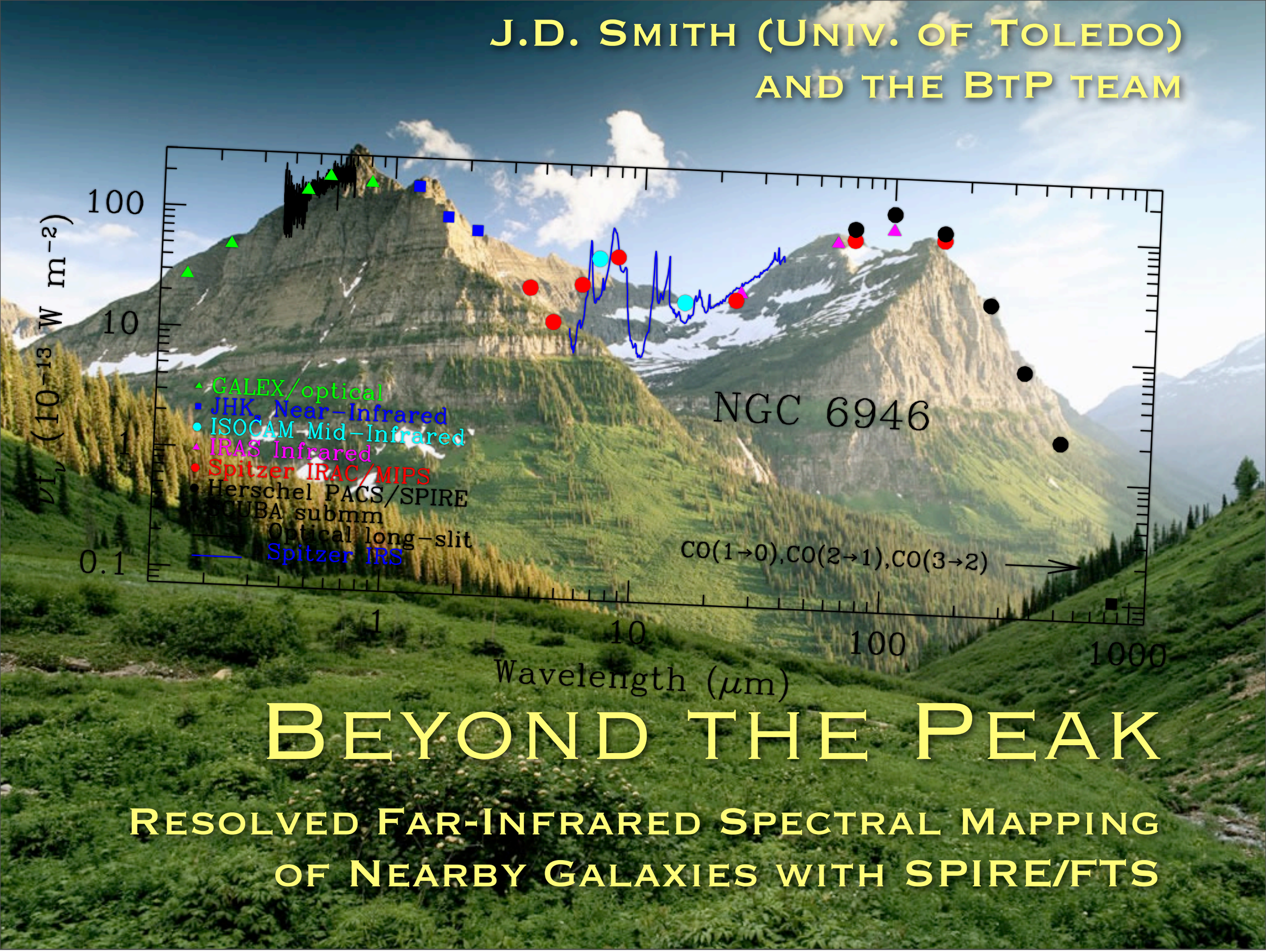
J.D. Smith (Univ. of Toledo)
and the BtP team

Beyond the Peak

Resolved Far-Infrared Spectral Mapping of Nearby Galaxies with SPIRE/FTS

J.D. Smith (Univ. of Toledo)
and the BtP team



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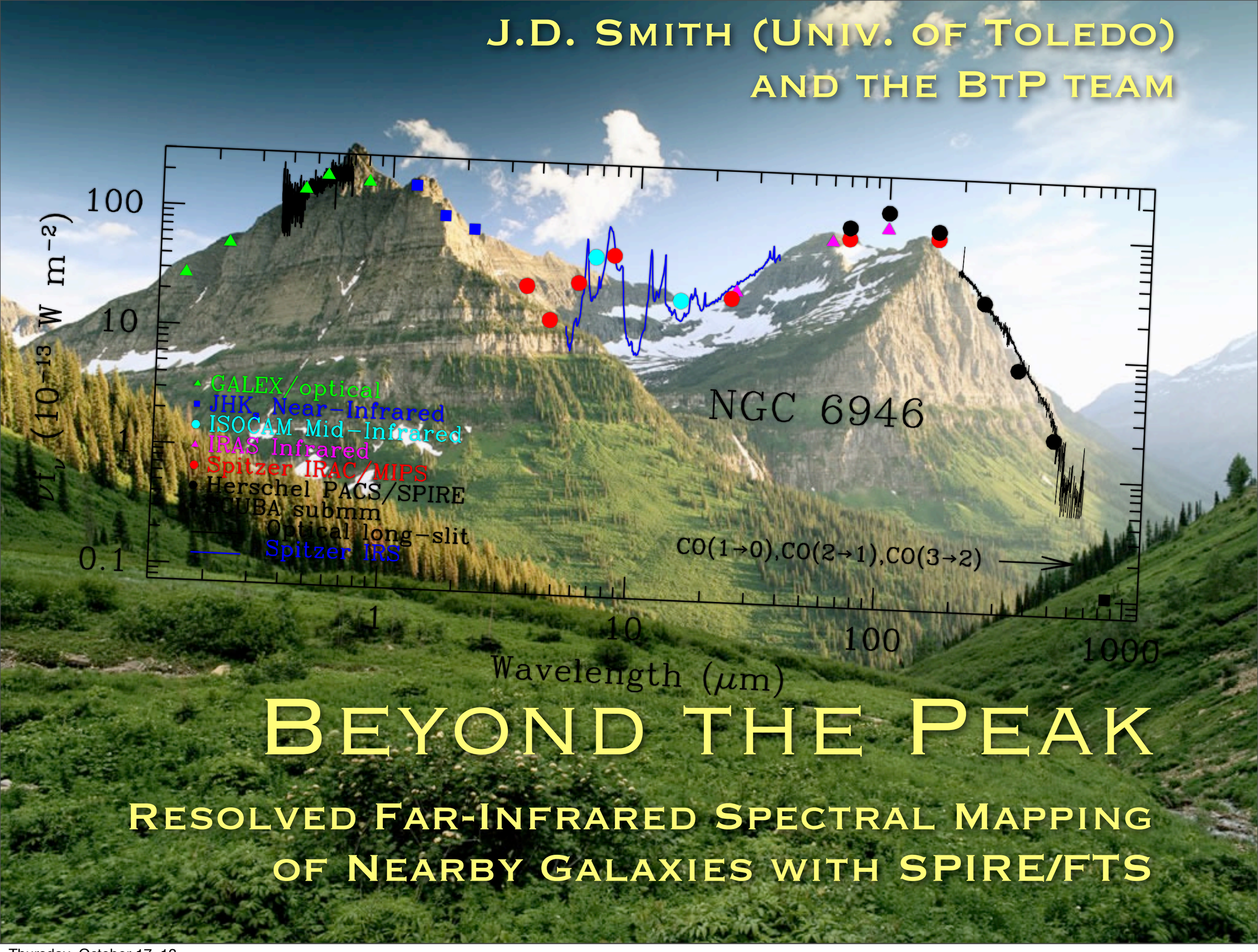

Beyond the Peak

Resolved Far-Infrared Spectral Mapping of Nearby Galaxies with SPIRE/FTS

Beyond the Peak: OverView

- ~150 hr OT1 program

- 22 Galaxies, 1 extra-nuclear region, drawn from KingFish survey

- High-resolution, fully sampled 200–600μm Mapping spectroscopy (~85% of it)

  - Continuum
  - CO J=4-3 to 13-12
  - [NII] 205μm
  - CI 370 & 609 μm
  - (H_2O, OH, ...)

Kingfish (Key Insights on Nearby Galaxies: a Far-Infrared Survey with Herschel)

http://www.ast.cam.ac.uk/research/kingfish

NGC 2841
NGC 3938
NGC 628
NGC 7793
NGC 3190
NGC 4826
NGC 2976
NGC 4254
NGC 3621
NGC 5055
NGC 3265
NGC 5474
NGC 4594
NGC 4736
NGC 7331
NGC 584
NGC 4321
NGC 855
NGC 1482
NGC 4579
NGC 3521
NGC 3184
NGC 3773
NGC 1404
NGC 5866
NGC 4725
NGC 1377
NGC 4559
NGC 6946
NGC 1316
NGC 5713
NGC 4569
IC 342
NGC 1266
NGC 3627
NGC 5457
NGC 2798
NGC 4536
NGC 925
NGC 1291
NGC 2146
NGC 3077
NGC 3049
NGC 1097
NGC 5398
NGC 337
NGC 4236
NGC 1512
NGC 4631
NGC 3198
NGC 3351
DDO 154
NGC 2915
DDO 165
NGC 5408
DDO 53
IC 2574
Holmberg I
Holmberg II
M81 Dw B
NGC 4625

Elliptical — S0 — Sa — Sb — Sc — Sd

SBa — SBb — SBc — SBd

Irregular

MIPS 24 μm / PACS 100 μm / SPIRE 250 μm

Beyond the Peak

NGC 2841
NGC 3938
NGC 628
NGC 7793
NGC 3190
NGC 4826
NGC 2976
NGC 5055
NGC 4254
NGC 3621
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NGC 5474
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Irregular
NGC 4625

MIPS 24 μm / PACS 100 μm / SPIRE 250 μm

- JD Smith, Toledo (PI)
- Lee Armus, SSC/Caltech
- Pedro Beirao, Paris Obs.
- Alison Crocker, Toledo
- Kevin Croxall, OSU
- Danny Dale, Wyoming
- Bruce Draine, Princeton
- Alberto Bolatto, Maryland
- Matt Bradford, JPL/ Caltech
- Elias Brinks, Hertfordshire
- Daniela Calzetti, UMass
- Brent Groves, MPIA
- Leslie Hunt, INAF, Arcetri
- Rob Kennicutt, Cambridge
- Johan Knapen, IAC
- Jin Koda, Stony Brook
- Kathryn Kreckel, MPIA
- Adam Leroy, NRAO
- Eric Murphy, SSC/Caltech
- Eric Pellegrini, Toledo
- Dimitra Rigopoulou, Oxford/RAL
- Erik Rosolowsky, Alberta
- Karin Sandstrom, MPIA
- Eva Schinnerer, MPIA
- Paul van der Werf, Leiden
- Laurent Vigroux, IAP
- Fabian Walter, MPIA
- Christine Wilson, McMaster
- Mark Wolfire, Maryland

MIPS 24 μm / PACS 100 μm / SPIRE 250 μm


NGC1097


NGC1266


NGC1377


NGC1482


NGC2798


NGC2976


NGC3077


NGC3351


NGC
3521


NGC3627


NGC4254


NGC4321


NGC4536


NGC
4569


NGC4631


NGC4736


NGC4826


NGC5055


NGC5457

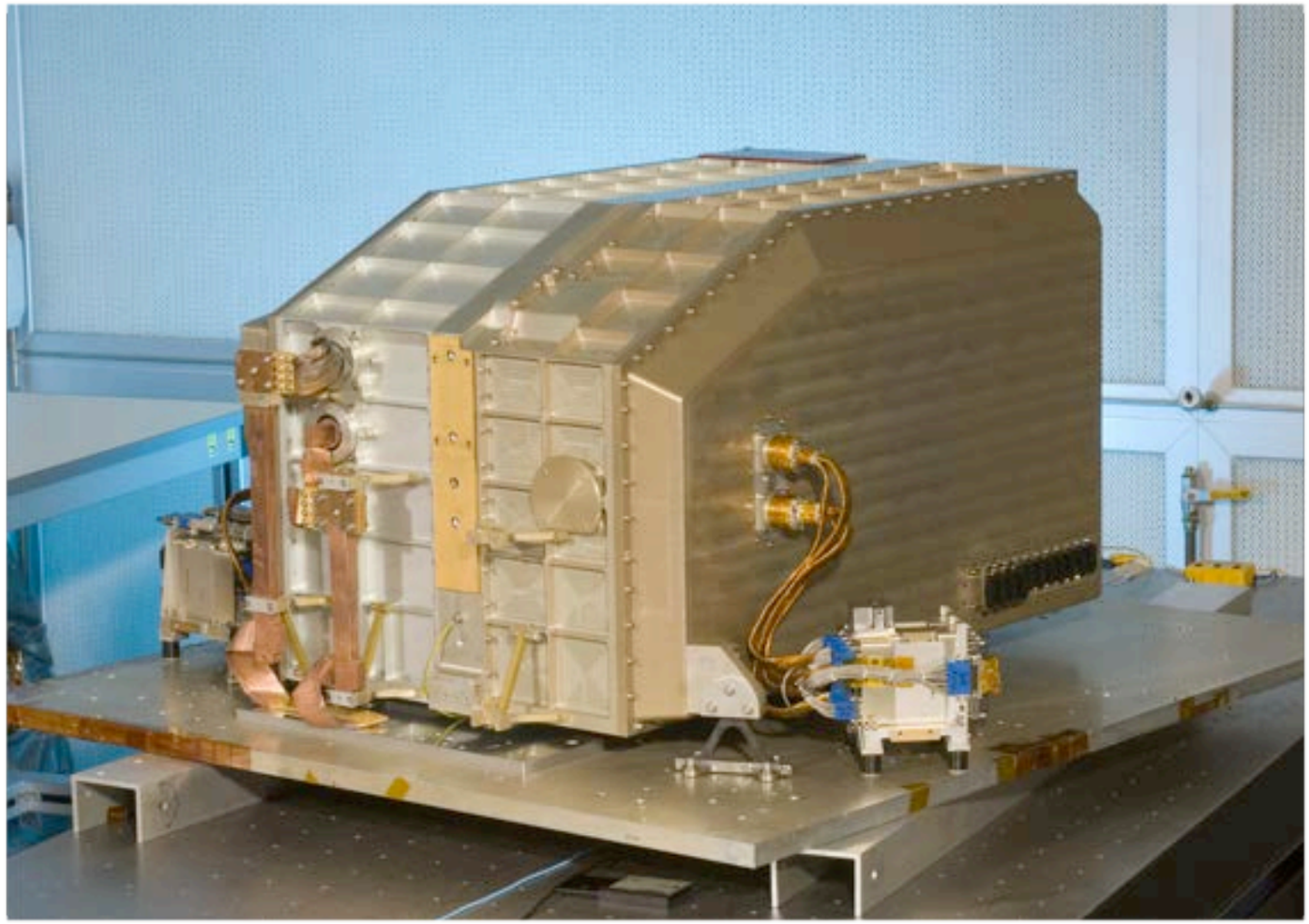

NGC5713


NGC6946


NGC
7331

Thanks SPIRE/FTS Team!

Post-Launch Sensitivity: Increased by 4x !!!



special thanks to D. Rigopolou, R. Hopwood, E. Polehampton

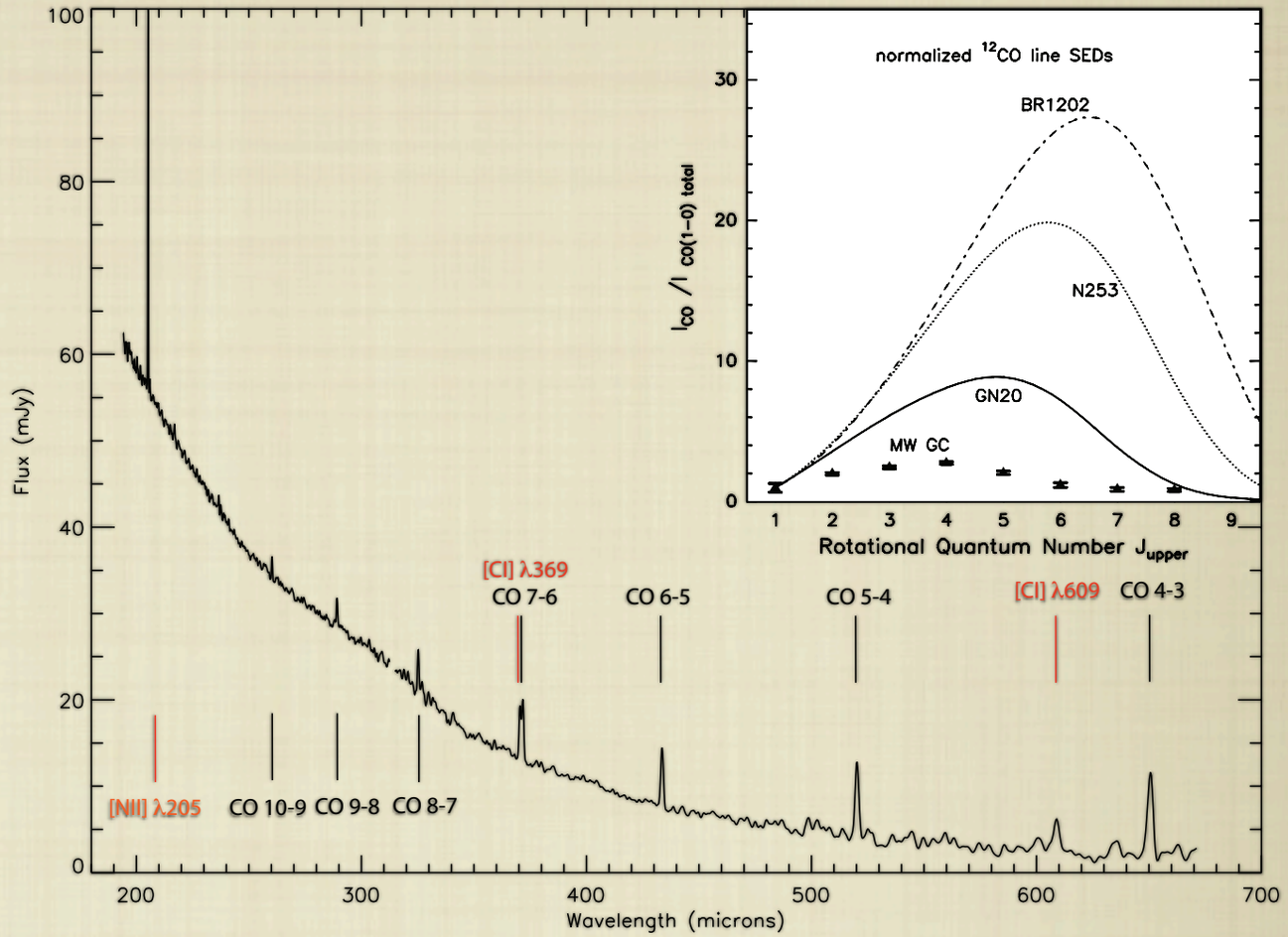
THANKS SPIRE/FTS TEAM!

POST-LAUNCH SENSITIVITY: INCREASED BY 4× !!!

