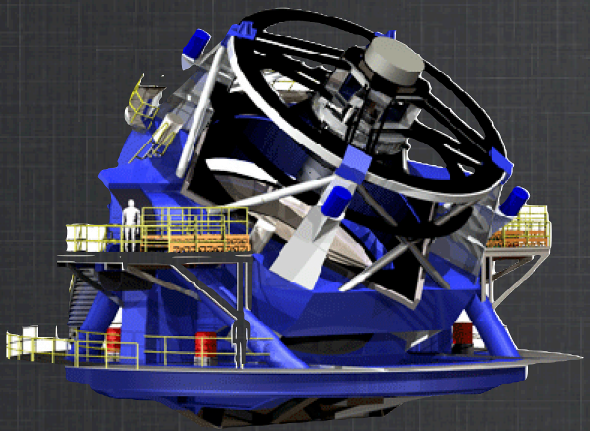
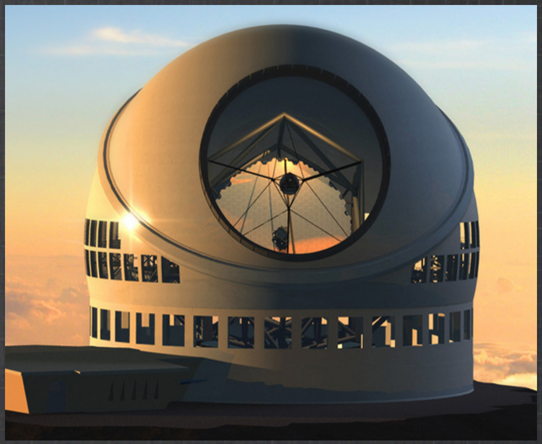
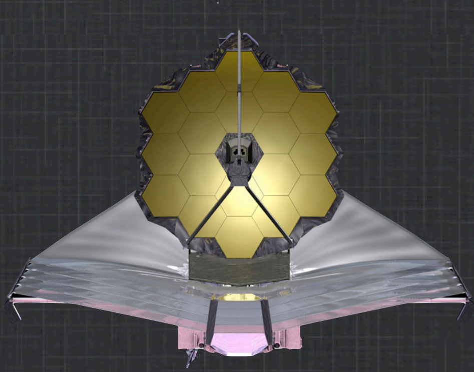




The US OIR system and JWST

M. Stiavelli, J. Kalirai, J. Lotz, R. Osten, M. Perrin
STScI



Topics

- HST experience
- JWST Capabilities and Timeline
  - What's missing
- Ground OIR system and JWST: three questions

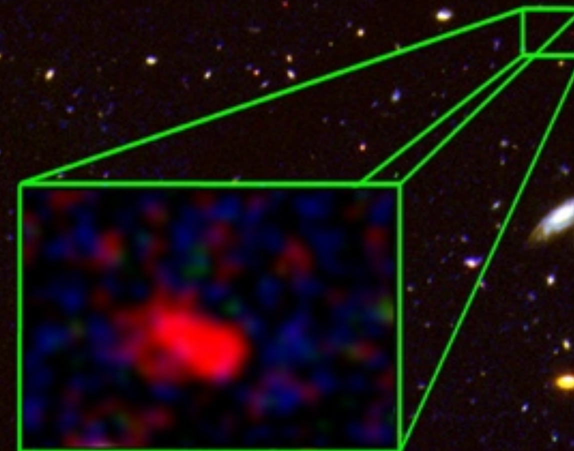
HST experience

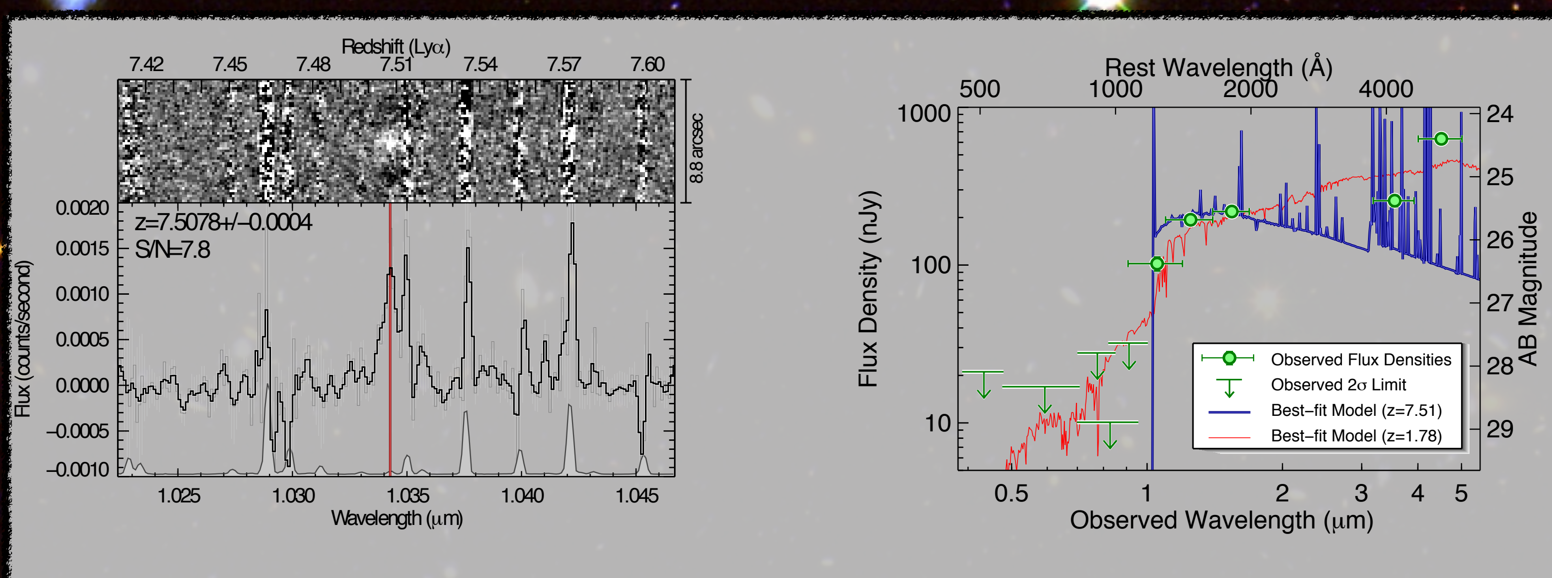
- Science productivity from HST has benefitted from synergies with the ground:
  - HDF, UDF : left to individual initiatives
  - exoplanet surveys with HST followup
  - GOODS, Frontier Fields : coordinated
  - Comet Shoemaker-Levy: coordinated

