

筑波大学宇宙史センター  
南極テラヘルツ望遠鏡  
観測理論合同ワークショップ  
(2021年3月25日)

# AGNとブラックホール

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- (A) 遠方AGNの観測
- (B) 近傍AGNとブラックホールの撮像

# (A) 遠方 A G N の観測 (1)

## High-z QSO/BH

z	Name	$L_{\text{IR}} (L_{\odot})$	$M_{\text{BH}} (M_{\odot})$	References
7.642 (131億年)	J0313-1806	$1.5 \times 10^{12}$	$(1.6 \pm 0.4) \times 10^9$	Wang+ (2021)
7.54	J1342+0928			Bañados+(2018)
7.5149	J1007+2115	$4.7 \times 10^{12}$	$(1.5 \pm 0.2) \times 10^9$	Yang+ (2020)
7.09	J1120+0641			Davies+(2018)
7.07	J124353+010038		$(3.3 \pm 2.0) \times 10^8$	Matsuoka+(2019a)
7.02	J025216-050331		$(1.39 \pm 0.16) \times 10^9$	Wang+ (2020) Yang+ (2019)
7.021	J0038-1527			Wang+ (2018)
7.01	J235646+001747			Matsuoka+(2019b)

Ly break (UV) → NIR → ALMA ([CII], dust)

課題：宇宙初期における **SMBHの形成?**

中小BHの衝突合体? ガスの降着? 他?

## (A) 遠方 A G N の観測 (2)

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課題 (SMBHはどのようにして形成されたか?) に向けて

- ✓ SMBHは、そもそもいつ ( $z$ ) 形成されたのか
- ✓ SMBHは、どのように質量が大きくなってきたのか?

$$M_{\text{BH}}(z)$$



- $z > 8$  でのAGN/BHの探査
- $z > 7$  でのAGN/BHの数を増やす → 統計的研究

### 問題点

- 観測=NIR ← 静止系=UV ⇒ ダストによる吸収
- ALMA=視野が狭い → NIRで発見されたものを観測



「ダストに埋もれたAGN (SFR大) が見えない」

# (A) 遠方 AGN の観測 (3)

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## @ 単一鏡による THz 掃天観測

- ✓ 観測 THz → 静止系 FIR, MIR  
⇒ ダストによる吸収の影響を受けない。
- ✓ 単一鏡 + 大規模カメラ = 超広視野 (>1度  $\phi$ )  
⇒ 超広域掃天観測  
可視・NIR に依存しない (で見えない) 天体探査

単一鏡で発見 ⇒ ALMA、光学望遠鏡等で詳細観測

## @ 単一鏡による広帯域観測

AGN/X-ray                      SB/UV  
Tk=150K~300K                      Tk=30K~50K

区別可能

- ・ 広域スペクトルで分離可能
- ・ AGN と SB の同時観測 ⇒ 銀河と BH の共進化

# (1. ダスト連続波の観測)

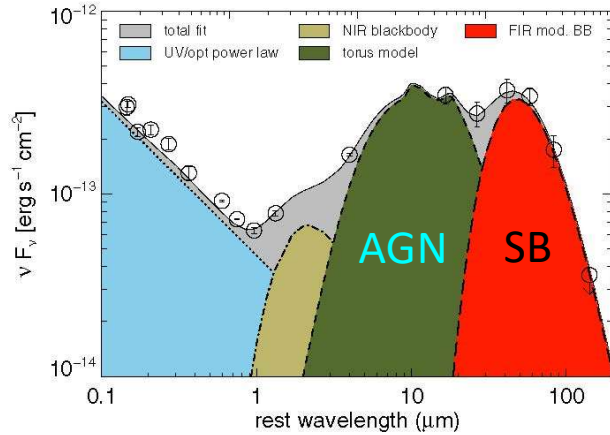


Figure 2. Schematic representation of the components used for SED fitting. As an example, we use the observed photometry of the  $z = 5.03$  QSO J1204-0021. (A color version of this figure is available in the online journal.)

