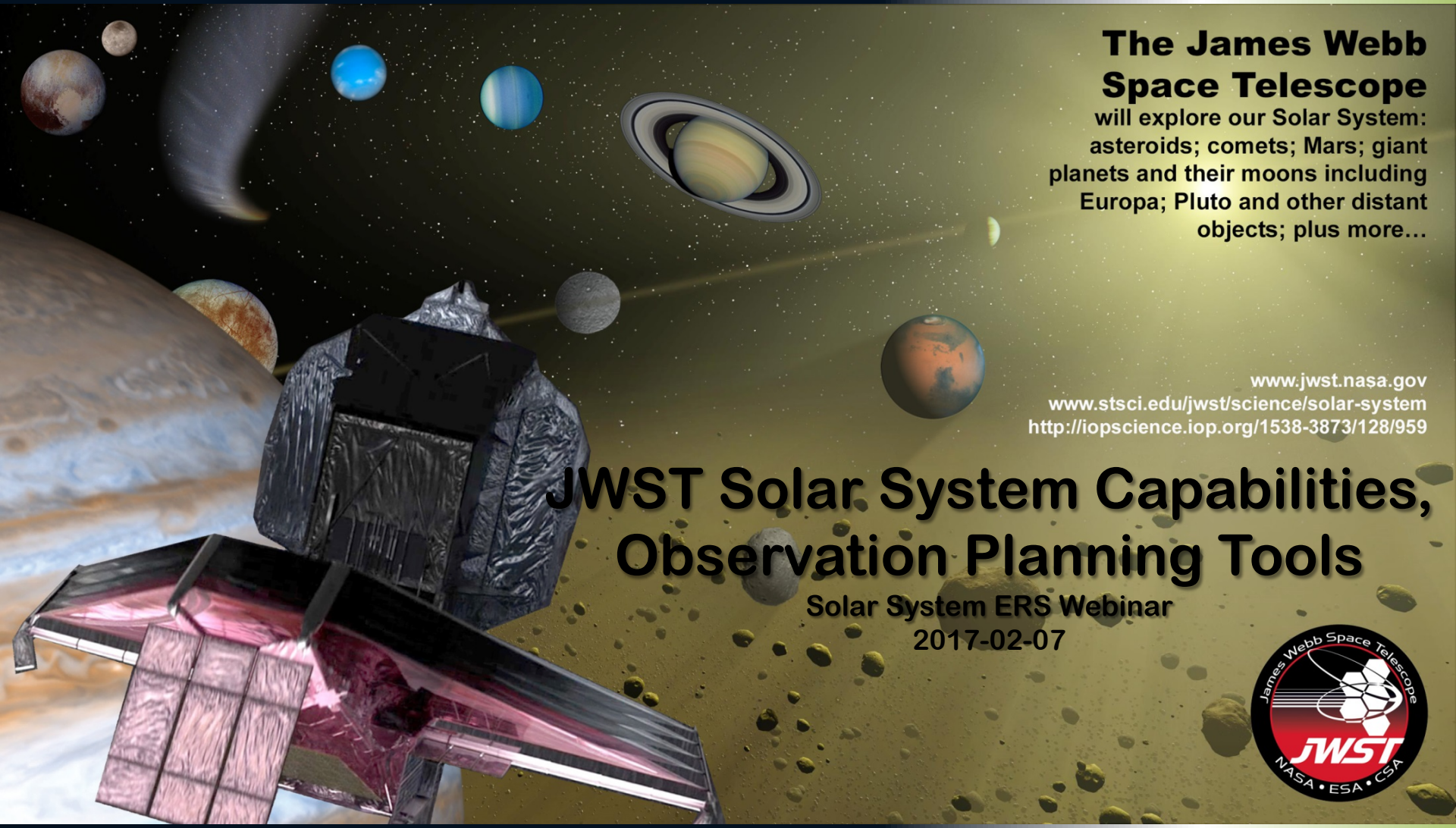


JWST Solar System Capabilities, Observation Planning Tools

Solar System ERS Webinar
2017-02-07

Stefanie Milam (GSFC, JWST Deputy Project Scientist for Solar System Science)

J. Stansberry (STScI, JWST Solar System lead)

JWST Science Instrument Overview

Instrument Modes, Sensitivity Comparison

JWST Imaging Modes

Mode	Instrument	Wavelength (microns)	Pixel Scale (arcsec)	Full-Array* Field of View
Simultaneous Imaging	NIRCam*	0.6 – 2.3	0.032	2.2 x 2.2′
	NIRCam*	2.4 – 5.0	0.065	2.2 x 2.2′
	NIRISS	0.9 – 5.0	0.065	2.2 x 2.2′
	MIRI*	5.0 – 28	0.11	1.23 x 1.88′
Aperture Mask Interferometry	NIRISS	3.8 – 4.8	0.065	------
Coronography	NIRCam	0.6 – 2.3	0.032	20 x 20″
	NIRCam	2.4 – 5.0	0.065	20 x 20″
	MIRI	10.65	0.11	24 x 24″
	MIRI	11.4	0.11	24 x 24″
	MIRI	15.5	0.11	24 x 24″
	MIRI	23	0.11	30 x 30″

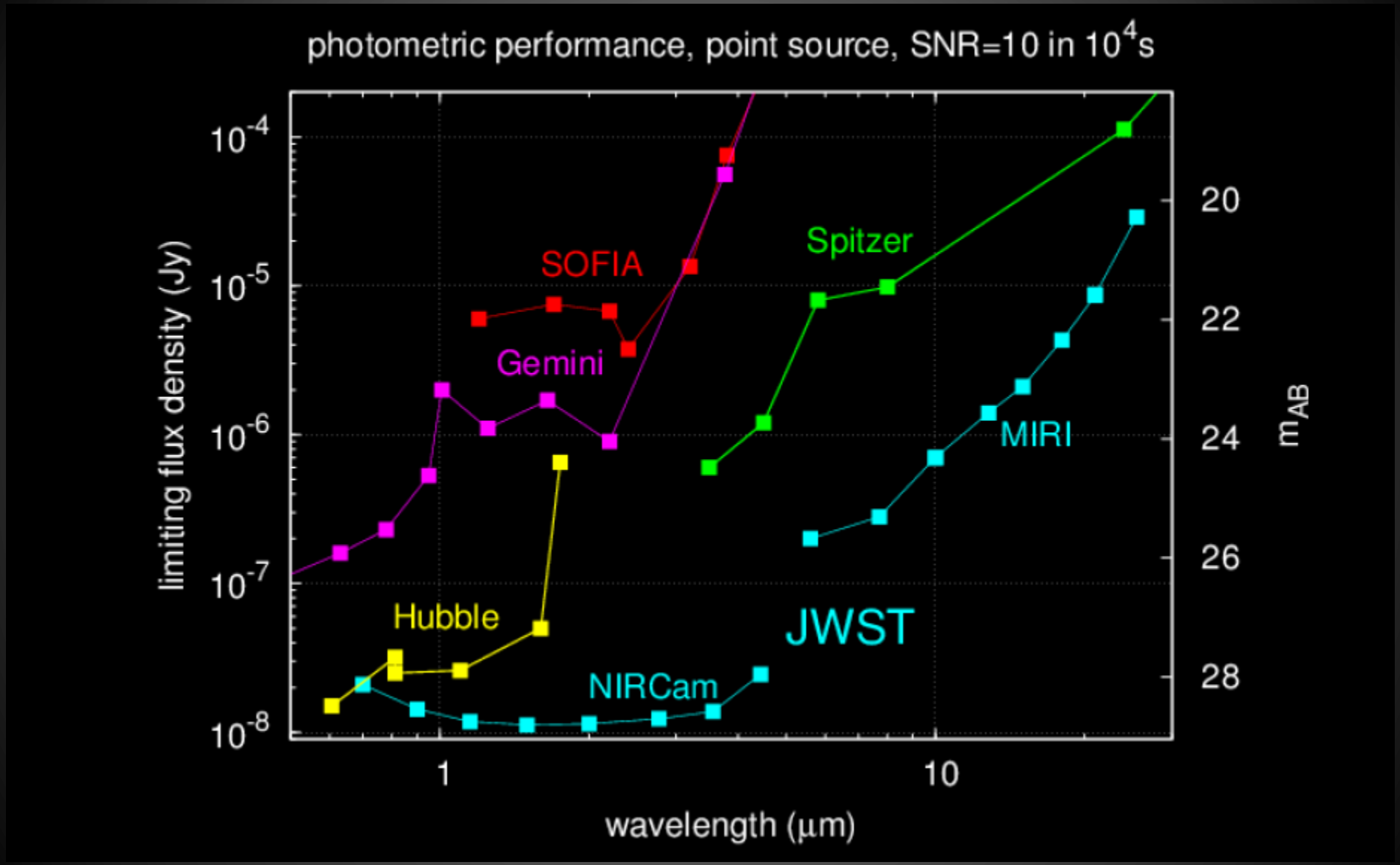
** Most useful for solar system observations

JWST Spectroscopy Modes

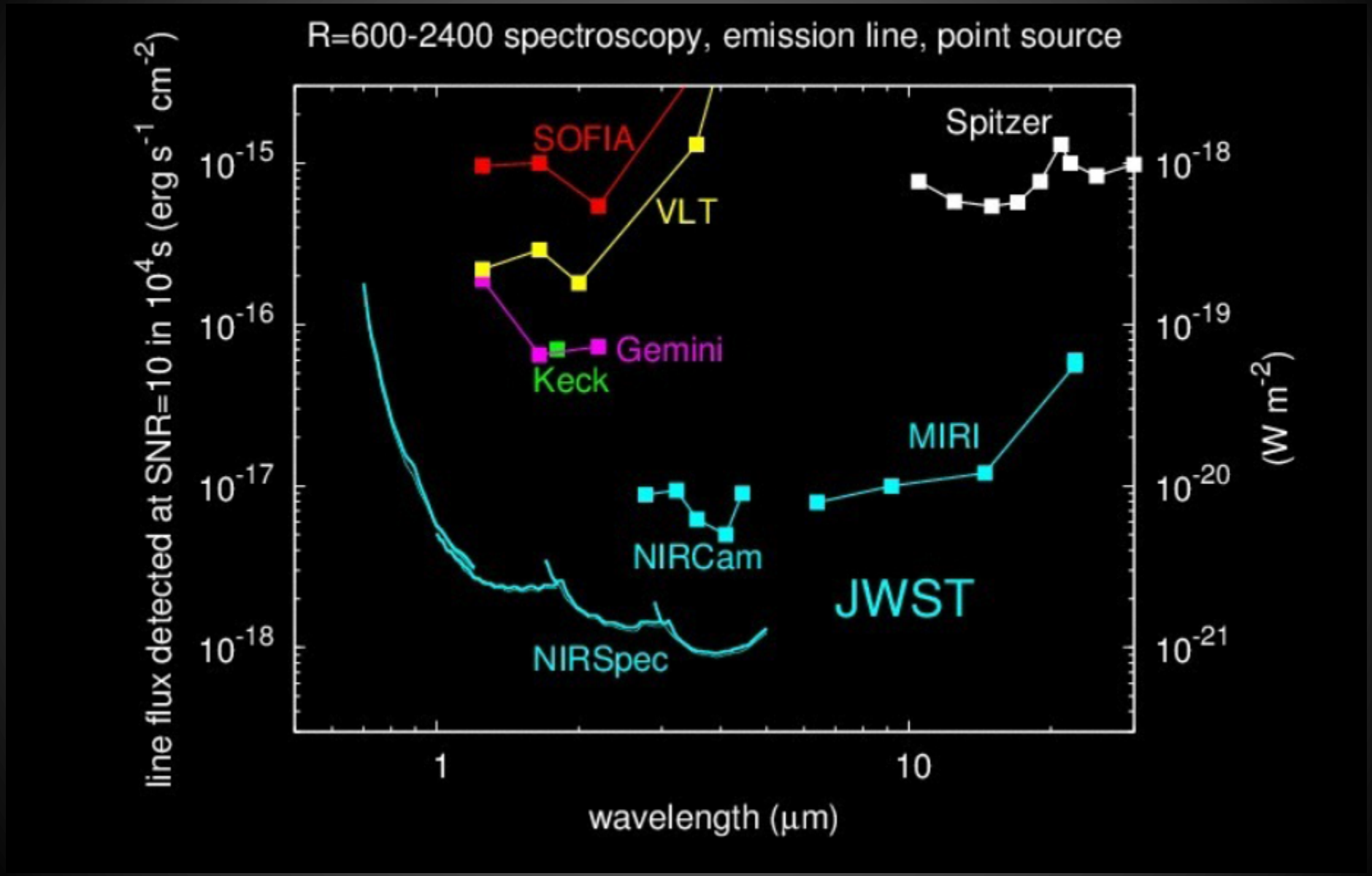
Mode	Instrument	Wavelength (microns)	Resolving Power ($\lambda/\Delta\lambda$)	Field of View / Slit Size
Slitless Spectroscopy	NIRISS	1.0 – 2.5	150	2.2′ x 2.2′
	NIRISS	0.6 – 2.5	700	single object
	NIRCam	2.4 – 5.0	2000	2.2′ x 2.2′
Multi-Object Spectroscopy	NIRSpec	0.6 – 5.0	100, 1000, 2700	3.4′ x 3.4′ with 250k 0.2 x 0.5″ microshutters
Single Slit Spectroscopy	NIRSpec	0.6 – 5.0	100, 1000, 2700	0.4″ x 3.8″ 0.2″ x 3.3″ 1.6″ x 1.6″ 0.2″ x 60″ (MSA)
	MIRI	5.0 – ~14.0	~100 at 7.5 microns	0.6″ x 5.5″ slit
Spectroscopic Imaging (IFU)	NIRSpec	0.6 – 5.0	100, 1000, 2700	3.0″ x 3.0″
	MIRI	5.0 – 7.7	3500	3.0″ x 3.9″
	MIRI	7.7 – 11.9	2800	3.5″ x 4.4″
	MIRI	11.9 – 18.3	2700	5.2″ x 6.2″
	MIRI	18.3 – 28.8	2200	6.7″ x 7.7″