SPECIAL THANKS TO D. RIGOPOLOU, R. HOPWOOD, E. POLEHAMPTON

Key science themes

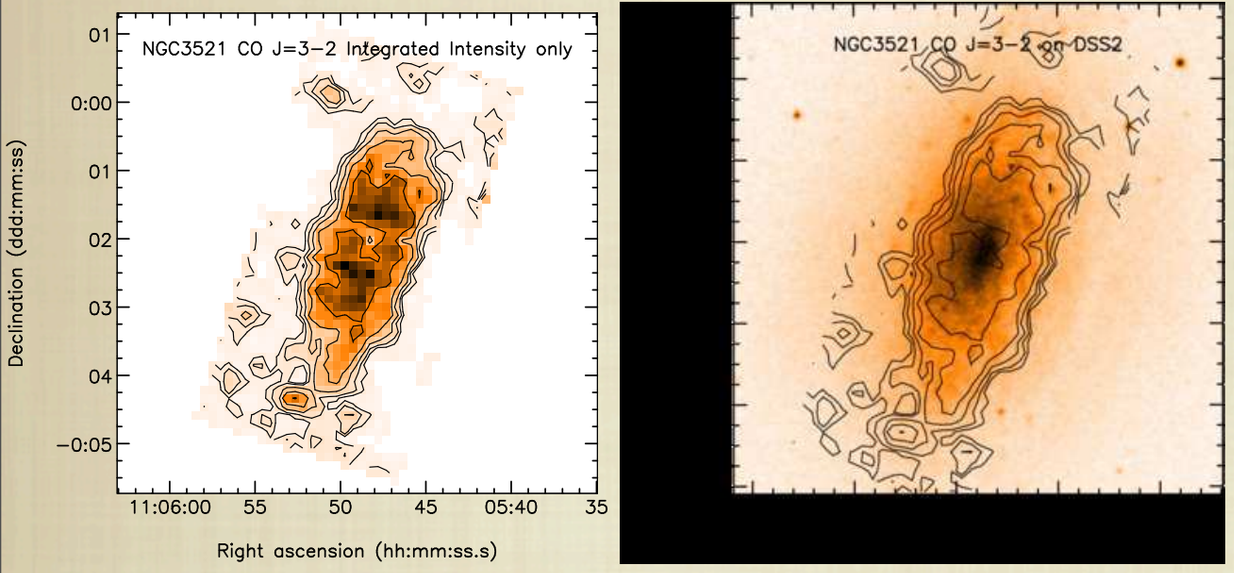
- **Resolved Gas:**
  - **CO Excitation Conditions**
  - **α_{CO} & SF-law**
  - **XDR vs. PDR**
  - **Ionized tracer**
  - **Diffuse Gas Fraction**
- **Dust: careful test of emissivity slope/flattening.**
- **High-Redshift prescriptions**



