Resolving the Interstellar Medium in Nearby Galaxies

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Nearby Galaxies

Studying the interstellar medium (ISM) in the Milky Way is challenging.

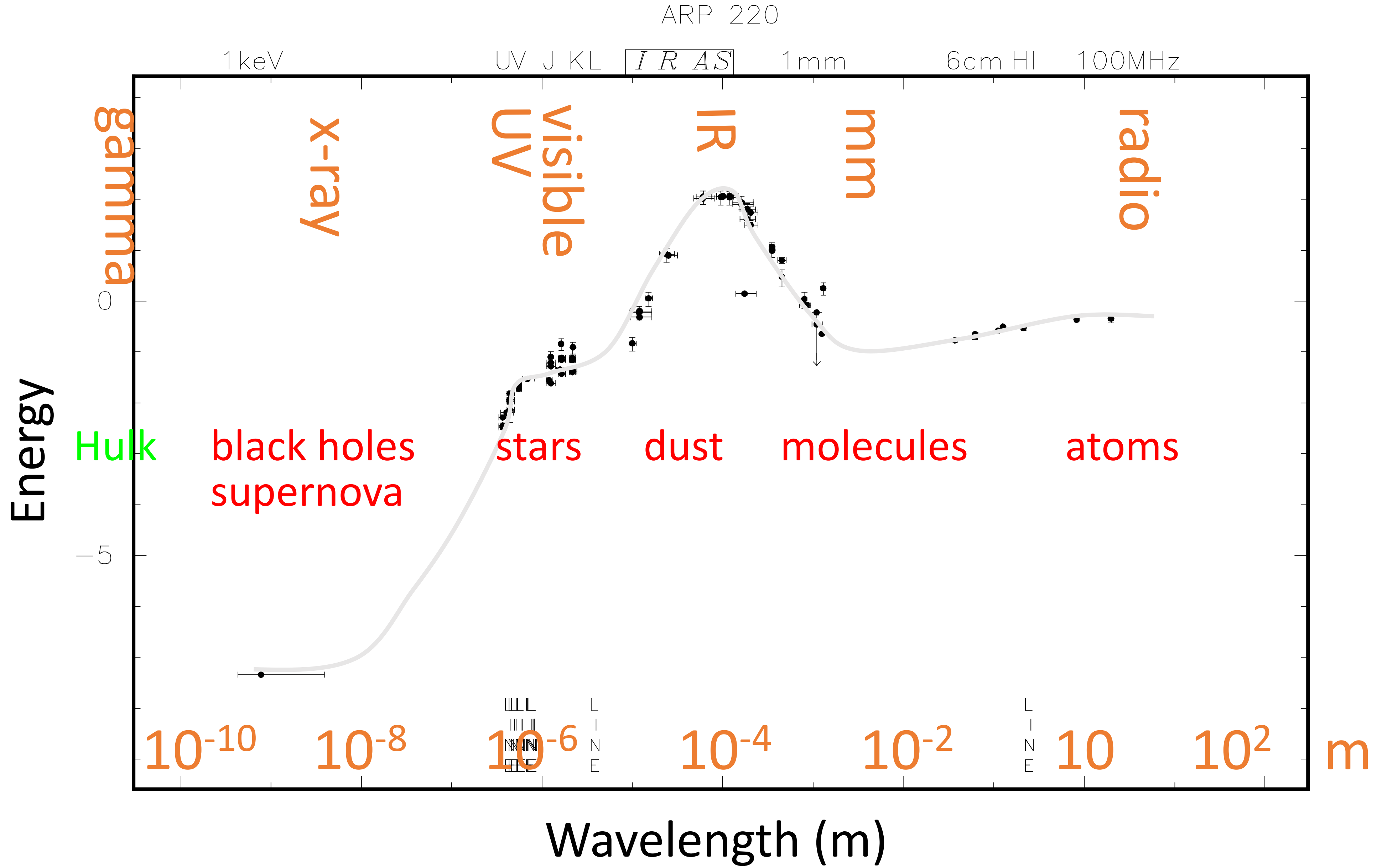
It is difficult to determine the effect of large scale structure and dynamics owing to our “trapped inside” view.

Studying the ISM in nearby galaxies allows a full view of galaxy structure and dynamics, but is hampered by the large distances to these galaxies.

Nearby Galaxies

We need powerful telescopes to resolve details.

Energy Distribution of a Galaxy

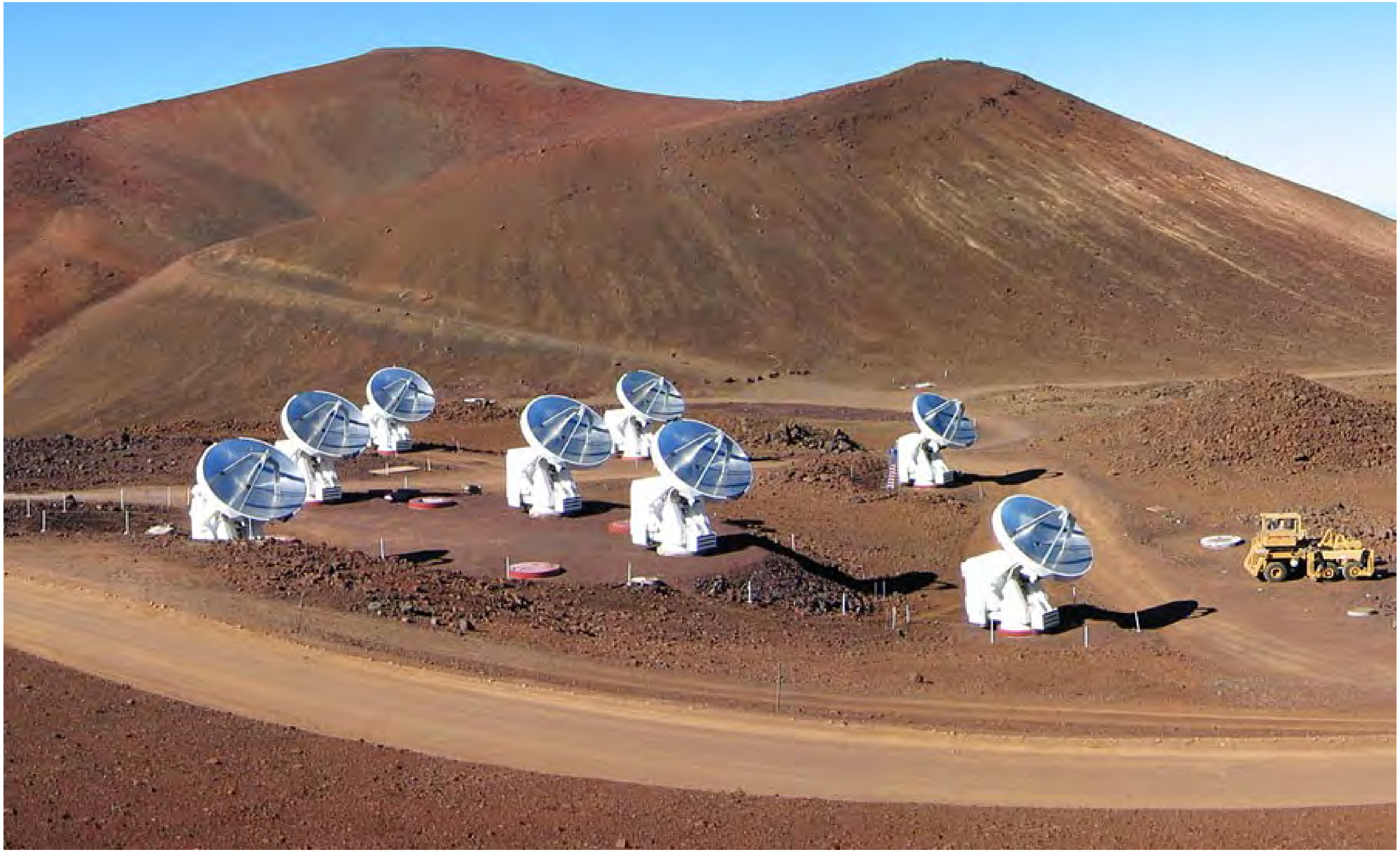


SMA Overview

The SMA is a pathfinding instrument comprised of eight 6 meter antennas on Maunakea, HI, designed for high spatial and spectral resolution imaging in submillimeter atmospheric windows.

