ORION^{II}

UV-VISIBLE PROBE

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Orion is a 1.2-meter class space telescope that will conduct the first-ever high spatial resolution survey of a statistically significant sample of visible star-forming environments in the Solar neighborhood to answer the question "**How often do solar systems form and survive in massive stellar environments?**". Within the Probe-class mission cost envelope *Orion* will provide 100 times greater imaging efficiency than currently exists on *HST*.

The *Orion* mission has a well-defined scientific program at its heart: a statistically significant survey of local, and intermediate sites and indicators of star formation to investigate and understand the range of environments, feedback mechanisms, and other factors that most affect the outcome of the star and planet formation process. This program relies on focused capabilities unique to space and that no other planned NASA mission will provide: near-UV/visible (200-1100nm) wide-field, diffraction-limited imaging.

Observing efficiency. The *Orion* imager has a field of view (FOV) of ~200 square-arcminutes, uses a dichroic to create optimized UV/blue and red/near-IR channels for simultaneous observing in 2 bandpasses, and employs modern detectors with substantial quantum efficiency gains, especially at red wavelengths, over the CCDs used in *HST's* cameras. We estimate discovery efficiency gains of factors of 100 for imaging with *Orion* relative to *HST* based on our design and assuming an Earth-Sun L2 orbit that provides long target visibility.

Necessary Technology. To deliver the performance cited for this mission, a new class of CCD detector is being developed with our partners at JPL to deliver DQE levels down to the blue edge of silicon that will match the DQE performance in the red, allowing us to build the Observatory with a dichroic splitter to simultaneously observe in the red and blue without taking a hit in observing efficiency or the quality of the images produced. The required technologies currently stand at a TRL of 4-5.

Mission Scale. This mission has been priced twice through Team X studies and has been found to exceed the *MIDEX* cost cap as currently defined ($250M FY 17) and therefore requires the Probe-class mission line to be possible.

Science investigation. We employ a step-wise approach to our observing program in which both imaging and spectroscopy contribute essential information to our investigation.

Step 1 — Conduct a census of all high-mass star formation sites within 2.5 kpc of the Sun to determine how frequently solar systems form and survive, and develop observational criteria connecting properties of the ionized gas to the underlying stellar population and distribution of protoplanetary disks.

Step 2 — Survey all major star forming regions in the Magellanic Clouds, where we can still resolve relevant physical scales and structures, access starburst analogs, and sample star formation in an initial regime of low metallicity applicable to high-redshift galaxies.

Step 3 — Extend the star formation survey to galaxies in the nearby universe in order to increase the range of galaxy interaction and metallicity environments probed. *Orion* can observe entire galaxies surveyed by *GALEX* and *Spitzer* with more than 100 times better spatial resolution.

Unique science that can only be conducted by *Orion*:

Precision Photometry: *Orion* provides a wide FOV with 0.05 to 0.1 arcsecond angular resolution. Stable PSFs combined with a stable focal-plane geometry will permit unprecedented precision in astrometry and photometry.

Outflow and Nebular Motions: The exquisite proper motion sensitivity of *Orion* will enable unique measurements of the motions of supersonic protostellar outflows and stellar wind bubbles to a distance of several kpc; the mildly supersonic motions of expanding HII regions to about 1 kpc; as well as the motions in planetary nebulae and supernova remnants.

The *Orion* survey of the Magellanic Clouds will be unique in its powerful combination of angular resolution, depth, and spatial coverage. Each of the Magellanic Clouds survey components is designed to obtain significant coverage in its domain. The broadband survey will be essentially complete in area coverage; the narrowband survey will cover 5% and 14% of the LMC and SMC, respectively, plus a sample of HII regions representative of the range of star-forming conditions in these galaxies.

Extragalactic stellar populations contain the histories of evolution of the baryonic components of galaxies. Challenges include the presence of multiple stellar population components along each sightline, effects of interstellar dust on observed SEDs, and the relatively low brightnesses of outer regions of galaxies relative to the sky. The *Orion* combination of a 14 arcmin FOV, high angular resolution, simultaneous access from the MUV to the NIR, and low sky background allow us to address all of these issues.

Orion Probe Mission Fact Sheet

Overview:

The *Orion* Probe mission is a 1.2m UV-visible observatory orbiting at Earth-Sun L2 that will conduct the first-ever high spatial resolution survey of a statistically significant sample of visible star-forming environments in the Milky Way, Magellanic Clouds, and nearby galaxies.

<u>Science Goals:</u> **"How frequently do solar systems form and survive?"**

1. Characterize global properties and star formation histories in massive star forming regions in the Milky Way.
2. Understand how environment influences the process of star and planet formation.
3. Track the evolution of and derive survivability criteria for low-mass proto-planetary disks in massive star forming regions, similar to where the Solar Nebula likely formed.
4. Understand the range of star and planet formation environments and how that dictates the range of masses, ages, and other important properties of resultant stars and planets
5. Leverage survey results from missions such as *Kepler* and *Spitzer* to allow characterization of observed stellar populations in concert with measured dynamical properties of the stars.

<u>Measurements:</u>

1. Image all massive star forming regions within 2.5 kpc of the Sun through a common set of continuum and emission-line filters with sufficient spatial resolution to distinguish Solar System-scale objects and structures.
2. Temporally monitor stars in regions to characterize the resulting stellar population, spectral type, binarity, accretion rates, rotation rates, jet dynamics, age and mass all as a function of environment.
3. Identify all exposed proto-planetary disks in nearby massive star forming regions, where most low-mass stars form, and quantify their sizes, orientations, opacities, and distributions.
4. Survey all massive star forming regions in the Large and Small Magellanic Clouds using the same filter set with sufficient spatial resolution to distinguish structures and processes that have Galactic analogs.
5. Survey a representative sample of Local Group and nearby galaxies – spanning a range of galaxy types, merger histories, and metallicities – using the same filter set with sufficient spatial resolution to distinguish individual star forming sites and internal HII region structure.

Performance Requirements and Implementation Summary:

Primary Mirror Diameter:	1.2m (yields ~0.1″ resolution at 5000Å)
Image Scale:	0.1 arcsec/pixel
Wavelength Coverage:	200 – 1000 nm
Field of View:	14′×14′ (~200 sq-arcmin on 8k×8k CCD array; 25× HST-WFC3)
Wavelength Multiplexing:	Dichroic split at ~510nm; optimized UV-blue and red-NIR channels
Survey Capability:	> 20 sq-degs per yr to surf. brightness of 1×10^{-16} ergs/cm^2/s/arcsec^2
Optical Design:	Three mirror anastigmat
Pointing/Stabilization:	10 (goal), 20 (core) mas over 1000s (similar to *Kepler*)
Filter Set:	Broad-band (R~4), medium-band (R~7), narrow-band (R~100)
Detector Efficiency:	CCD DQE: ~80% at 6563Å; ~60% at 3727Å; ~50% in UV
Required Technology Maturity:	Both CCDs and optic elements are at TRL 4-5
BB Photometry Accuracy:	1% relative, 5% absolute (nominal CCD performance)
Data Volume & Telemetry:	~80 GB per day raw; Ka-band science return (similar to *Kepler*)
Esimated Mission Cost:	$358M FY17, excluding LV, based on Team X studies (2) extrapolated to FY17
Launch Vehicle:	TBD to L2 orbit
Mission Duration:	3-yr nominal mission (~30 month science phase); 3-yr extended mission

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Science & Technology Related Missions: *HST-WFPC2, HST-WFC3, GALEX, Spitzer, Kepler, WISE, JWST, WFIRST*