(Leipski+2014)

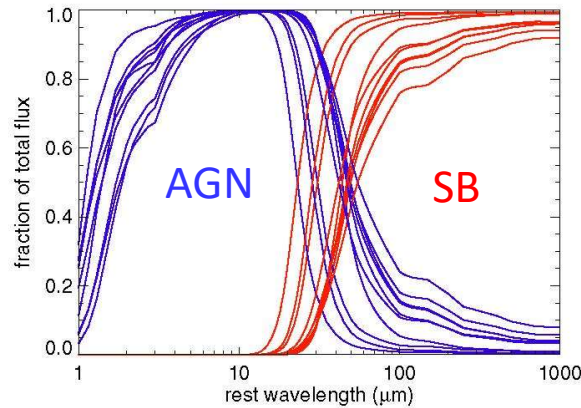


Figure 4. For the 10 objects where the FIR component could be well constrained due to additional millimeter data (see Figure 3) we here show its relative contributions (red) compared to the presumably AGN-heated dust (NIR blackbody plus torus model; blue) as a function of wavelength. For these FIR-bright sources, the FIR component dominates the total infrared emission at  $\lambda_{\text{rest}} \gtrsim 50 \mu\text{m}$ .

rest  $\lambda \sim 20\text{-}60 \mu\text{m}$   $\Rightarrow$   $z > 7$   $\lambda \sim 160\text{-}480 \mu\text{m}$   
 THz, submm