The SMA is a collaborative project of the Smithsonian Astrophysical Observatory, part of the Harvard-Smithsonian Center for Astrophysics,and the Academia Sinica Institute of Astronomy and Astrophysics (Taiwan)

Interferometry in one slide



Interferometry in one slide

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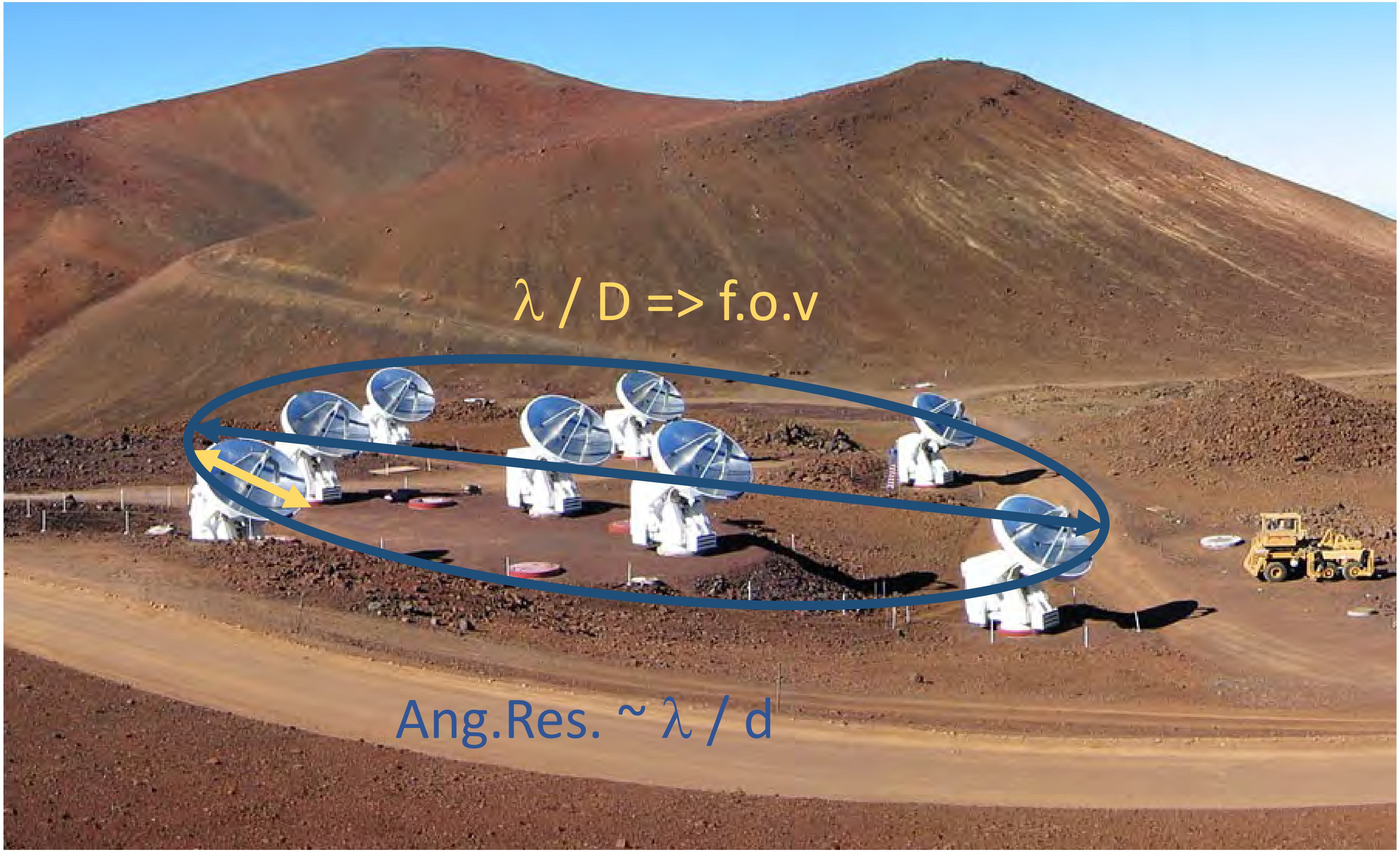

SMA Specs

Antennas: 8 antennas of 6 m diameter

Configurations: 24 pads in four rings

baseline lengths 8 - 508 m,

subarcsecond resolution, best ~0.25’’ (at 400 GHz)





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Receivers:	max 8 per antenna; always 2 simultaneously, each single pol.
	full frequency coverage of atmospheric windows
	dual polarization, "A" & "B" combinations allowed
	'230' 177-256 GHz (A)
	'345' 256-360 GHz (A)
	'240' 205-280 GHz (B)
	'400' 325-420 GHz (B)

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Correlator: Bandwidth: 32 GHz (2 SB x 8 GHz x 2 Rx's)

Uniform 139 kHz resolution at all times!

Every observation is a spectral survey!

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rms in 8h in 1.5 mm PWV = 0.18 mJy @ 230 GHz