** Most useful for solar system observations

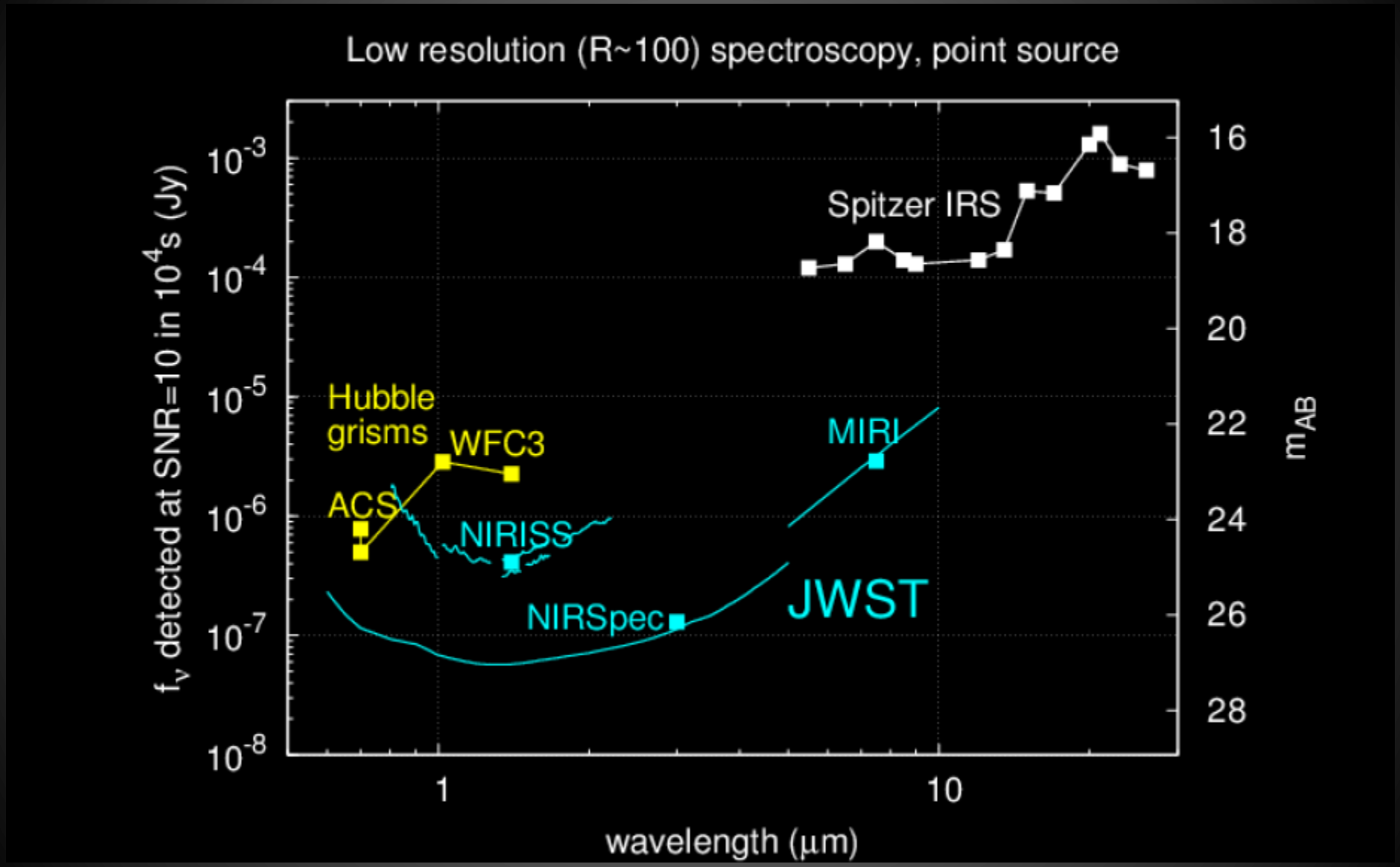
Photometric Sensitivity



Medium Resolution Spectral Sensitivity

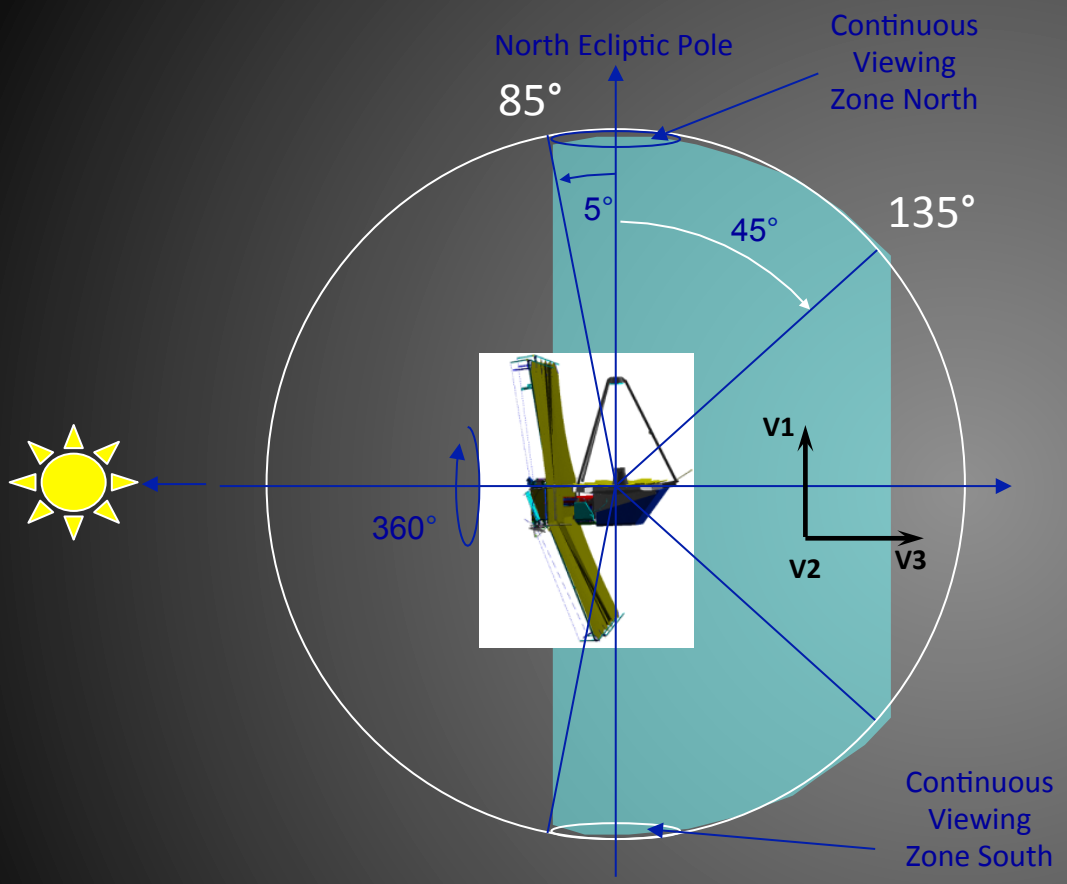


Low Resolution Spectral Sensitivity



JWST Operations for Moving Targets

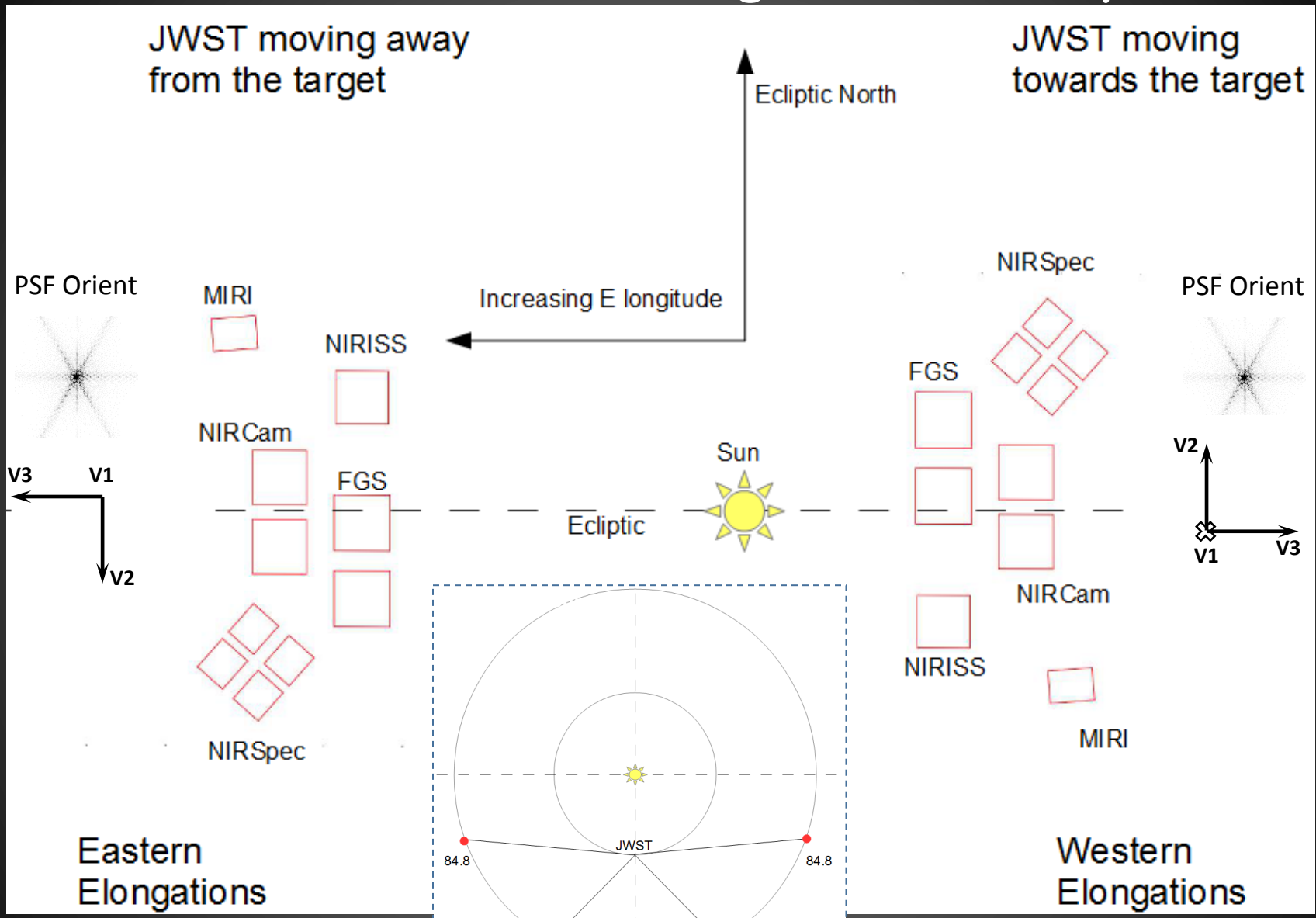
JWST Field of Regard



- Observatory thermal design defines the allowed Solar orientations
  - Solar elongation 85° to 135° (like Spitzer, Herschel)
  - Roll ±5° about line of sight
- JWST can observe the whole sky every year while remaining continuously in the shadow of its sunshield.
  - Instantaneous Field of Regard is an annulus covering 35% of the sky
  - The whole sky is covered twice each year with small continuous viewing zones at the Ecliptic poles