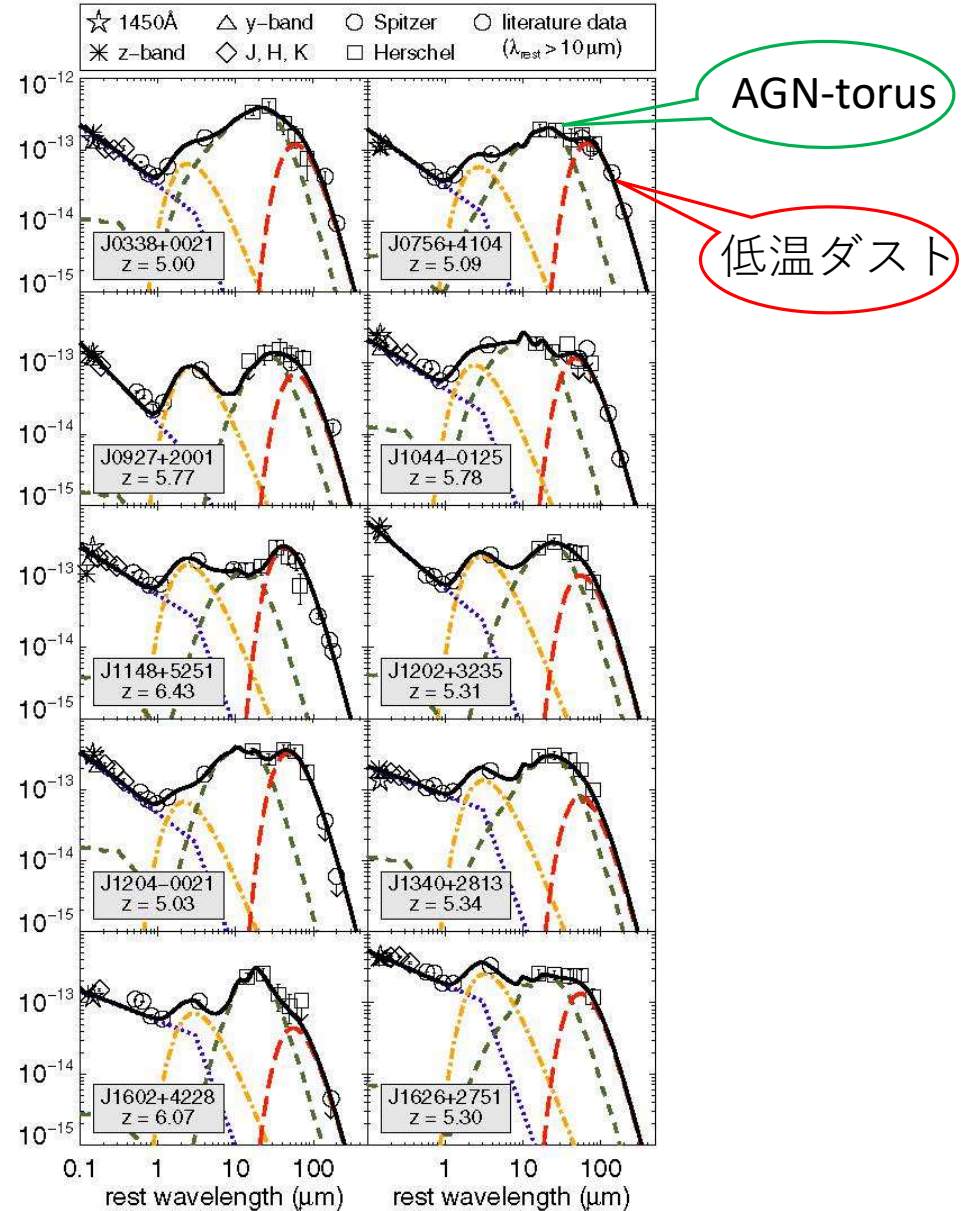
