

ALMAデータを用いたスパースモデリングによる 系外活動銀河の超解像度イメージング

Super-resolution imaging using Sparse Modeling
for ALMA observations of NGC1068

Nagoya Univ. M2 Yohei Togami

(Mail: y.togami@a.phys.nagoya-u.ac.jp)

Yoichi Tamura, Akio Taniguchi,
Tsutomu Takeuchi, Suchetha COORAY, Kai T. KONO (Nagoya Univ.)



NAGOYA
UNIVERSITY

Overview

1. Introduction

- Importance of resolving AGN
- Sparse Modeling

2. Target

- previous studies
- data

3. Current results

4. Discussion

5. Summary / Future works

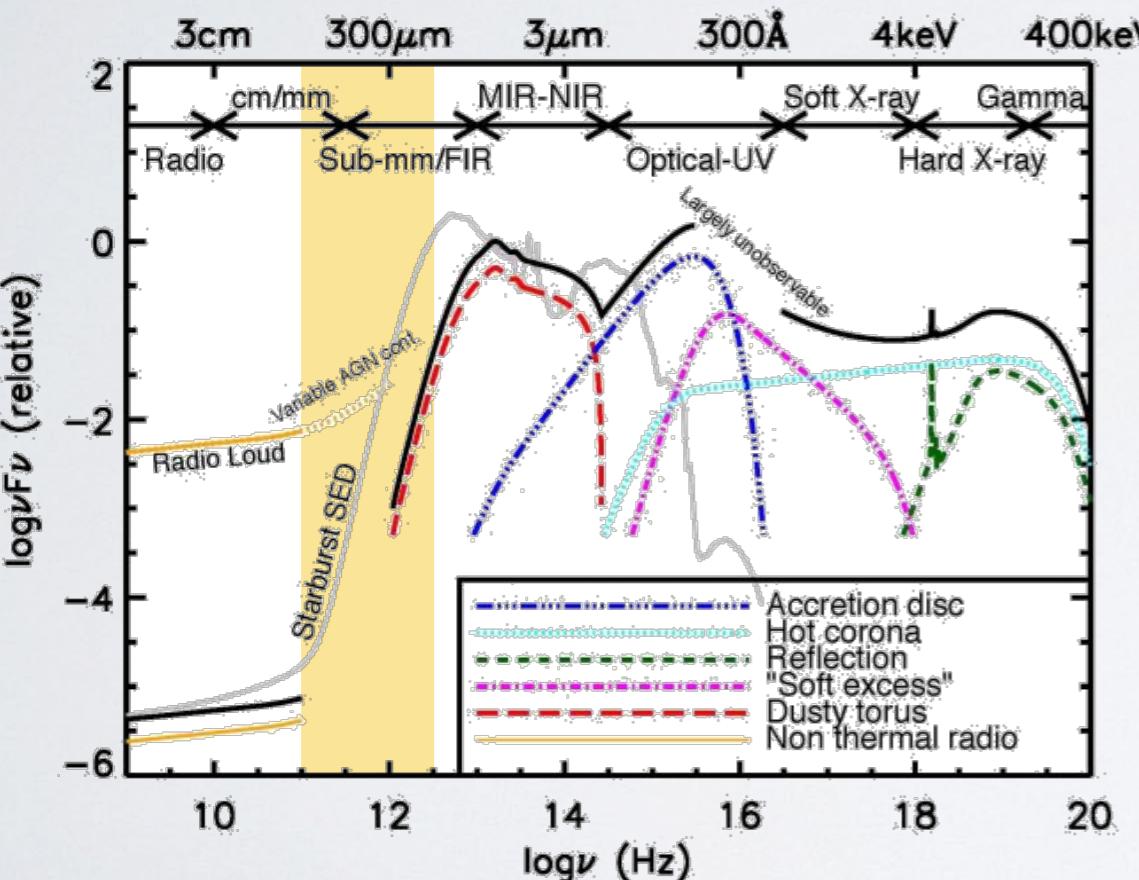
Importance of resolving AGN

AGN(Active galactic nuclei)

AGN is one of the most “compact” and “active” object

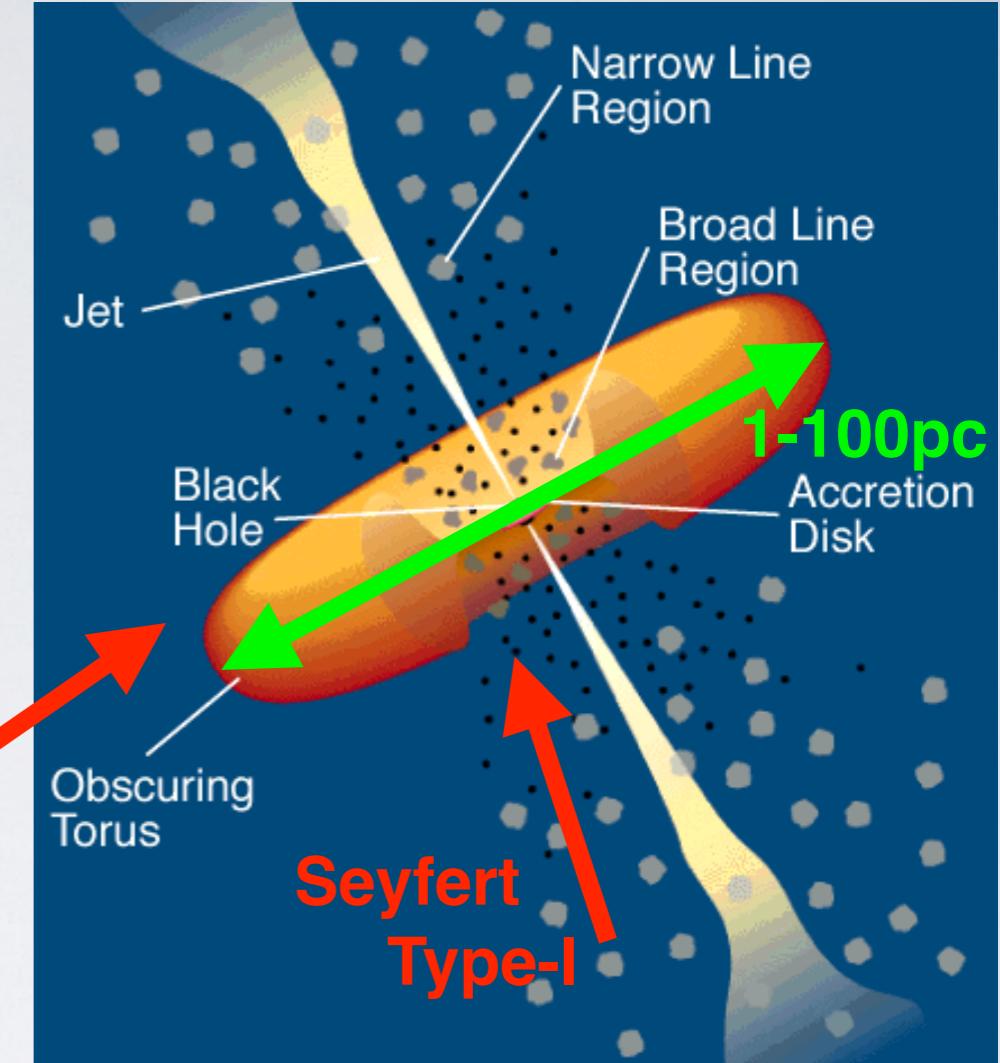
SMBH ($10^6 - 10^{10} M_{\odot}$), dust torus, jet...

Many radiative process



(<https://ned.ipac.caltech.edu/level5/March18/Hickox/Hickox1.html>)

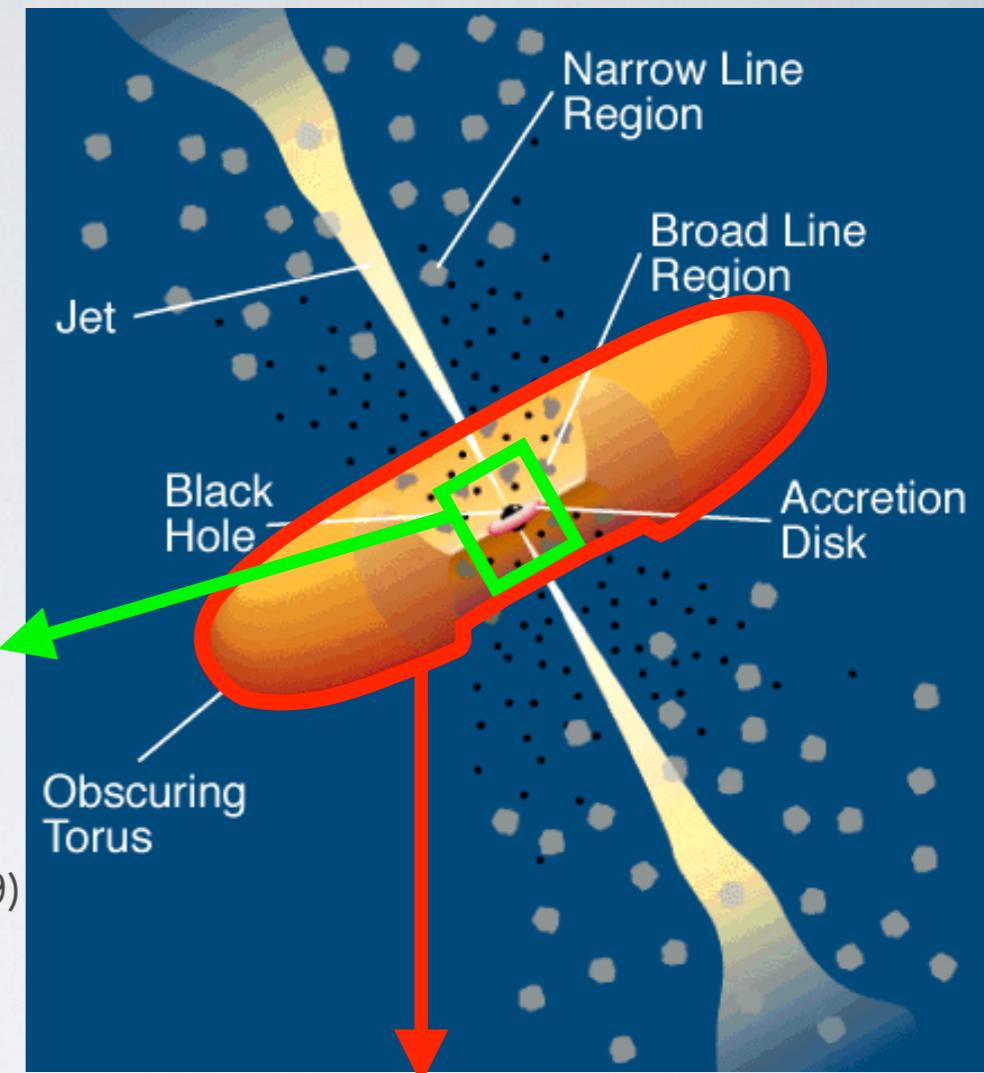
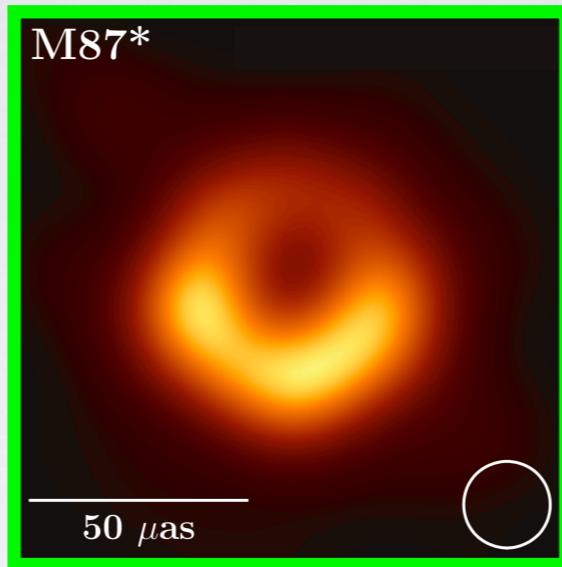
→ mm~submm is “bridge” frequency
which could trace many radiative process