= 0.60 mJy @ 348 GHz

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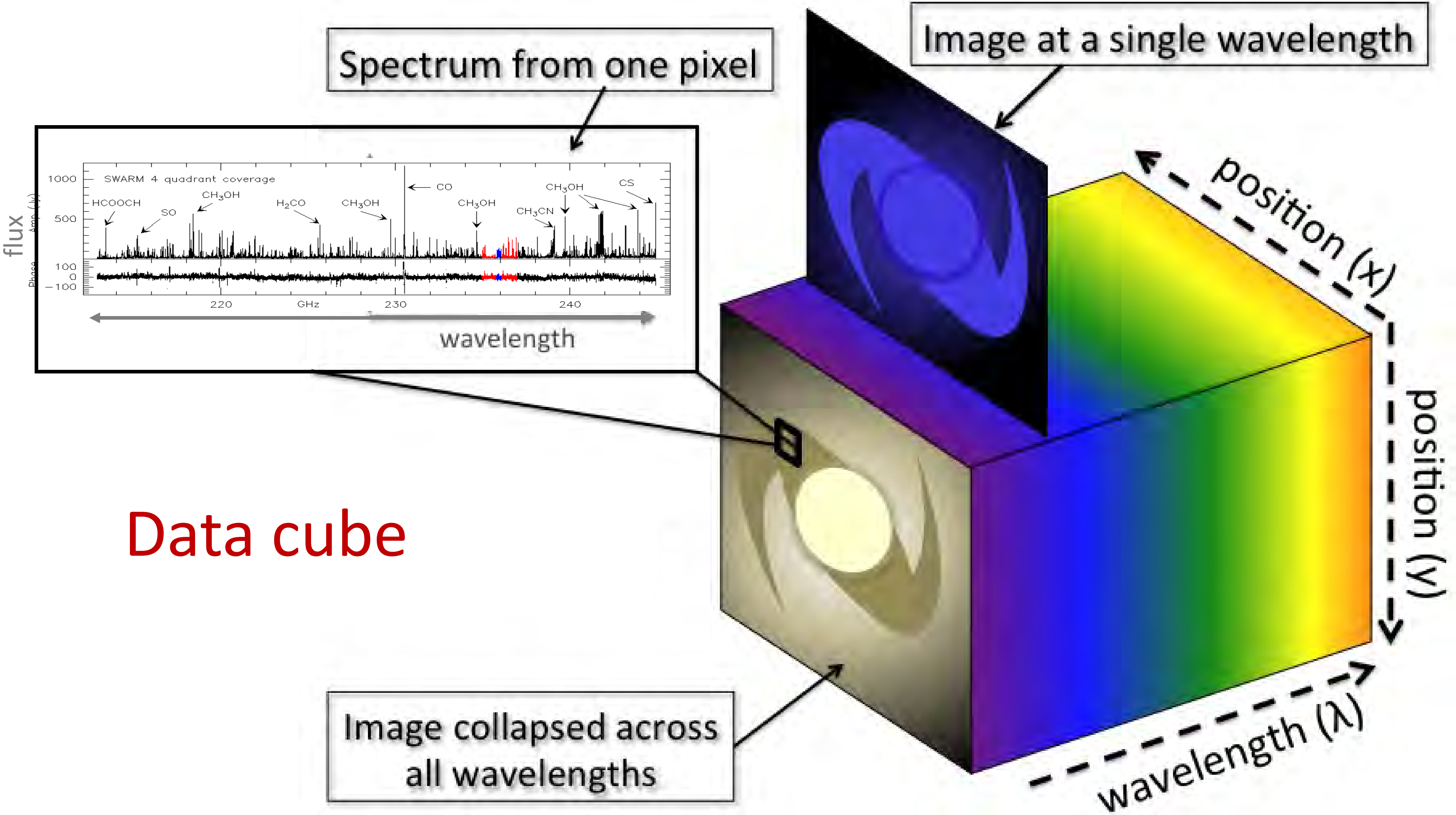
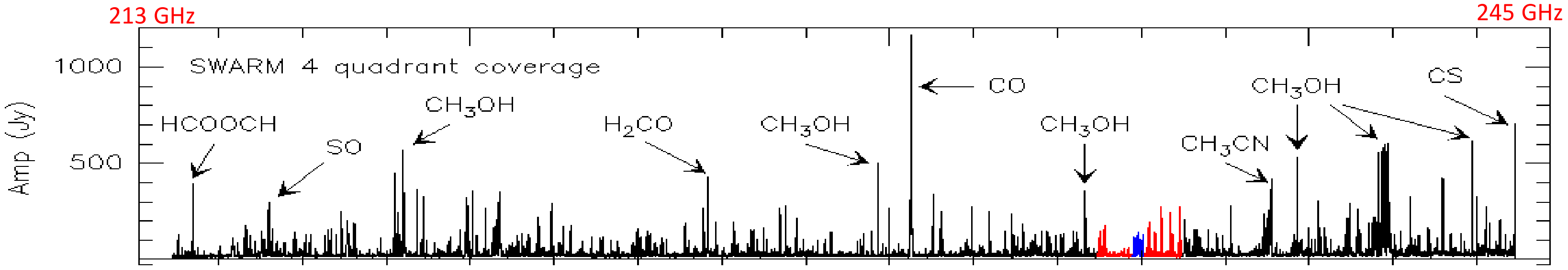
Data cube



Spectrum from one pixel
Image at a single wavelength
Image collapsed across all wavelengths
position (x)
position (y)
wavelength (λ)
flux
wavelength
SWARM 4 quadrant coverage
1000
500
100
0
−100
HCOOCH
SO
CH3OH
H2CO
CO
CH3CN
CS
220
GHz
230
240

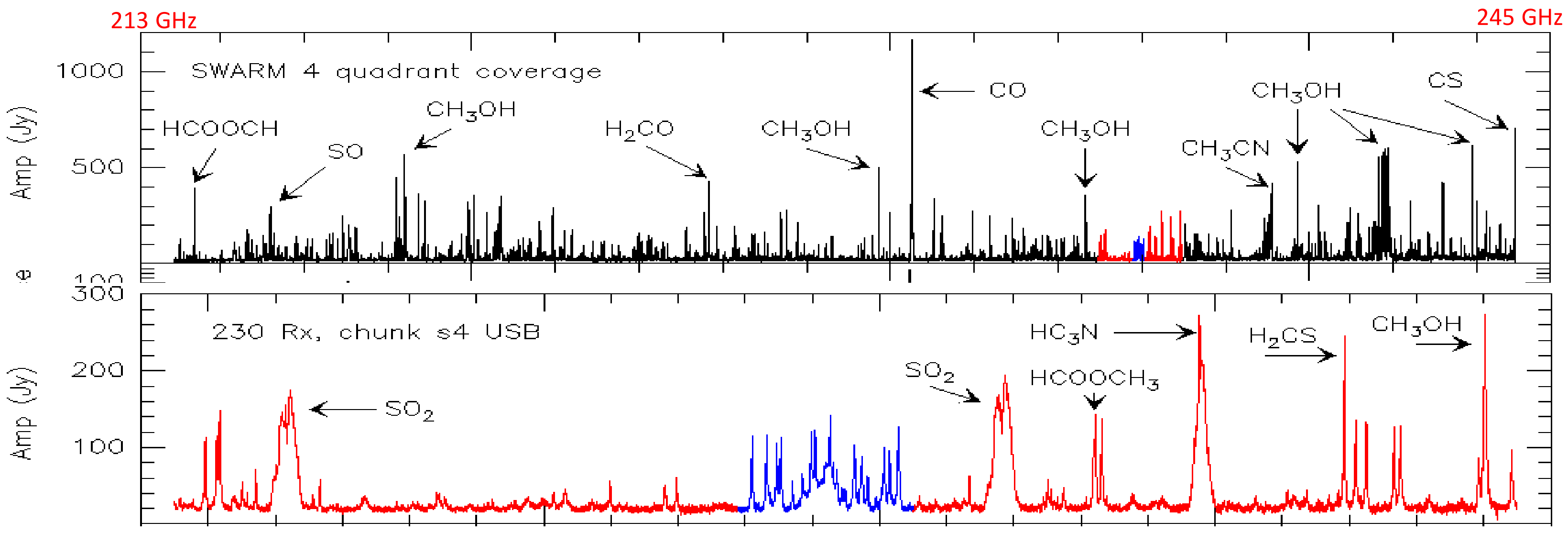
Orion BNKL -SWARM Demonstration



32 GHz

(230K channels)