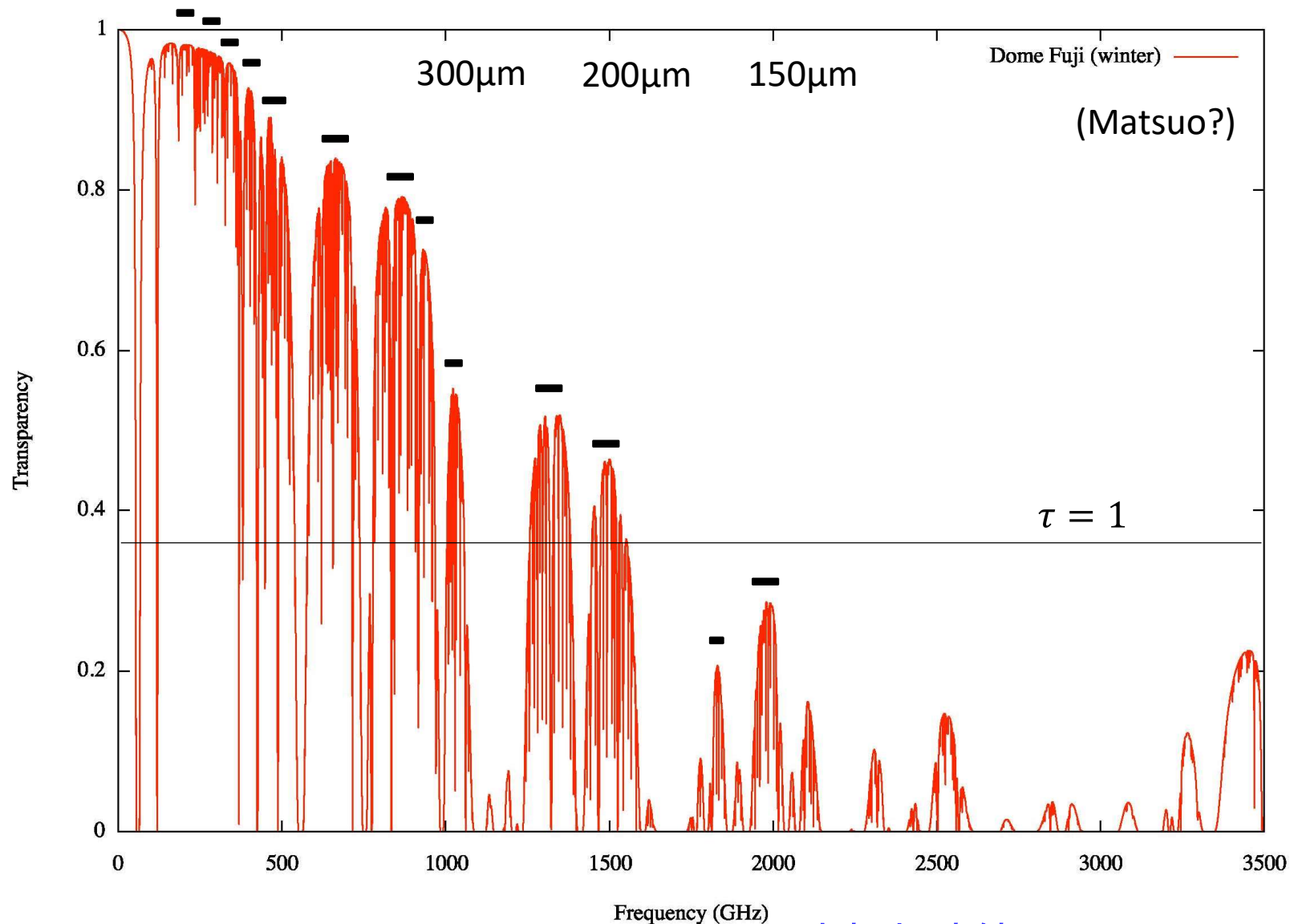