Solar System Targets: Observations occur near quadrature, not at opposition

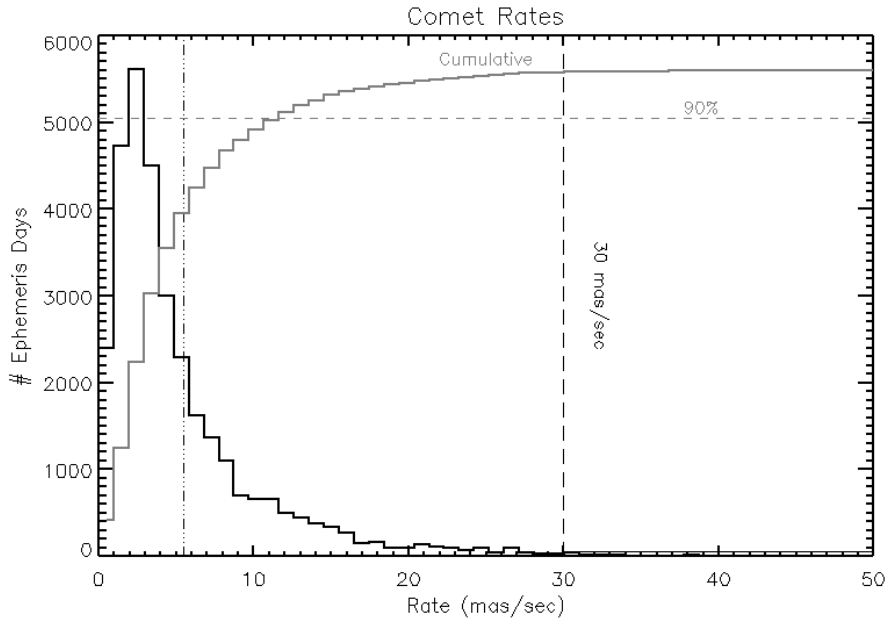
JWST Instrument FOVs for Targets in the Ecliptic Plane

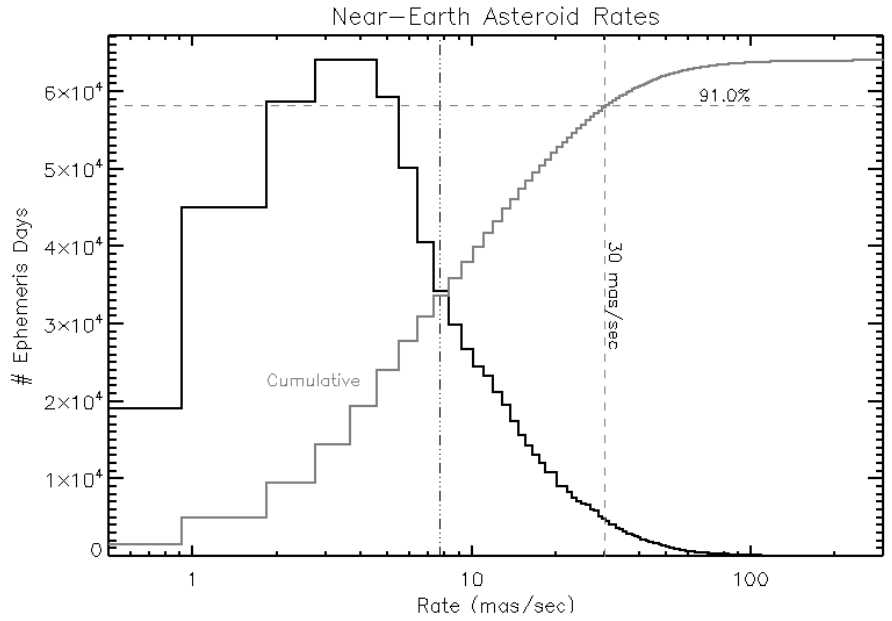


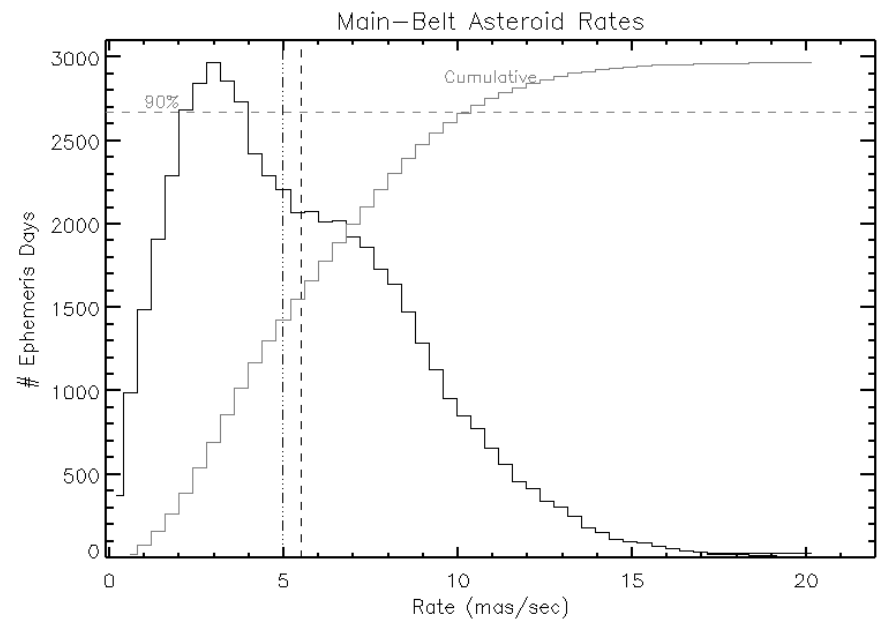
Moving Targets Tracking

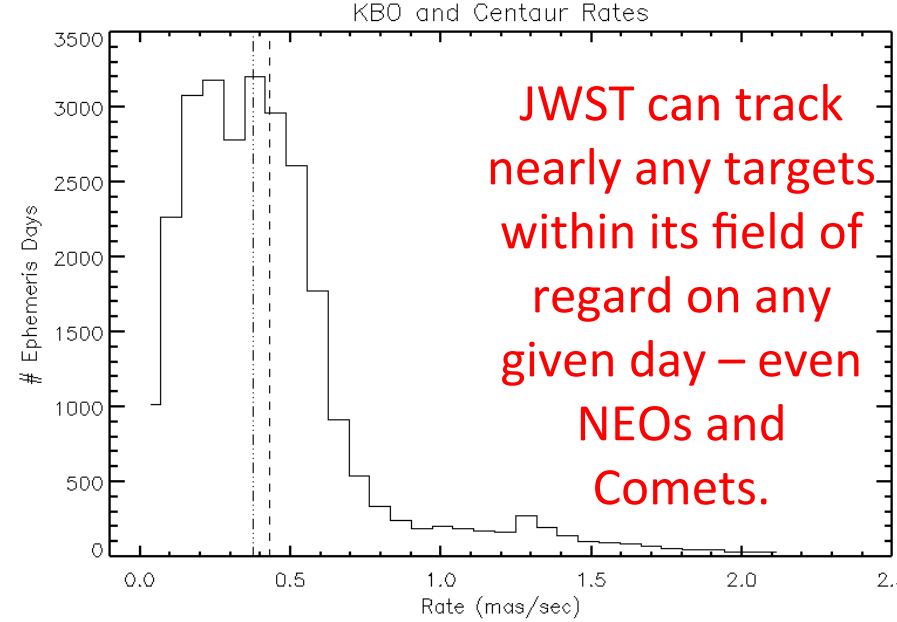
- Non-sidereal tracking – **Implemented**.
  - Rates up to 30 mas/s (108’’/hr) supported (max rate of Mars)
    - Modeling shows excellent pointing stability (< 7mas NEA), ~same as fixed targets
  - The moving-target is fixed in detector frame while exposing
    - Dithers, mosaics supported (slightly higher overheads)
  - ~1 mag brighter guide stars required for moving targets
    - Some small impact on schedulability for targets at high galactic latitude
  - Long (~1hr+ tracks), and observations are possible
    - Will use multiple guide stars

How Fast are Moving Targets Moving?





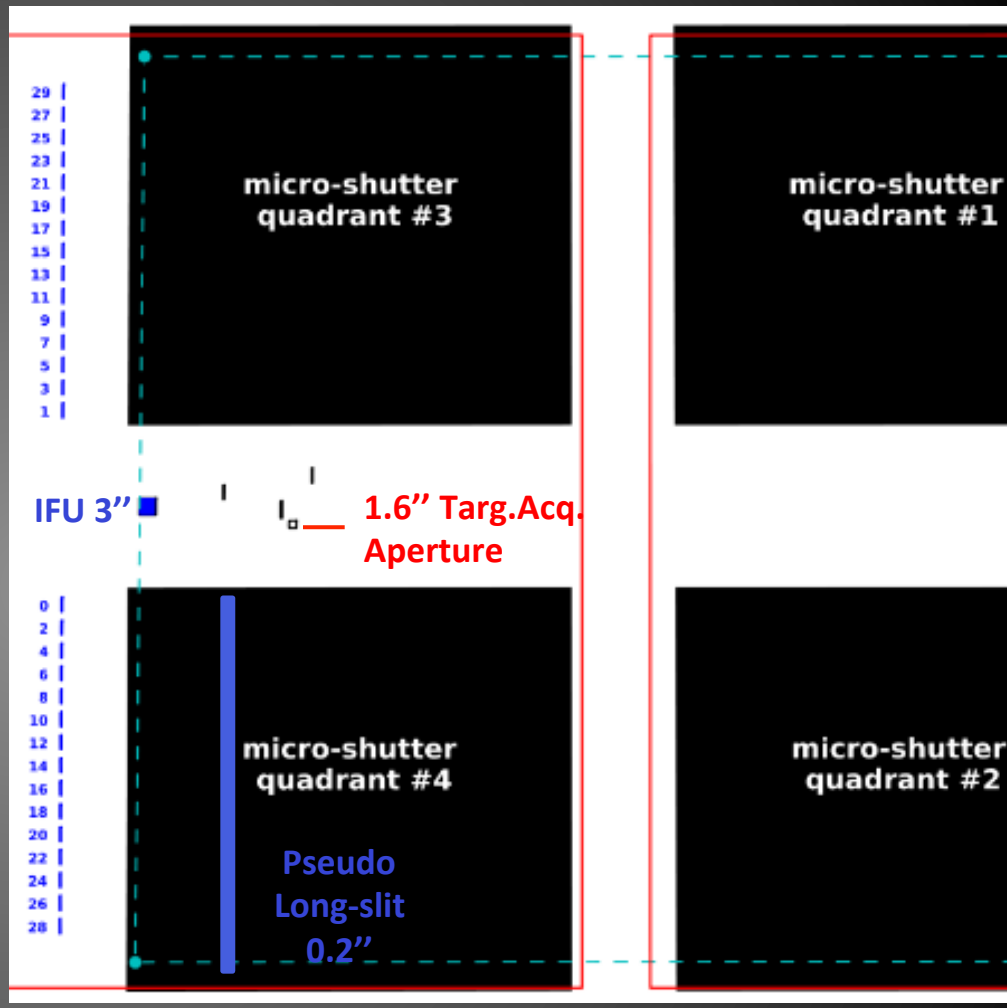




JWST can track nearly any targets within its field of regard on any given day – even NEOs and Comets.