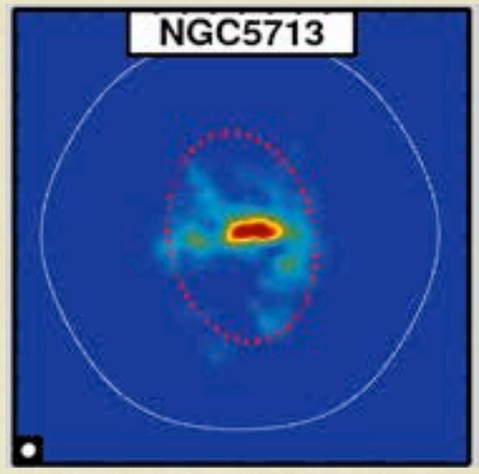
Rigopoulou+

Ground-CO

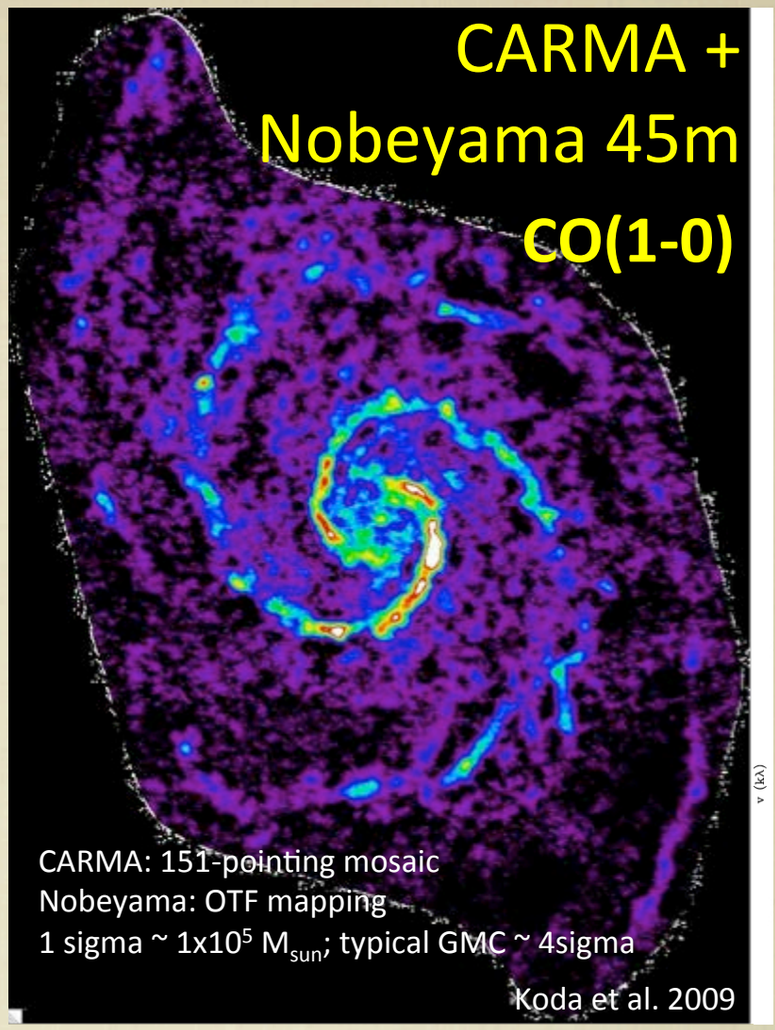
NGLS (3⇒2): Wilson+



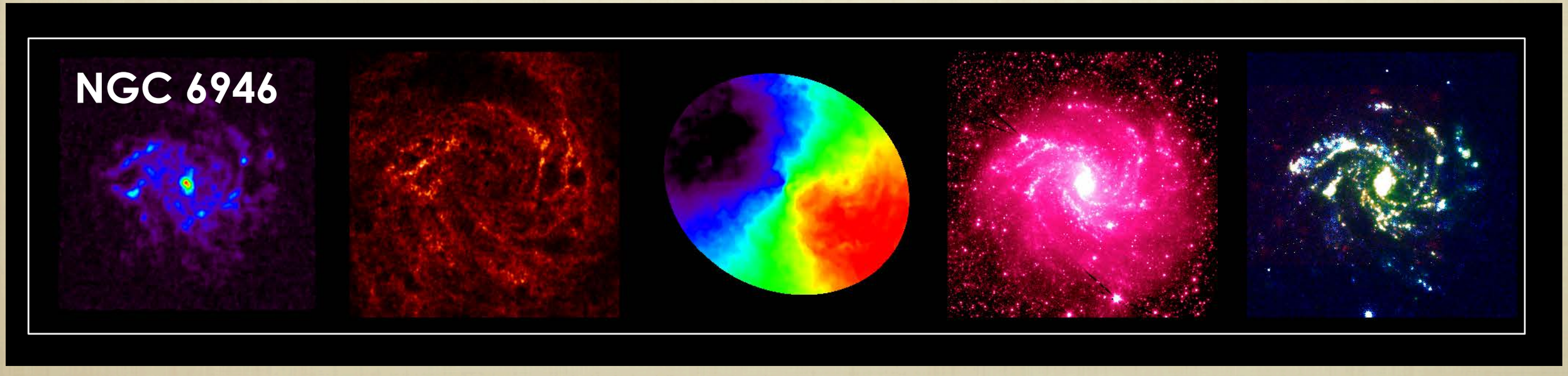
Carma Sting (1⇒0): Bolatto



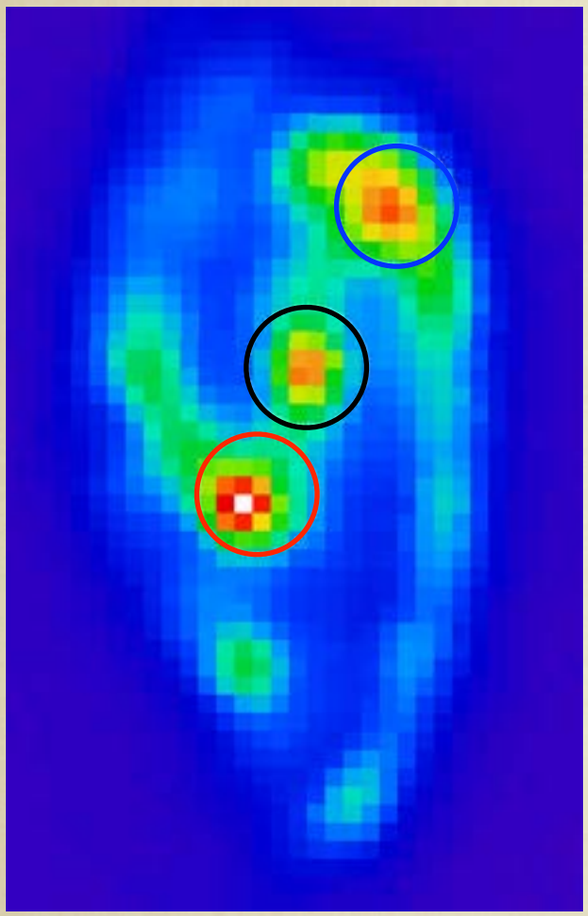
Canon (1⇒0): Koda+

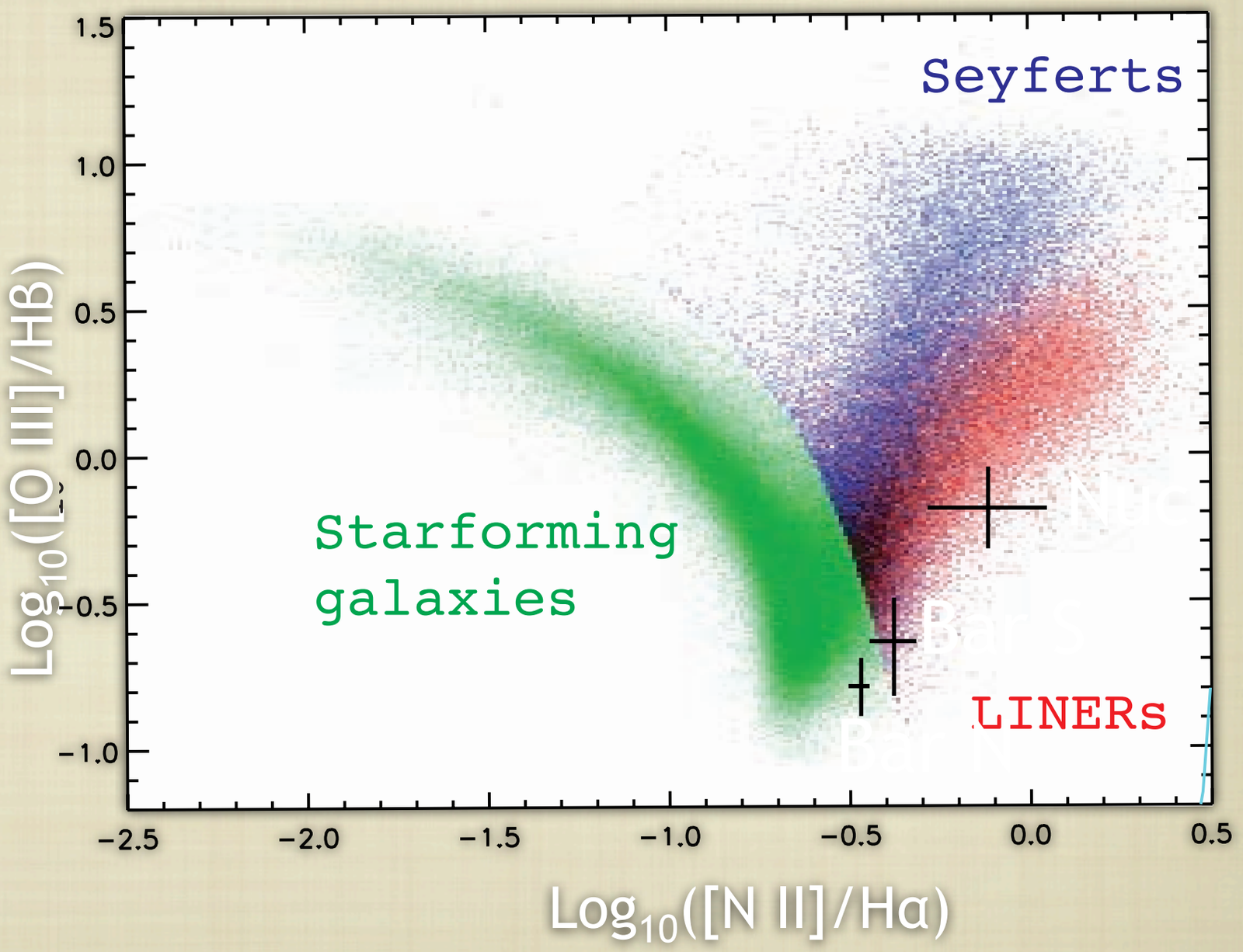


Heracles (2⇒1): Leroy/Walter+

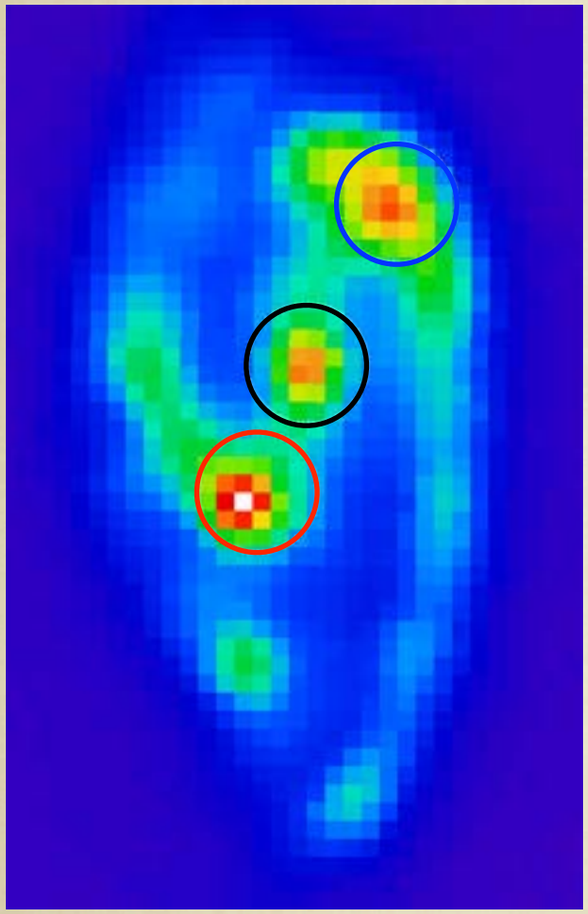


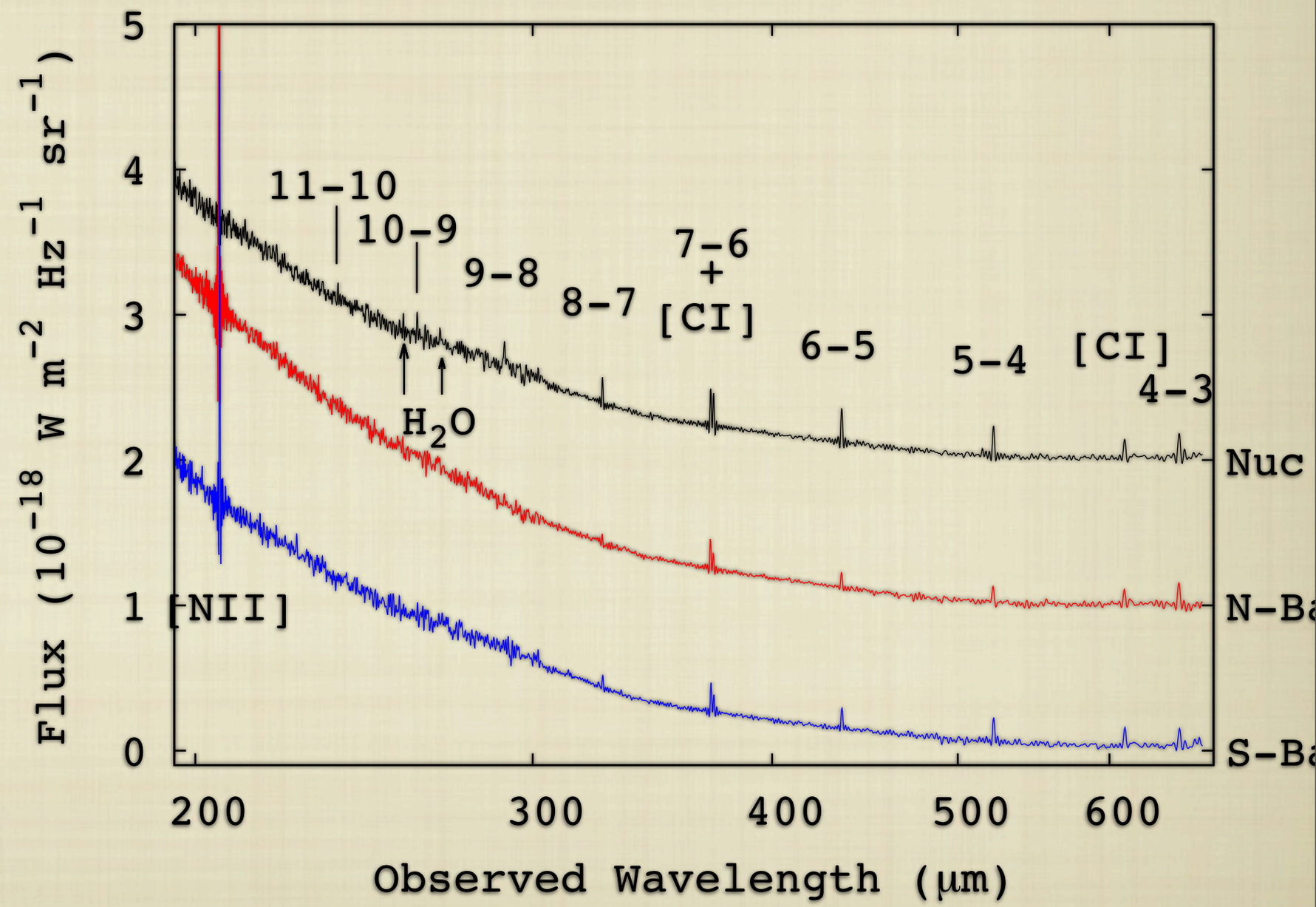
Example: NGC3627



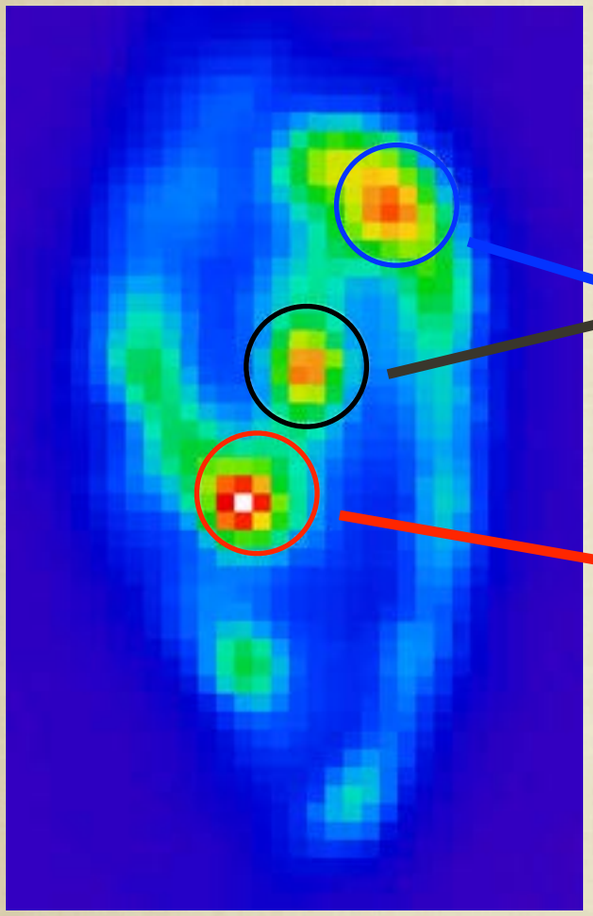


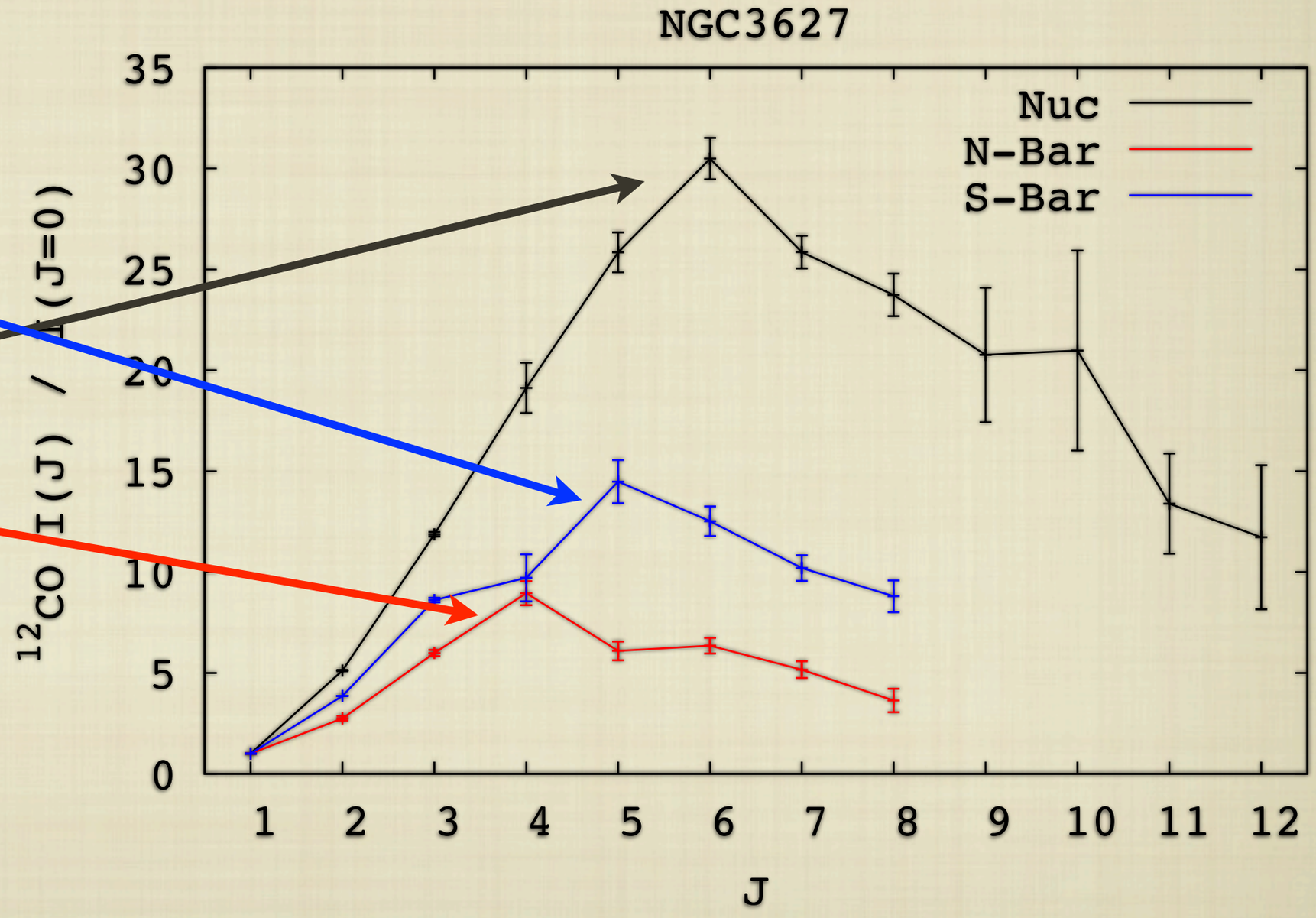
Example: NGC3627





Example: NGC3627





Mapping: [NII] 205μm

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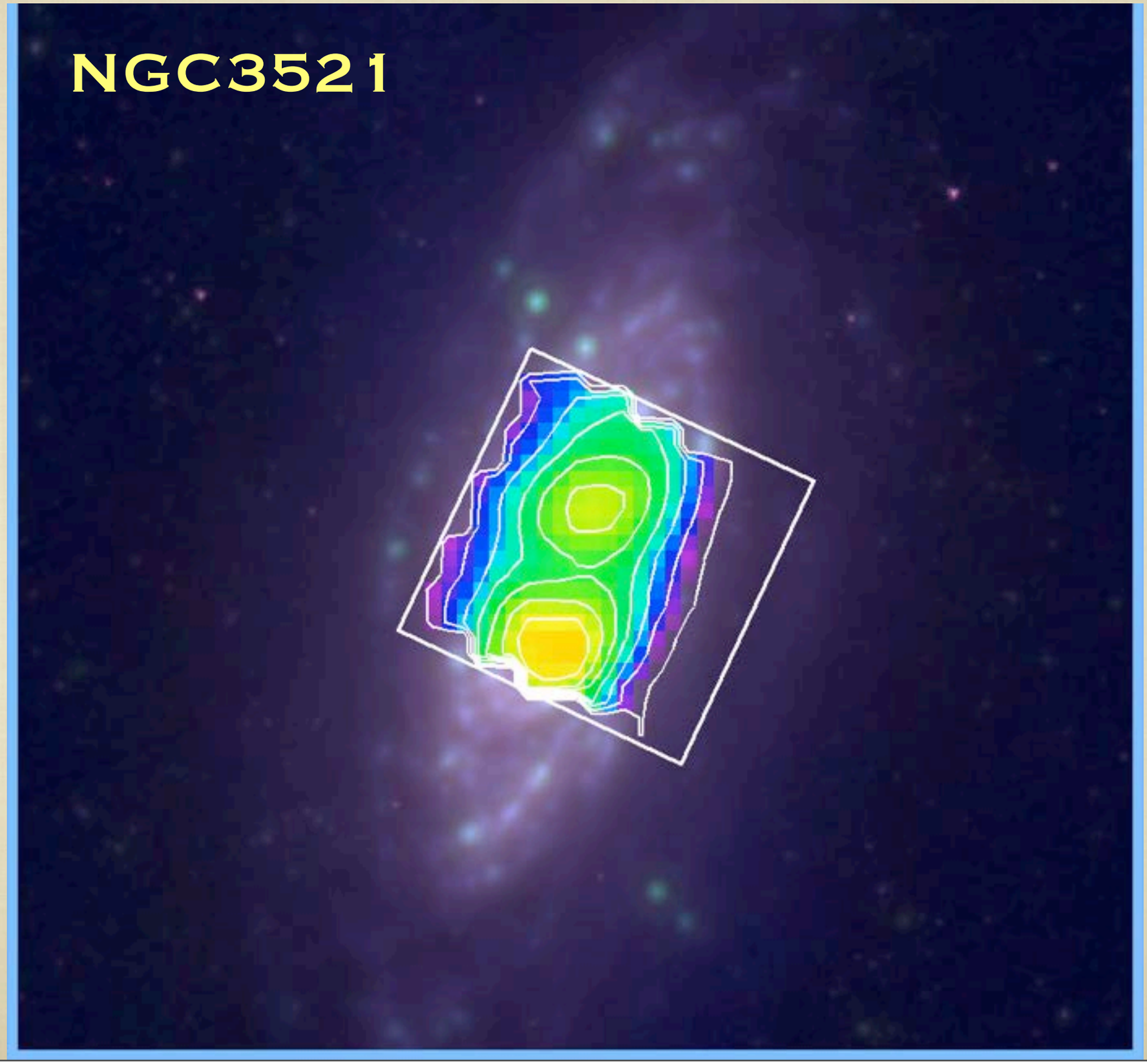

[NII] 205μm Mapping

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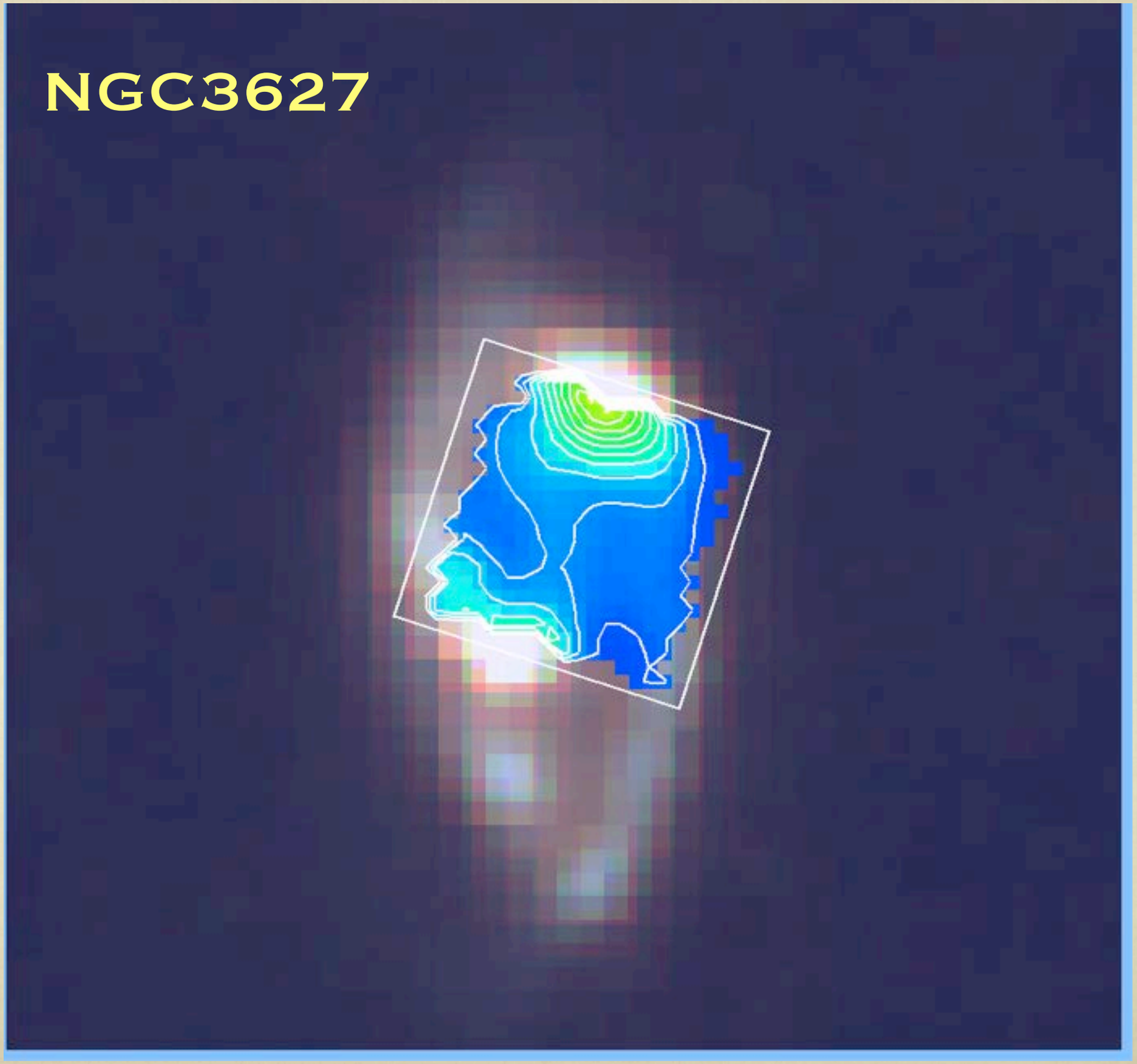
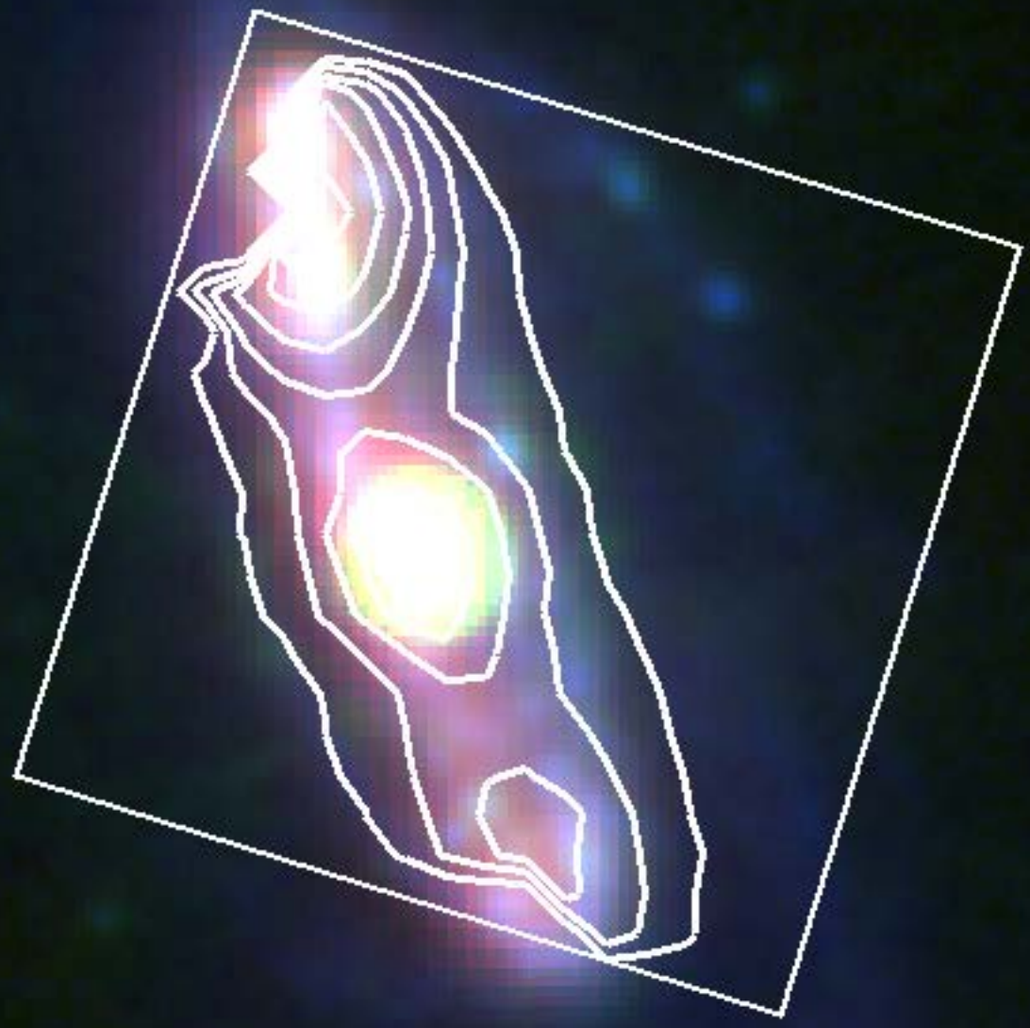


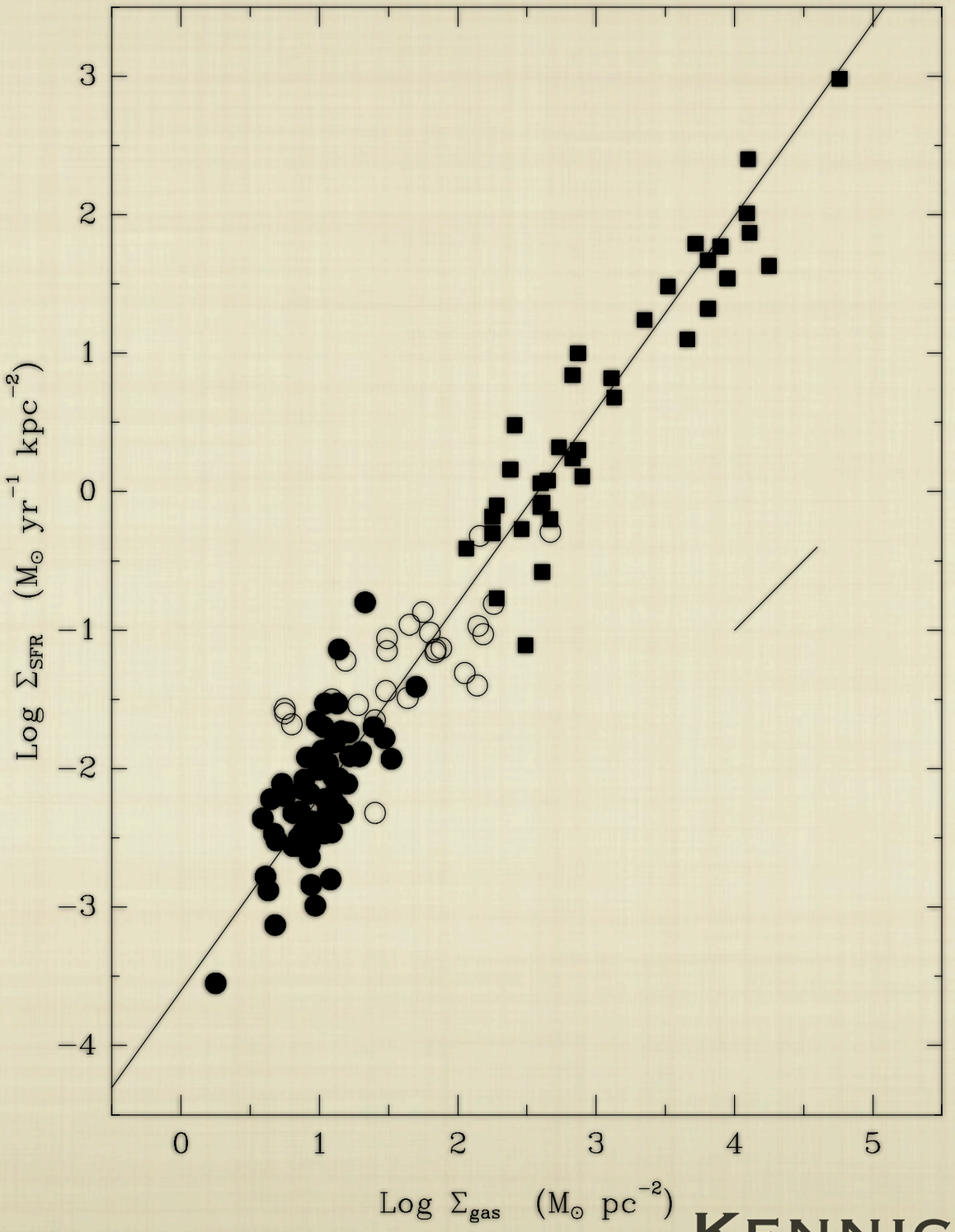
NGC4569

[NII 205μm]



How do Galaxies Assemble Stars?