(www.kusastro.kyoto-u.ac.jp/~iwamuro/LECTURE/AGN/agn.html)

To restrict AGN unified model,
mm~submm wavelength must play important role

Importance of resolving AGN

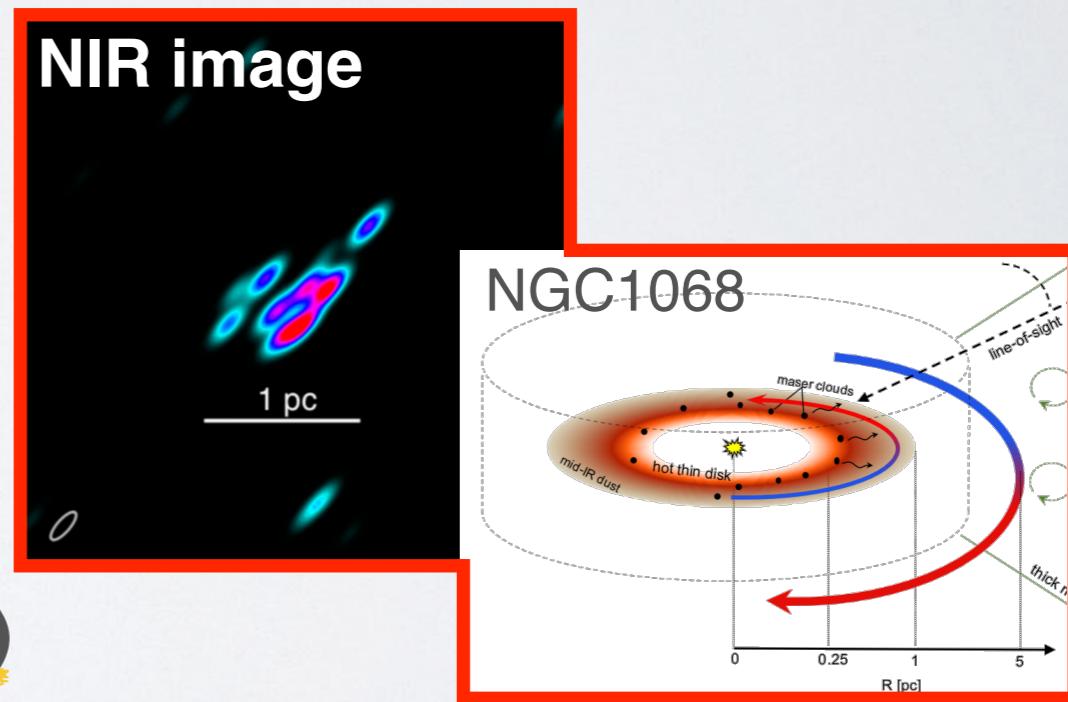


Faint components of the AGN
haven't been revealed enough

ALMA alone cannot achieve
required spatial resolution

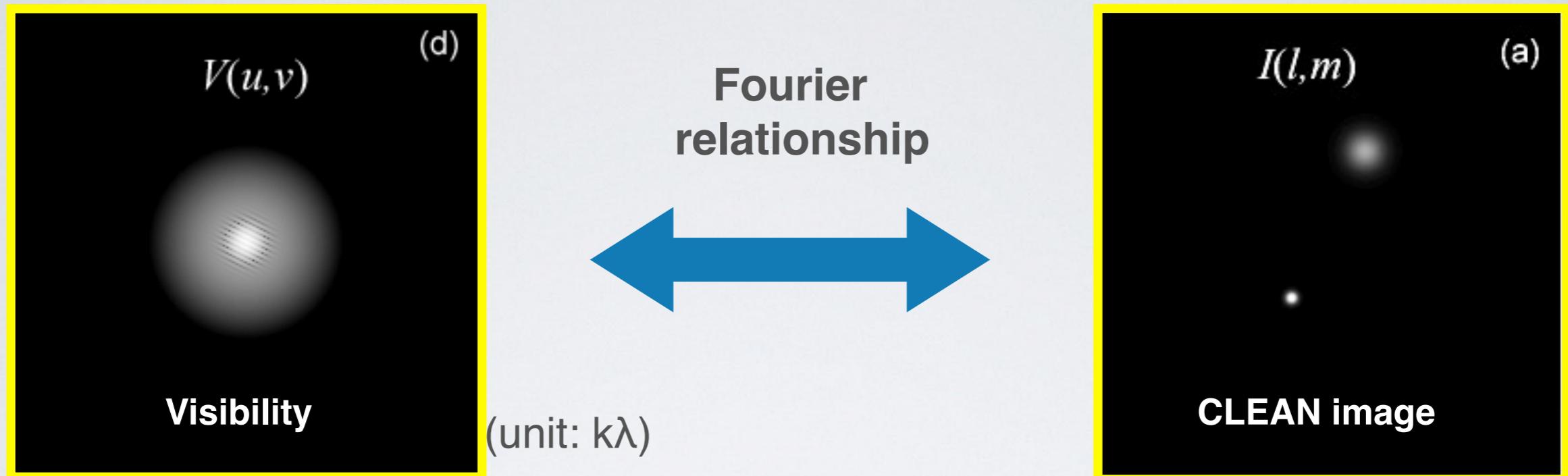


Combination of ALMA and Sparse Modeling(SpM)



(GLAVITY Collaboration(=GC) 2019)

Conventional method : CLEAN

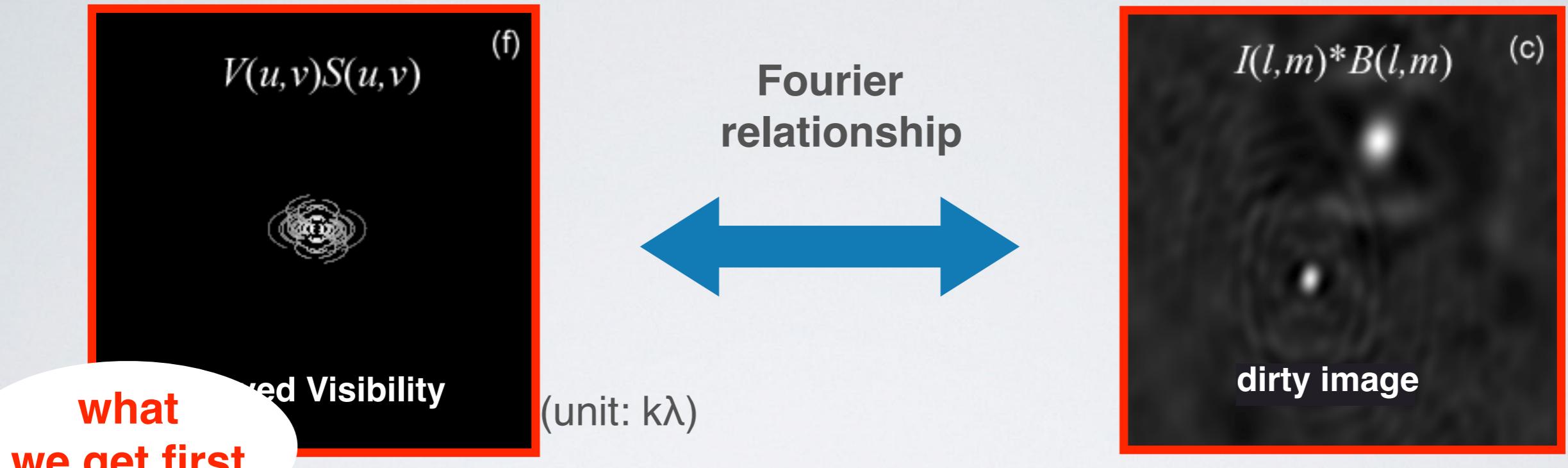


(image : <https://web.njit.edu/~gary/728/Lecture6.html>)

$$\underset{\text{Visibility}}{V_{d=N}} = \underset{\text{FT matrix}}{A} \underset{\text{Image}}{I_{d=M}} \quad (\text{d : dimension})$$

generally, $N < M \rightarrow \text{"ill-posed problem"}$

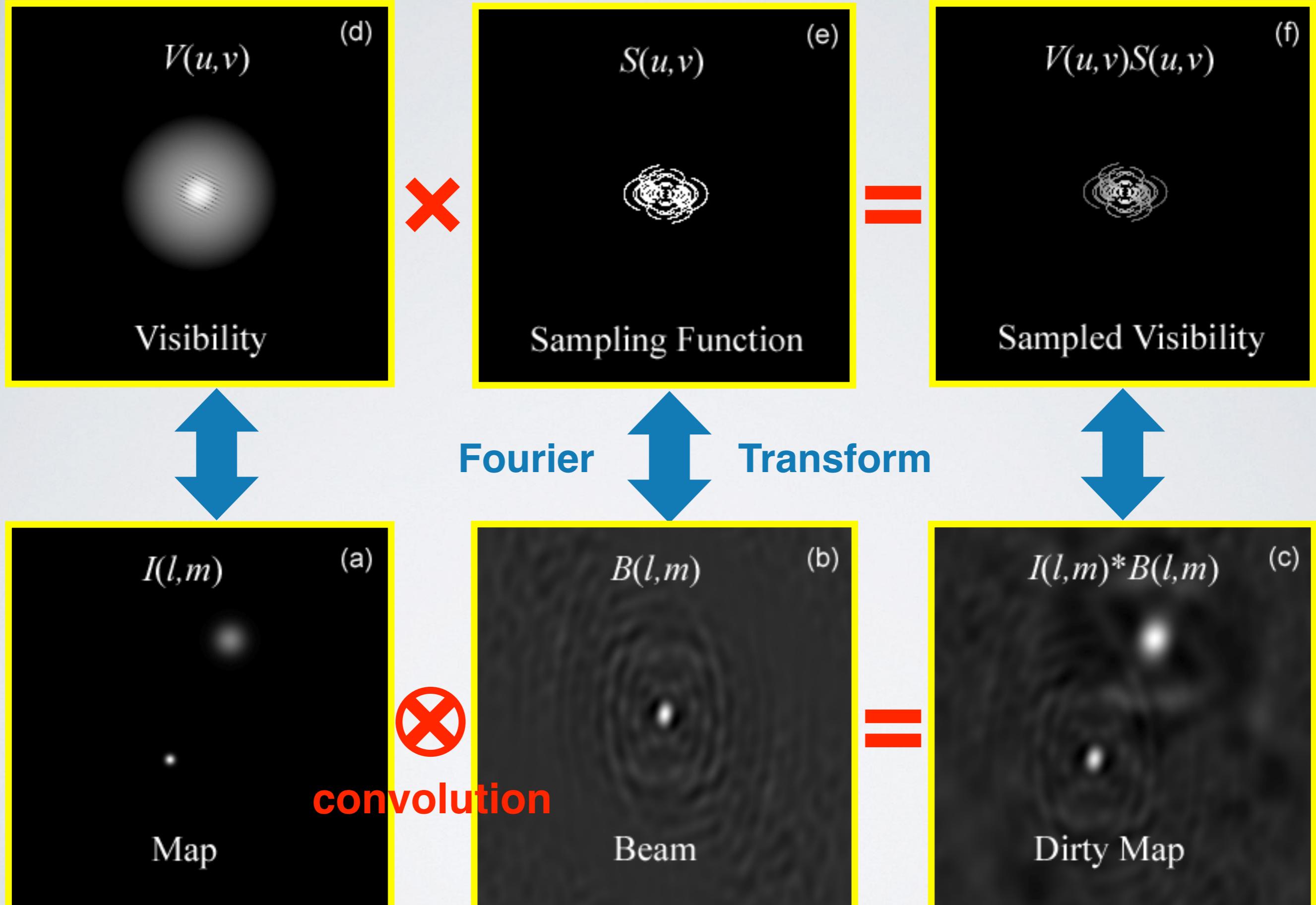
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(image : <https://web.njit.edu/~gary/728/Lecture6.html>)

