

**For establishing a new diagnostic method
- synergy with ALMA and TAO/MIMIZUKU -**

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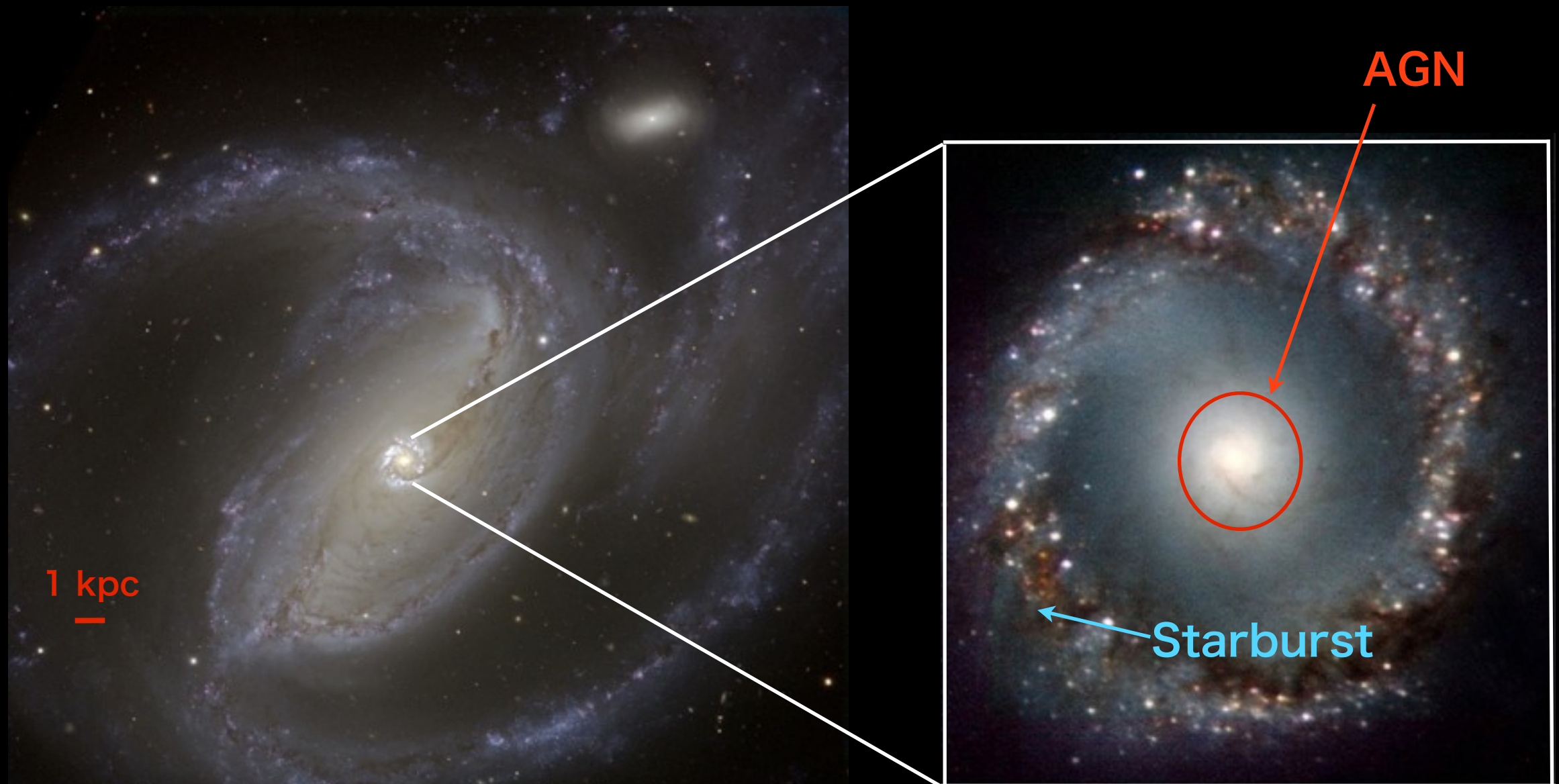
Today's Menu

1. Introduction
2. ALMA Observation
3. A possible study with TAO/MIMIZUKU

1. Introduction

The Quest for a Robust AGN Diagnostic

Energy diagnostics by mm/submm spectroscopy



- Our immediate objective: establishing a diagnostic tool of energy sources in mm/submm
→ discriminate between AGN and Starburst
- Study the co-evolution of AGN - host galaxy.

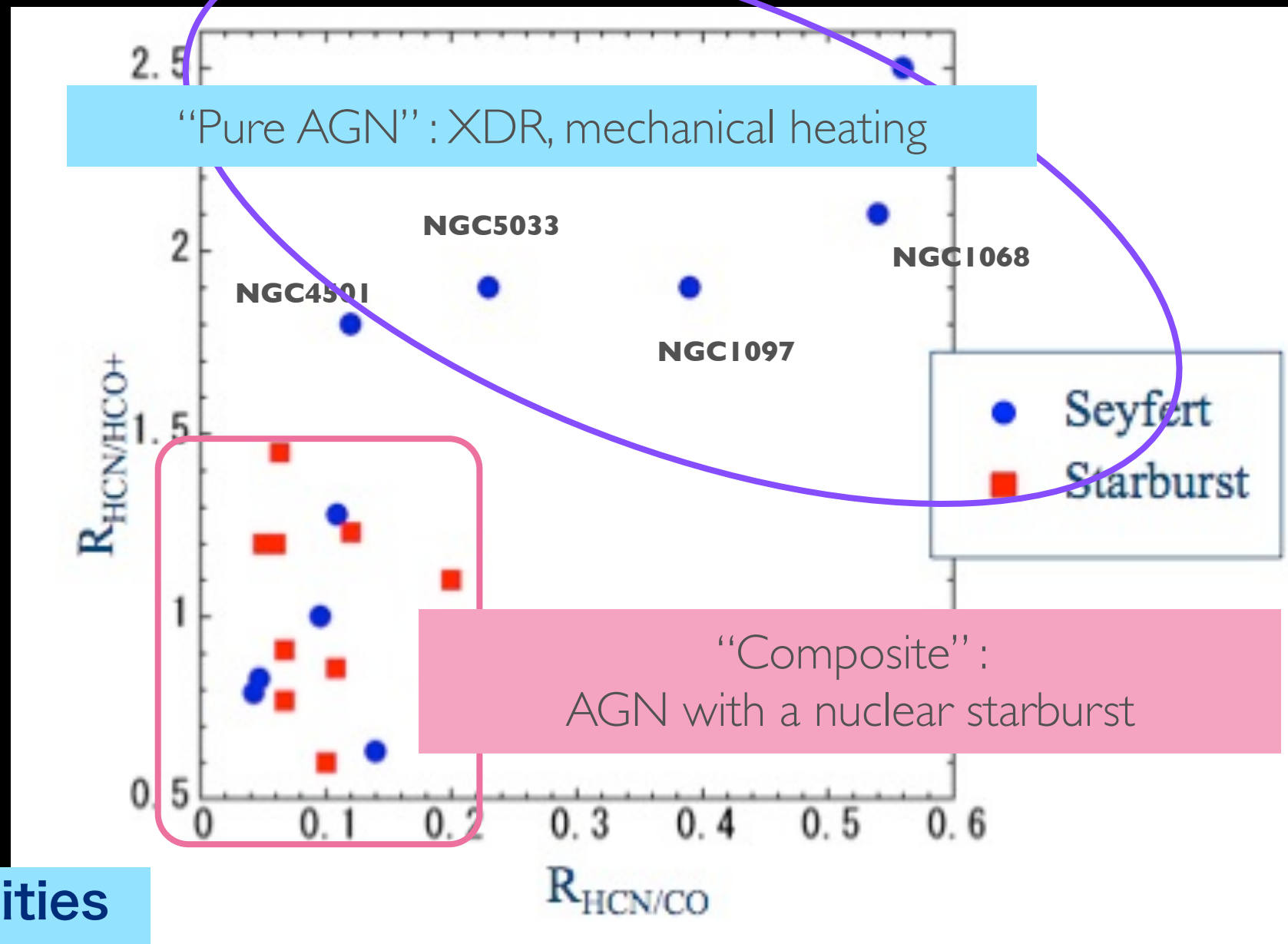
“BEFORE ALMA”

How to discriminate between AGN and SB: HCN/HCO⁺ vs. HCN/CO diagram

The cause of this HCN enhancement is still an open question

- Fractional abundance ?
- Excitation condition?
- IR pumping ?

