New ALMA Observation at 1au Resolution for TW Hya;
Resolved Structure and Time Variation of a Localized Substructure in the Disk

Takashi Tsukagoshi[1] (takashi.tsukagoshi.astro@gmail.com)

T.Muto[2], H.Nomura[3], R.Kawabe[3], K.Kanagawa[4], S.Okuzumi[5], S.Ida[5], C.Walsh[6], T.Millar[7], S.Takahashi[8], J.Hashimoto[9], T.Uyama[10], M.Tamura[11]

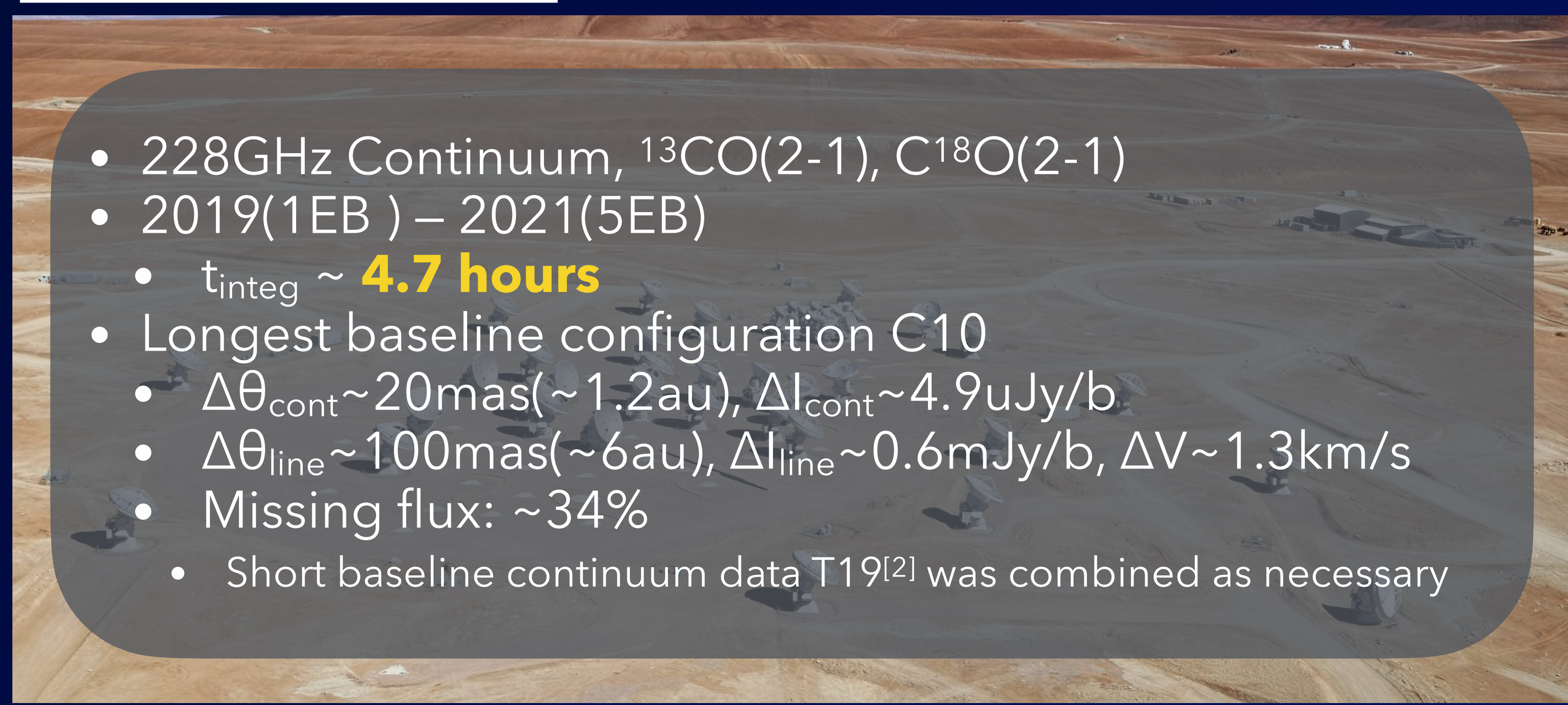
1: Ashikaga Univ., 2: Kohgakuiin Univ., 3: NAOJ, 4:Ibaraki Univ., 5: Tokyo Institute of Tech., 6: Univ. of Leeds, 7: Queen's Univ. Belfast, 8: Kagoshima Univ., 9: Astro Biology Center, 10:Caltech, 11: Univ. of Tokyo