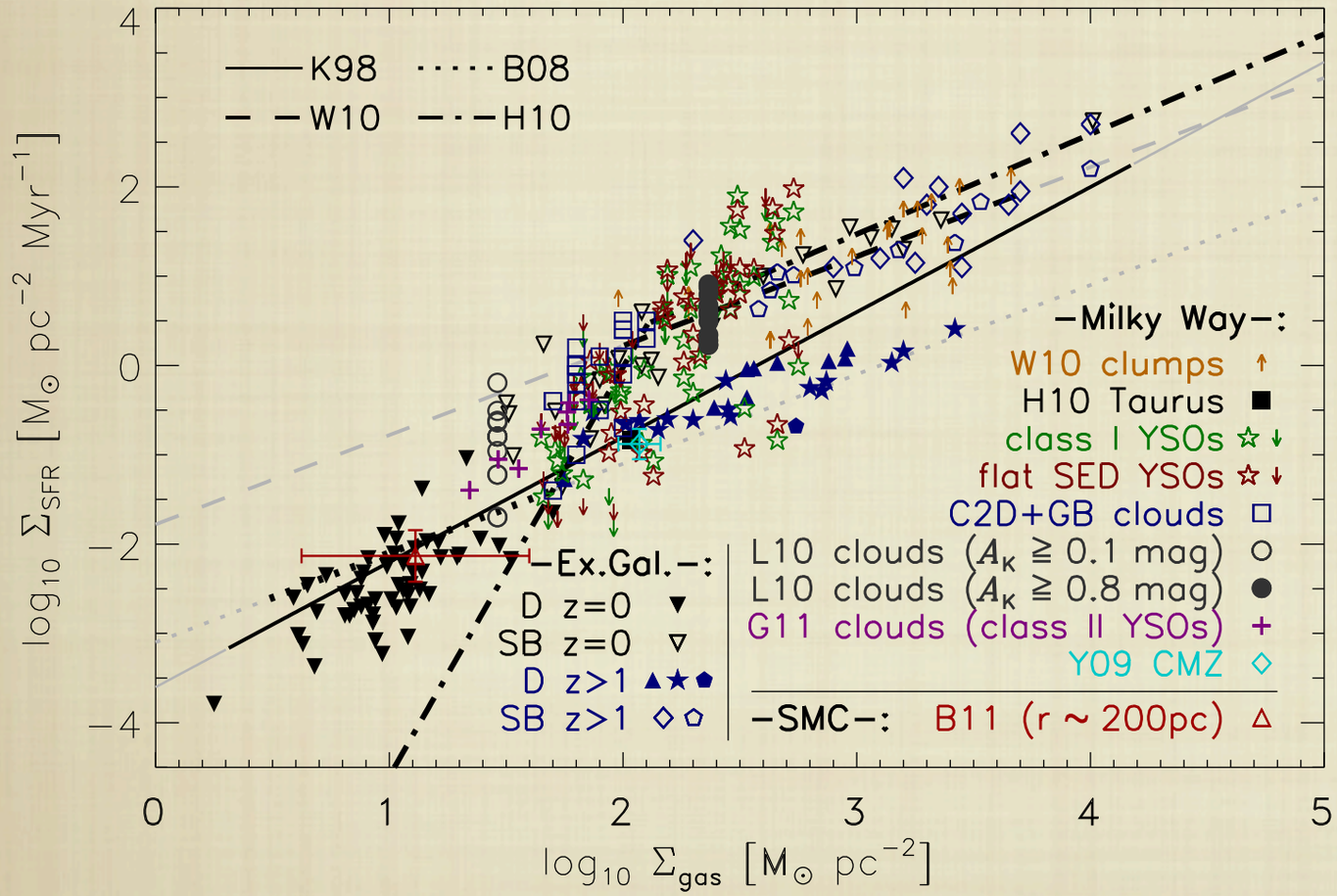
The Story, 15 years ago



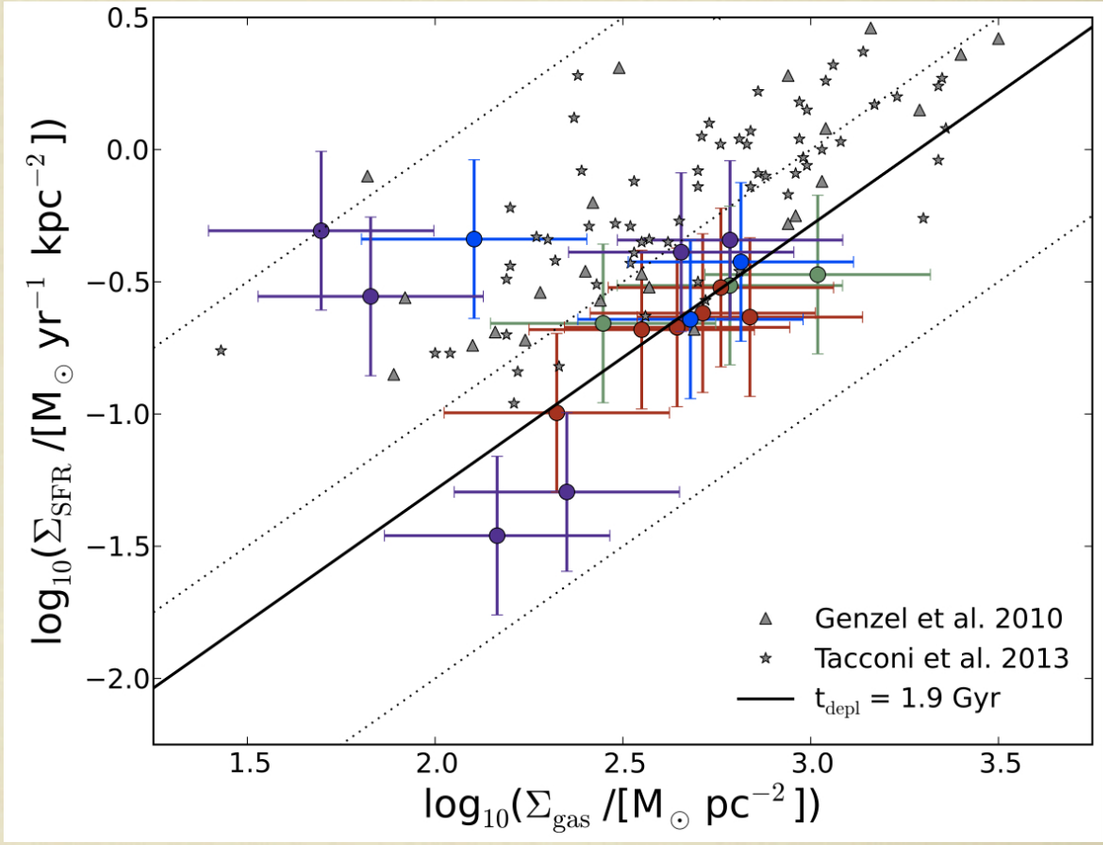
Kennicutt 1997

How do Galaxies Assemble Stars?

The Story, today



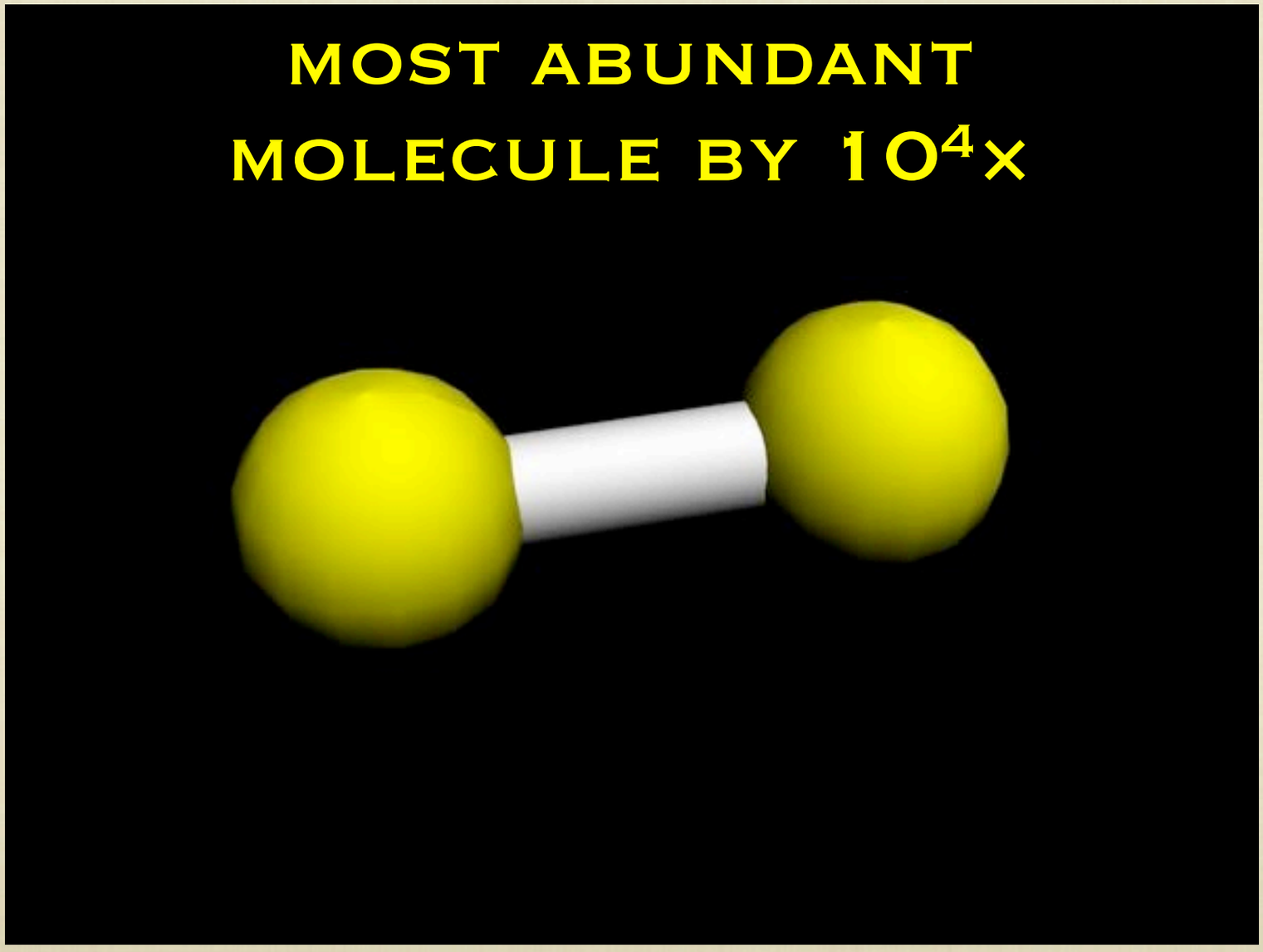
Federath, 2013



Freundlich+ 2013

What we want: The H_2 molecule

MOST ABUNDANT MOLECULE BY 10^4x



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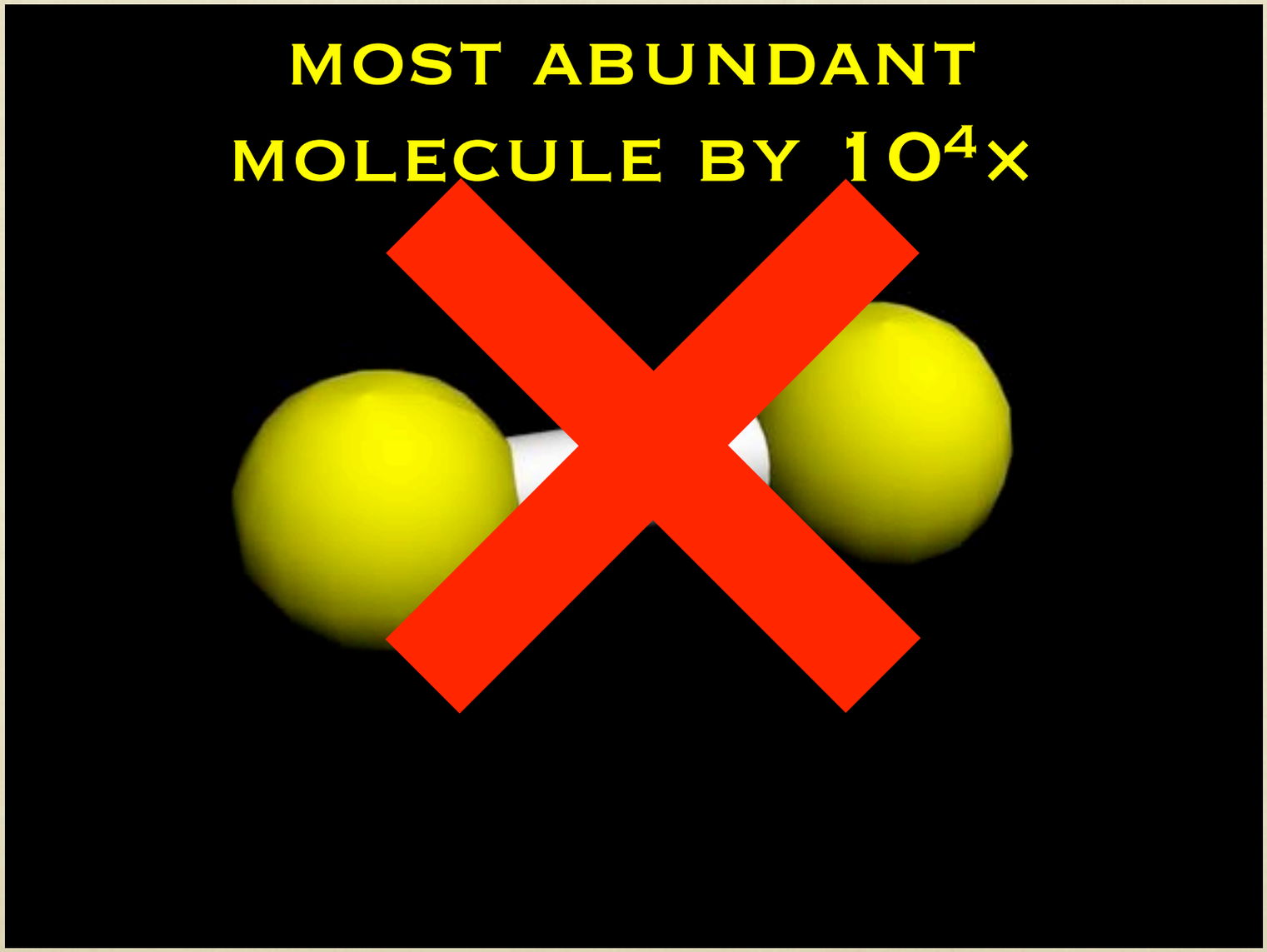

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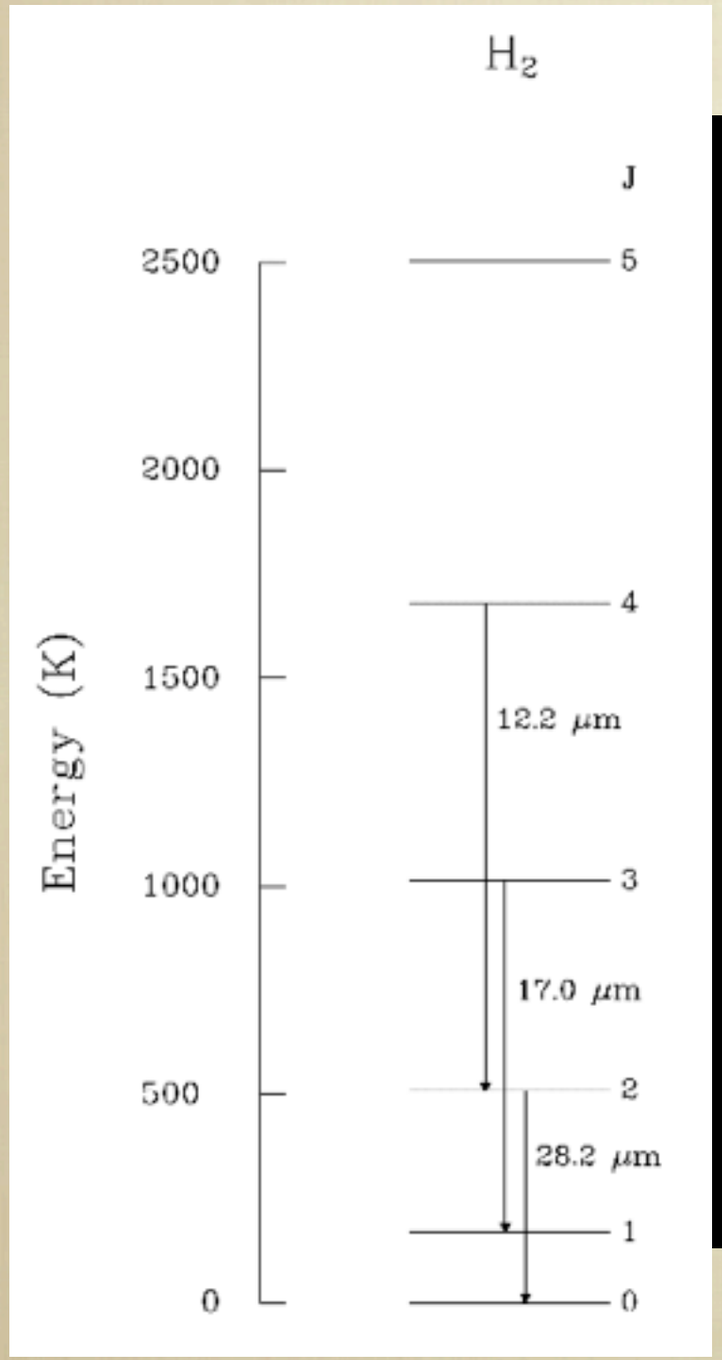
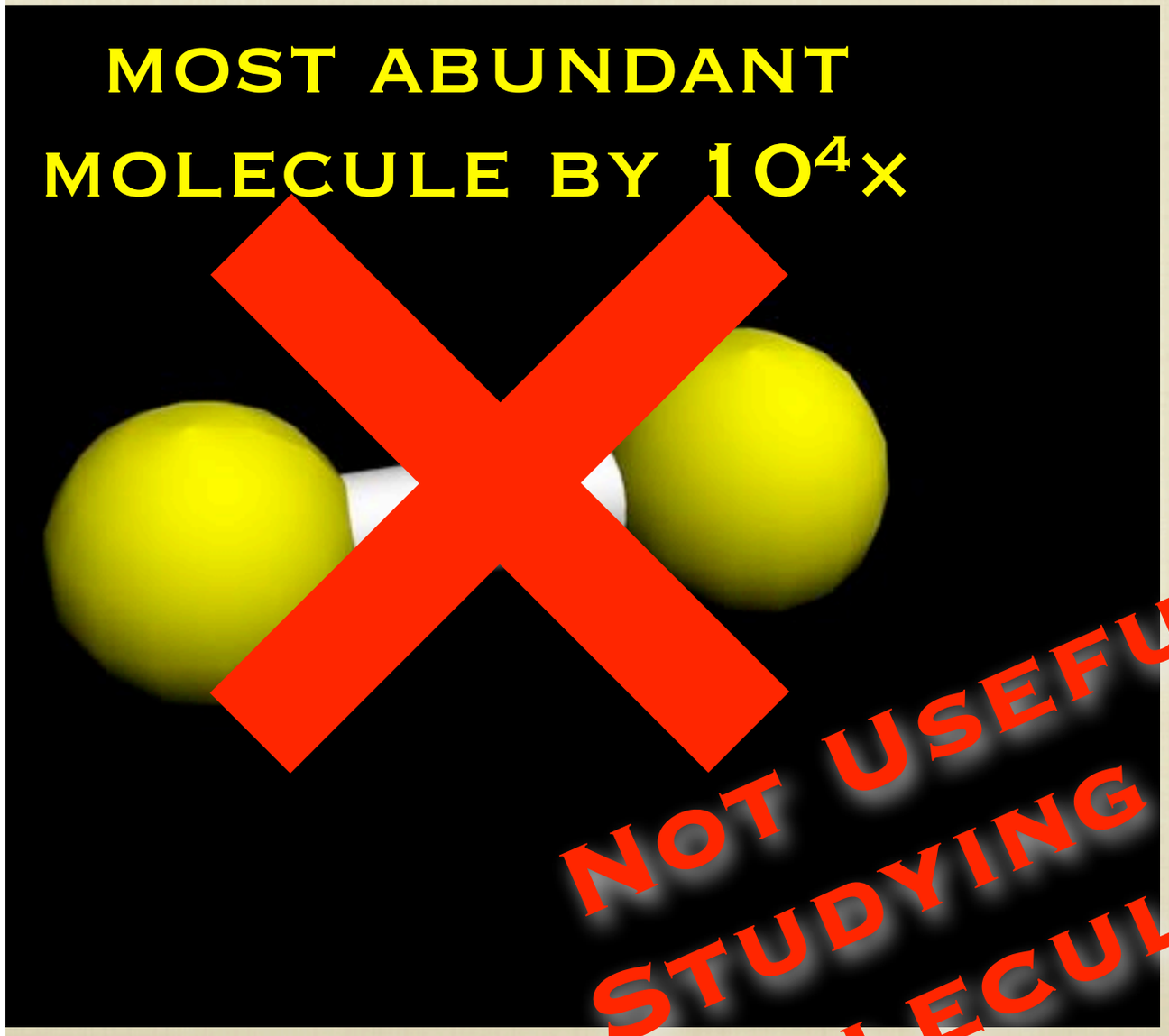
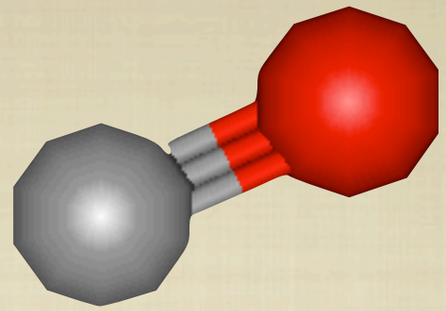
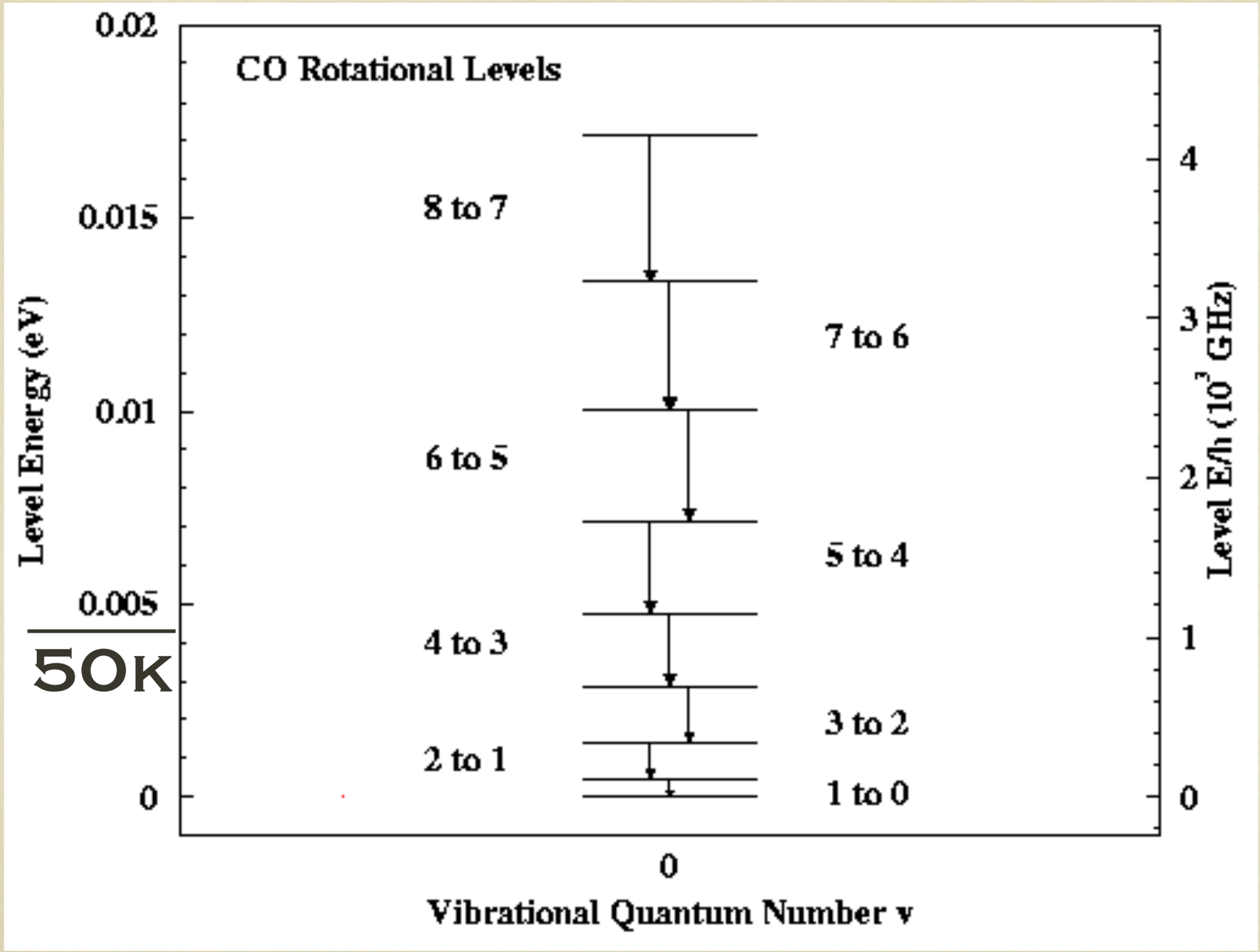




