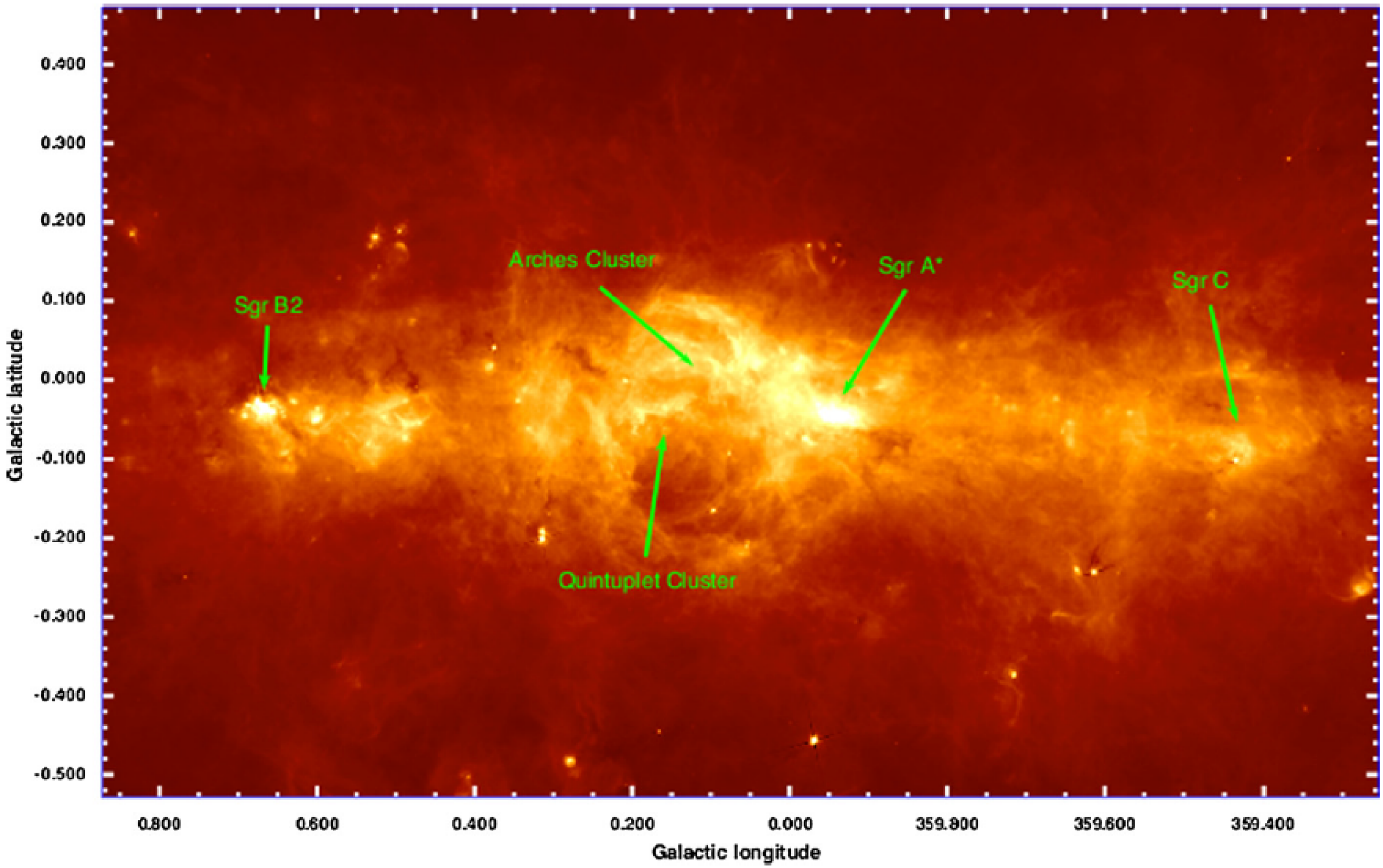


Mopra Survey – P.A. Jones et al. 2012

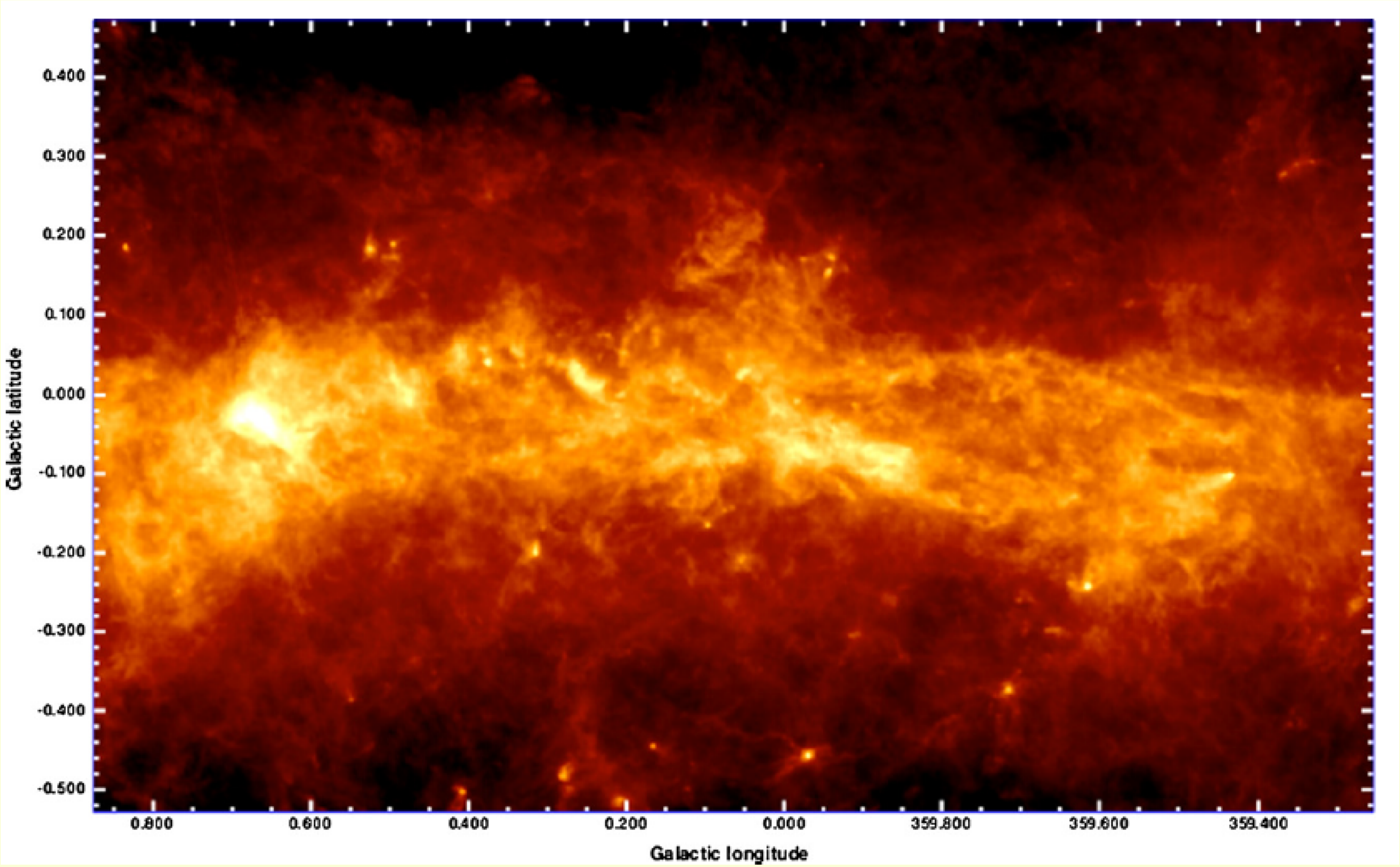


Shock diagnostics