Figure 3. SEDs of the 10 quasars detected in at least four *Herschel* bands. The plots show  $\nu F_\nu$  in units of  $\text{erg s}^{-1} \text{cm}^{-2}$  over the rest frame wavelength. The colored lines indicate the results of a multi-component SED fit as described in Section 4.1. They consist of a power-law (blue dotted), a blackbody of  $T \sim 1200 \text{ K}$  (yellow dash-dotted), a torus model (green dashed), and a modified blackbody of  $\sim 47 \text{ K}$  (see Table 6; red long dashed). The black solid line shows the total fit as the sum of the individual components.

# (可能か?) ダストスペクトル決定用

## 小数ピクセル多波長MKIDSカメラ@ヘテロダイン焦点



南極望遠鏡



## (2. スペクトル線の観測)

(例) Mrk231

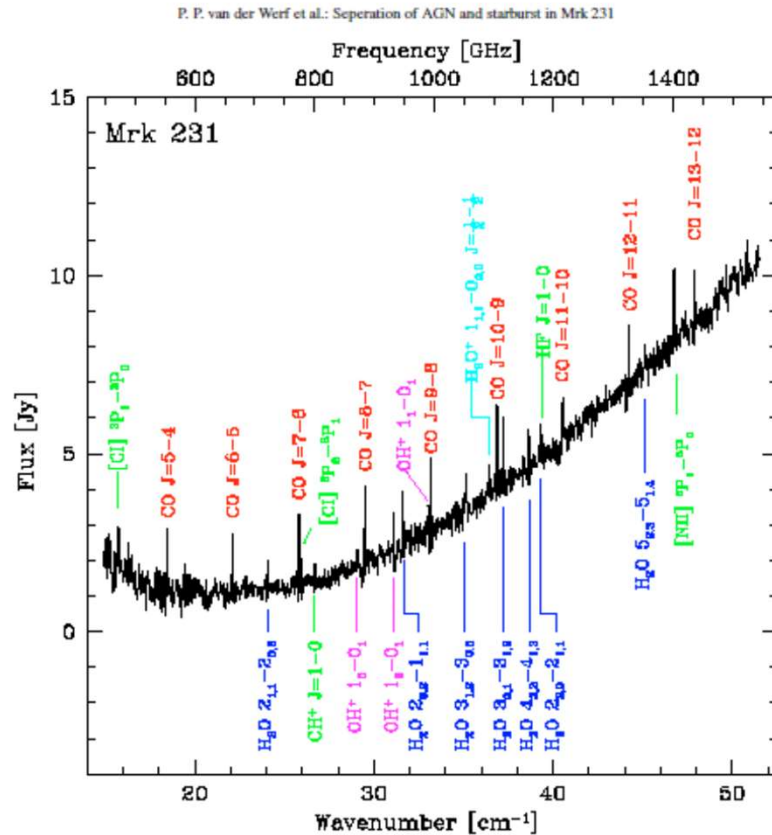


Fig. 1. SPIRE FTS spectrum of Mrk 231. Line identifications are given in red for CO lines, in blue for H<sub>2</sub>O, in magenta for OH<sup>+</sup>, in cyan for H<sub>2</sub>O<sup>+</sup>, and in green for the remaining lines.

ハーシェル衛星(van der Werf+ 2010)

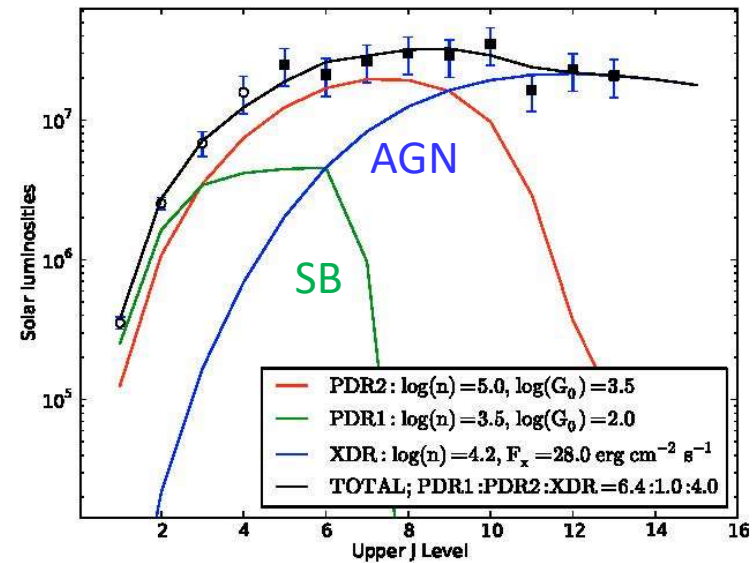


Fig. 2. Luminosities of CO lines from Mrk 231. Filled symbols represent measurements from the SPIRE FTS spectrum, while ground-based measurements are denoted with open symbols. Coloured lines indicate two model PDR components (red and green lines) and an XDR component (blue line). The sum of these three components is indicated by the black line and fits the CO measurements. In the legend,  $n$  denotes the number density of hydrogen nuclei ( $n = n_{\text{H}} + 2n_{\text{H}_2}$ ) in  $\text{cm}^{-3}$ ,  $G_0$  denotes the incident UV flux in units of  $1.6 \times 10^{-3} \text{ erg s}^{-1} \text{ cm}^{-2}$  for the PDRs, and  $F_x$  the incident X-ray flux for the XDR. The legend also indicates the relative emitting areas of the three components.

ダストに埋もれたAGN探査

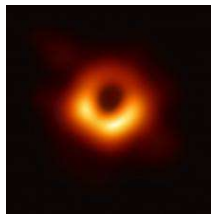
For middle ~ high  $z$

$$\frac{CO(J = 12 - 11)}{CO(J = 4 - 3)} \begin{cases} \gg 1 & (\text{AGN}) \\ \ll 1 & (\text{SB}) \end{cases}$$

# (B) 近傍AGNとブラックホールの撮像

M87 (+ Sgr A\*)

