Building for the James Webb Space Telescope: The Near-Infrared Camera

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02 June 2008

American Astronomical Society, St. Louis, MO

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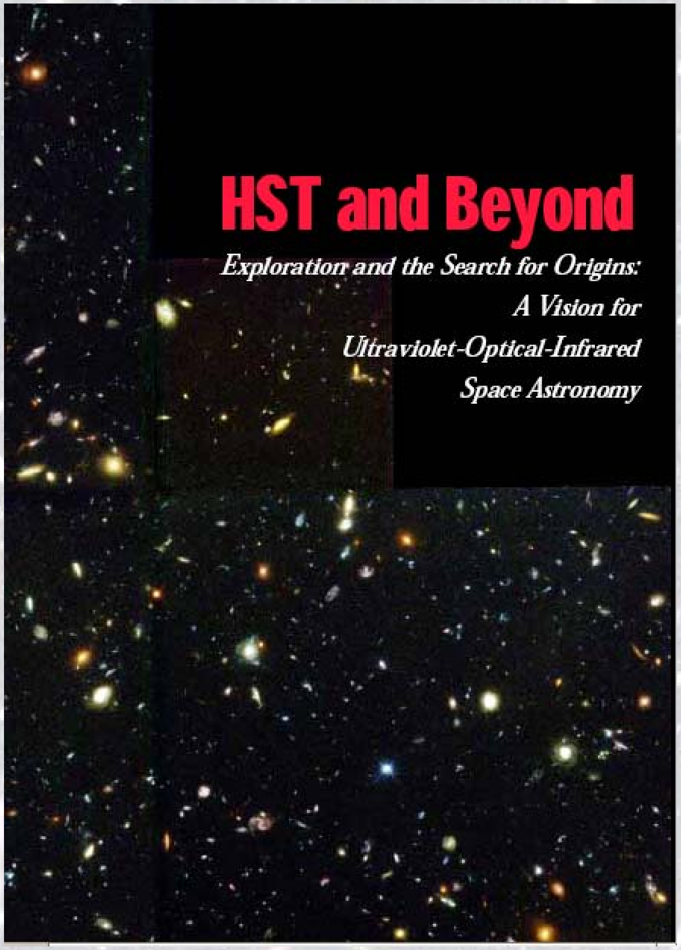
A PI's Motivation

A Journey Begun in ~1998

JWST has been contemplated for quite awhile -- started with “HST and Beyond” which recommended a 4-m

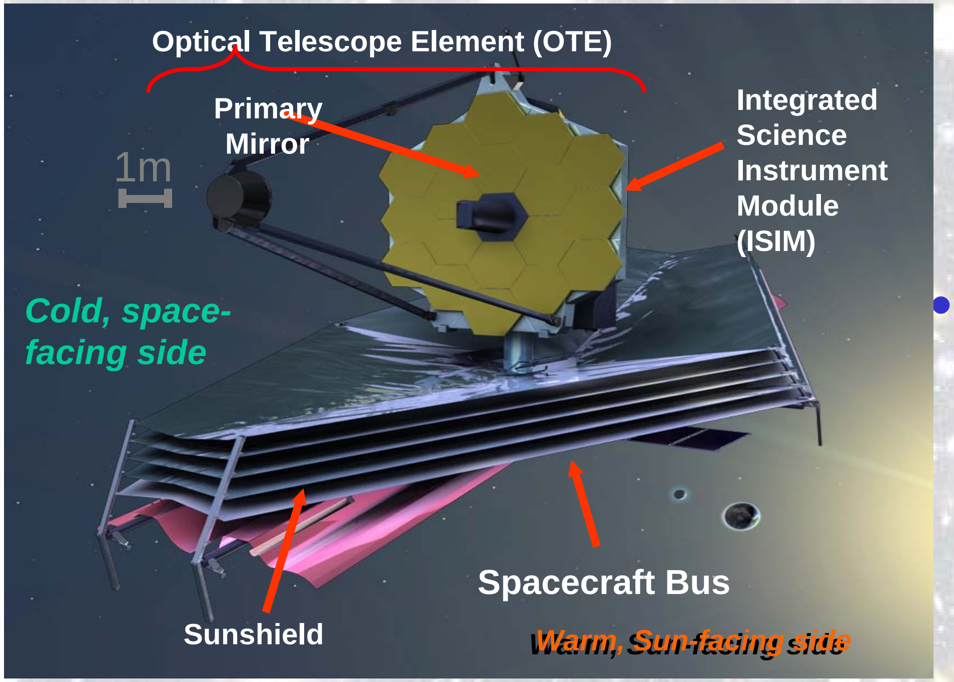
Dan Goldin upped the ante to an 8-meter – reality forced a reduction back to 6.5-meter



HST and Beyond

Exploration and the Search for Origins:
A Vision for
Ultraviolet-Optical-Infrared
Space Astronomy