→ to check these possibilities
is our immediate objective!



Kohno et al. 2001 (astro-ph/0206398)

Kohno 2005 (astro-ph/0508420)

Kohno et al. 2008, ApSS, 313, 279

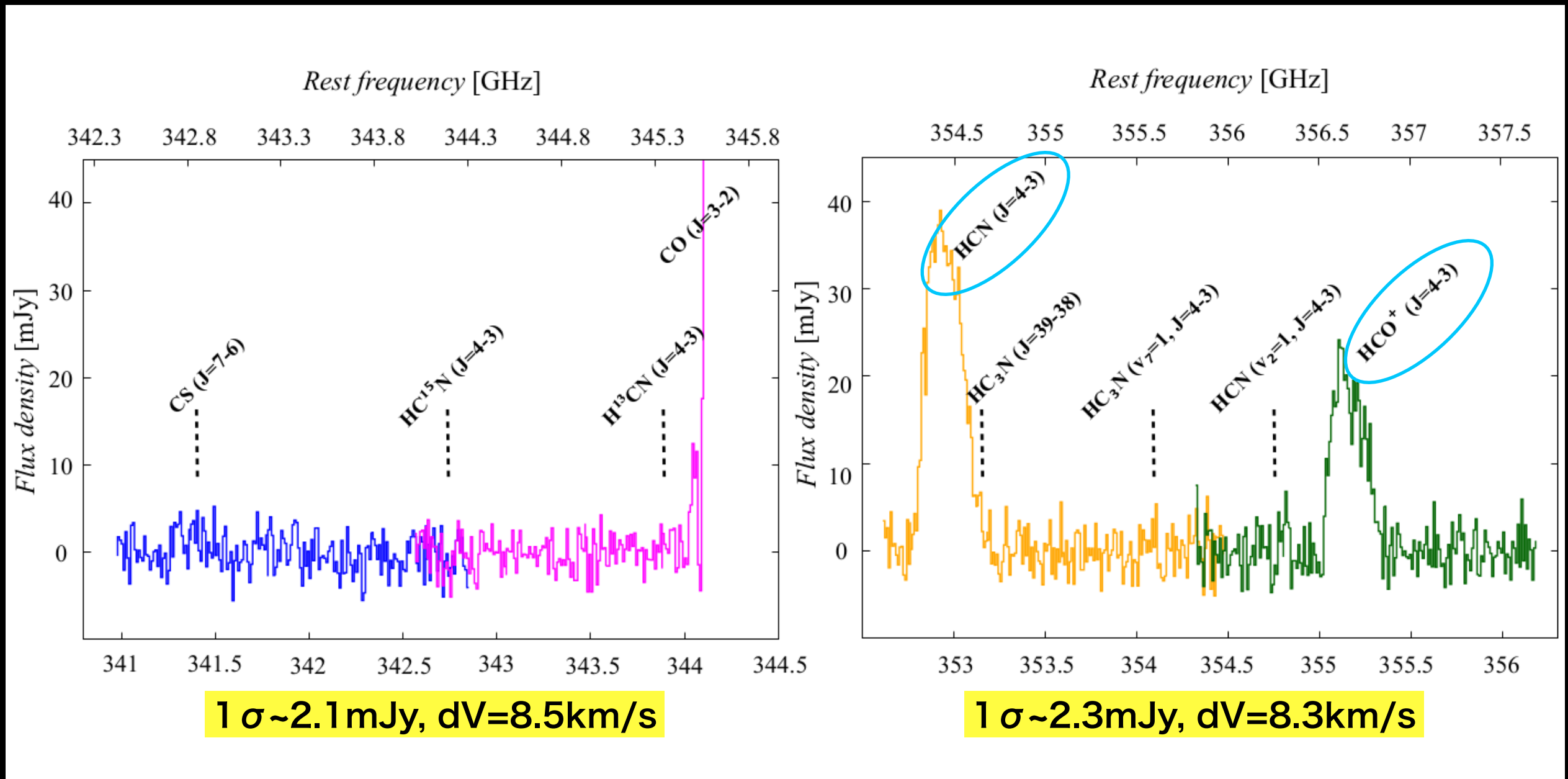


2. ALMA Observation of the central 100pc region of nearby type-1 LLAGN NGC 1097

T.Izumi, K.Kohno, Y.Tamura, A.Taniguchi,
and other NGC1097 collaborators.