HST + ground-based O/IR synergy

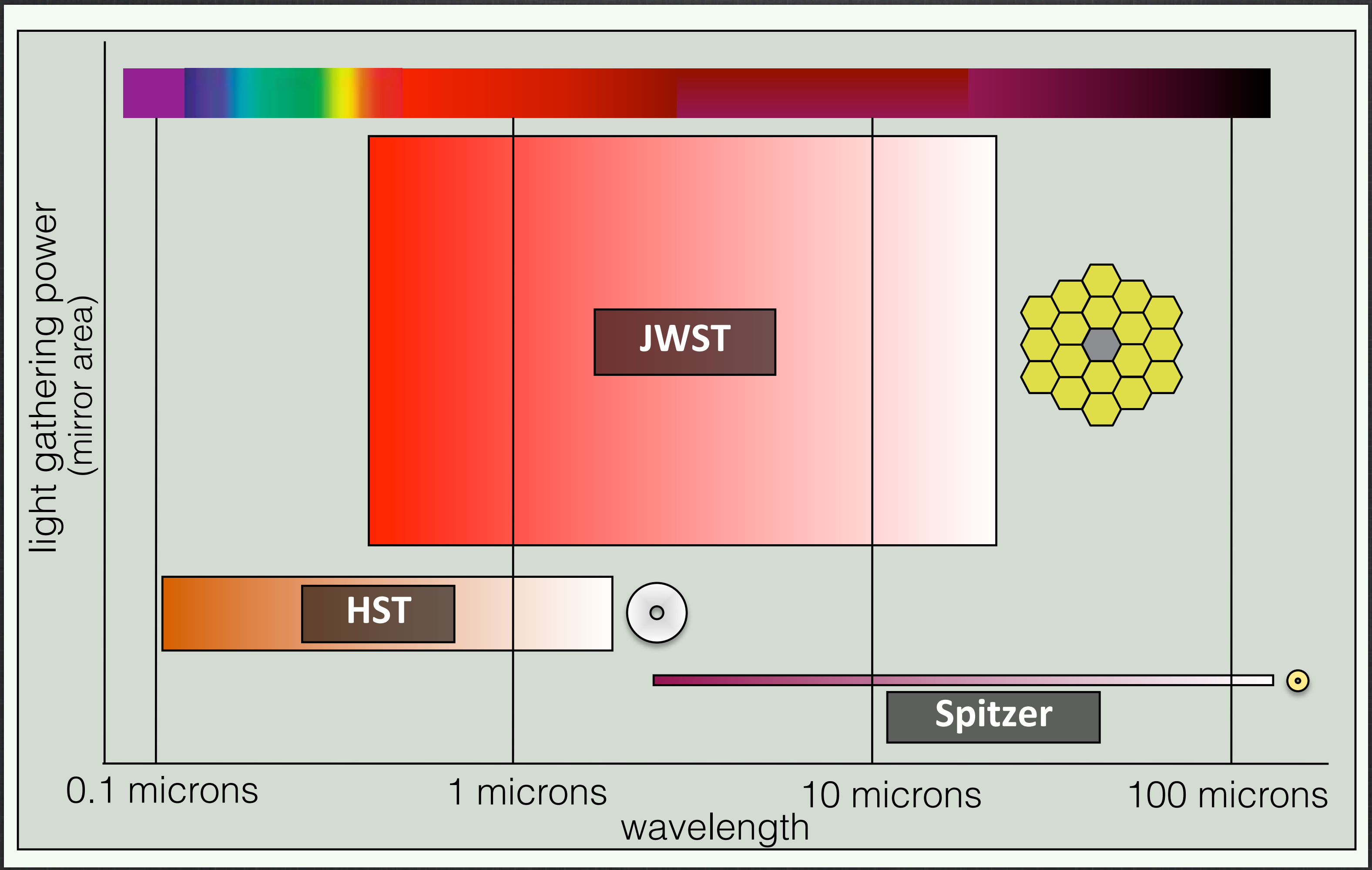
highest redshift galaxy z=7.51

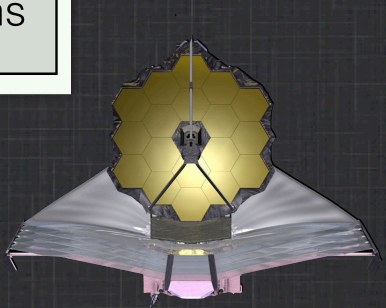
candidate found in CANDELS
Lyα detected with Keck/MOSFIRE
(* public NASA time)
Finkelstein et al 2013 Nature 502 524