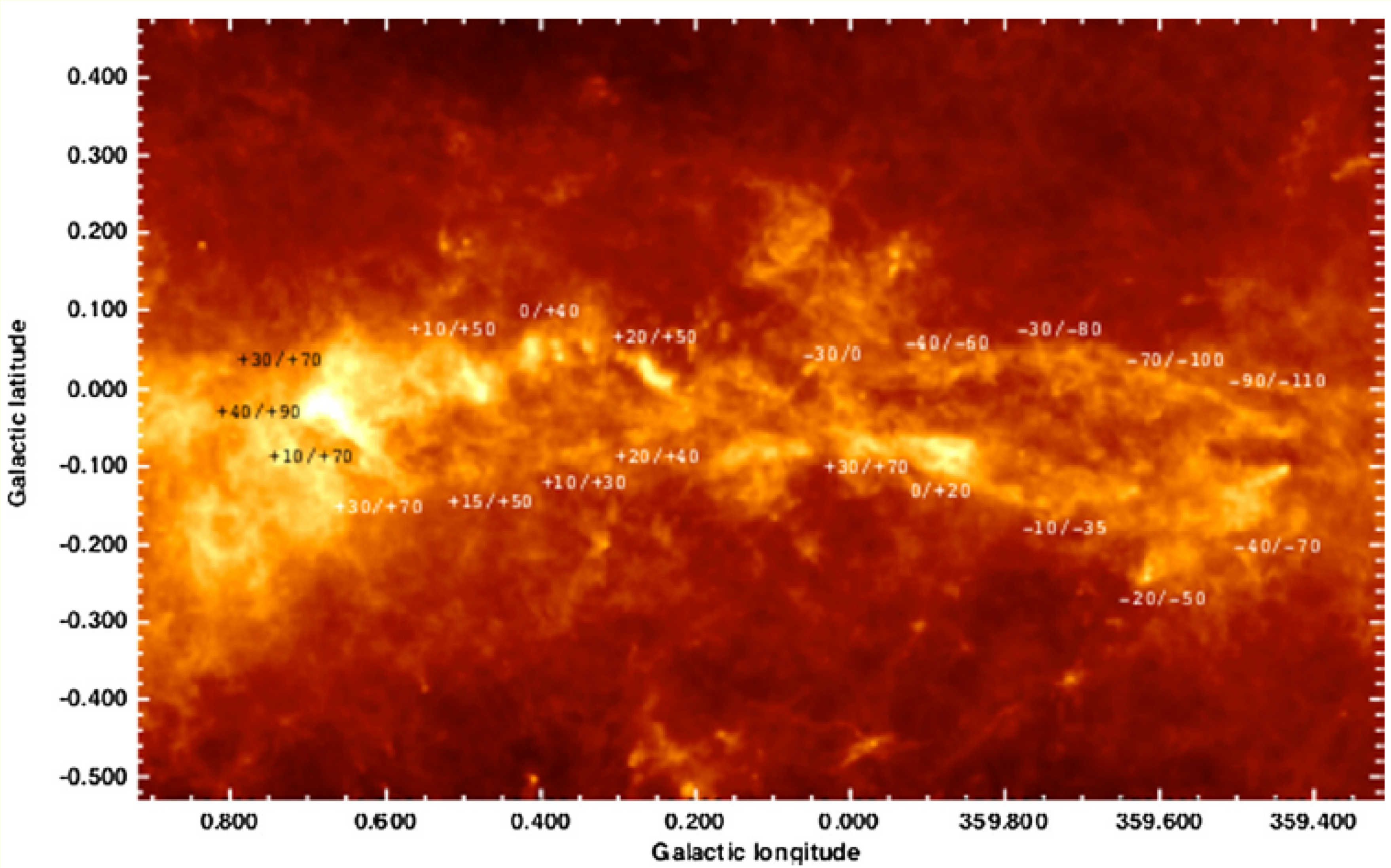
Ott et al. 2013



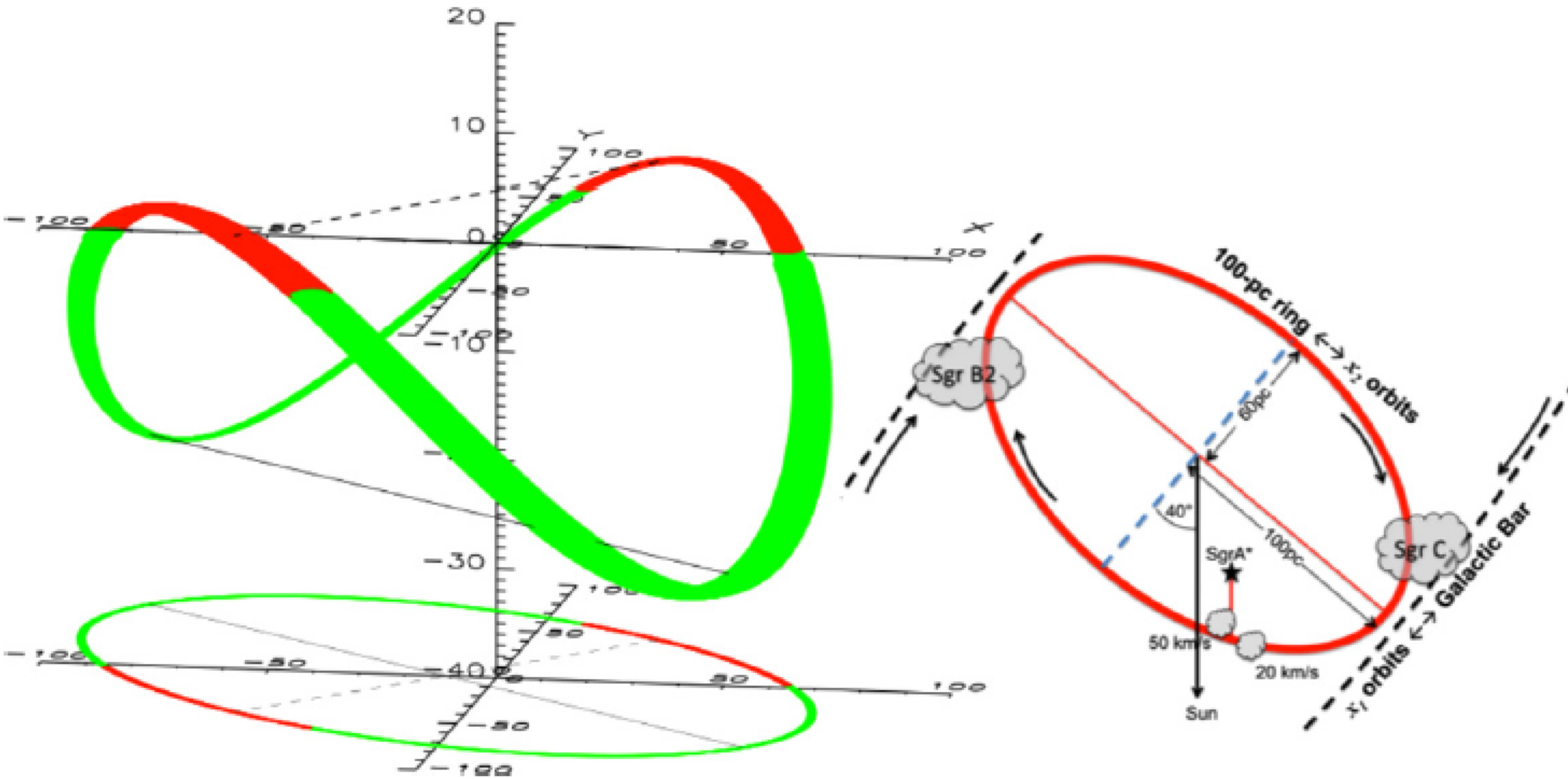
Herschel PACS 70 μm --- Molinari et al. 2011