We report the results of our new ALMA observations for the TW Hya disk at 1au resolution in the Band 6 continuum and ^{13}CO and $C^{18}O$ molecular lines conducted in Cycle 7. Our observation confirmed the presence of a localized, blob-like continuum emission at a radius of 52 au, as previously reported by Tsukagoshi et al. (2019), and we found that it moves in a clockwise direction during the observation epochs in 2017 and 2021. The rotation velocity is 3.3 km/s, comparable to the Keplerian rotation. No radial motion was found. Moreover, we identified substructures within the blob emission that are separated into two components along the azimuthal direction. The separation of the components was 0.6 au, and their distribution was slightly skewed inward toward the downstream-side. The brightness temperature was roughly 8 K, suggesting that the components are not self-luminous. By fitting the radial profile of the gap at 1 au, we found that the gap shape cannot be reproduced by a simple power-law form, which implies that the innermost disk has been dissipated or that there is a bump at the outer edge of the gap. The molecular line emission was only detected within a radius of approximately 25 au, and we did not detect any gas emission component associated with the blob-like continuum emission.

Introduction

- Detection of a substructure related to a forming planet is a promising way to investigate the planet formation process
  - Gaps, rings, and/or asymmetry
  - Localized small-scale substructure in PPDs, i.e., **Circumplanetary disk (CPD)**
    - Ex.) PDS70[1], **TWHya**[2], Elias 2-24[3]
- Target: TWHya:
  - Nearest T Tauri star (d=60.1pc)
  - K6 star, t_*=10Myr, Face-on (Inc.=5.8°)
  - Resolved substructures[4,5,6]
  - **Blob-like au-scale substructure at 52au**[2]