ALMA data: K.Kohno
SMA data: Pei-Ying Hsieh

Band 7 spectrum at the 860 μm peak position

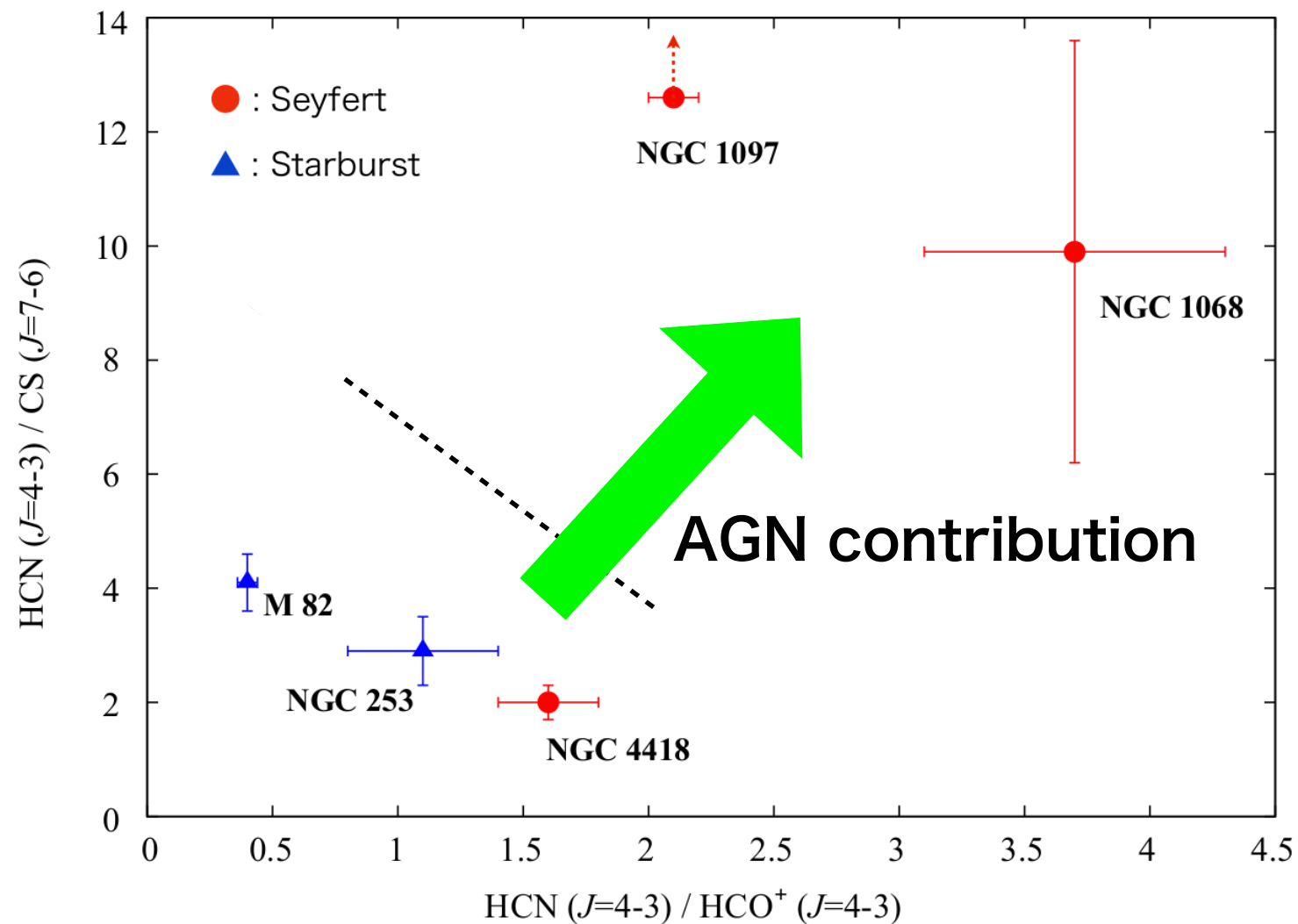


High HCN/HCO⁺ ratio even in (4-3) transition
Very good S/N as if they were CO!

No HCN(v=1, J=4-3) and CS(7-6) emission!

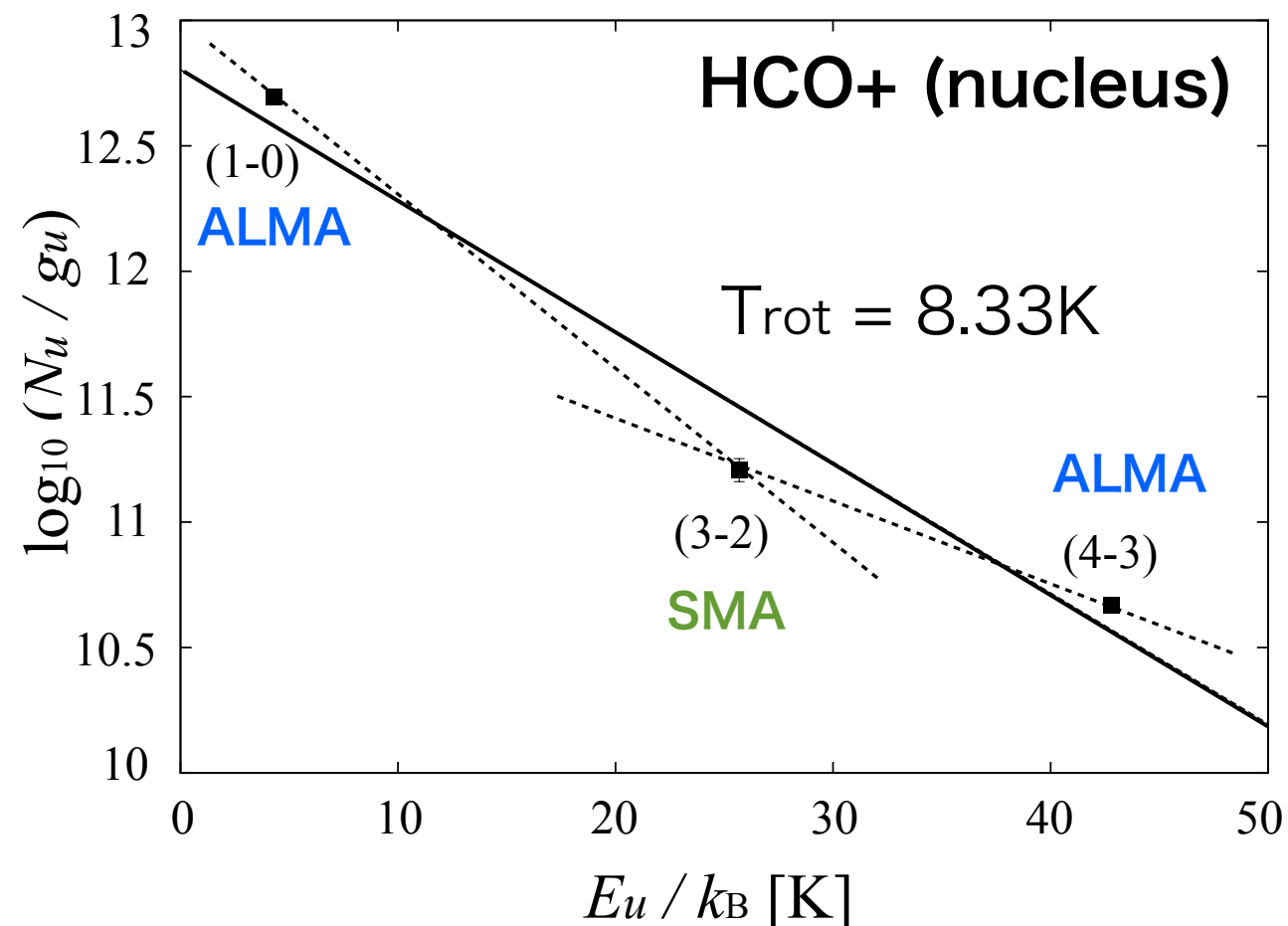
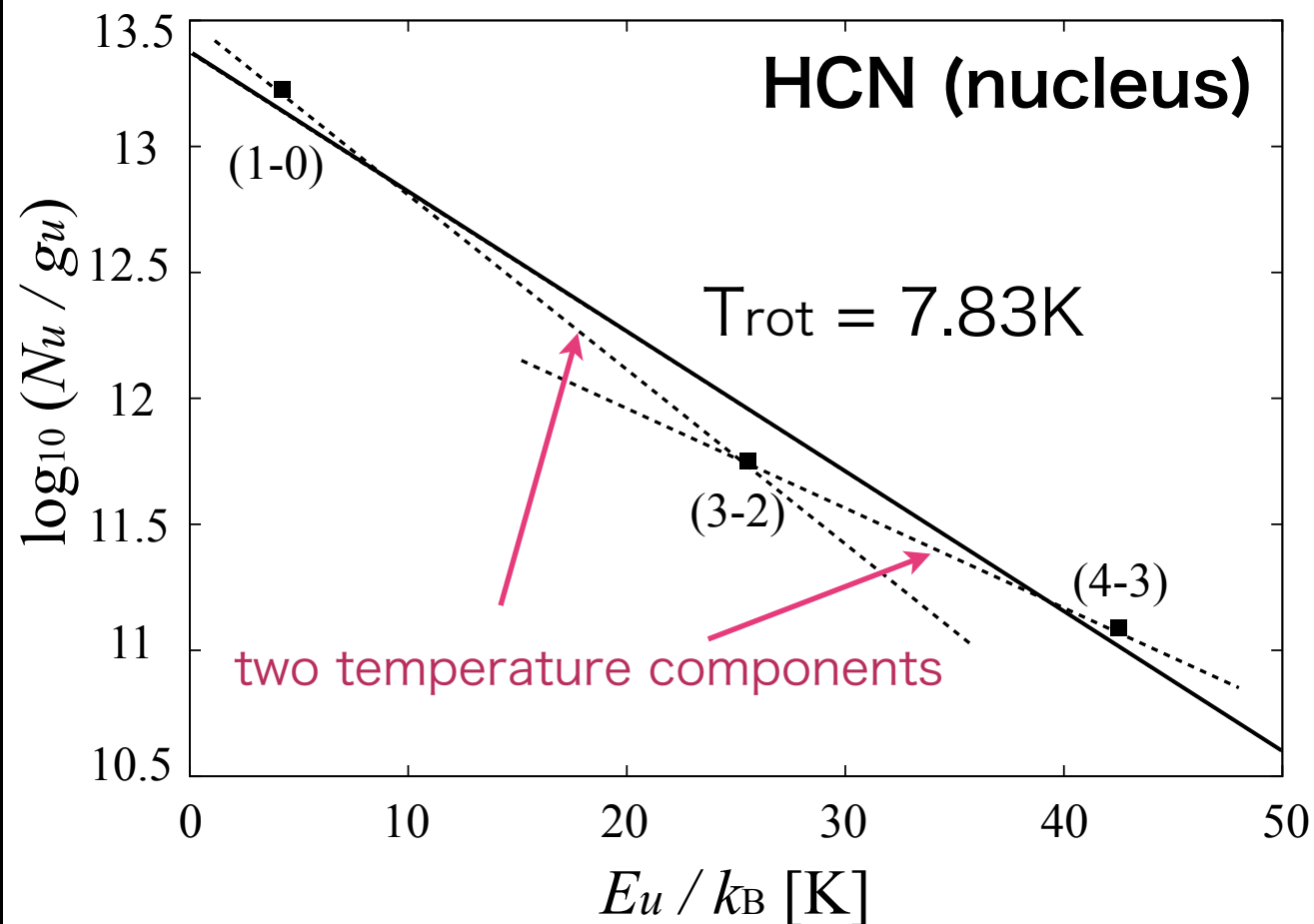
Just ~1h on-source integration!