Sparse Modeling (SpM)

A statistical method that estimates a solution by assuming
“the solution is sparse enough”

CLEAN :
resolution is limited by
longest baseline

SpM :
resolution isn't limited by
longest baseline

Group of
point-source

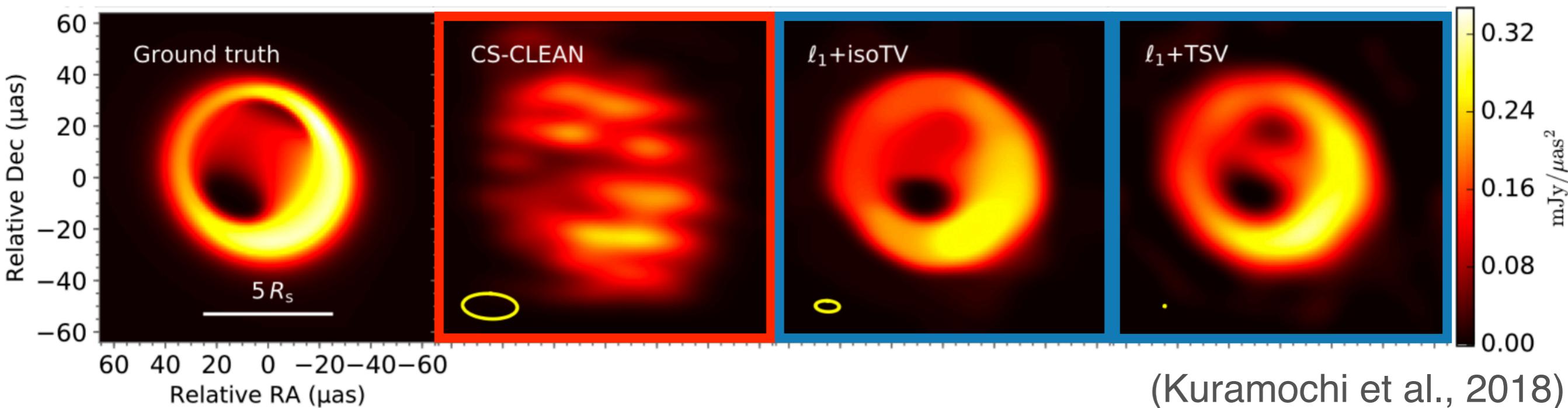
+

Bright
↓
emission

Structure is
smooth

+

Target is
small

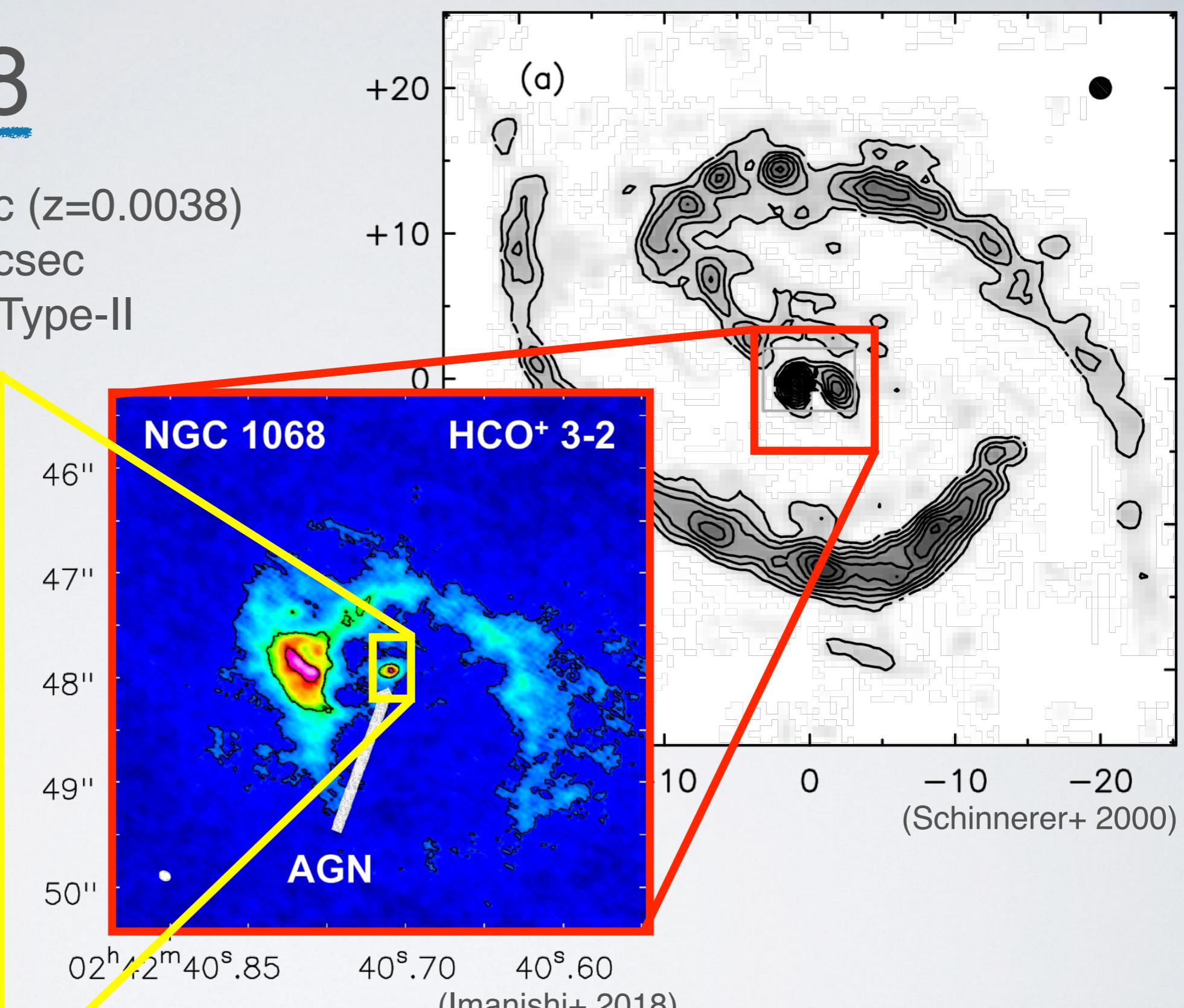
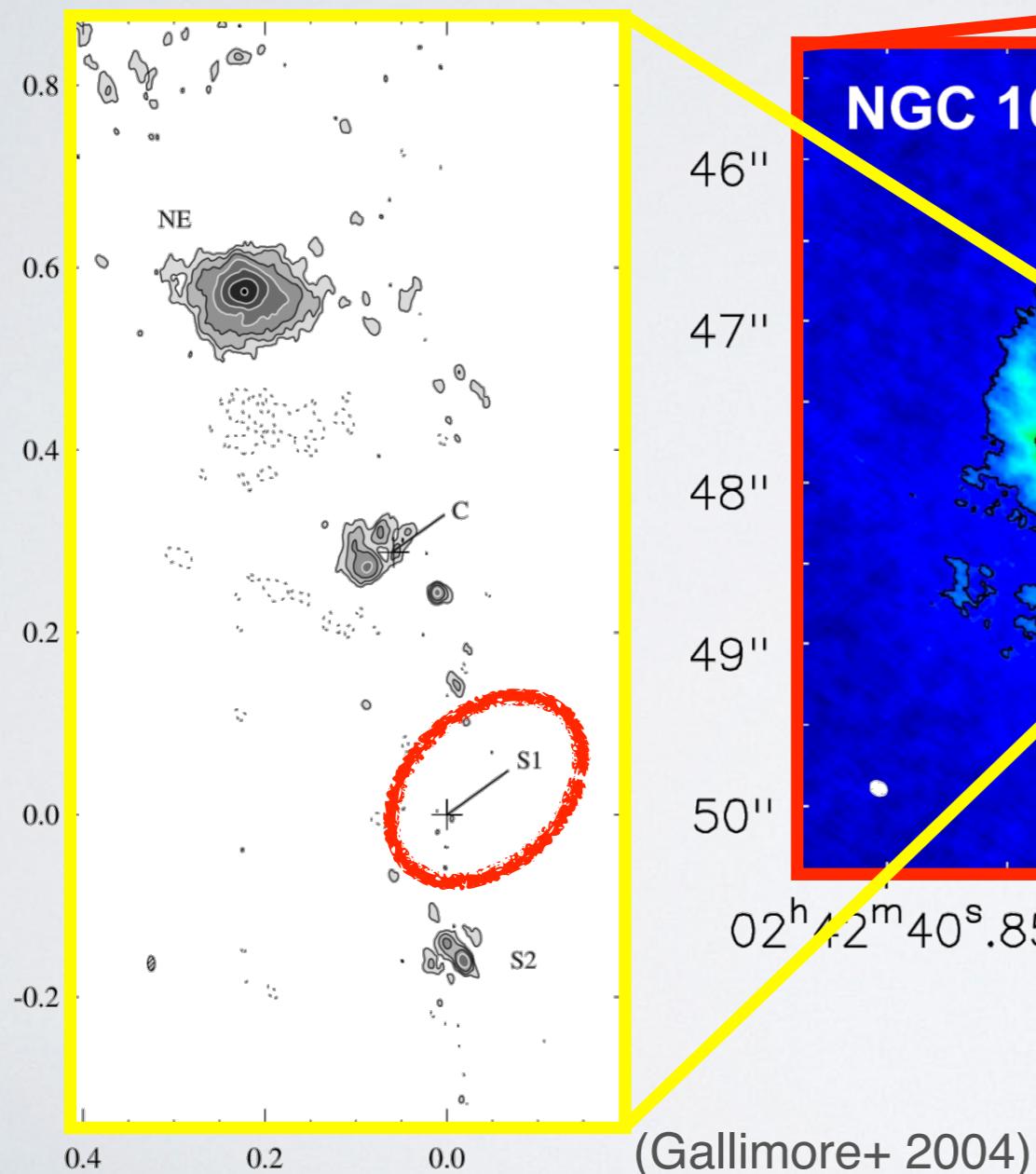