NIRSpec Target Acquisition, Slits, IFU

- NIRSpec TA for moving targets is not easy
  - 1.6'' square aperture
    - Ephemeris of target must be accurate!
  - Centroid calculated on-board
  - Target can be accurately (<10mas) positioned in the IFU, any of the fixed slits, or in a pseudo long-slit in the microshutter array



Solar System Science Highlights

12 JWST Solar System Papers

https://iopscience.iop.org/1538-3873/128/959 & 960

- **Asteroids** (Andy Rivkin, JHU/APL)
- **Comets** (Chick Woodward, U. Minnesota)
- **Giant Planets, JWST Overview** (Jim Norwood, NMSU)
- **Mars** (Geronimo Villanueva, GSFC)
- **NEOs** (Cristina Thomas, GSFC)
- **Occultations** (Pablo Santos-Sanz, IAA-CSIC, Spain)
- **Rings** (Matt Tiscareno, Cornell)
- **Satellites** (Laszlo Kestay, USGS)
- **Titan** (Conor Nixon, GSFC)
- **TNOs** (Alex Parker, SwRI)
- JWST Solar System Capabilities (Milam, GSFC)

JWST Instruments & APT Templates

NIRCam: 0.6 – 5 um imager, slitless grisms,
32 / 65 mas pixels (SW / LW)

- Imaging **
  - Simultaneous 0.6-2.3 & 2.4-5.0 micron imaging
  - Mapping (2.2' x 5' FOV)
  - Bright extended sources (10" – 1.1' FOV)
- Coronagraphy
  - ~0.5" inner working angle
- Time Series **
  - High-cadence, long duration photometry
- Grism Time Series **
  - High-cadence, long duration slitless spectroscopy
- Grism Imaging
  - Wide-field slitless spectroscopy

NIRISS: 0.8 - 5 um imager & spectrometer

- R = 150 0.8 – 2.2 um slitless spectra
- R = 700 0.8 – 2.5 um slitless spectra
- Imaging in 7 bands
- Aperture-masking Intererometery **
  - 2.6 – 5um, 65mas resolution

NIRSpec: 0.7 – 5 um spectrometer

- R = 100, 1000, 2700
- 3 settings for full coverage at R > 100
- IFU Spectroscopy **
  - 3"x3" FOV, 100mas pixels
- Fixed Slits
  - 0.2" & 0.4" x 3.8", 1.6"x1.6"
- Multi-shutter Array (Pseudo long-slit **)
  - 0.2" x 0.46" slitlets

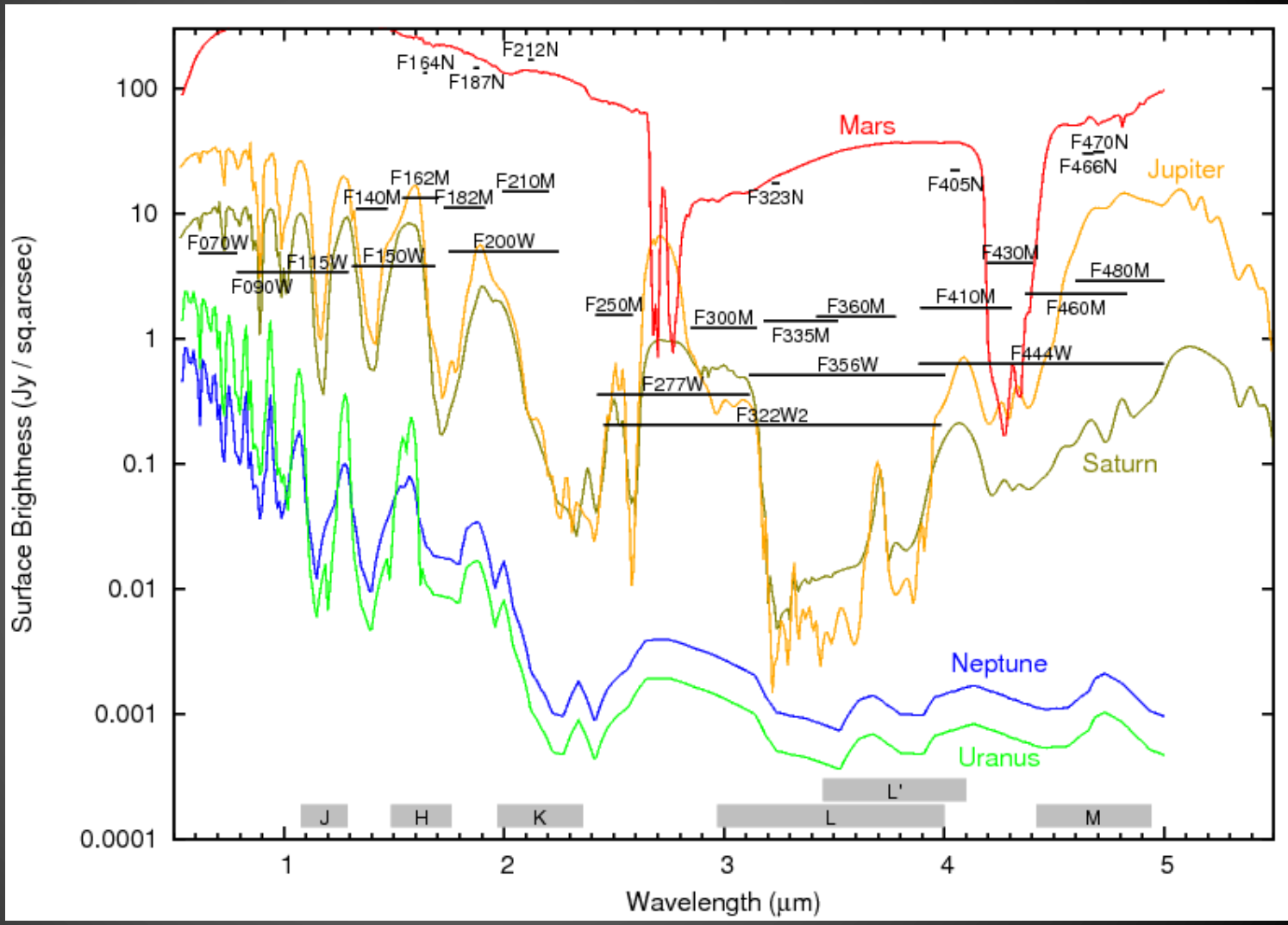
MIRI: 5 - 28 um imager & spectrometer

- R = 100 5 – 14 um slit spectra
- Imaging **
  - 9 bands
  - 110 mas pixels
- IFU Spectroscopy **
  - 4"x4" FOV, 110mas pixels, R=2000
  - 5 – 28 um (4 settings for full coverage)
- Fixed Slit **
  - 0.6" x 5.5", R=100, 5 – 14 um in one shot

** Most useful for solar system observations

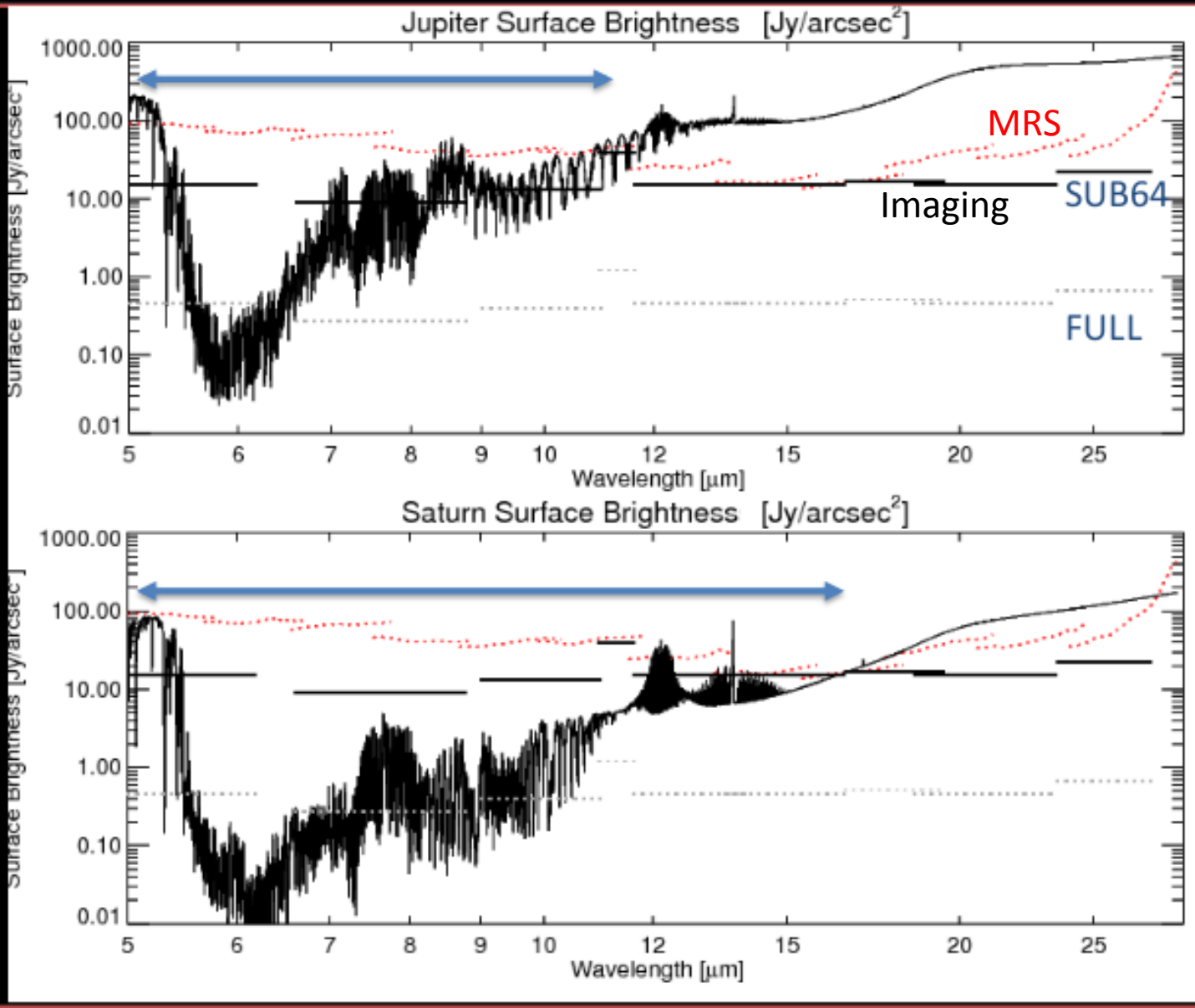
Giant Planet Imaging with NIRCam

- Bright limits for 640x640 subarrays
- 160x160 limits are 15x higher



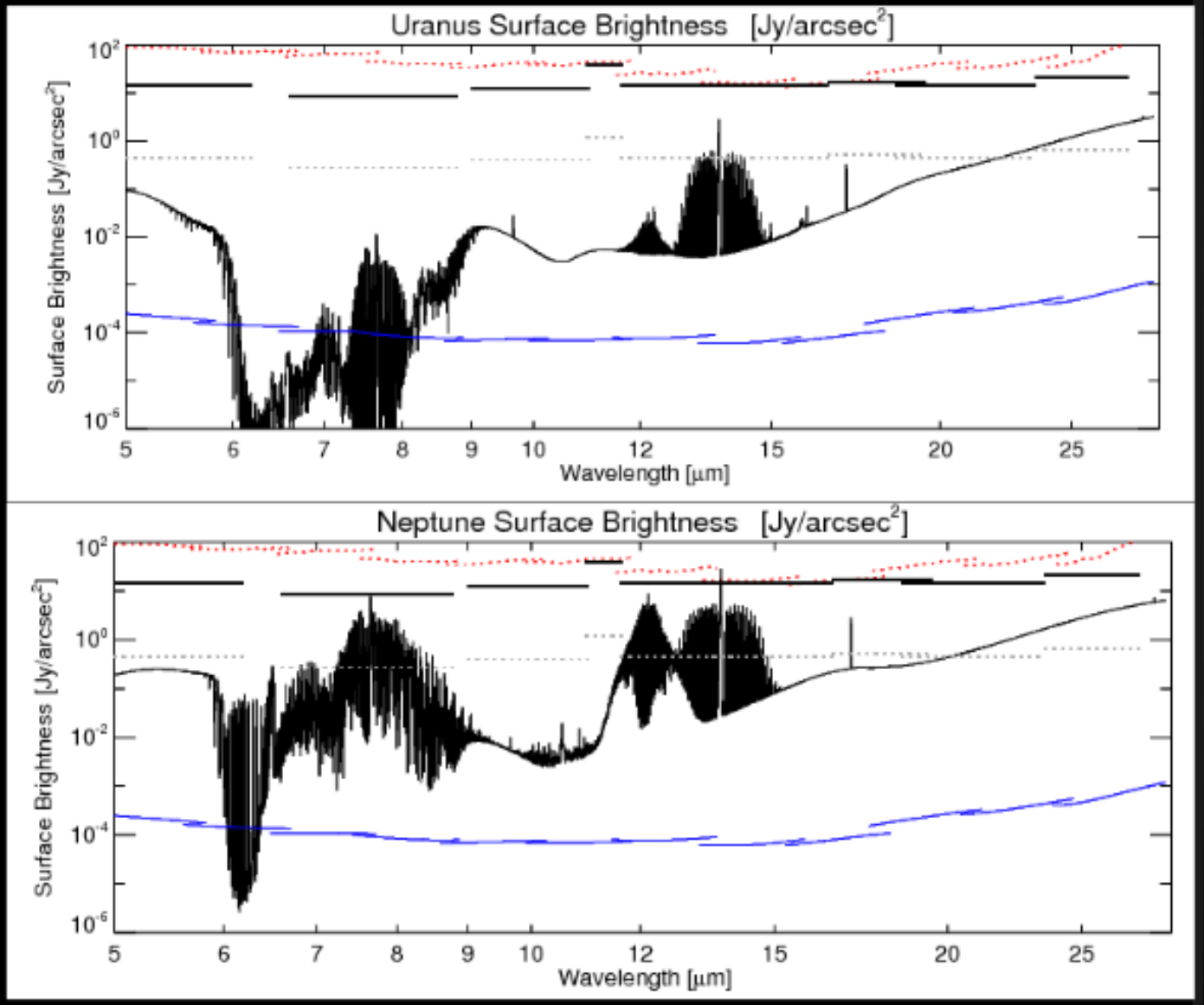
Saturation Issues for Jupiter/Saturn (MIRI)

- Jupiter saturates in all filters; MRS 5-11 μm may be feasible.
- Saturn imaging < 12 μm; MRS 5-16 μm.
- Saturation doesn't break detectors – just renders data unusable in certain ranges.