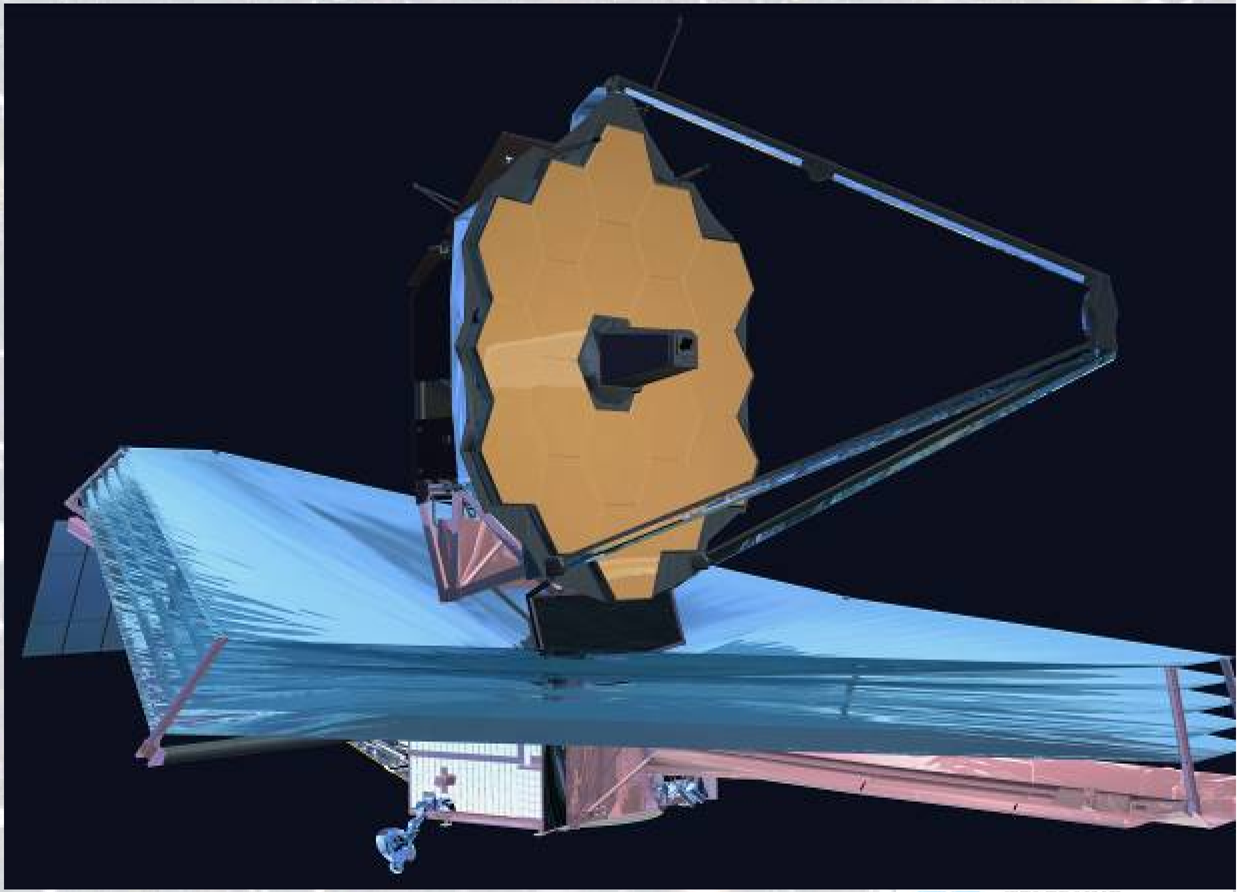
What’s NIRCam?



- NIRCam is the near-infrared camera (0.6-5 microns) for JWST
  - Refractive design to minimize mass and volume
  - Dichroic used to split range into short (0.6-2.3μm) and long (2.4-5μm) sections
  - Nyquist sampling at 2 and 4μm
  - 2.2 arc min x 4.4 arc min total field of view seen in two colors (40 MPixels)
  - Coronagraphic capability for both short and long wavelengths
- NIRCam is the wavefront sensor
  - Must be fully redundant
  - Dual filter/pupil wheels to accommodate WFS hardware
  - Pupil imaging lens to check optical alignment

JWST Overview

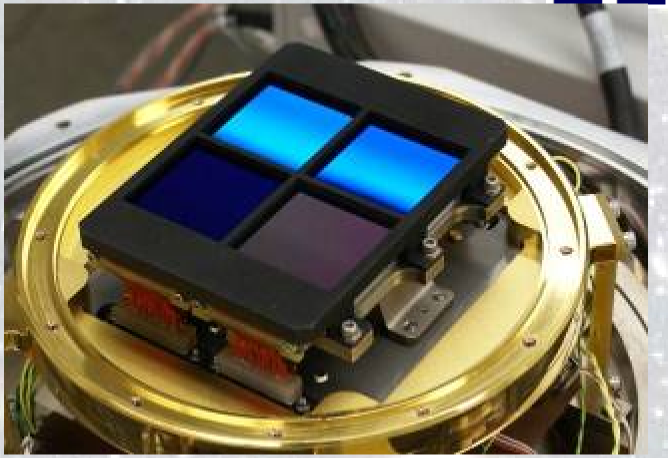
- 25 m^2 collecting area using a segmented primary with 6.6-m tip-to-tip diameter: Resolution at 2μm = 0.06 arc sec
- L2 orbit enables passive cooling to ~45K for primary mirror, ~35K for instruments
- Four instruments:
  - NIRCam, 0.6-5 µm
  - NIRSpec, 0.6-5 µm, R~100-3000 and multi-object
  - FGS + TF, 1.8-4.8 µm R~100
  - MIRI, 5-28 µm, camera + R~2500 IFUs
- To be launched in 2013 on an Ariane V



Project is moving!