NGC1068

Distance: 14.4Mpc ($z=0.0038$)

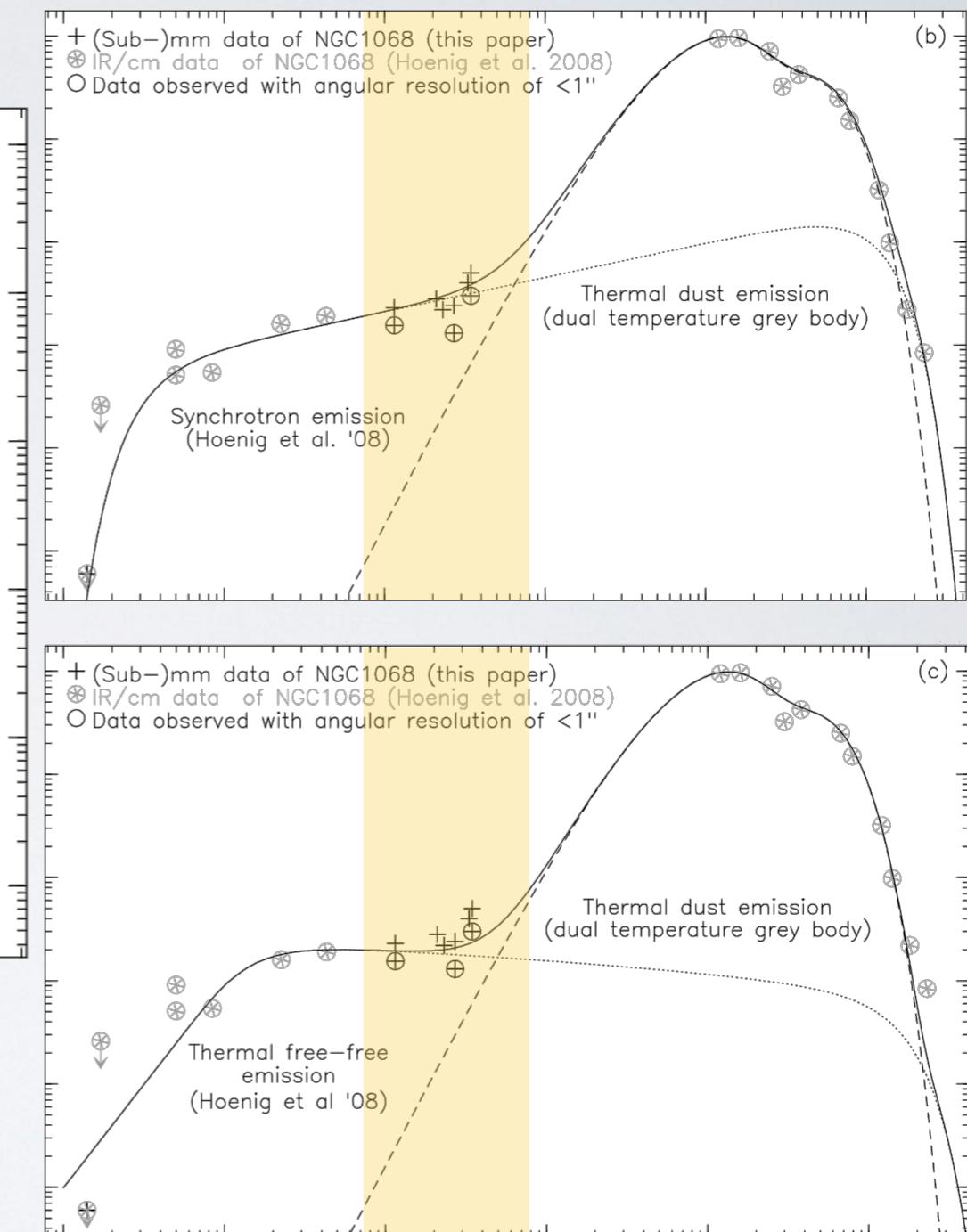
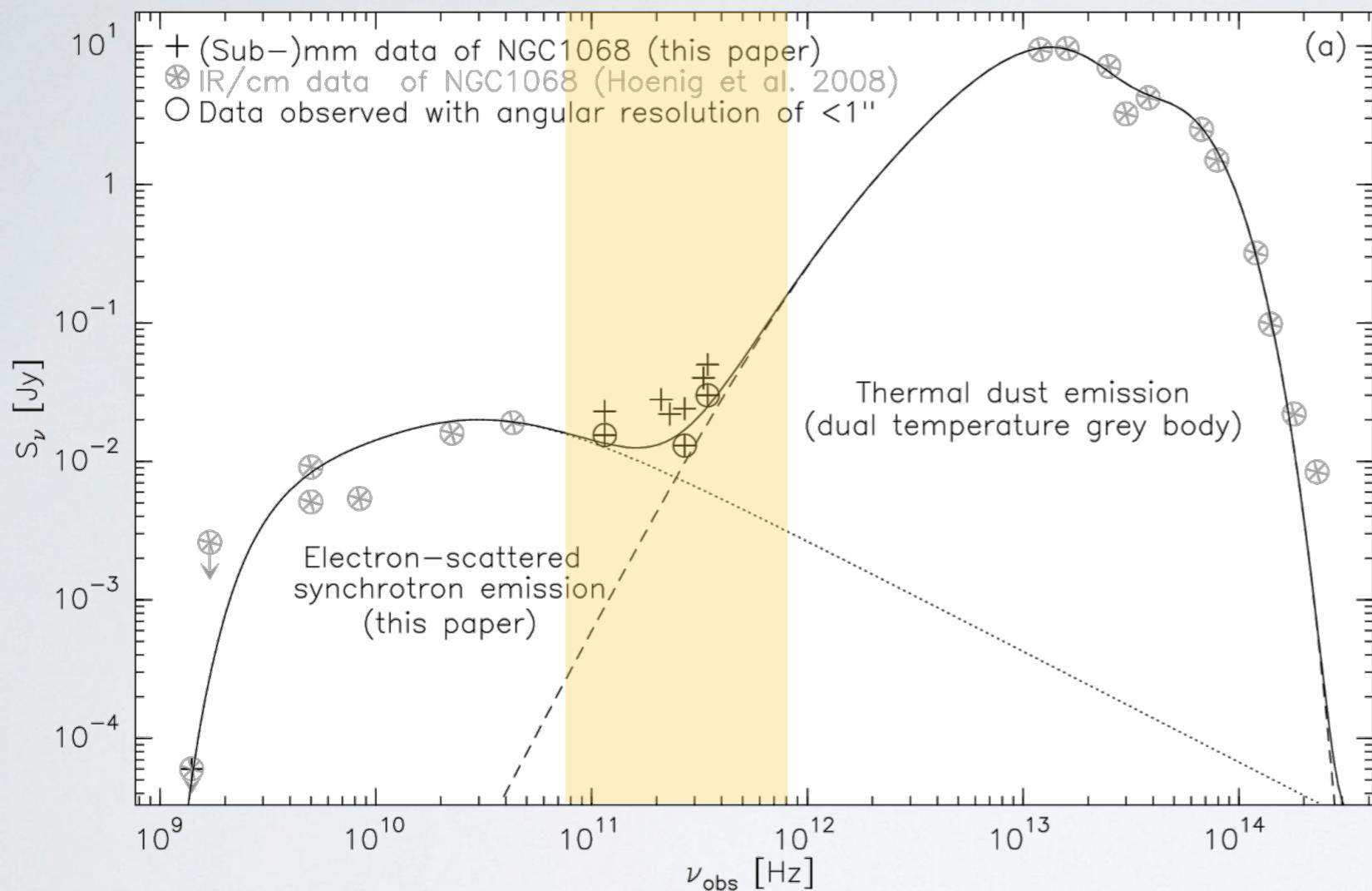
Scale: 70pc/arcsec

AGN type: Seyfert Type-II



The origin of the radio component

Lack of observations with high spatial res. of $< \sim 0.3\text{arcsec}$
disable us to specify the radio component

