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A Preliminary Search for Planets and Exozodiacal Emission Around α Centauri A with JWST/MIRI

Aniket Sanghi [1,2,*] Charles Beichman [3,4,*] Dimitri Mawet [1,4] William O. Balmer [5,6] Jorge Llop-Sayson [4] Laurent Pueyo [6] Pierre Kervella [7,8] Anthony Boccaletti [7] Pierre-Olivier Lagage,[9] Max Sommer [10] Mark Wyatt [10] Nicolas Godoy [11] Elodie Choquet [11] Kevin Wagner [12] Jonathan Aguilar [6] Rachel Akeson [3] Ruslan Belikov [13] Alexis Bidot,[6] Geoffrey Bryden [4] Edward Fomalont [14,15] Thomas Henning [16] Dean Hines [6] Renyu Hu [4] Jarron Leisenring [17] Jack J. Lissauer [13] Billy Quarles [18] Michael Ressler [4] Eugene Serabyn [4] Marie Ygouf [4] and Mantas Zilinskas [4]

[1] *Cahill Center for Astronomy and Astrophysics, California Institute of Technology, 1200 E. California Boulevard, MC 249-17, Pasadena, CA 91125, USA*
[2] *NSF Graduate Research Fellow*
[3] *NASA Exoplanet Science Institute, Caltech-IPAC, Pasadena, CA 91125, USA*
[4] *Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA*
[5] *Department of Physics & Astronomy, Johns Hopkins University, 3400 N. Charles Street, Baltimore, MD 21218, USA*
[6] *Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA*
[7] *LIRA, Observatoire de Paris, Université PSL, Sorbonne Université, Université Paris Cité, CY Cergy Paris Université, CNRS, 5 place Jules Janssen, 92195 Meudon, France*
[8] *French-Chilean Laboratory for Astronomy, IRL 3386, CNRS and U. de Chile, Casilla 36-D, Santiago, Chile*
[9] *Université Paris-Saclay, Université Paris Cité, CEA, CNRS, AIM, 91191 Gif-sur-Yvette, France*
[10] *Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK*
[11] *Aix Marseille Univ., CNRS, CNES, LAM, Marseille, France*
[12] *Department of Astronomy and Steward Observatory, University of Arizona, USA*
[13] *Space Science & Astrobiology Division, Building 245, NASA Ames Research Center, Moffett Field, CA 94035, USA*
[14] *National Radio Astronomy Observatory, 520 Edgemont Rd., Charlottesville, VA 22903, USA*
[15] *ALMA, Vitacura, Santiago, Chile*
[16] *Max-Planck-Institut für Astronomie (MPIA), Königstuhl 17, 69117 Heidelberg, Germany*
[17] *Steward Observatory, University of Arizona, Tucson, AZ 85721, USA*
[18] *Department of Physics and Astronomy, East Texas A&M University Commerce, TX 75428, USA*

ABSTRACT

We present F1550C (15.5 μm) coronagraphic imaging observations of the nearest solar-type star α Cen A using the *James Webb* Space Telescope (JWST) Mid-InfraRed Instrument (MIRI). The observations, executed in February 2025, were compromised by having only one successful roll and degraded performance due to a position mismatch ($\Delta r \sim 10$ mas) between α Cen A and the best-matching reference observation behind the MIRI coronagraph. We set preliminary upper limits on both the presence of a planet and an exozodiacal dust disk. The observations are sensitive to a planet heated by α Cen A (200–250 K) with a radius $\gtrsim 1\ R_{\rm Jup}$ at a separation of $1\farcs5$ (2 au) and zodiacal dust emission at the level of $\gtrsim$ 5–10 times the brightness of our own zodiacal cloud. A complete analysis of all JWST/MIRI observations of α Cen A is forthcoming in Paper I (Beichman & Sanghi et al. 2025, in preparation) and Paper II (Sanghi & Beichman et al. 2025, in preparation).

1. JWST/MIRI CORONAGRAPHIC OBSERVATIONS

α Centauri A (α Cen A) is an exceptional but challenging target for exoplanet searches (C. Beichman et al. 2020). α Cen A's proximity (1.34 pc) means that a gas giant planet or zodiacal dust cloud heated by the star and located within the region of stability ($\lesssim 3''$; B. Quarles & J. J. Lissauer 2016) might be directly resolved with JWST at 10–15 μm. The challenges to finding such a planet are both theoretical and practical.

Corresponding author: Aniket Sanghi
Email: asanghi@caltech.edu
[*] Shared first authorship.