New diagnostic method: Submm-HCN diagram



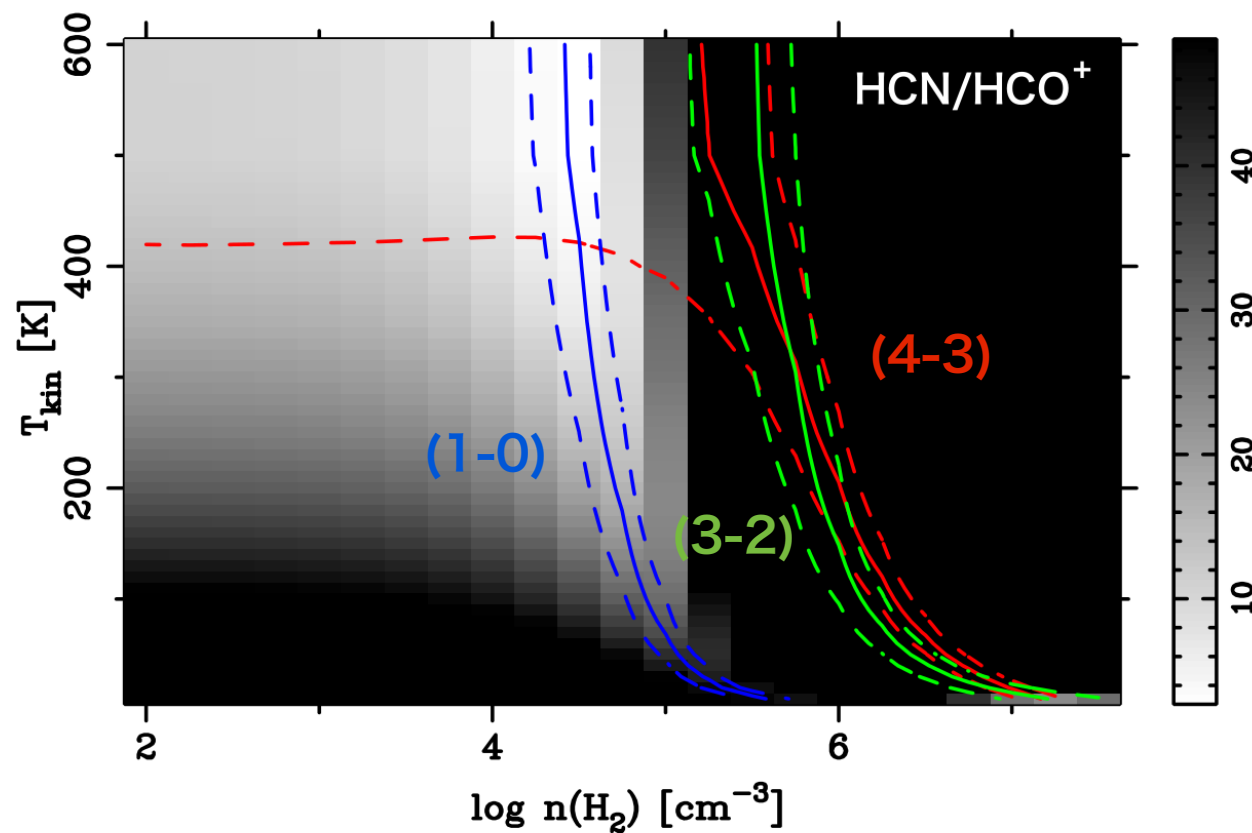
- interferometric observation: high angular resolution
- submm observation: high-z applicable
- we can also get kinematic information!
- however, “Sulfur-line” is typically weak...
- We need a new, evolved diagram!