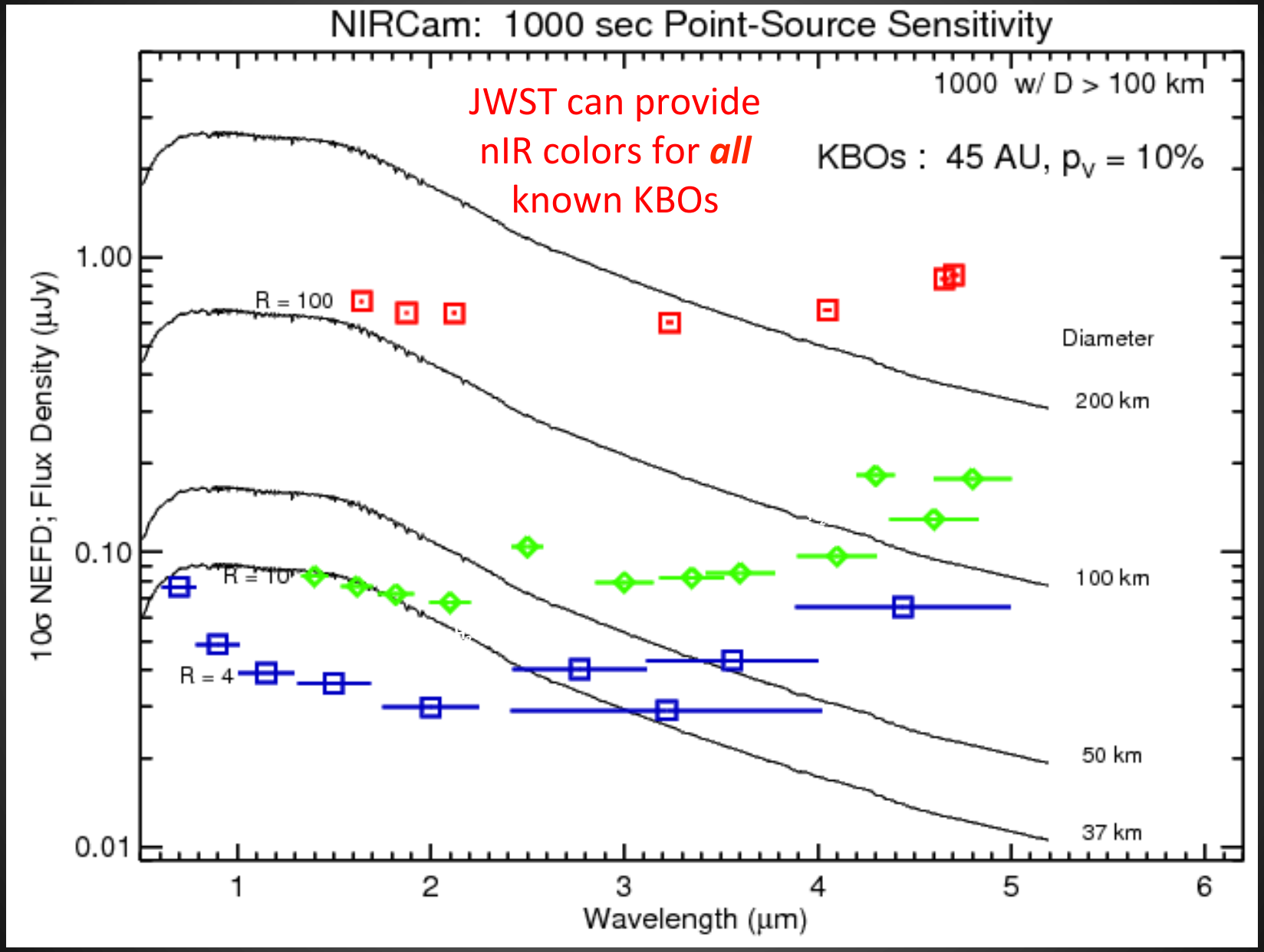


Full Capabilities for Uranus/Neptune (MIRI)

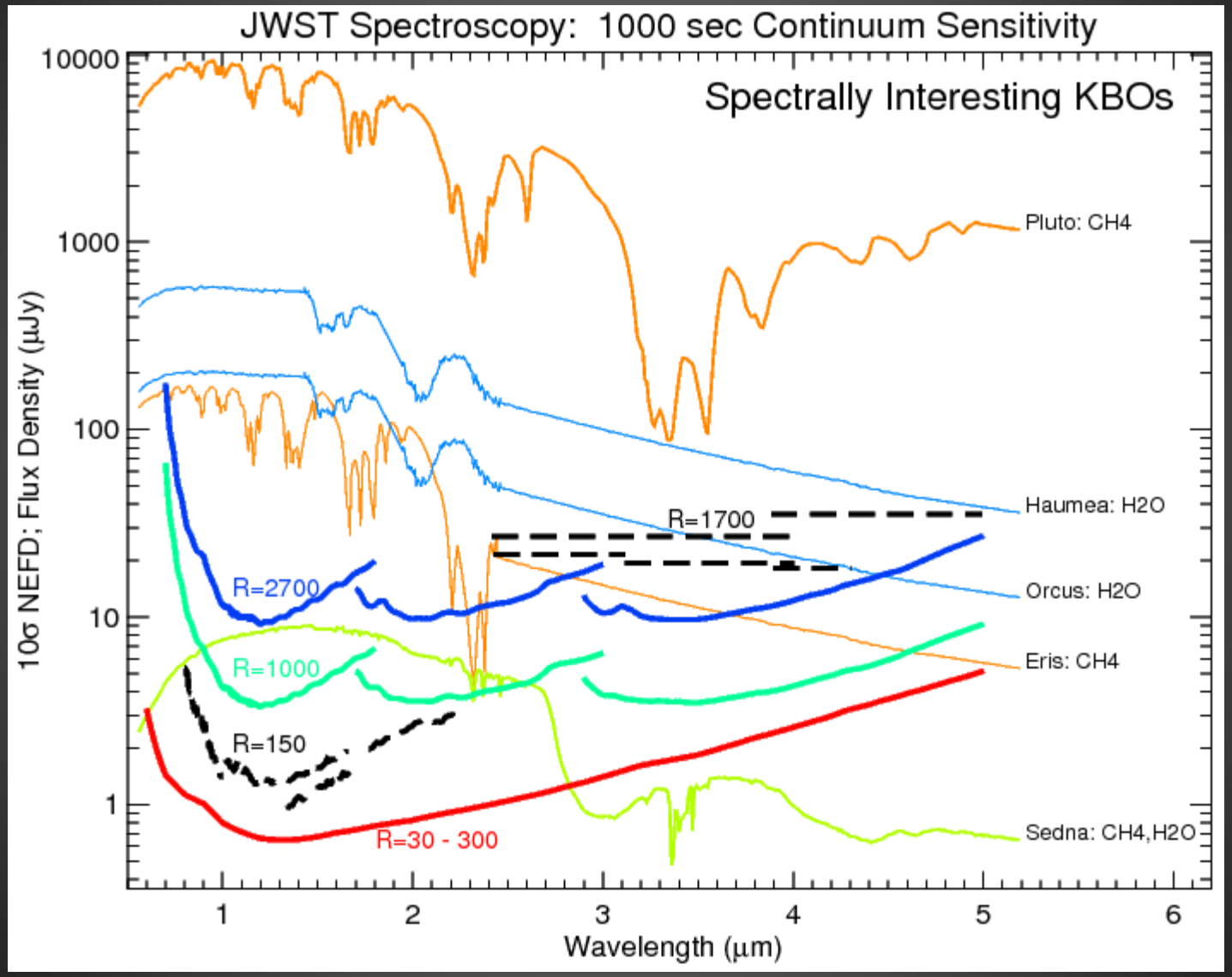
- Imaging and spectroscopy in all filters and MRS channels.
- Large contrasts within a channel – care to minimise latents between SHORT/MED/LONG exposures.
- Blue line – MRS sensitivity to continuum source, SNR=10 in 10,000 sec (Glasse et al., 2015).
- *Lacks shot noise, fails to account for higher noise as a target flux increases.*



KBO Photometry with NIRCam

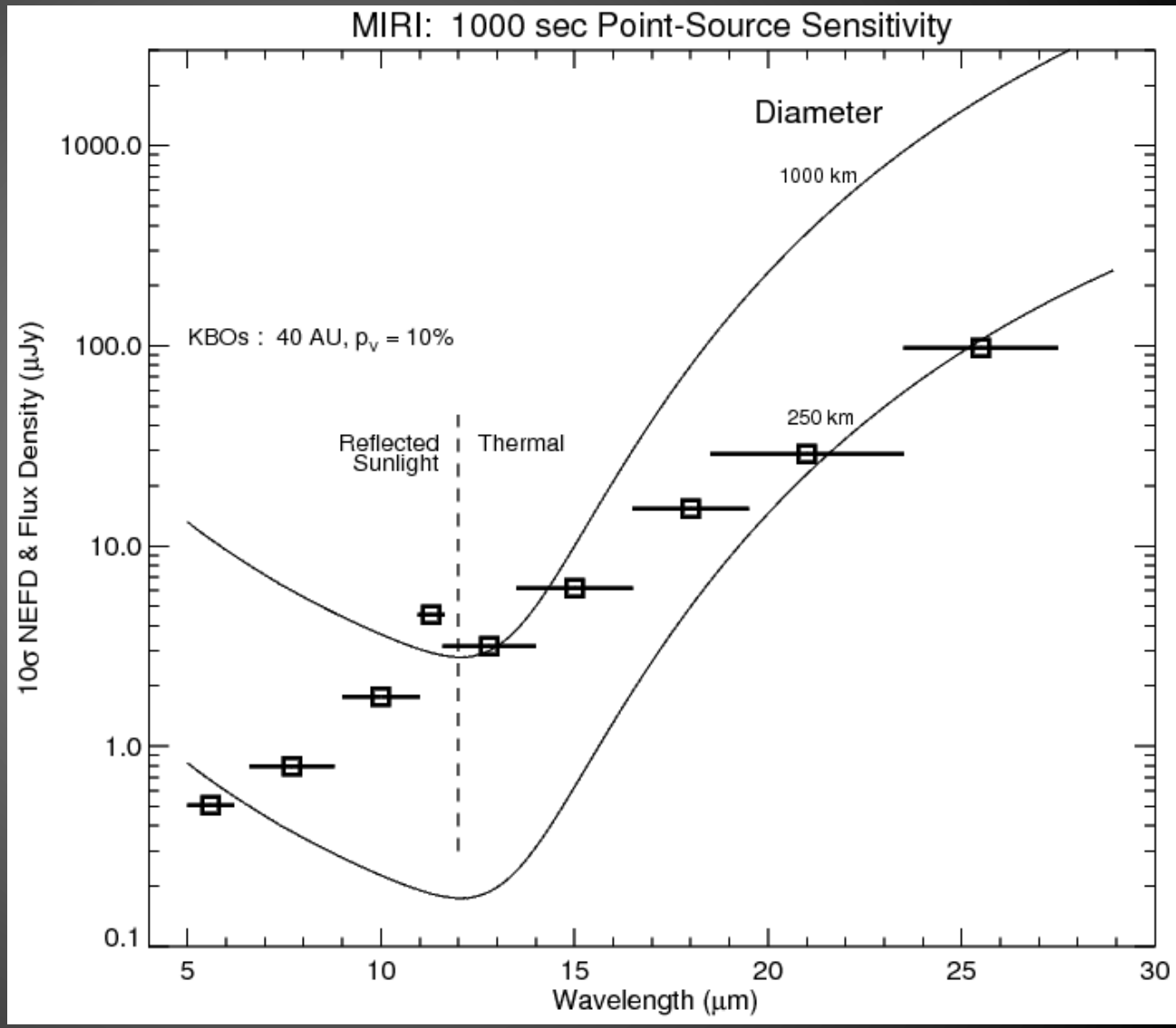


KBO Spectroscopy with NIRSpec



KBO Thermal Radiometry with MIRI

- MIRI can measure temperature distributions for medium-sized KBOs
- Sensitivity well matched to that of ALMA
- Valuable for
  - Thermal inertia
    - Composition
    - Regolith structure
  - Emissivity
  - Albedo
- Best when combined with measurements at >50 microns



PASP Special Issue
(Jan 4, 2016)

Innovative Solar System Science with the James Webb Space Telescope

Stefanie Milam, Special Editor

http://iopscience.iop.org/1538-3873/128/959

11 topical papers

http://iopscience.iop.org/1538-3873/128/960

1 high-level paper (Norwood et al.)