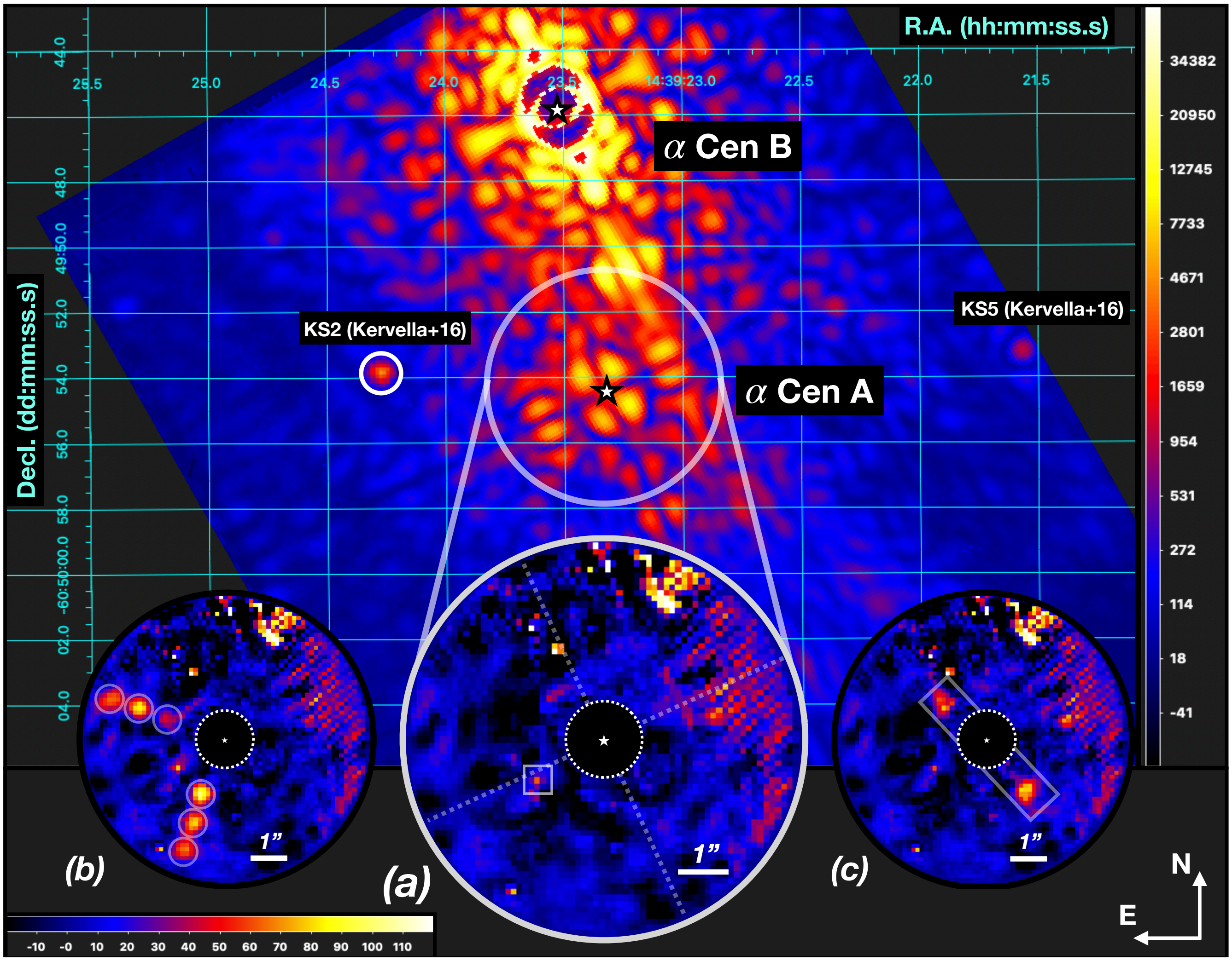

Figure 1. F1550C image of α Cen AB. α Cen B is saturated near the top and α Cen A is behind the F1550C mask near the center. Two known background stars are labeled (KS2 inset, detected after PSF subtraction; and KS5). The (right) colorbar (for the Stage 2b image) is logarithmically scaled in MJy/sr. A $\approx 3''.5$ radius region around α Cen A is expanded. (a) The original α Cen AB PSF-subtracted image. Dashed lines indicate the FQPM boundaries. A likely artifact is boxed. (b) An identical reduction after injecting `STPSF` planet models (circled). (c) An identical reduction after injecting an exozodiacal disk model (boxed). The (bottom) colorbar (for the reduced images and KS2) is linearly scaled in MJy/sr.