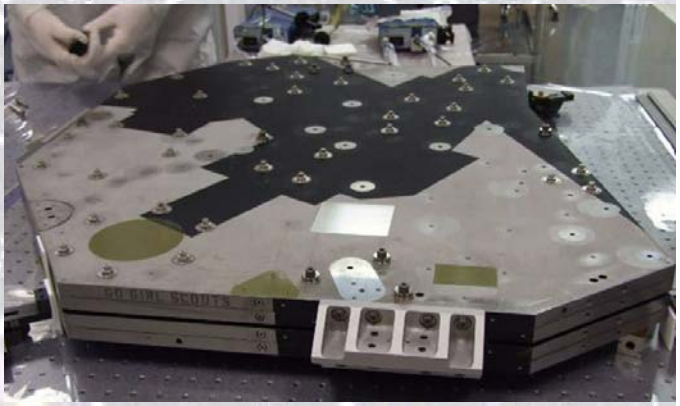
- Primary mirror segments and detectors are already in production
- Instruments are building verification and engineering test units

MIRI Verification model prior to testing.

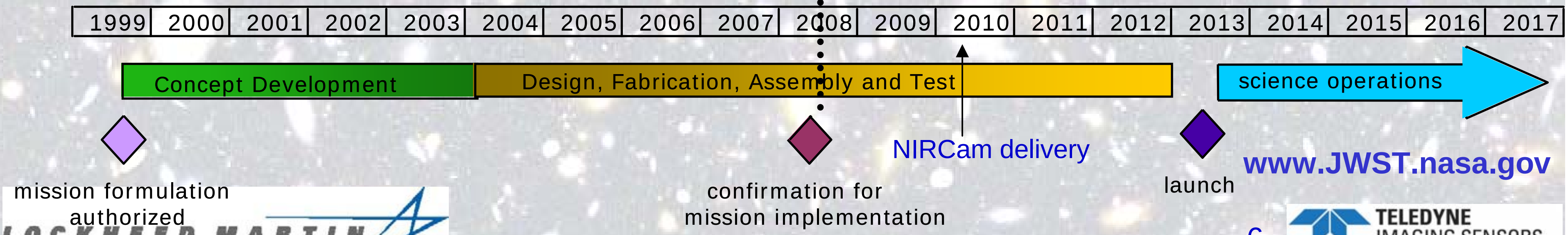


NIRCam qualification focal plane.

NIRCam ETU bench.



today



1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017

Concept Development

Design, Fabrication, Assembly and Test

science operations

mission formulation authorized

confirmation for mission implementation

NIRCam delivery

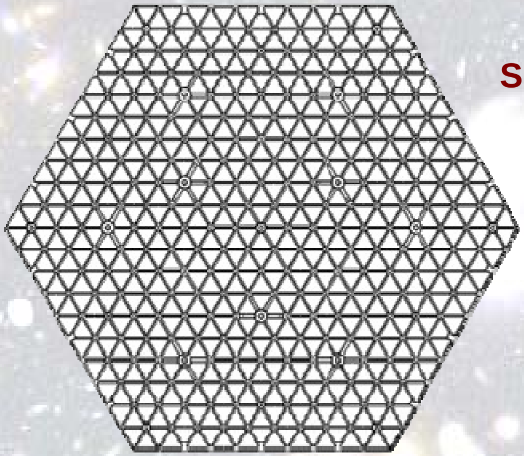
launch

www.JWST.nasa.gov

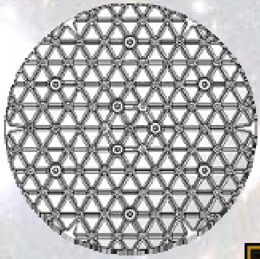
Mirror Fabrication

- JWST mirrors made of beryllium
- Lightweight and stable at 40 K

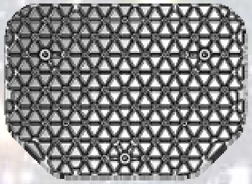
Raw Be billet (two mirrors)