Multi-transitional LTE analysis



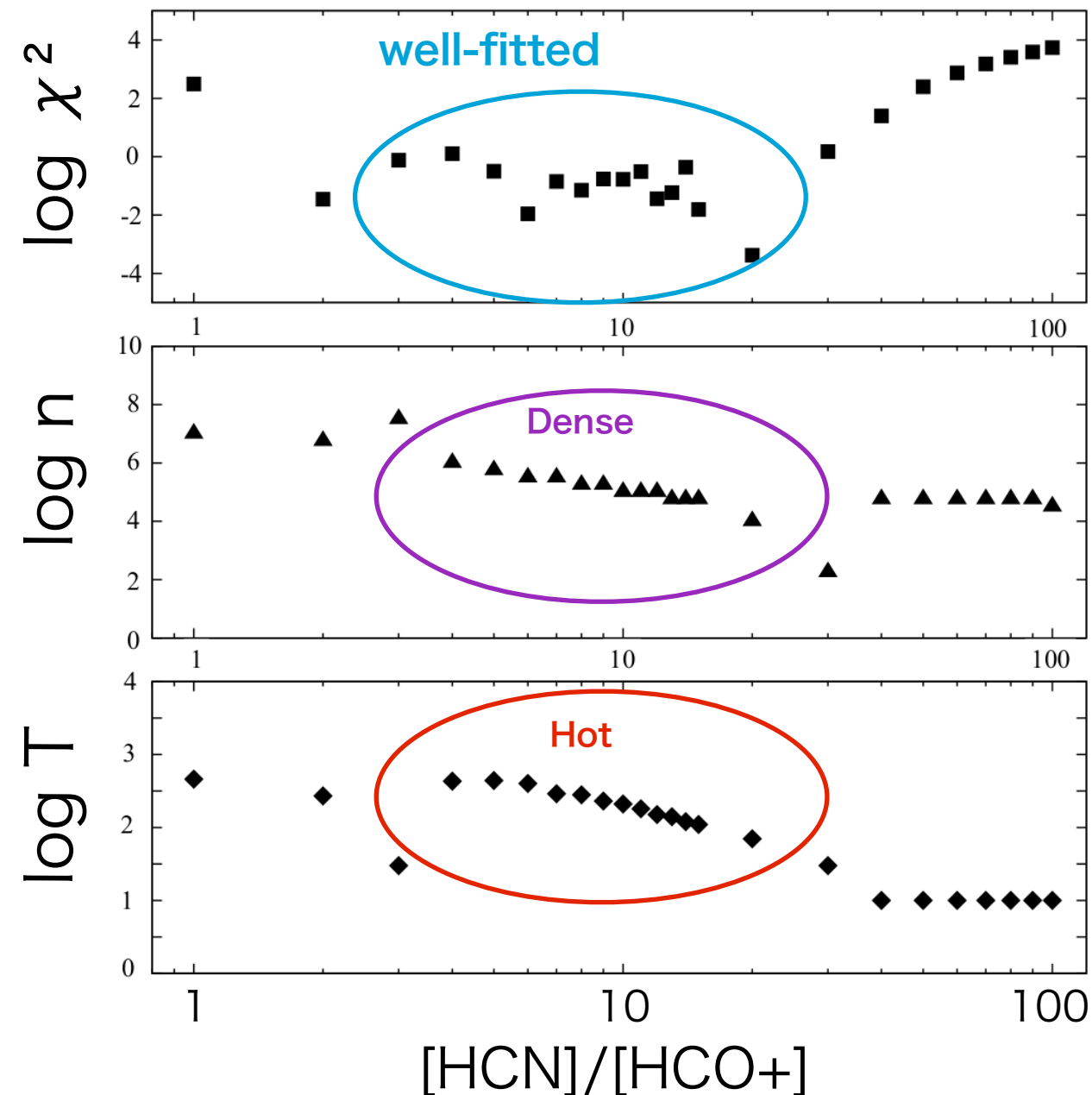
| | NGC1097 (nucleus) | NGC1068 | NGC1097 (SB ring) | NGC253 |
|--------------------------------|----------------------|--------------------|----------------------|---|
| N(HCN)/N(HCO+) | 3.36 ± 0.59 | 2.64 ± 0.39 | 2.15 ± 0.38 | 1.67 ± 0.71 |
| angular resolution [arcsec] | 4.4x2.7 | 28 | 4.4x2.7 | 27 |
| Ref. | this work | Aladro et al. 2013 | this work | Knudsen et al. 2007 Paglione et al. 2007 |

Multi-transitional non-LTE analysis



high-J ($J \geq 3$) and low-J ($J < 3$) lines are seen to be emitted from different region

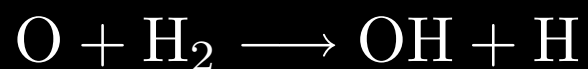
→ we use high-J lines here



These high-J molecules are emitted from dense ($n=10^4$ - 10^6 /cc), hot ($T=70$ - 450 K) region.

High temperature chemistry

- The key reaction is, creation of “water”. ==> lack of “O” atom!



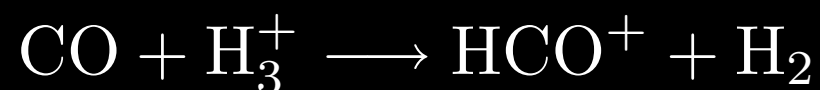
- About HCN...



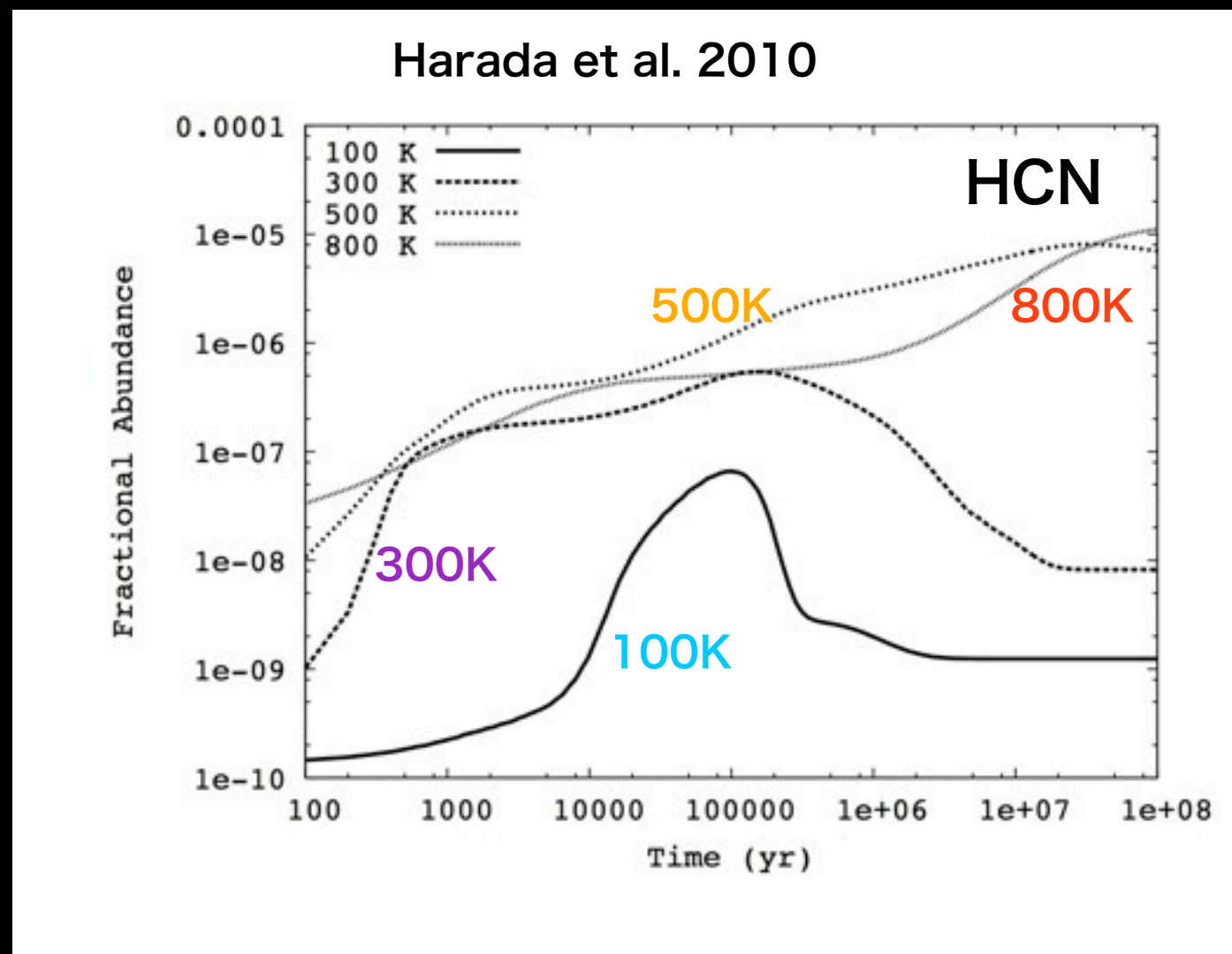
Lack of “O” ==> effective-carbon rich condition (also increase HCN)

- About HCO+...