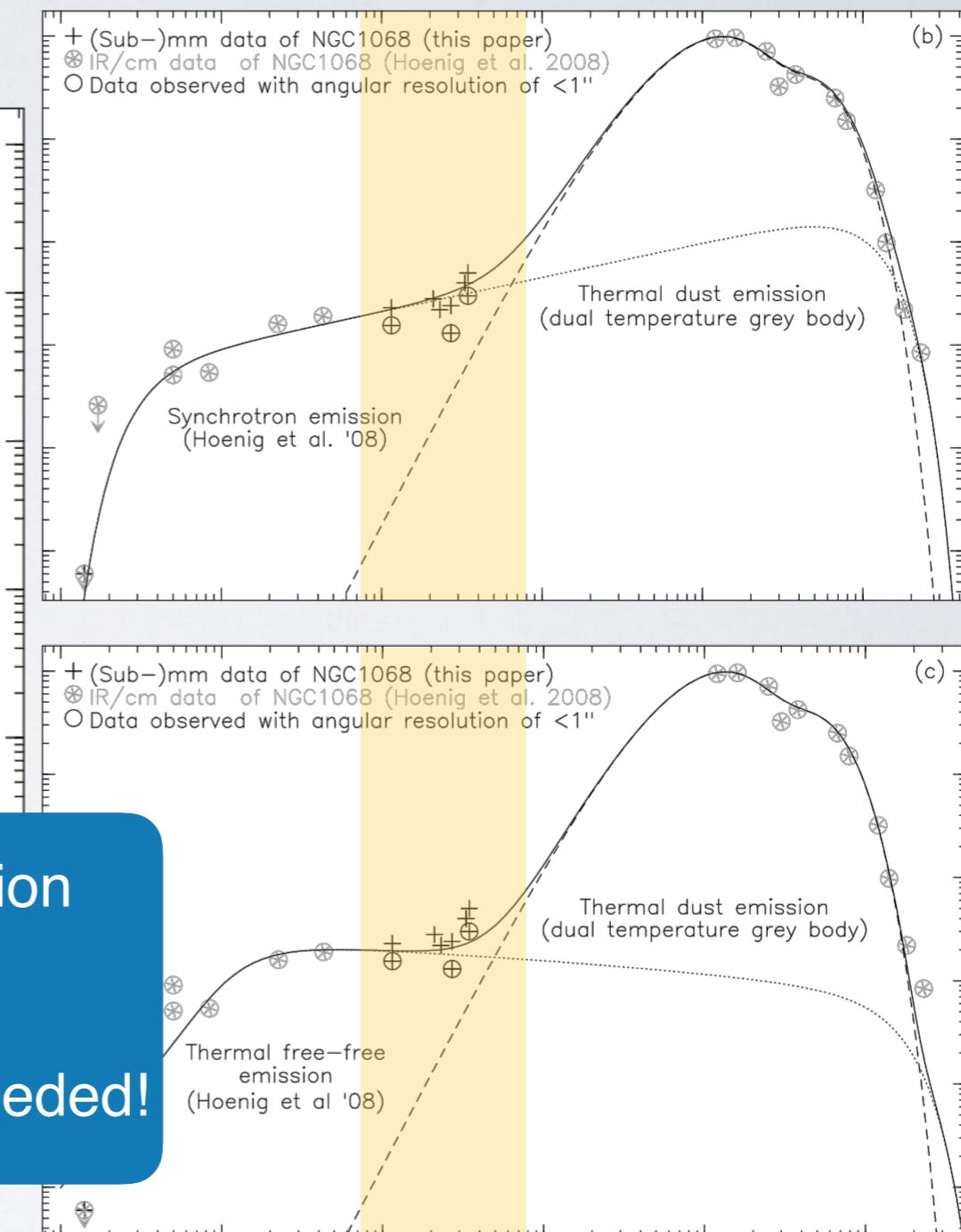
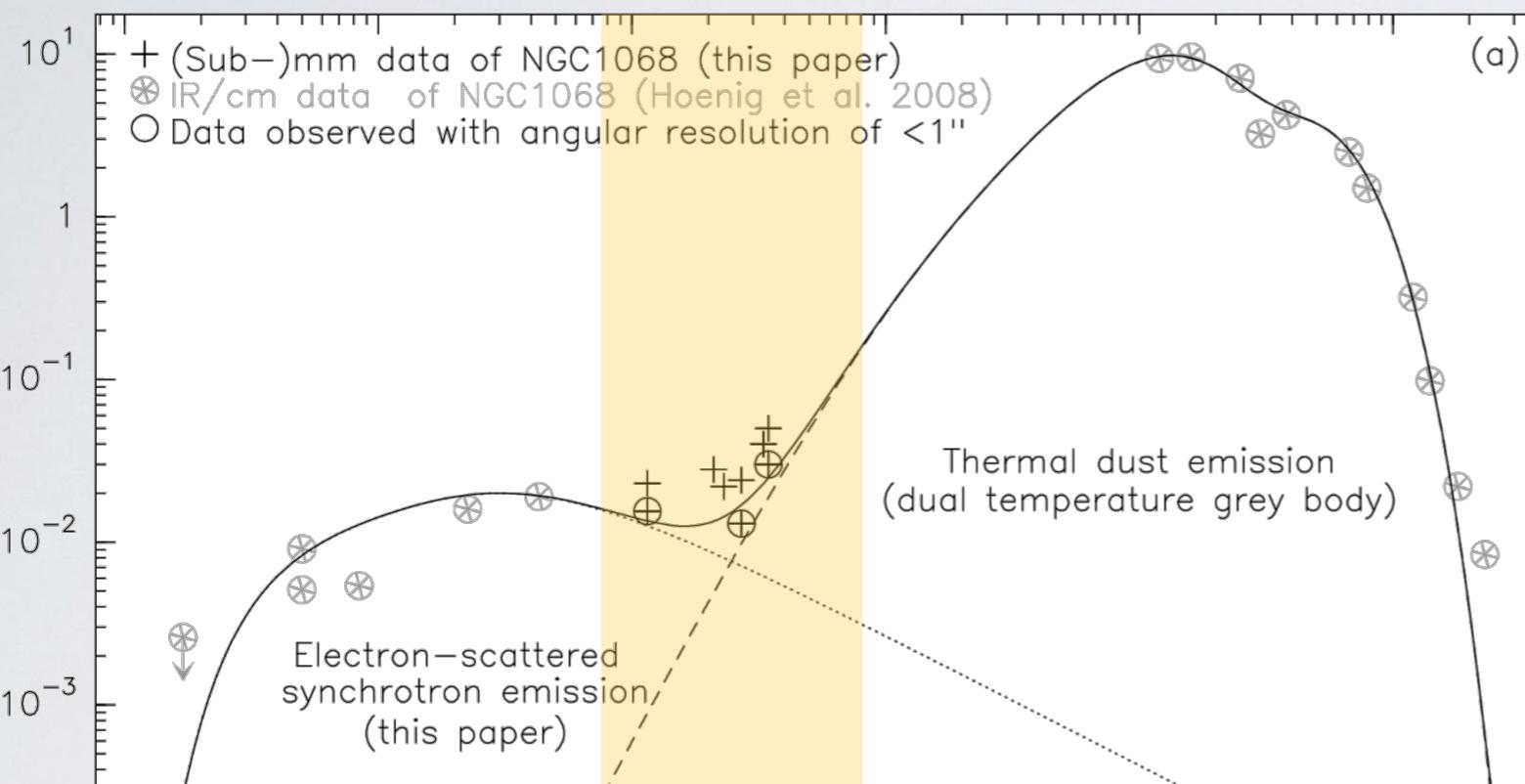


ESSE model is the most likely candidate

(Krips+ 2011)

The origin of the radio component

Lack of observations with high spatial res. of $< \sim 0.3\text{arcsec}$
disable us to specify the radio component



ESSE is thought to be emitted from the central region

→ To specify the origin like this,
not only SED but also the “spatial distribution” are needed!

ESSE model is the most likely candidate

(Krips+ 2011)

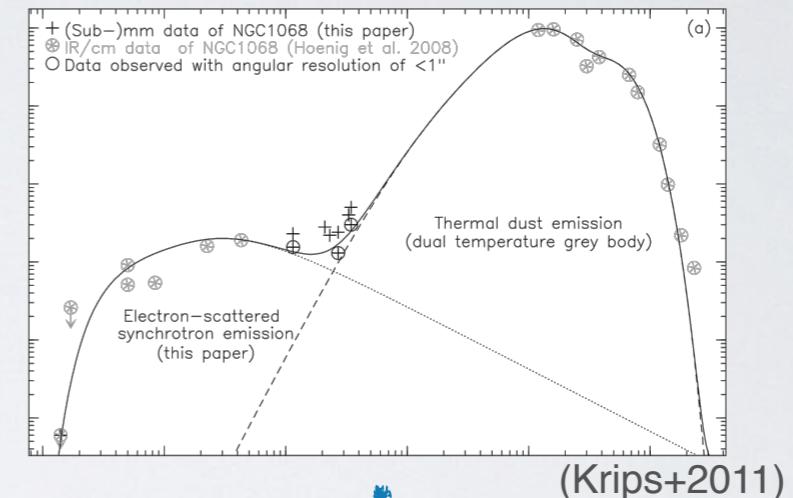
Method of this work

SpM (PRIISM software (Nakazato+2019))
ALMA telescope



Credit: ALMA (ESO/NAOJ/NRAO)

nuclear **SED** fitting



Resolve the AGN region with multi-wavelength

Identify the origin of the radio emission and the dust feature

Data

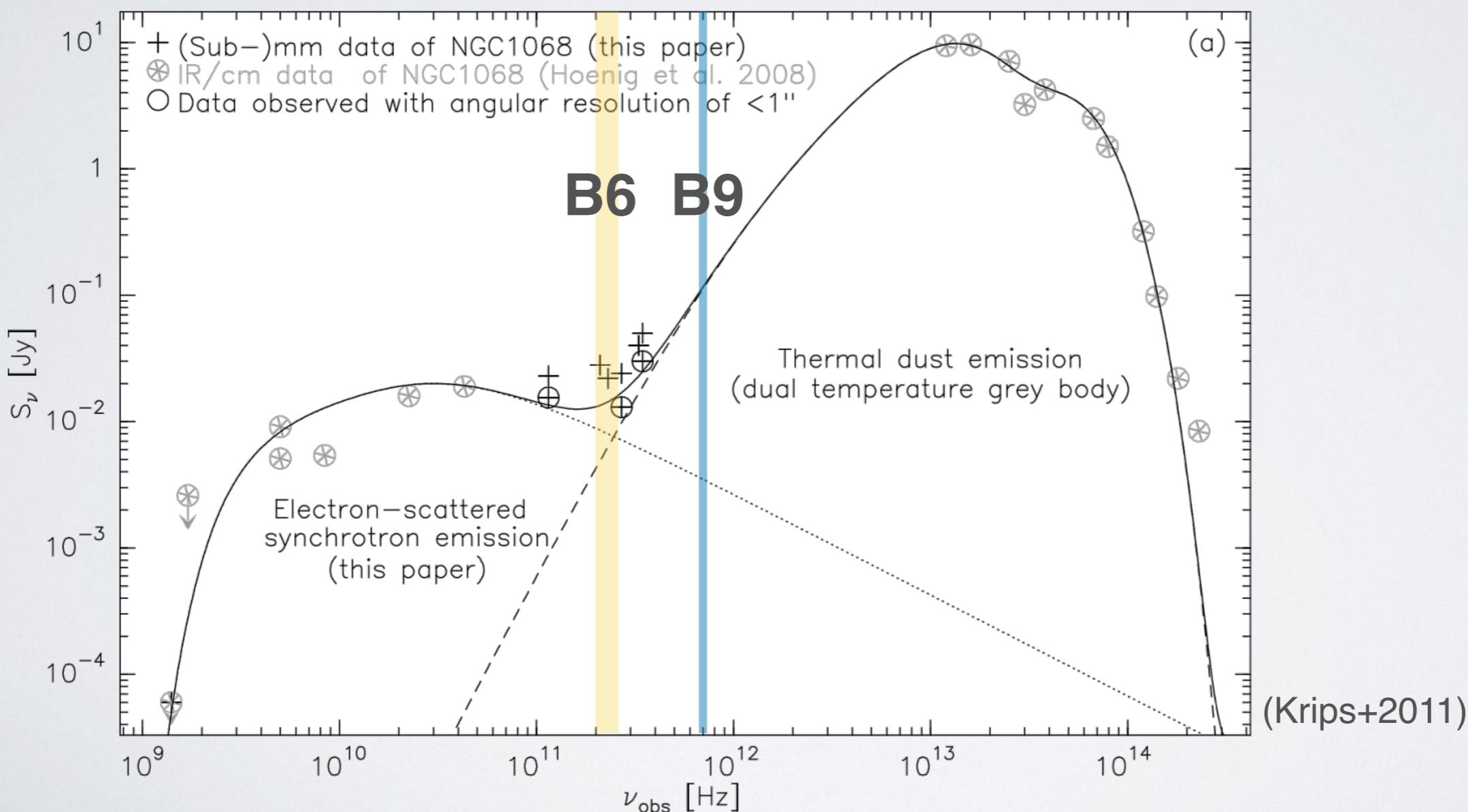
1) ALMA Band 6 data

- 210-230, 245-265GHz
- resolution : 0''.02
- radio? dust?