Primary mirror segment



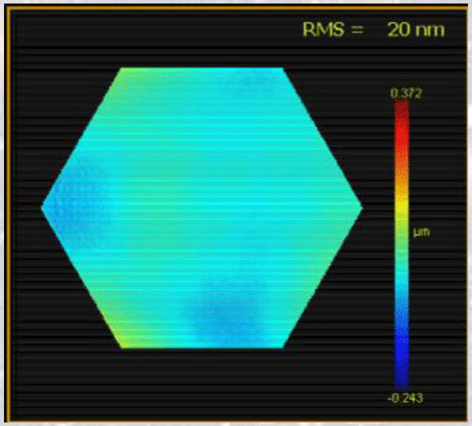
Secondary mirror

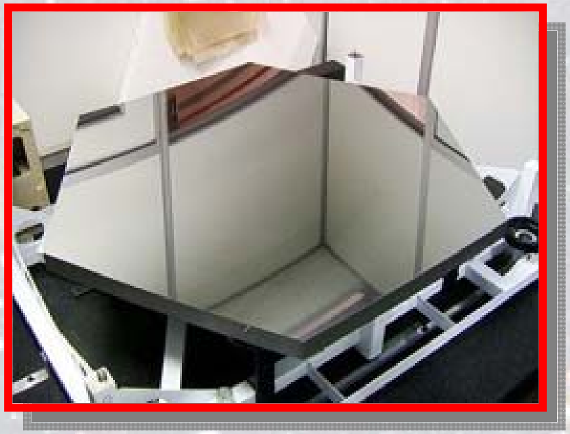


Tertiary mirror

- Machined, lightweighted mirrors
- 95% of material is removed

- Polished mirrors
- Mirror segment figure ~ 20 nm

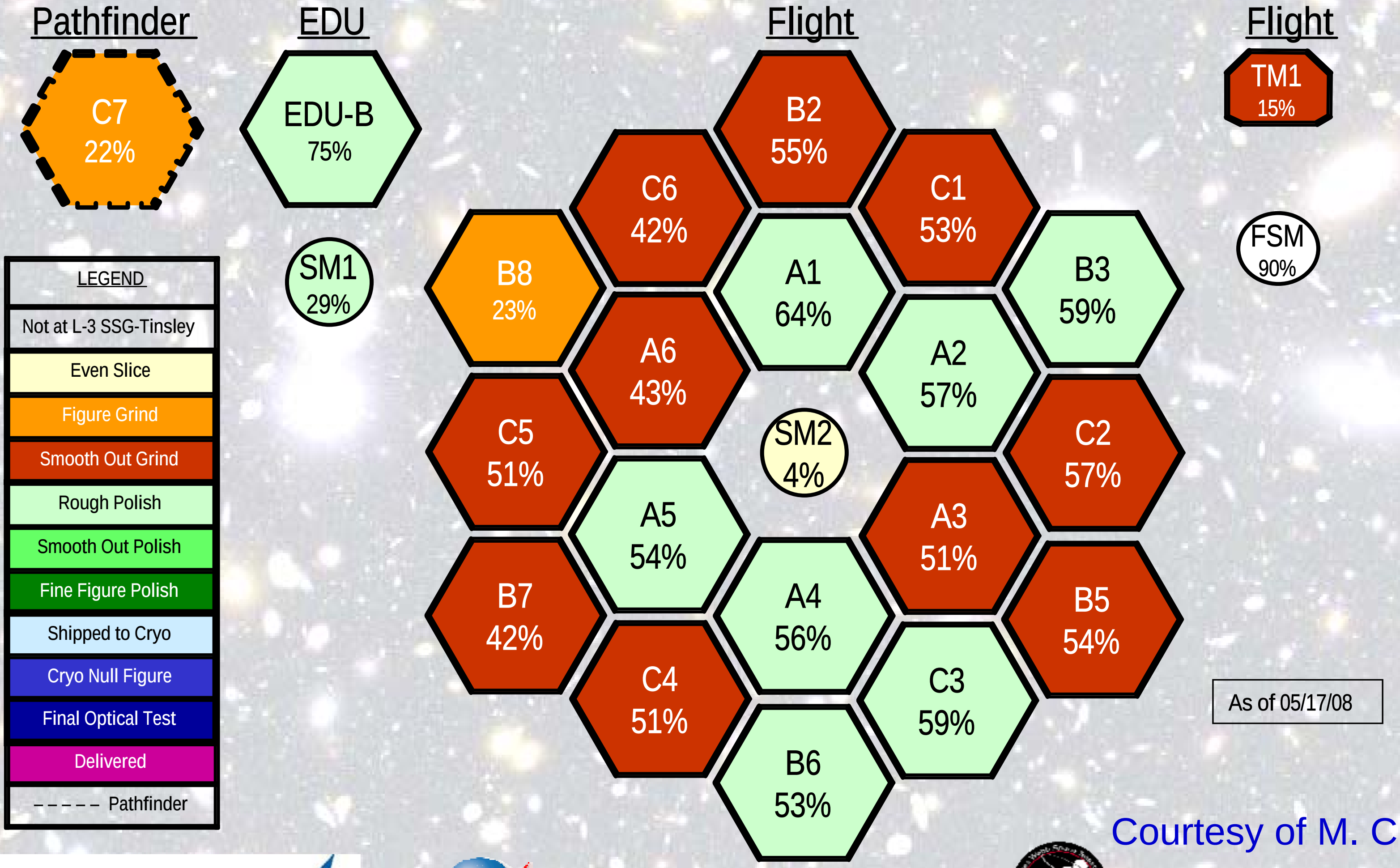




Courtesy of M. Clampin

Mirror Polishing on Schedule

- JWST has all 18 flight mirrors undergoing polishing at Tinsley



Pathfinder

C7
22%

EDU

EDU-B
75%

SM1
29%

Flight

B2
55%

C6
42%

C1
53%

B8
23%

A1
64%

B3
59%

A6
43%

A2
57%

C5
51%

SM2
4%

C2
57%

A5
54%

A3
51%

B7
42%

A4
56%

B5
54%

C4
51%

C3
59%

B6
53%

Flight

TM1
15%

FSM
90%

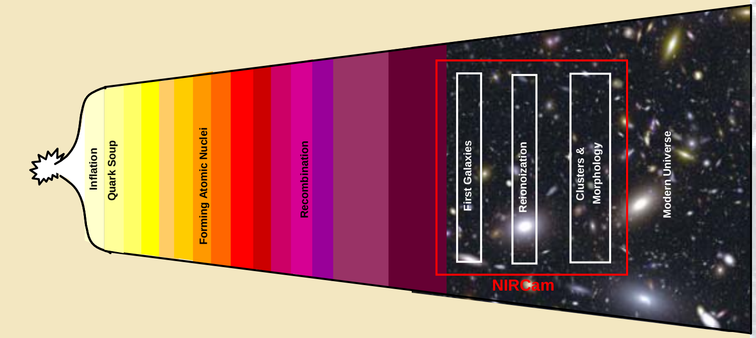
LEGEND

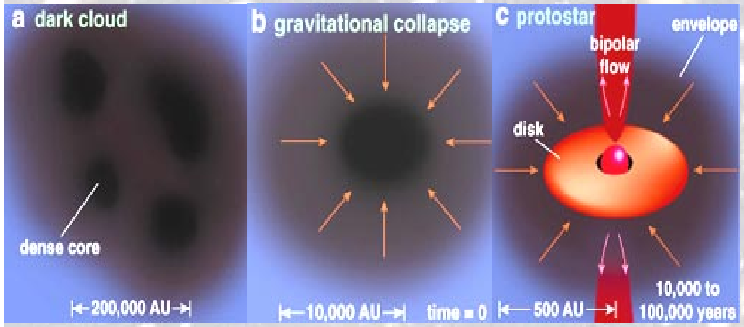
- Not at L-3 SSG-Tinsley
- Even Slice
- Figure Grind
- Smooth Out Grind
- Rough Polish
- Smooth Out Polish
- Fine Figure Polish
- Shipped to Cryo
- Cryo Null Figure
- Final Optical Test
- Delivered
- – – – – Pathfinder