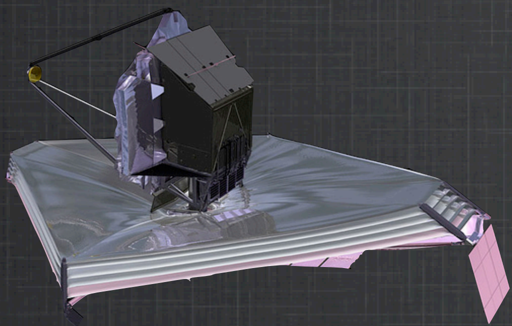


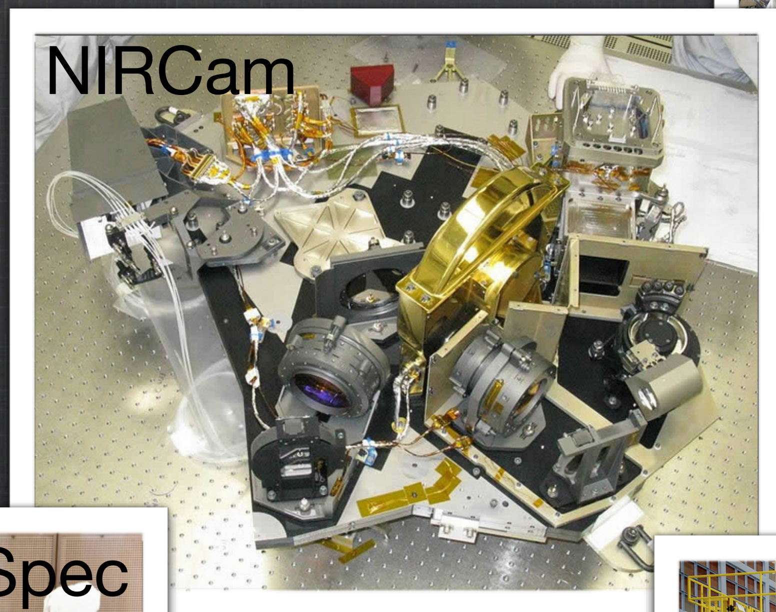
JWST Wavelength coverage





JWST Instrument Capabilities

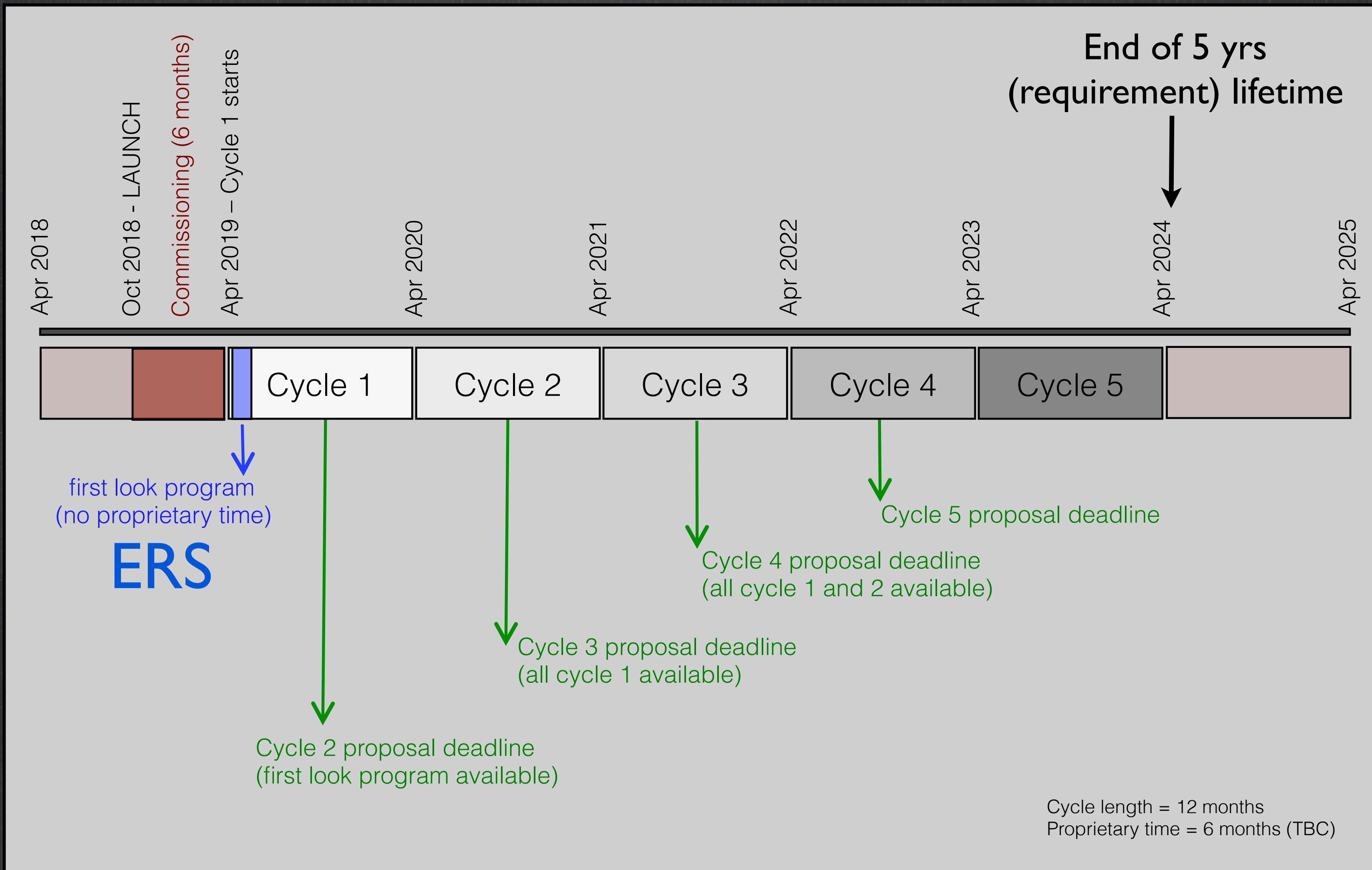




What is JWST missing?

- spectroscopy at R> 3000
- imaging and spectroscopy in the UV and blue
- large field of view for finding rare objects
- polarimetry

JWST Proposal Cycles



Questions

- What do you see as the key ground-based OIR needs for accomplishing JWST science?
- What are your plans for spectroscopic, optical, and coronographic follow-up from the ground?
- What changes would you make to the OIR System to enable the best science from space?

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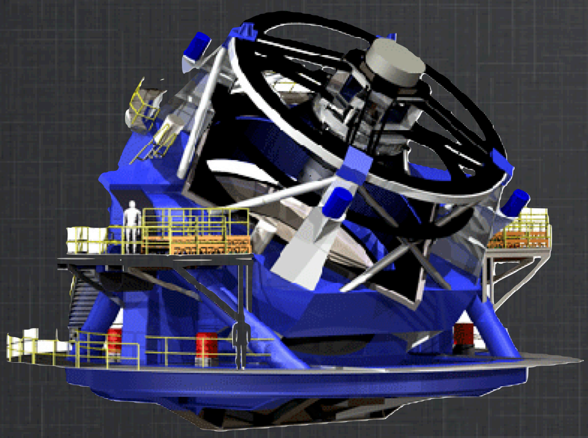
What do you see as the key ground-based OIR needs for accomplishing JWST science?

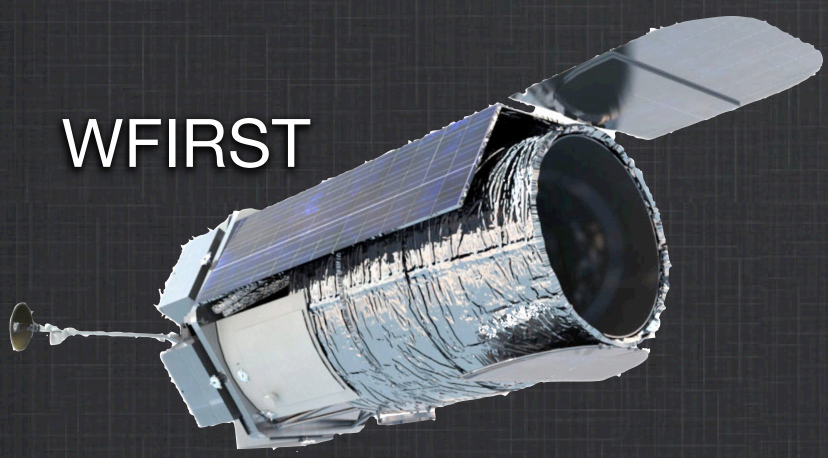
- JWST needs are related to finding suitable targets (LSST) and obtaining complementary data for capabilities not supported by JWST (Gemini, LSST, GSMT).
- Early-release of LSST data would ensure overlap with JWST prime mission.