Herschel SPIRE 250 μm --- Molinari et al. 2011



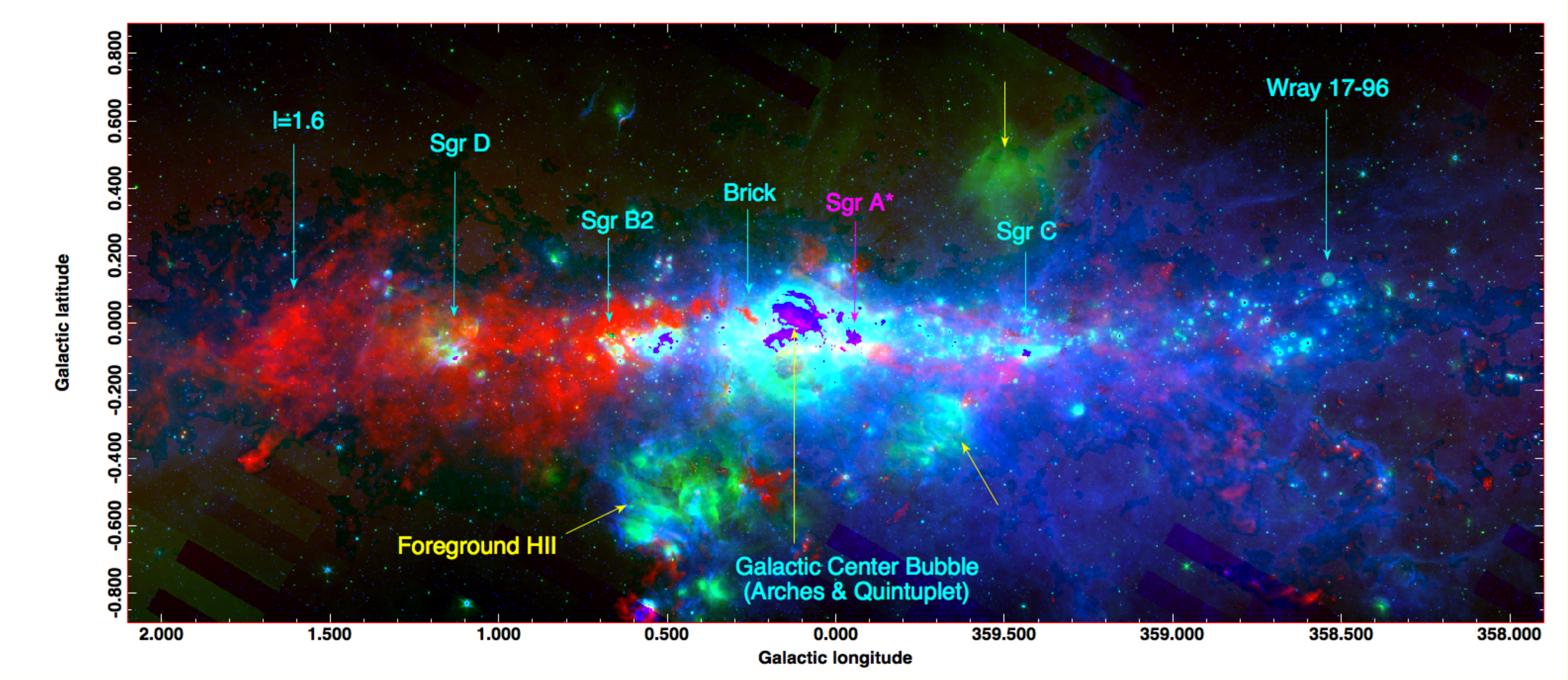
Dust column density map -- Molinari et al 2011
Dust temperatures – 15–40 K



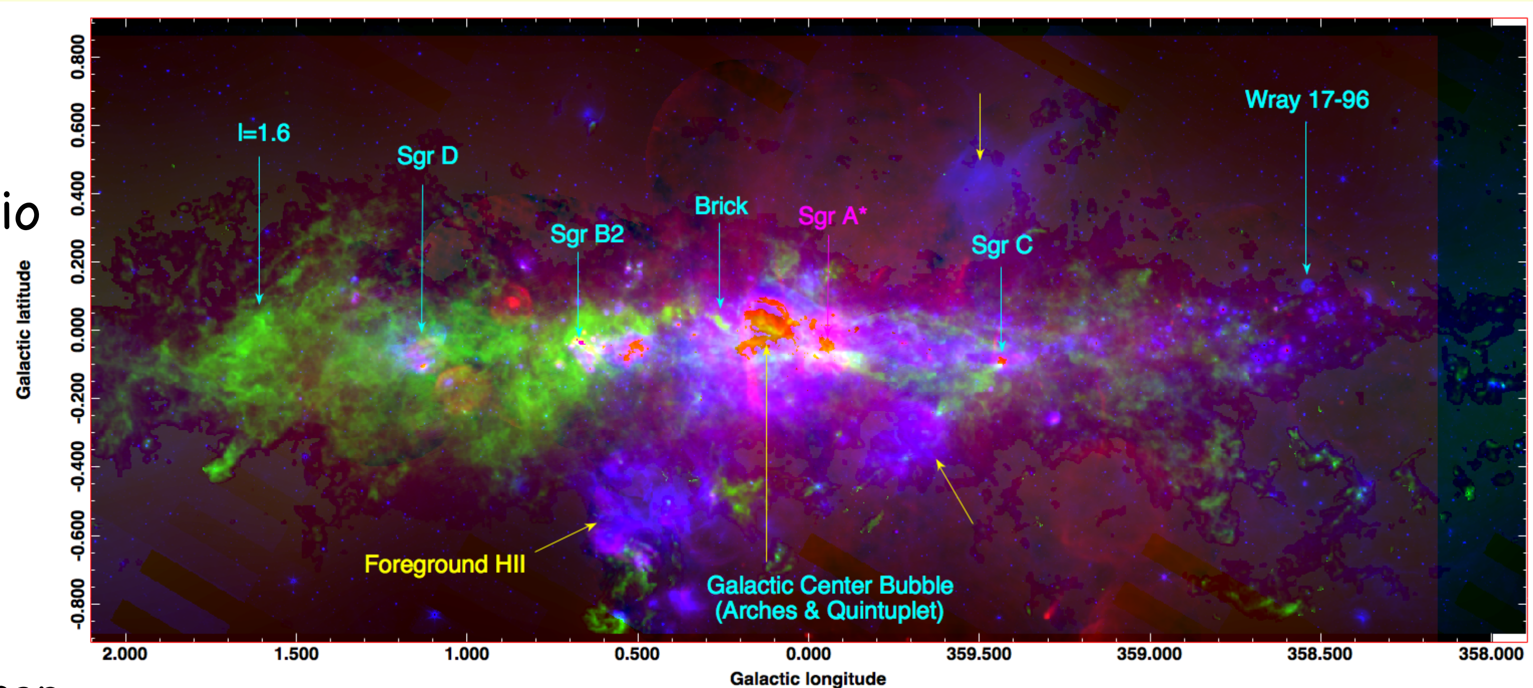
Twisted ring model of Molinari et al. 2011

3-color composite (John Bally, personal communication):