+

2) ALMA Band 9 data

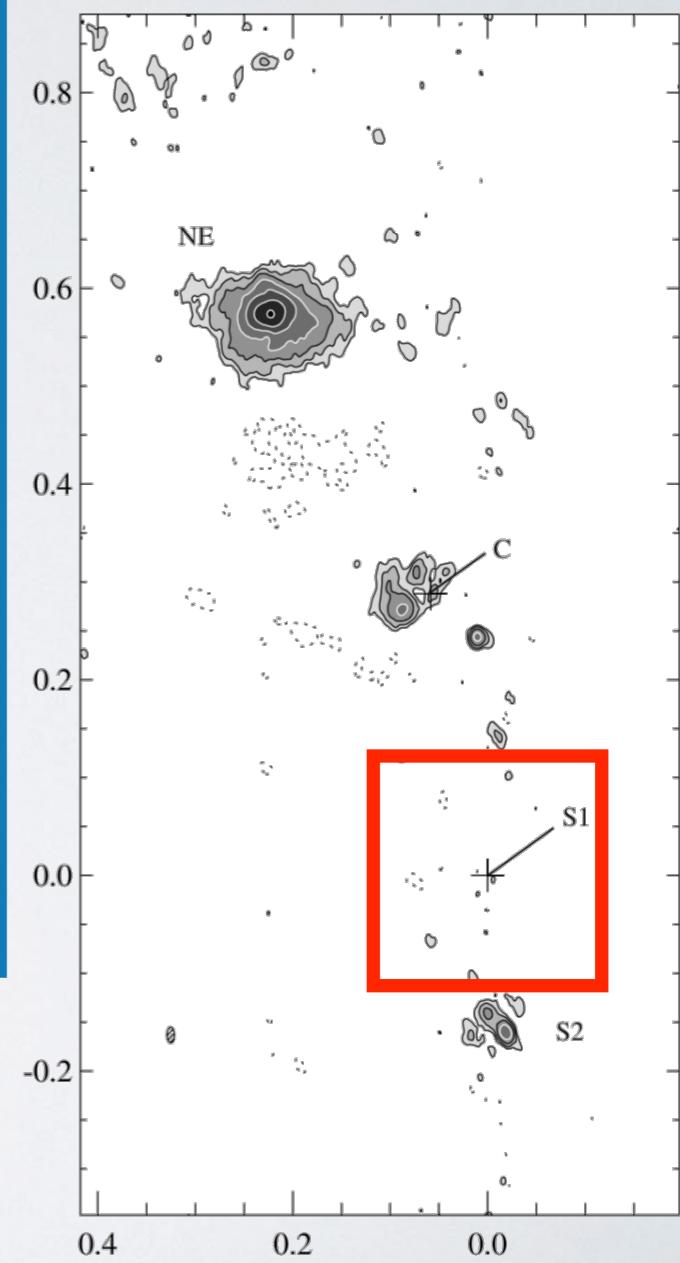
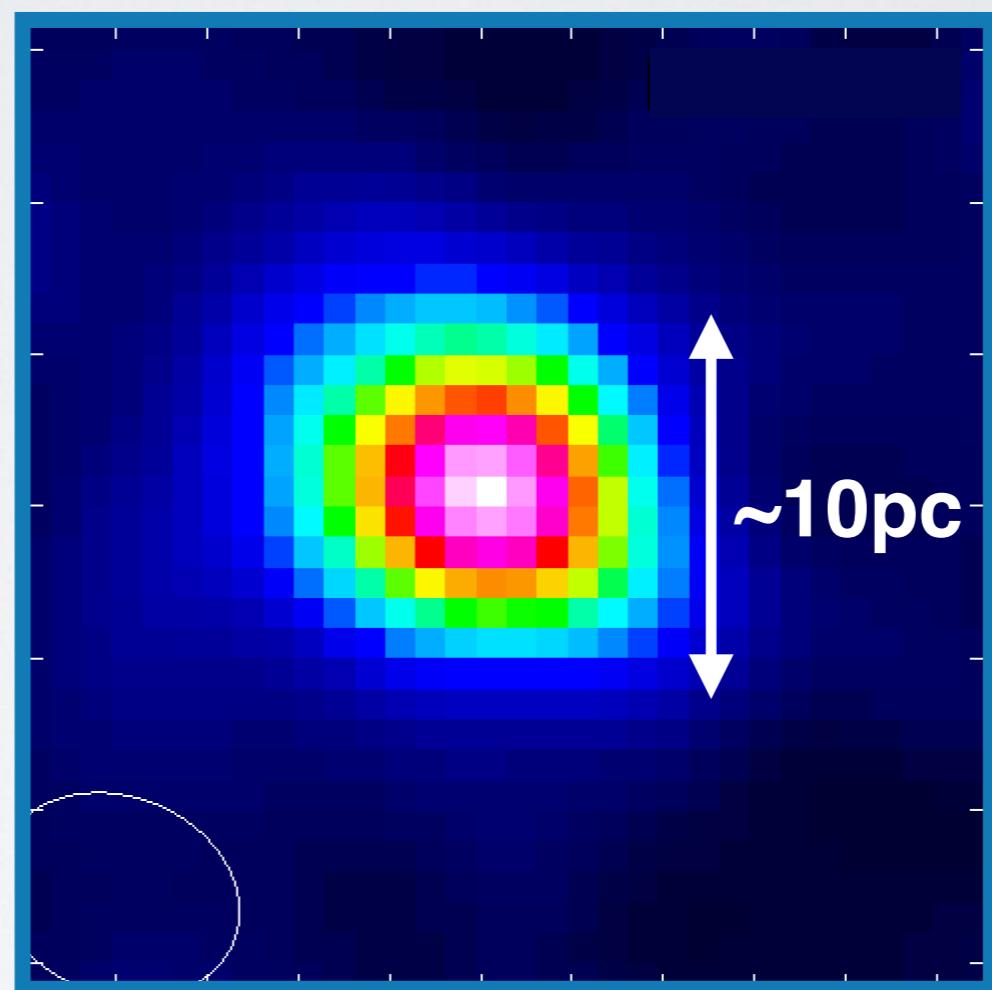
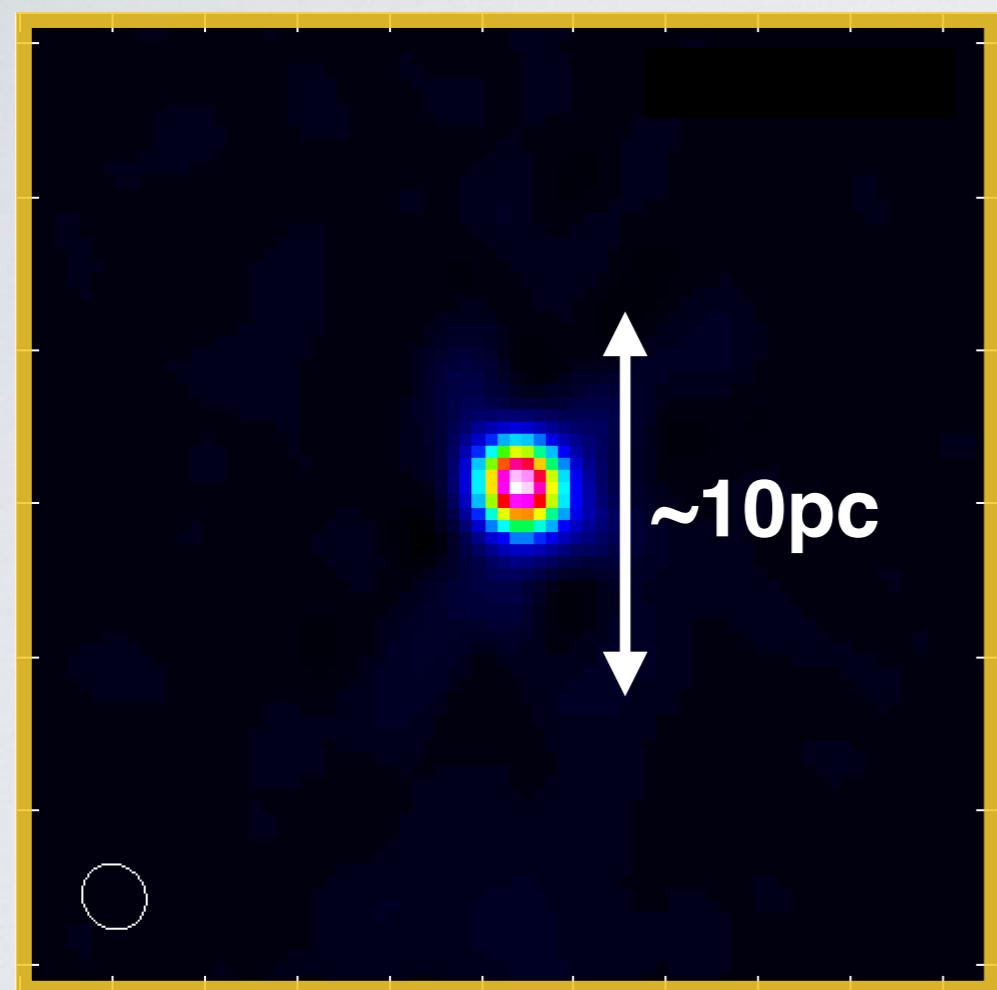
- 675-690, 690-705GHz
- resolution : 0''.07
- Dust emission



