5882 - Composition, Origin, and Fate of the Four Newborn Planets in the V1298 Tau System

Cycle: 3, Proposal Category: GO

INVESTIGATORS

Name	Institution
Prof. Fei Dai (PI)	**University of Hawaii**
Prof. Erik Petigura (CoI) (CoPI)	University of California - Los Angeles
Dr. John Livingston (CoI)	Astrobiology Center of NINS
Dr. Ian Crossfield (CoI)	University of Kansas Center for Research, Inc.
Dr. James Edward Owen (CoI)	University of California - Los Angeles

OBSERVATIONS

Folder	Observation	Label	Observing Template	Science Target
Observation Folder				
	2	V1298 Tau e	NIRSpec Bright Object Time Series	(1) V-V1298-Tau
	3	V1298 Tau e	NIRSpec Bright Object Time Series	(1) V-V1298-Tau

ABSTRACT

NASA's Kepler mission revealed that small planets between the size of Earth and Neptune are ubiquitous. Moreover, such planets are often found in tightly-packed multi-planet systems. The present-day patterns in the sizes and orbits of 'compact multis' are relics of the planet formation process. While the patterns are unambiguous, the physical processes that produce them remain mysterious. Fundamental questions about the formation of small planets remain unanswered. A key obstacle is the shortage of young planets with well-characterized bulk and atmospheric properties.

The best way to make progress is to characterize the progenitors of Kepler multis at young ages, at different stages in their formation. The planetary system around the 20–30 Myr star V1298Tau is such a progenitor. We propose to construct a homogenous library of NIR transmission spectra of all

four planets in the V1298Tau system using NIRSpec/G395H. These spectra will reveal atmospheric carbon-to-oxygen ratio (C/O), mean metallicity [Fe/H], envelope entropy, and cloud/haze properties. These measurements, in turn, will enable insights into where the planets formed in their disks, whether they experienced significant migration, the rate of cooling and the extent of envelope loss by 20–30 Myr. The homogeneous nature of this dataset enables planet-to-planet comparisons in the same system, which removes uncertainties from the modeling and interpretation and leads to a deeper understanding of the system.

OBSERVING DESCRIPTION

We propose to observe a single transit of V1298Tau d and e each using NIRSpec in the Bright Object Time Series (BOTS) mode. V1298Tau is too bright for target acquisition, so we will use the Wide Aperture Target Acquisition (WATA) mode on a nearby star Gaia DR3 518863316719846404. The acquisition star is J = 14.8, below the J =11.8 WATA saturation limit, and 20" from the V1298tau. We will use the G395H/F290LP grism/filter combination, which provides R ~ 600 spectra over 2.8-5.2 microns. The transits themselves are 5.6 hours and 7.5 hours, respectively. Transit observations are differential measurements, and SNR per hour of telescope time is maximized when equal in- and out-of-transit photometry is collected. Thus, we request an equal amount of time out of transit. We used PandExo to compute the optimum number of groups per integration given the star's brightness and SED, while ensuring that no pixel exceeded 75% the saturation level. The optimum number was 8 groups per integration, which achieves a peak SNR of 217 per reduced pixel per 8 second integration. The achieved duty cycle is 78%. We used PandExo to compute the expected SNR of the transit spectrum used in the proposal. We determined we could measure the depth of V1298Tau d to ~25 ppm within a spectral channel of width R = 40. Observations of planets d and e must occur before, during, and after transits that take place every 12 and 48 days, respectively. Observing windows are centered on the forecasted transit midpoint based on our TTV model. The timing uncertainties are about 10 min, much smaller than the duration of observations.

Proposal 5882 - Targets - Composition, Origin, and Fate of the Four Newborn Planets in the V1298 Tau System

<table>
<tr><td></td><td>#</td><td>Name</td><td>Target Coordinates</td><td>Targ. Coord. Corrections</td><td>Miscellaneous</td></tr>
<tr><td rowspan="6">Fixed Targets</td><td>(1)</td><td>V-V1298-Tau</td><td>RA: 04 05 19.5910 (61.3316292d)</td><td>Proper Motion RA: 5.413 mas/yr</td><td></td></tr>
<tr><td></td><td></td><td>Dec: +20 09 25.31 (20.15703d)</td><td>Proper Motion Dec: -16.052000023591972 mas/yr</td><td></td></tr>
<tr><td></td><td></td><td>Equinox: J2000</td><td>Epoch of Position: 2015.5</td><td></td></tr>
<tr><td colspan="5">Comments: Science target. This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=Star
Description=[Exoplanets, K dwarfs, Young stellar objects]
Extended=NO</td></tr>
<tr><td>(2)</td><td>Gaia-DR3-
51886331671984640</td><td>RA: 04 05 18.6204 (61.3275850d)</td><td>Proper Motion RA: 20.101 mas/yr</td><td></td></tr>
<tr><td colspan="5">Dec: +20 09 11.10 (20.15308d)   Proper Motion Dec: -12.851999963459093 mas/yr
Equinox: J2000   Epoch of Position: 2000