- Red: dust column density (Herschel)
- Green: 24 μm MIPS
- Blue: 8 μm IRAC



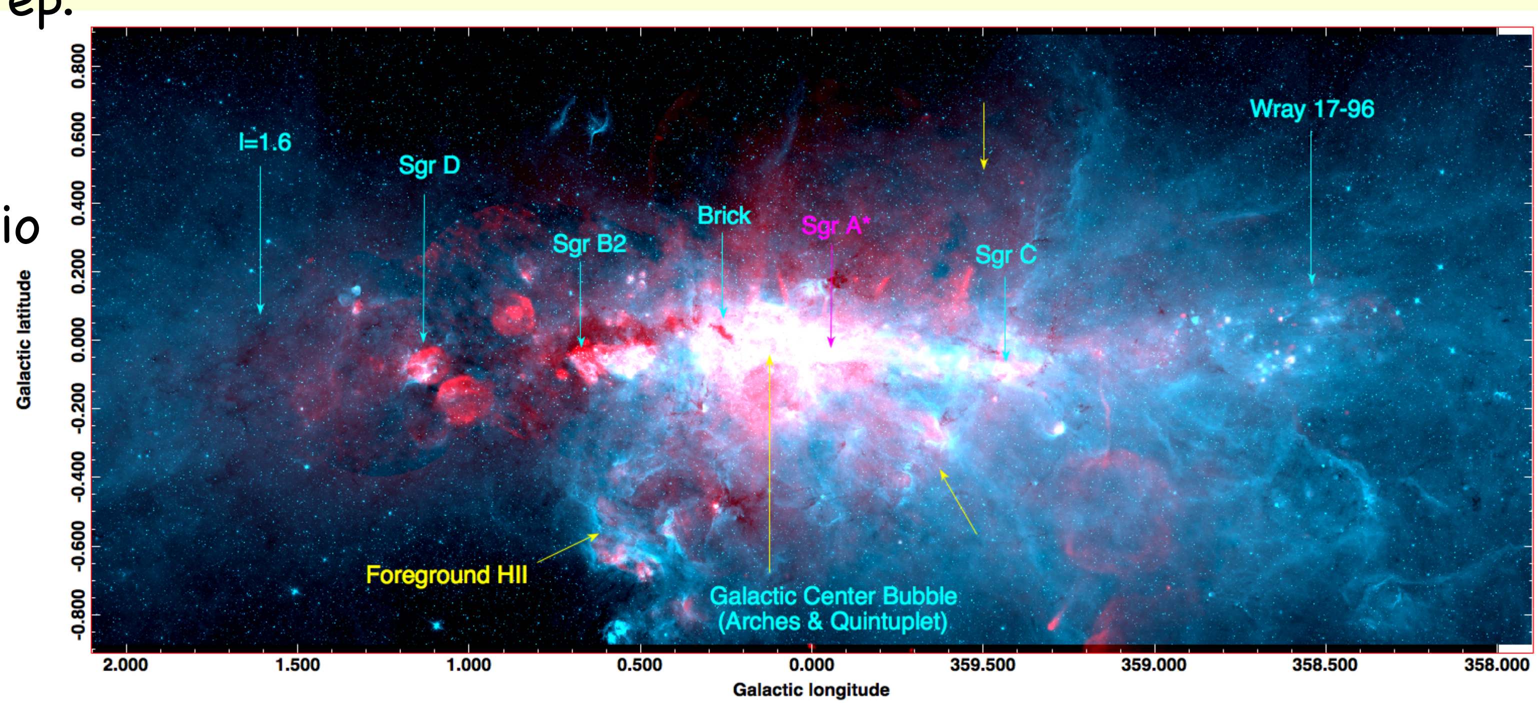
R: 20cm radio
G: column
B: 24 μm



J. Bally, in prep.

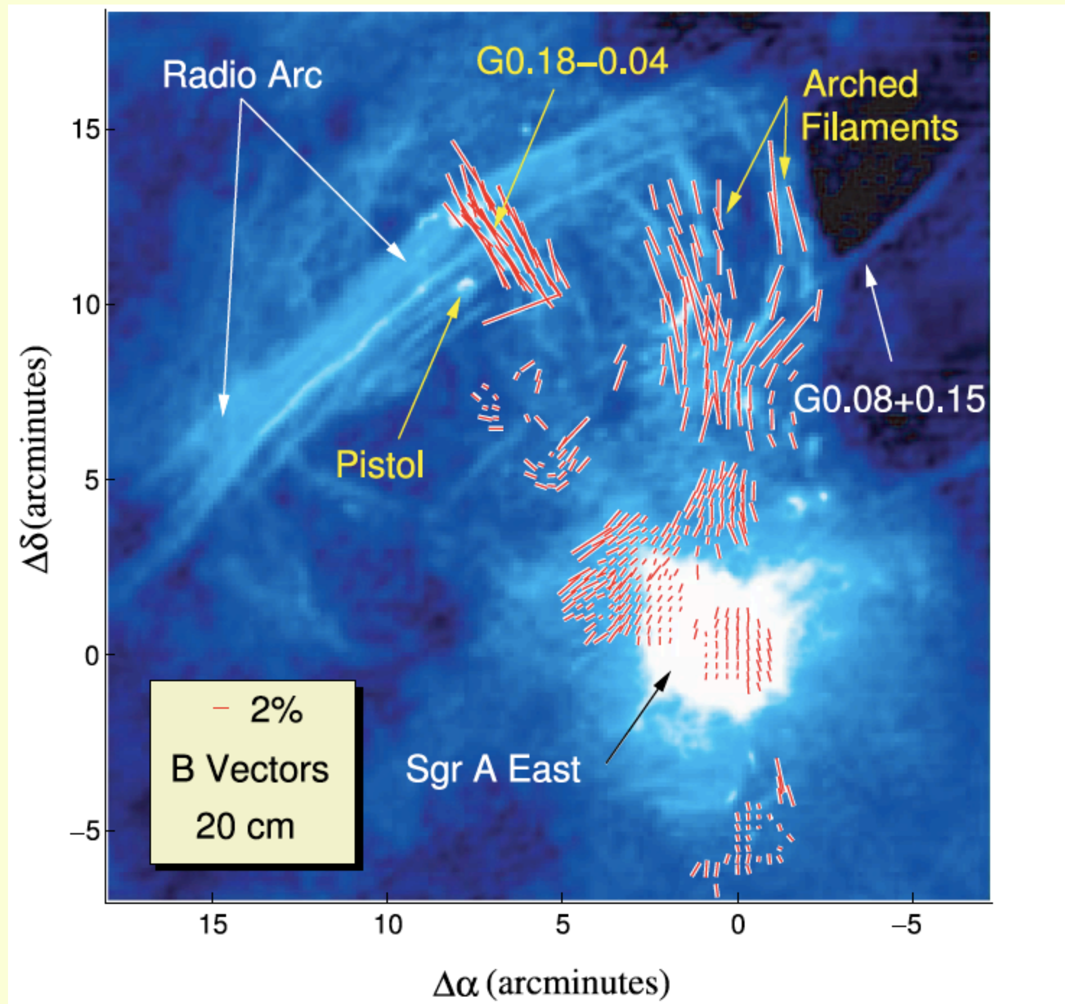
R: 20cm radio

B: 8 μm



CONTEXT:
The Legacy of the KAO and the Promise of SOFIA

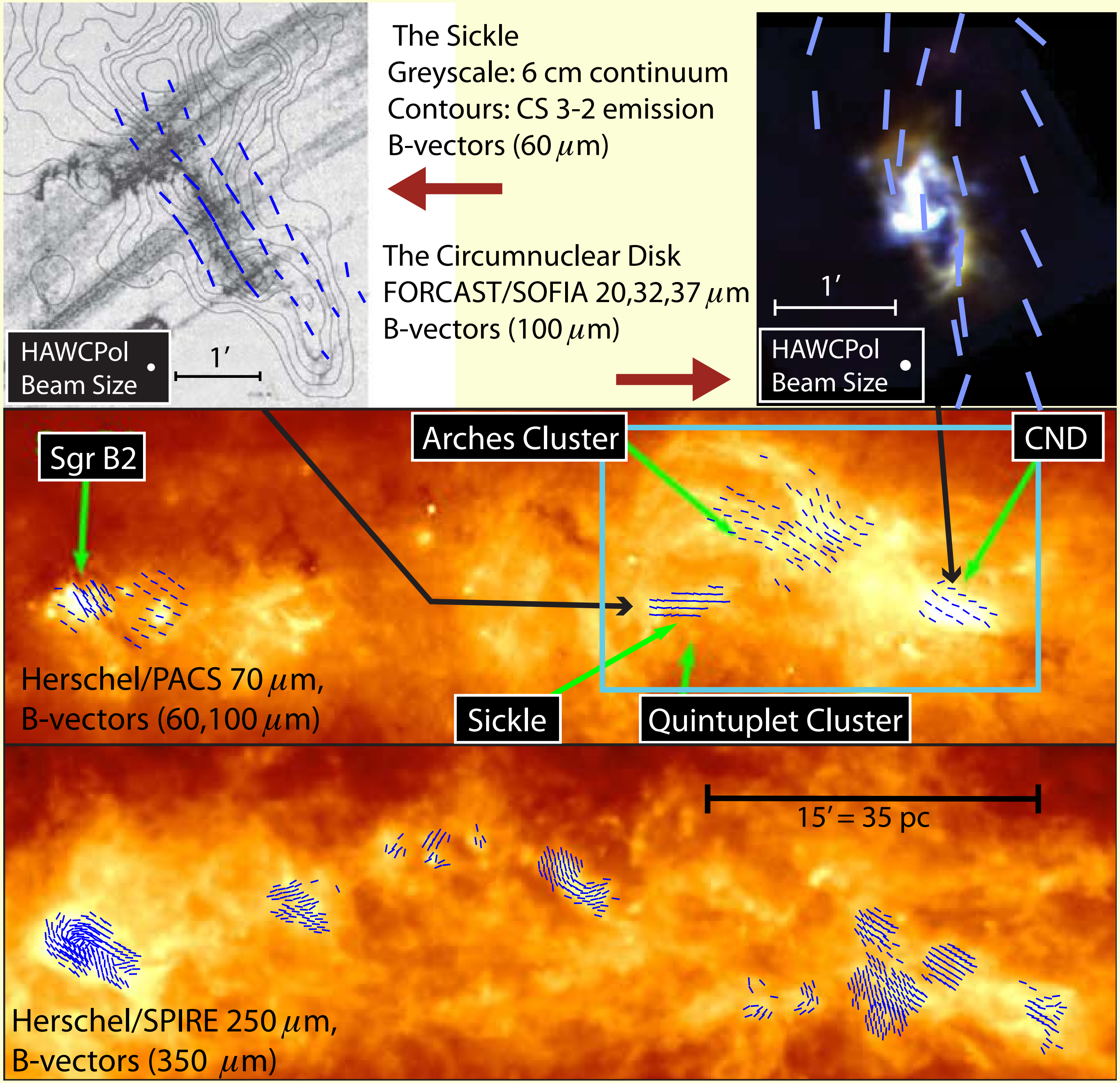
Magnetic field vectors inferred from far-IR polarization measures of thermal emission from aligned dust grains
(Chuss et al. 2003)



The Debut of HAWC+ → 2016

Far-IR imager

53, 89, 155 & 214 μm
5.3”, 8.9”, 16” ,22"
+
polarimeter



Novak+ 2003, Chuss+ 2003, Nishiyama+ 2010, Molinari+ 2011

Outstanding question #1:

What heats Galactic center clouds to such high temperatures?
→ Most GC gas: 40 – 80 K, from a variety of molecular probes.