Formation,

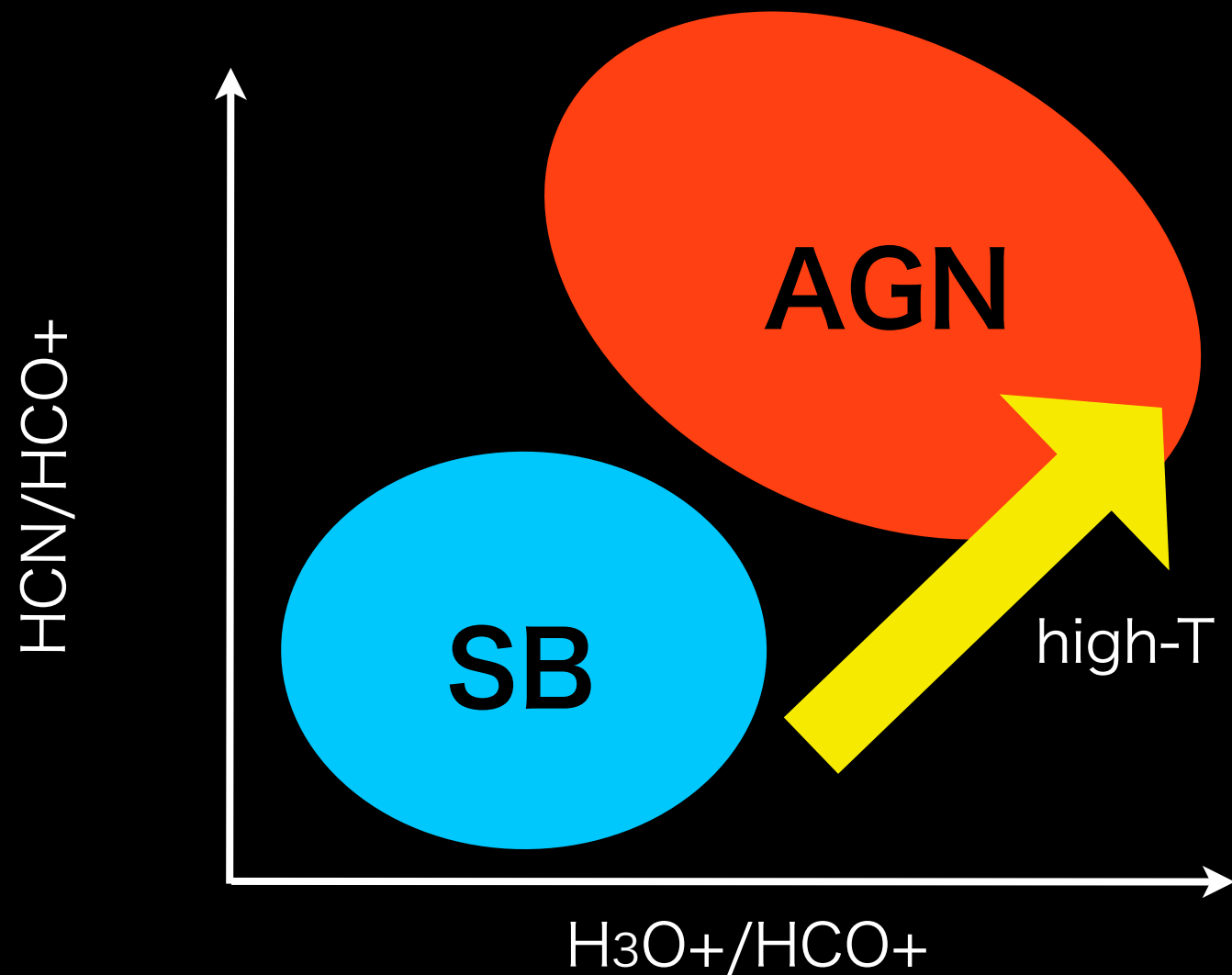


Destruction



High HCN/HCO+ ratio can be explained!

What I want to do in the future!



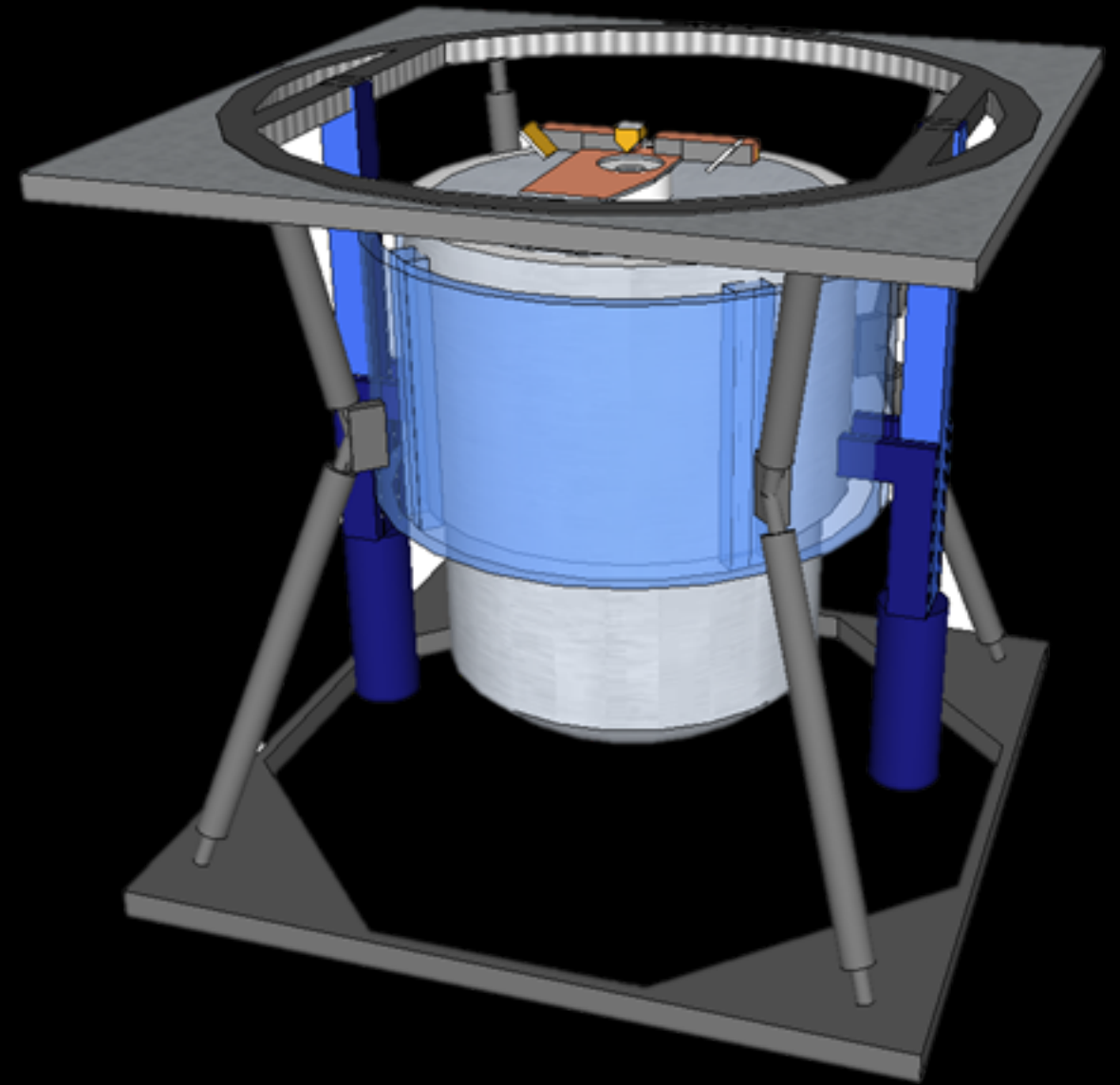
- high-z applicable
- Clear chemical background
- useful to study the AGN-host galaxy co-evolution.
- We have to confirm, $T(\text{AGN}) > T(\text{SB})$ at molecular cloud scale

3. What we can do with TAO/MIMIZUKU?

TAO/MIMIZUKU

Special point (I think)

- wide range of λ
(2-38 μm)
- diffraction limited
resolution @ $\lambda > 8\mu\text{m}$
- located in Atacama!