What we get: The CO Molecule





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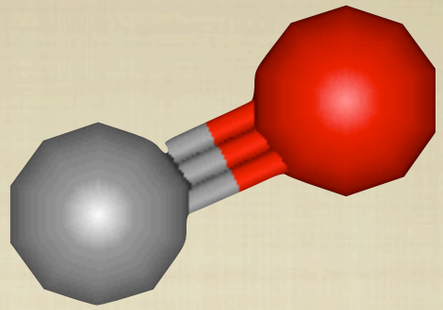

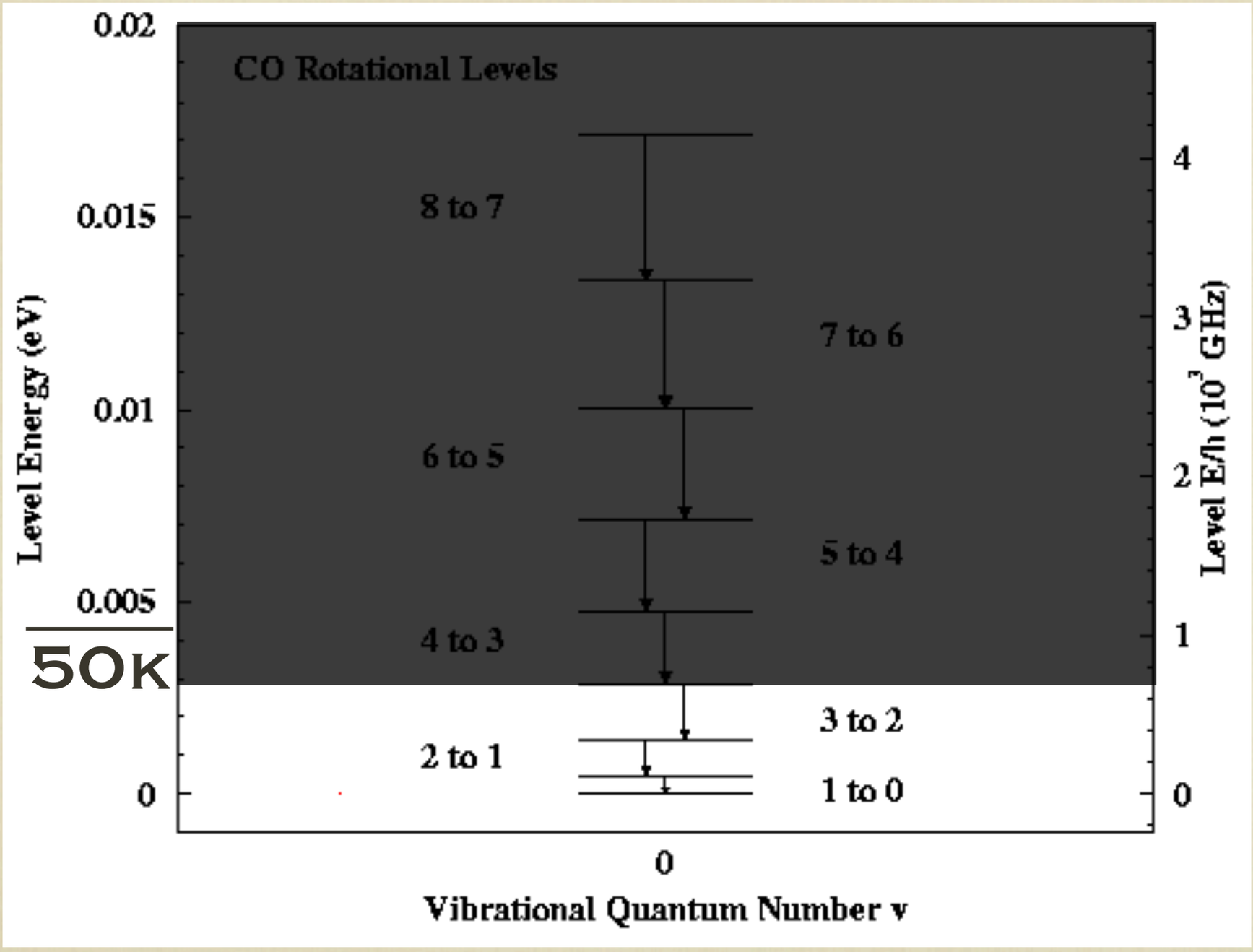

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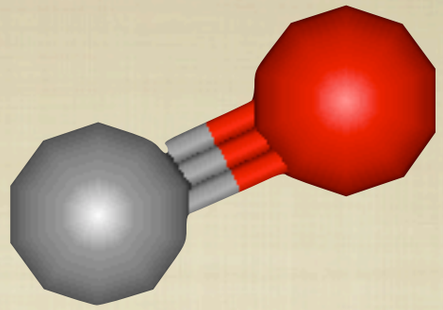
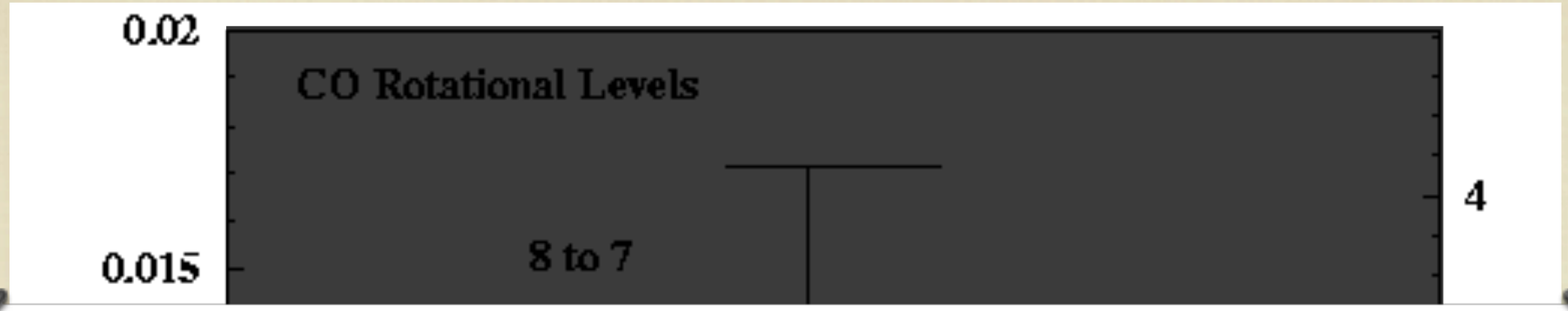
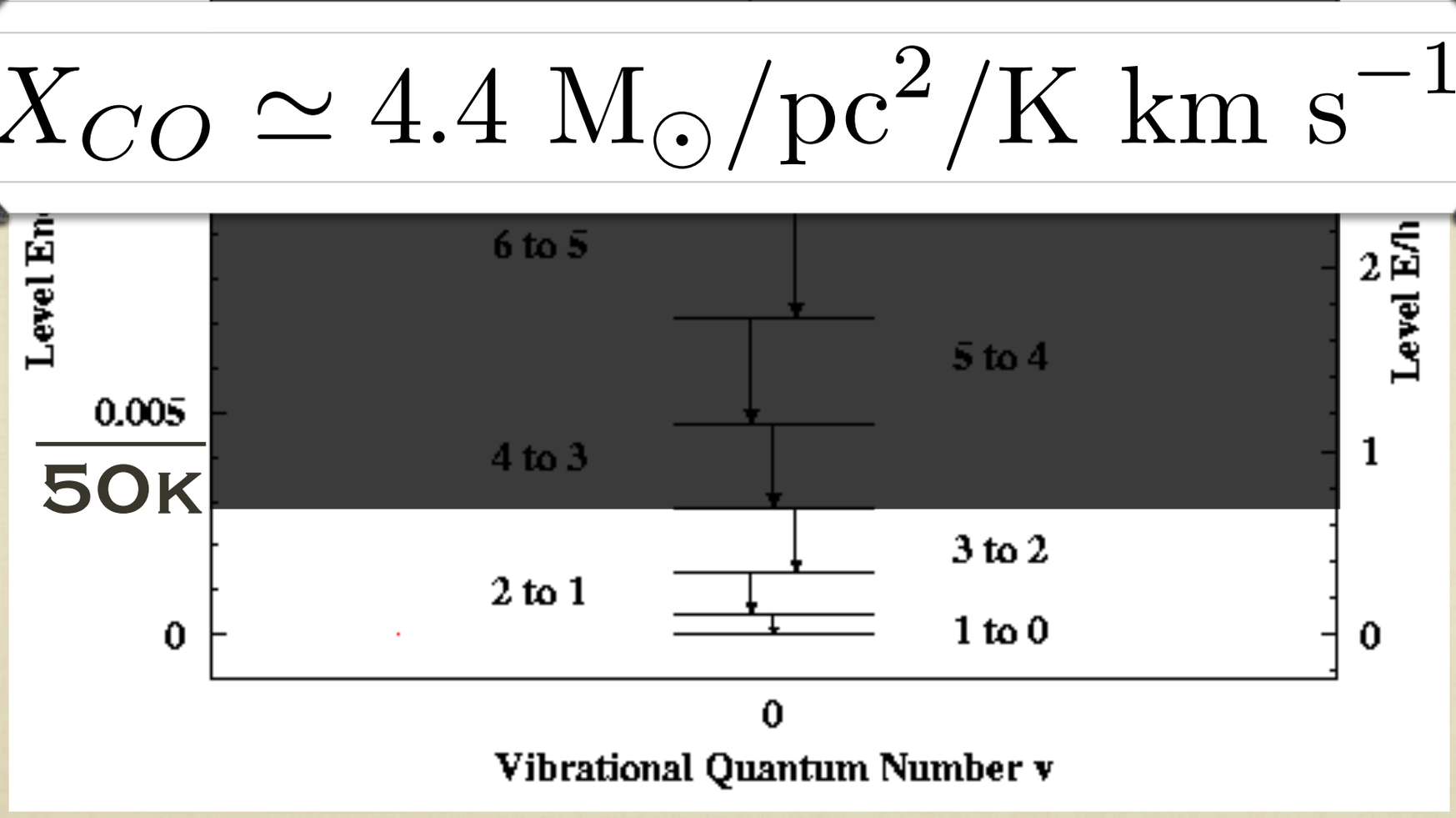
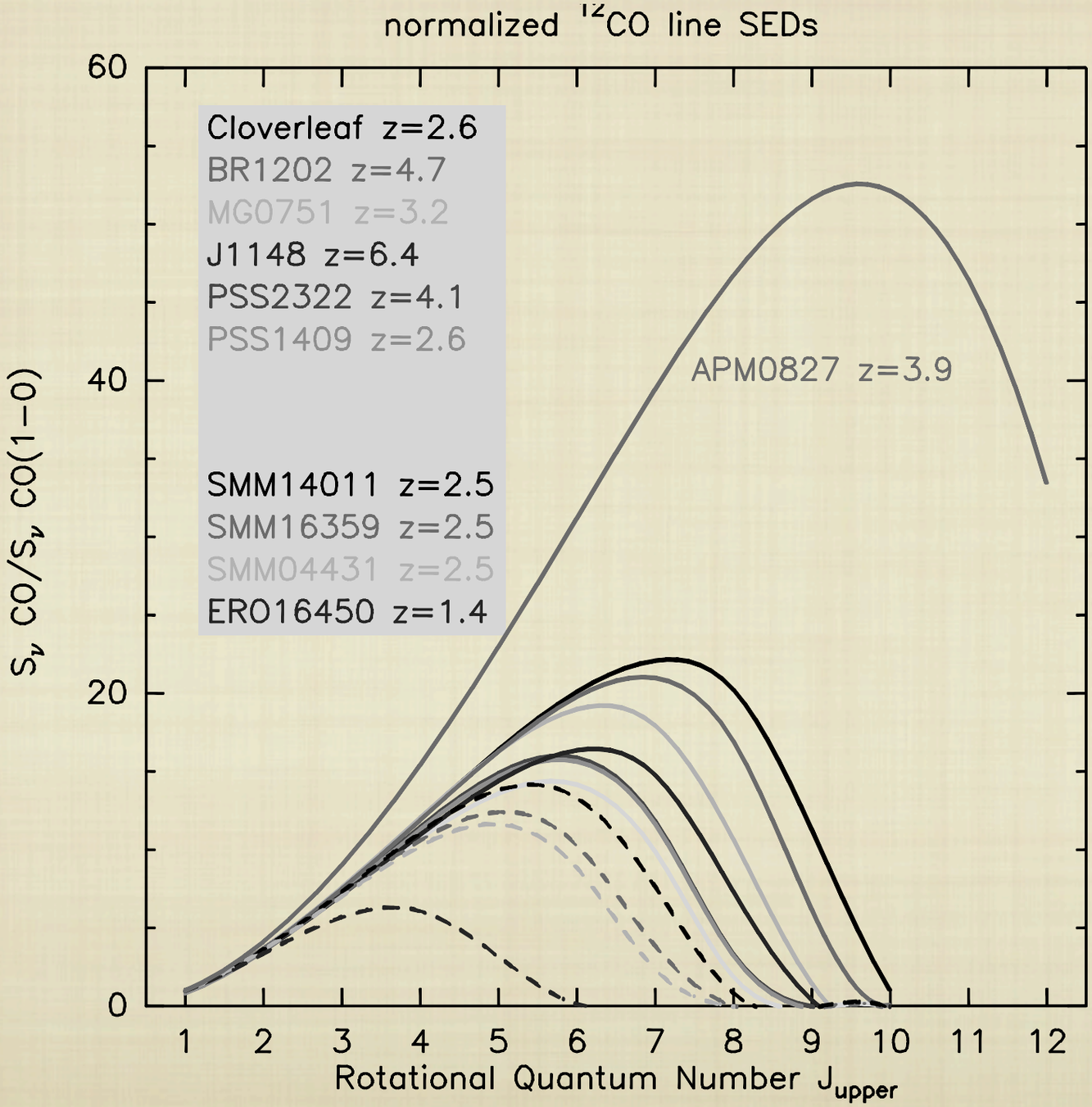




$$X_{CO} \simeq 4.4\ \mathrm{M}_\odot/\mathrm{pc}^2/\mathrm{K\ km\ s}^{-1}$$

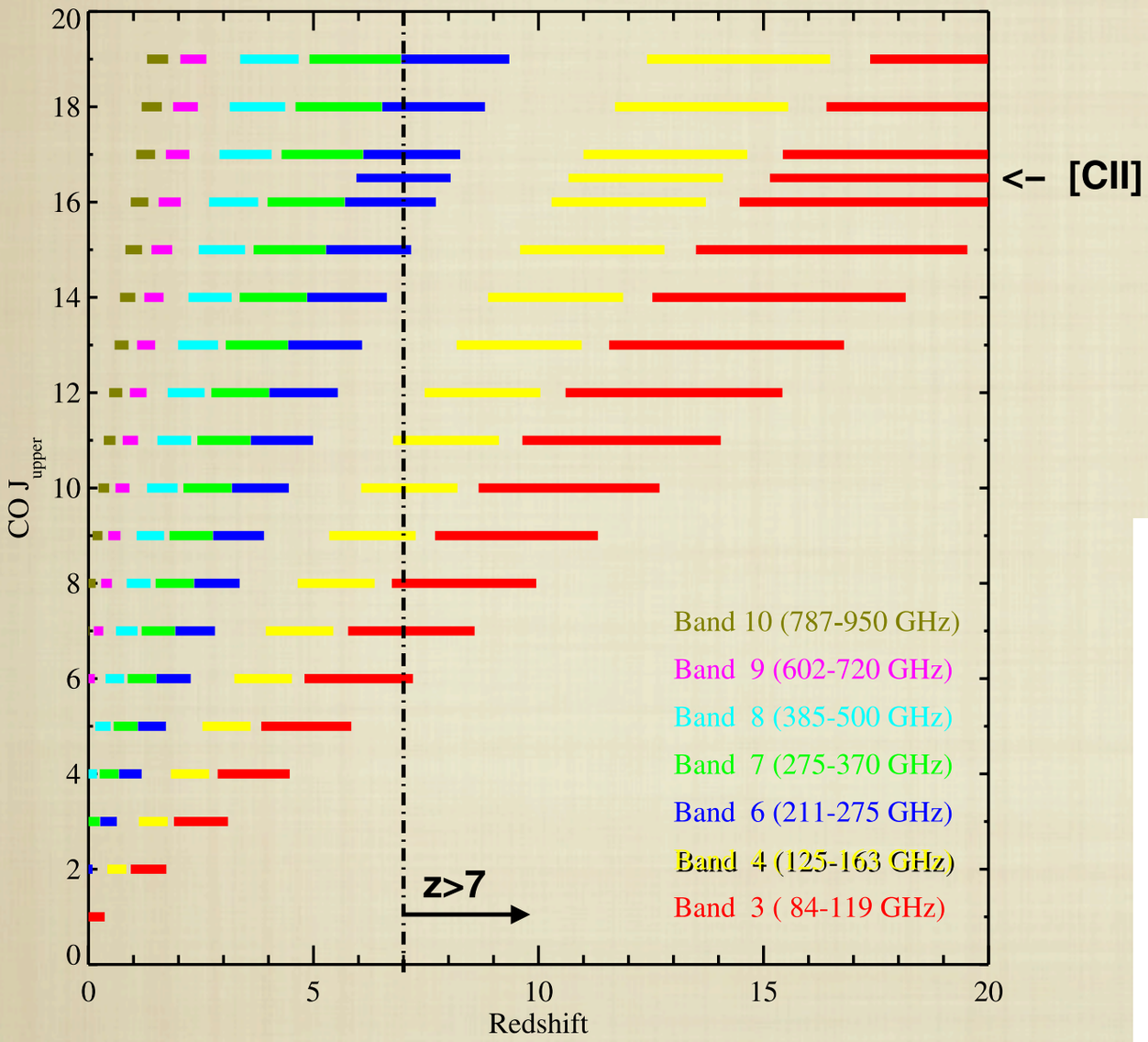


CO "SLED"

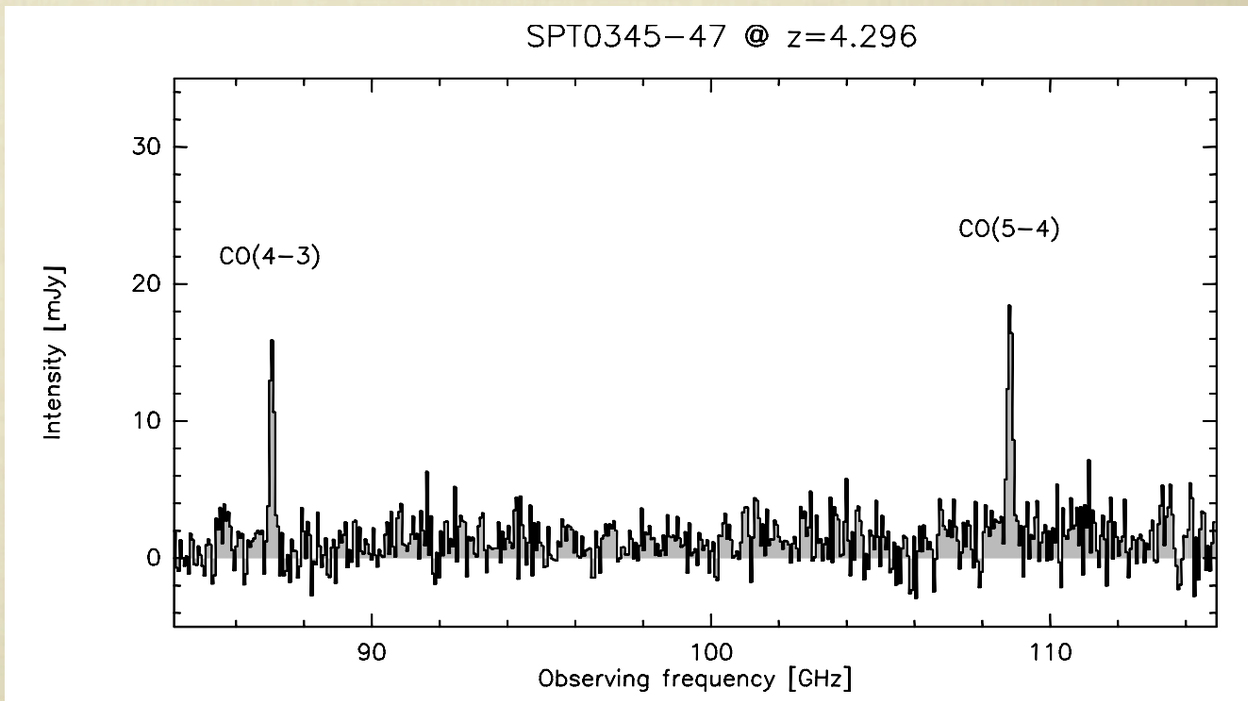


Weiss+ 2007

High-z applications



"The ability to detect spectral line emission from CO or CII in a normal galaxy like the Milky Way at a redshift of z = 3, in less than 24 hours of observation."