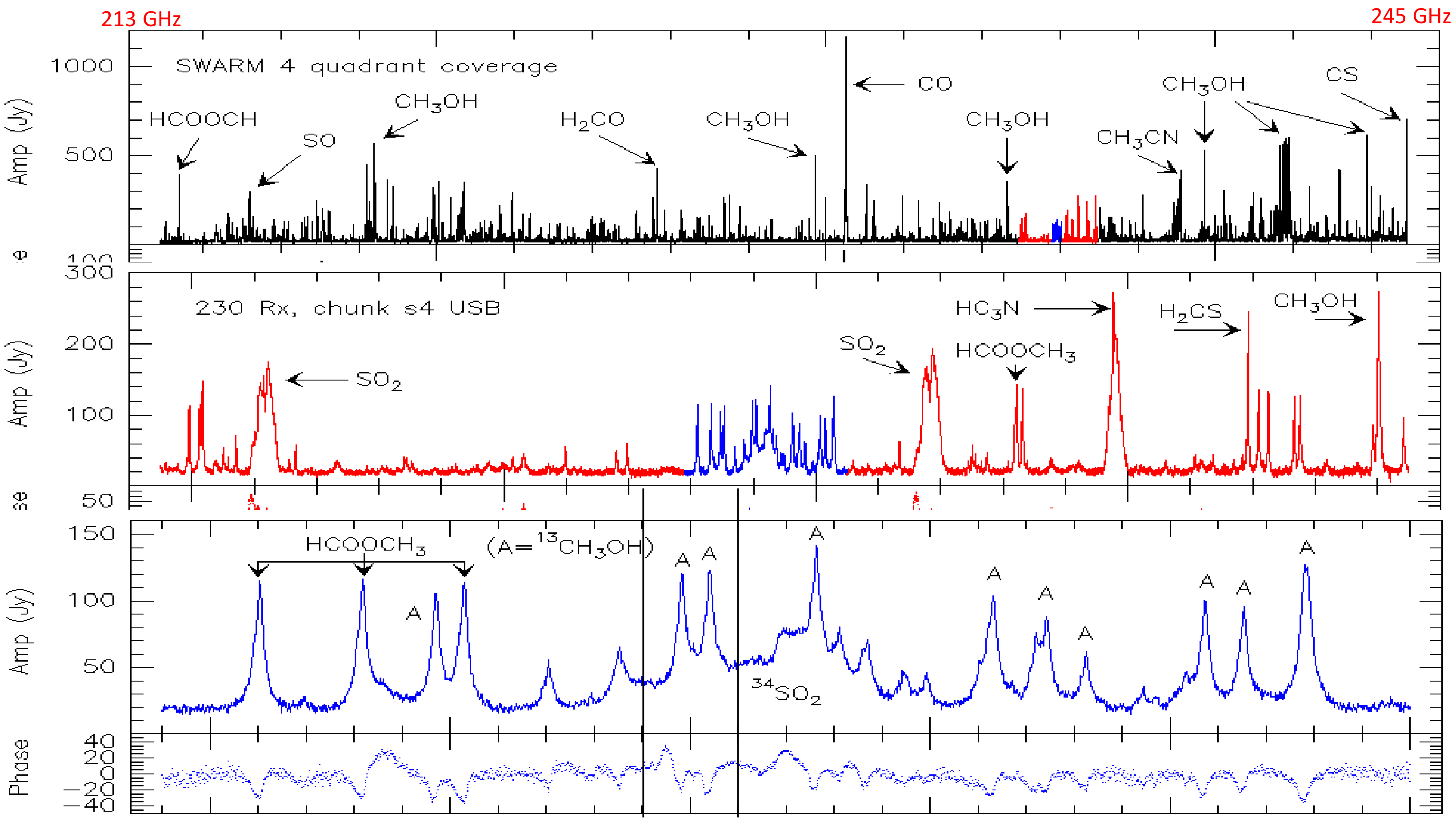
Orion BNKL -SWARM Demonstration



32 GHz
(230K channels)

2 GHz

Orion BNKL -SWARM Demonstration

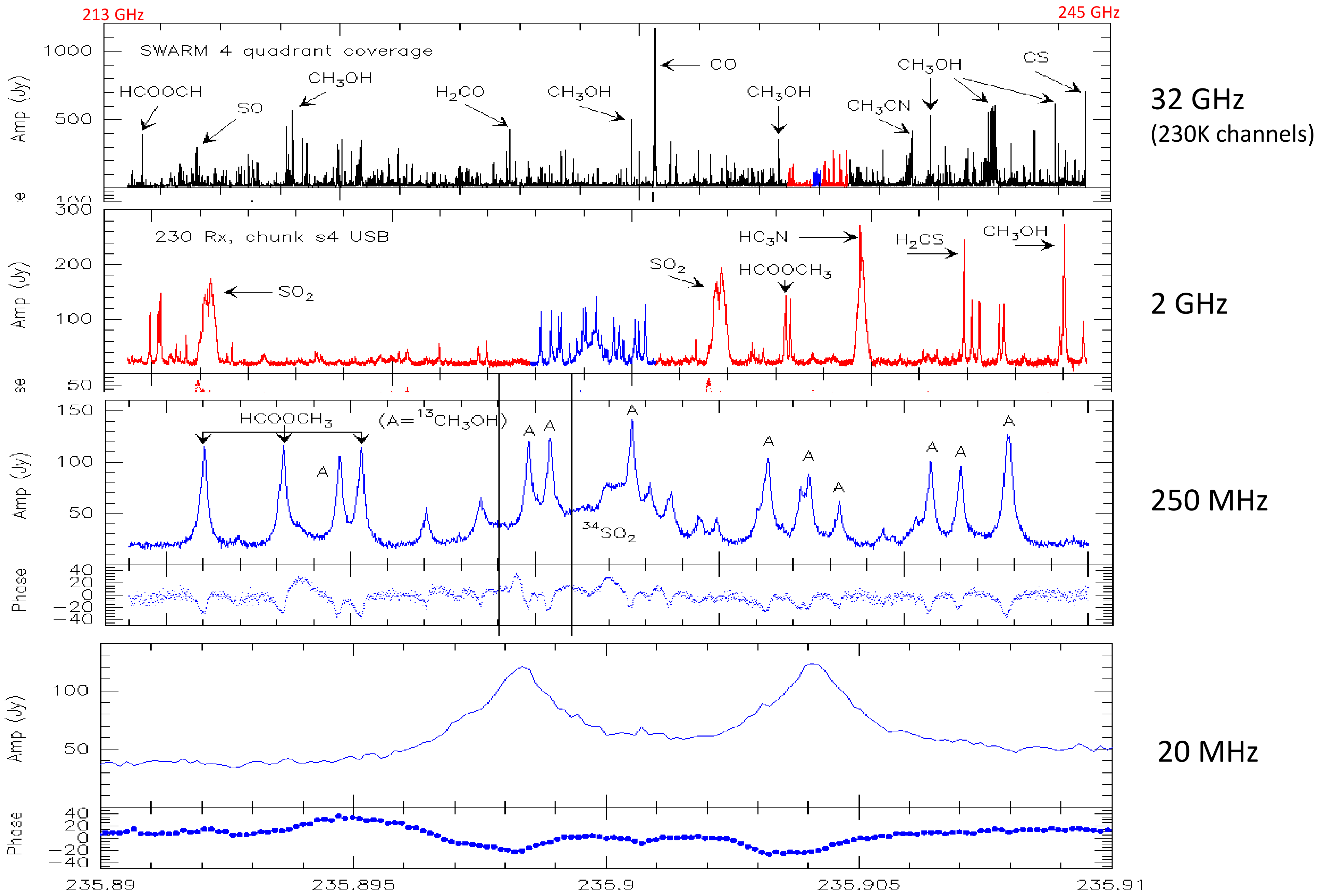


32 GHz
(230K channels)

2 GHz

250 MHz

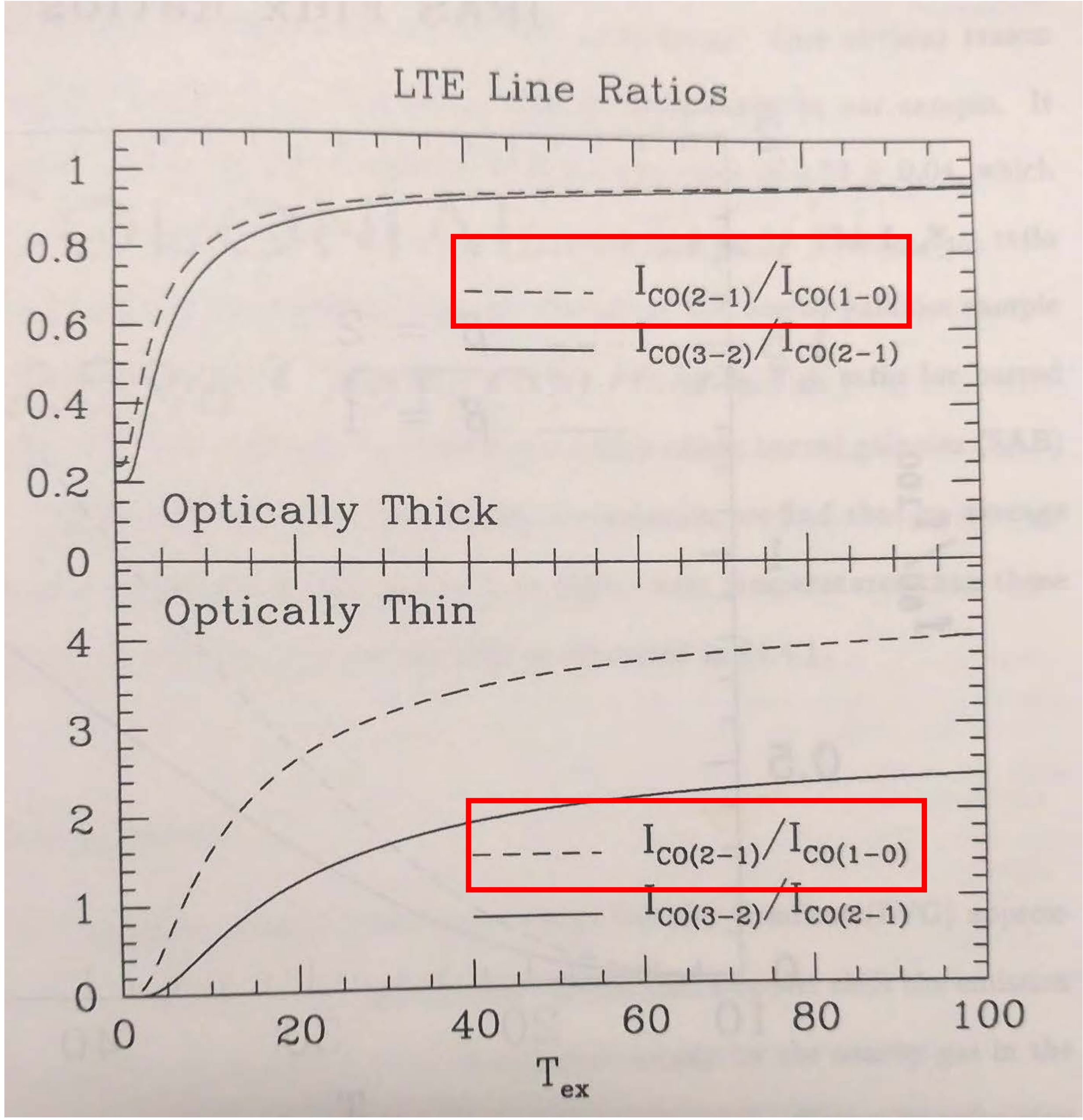
Orion BNKL -SWARM Demonstration



Science:

- Molecular Hydrogen is the dominant component of the ISM, but it has very few useful transitions which emit detectable photons.
- While CO J=1-0 is the standard H_2 tracer, you need the higher J transitions and isotopes to measure properties such as temp, density, opacity etc.
- *The flux ratio of CO J=2-1/J=1-0 emission is a crude tracer of temperature.*
- M51 offers best opportunity to study gas property variations across spiral arms, spurs, and galaxy nuclei at high spatial resolution and offers access to large sample of accompanying data (Spitzer, VLA, HST, etc)

Science:



LTE Line Ratios
1
0.8
0.6
0.4
0.2
0
$I_{CO(2-1)}/I_{CO(1-0)}$
$I_{CO(3-2)}/I_{CO(2-1)}$
Optically Thick
Optically Thin
4
3
2
1
0
$I_{CO(2-1)}/I_{CO(1-0)}$
$I_{CO(3-2)}/I_{CO(2-1)}$
0
20
40
60
80
100
T_{ex}