To Observe H₂ pure rotational emission

UV

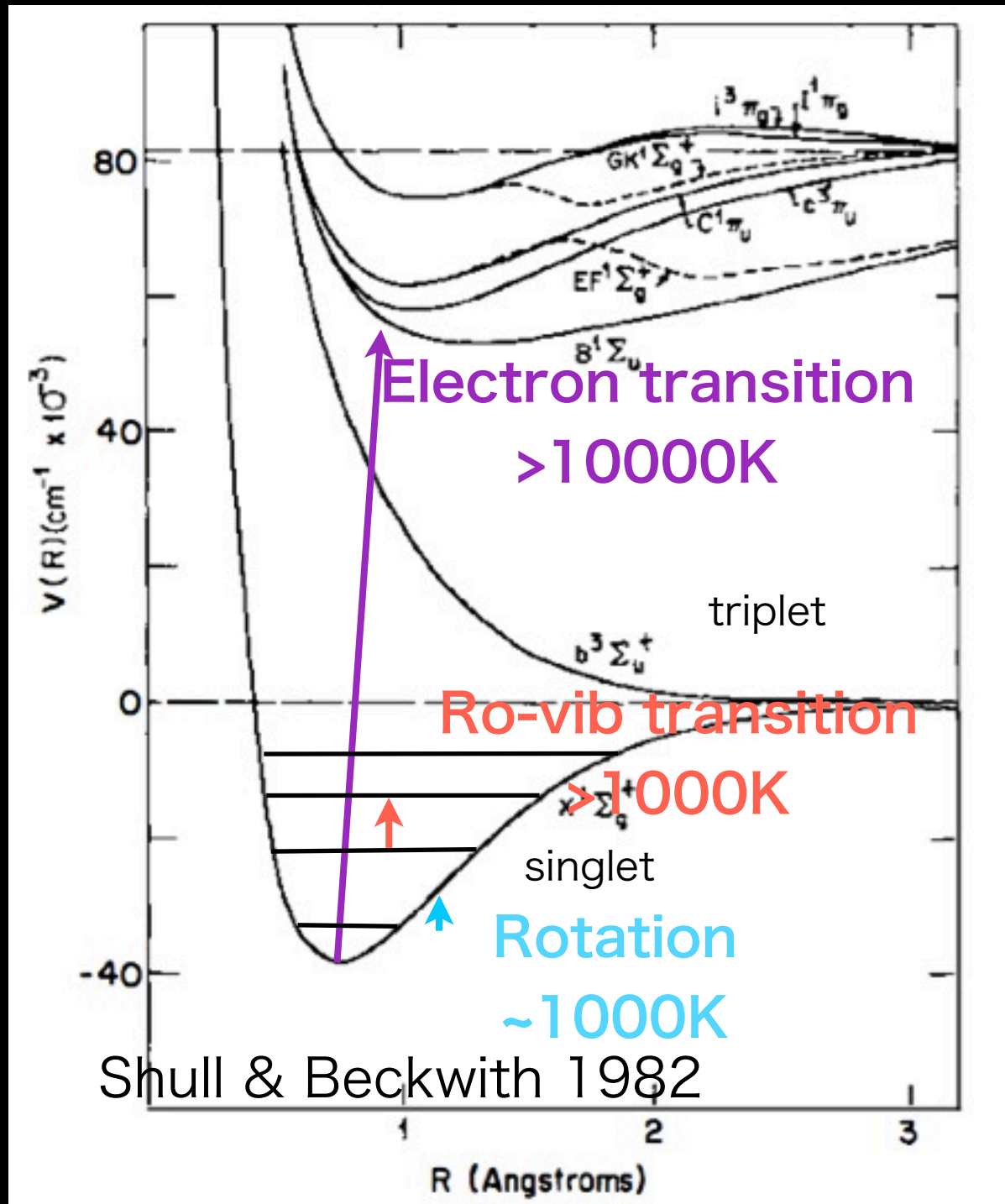
- Lyman/Werner band
- Electron transition

NIR

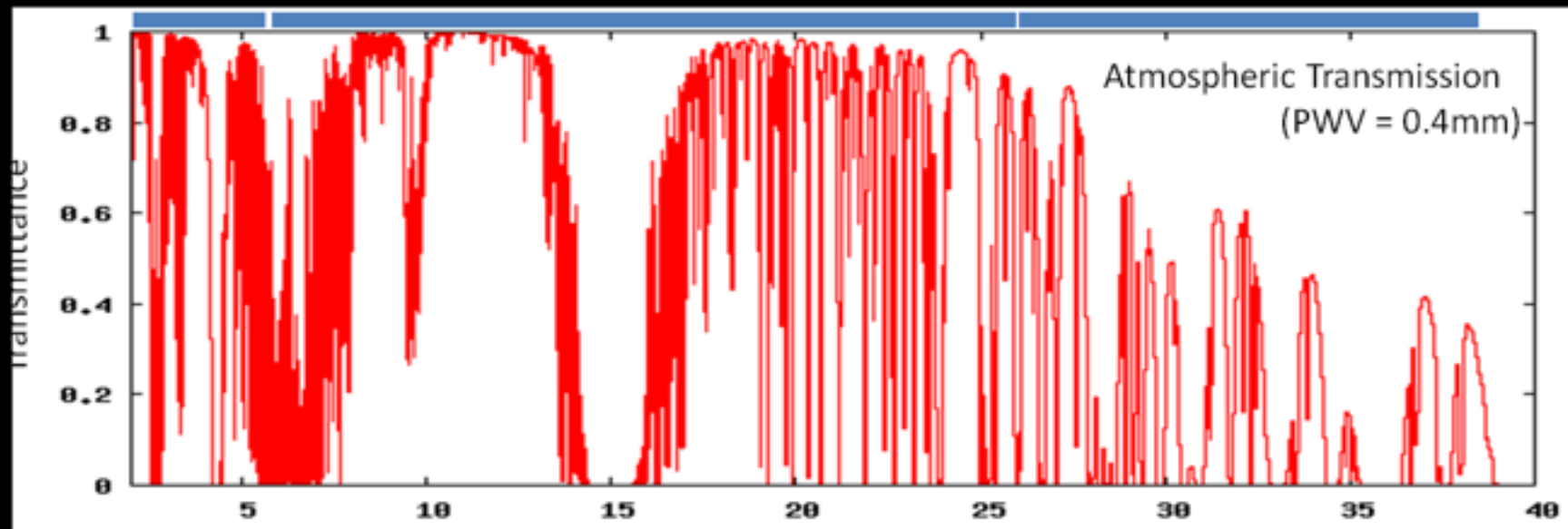
- Ro-vibration transition
→ both thermal and non-thermal (confusing!)