Walter & Carrili, 2008

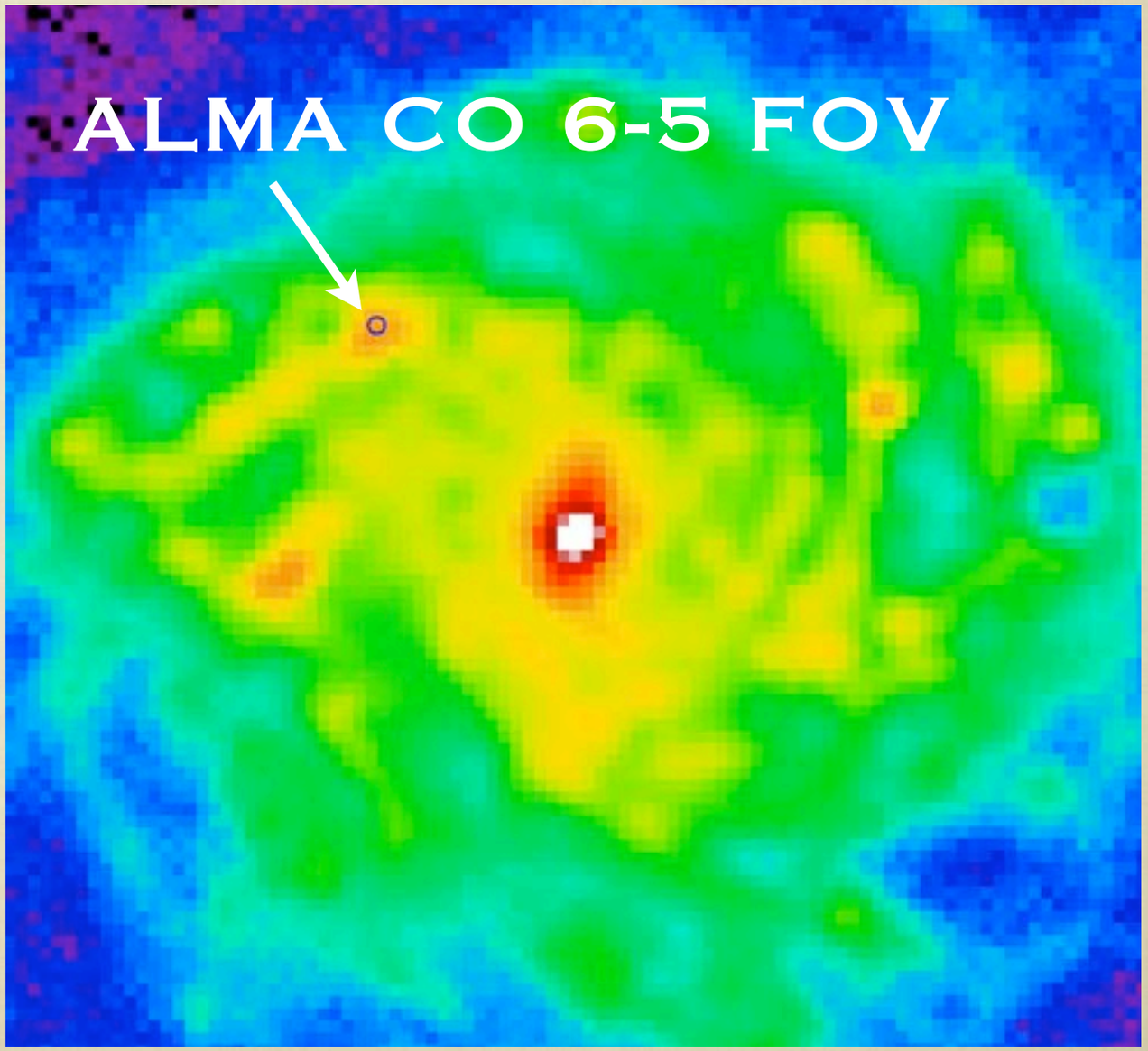
J. Vieira

Use ALMA?

- ✓ Fantastic Sensitivity.

- ✗ Very limited Field of View.

- ALMA is not ideally suited to providing a calibration of gas excitation.



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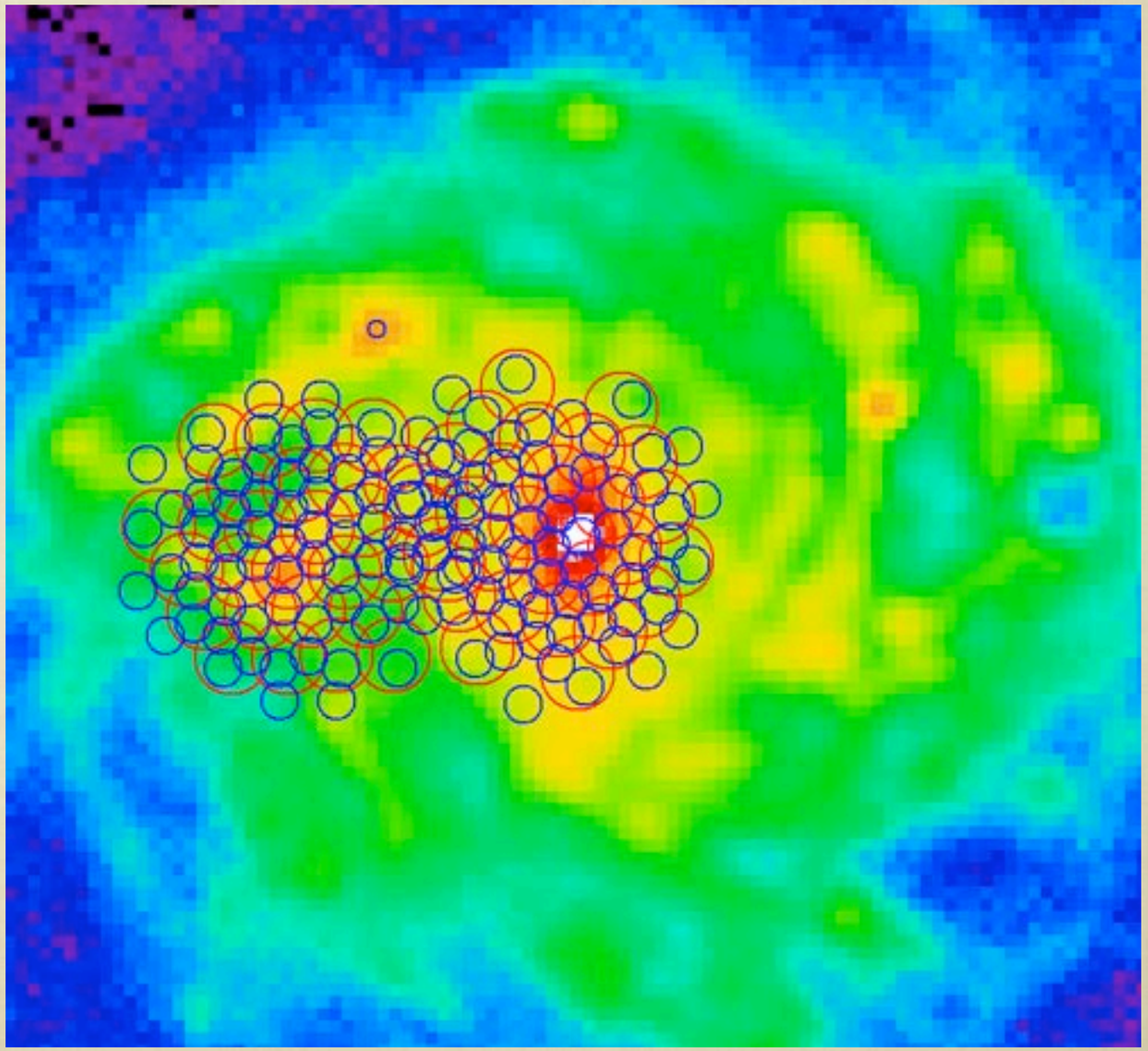
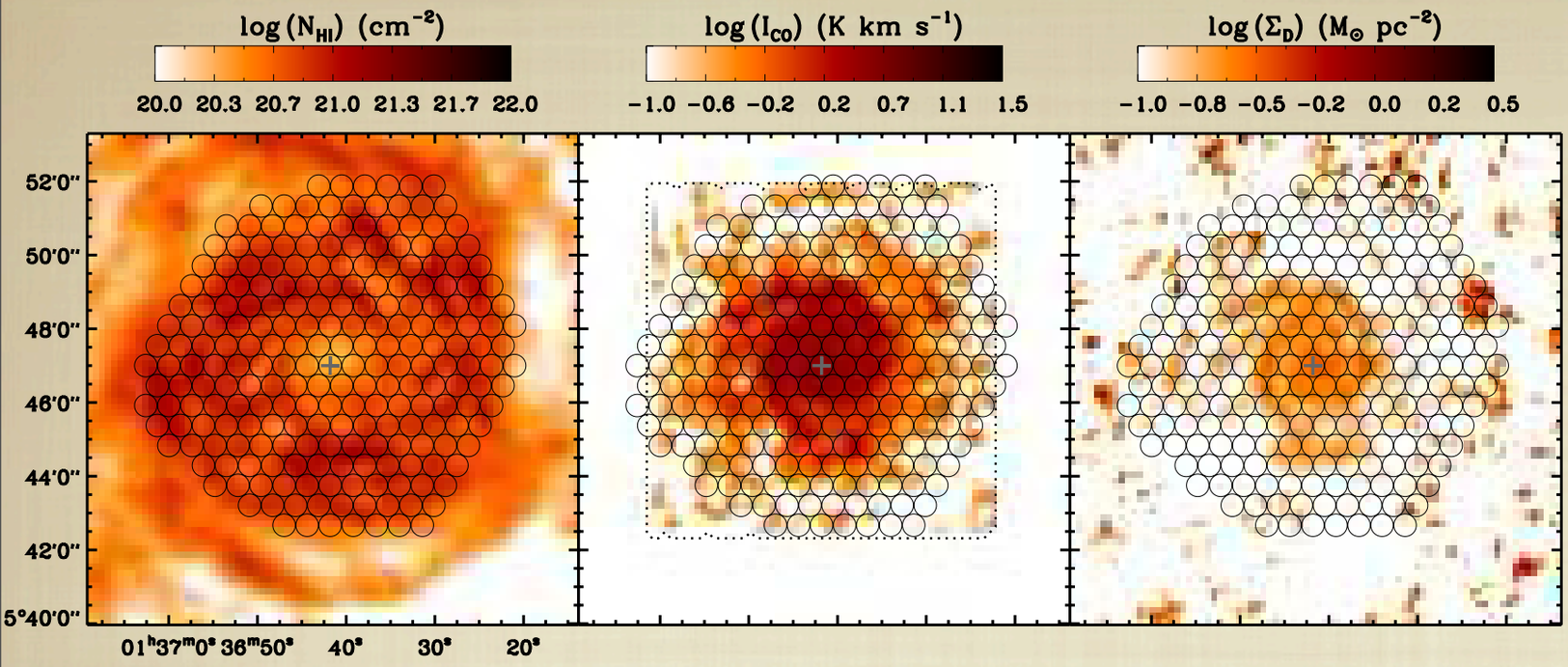
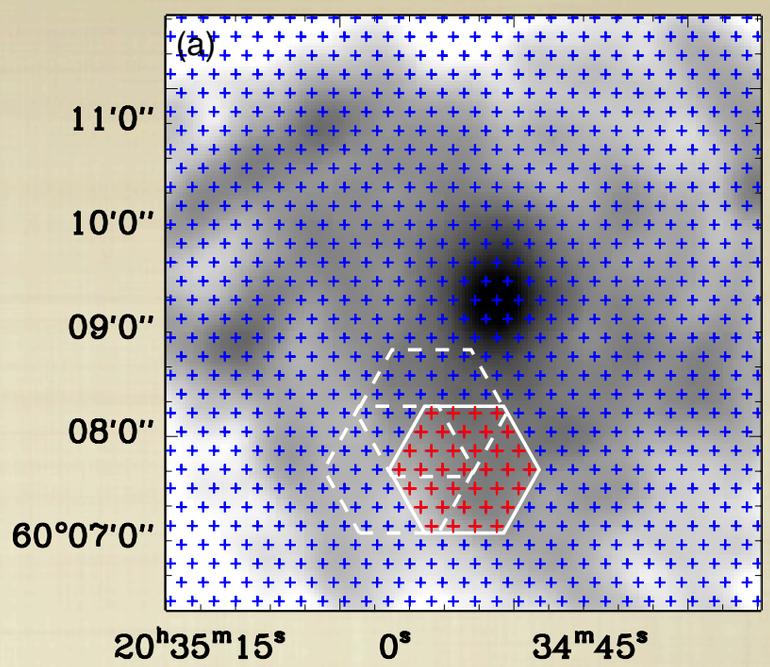
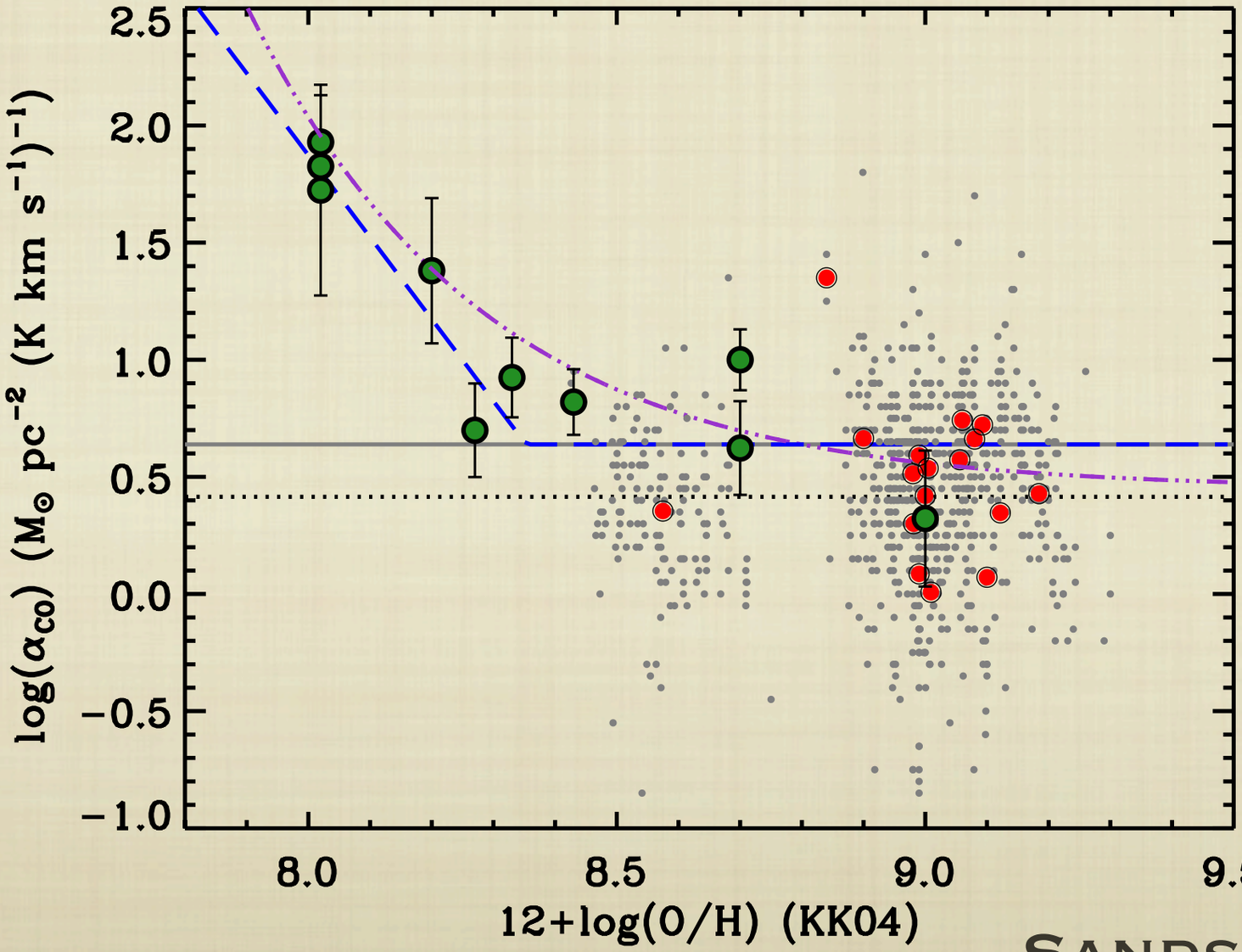