Data

1) ALMA Band 6 data
• 210-230, 245-265GHz

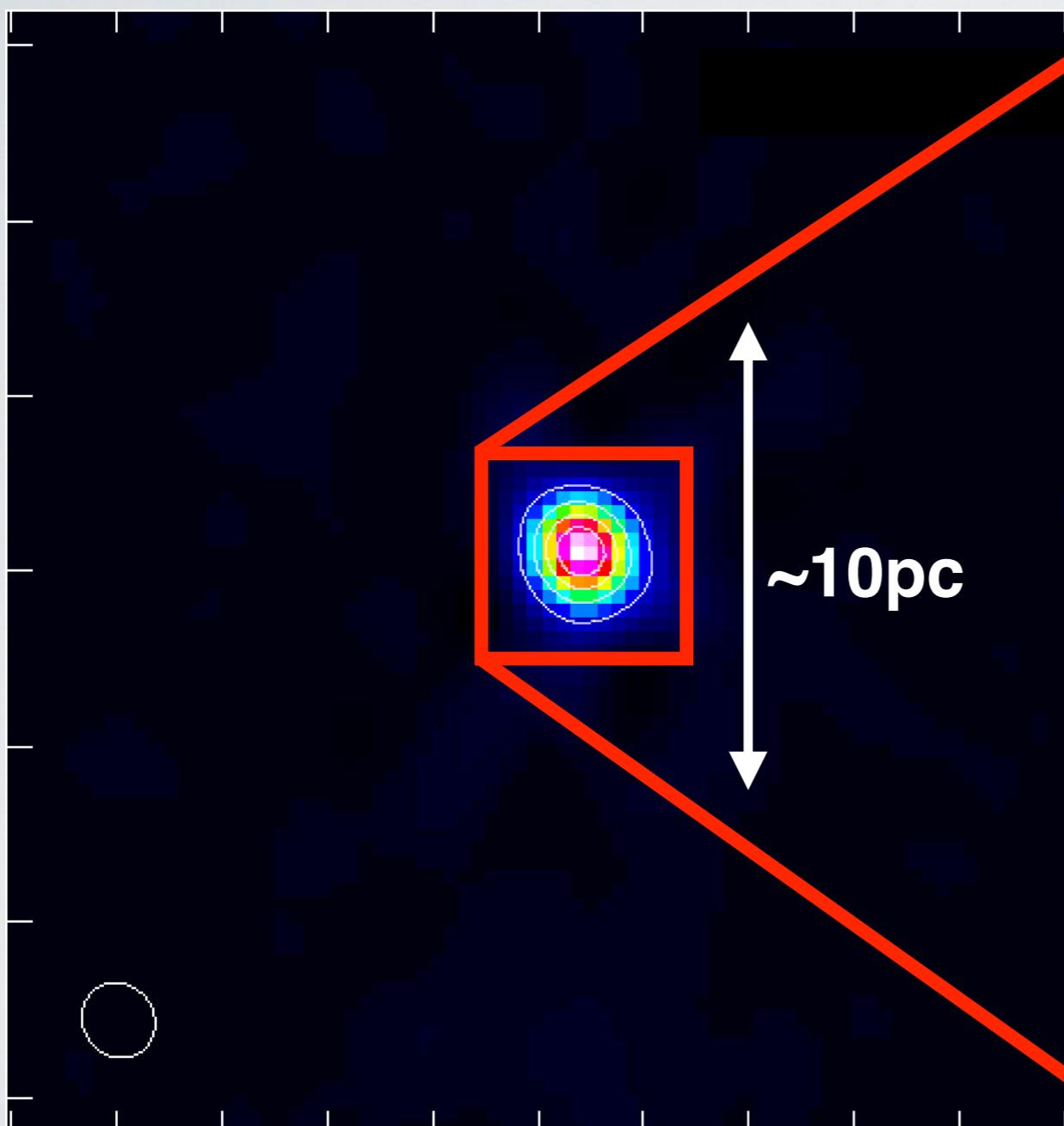
2) ALMA Band 9 data
• 675-690, 690-705GHz



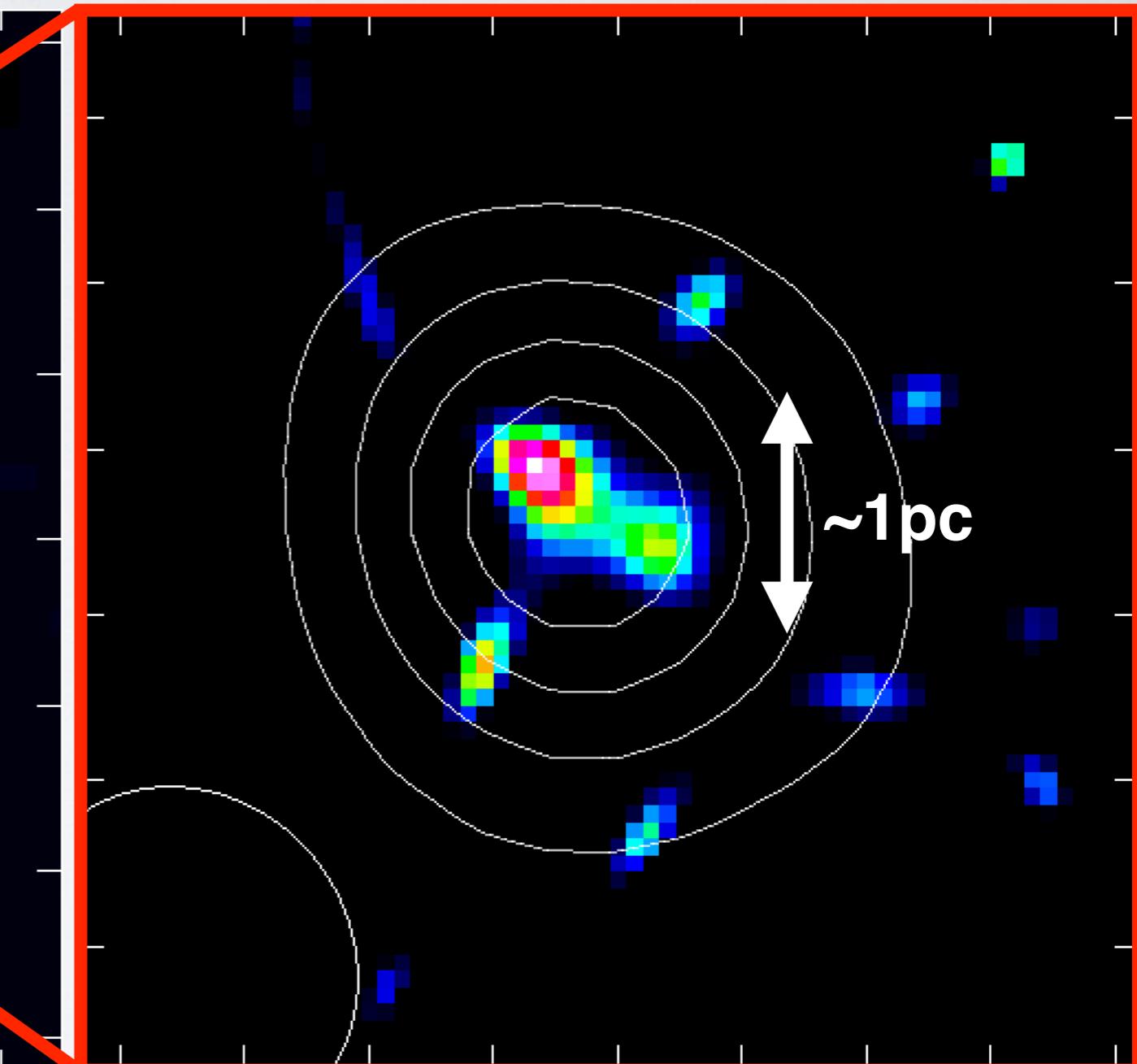
These images are produced by conventional method, CLEAN

SpM on Band 6 (240GHz) data

Conventional method (CLEAN)

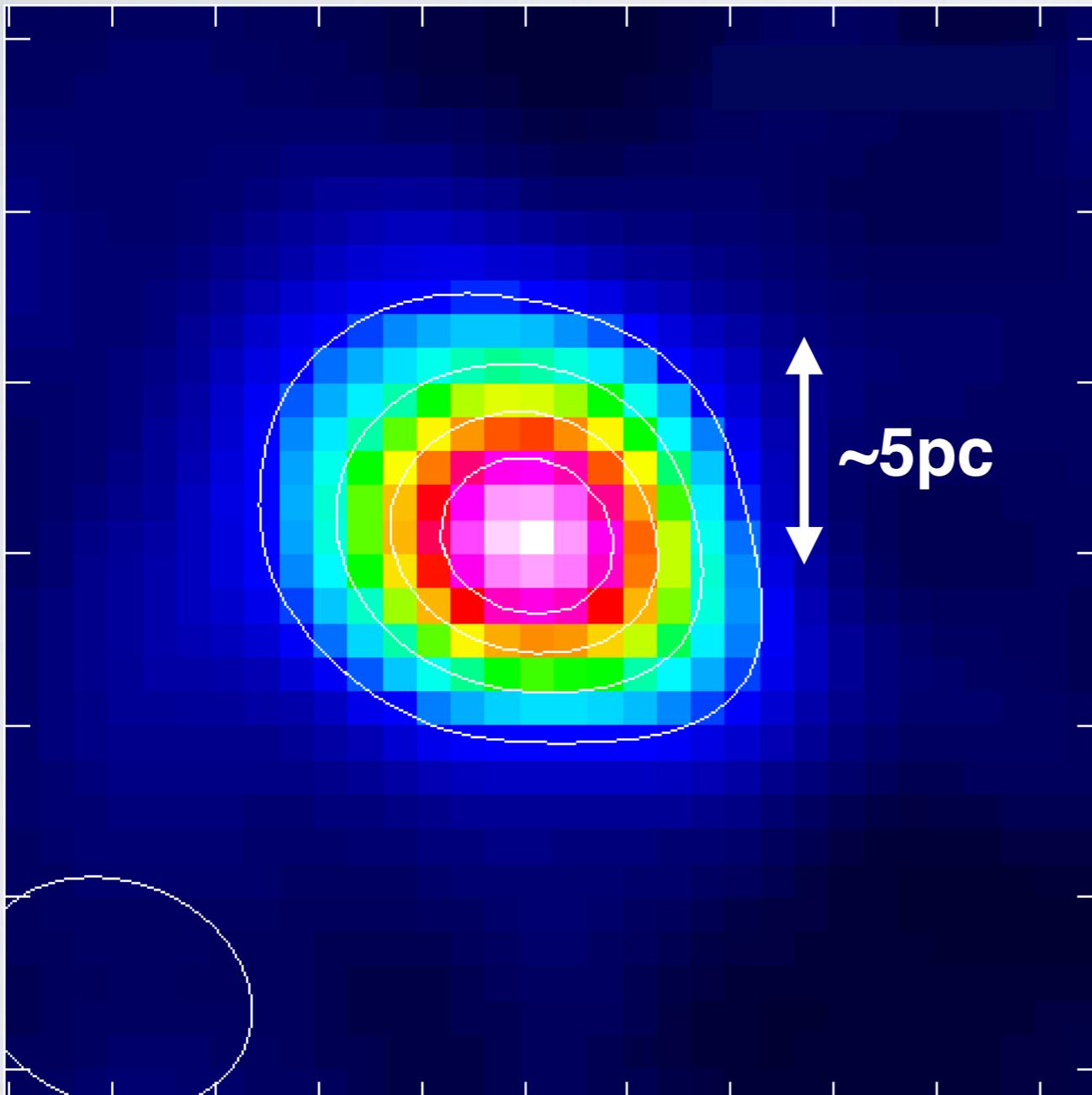


New method (SpM)

