National Aeronautics and Space Administration

FY24 Strategic Initiatives Research and Technology Development (SRTD)

Enabling Future Far-Infrared Astrophysics Missions for the Study of Planetary Origins

Principal Investigator: Klaus Pontoppidan (326)**; Co-Investigators:**

Strategic Focus Area: Strategic Pathways to Future Mission Leadership in Astrophysics **| Strategic Initiative Leader:** Charles Lawrence

Objectives:

- Support the development of the Probe far-infrared mission for Astrophysics (PRIMA). Lead the PRIMA planet formation science area, optimize technology trade-offs between far-infrared discovery space and affordability.
- Use an extensive JWST mid-infrared data set to discover and characterize the distribution of water and organics from the interstellar medium to the inner regions of planet-forming disks. Use this work to drive key PRIMA science cases.

Background:

To understand the typical chemical environment of exoplanetary system formation we must develop new facilities to explore the mid- to far-infrared wavebands, and out to the submillimeter range. This region traces simple molecules at temperatures corresponding to the inner, planet-forming regions of protoplanetary disks. In particular water emission from beyond ~1 AU is traced in the far-infrared, up to, and including the ground-state lines at 179 and 558 micron, and the HD ground- state line at 112 micron may be a unique tracer of planet-forming mass.

Approach and Results:

PRIMA formulation: The design of the PRIMA detectors trade science-driven noise and dynamic-range requirements with parameters such as multiplexing, readout electronics, and readiness risk. Develop methods for rapid turnaround of science impact evaluations of technology decisions will reduce cost and risk, while maximizing the science potential of the PRIMA mission (and other astrophysics missions).

→ A competitive step-1 proposal for PRIMA to the NASA APEX 2023 call was submitted, including a high-resolution spectroscopic mode to observe water in protoplanetary disks, and measure their total gas masses using the HD 1-0 line.

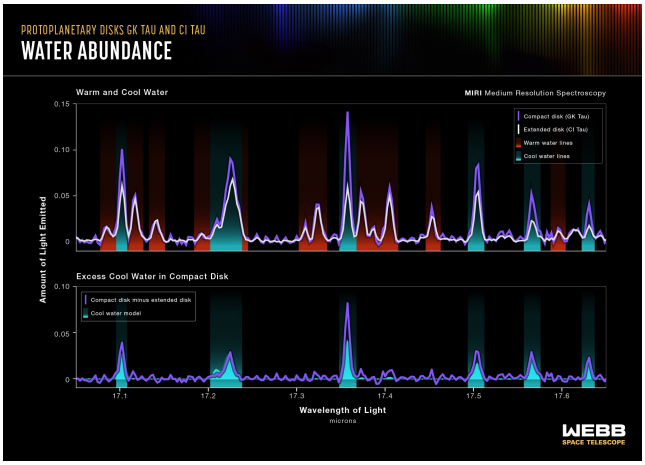
The JWST Disk Infrared Spectroscopic Chemistry Survey (JDISCS): This is the largest planet-formation program to date on JWST and includes MIRI spectra of ~100 protoplanetary disks

→ Demonstrated high signal-to-noise calibration (SNR>300) across the full MIRI wavelength range (5-28 micron) for detection of rare species (Pontoppidan et al. 2024).
→ Discovered aligned protostellar outflows in the Serpens star-forming region with JWST-NIRCam (Green, Pontoppidan et al. 2024 + NASA press release).
→ Discovered excess cold water vapor inside the snowline in disks that have experienced strong pebble drift (Banzatti, Pontoppidan et al. 2023 + NASA press release).

Significance/Benefits to JPL and NASA:

The 2020 Decadal Survey laid out a pathway for a new class of Probe astrophysics missions. A Far-infrared Probe mission concept is particularly important for JPL in that it drives continued development of low-noise detectors appropriate for a cryogenic platform, innovative technology for high-resolution infrared spectroscopy, and operations concepts for optimal exploration of previously unexplored far-infrared discovery space.

Press release 1.5-4.5 micron NIRCam image of the Serpens Star forming region, showing aligned protostellar outflows glowing in emission from rotational H2 lines (from Green, Pontoppidan et al. 2024, ApJ). Many of the protoplanetary disks in this cluster may be PRIMA targets.



MIRI spectra of protoplanetary disks from JDISCS showing the presence of excess cold water in disks that are compact (have small radii) as observed in millimeter-sized dust grains with ALMA (from Banzatti, Pontoppidan et al. 2023, ApJ). This type of excess will be much better characterized using cold water lines observed with PRIMA.

Publications:

- Munoz-Romero, Banzatti, Oberg, Pontoppidan, et al., 2024, ApJ, in press
- Green, Pontoppidan, Reiter, et al., 2024, ApJ, 972, 5
- Salyk, Yang, Pontoppidan et al., 2024, ApJ, in press
- Arulanantham, McClure, Pontoppidan et al., 2024, ApJ, 965, 13
- Munoz-Romero, Oberg, Banzatti, Pontoppidan et al., 2024, ApJ, 694, 36
- Pontoppidan et al., 2024, ApJ, 963
- Xie, Pascucci, Long, Pontoppidan et al., 2023, 959, 25
- Banzatti, Pontoppidan et al., 2023, ApJ, 957, 22

PI/Task Mgr. Contact Information:

Klaus Pontoppidan
(klaus.m.pontoppidan@jpl.nasa.gov)

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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