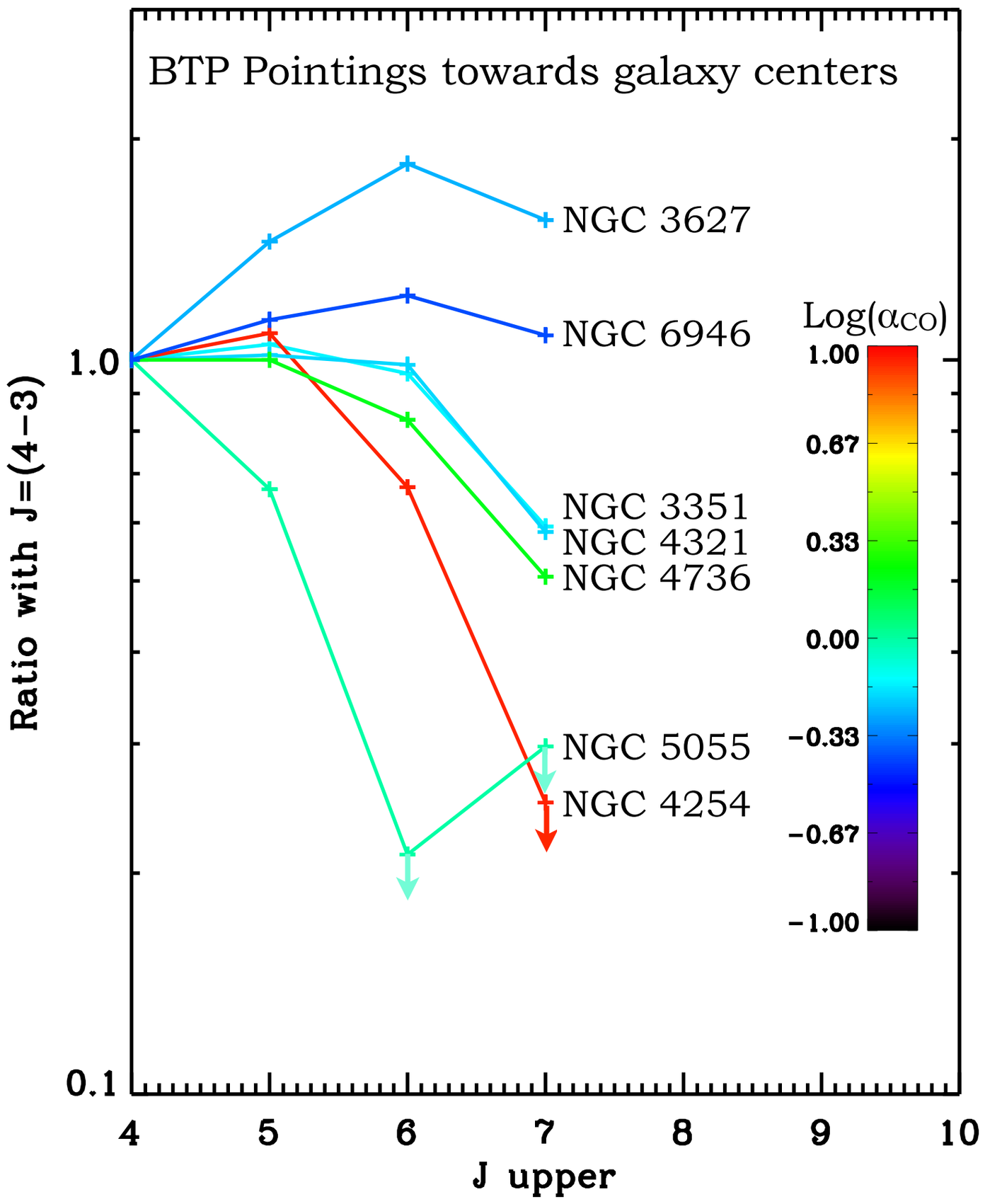


XCO

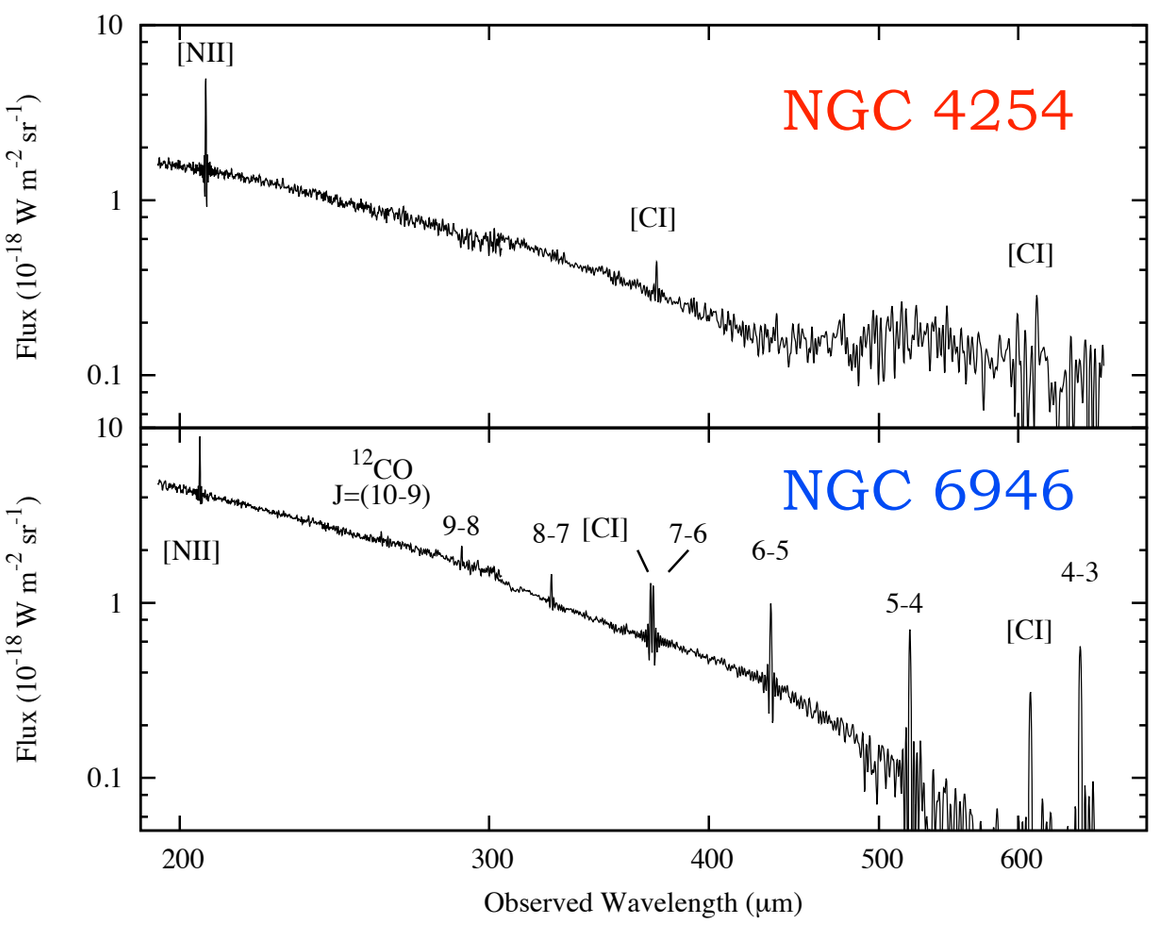


SANDSTROM+ 2013

Evidence for enhanced CO excitation in centers with low α_{CO} from BTP.



Many galaxy centers peak at J~6, similar to M82.

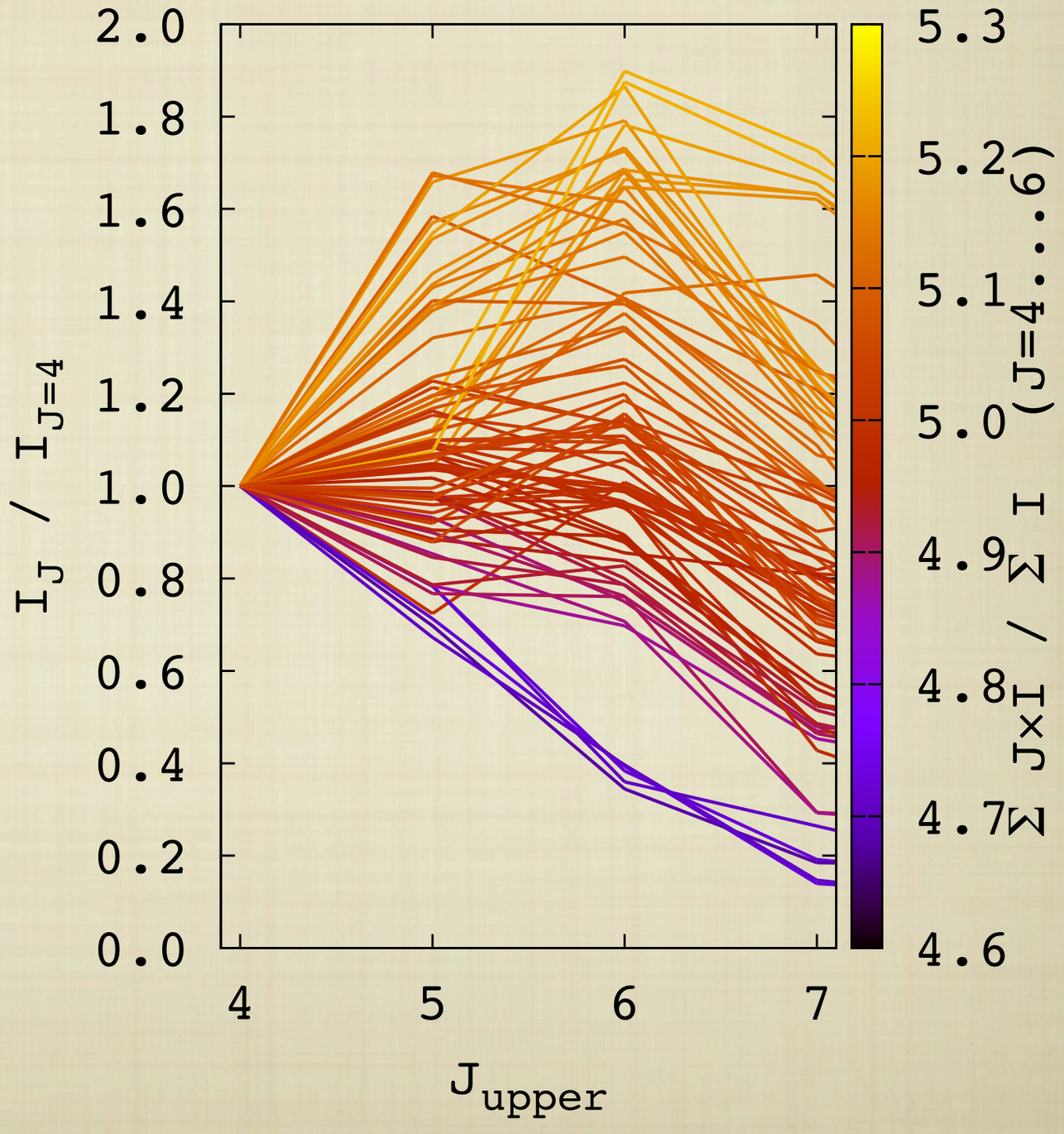


Sandstrom+, in prep

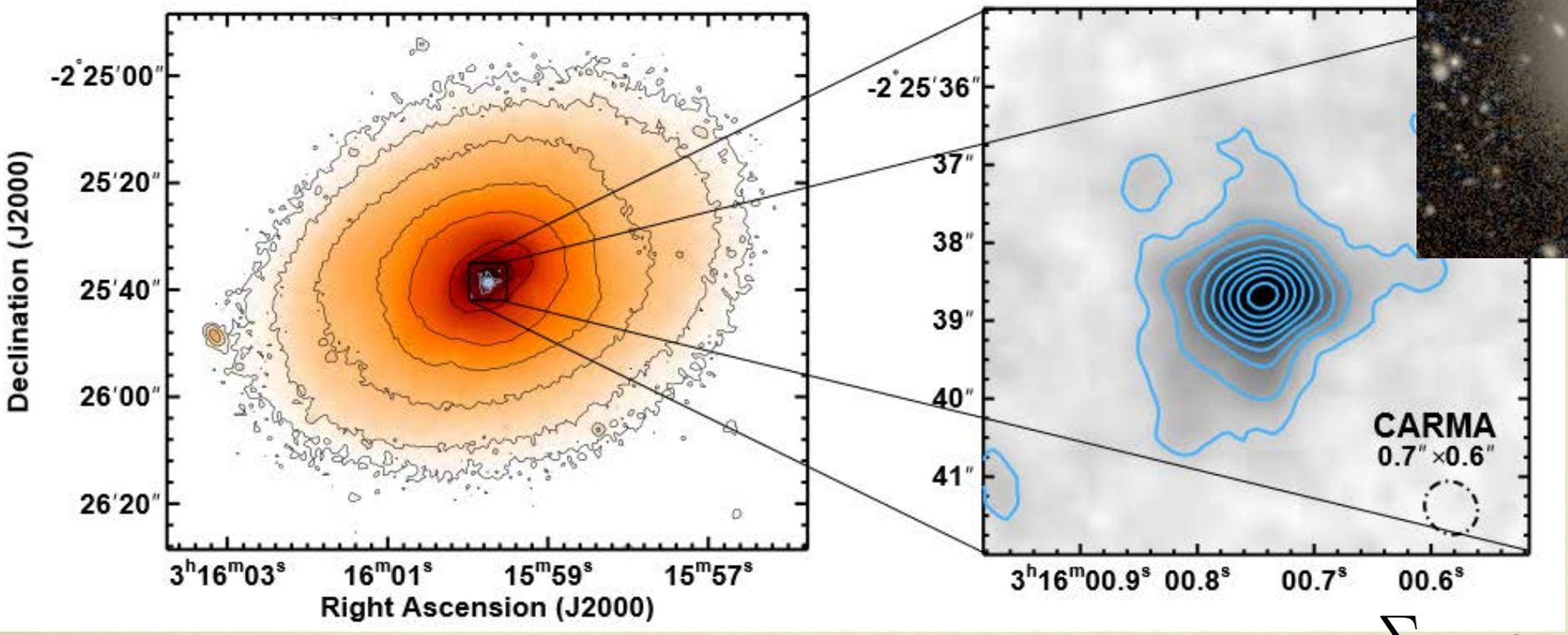
Empirical Correlations

- What is the typical range of CO excitation conditions?
- What 2nd order parameters control <J>?

Resolved BtP SLEDs at 5kpc scale



NGC1266

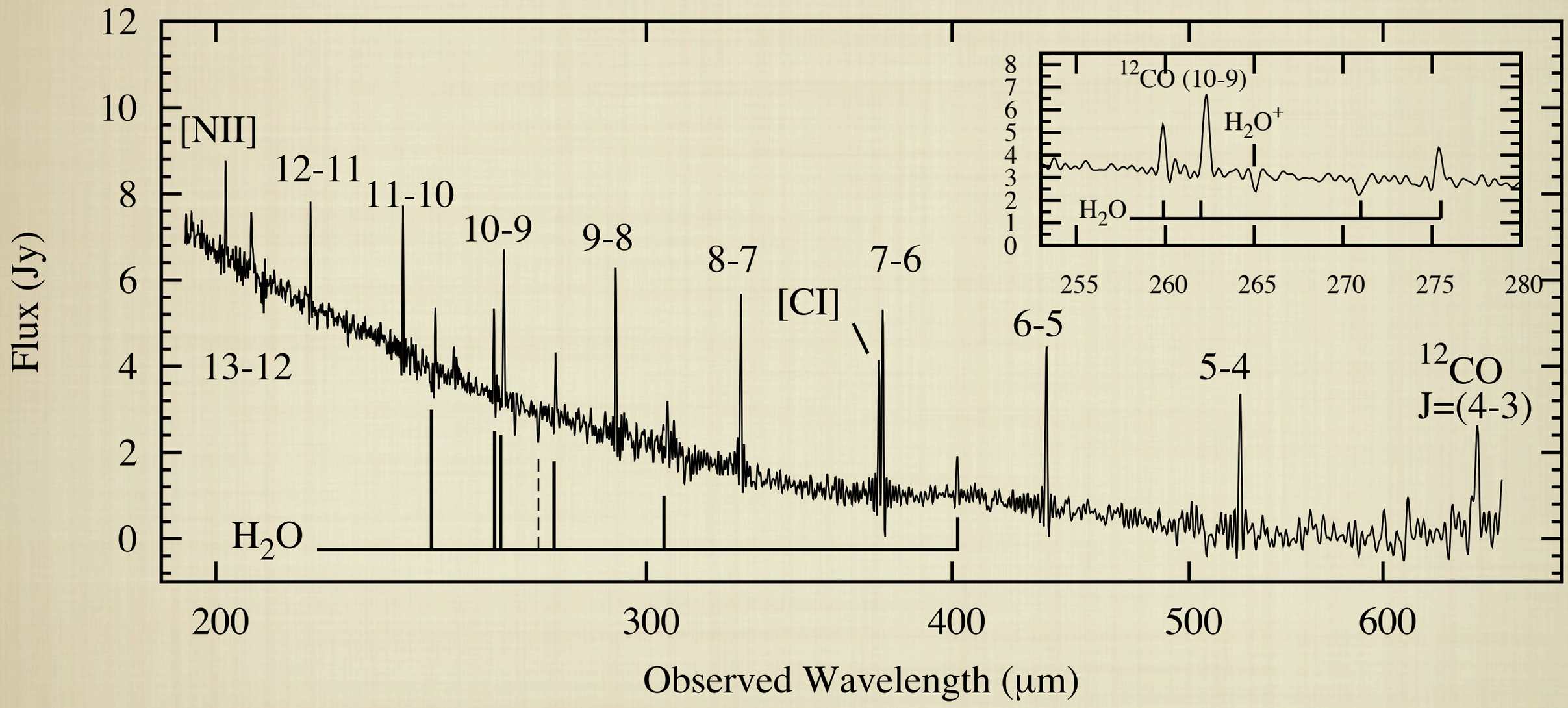


ALATALO+ 2011

$$\Sigma_{H_2} \sim 3 \times 10^4 \, \mathrm{M}_\odot / \mathrm{kpc}^2$$

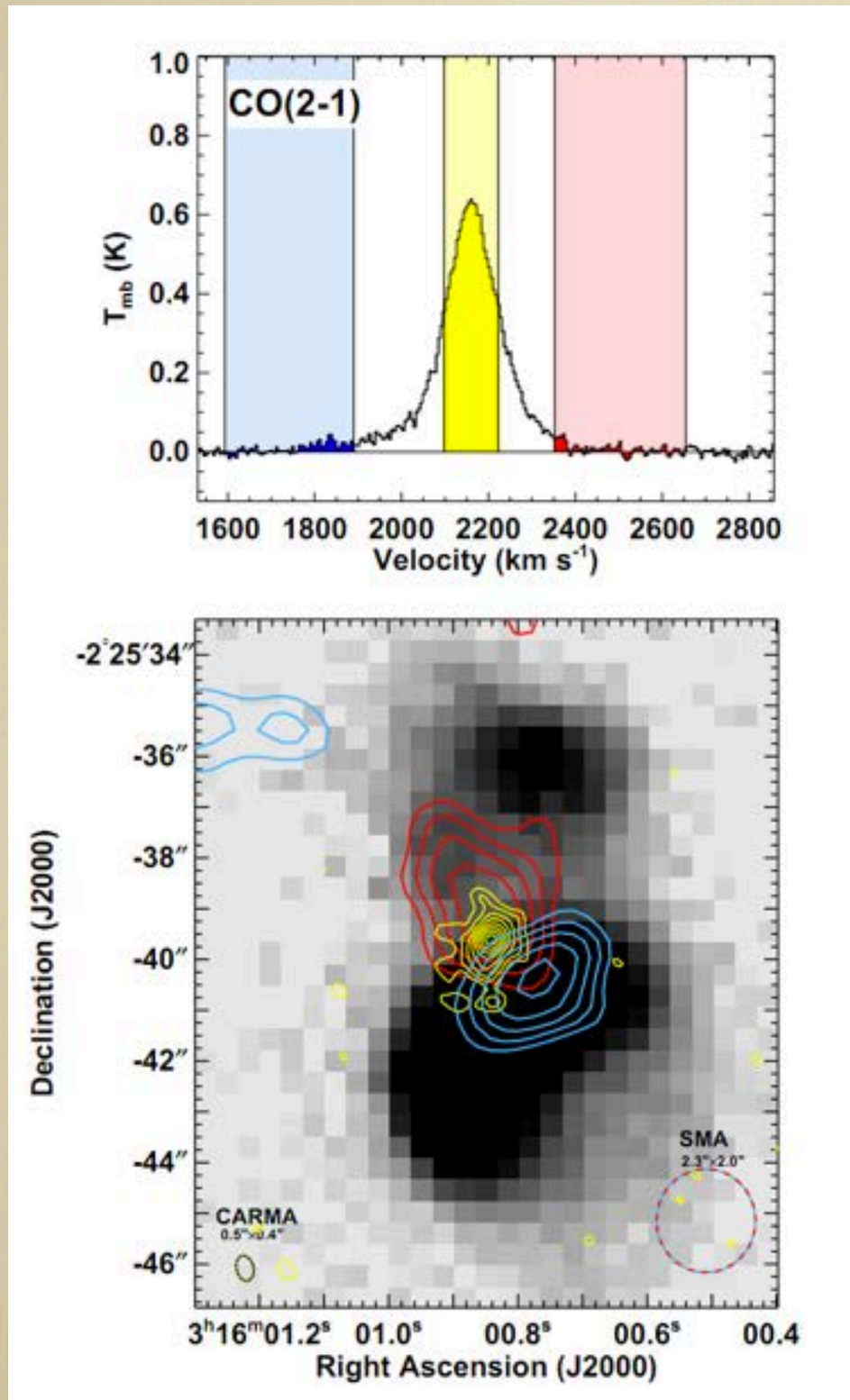
- Buried at the core of a "red and dead" galaxy at 30Mpc
- 10^9 M⊙ molecular Gas disk packed into 60pc: similar size, **100x more mass** than a Giant Molecular Cloud.