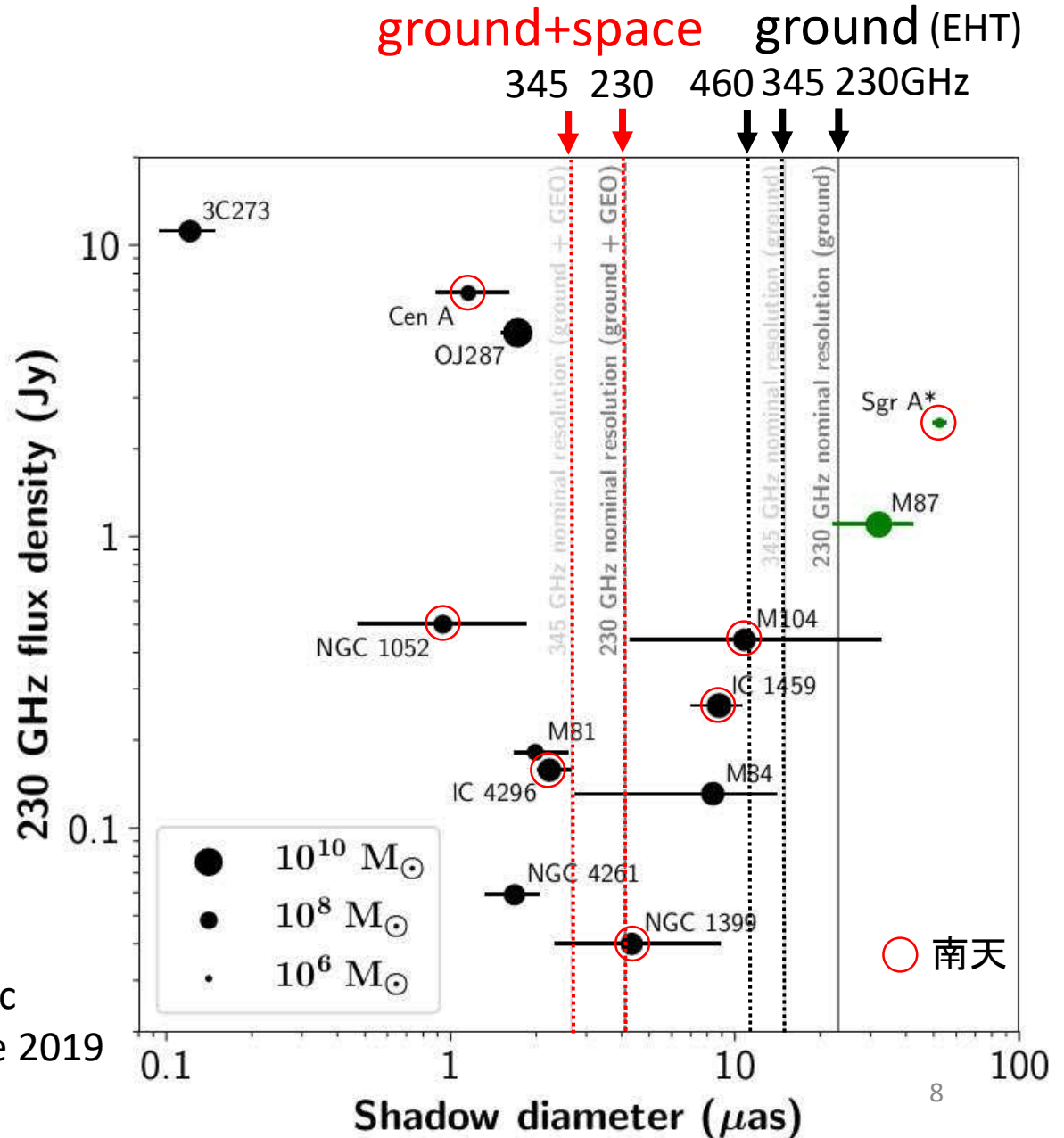
→ ケーススタディー



もっと多くのAGN

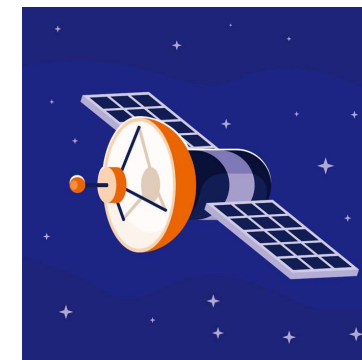
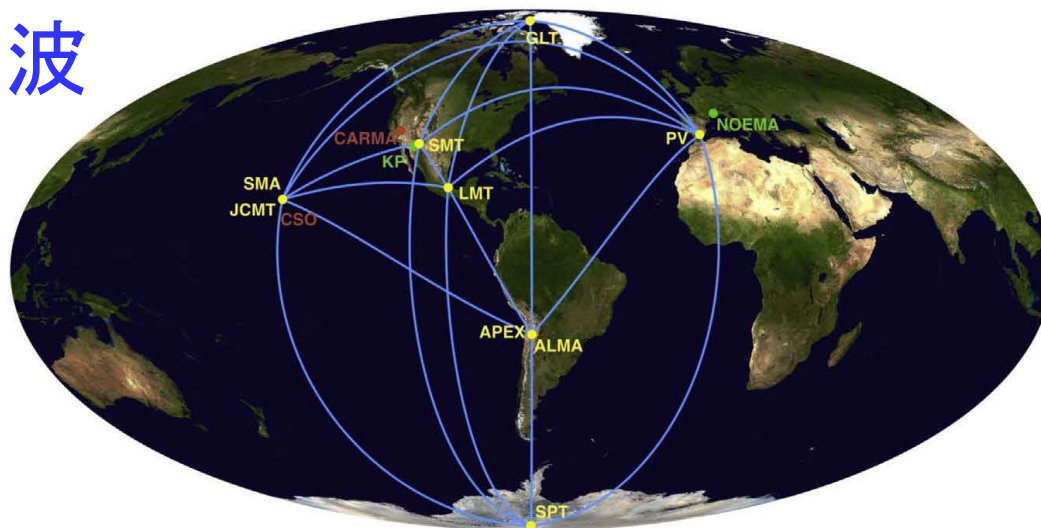