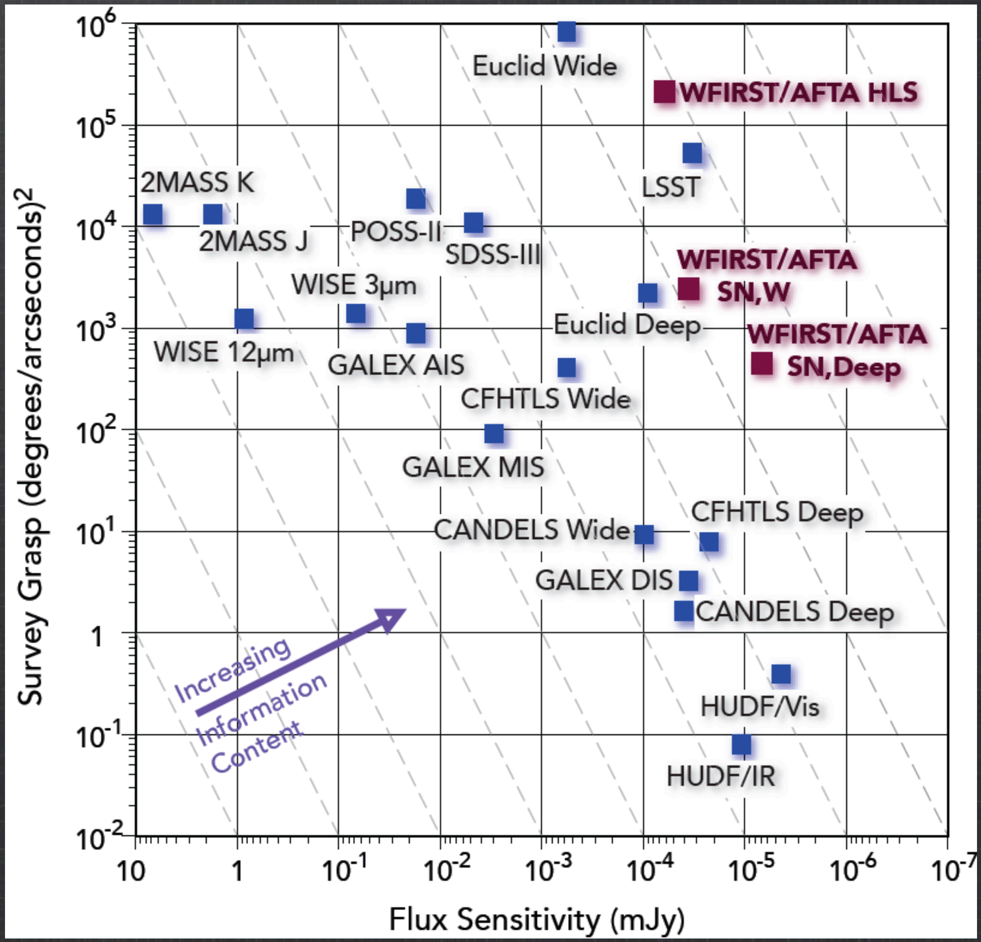
2020s Discovery: A New Sample with LSST + WFIRST

LSST



WFIRST

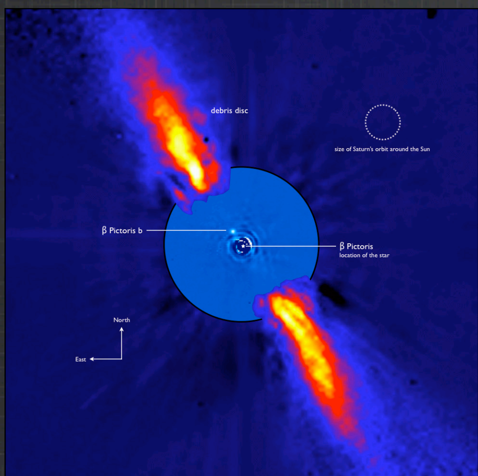




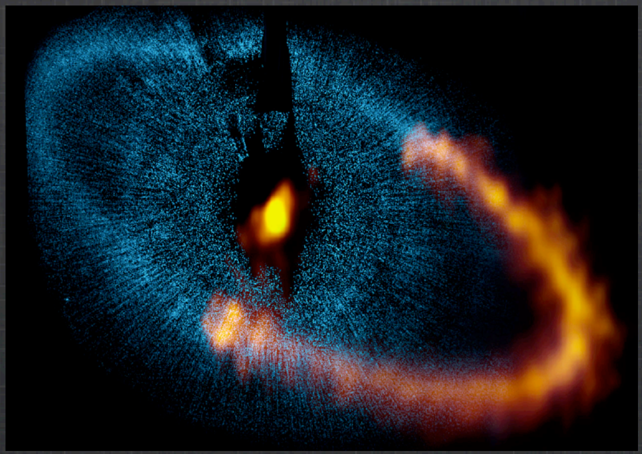
P. Cote & D. Benford

Planetary systems and the origins of life

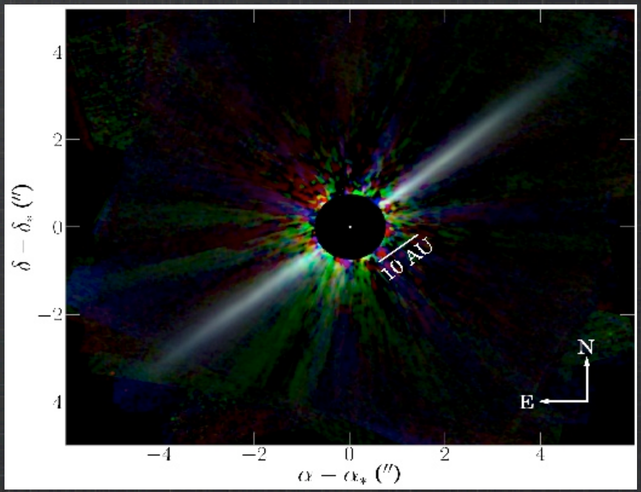
Debris disks as signposts of planets: high contrast optical/IR imaging of exozodiacal disks around nearby stars with GPI, GSMT. JWST could focus on those with fainter disks, thermal emission in mid-IR; scattered light in OIR. Ring morphology →dynamical history, properties of planets near the ring.