M51

D = 8 Mpc
1” = 40 pc

HST

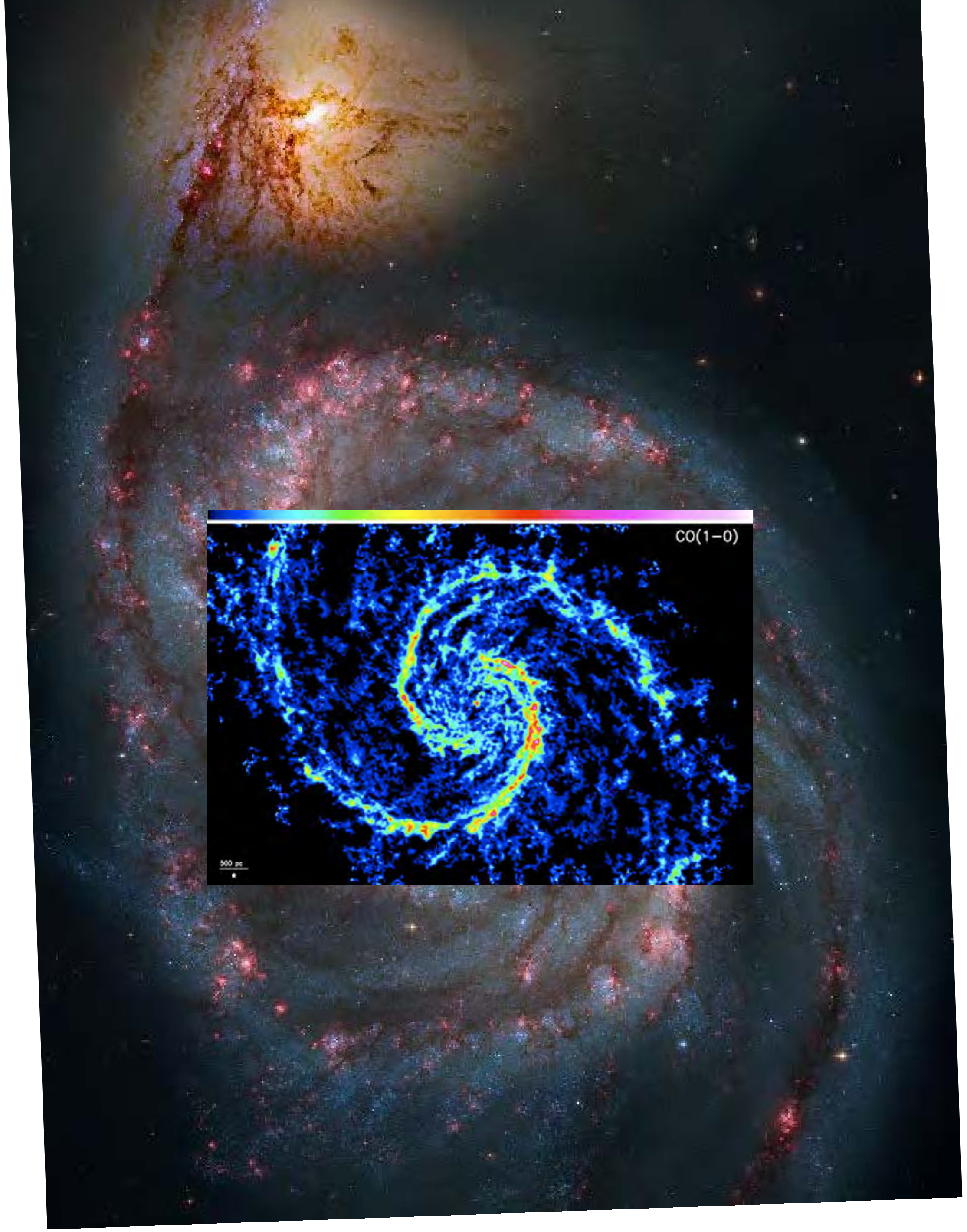
M51

Region covered by Plateau du Bure CO J=1-0 map.

~ 10 kpc x 6 kpc
(270“ x 170”)

M51

CO J=1-0 (1” res)

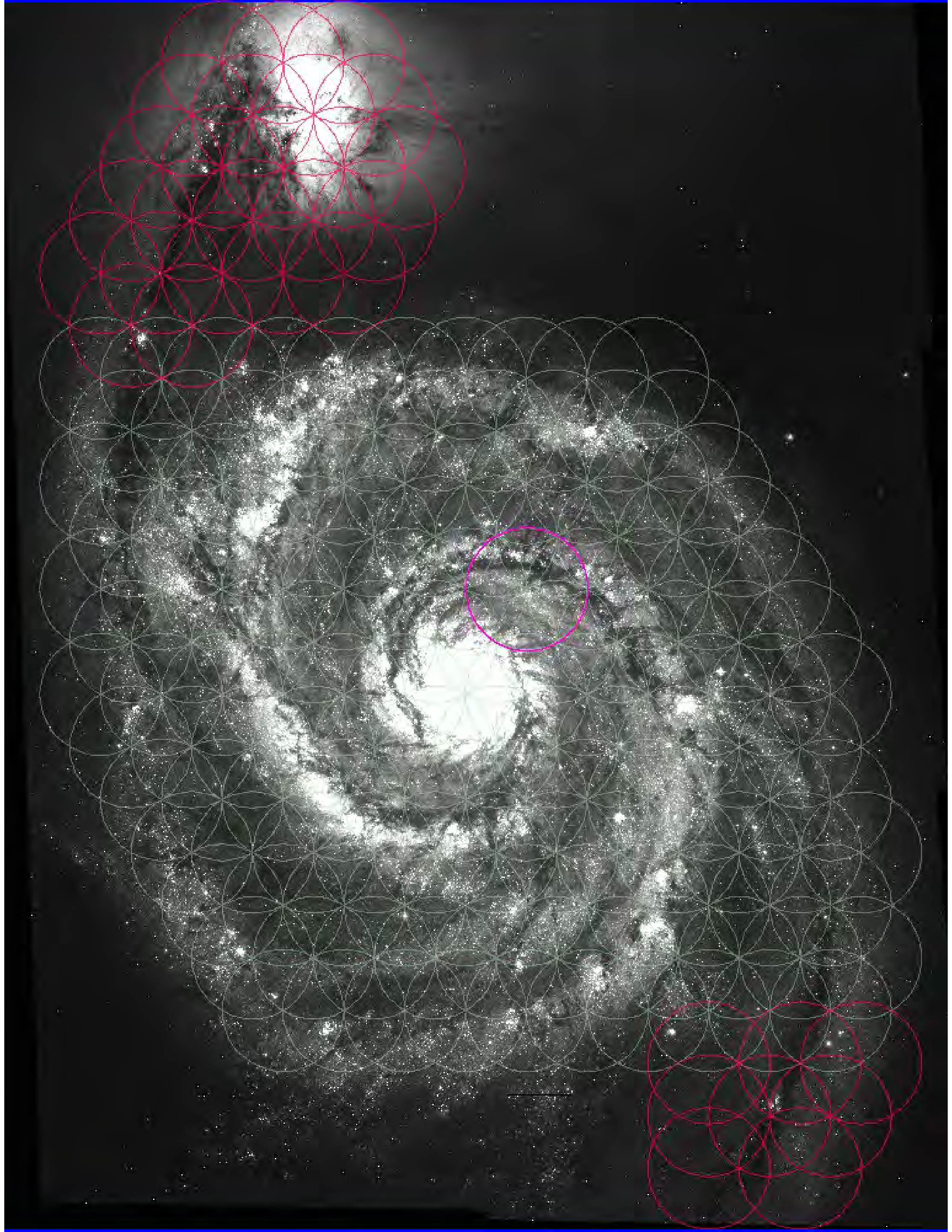


169 hours observing time
(126 hours ‘on-source’)

PdBI Arcsecond
Whirlpool Survey
(PAWS)

(Schinnerer *et al.* 2013)