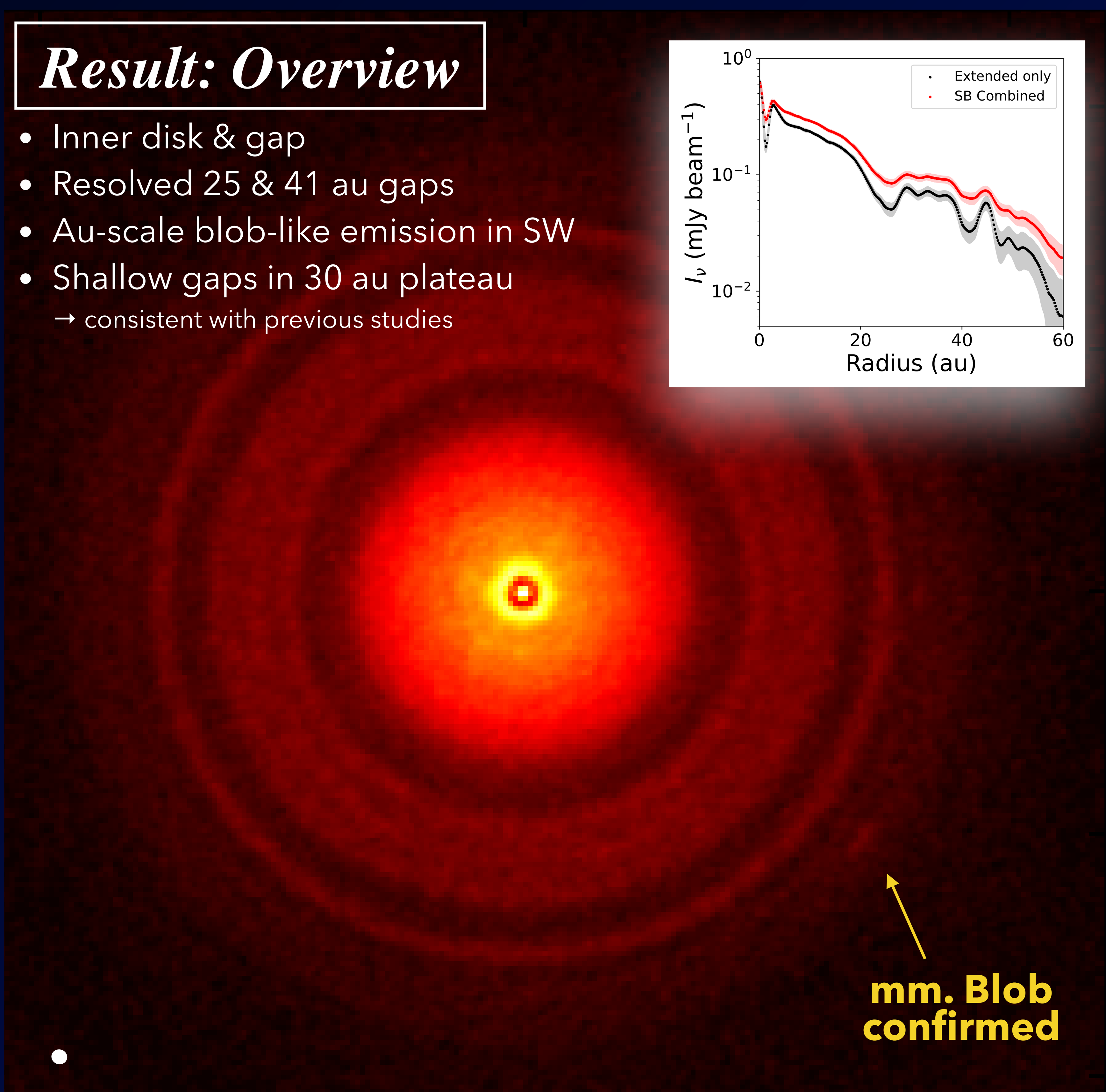
Observations



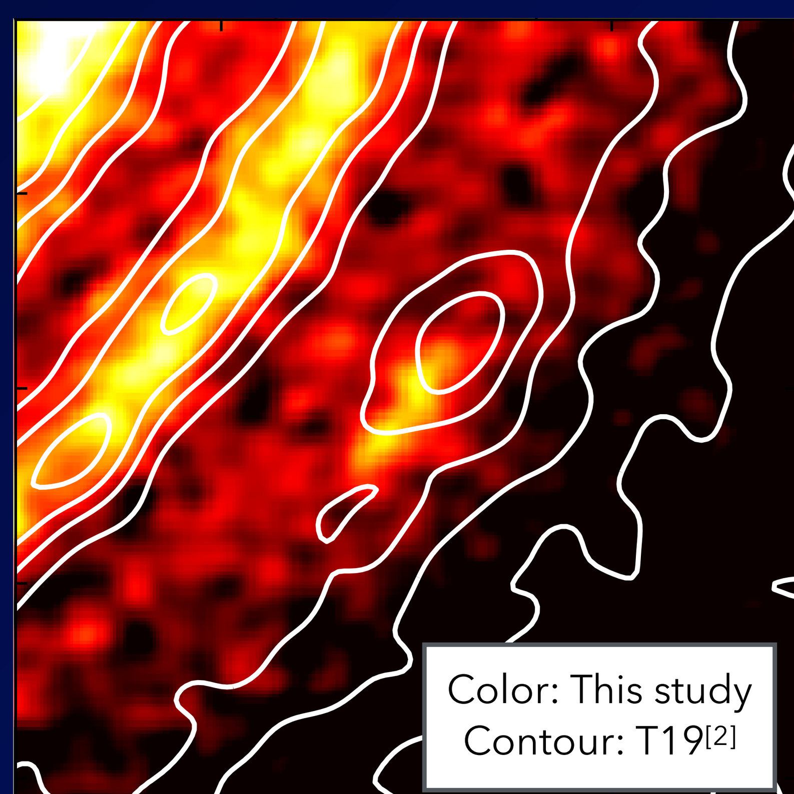
- 228GHz Continuum, ^{13}CO(2-1), $C^{18}O$(2-1)
- 2019(1EB) – 2021(5EB)
  - t_{integ} ~ **4.7 hours**
- Longest baseline configuration C10
  - $\Delta\theta_{cont}$~20mas(~1.2au), ΔI_{cont}~4.9uJy/b
  - $\Delta\theta_{line}$~100mas(~6au), ΔI_{line}~0.6mJy/b, ΔV~1.3km/s
  - Missing flux: ~34%
    - Short baseline continuum data T19[2] was combined as necessary