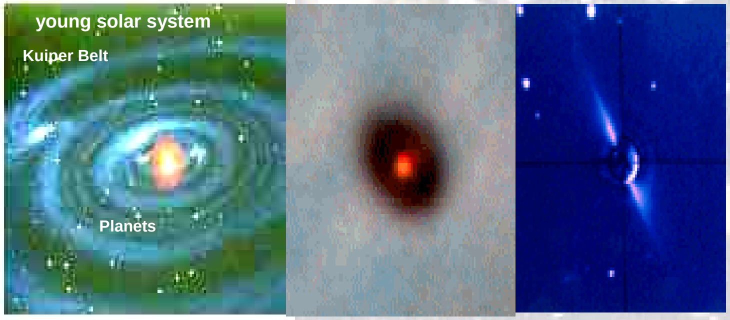
As of 05/17/08

Courtesy of M. Clampin

NIRCam's Role in JWST's Science Themes







The First Light in the Universe:
Discovering the first galaxies, Reionization
NIRCam executes deep surveys to find and categorize objects.

Period of Galaxy Assembly:
Establishing the Hubble sequence, Growth of galaxy clusters
NIRCam provides details on shapes and colors of galaxies, identifies young clusters

Stars and Stellar Systems: Physics of the IMF, Structure of pre-stellar cores, Emerging from the dust cocoon
NIRCam measures colors and numbers of stars in clusters, measure extinction profiles in dense clouds

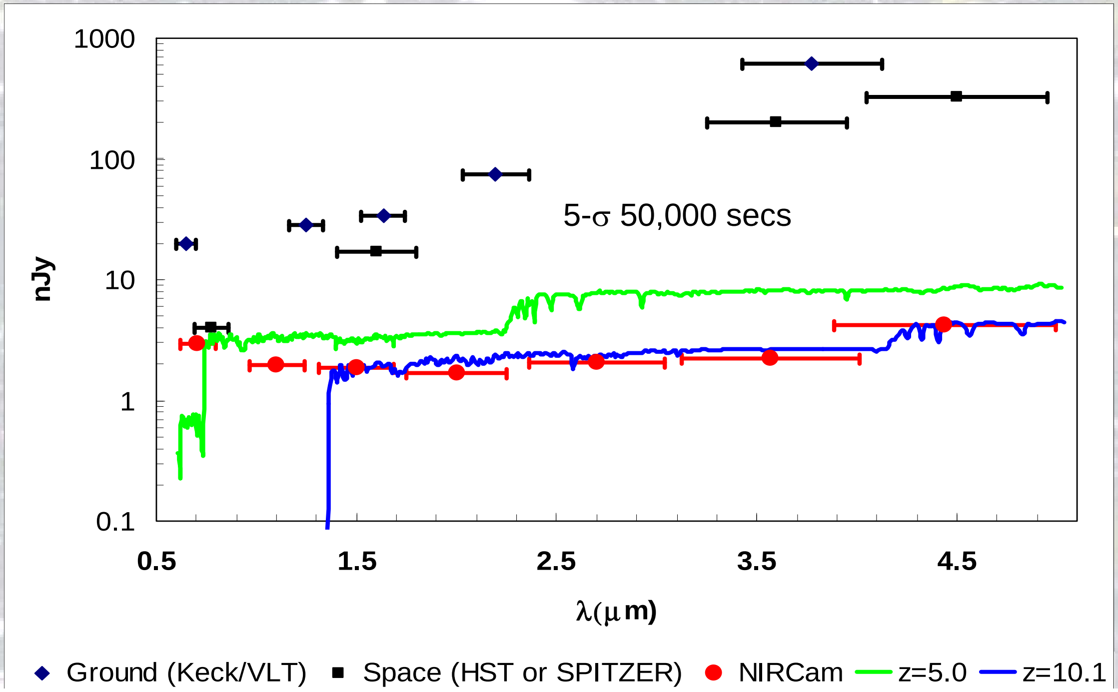
Planetary Systems and the Conditions for Life: Disks from birth to maturity, Survey of KBOs, Planets around nearby stars
NIRCam and its coronagraph image and characterize disks and planets, classifies surface properties of KBOs