→ 一般法則

S. S. Doeleman, etc  
 "Astro2020 Science 2019  
 White Paper"

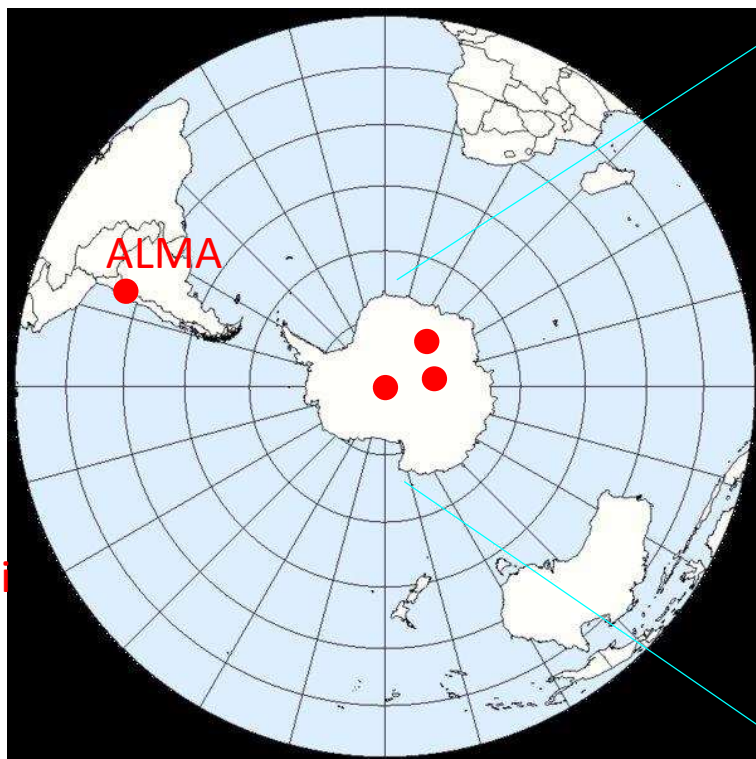




# サブミリ波 VLBI



人工衛星



●  
Hawaii