Data Pipeline for Moving Targets

Moving-target Pipeline Overview

- Calibration pipeline data product "levels":
  1. Data formatting, science-frame re-orientation, MT WCS information added
  2. Calibrated single-exposure count-rate images; flux conversion, wavelength cal.
  3. Combine Level-2 products ➔ coadd exposures, mosaicking, etc.

- Single-exposure calibration processing (level 2):
  - **Science target is 'fixed' in the detector frame (telescope tracking)**
    - **Detector-level calibration steps are the ~same as for fixed targets**

- Multi-exposure calibration processing (level 3):
  - **Coaddition of exposures occurs in the co-moving frame of the target**
    - Existing fixed-target algorithms will be used
    - ***HST Pipeline has never done this***
    - Same approach used by Spitzer and Herschel

Astronomer's Proposal Tool (APT) for Moving Targets

An extensive chart packet about APT for moving targets will be posted at jwst.stsci.edu/events

Look for today's event at that URL

APT example proposal for moving targets is also in the works (accessible from APT -> File -> JWST Demonstration Proposals)

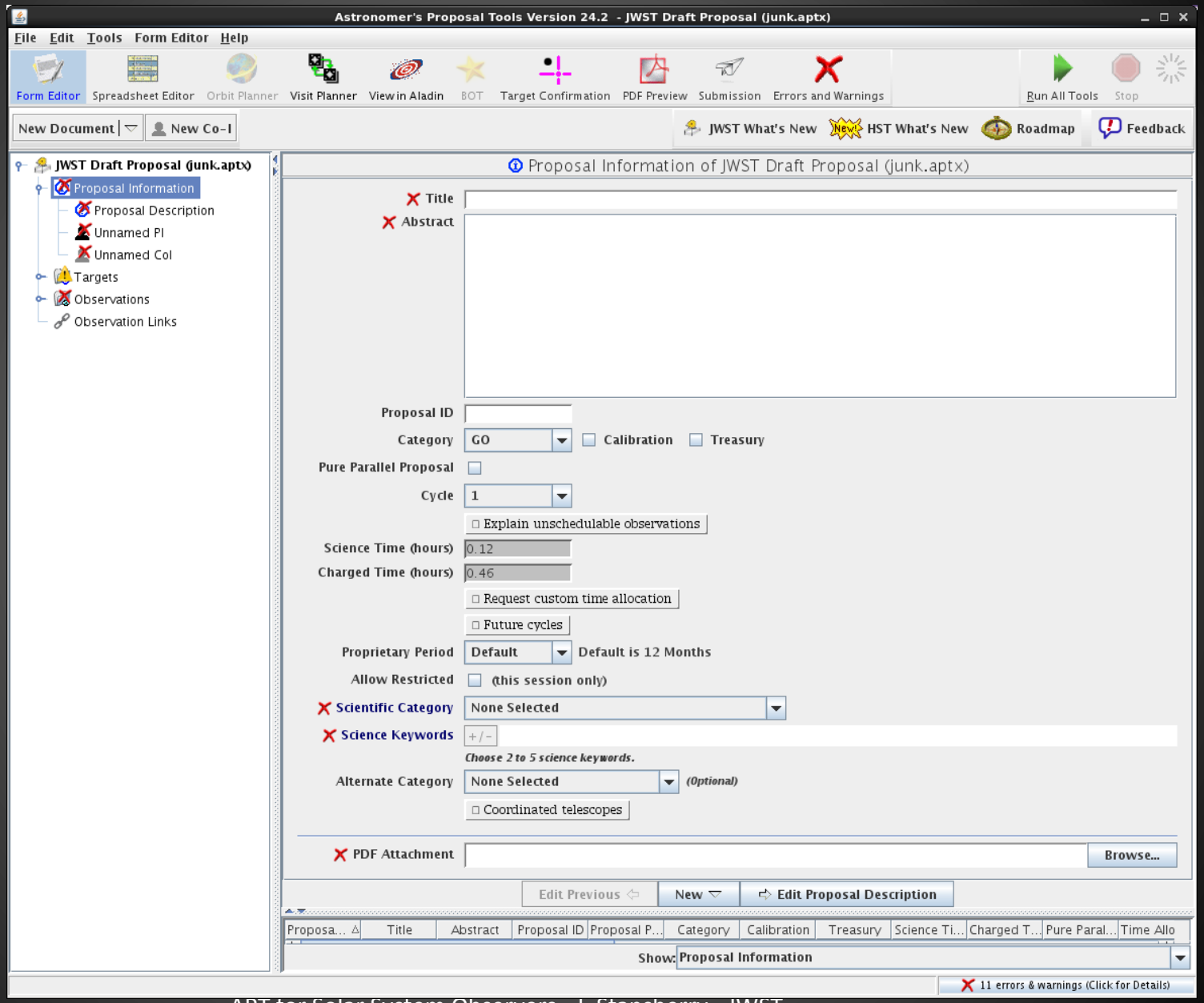
What is APT?

- APT is your tool for
  - Designing JWST (and HST) observations
    - Defining targets
      - Standard targets: Planets, Dwarf Planets, Satellites, Longitudes, etc.
      - Comets, asteroids, new satellites
    - Defining Observations
      - Pick Instrument (NIRCAM, NIRSpec, MIRI, NIRISS)
      - Pick Science Template (e.g. Imaging, IFU Spectroscopy, …)
        - Optionally set up Target Acquisition
        - Define Exposure Specifications (filter and/or disperser plus detector readout parameters)
    - Defining scheduling constraints on observations
      - Date/time
      - Separation from another body
      - Apparent rate of motion
      - Phase angle, distance, etc.
    - Evaluating schedulability of observations
    - Submitting your Proposals

Java Application available at http://apt.stsci.edu

APT: Starting a Proposal

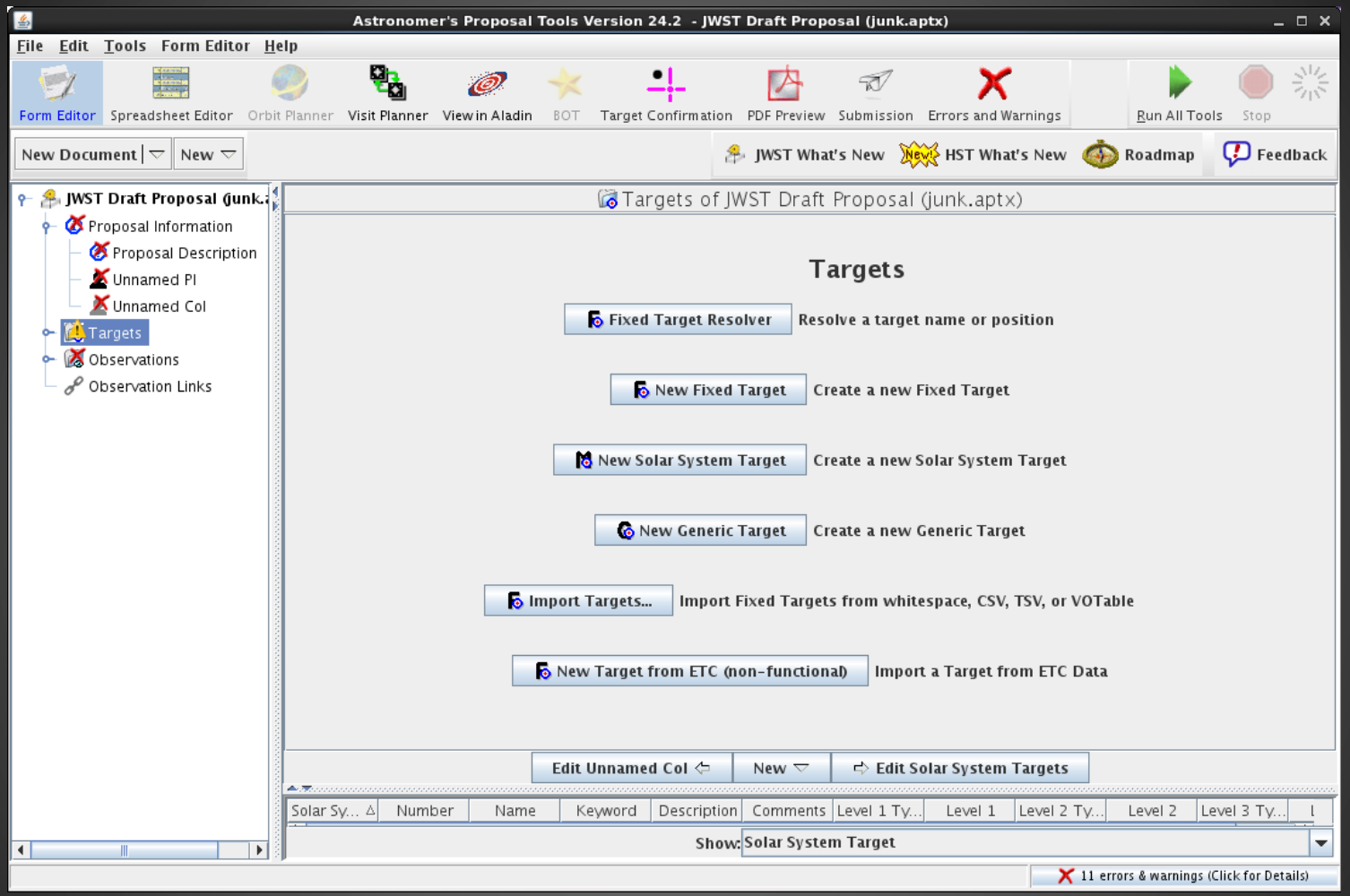
You can create JWST proposals now with APT



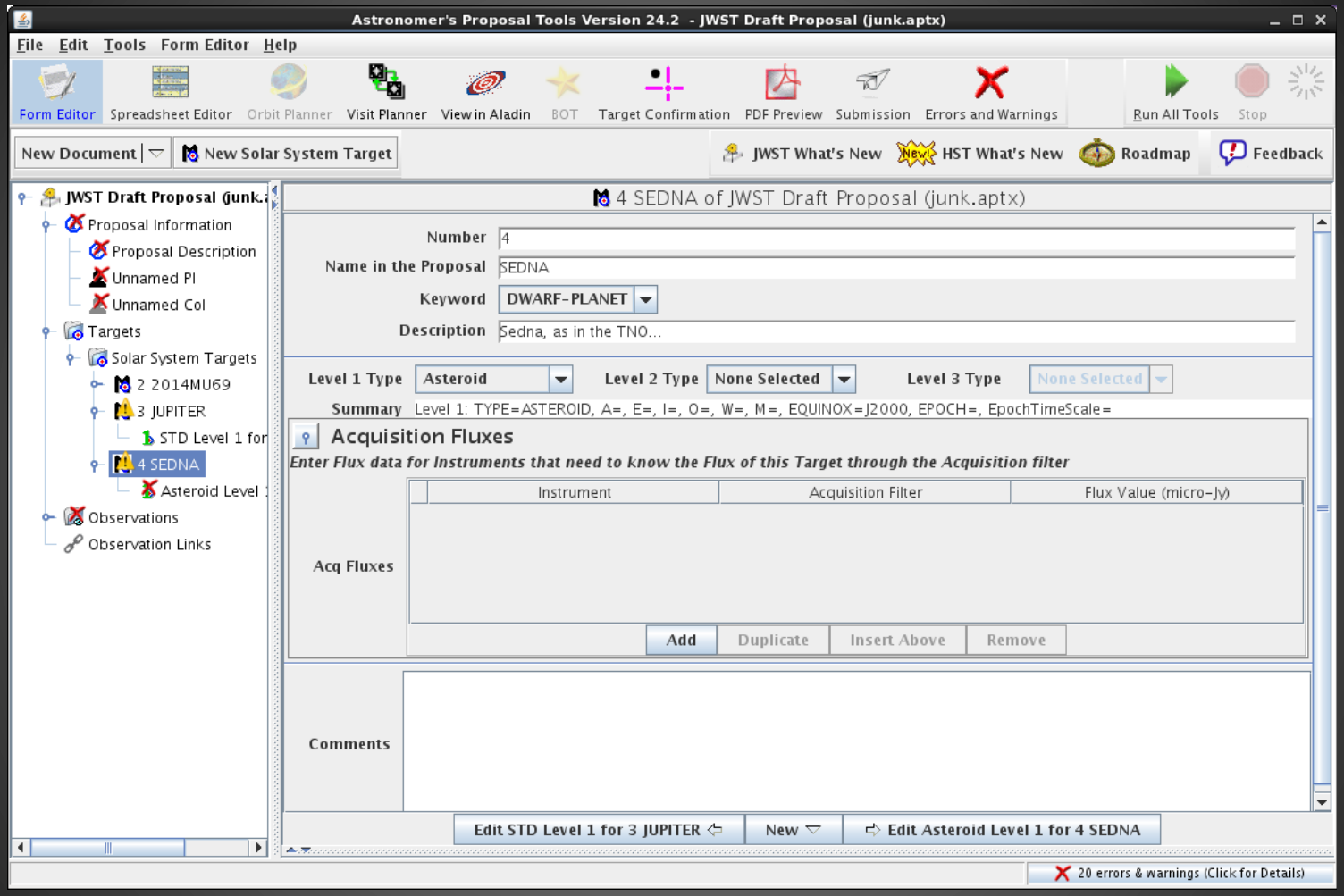
APT Moving Target Specifications

- Inherits many capabilities from HST
  - MT "Level-1 Types"
    - Standard (planets and their satellites)
    - Comet (suports non-gravitational orbit perturbations)
    - Asteroid (everything else)
  - Interface to JPL Horizons
    - Retrieval of NAIF ID/names and orbital elements
- The target specification is the only thing you do differently to observe moving targets
  - Observations may then be specified using all instrument modes