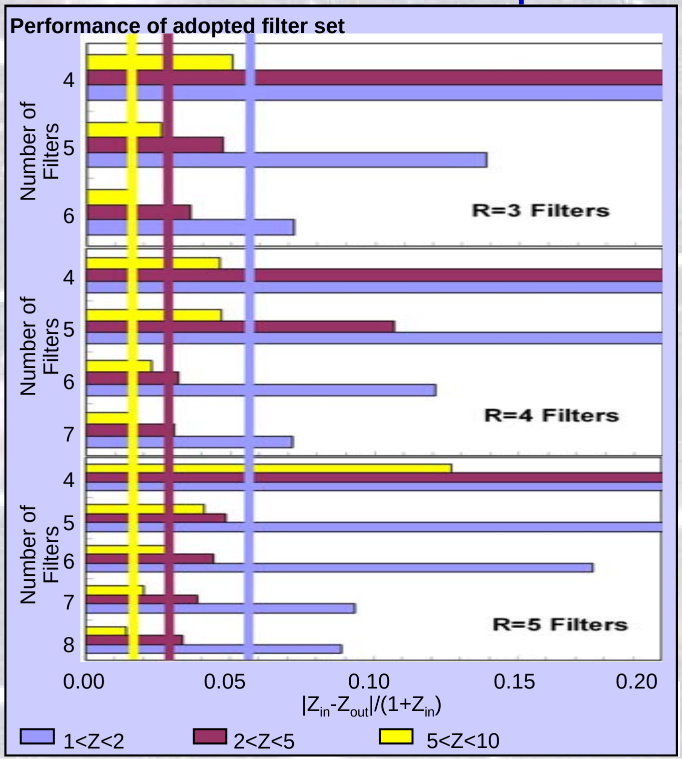
NIRCam Science Requirements (1)

Detection of first light objects requires:

- **Highest possible sensitivity – few nJy sensitivity is required.**
- **Fields of view (~10 square arc minute) adequate for detecting rare first light sources in deep multi-color surveys.**
- **A filter set capable of yielding ~4% rms photometric redshifts for >98% of the galaxies in a deep multi-color survey.**

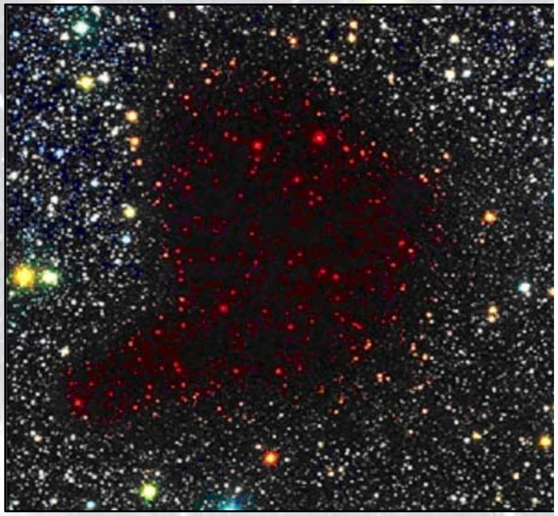
- Observing the period of galaxy assembly requires in addition to above: high spatial resolution for distinguishing shapes of galaxies at the sub-kpc scale (at the diffraction limit of a 6.5m telescope at 2µm).

