OBSERVING REQUEST
Telescope Access Program, China

Year: 2025 **Term:** A **Proposal type:** short-term

Investigating the Circumstellar Accretion Disk and Outburst Activity of PR Ori B Using Near-Infrared Imaging

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Abstract of Scientific Justification

FUors are a type of outburst observed in young stellar objects, characterized by sustained increases in bolometric luminosity and spectra dominated by viscously heated accretion disks. Studying FUors is essential for understanding the accretion process through which stars gain mass and the evolution of planetary systems. However, the mechanisms driving accretion variability in FUors are yet to be thoroughly explored, with competing theories involving disk instabilities, external perturbations, or magnetic processes. PR Ori B was identified as an active FUor object in August 2024. The ongoing outburst of PR Ori B presents a unique and timely opportunity to study FUor phenomena in greater detail. Through analyzing spatially resolved images, we can take advantage of the unique observational opportunity presented by PR Ori B's ongoing outburst to advance our understanding of FUor systems, accretion variability, and their role in star and planet formation.

Summary of observing runs requested for this project

Run	Telescope	Instrument	PI	AO	Nights	Hours	Moon	Scheduling: Optimal	Scheduling: Acceptable	Sharing: Poss.	Sharing: Adv.
1	JWST	NIRCam			/	3.3	/	Jan–Dec	Jan–Dec	yes	yes

Scheduling constraints and unusable dates *(up to 4 lines)*: None

no text past this line

A ⋆ appended to the proposal type indicates a continuation proposal; a ⋆ appended to the name of a proposer indicates the proposer is a (graduate) student; a proposer whose name is underlined is certified on the proposed telescope/instrument combination; if a ∗ appears within the PI or AO box in the observations summary table, the instrument is a PI instrument and/or Adaptive Optics are requested – signatures are required on the next page.

Target list (attach list if longer than 26 objects)

#	Object	RA	Dec	mag / color / type / redshift / comment / etc.
1	PR Ori B	05:36:24.80	-06:17:31.0	H=11.17

If this program uses a PI instrument, attach the approval email from the PI to this proposal. N/A

Graduate students *(provide the following information for **each** student named as PI or CoI on the cover page.)*

Student's Name	Advisor's Name	Thesis
		no

Scientific Justification *Describe the overall significance to astronomy and within the proposal's discipline. Limit text to one page, with a limit of two additional pages for figures, captions, and references.*

(I) Background and motivation. FUors are a type of outburst observed in young stellar objects, characterized by sustained increases in bolometric luminosity and spectra dominated by viscously heated accretion disks. Studying FUors is essential for understanding the accretion process through which stars gain mass and the evolution of planetary systems. However, the mechanisms driving accretion variability in FUors are yet to be thoroughly explored, with competing theories involving disk instabilities, external perturbations, or magnetic processes. PR Ori B was identified as an active FUor object in August 2024 (Pena et al. 2024). The ongoing outburst of PR Ori B presents a unique and timely opportunity to study FUor phenomena in greater detail, but there are no spatially resolved images of PR Ori B since its latest outburst. *Therefore, spatially resolved photometry of PR Ori B is urgently needed.*

(II)The proposed observations. We propose to obtain spatially resolved images of the FUor object PR Ori B during its ongoing outburst. The JWST with NIRCam is highly efficient for near-infrared observations. When the images are taken, we will investigate the spatial structure of the disk surrounding PR Ori B and the associated accretion flows onto its central star. These observations will provide critical insights into the morphology of the accretion disk and the interaction between the disk and the central star, allowing us to further our understanding of the accretion processes in FUor objects.

(III) Science. Our primary scientific goal is to analyze the structure of the disk around PR Ori B and compare it with previously observed FUor disks. By identifying commonalities and differences, we aim to test and refine extant disk models, particularly those related to disk morphology and accretion dynamics.

In addition, we will investigate the ongoing accretion process by analyzing the inward accretion flows visible in the observed images. These observations will provide critical constraints on present accretion theories, including the mechanisms driving variability, such as gravitational instabilities or magnetic processes (Fischer et al. 2023).

Furthermore, we aim to: 1. Study disk-star interactions during the active accretion phase to identify features such as hot spots or funnel flows. 2. The spiral structure of the disk around PR Ori B can be resolved, enabling the identification of substructures such as arms, gaps, and ring-like features. These may provide evidence of ongoing planet formation or perturbations caused by unseen companions. 3. Compare the disk morphology to models that predict the influence of giant planets on spiral arms, further providing information on the system's dynamical state and the processes driving the outburst in FUor stars like PR Ori B. 4. Look for signatures of outflows or winds associated with the accretion process, which could shed light on angular momentum transport and mass loss. 5. The selected narrow and medium-band filters are optimized to capture hydrogen emission lines and continuum features. Combined with existing multi-wavelength datasets (Gaia, IRTF), we can create a holistic view of PR Ori B's disk and accretion activity, which will also offer a detailed characterization of the disk's material properties.

Through these analyses, our goal is to take advantage of the unique observational opportunity presented by PR Ori B's ongoing outburst to advance our understanding of FUor systems, accretion variability, and their role in star and planet formation.