NGC1266 Beyond the Peak

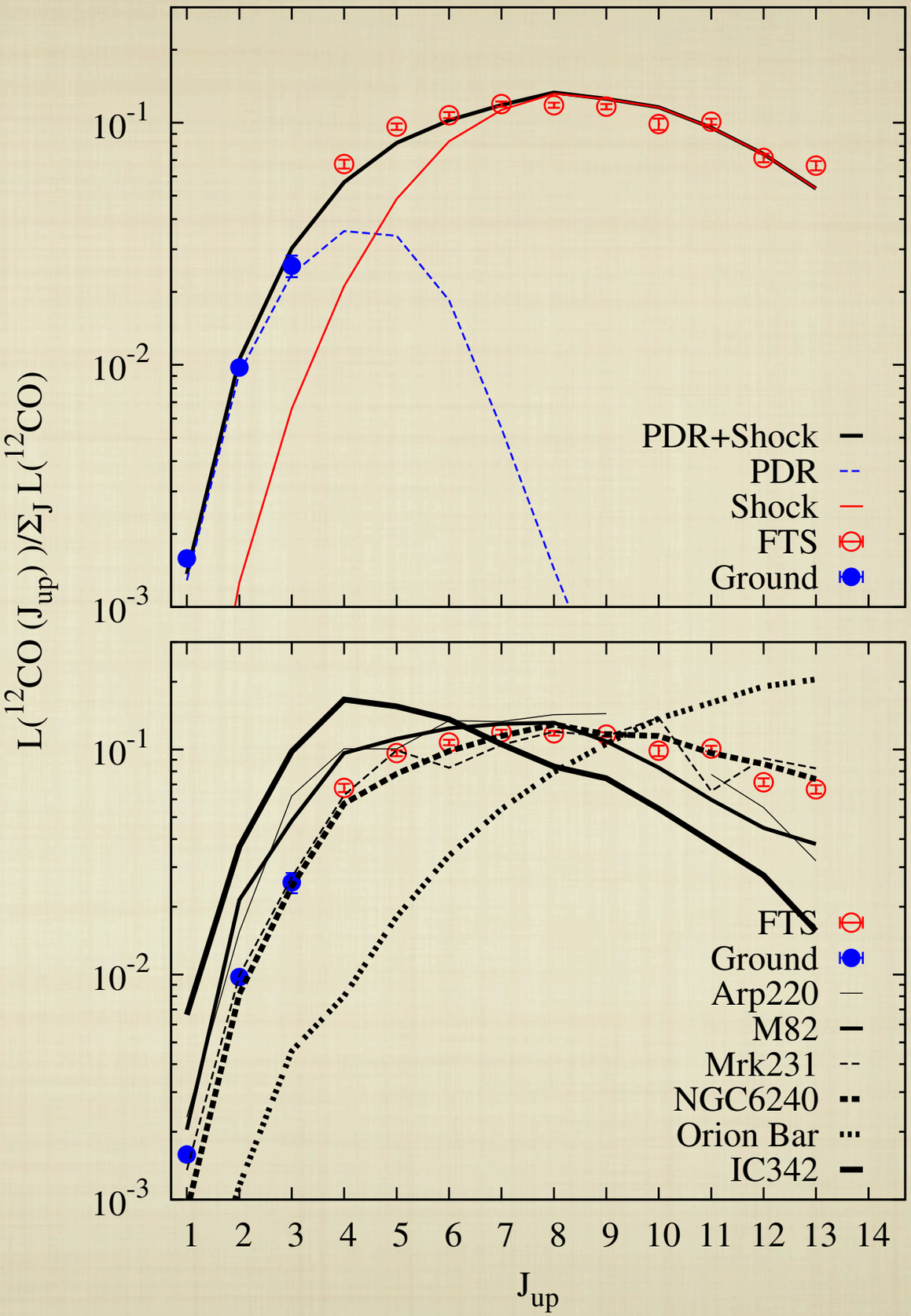


Pelligrini+, ApJL submitted

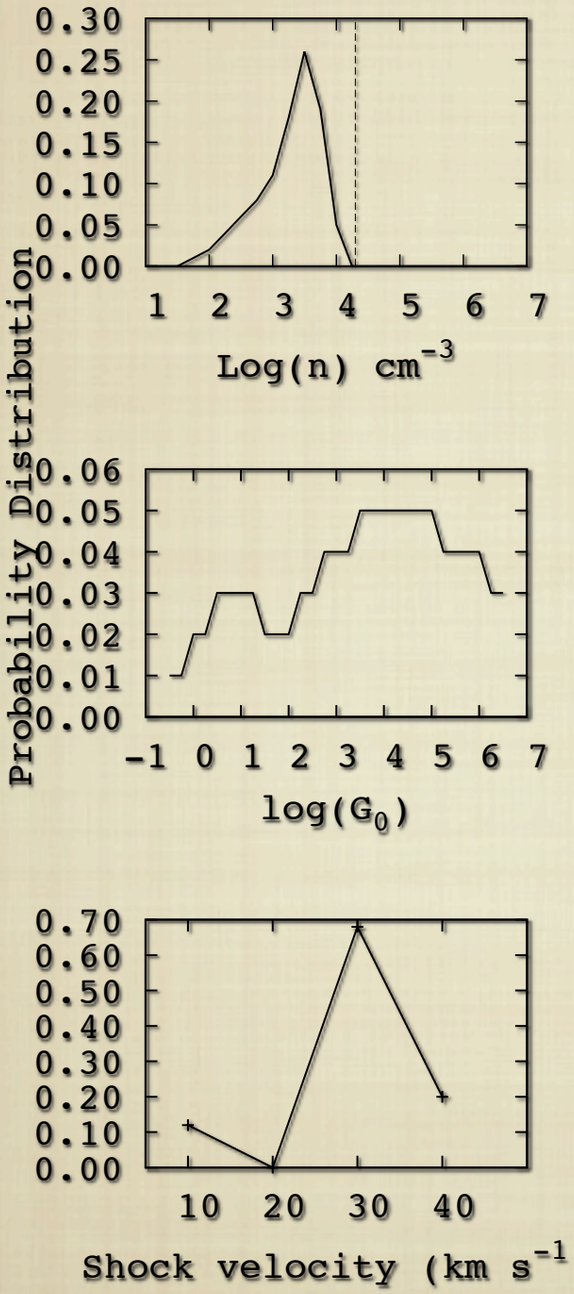
v~200km/s outflow @3xSFR

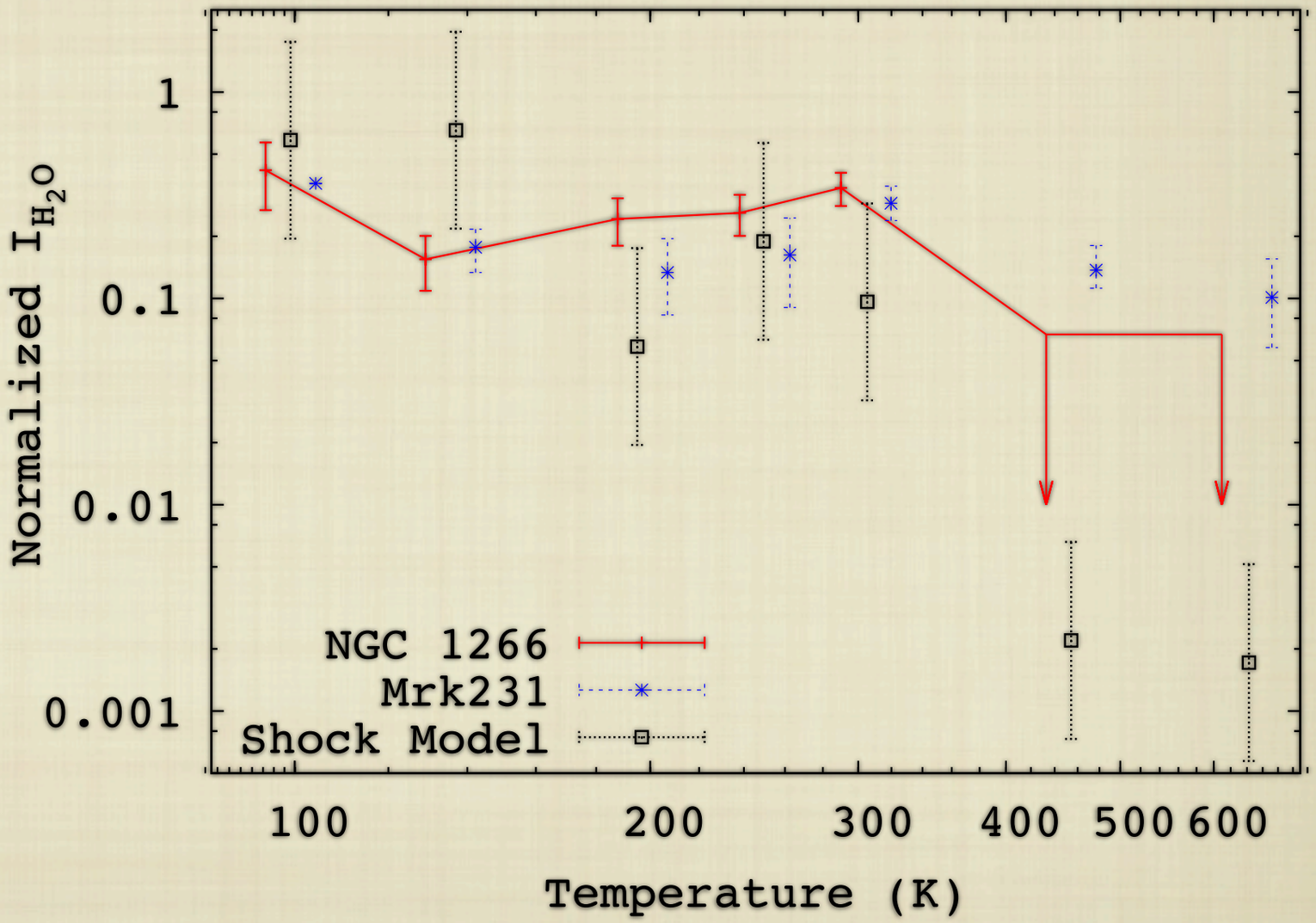


Pellegrini+ submitted



Water: The Shocking Truth

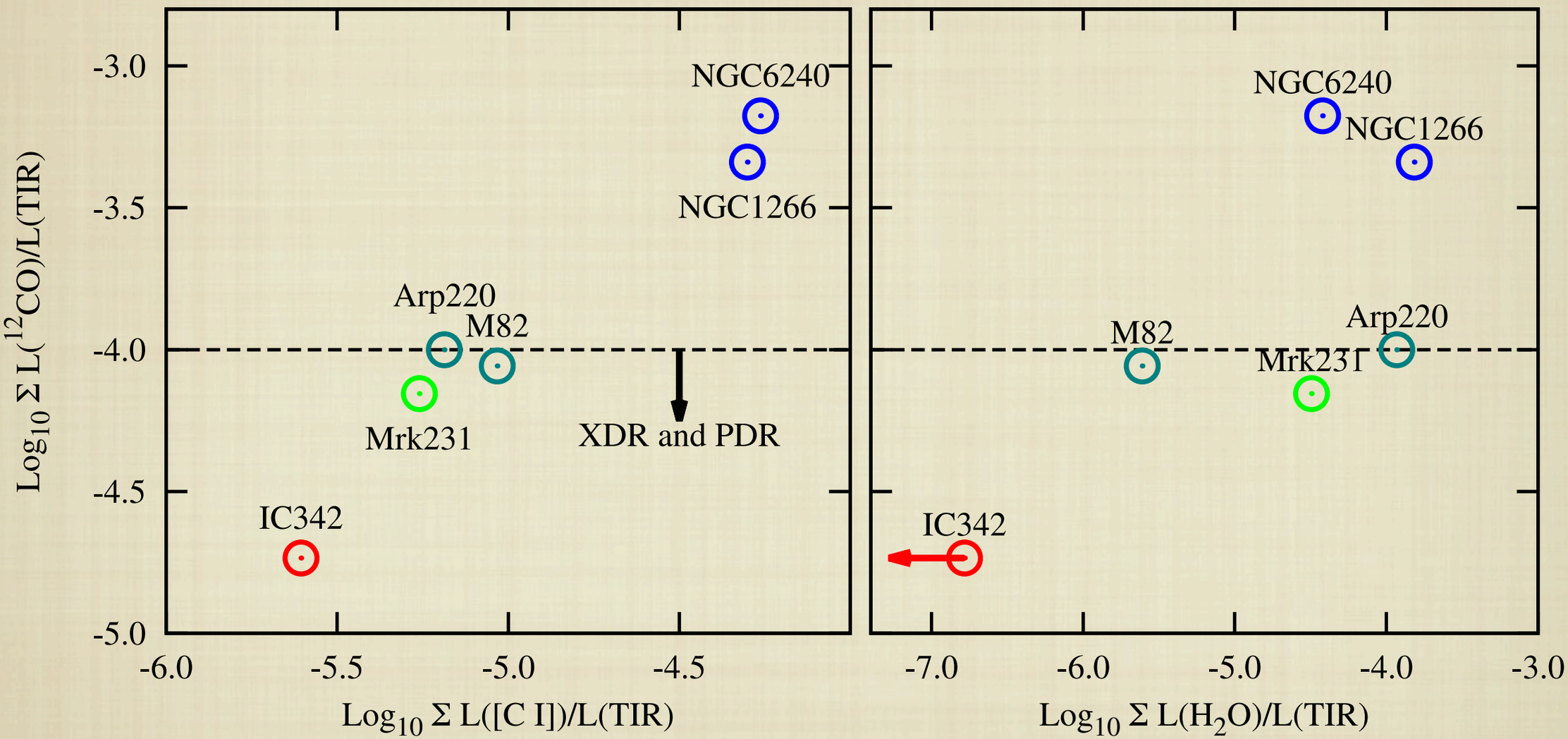




Pellegrini+ submitted

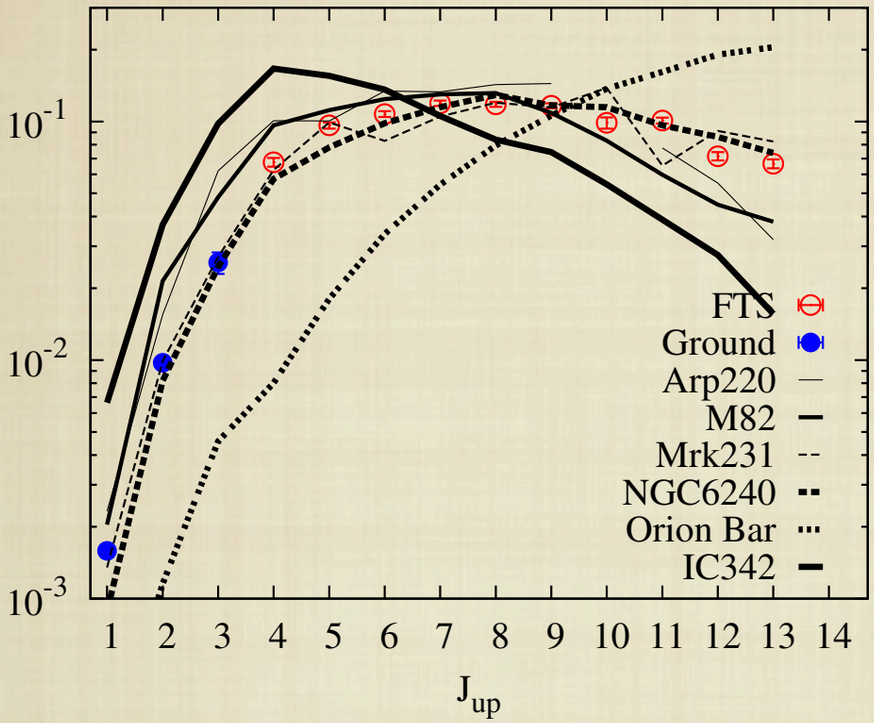
A Under-Luminous ULIRG?

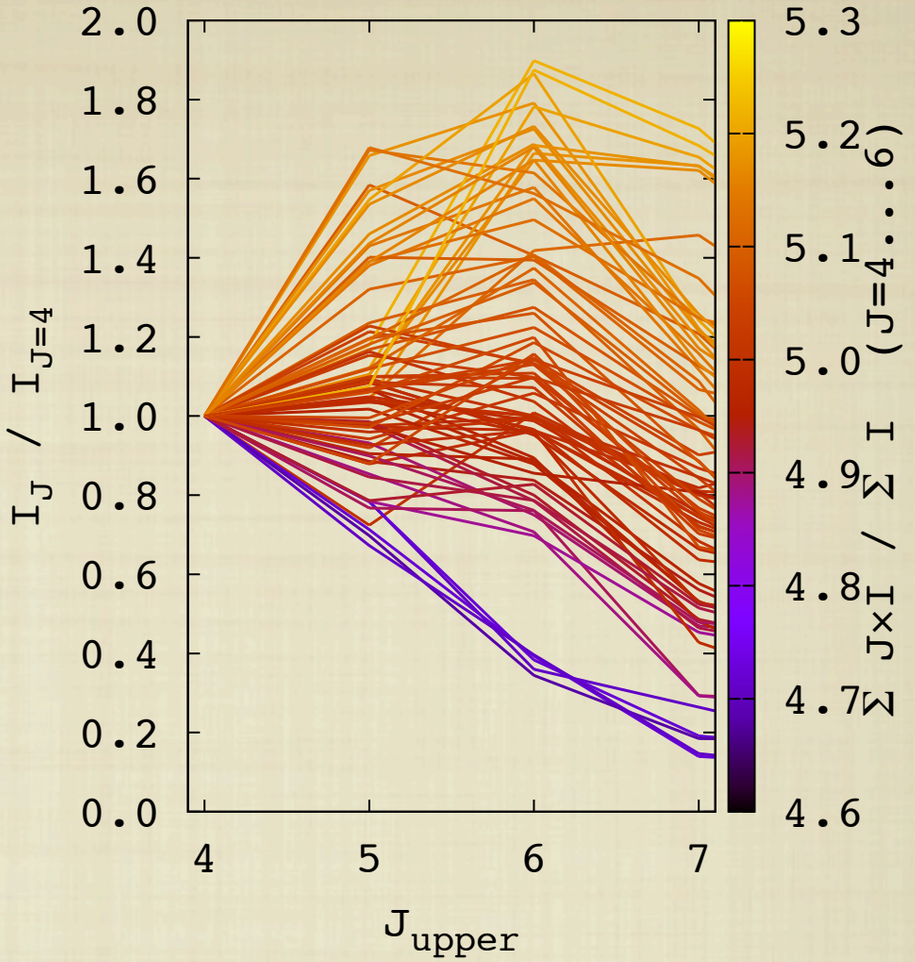
and.... The significance of line/continuum



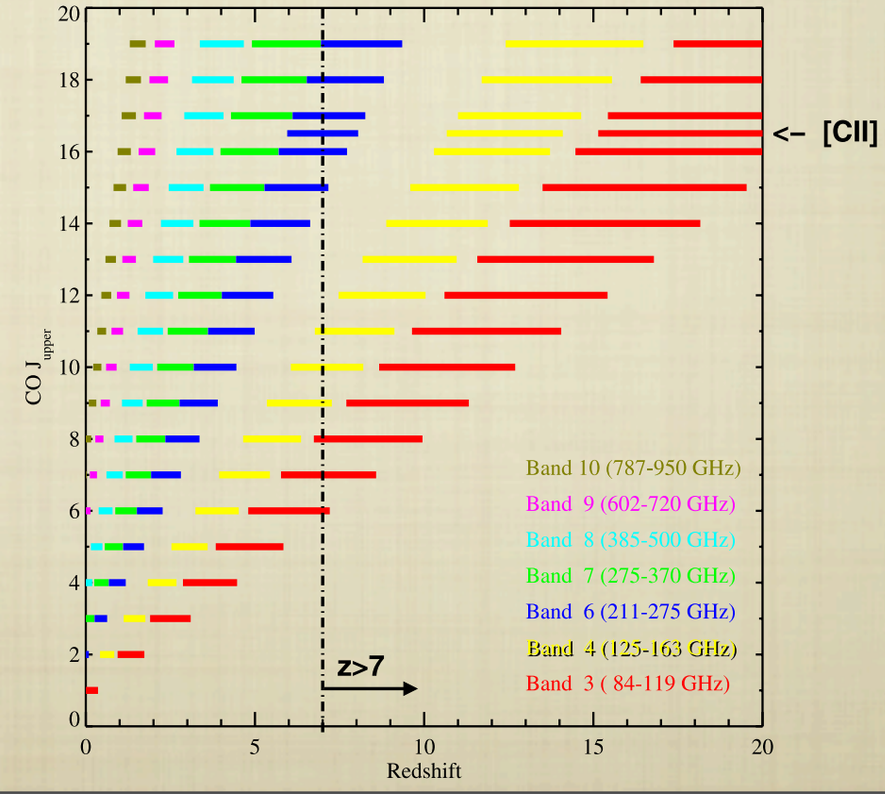
Pellegrini+ submitted

SUMMARY


FTS
Ground
Arp220
M82
Mrk231
NGC6240
Orion Bar
IC342
10^{-1}
10^{-2}
10^{-3}
1 2 3 4 5 6 7 8 9 10 11 12 13 14
J_{up}


I_J / $I_{J=4}$
J_{upper}
Σ JxI / Σ I (J=4...9)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4
5
6
7
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6


[NII] 205μm


<- [CII]
CO J_{upper}
Redshift
z>7
Band 10 (787-950 GHz)
Band 9 (602-720 GHz)
Band 8 (385-500 GHz)
Band 7 (275-370 GHz)
Band 6 (211-275 GHz)
Band 4 (125-163 GHz)
Band 3 (84-119 GHz)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20