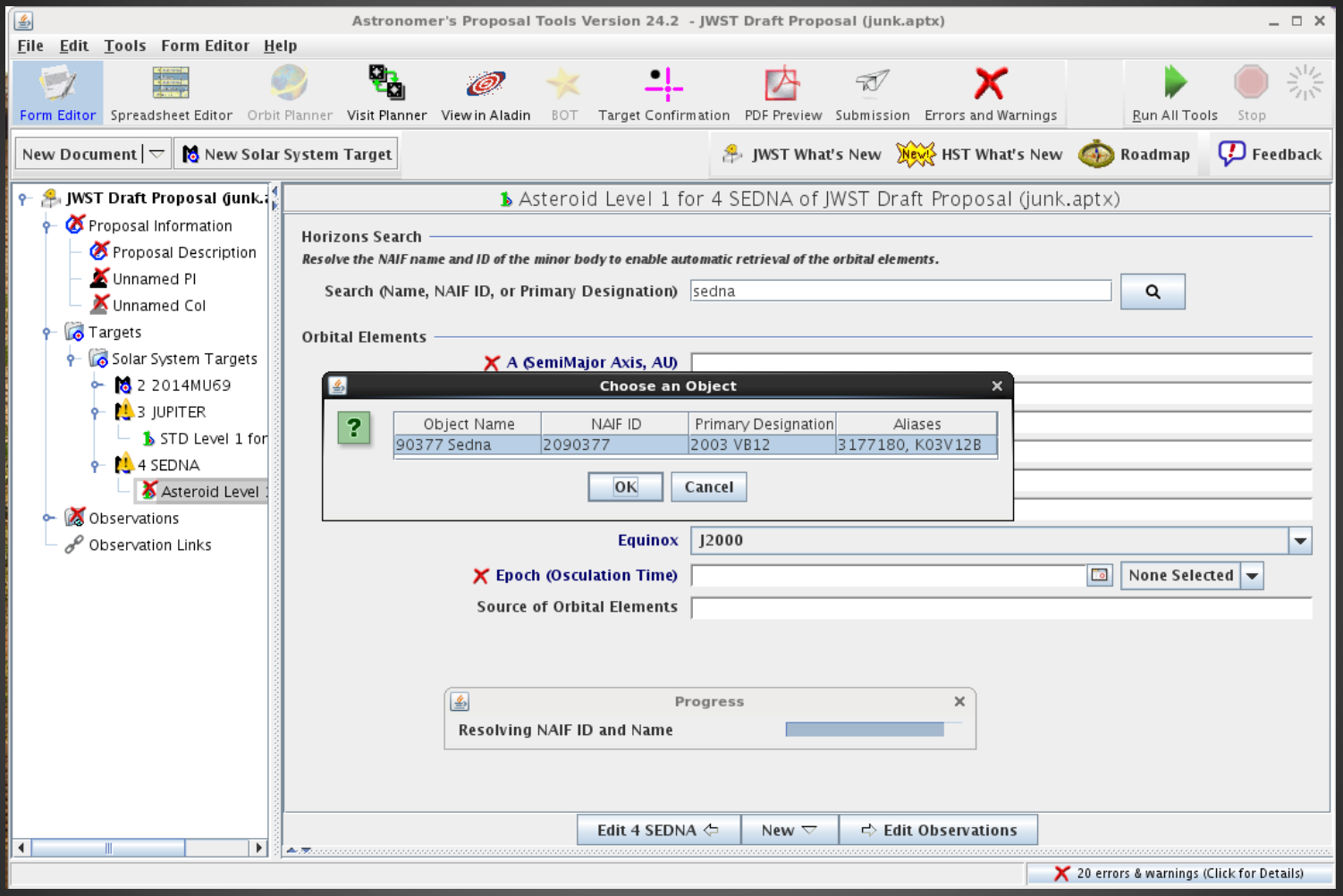
Top Level Target Interface



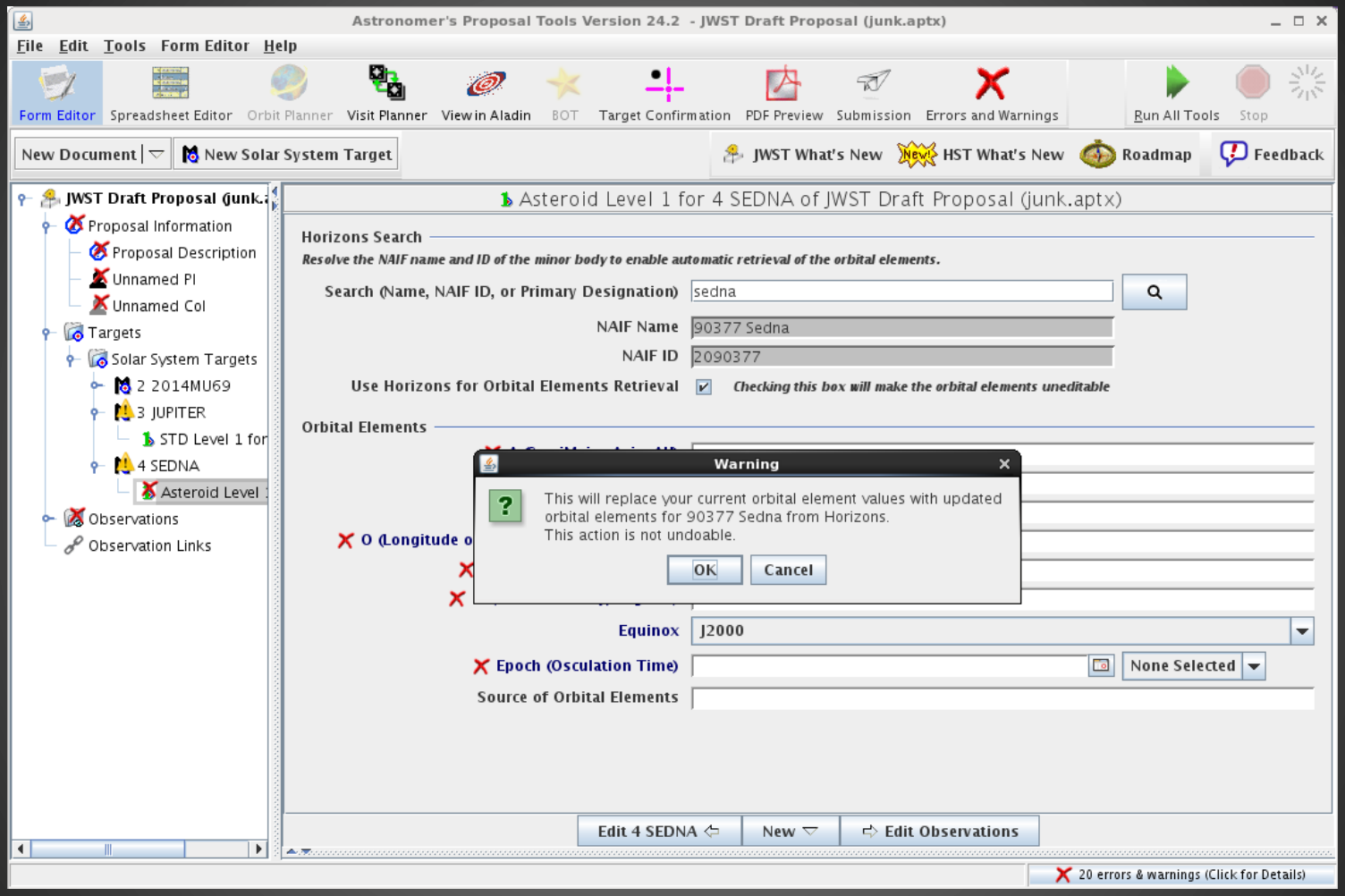
Minor Body Interface



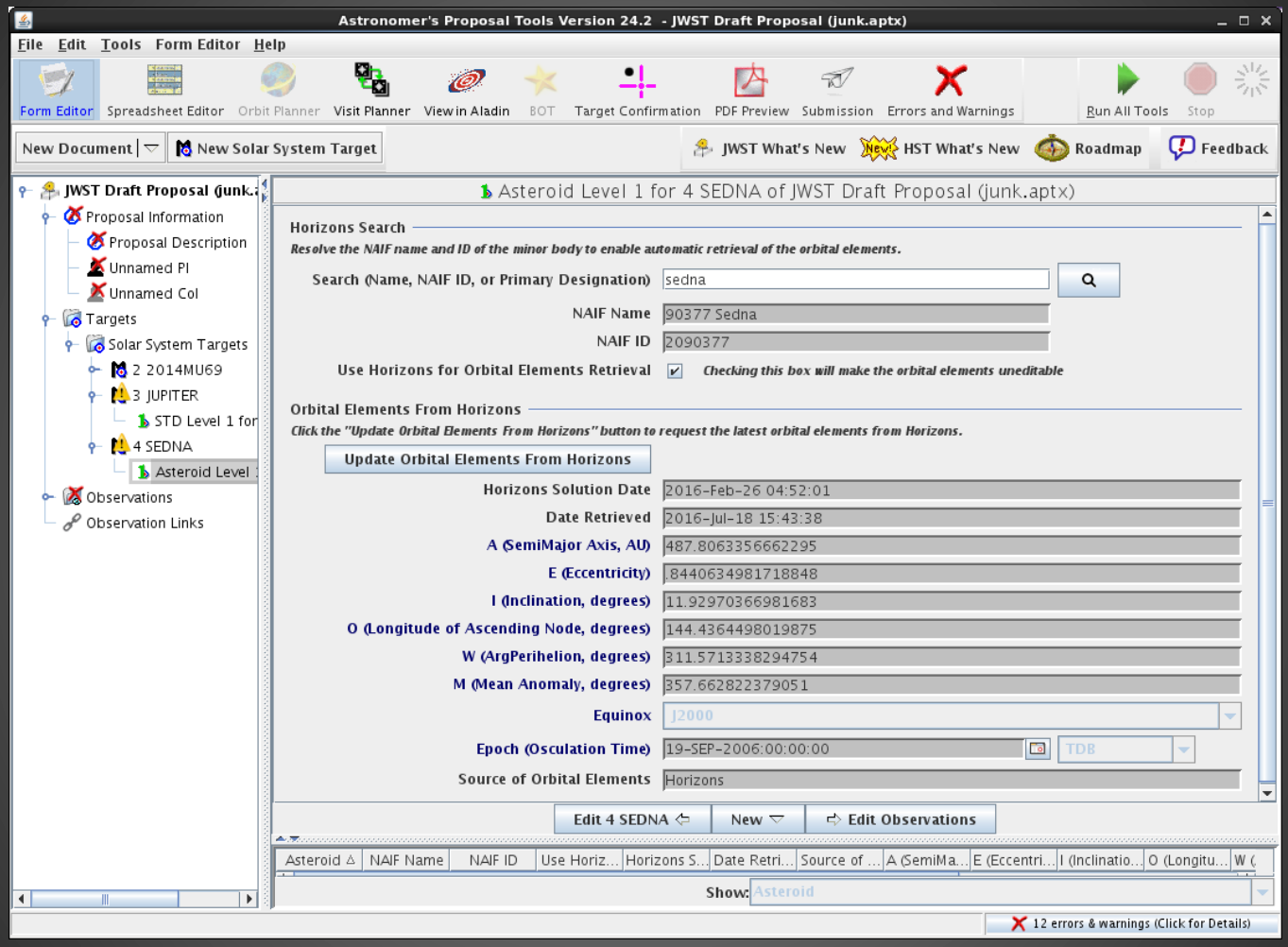
Minor Body: NAIF Search Capability



Minor Body Elements Retrieval

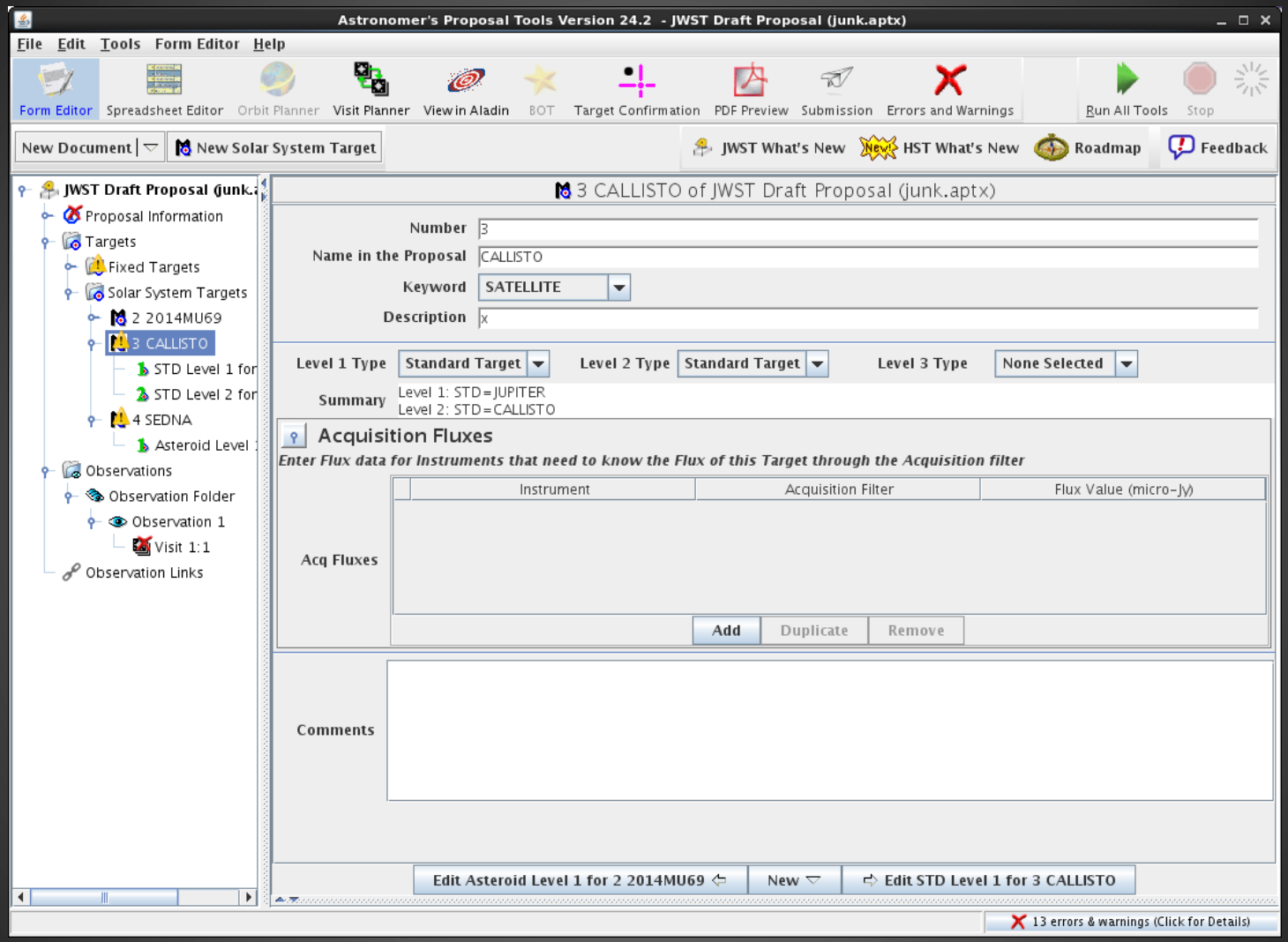


Minor Body Elements Retrieval



Filling this form used to be a manual process of cut/paste.

“Standard” Targets – Levels 1 & 2



Exposure Time Calculator (ETC) for Moving Targets

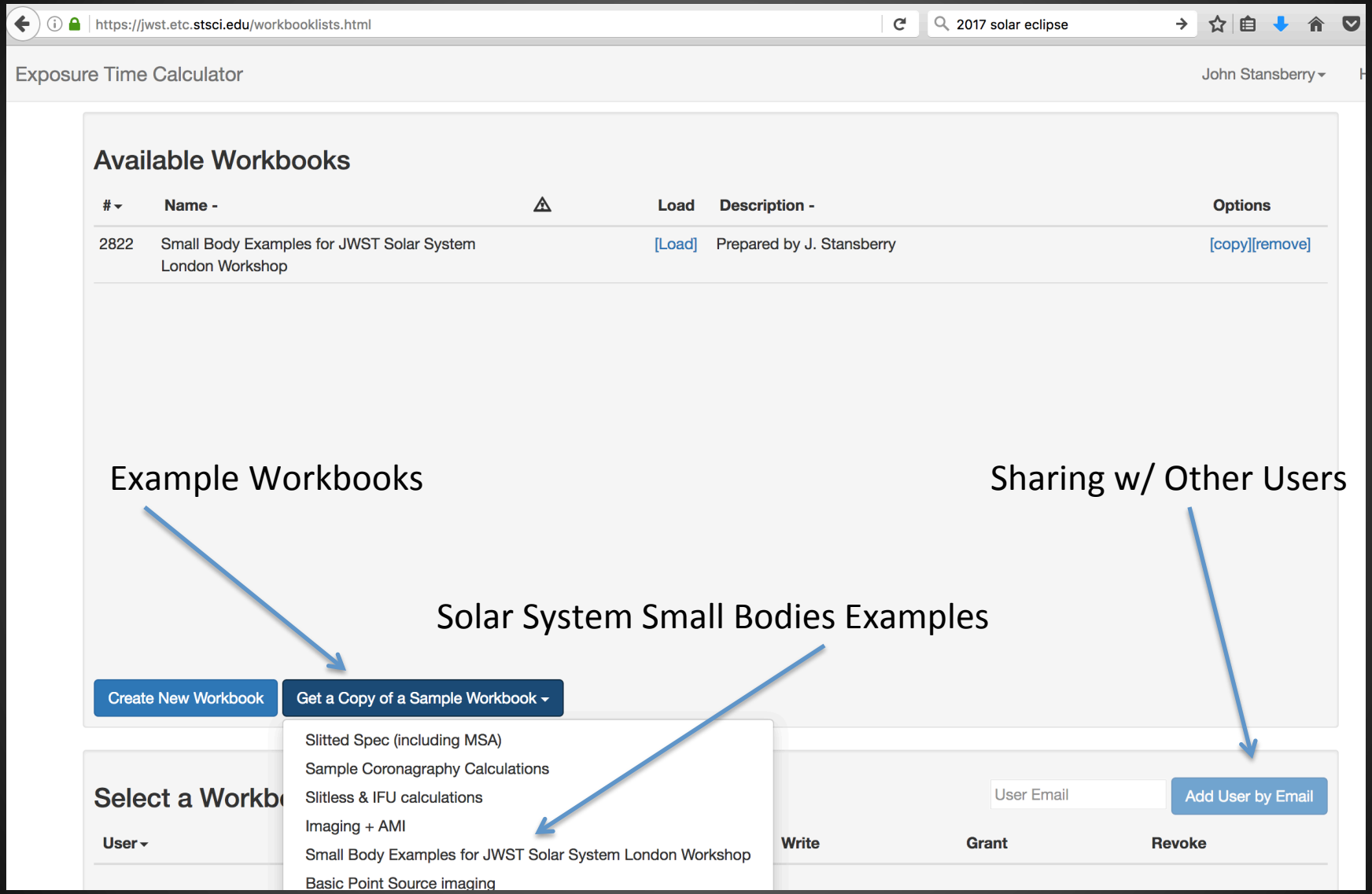
What is the ETC?

- The JWST ETC is… different from what you are probably used to
  - Web-based GUI interface
  - Simulates throughput, all noise components
  - Is 'scene based' – all calculations are 2D (3D for spectra)
  - Result is an SNR image, plus SNR for specified measurement method (aperture)

  - Is a complex tool that takes time to learn
  - Has no specific capabilities for simulating moving targets
- Use of the ETC is *required* to justify proposal time requests
  - Create a 'MyST' account to use it (and archive)
- ETC workbooks
  - Sets of user-defined calculations
  - May be shared with other users

Web Application available at http://jwst.etc.stsci.edu

ETC Example Workbooks



ETC Comet Nucleus + Coma Example

Calculations | Scenes and Sources | Upload Spectra | Caveats and Limitations

ID	Name	Sources	# Calcs
1	Asteroid, reflected +	2,3	0
2	Comet nucleus & co	2,3,4,5	3

New | Add Source | Remove Source | Delete

Select a Source

ID	Plot	Name	Scenes	# Calcs
2	☐	Nucleus Thermal	1,2	3
3	☑	Nucleus Reflecte	1,2	3
4	☐	Coma Reflected,	2	3
5	☐	Coma Thermal,	2	3

New | Delete

Source Editor