Comments: Acquisition target. This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=Star
Description=[M dwarfs]
Extended=NO</td></tr>
</table>

Observation

Proposal 5882, Observation 2: V1298 Tau e   Tue Feb 11 00:00:14 GMT 2025

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Diagnostics

(V1298 Tau e (Obs 2)) Warning (Form): Exposure Duration exceeds the limit of 10000.0 seconds. Above this limit it is possible that a High Gain Antenna move may occur during the exposure.

(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	V-V1298-Tau	RA: 04 05 19.5910 (61.3316292d)	Proper Motion RA: 5.413 mas/yr	
		Dec: +20 09 25.31 (20.15703d)	Proper Motion Dec: -16.052000023591972 mas/yr	
		Equinox: J2000	Epoch of Position: 2015.5	

Comments: Science target. This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=Star
Description=[Exoplanets, K dwarfs, Young stellar objects]
Extended=NO

Acquisition

#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	2 Gaia-DR3-51886331671984640	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	175351.3

Template

Subarray

SUB2048

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	G395H/F290LP	NRSRAPID	8	6750	1	1	6750	54934.74	175351.2

Special Requirements

Between Dates 29-AUG-2024:22:24:00 and 29-AUG-2024:23:24:00
Between Dates 22-JAN-2025:22:56:00 and 22-JAN-2025:23:56:00
Between Dates 23-SEP-2025:07:45:00 and 23-SEP-2025:08:45:00
Between Dates 16-FEB-2026:08:14:00 and 16-FEB-2026:09:14:00
Time Series Observation
No Parallel Attachments

Observation

Proposal 5882, Observation 3: V1298 Tau e   Tue Feb 11 00:00:14 GMT 2025

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Diagnostics

(V1298 Tau e (Obs 3)) Warning (Form): Exposure Duration exceeds the limit of 10000.0 seconds. Above this limit it is possible that a High Gain Antenna move may occur during the exposure.

(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 3:1) Warning (Form): Visit schedulable, but most scheduling windows are when JWST is pointed in direction of greatest micrometeoroid impact risk. This is likely due to scheduling special requirements.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	V-V1298-Tau	RA: 04 05 19.5910 (61.3316292d)	Proper Motion RA: 5.413 mas/yr	
		Dec: +20 09 25.31 (20.15703d)	Proper Motion Dec: -16.052000023591972 mas/yr	
		Equinox: J2000	Epoch of Position: 2015.5	

Comments: Science target. This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=Star
Description=[Exoplanets, K dwarfs, Young stellar objects]
Extended=NO

Acquisition

#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	2 Gaia-DR3-51886331671984640	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	175351.3

Template

Subarray

SUB2048

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	G395H/F290LP	NRSRAPID	8	6750	1	1	6750	54934.74	175351.2

Proposal 5882 - Observation 3 - Composition, Origin, and Fate of the Four Newborn Planets in the V1298 Tau System

Special Requirements	
	Between Dates 12-MAR-2025:15:05:00 and 12-MAR-2025:16:05:00
	Between Dates 30-APR-2025:07:15:00 and 30-APR-2025:08:15:00
	Between Dates 17-JUN-2025:23:26:00 and 18-JUN-2025:00:26:00
	Between Dates 05-AUG-2025:15:36:00 and 05-AUG-2025:16:36:00
	Between Dates 23-SEP-2025:07:46:00 and 23-SEP-2025:08:46:00
	Between Dates 10-NOV-2025:23:57:00 and 11-NOV-2025:00:57:00
	Between Dates 29-DEC-2025:16:07:00 and 29-DEC-2025:17:07:00
	Between Dates 16-FEB-2026:08:18:00 and 16-FEB-2026:09:18:00
	Between Dates 06-APR-2026:00:28:00 and 06-APR-2026:01:28:00
	Between Dates 24-MAY-2026:16:39:00 and 24-MAY-2026:17:39:00
	Between Dates 12-JUL-2026:08:50:00 and 12-JUL-2026:09:50:00
	Between Dates 30-AUG-2026:01:02:00 and 30-AUG-2026:02:02:00
	Between Dates 17-OCT-2026:17:13:00 and 17-OCT-2026:18:13:00
	Between Dates 05-DEC-2026:09:26:00 and 05-DEC-2026:10:26:00
	Between Dates 23-JAN-2027:01:39:00 and 23-JAN-2027:02:39:00
	Between Dates 12-MAR-2027:17:52:00 and 12-MAR-2027:18:52:00
	Time Series Observation
	No Parallel Attachments