Result: Overview

- Inner disk & gap
- Resolved 25 & 41 au gaps
- Au-scale blob-like emission in SW
- Shallow gaps in 30 au plateau
  - → consistent with previous studies



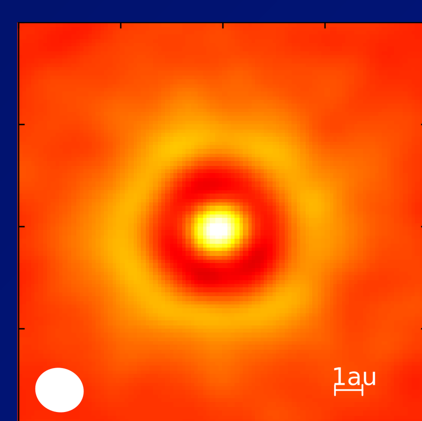
Result: Structure and time variation of blob



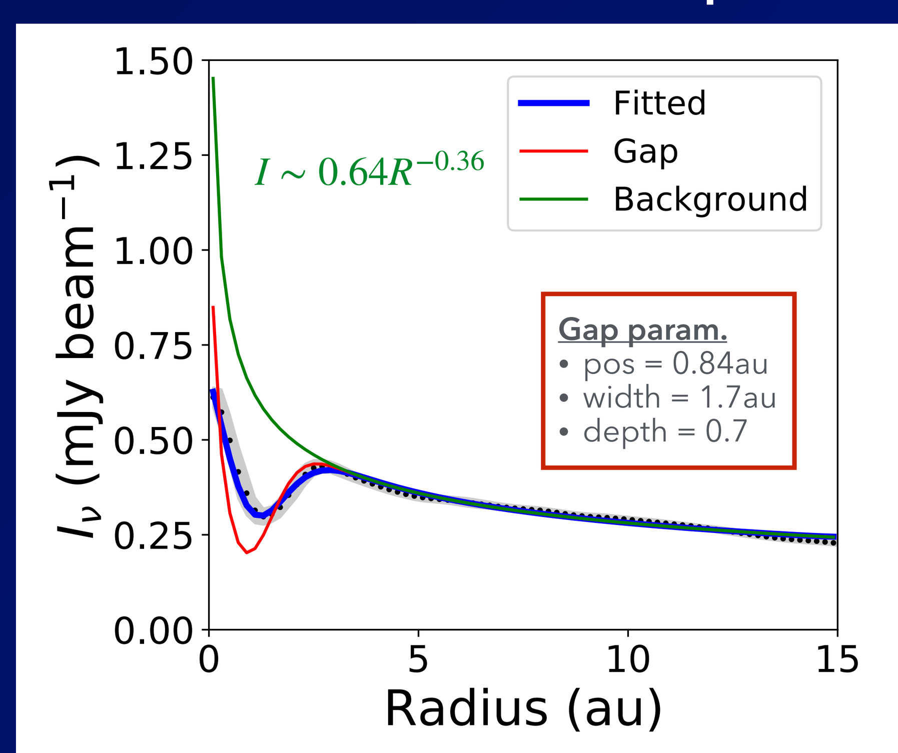
- **Blob moves toward SE**
  - Disk is in clockwise
    - → consistent with CO spiral pattern[7]
  - $v_\phi \sim 3.3$ km s^{-1}
    - → Keplerian rotation at 52au
- **No radial migration was found**
- **Emission is resolved into two peaks**
  - $T_B \sim 8$ K
    - → Unlikely self-luminous source
      - Consistent with no H_α counterpart[8]
  - Skewed to the downstream side
    - → Non-dynamical structure
  - **Origin is still unclear**