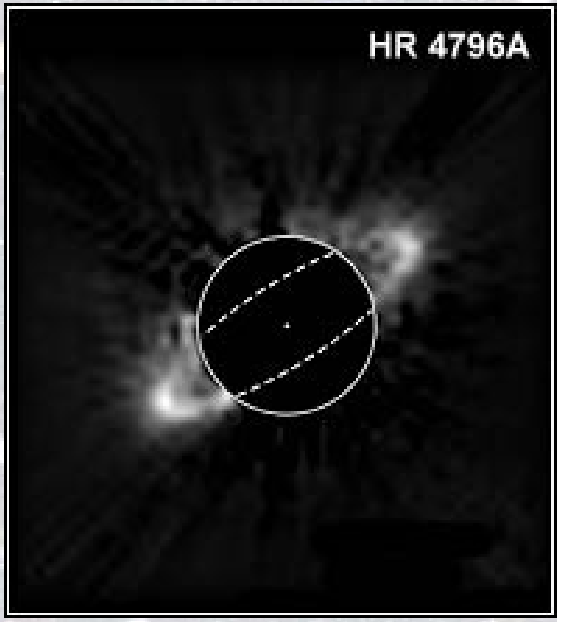




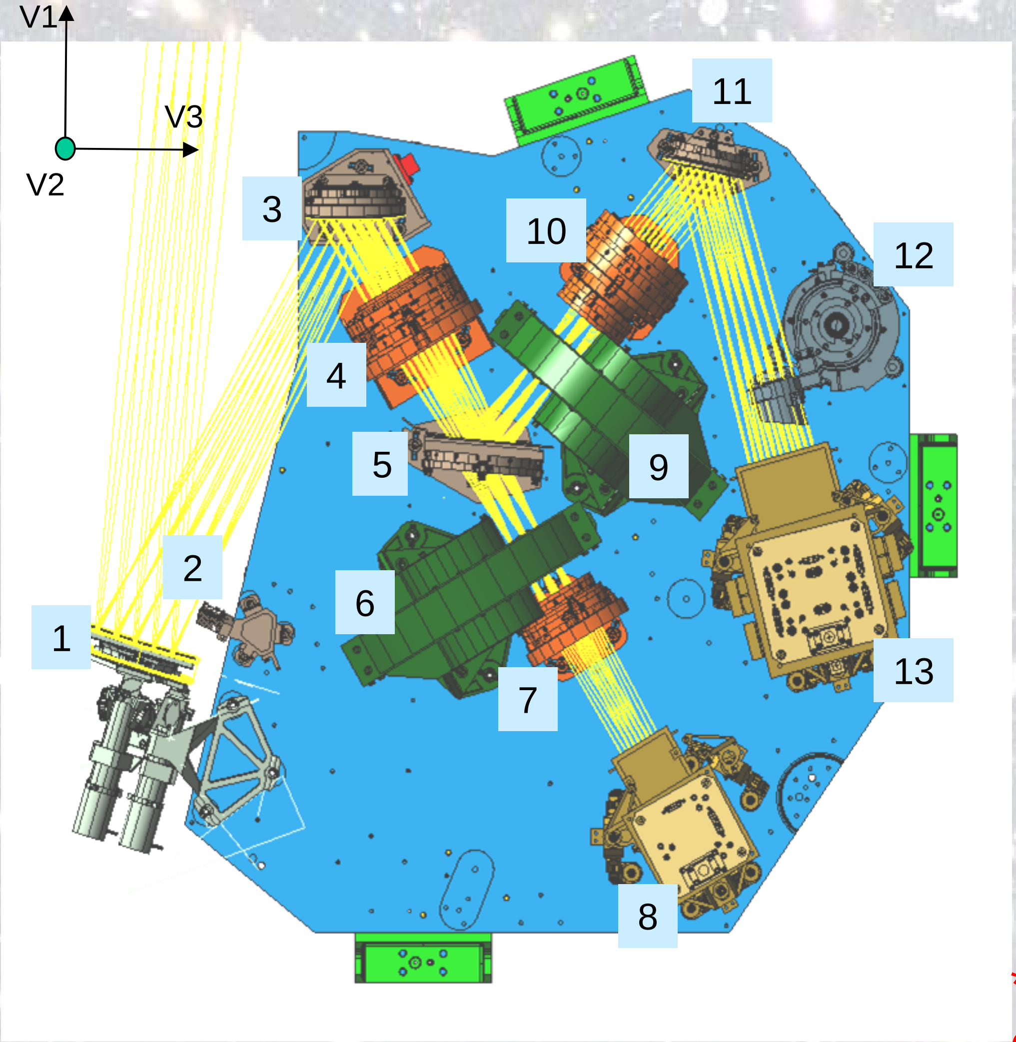
NIRCam Science Requirements (2)

- Stars and Stellar Systems:
  - ➢High sensitivity especially at $\lambda > 3\mu m$
  - ➢Fields of view matched to sizes of star clusters (> 2 arc minutes)
  - ➢High dynamic range to match range of brightnesses in star clusters
  - ➢Intermediate and narrow band filters for dereddening, disk diagnostics, and jet studies
  - ➢High spatial resolution for testing jet morphologies
- Planetary systems and conditions for life requires:
  - ➢Coronagraph coupled to a selection of filters
  - ➢Broad band and intermediate band filters for diagnosing disk compositions and planetary surfaces
  - ➢Addition of long wavelength slitless grisms enhances transit spectroscopy