β Pic disk (ESO; Lagrange)



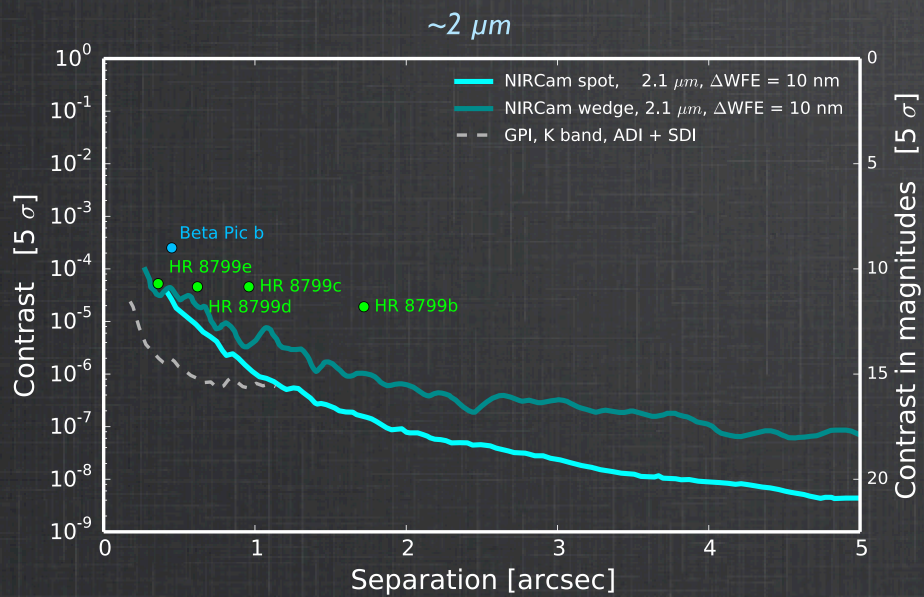
Fomalhaut disk in mm & optical (Boley et al. 2012)

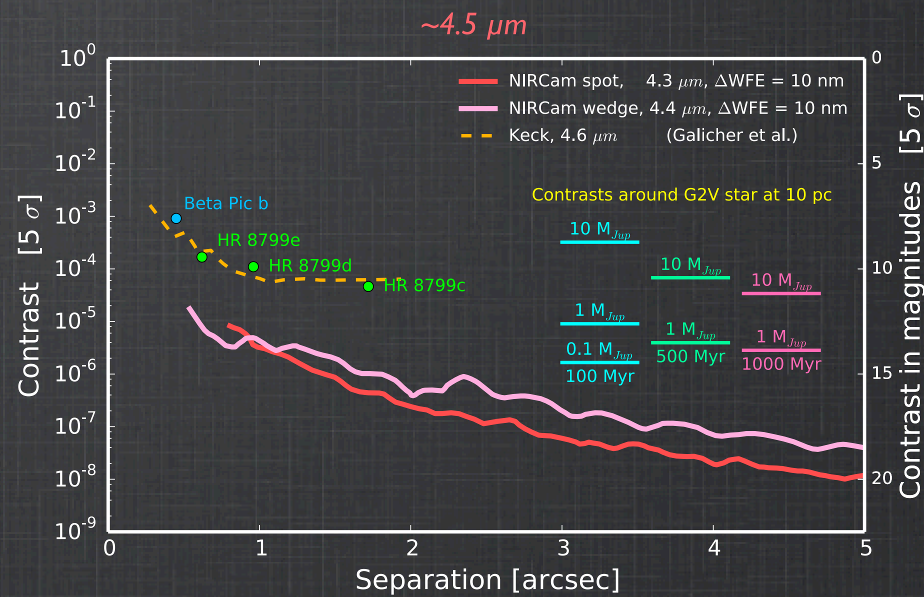


AU Mic disk (Fitzgerald et al. 2007)

Solar System census: LSST will discover many small bodies in the solar system including hazardous near-Earth objects. It will be of major scientific value in advancing the exploration of primitive bodies extending out into the Kuiper belt. JWST will be able to study the properties of KBOs and comets through NIR spectra and MIR photometry, leading to constraints on how circumstellar disks around other stars form and evolve.

Exoplanet Imaging with AO & JWST





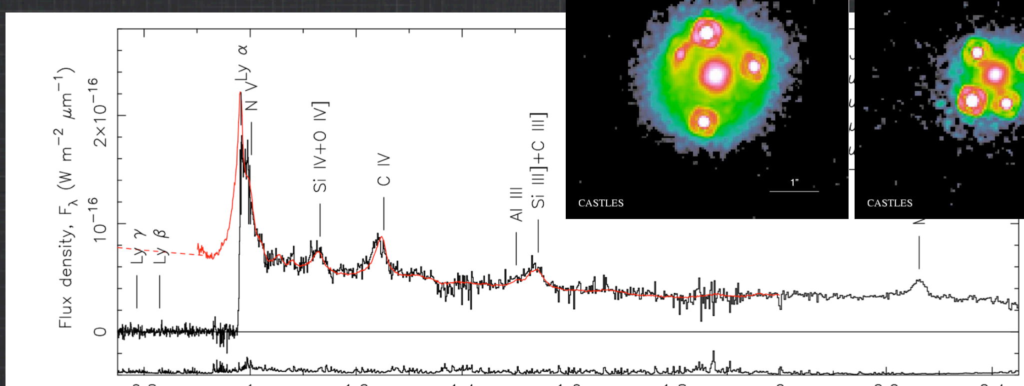
- New AO systems (GPI, SPHERE, MagAO, LBT AO) are now reaching contrasts of 10^{-7}-10^{-6} at a fraction of an arcsecond. Over the next few years they will obtain images and spectra of dozens of young Jovian exoplanets through large surveys of hundreds of stars.
  - 8-m AO strengths: large surveys, sensitivity to Jovian planets as close as 0.1" separation.
- JWST will excel at detailed characterization of these worlds, particularly at > 3 μm, and will be sensitive to lower mass planets (Saturn and maybe Neptune mass) at wider separations.
  - JWST strengths: mid-IR imaging and spectroscopy, greatest sensitivity to wide separation planets.
- Similar instruments on GSMT would improve the inner working angle but at about the same level of contrast. Dedicated "Extreme AO" instruments won't be available at first light.
  - GSMT strengths: R>3000 spectroscopy of planets discovered earlier by the 8-m instruments. Possibly rocky planets in the habitable zones of nearby M dwarfs, separations < 0.04".