MIR

- Pure rotation transition
→ **thermal**



Strategy

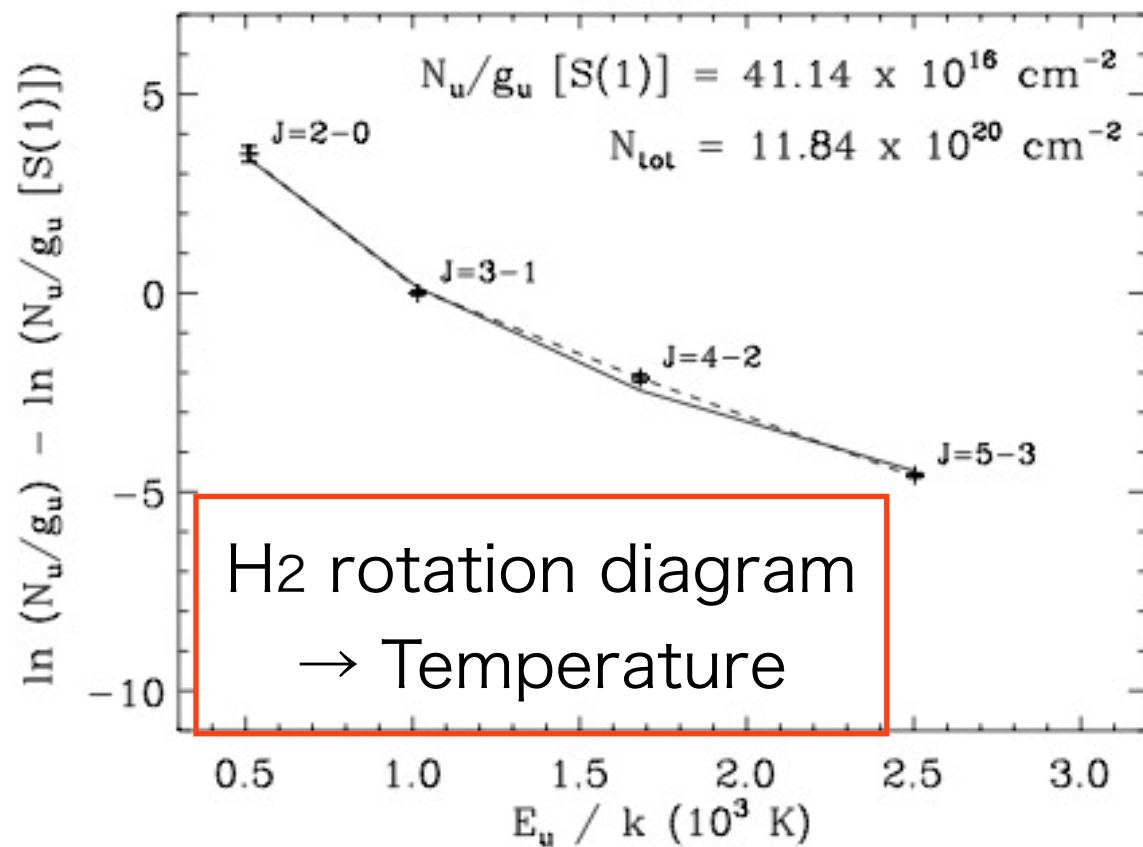


S(1) - S(3) can be observed with MIMIZUKU/
MIR-S channel (R~230).

| Transition | Notation | Rest λ [μm] | E_u/k [K] | A [10^{-11}s^{-1}] |
|------------|----------|----------------------------------|-------------|---------------------------------|
| J=2-0 | S(0) | 28.219 | 510 | 2.95 |
| J=3-1 | S(1) | 17.035 | 1015 | 47.6 |
| J=4-2 | S(2) | 12.279 | 1681 | 275.0 |
| J=5-3 | S(3) | 9.665 | 2503 | 980.0 |

Strategy

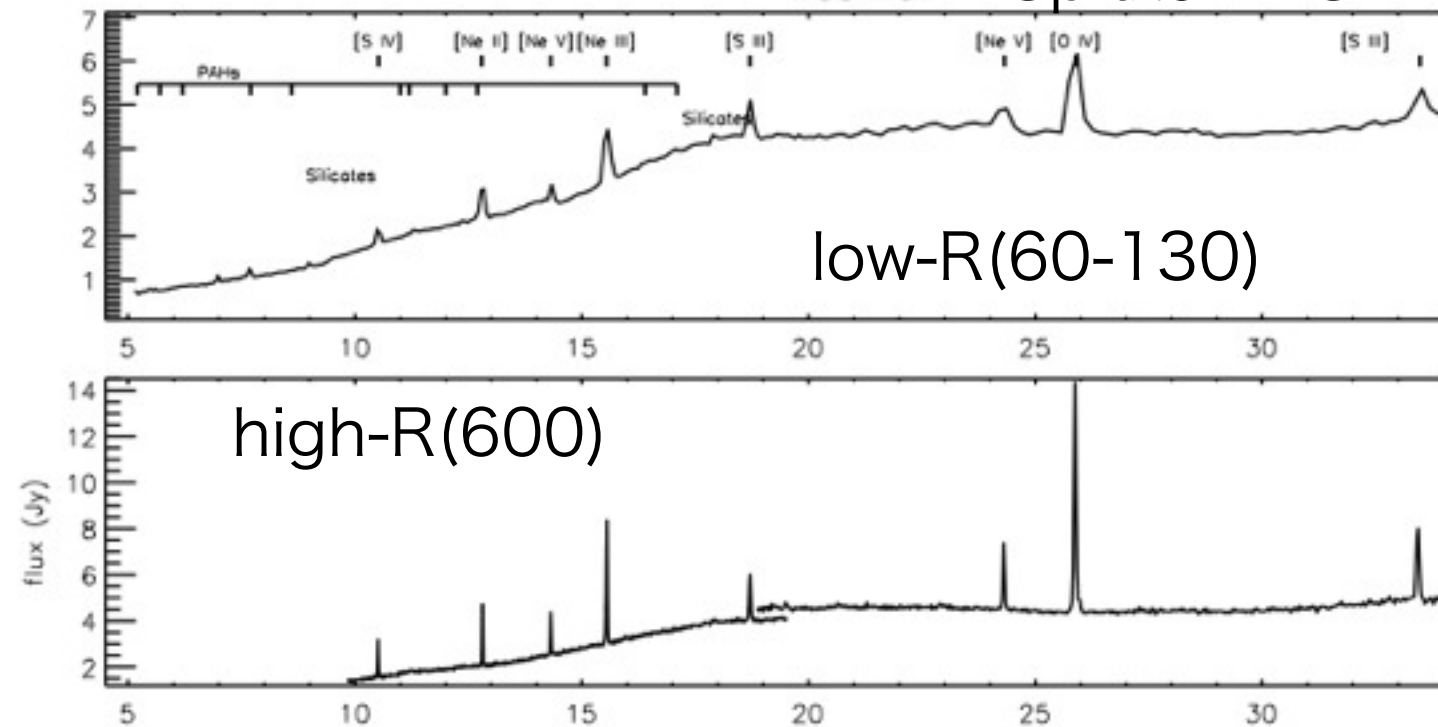
Roussel et al. 2007 N1097



Weedman et al. 2005

NGC4151

Spitzer IRS



- The spectral resolving power of MIMIZUKU is $R \sim 200$.
- This R would be OK for a pilot study, but higher $R(>600)$ is much more preferable!
- A very superior point of TAO/MIMIZUKU is its **high angular resolution!**

Summary

- High temperature would be the key to study the AGN-specific features.
- We propose a new diagnostic method, but it needs to be tested.
- Molecular hydrogen is one of the tracer of hot environments, and it can be observed with TAO-site.
- MIMIZUKU's wide wavelength coverage and high angular resolution of TAO/MIMIZUKU is suitable to study this topic.
- Higher resolving power is thus strongly desired to investigate line emission.