1. Planet formation is suppressed in close binary systems (e.g., A. L. Kraus et al. 2016).
2. Radial velocity observations limit the mass of any planet ($P < 1000$ days) orbiting α Cen A to $M_p \sin i \lesssim 100\ M_\oplus$ ($\lesssim 0.3\ M_{\rm Jup}$; L. Zhao et al. 2018).
3. α Cen A is too bright for direct target acquisition, requiring a blind telescope offset ($\sim 1'$) from a background star. The offset must place α Cen A behind MIRI's Four Quadrant Phase Mask (FQPM) with $\sim$10 mas accuracy to avoid contrast degradation.
4. α Cen A's large proper motion ($\approx 3''.7$ yr^{-1}) and parallax (750 mas) must be carefully accounted for to determine its exact position during the observation (R. Akeson et al. 2021).
5. α Cen B is presently $\approx 9''$ away and contributes its full brightness to the planet search region.

α Cen A was observed in August 2024 (#1618), February 2025 (#6797) and April 2025 (#9252). We present preliminary results from February 2025 for which only a single α Cen A roll was successful. The reference star ϵ Mus was observed using the 9-point dither pattern and at the detector position of α Cen B to enable the subtraction of α Cen A and α Cen B.

2. DATA REDUCTION

The raw (*uncal.fits) data were obtained from MAST (doi:10.17909/cb0x-rn85) and reduced using `spaceKLIP` (A. Carter et al. 2025). The reduction followed A. L. Carter et al. (2023, §2.4), skipped flat fielding, and used the algorithm in T. D. Brandt (2024a,b) to detect "jumps". We then subtracted α Cen A and α Cen B using a reference library consisting of both the on- and off-axis ϵ Mus integrations. We applied the PCA-KLIP algorithm (using `vip`; V. Christiaens et al. 2023) in five concentric annuli centered at $\{1'', 1''.5, 2'', 2''.5, 3''\}$ each with a size of 1 FWHM ($\approx 0''.5$). The optimal number of principal components is the value at which the standard deviation of the residuals drops below a tolerance value of 0.1. The final PSF-subtracted image is shown in Figure 1a. In some reductions, a "source" was prominent $\approx 1''.4$ South-east of α Cen A (boxed in Figure 1a). However, this source is dominated by a central bright pixel and not well-fit by a `STPSF` model (M. D. Perrin et al. 2014). It is located next to the FQPM boundary and likely a residual artifact. The background object KS2 (P. Kervella et al. 2016, $\sim$1 mJy in F1550C), recovered using PCA-KLIP (Figure 1), shows the morphology of a true source. The background source KS5 is seen at the edge of the field. Overall, no significant point sources or disk features were detected within $3''.5$ of α Cen A in February 2025.

3. PRELIMINARY LIMITS ON PLANETS AND EXOZODIACAL EMISSION

We injected `STPSF` models in the Stage 2b integrations at (flux, separation) of (1 mJy, $3''$), (1.5 mJy, $2.25''$), (2 mJy, $1.5''$) at position angles of maximum coronagraph throughput and minimum α Cen B contamination, and successfully recovered them (Figure 1b). The ATMO 2020 models ($\log g = 3.0$ dex; M. W. Phillips et al. 2020) predict that a $\gtrsim 1\ R_{\rm Jup}$ ($\gtrsim 120\ M_{\oplus}$) planet heated by α Cen A to 200–250 K would emit $\sim$2 mJy at 15.5 μm. The detectability of VLT/NEAR candidate C1 ($\approx 0''.85$; K. Wagner et al. 2021) depends on its orbit and 15.5 μm flux and will be discussed in future papers.

We injected PSF-convolved exozodiacal disk models, simulated as asteroid belt analogues confined between 2–3 au (J. K. Rigley & M. C. Wyatt 2020). The disk orientation and inclination were matched to the α Cen AB orbit. We can recover a synthetic disk with a 15.5 μm flux ratio $F_{\rm dust}/F_{\star} = 6.4 \times 10^{-4}$ (Figure 1c), which is $\sim$5$\times$ that of the Solar System's zodiacal emission of 1.3×10^{-4} (G. M. Kennedy et al. 2015) and corresponds to an upper limit of $L_{\rm dust}/L_{\star} < 8.3 \times 10^{-7}$ ($\sim 10^{-7}$ for the Solar System), calculated using the spectral energy distribution of the injected disk model.

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