Complementary strengths for exoplanet imaging in the 2020s

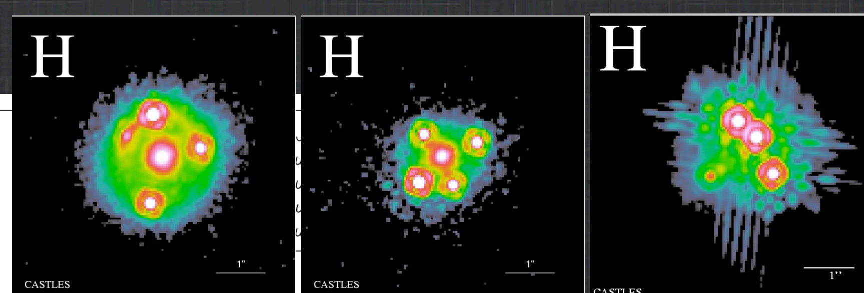
High Contrast AO	JWST
Jovian planet detection	Planet spectroscopy & characterization
Disk imaging in the near-IR	Disk imaging & spectroscopy in the mid-IR
Higher angular resolution	Greater sensitivity
Smaller inner working angles	Larger field of view
Polarimetry	Total intensity with fewer subtraction biases
Young Jupiter twins	Young Saturn twins
Some results in visible light	Fainter (younger/farther) science targets

First light and reionization, assembly of galaxies

- Discovery of high-z QSOs with LSST and characterization of their Lyman α forest with GSMT and JWST.
- Discovery of pair instability SNae with LSST. JWST and GSMT will carry out follow-up spectroscopy.
- Strong gravitational lenses. LSST will discover thousands of strongly lensed galaxies and many QSOs. Follow up studies of these objects with JWST will allow characterization of dark halo properties, and substructure, and constraints to dark energy.



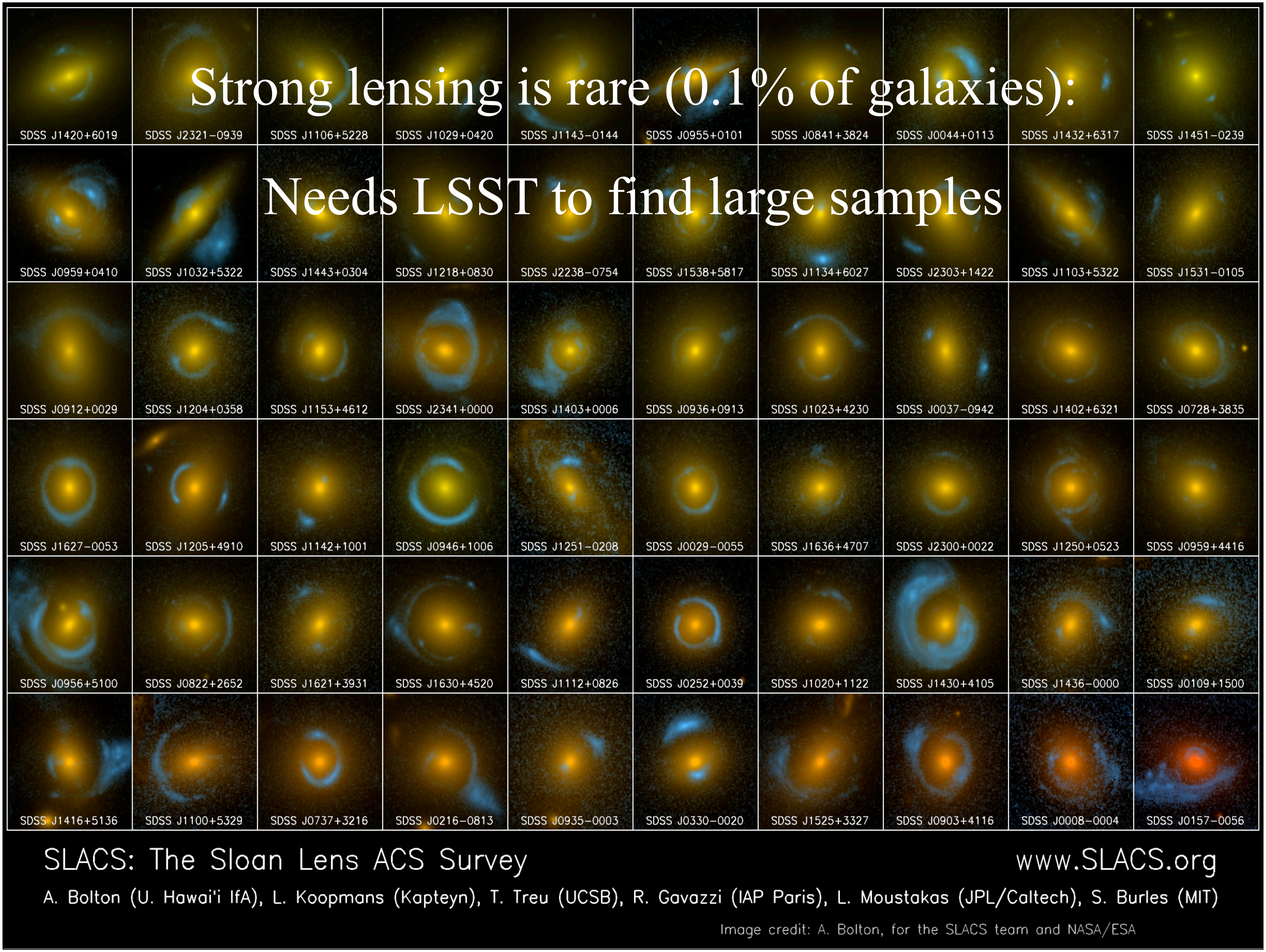
Mortlock et al. 2011



Kochanek et al. 1999

Strong lensing is rare (0.1% of galaxies):

Needs LSST to find large samples

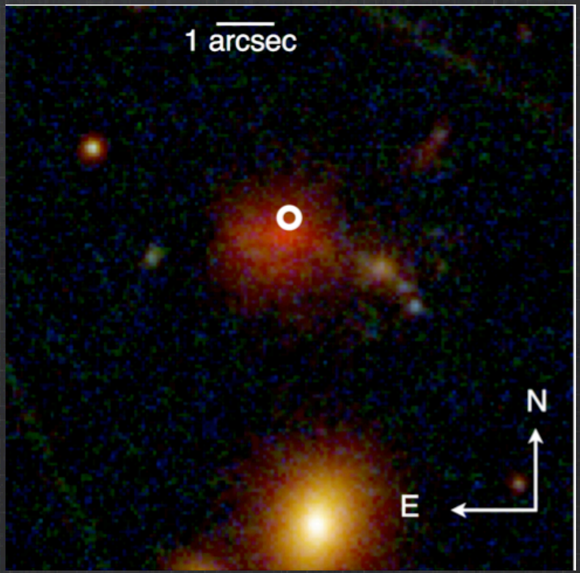


JWST follow-up of rare LSST transients

Example:

- Type Ia SN going off in a multiply imaged galaxy can break mass-sheet degeneracy.

This requires complex selection algorithms (“brokers”) with access to a sophisticated catalog feeding JWST target of opportunity activation.