ID | Continuum | Renorm | Lines | Shape | Offset

Normalize Source Flux Density

Renormalization applied after redshift

○ Normalize at wavelength

0.1 | flam

lambda | 2 | μm

● Normalize in bandpass

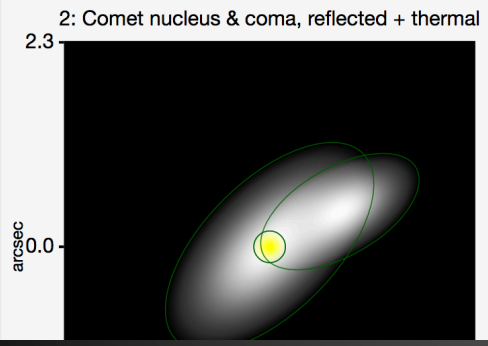
18 | vegamag | at

○ JWST | MIRI/IMAGING | F560W

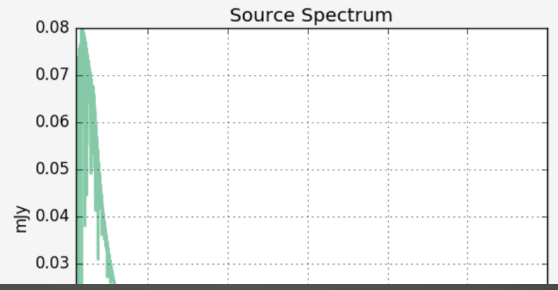
○ HST | WFC3/IR | F098M

Source selected: 3 | Reset | Save

Scene Sketch



Source Spectrum Plots



Calculations | Source Warnings | Source Errors

ID	Name	Scene
1	miri_imaging	2
2	nircam_lw_imaging	2
3	nircam_sw_imaging	2

ETC Demo / Training

- Example solar system workbook within the ETC are available now
- Info / Demos about the ETC
  - Available in JWST Community Lecture Series
    - jwst.stsci.edu/events
      - Look for 2017-01-17 lecture about Pandeia, by K. Pontoppidan
      - Attend 2017-02-21 event, ETC Demo, by S. Ravindranath
- Solar System ETC webinar
  - Need to schedule one SOON to support ERS.
  - Keep an eye on DPS and PEN email announcements
  - Community effort to provide moving target wrapper for Pandeia?
- Pandeia – the JWST ETC Engine
  - https://jwst-docs.stsci.edu/display/JPP/JWST+ETC+Batch+Expansions
  - https://github.com/spacetelescope/JWSTUserTraining2016

jwst.etc.stsci.edu

Summary

- Get the PASP special issue papers
  - iopscience.iop.org/1538-3873/128/959 & 960
- Download APT
  - apt.stsci.edu
- Start looking at user documentation
  - jwst-docs.stsci.edu
  - Moving target documentation is in the works…
- Form your ERS teams, submit NOI by March 3!

Contact / Follow-up / Help Desk:

jstans@stsci.edu stefanie.milam@nasa.gov stsci.service-now.com/jwst