# JWST Telescope Scientist GTO Program: Abstract

## *1. Introduction*

The JWST Telescope Scientist (TS) Guaranteed Time Observer (GTO) Team consists of the following people:

- Jay Anderson
- Mark Clampin (NASA/GSFC) [Science PI]
- Nikole Lewis (STScI)
- Matt Mountain (AURA) [Telescope Scientist]
- Marshall Perrin (STScI)
- Laurent Pueyo (STScI)
- Sara Seager (MIT)
- Remi Soummer (STScI)
- Jeff Valenti (STScI)
- Roeland van der Marel (STScI) [Administrative PI]

The TS GTO science program has three components:

1. Transiting Exoplanet Spectroscopy (**Clampin**, Lewis, Seager, Valenti)
2. Exoplanet and Debris Disk Coronagraphic Imaging (Perrin, Pueyo, **Soummer**)
3. Local Group Proper Motion Science (Anderson, **van der Marel**)

The contributing team members are listed, with the subject lead in bold. TS Mountain provides high-level direction for the overall program. The 210 hrs of GTO time available to the TS Team are approximately divided between these topics as 60%, 30%, and 10%, respectively.

## *2. Transiting Exoplanet Spectroscopy*

Exoplanets that transit their host star as viewed from earth represent our best opportunity for atmospheric characterization studies with observational facilities like JWST. These transiting exoplanets allow their atmospheres and/or surfaces to be probed through high-precision (<1%) relative spectrophotometric observations obtained throughout the planet's orbit. Atmospheric transmission spectra obtained as the planet passes in front of the host star probe the chemical composition of the planet's atmosphere. The dayside thermal structure and emission spectrum of the planet are probed with secondary eclipse observations. Emission measurements as a function of orbital phase can map the longitudinal thermal structure of the planet since most transiting exoplanets are on short period orbits within the tidal locking radius of their host star.

JWST will for the first time provide for spectroscopic (R > 100) observation of systems hosting transiting exoplanets over the critical wavelength range from 0.6 to 28 microns. Our team will take advantage of JWST's spectral coverage and resolution to characterize a small number of exoplanets in exquisite detail. We plan to focus our efforts on single representative members of the hot-Jupiter ($M_p \sim M_{Jupiter}$, $T_{eq} > 1200$ K), warm-Neptune ($M_p \sim M_{Neptune}$, $T_{eq} < 1200$ K), and super-Earth ($M_p > M_{Earth}$) populations.

Our team plans also to initiate a detailed atmospheric modeling effort to produce theoretical spectra for archetypical members of our selected exoplanet populations. This will include detailed chemical and radiative transfer modeling to identify spectral ranges where important insights might be gained with increased SNR and/or spectral resolution. We will also consider how combinations of transit, eclipse, and phase-curve observations might reveal fundamental processes in the planet's atmosphere, such as atmospheric circulation.

## *3. Exoplanet and Debris Disk Coronagraphic Imaging*

Dramatic progress in exoplanetary systems imaging has occurred since the first generation of space coronagraphs on HST (NICMOS, STIS, ACS). While HST remains at forefront of both exoplanetary and circumstellar disk science, ground-based instruments have improved by three orders of magnitudes over the past decade. JWST will extend the current state of the art with a larger set of superior coronagraphs and greater sensitivity across more than a factor of 10 in wavelength, making it extraordinarily capable for detailed imaging characterization of planets and disks. We will address specific questions about nearby exoplanetary systems, while also optimizing observing strategies across the breadth of JWST's high-contrast imaging modes, as follows:

(a) Deep, multi-wavelength observations of selected nearby stars hosting known debris disks & planets. We will use the NIRCam and MIRI coronagraphs across the full range of JWST wavelengths, and perhaps MIRI MRS spatially resolved spectroscopy. Each comprehensive dataset will support a variety of investigations addressing both disk characterization and exoplanet detection & characterization.

(b) Characterization of Planetary Systems around Cool M Stars. We will observe young and dusty M dwarfs, to complement observations of the closer but older M dwarf samples under consideration by other GTO groups. JWST observations will dramatically exceed HST images in their ability to address questions about the properties of dust rings, while the more favorable contrast ratios of planets relative to M dwarf hosts will enable sensitivity to relatively low mass planetary companions.

(c) Characterizing of Planetary Variability and Atmospheric Structure. We will conduct JWST coronagraphic time series observations of a young self-luminous planet whose variability will have been identified in the near IR (by HST or from the ground). The longer wavelengths accessible to JWST will enable detailed characterization of the atmospheric dynamics. We will conduct this observation in filters sensitive to water and carbon molecular features. This will also yield precise insights into the role of gravity on cloud structure and chemistry in the atmosphere of young giant exoplanets.

## *4. Local Group Proper Motion Science*

Structures in the Universe cluster on various scales. Our Milky Way Galaxy (MW) belongs to a small group, called the Local Group (LG). To understand the LG, it is necessary to study the dynamics of its galaxies, and of its constituent components, such as individual stars, star clusters, and tidal streams. The present-day dynamics contain an imprint of the initial conditions, and also reflect subsequent evolution. Moreover, dynamical measurements are necessary to constrain the amount and distribution of dark matter, since dynamics, structure, and mass are tied together through the effects of gravity.

Almost everything that is known about LG dynamics is based on observations of line-of-sight (LOS) velocities, which provide only limited, one-dimensional information. An important step forward is to determine fully three-dimensional velocities, by also measuring proper motions (PMs) in the plane of the sky. The ongoing GAIA mission will revolutionize our dynamical understanding of the Milky Way, through its all-sky PM survey of stars down to 20th magnitude. However, this does not reach old stellar populations beyond ~100 kpc. Therefore, space-based observatories will continue to provide the state of the art for Local Group studies in the distance range from 100 kpc to 1 Mpc.

We will use JWST to observe stars, clusters, and tidal streams in LG (dwarf) galaxies to measure PMs (either by comparison to existing HST data, or by comparison to future epochs of JWST data). This will shed light on their dynamics, structure, and formation. Data-model comparisons will allow us to address questions such as: (a) what is the amount and distribution of dark matter in (the) LG (galaxies)? (b) what can we learn about the central black hole in the Galactic Center, or at the centers of globular clusters and other LG galaxies? (c) what is the amount and character of satellite infall into the MW and LG? (d) are the 3D motions consistent with previously inferred planar distributions of satellites around the MW and M31? etc.