CLASH lensed SN, Patel et al. 2014

Questions

- What do you see as the key ground-based OIR needs for accomplishing JWST science?
- What are your plans for spectroscopic, optical, and coronographic follow-up from the ground?
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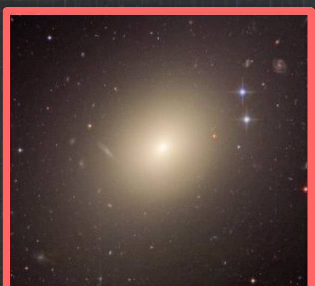
What are your plans for spectroscopic, optical, and coronographic follow-up from the ground?

- JWST small field of view makes it likely that most discoveries will be faint: pencil beam surveys are more natural than wide area searches.
- Followups will be with complementary capabilities.

First Galaxies - JWST + GSMT

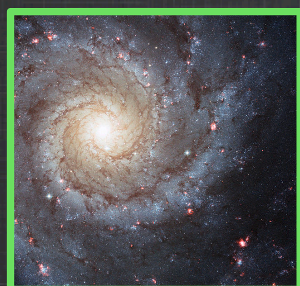
1) HST z = 8 galaxies show multiple clumps, but z = 10 galaxies are not resolved.
Possible that <100 pc scales of highest redshift galaxies will still not be resolved by JWST
GSMT with AO provides much higher resolution to study galaxy morphologies.

Elliptical



Abell S0740
Blakeslee

Spiral

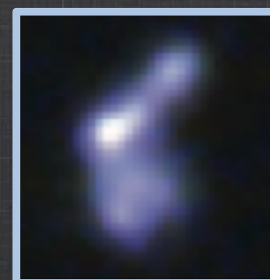


M74
Chandar

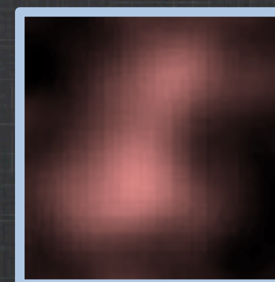
Irregular Starburst

Antennae
Whitmore

Clump clusters, chains



in CANDELS
z = 2.05
Wuyts12



A1689-zD1*
z ~ 7.8
Bradley08

Single Clump?

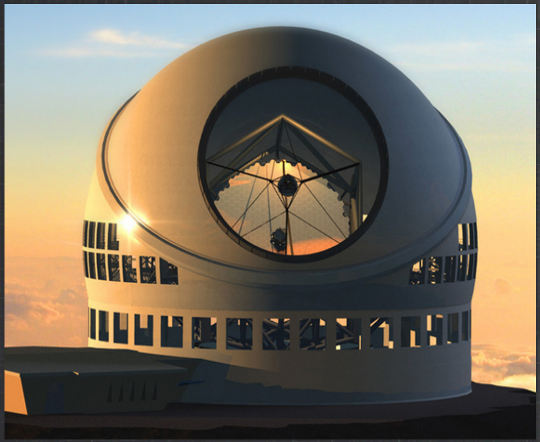
in CLASH*
MACS0647-JD
z ~ 10.8; Coe13

(*graphic from D. Coe*)

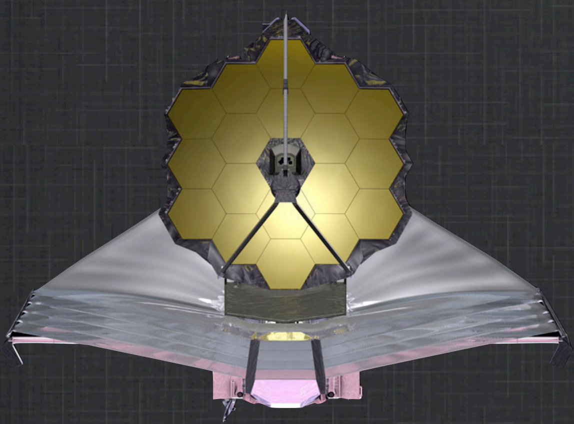
2) Measuring the kinematics of faint dwarf galaxies will require R>3000. This can be done by GSMT with AO. AO-fed IFU will measure velocity fields in the larger objects.

Stellar populations - JWST + GSMT

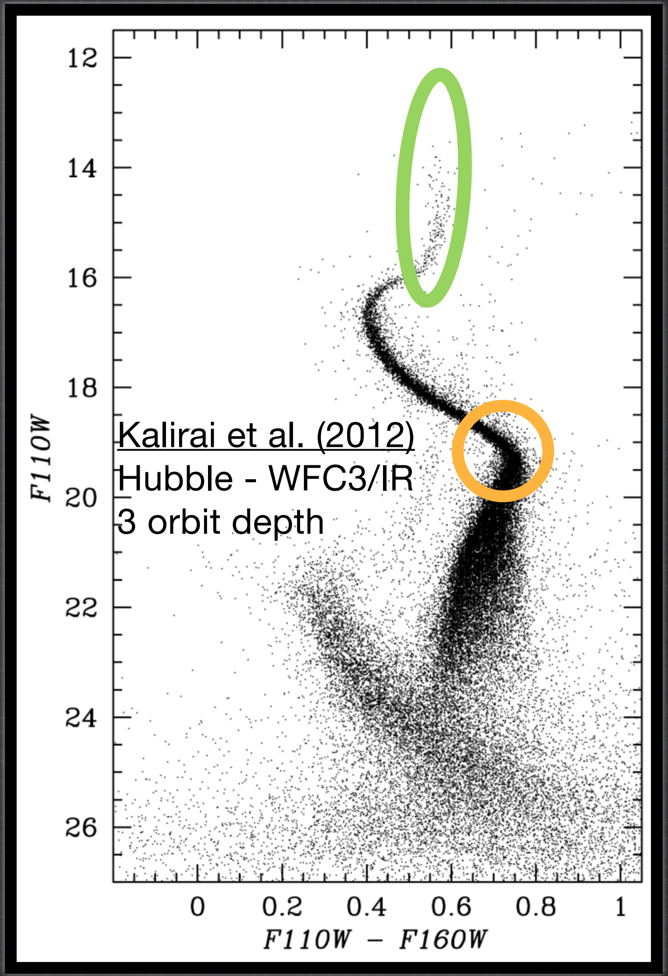
Maximum leverage from panchromatic data: LSST+GSMT+JWST