M51

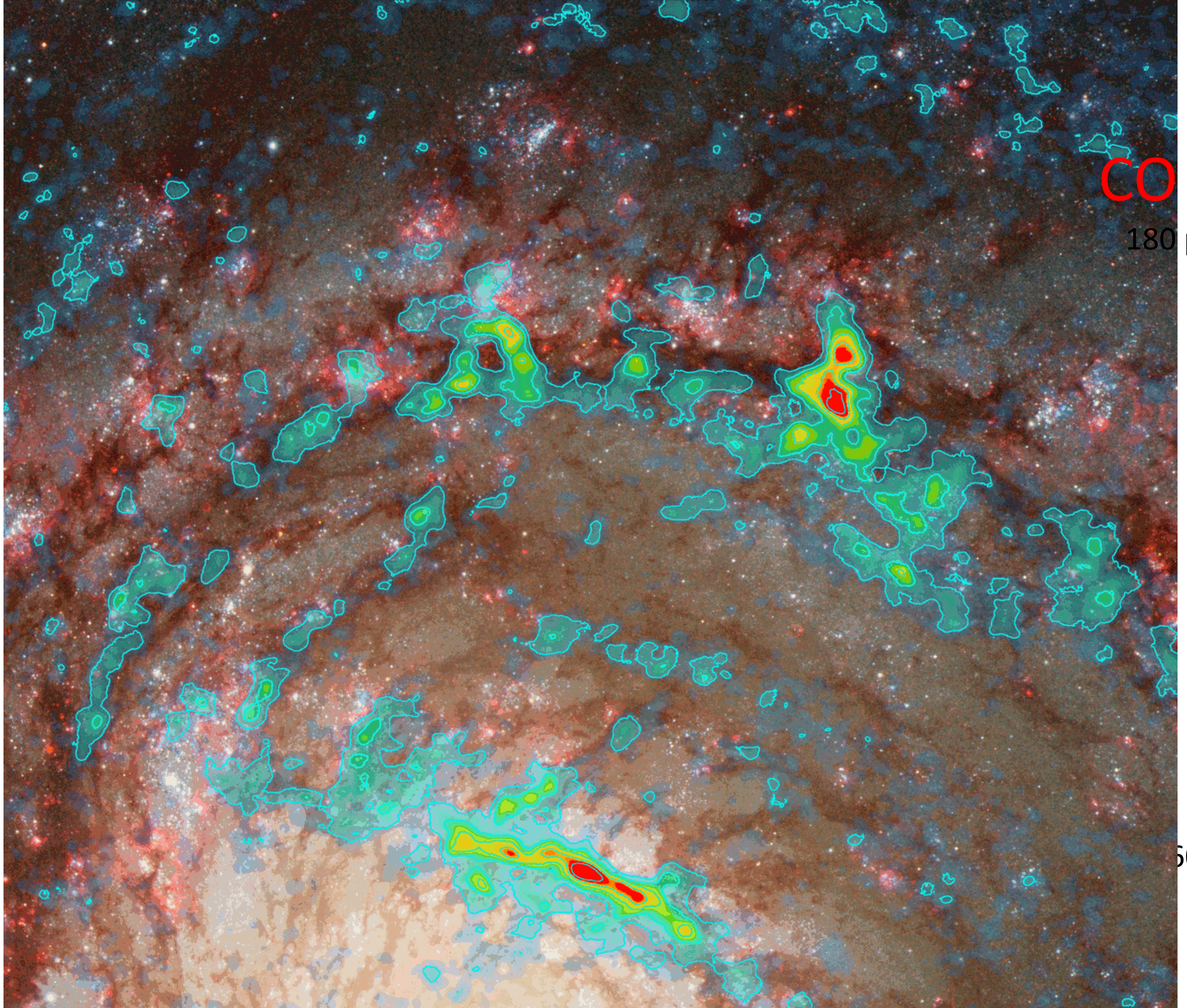


CO J=2-1

180 pointings

~400”x600”