Result: Structure of the gap at 1au

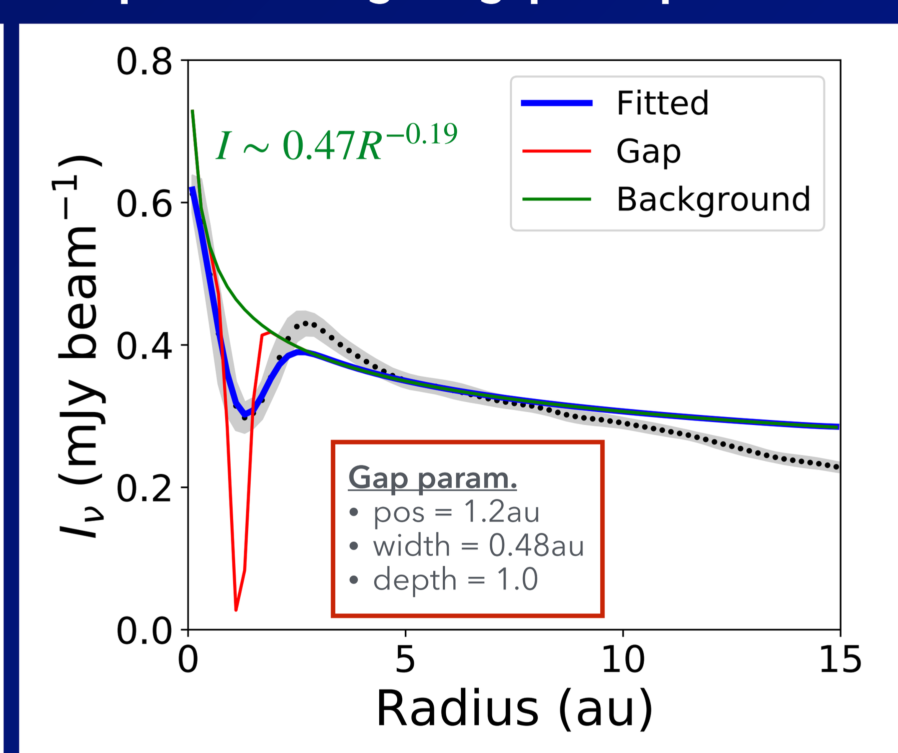
- Short baseline data T19[2] were added to derive accurate flux density
- Modeling of intensity profile
  - Model1: Power-law to fit the profile at >~3au
  - Model2: Power-law to fit the inner disk emission