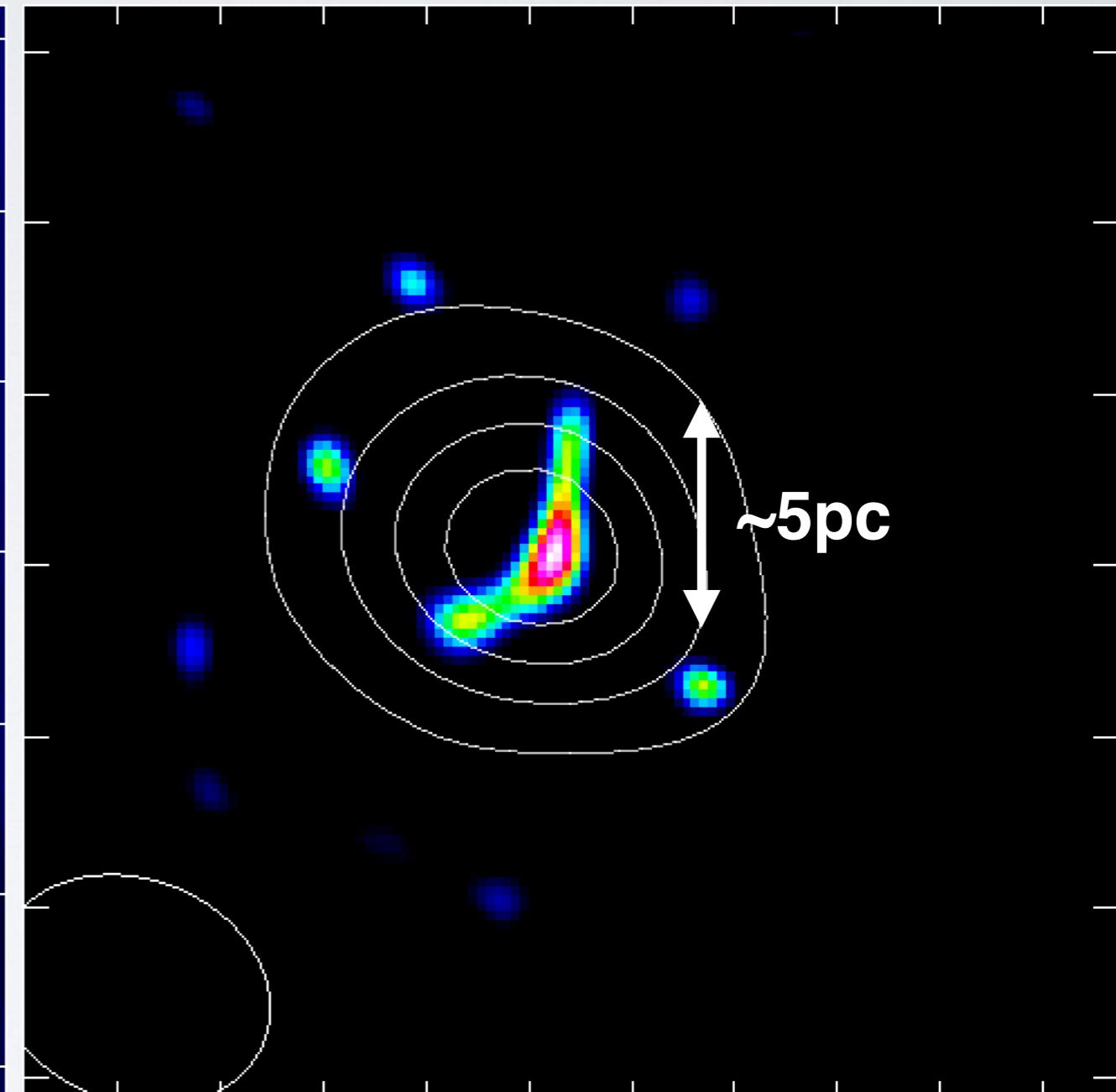


SpM on Band 9 (690GHz) data

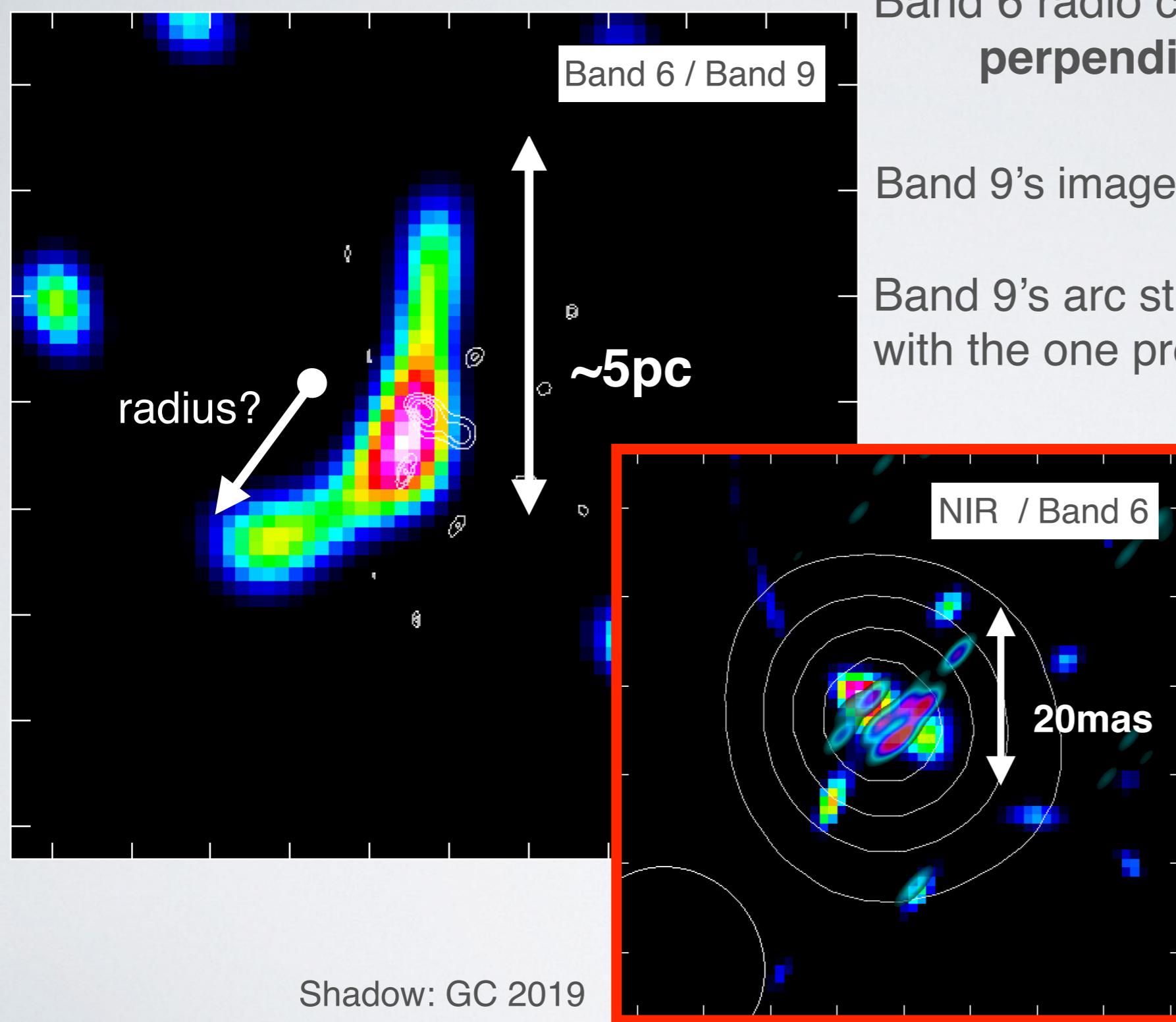
Conventional method (CLEAN)



New method (SpM)



Interpretation of SpM results



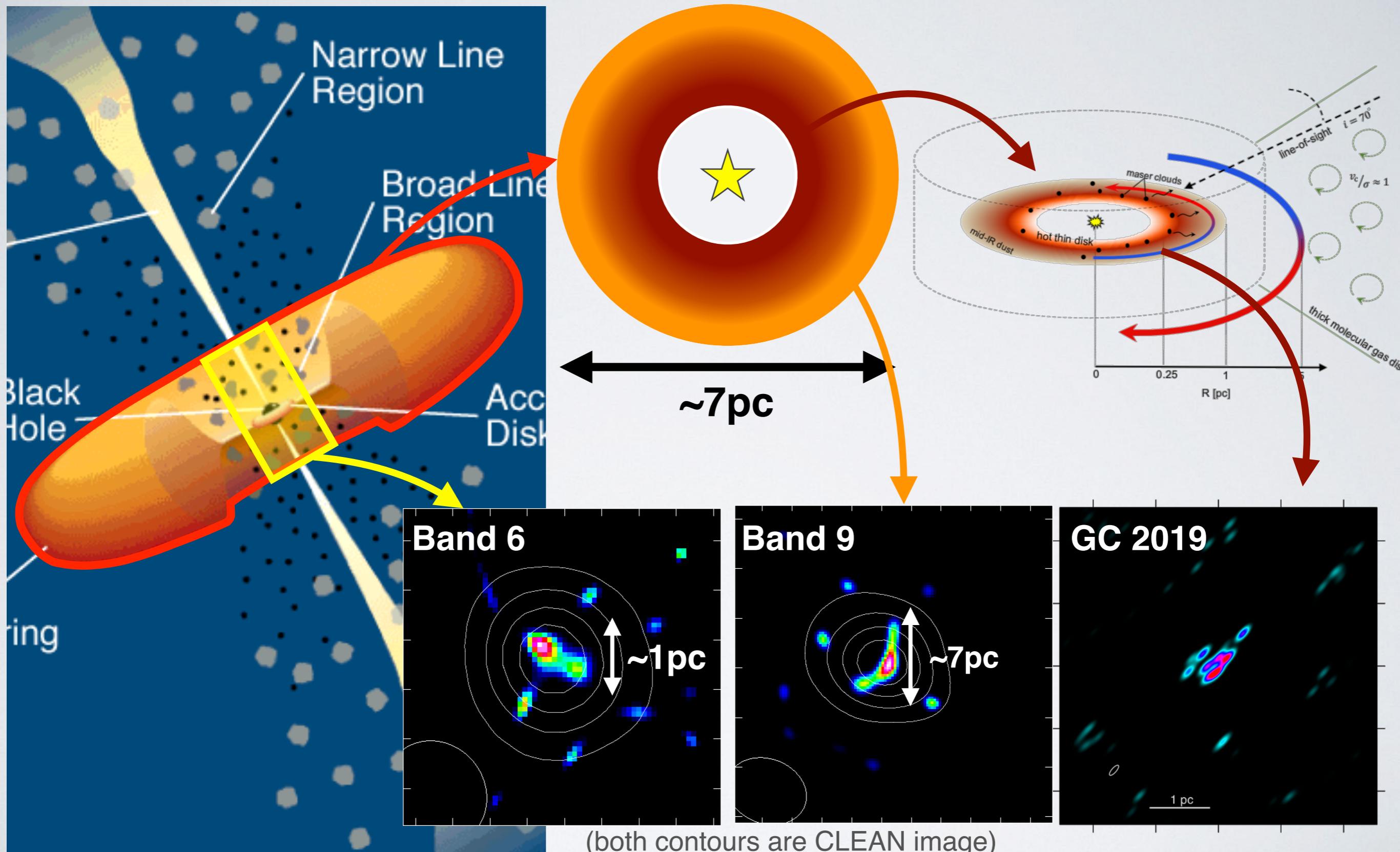
Band 6 radio component has
perpendicular structure to the dust.

Band 9's image is seem to be closely
related with the dust

Band 9's arc structure has comparable radius
with the one predicted in Garcia-Burillo+2016

The astrometric uncertainly
NIR : ~20mas
radio : ~1.5mas

AGN-schematic model of NGC1068



Summary

SED in previous study

Radio component and the dust feature are still unclear

Band 6 → “electron-scattered synchrotron emission (ESSE)”

Band 9 → dust component

SpM on ALMA Band 6 and Band 9 data

Band 6 : subpc-scale **jet-like** structure which is perpendicular to the dust

Band 9 : pc-scale arc structure which is thought to trace the dust

Future work

The astrometry uncertainty

SpM-image validation

SED fitting

→ y.togami@a.phys.nagoya-u.ac.jp