M51

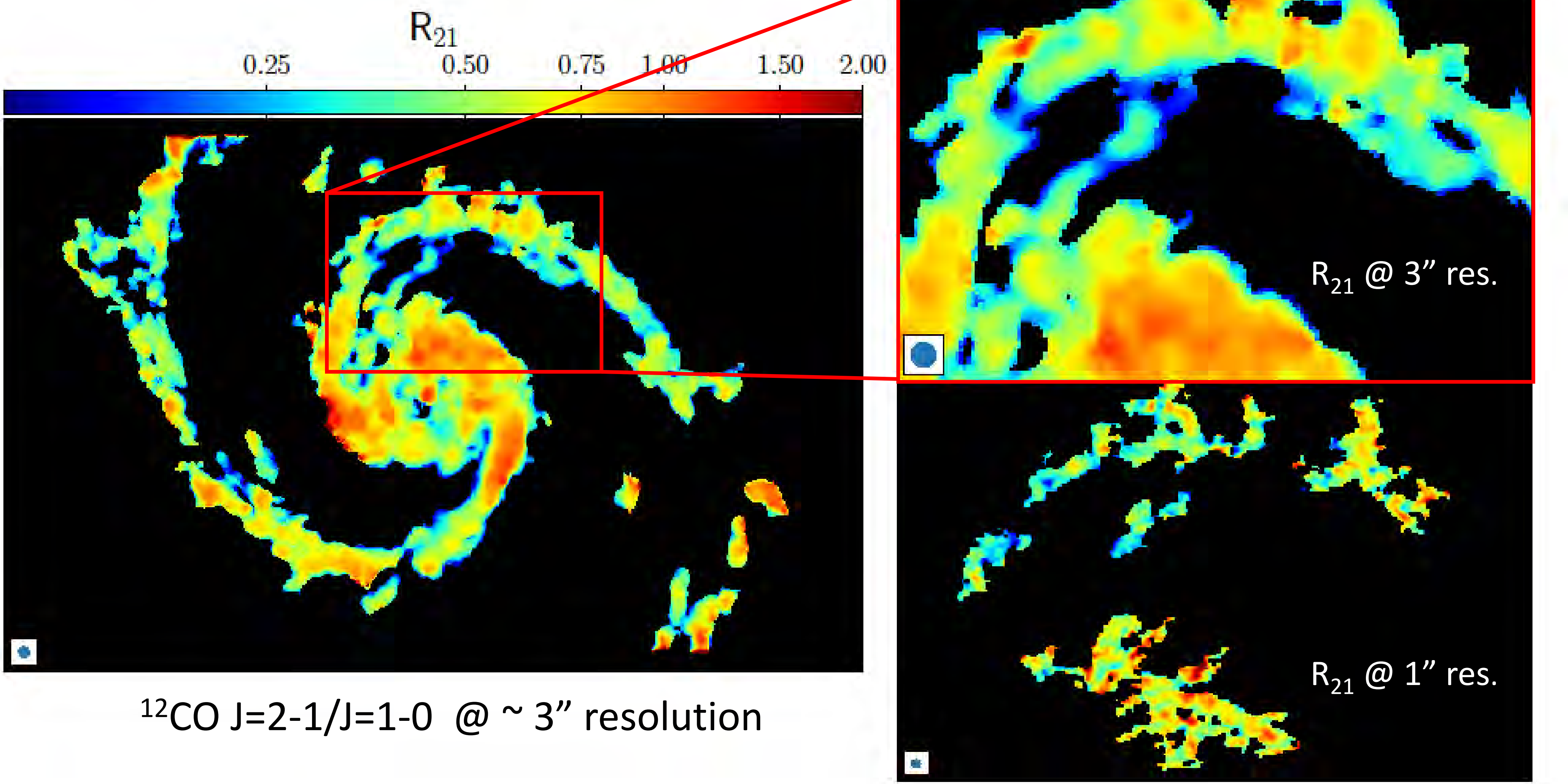


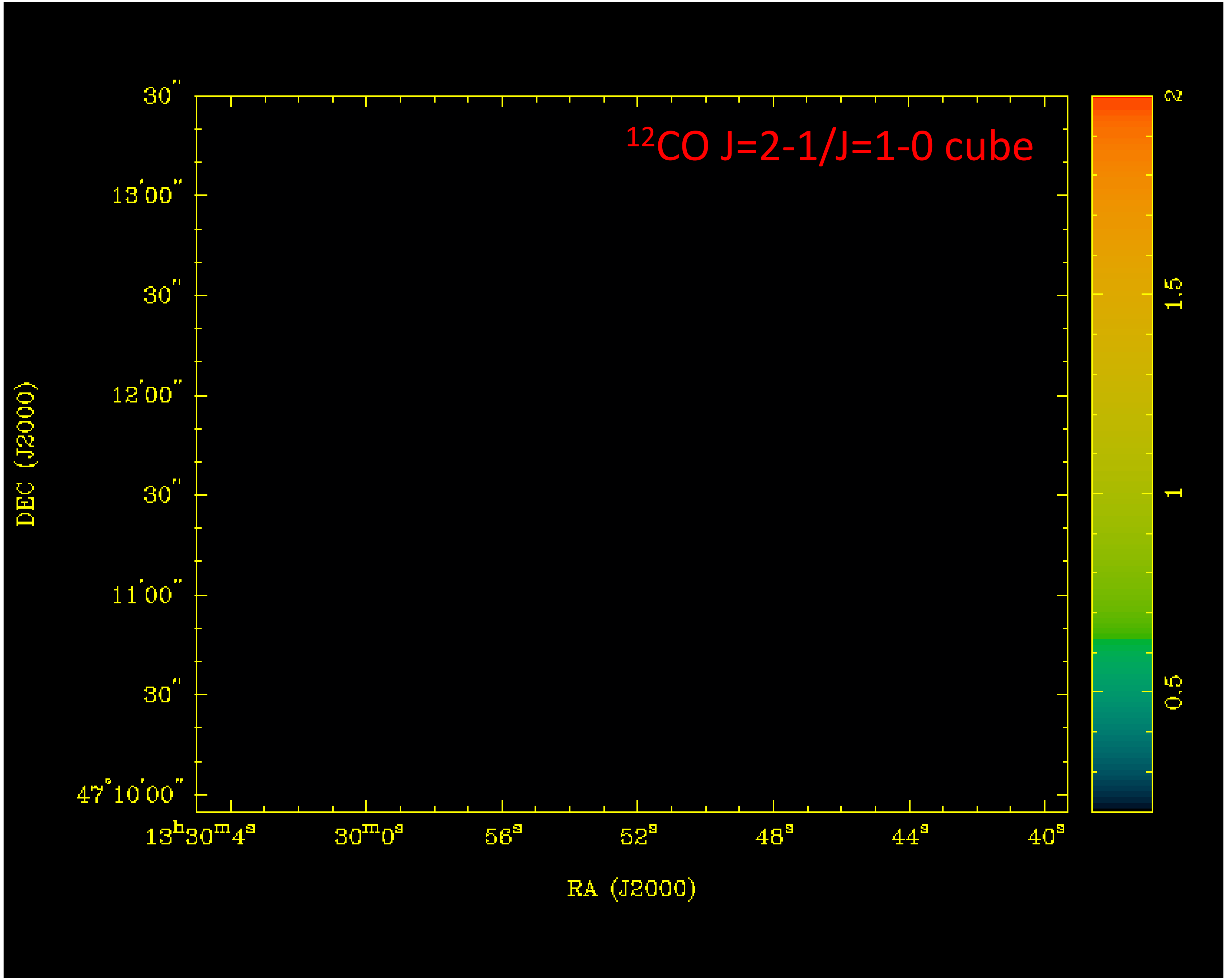
CO J=2-1

180 pointings

500”

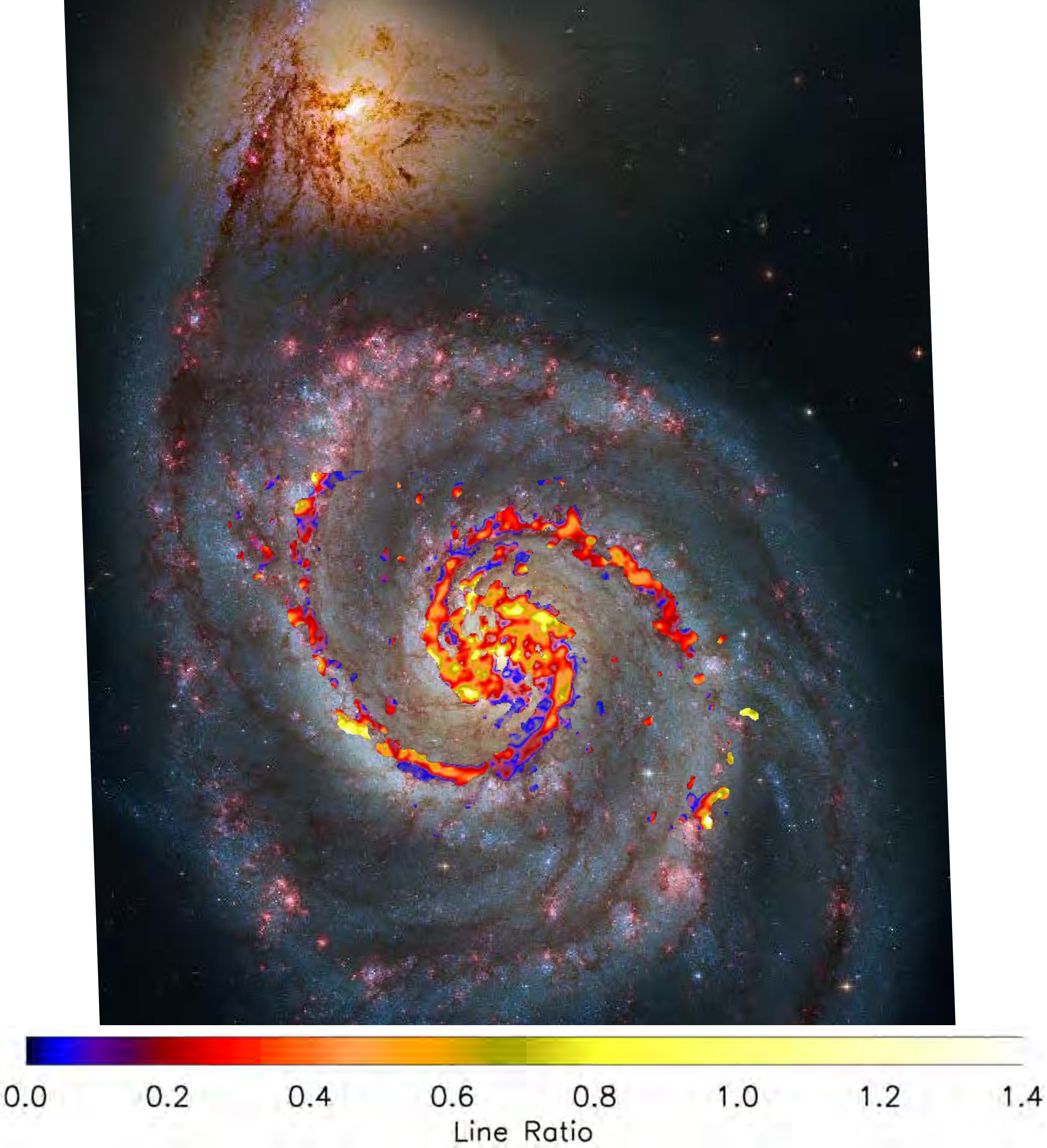
Early Science Results:





12CO J=2-1/J=1-0 cube
DEC (J2000)
RA (J2000)
30"
13'00"
30"
12'00"
30"
11'00"
30"
47°10'00"
13h30m4s
30m0s
56s
52s
48s
44s
40s
2
1.5
1
0.5

M51



Summary

We have used the SMA to map CO J=2-1 in the *entire* M51 system.

We have created CO J=2-1 / J=1-0 line ratio allowing us to estimate gas temperatures and density which can be compared to star formation activity and dynamical structures.

We also have ^{13}CO and $C^{18}O$ J=2-1 which allows full radiative transfer modeling of density and temperatures across the entire system.