Mills & MM 2013 – hot ammonia
400 K !!

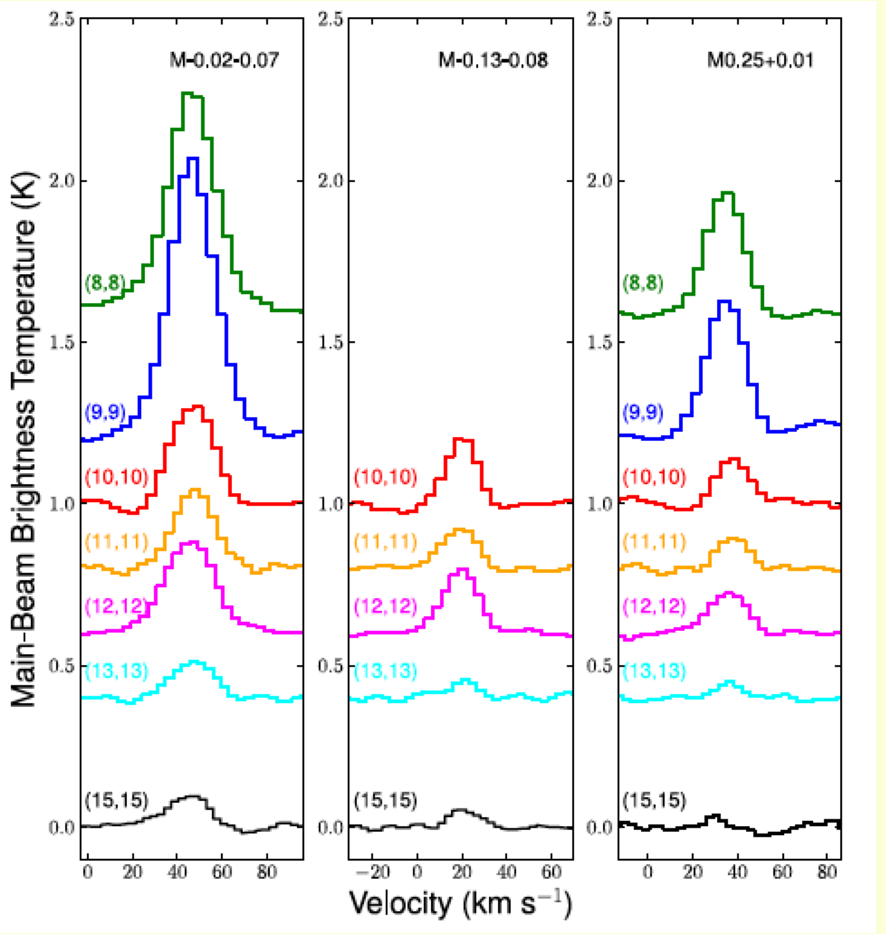
Rodriguez-Fernandez+ - Also some hot H_2

- Constituting ~10% of the NH_3 column
- Preferred heating mechanism

↓

Internal shocks resulting from the dissipation of supersonic turbulence.

(other potential heating mechanisms: X-ray flashes, dissipation of MHD waves by ion-neutral friction, cosmic rays)



Far-IR tools to investigate the hot components of the CMZ:

Spectroscopy –

- High-J CO lines
- Far-IR water lines
- HD ⟶

Transition	λ (μm)	E_u/k (K)
1–0 R(0)	112.07	128.4
2–1 R(1)	56.23	384.3
3-2 R(2)	37.70	765.9
4–3 R(3)	28.50	1270.7

G. Melnick

→ Decoupling density and temperature

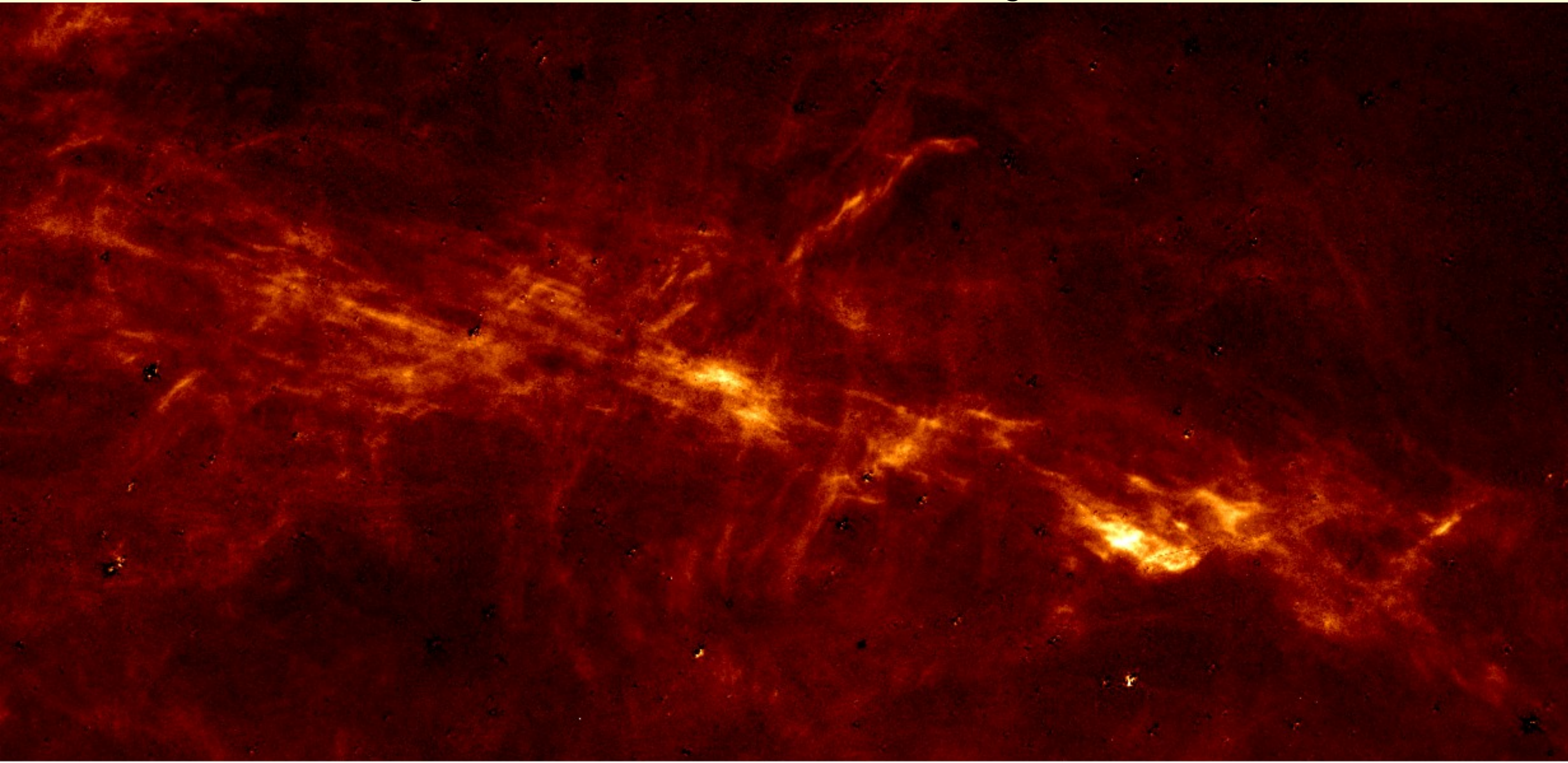
Imaging (interferometric) –

- Resolving dust emission from the shocks, or
- Locating the heating sources →
  temperature maxima & gradients

Outstanding question #2:

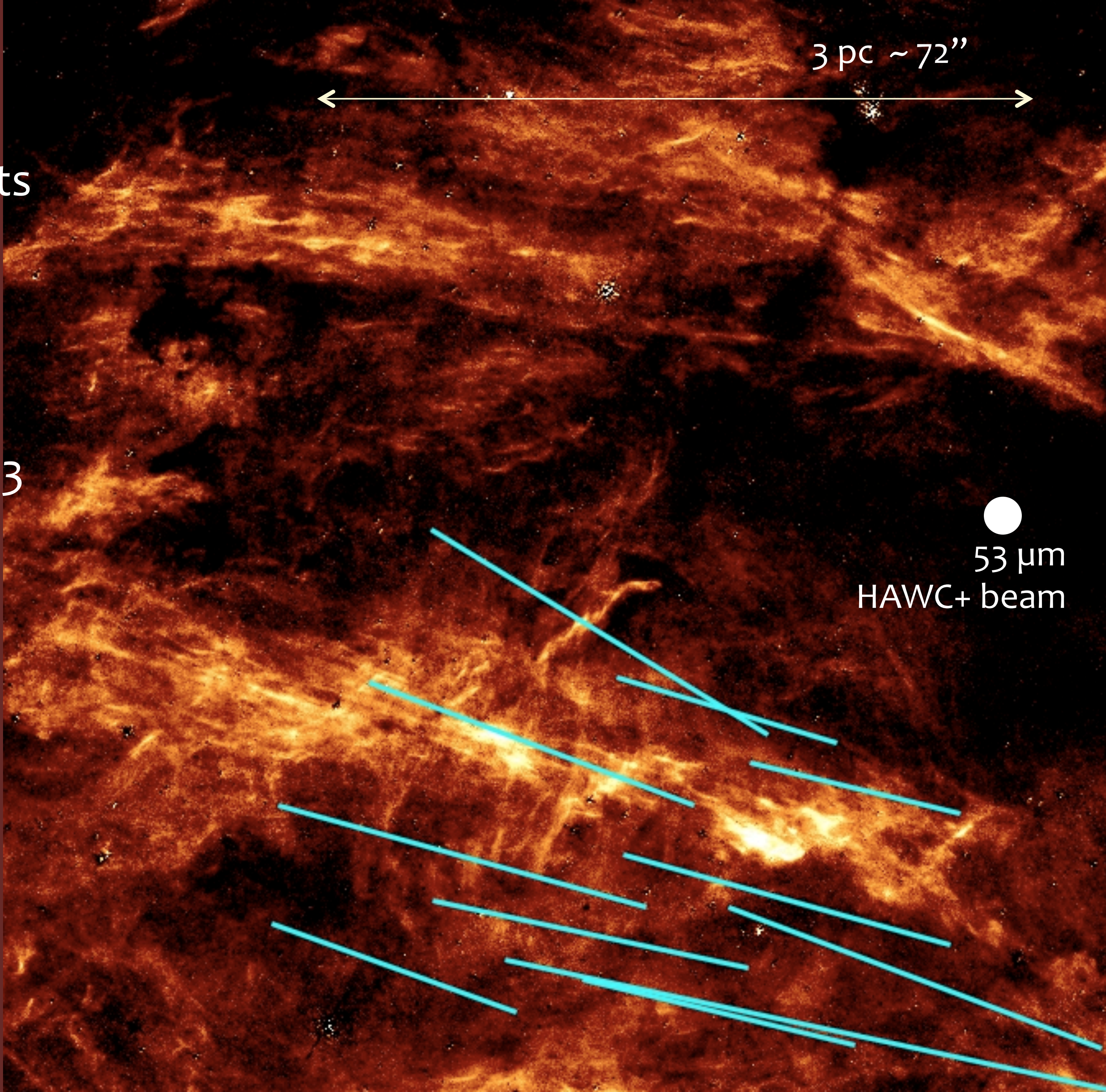
Is the internal structure of molecular clouds in the GC organized by the strong magnetic field?

Paschen-α image (HST/NICMOS) - an HII region on a cloud surface



Paschen-α
in the
Arched filaments

(some)
B-vectors from
Chuss et al. 2003

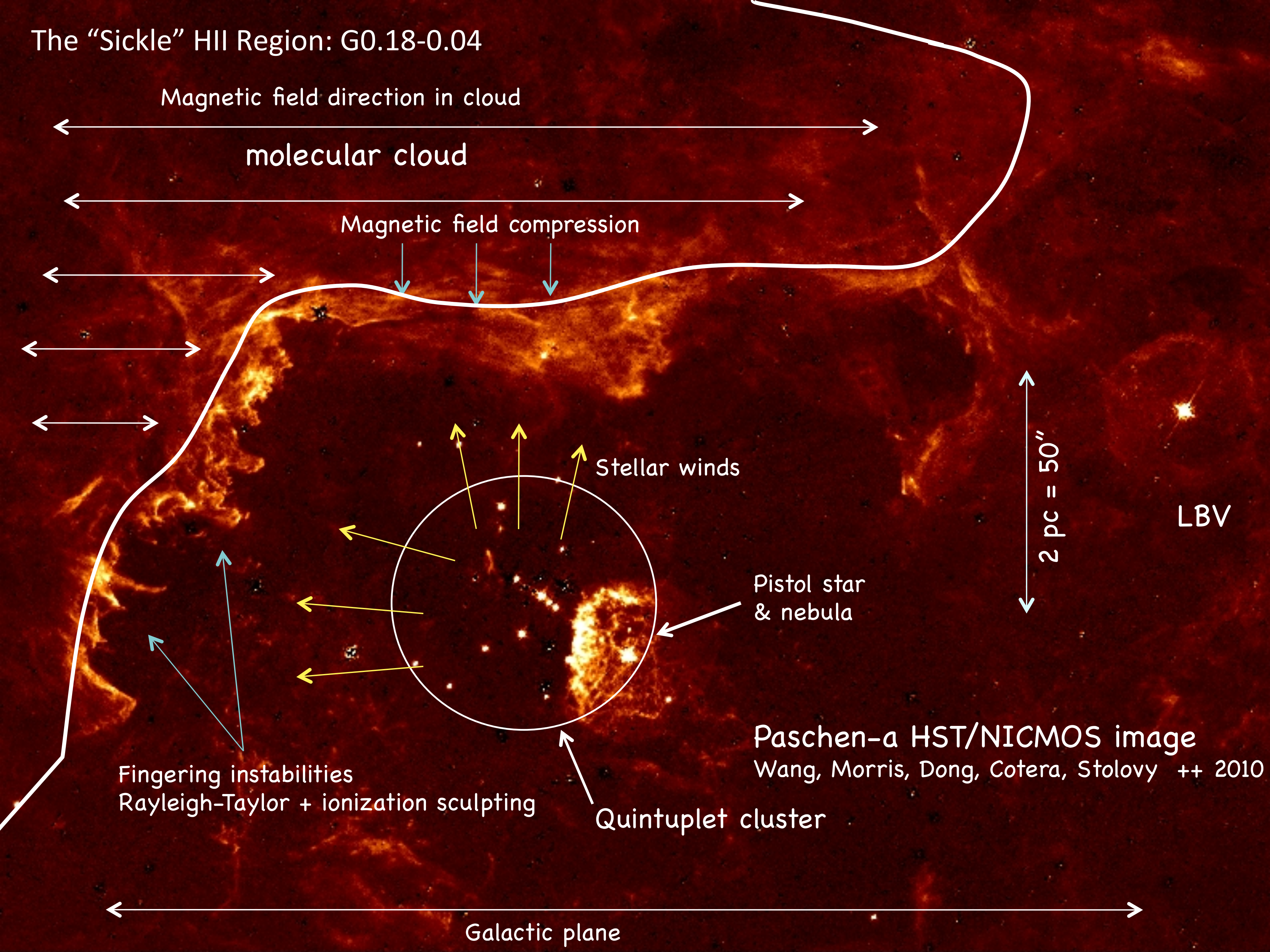


Outstanding question #3:

What is the detailed character of the violent feedback from the massive stellar clusters upon clouds in the CMZ?

This question has numerous facets:

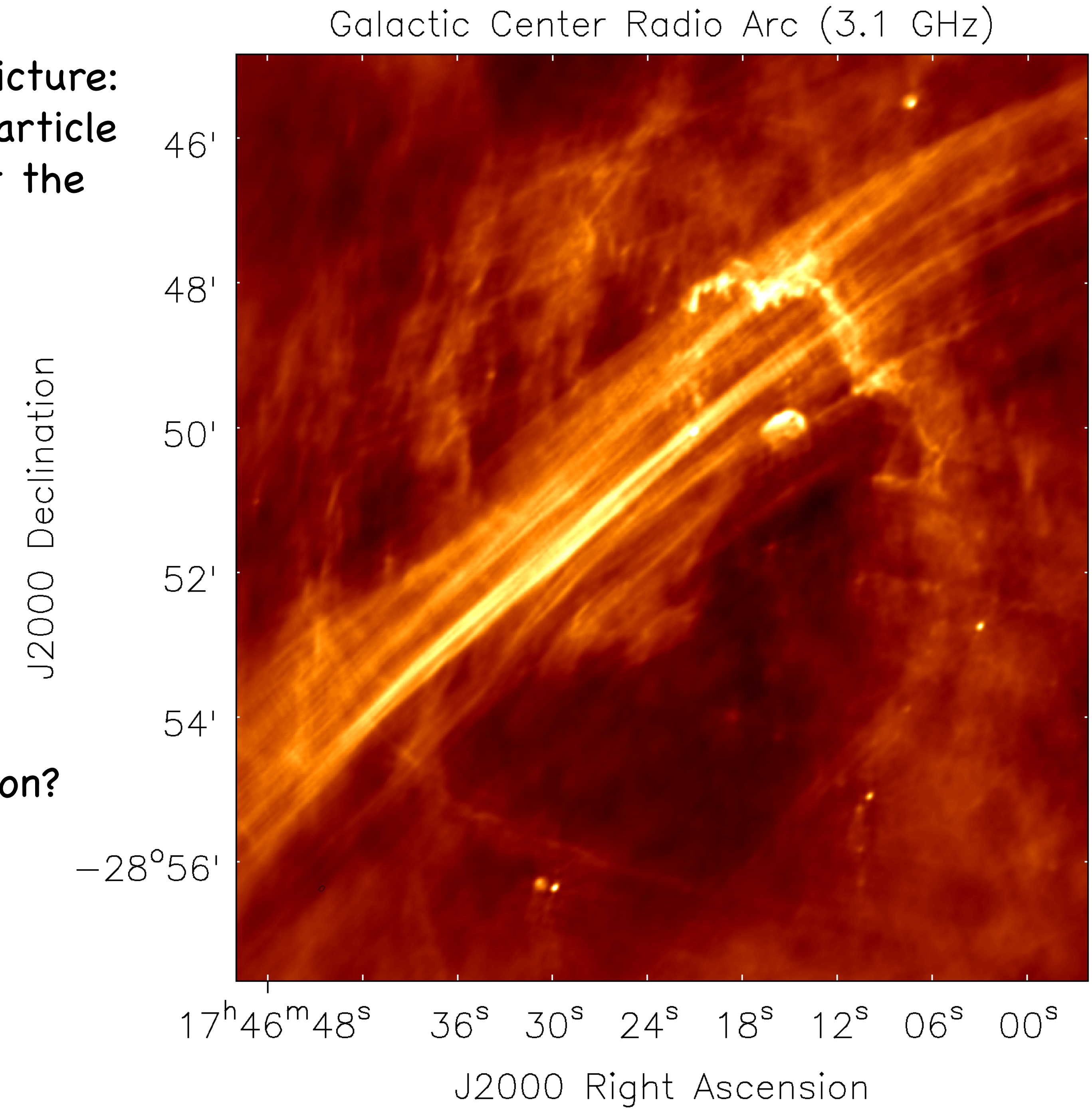
- simple hydrodynamics
- magnetohydrodynamics
- shocks and shock chemistry
- relativistic particle production
- photodissociation regions


The "Sickle" HII Region: G0.18-0.04
Magnetic field direction in cloud
molecular cloud
Magnetic field compression
Stellar winds
2 pc = 50"
LBV
Pistol star
& nebula
Paschen-a HST/NICMOS image
Wang, Morris, Dong, Cotera, Stolovy ++ 2010
Fingering instabilities
Rayleigh-Taylor + ionization sculpting
Quintuplet cluster
Galactic plane

The bigger picture: Relativistic particle production at the interface

→

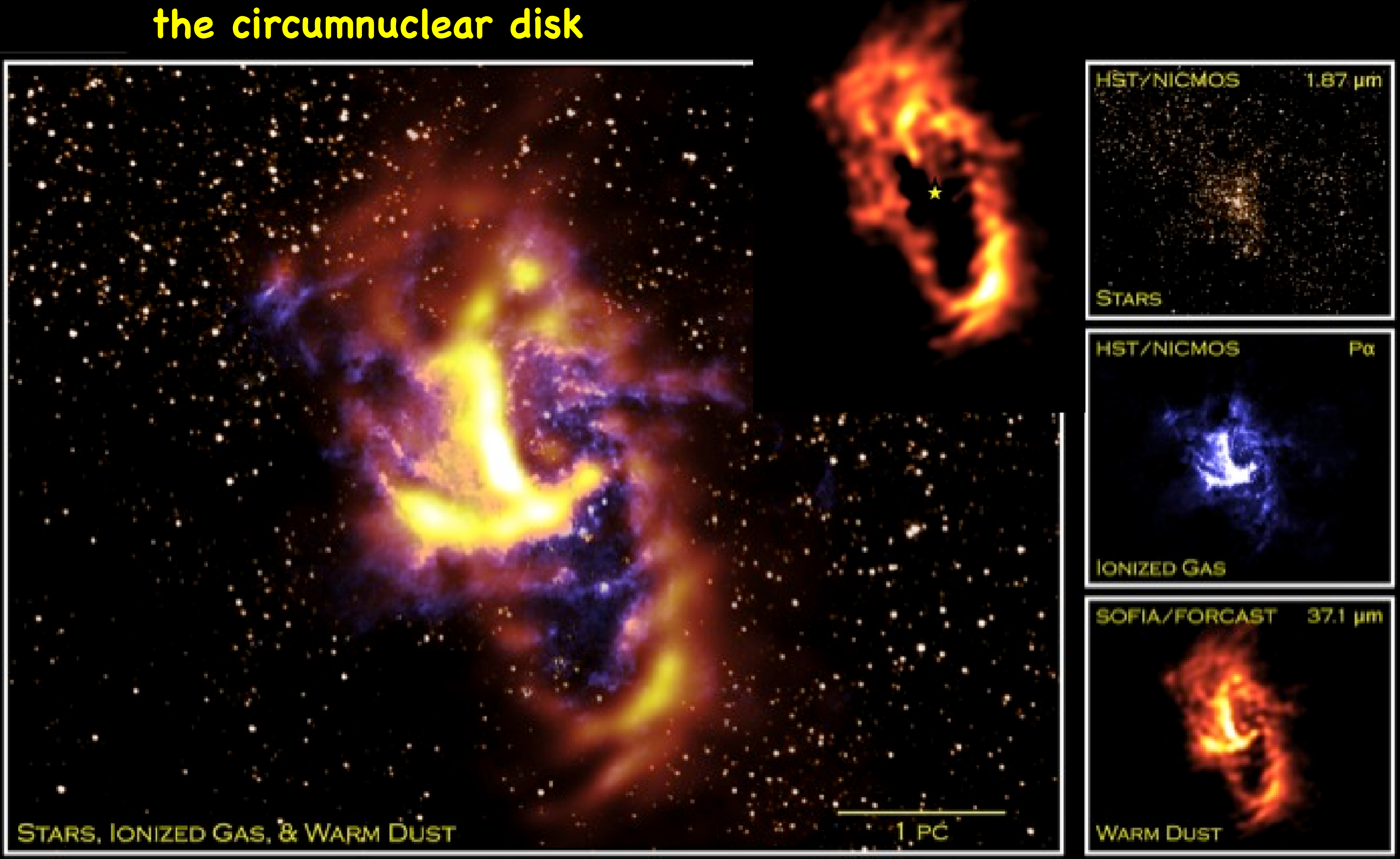
Non-thermal far-IR emission?



C.C. Lang, MM et al. in prep.

Another example of feedback from a massive young cluster →

the circumnuclear disk



Ryan Lau, Terry Herter, MM, Eric Becklin, Joe Adams – SOFIA/FORCAST

Where does the far-IR come in?

→ high-resolution imaging with a far-IR interferometer would be a key contributor to an investigation of the interface.

ALMA can give us the dynamics of the thermal gas, both molecular and ionized.