References

Fischer, W. J. et al. (July 2023). "Accretion Variability as a Guide to Stellar Mass Assembly". In: *Protostars and Planets VII*. Ed. by S. Inutsuka et al. Vol. 534. Astronomical Society of the Pacific Conference Series, p. 355. DOI: 10.48550/arXiv.2203.11257. arXiv: 2203.11257 [astro-ph.SR].

Pena, Carlos Contreras et al. (Aug. 2024). "The FUor outburst of PR Ori B". In: *The Astronomer's Telegram* 16776, p. 1.

Wagner, Kevin et al. (Apr. 2024). "JWST/NIRCam Imaging of Young Stellar Objects. I. Constraints on Planets Exterior to the Spiral Disk Around MWC 758". In: *AJ* 167.4, 181, p. 181. DOI: 10.3847/1538-3881/ad11d5. arXiv: 2401.02830 [astro-ph.EP].

Experimental Design *Describe your overall observational program design. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? Include information such as why the specific targets were selected, the sample size, the analysis plan, instrument choice, etc. Also briefly explain what expertise or effort each team member will contribute to the project. Describe any necessary non-standard calibrations (**up to one page**).*

(I) Overall program Our observational program focuses on obtaining spatially resolved photometric data of PR Ori B, a young stellar object currently undergoing an FUor outburst. These data will provide critical insights into the structure of the accretion disk and the ongoing accretion processes. JWST is uniquely suited to this task due to its high spatial resolution and sensitivity in the near-infrared, making it ideal for probing the small-scale structures of the disk and accretion flows. The proposed observations will serve as a vital dataset to refine current accretion and disk models.

(II) Target selection and image data. PR Ori B was selected as the primary target due to its recent identification as an active FUor and its current brightness of H = 11.17 and JWST with NIRCam will enable us to resolve structures within its accretion disk down to 50 AU. The selected bands are particularly well-suited for probing the detailed structure of the disk. The imaging data will be processed using standard JWST pipeline techniques, followed by the pipeline that we have developed based on publically available packages.

To enhance the visibility of the disk structure around PR Ori B, we will minimize the contamination from the central star's scattered light. We will employ the following strategies: 1. Dithering observations: We will use a carefully designed dithering pattern to reduce artifacts caused by the central star's PSF and to improve the spatial resolution of the disk. 2. PSF subtraction: Post-processing techniques, including PSF subtraction using reference stars, will be applied to effectively remove the stellar contribution from the disk region.

(III) Telescope and instrument. We propose to use JWST with NIRCam and F187N, F200W, F405N, and F410M filters to obtain high-resolution photometric images of PR Ori B. These filters provide an optimal balance between capturing the emission from the disk's hydrogen features and its continuum properties. We plan to obtain a series of short exposures to avoid saturation while maintaining a high signal-to-noise ratio for precise photometry and structural analysis. Standard calibrations, including flat-field and dark correction, will be applied.

Technical Justification *Justify the instrument configuration, the required signal-to-noise, exposure times. All requests for dark or gray time must include a detailed justification for the requested lunar phase. Specify the total time needed, and (if applicable) the minimum requested time (**up to one page**).*

(I) Total request We will conduct our survey in filters F187N, F200W, F405N, and F410M, which is well-suited for probing the disk material and accretion flow around PR Ori B. Using JWST's Exposure Time Calculator (ETC), we optimized the observing parameters to balance sensitivity, resolution, and efficiency. The parameters are set as below according to a similar reaserch before (Wagner et al. 2024): Subarray: We selected SUB160P, which is ideal for observing extended sources such as disks around young stars. Readout Pattern: The RAPID readout mode was chosen to minimize read noise and achieve high temporal resolution. Dithering: A 4-point dither pattern was adopted to improve sensitivity by mitigating detector artifacts, bad pixels, and flat-fielding errors.

The calculated total exposure time per filter is 2947 seconds, considering integrations and dithers. For observations in all four bands (F187N, F200W, F405N, and F410M), the cumulative exposure time is 3.3 hours.

For our observations of PR Ori B with NIRCam, we propose using the direct imaging mode without employing a coronagraph. This approach is informed by similar observations of MWC 758, as mentioned before. Below, we outline the rationale for this choice and our planned techniques for suppressing the stellar PSF and enhancing disk detection: 1. Direct imaging reduces overhead compared to coronagraphic modes, enabling more efficient data acquisition, especially for faint extended sources like disks. 2. The protoplanetary disk of PR Ori B, like that of MWC 758, likely exhibits spiral arms and gaps extending to several hundred au. Direct imaging allows these structures to remain unobscured by the coronagraph's mask, facilitating detailed morphological studies. 3. Using the same technic illustrated in the cited paper, observations will be performed at two spacecraft roll angles separated by 10°. This approach keeps the stellar PSF fixed while allowing the disk's signal to shift due to field rotation. Post-processing can then subtract the stellar PSF effectively while preserving disk features.

References

Fischer, W. J. et al. (July 2023). "Accretion Variability as a Guide to Stellar Mass Assembly". In: *Protostars and Planets VII*. Ed. by S. Inutsuka et al. Vol. 534. Astronomical Society of the Pacific Conference Series, p. 355. DOI: 10.48550/arXiv.2203.11257. arXiv: 2203.11257 [astro-ph.SR].

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