Model1 fit result:
'Reduced' inner disk emission is required

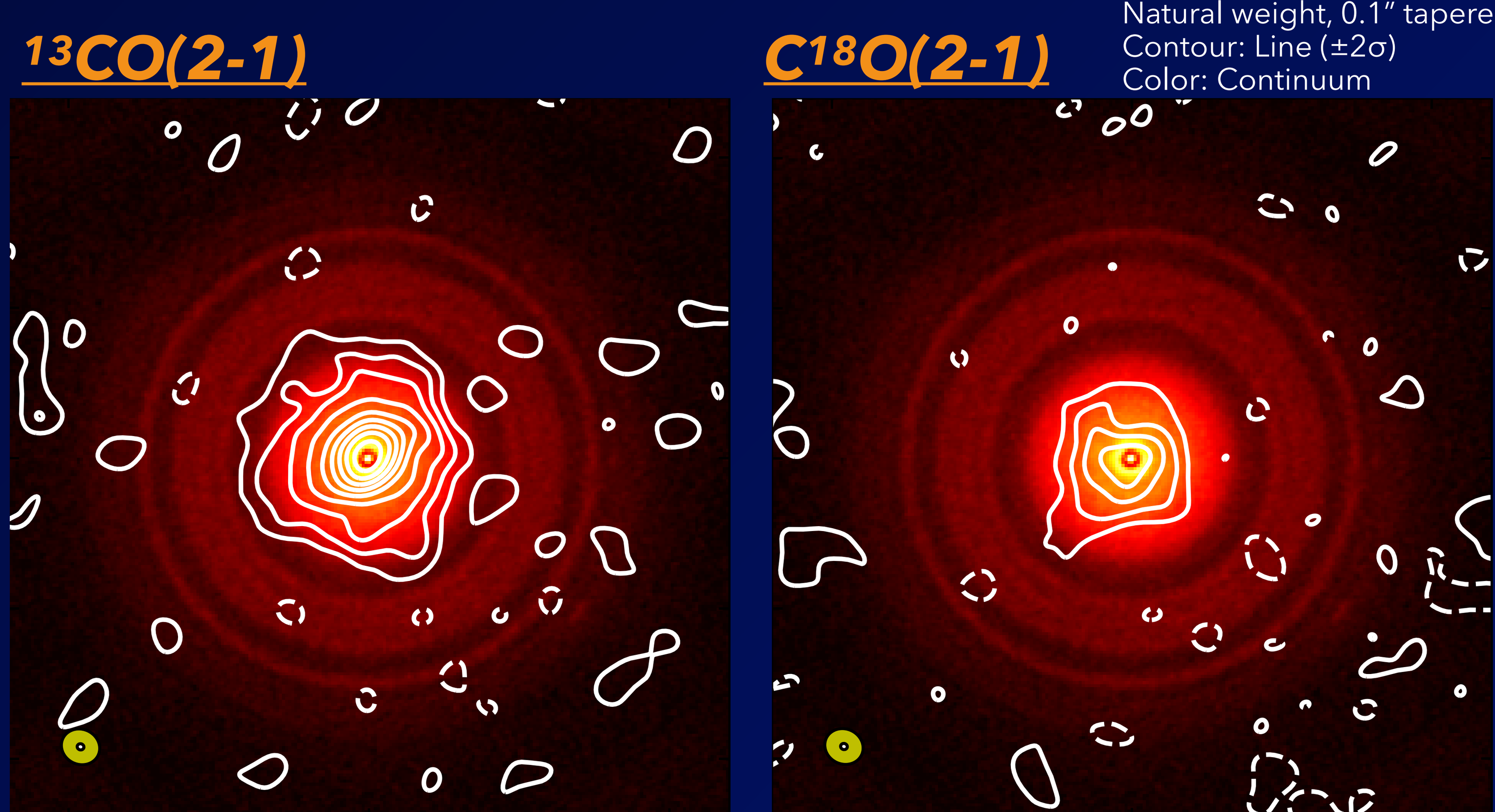


Model2 fit result:
Bump at outer edge of gap is required



Result: No gas emission at the blob

Natural weight, 0.1" tapered
Contour: Line (±2σ)
Color: Continuum



- No 'compact' gas emission associated with the blob
- Short baseline data should be combined to deduce the upper limit of physical parameters
- Non-Keperian high-velocity component was found in ^{13}CO
  - → Consistent with line pressure broadening[9]

References

[1] Isella, A. et al., 2019, ApJL, 879, L25, [2; **T19**] Tsukagoshi, T. et al., 2019, ApJL, 878, L8, [3] Pinte, C. et al., 2023, arXiv:2301.08759, [4] van Boekel, R. et al., 2017, ApJ, 837, 132, [5] Andrews, S. et al., 2016, ApJL, 820, L40, [6] Tsukagoshi, T. et al., 2016, ApJL, 829, L35, [7] Teague, R. et al. 2019, ApJL, 884, L56, [8] Huélamo, N. et al., 2022, A&A, 668, 138, [9] Yoshida, T., et al. 2022, ApJ, 932, 126