But the luminous energy of the massive cluster is deposited in The dust. Far-IR mapping elucidates…

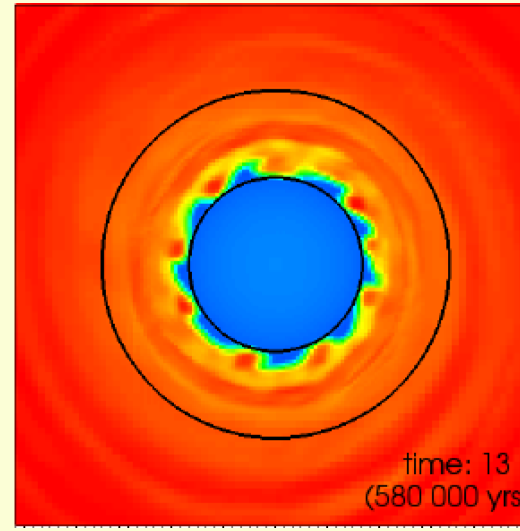
- The porosity of the interface
- The role of radiation pressure versus winds in shaping the interface (e.g., instabilities)
- Whether compression at the interface has provoked star formation

Clumps in the circumnuclear disk

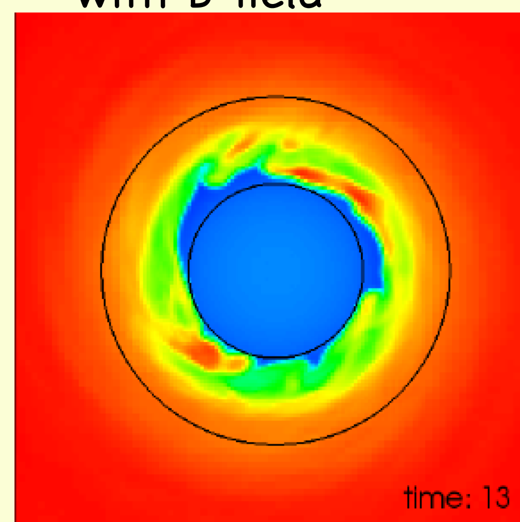
- Instabilities?
- Or a signal that the disk is a transient feature (tidal shear quickly eliminates clumps)

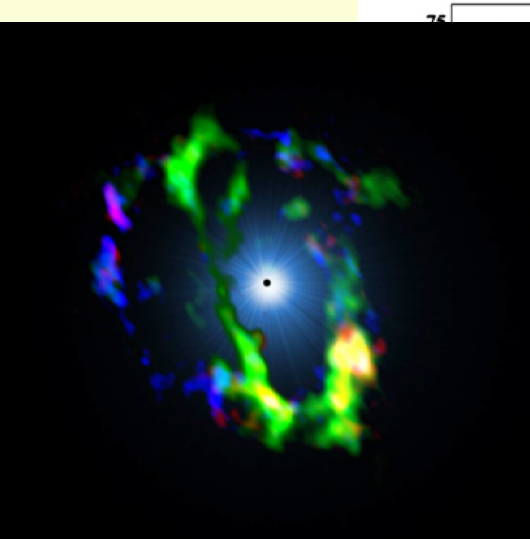
Numerical Models:

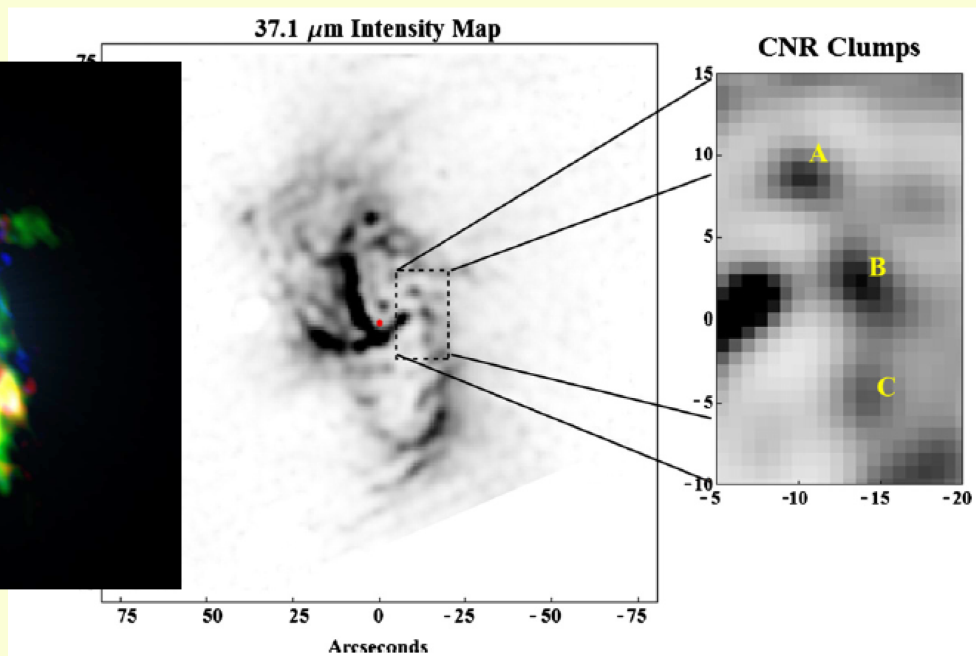
- no B field



- with B field







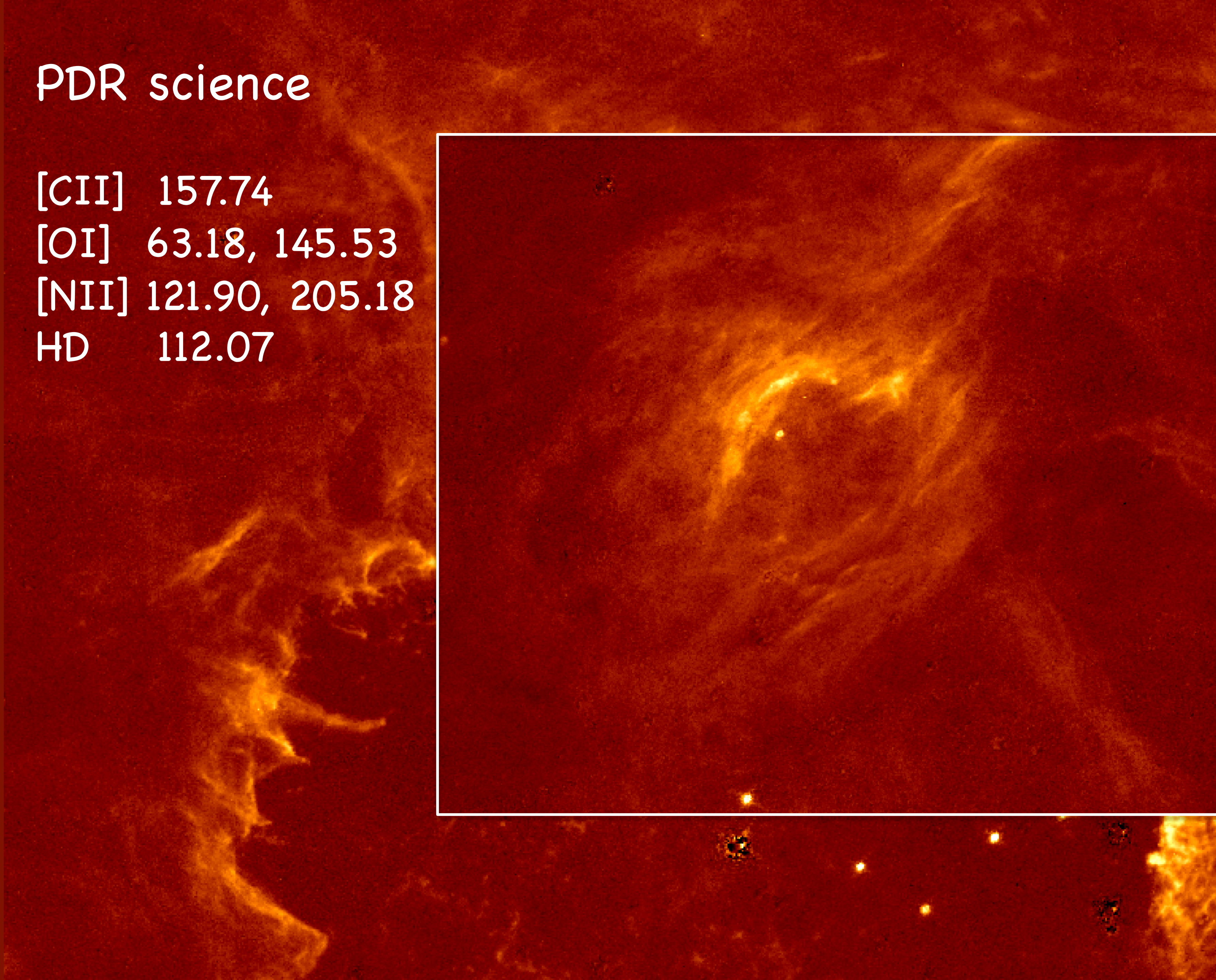
Molecules
S. Martin+ 2012

37 μm, Lau et al. 2013

M. Blank, MM et al. 2015

PDR science

[CII] 157.74
[OI] 63.18, 145.53
[NII] 121.90, 205.18
HD 112.07



A caveat ....

The Galactic center is bright...

So sensitivity is not a major issue, in general
(weak spectral lines and sensitive polarization measurements notwithstanding)

But planning for a far-IR surveyor will need to take into account the fact that many space-borne detectors have saturated when observing the GC.

This can be avoided with higher spatial and/or spectral resolution

Questions?