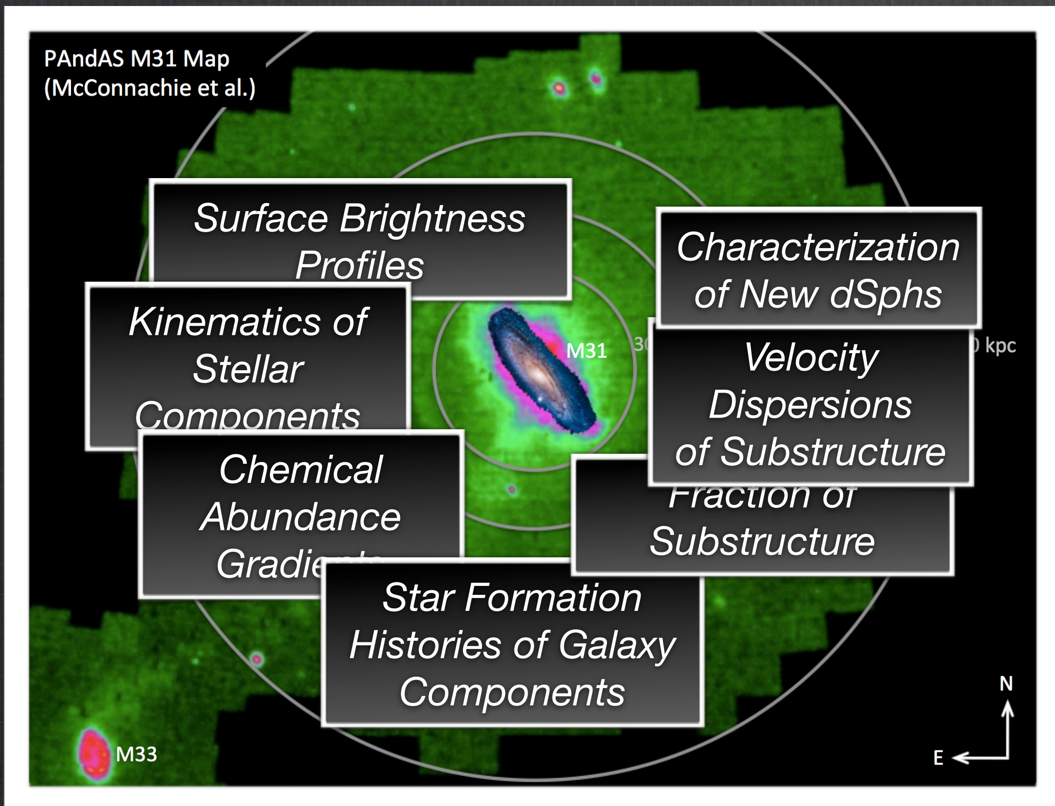
GSMT
High resolution spectroscopy at the tip of the RGB and medium resolution spectroscopy at the base of the RGB, out to the edge of the Milky Way in <1 hour



JWST
High precision IR photometry >1 mag below the "kink", out to the edge of the Milky Way in < 1 hour



The Local Volume - LSST+ JWST + GSMT



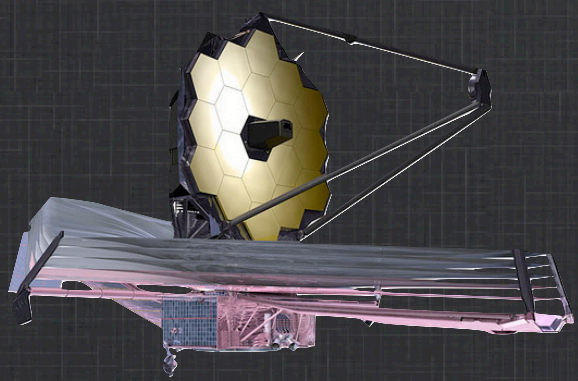
- LSST will find fainter dwarf galaxies and substructure
- GSMT will measure radial velocities for individual stars
- JWST will provide proper motions for the same stars
- 3D velocities will enable dynamical studies without having to make assumptions on orbital anisotropy

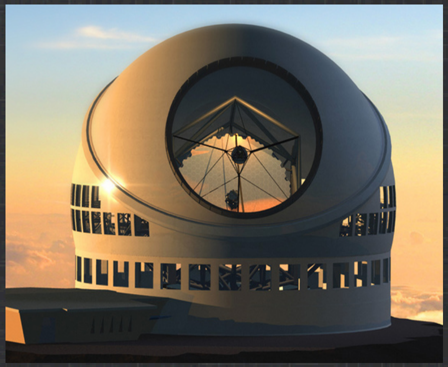
Exoplanets - JWST + GSMT

1.) Planet Formation - Measure the initial conditions of Planetary Systems.
GSMT - Pushes direct measurement of newly forming planets to nearest star forming regions
JWST - Mid-IR spectroscopy provides characterization for outer planets in the same systems

2.) Complement transits (e.g. from Kepler or TESS) with precision radial velocity measurements.

3.) Planet characterization and search for biomarkers.
JWST - Obtains spectroscopy of transiting planets found by TESS and ground surveys
GSMT - Direct imaging building on GPI, UV/optical spectroscopy





Birth of stars and protoplanetary systems, planetary systems and the origins of life

- *Brown dwarfs*

- Labs for studying processes in extrasolar giant planets.
- Near- and mid-infrared spectra with JWST will explore sub-stellar atmospheric structures.
- Optical linear polarization (Gemini, GSMT) can arise from disks, or surface heterogeneities (cloud patterns or asymmetries caused by oblateness). Measurement constrains dust distribution and oblateness.

- *Origins of life*

- Characterize the stars which host planetary systems.
- High resolution spectroscopy for better constraints on stellar properties (e.g. Lithium/ Metallicity for age constraint, v*sini* for rotation/activity).
- Spectropolarimetry for stellar magnetic field measurements (important for stellar activity modelling of space weather effects).
- These measurements will help downselect targets for JWST followup.

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When and where

- JWST is an all-sky telescope, consequently the JWST community will benefit scientifically from ground-based coverage from both Northern and Southern GSMTs.
  - of the two continuous viewing zones for JWST the one in the North is the most suitable for extra-galactic surveys. The southern one is centered on the LMC.
- JWST has a finite lifetime: 5 yr requirement and 10 yr goal. Optimal synergies will be possible for observatories that come in line before 2024.

Leveraging LSST

- LSST has the largest active and organized community. Thus, LSST has an opportunity to lead the discussion of community engagement with the other missions.
- Full exploitation of LSST demands a set of well tuned event brokers that can distinguish routine transients from highly unusual events; that process will necessarily involve a rapid means of matching new LSST data against a reference catalogue that includes parameters such as photo-z as well as important classes of objects such as strong gravitational lenses.

Coordination

- Joint proposals, e.g. JWST+GSMT, similarly to what done between HST and NRAO or HST and Chandra/XMM/Spitzer.
- Explore options for rapid-response LSST follow-up programs with JWST non-proprietary datasets.
- Coordinated science projects, e.g., similarly to what is done for the Frontier Fields.