NIRCam Optical Train Today

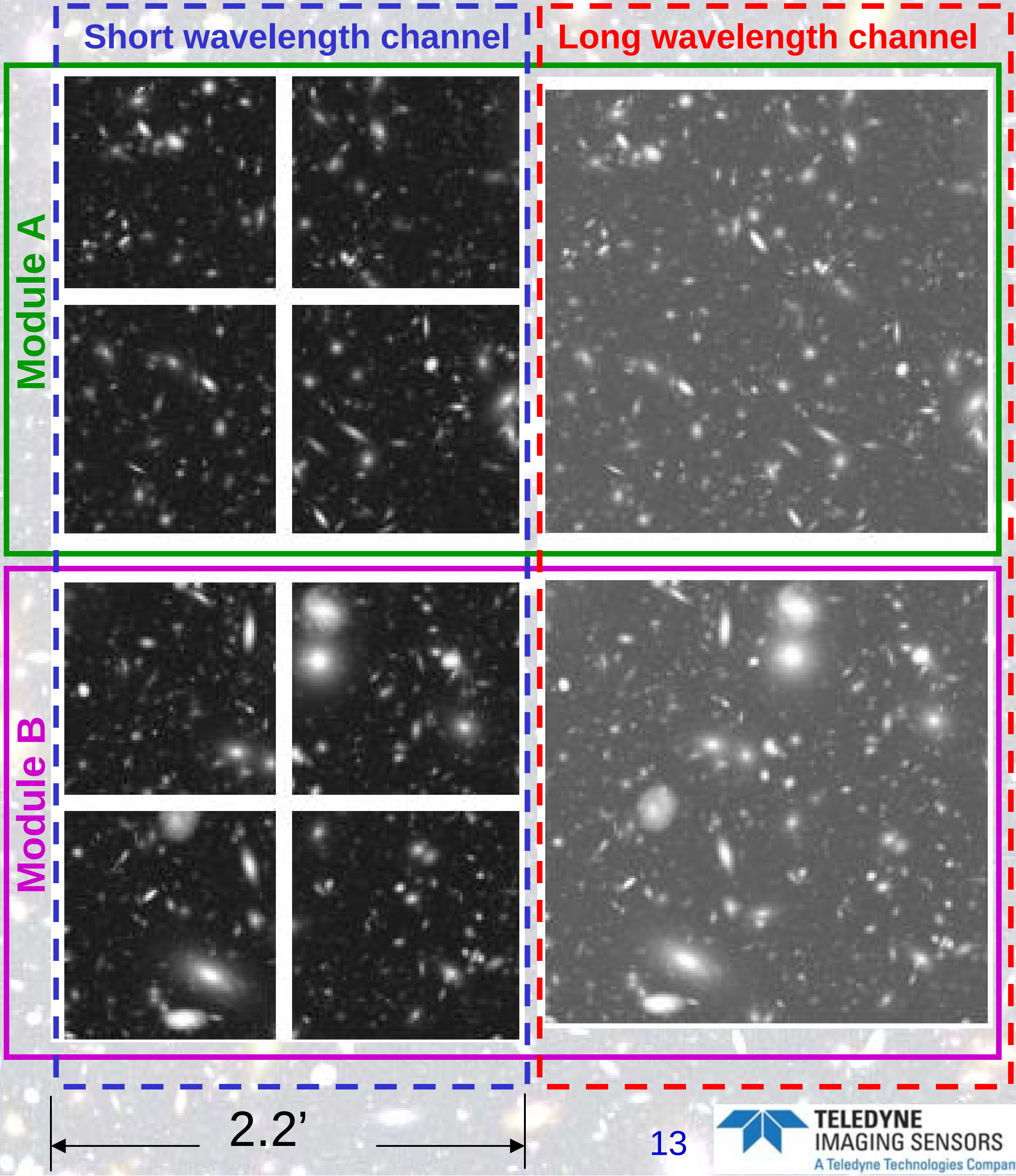


1	Pick-off Mirror assembly **
2	Coronagraph
3	First Fold Mirror
4	Collimator lens group
5	Dichroic Beamsplitter
6	Longwave Filter Wheel Assembly
7	Longwave Camera lens group
8	Longwave Focal Plane
9	Shortwave Filter Wheel Assembly
10	Shortwave Camera lens group
11	Shortwave Fold Mirror
12	Pupil Imaging Lens **
13	Shortwave Focal Plane

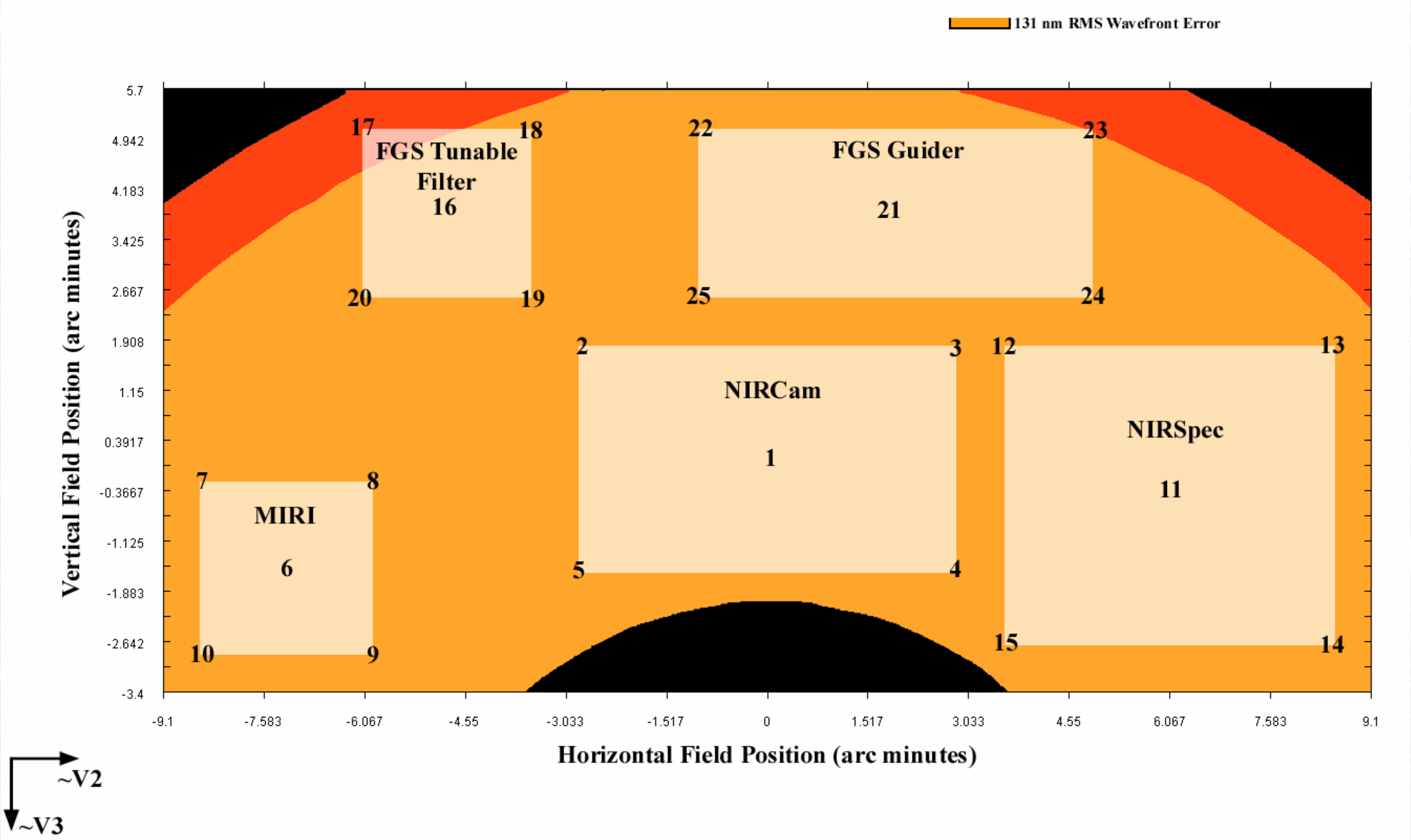
** These items + bench design changed from original proposal

2 Channels Per Module

- Each module has two bands (0.6 microns to 2.3 microns and 2.4 microns to 5 microns)
  - Deep surveys will use ~7 wide band filters (4 SW, 3 LW, 2x time on longest filter)
  - Survey efficiency is increased by observing the same field at long and short wavelength simultaneously
- SW pixel scale is 0.032”/pix; long is 0.064”/pix

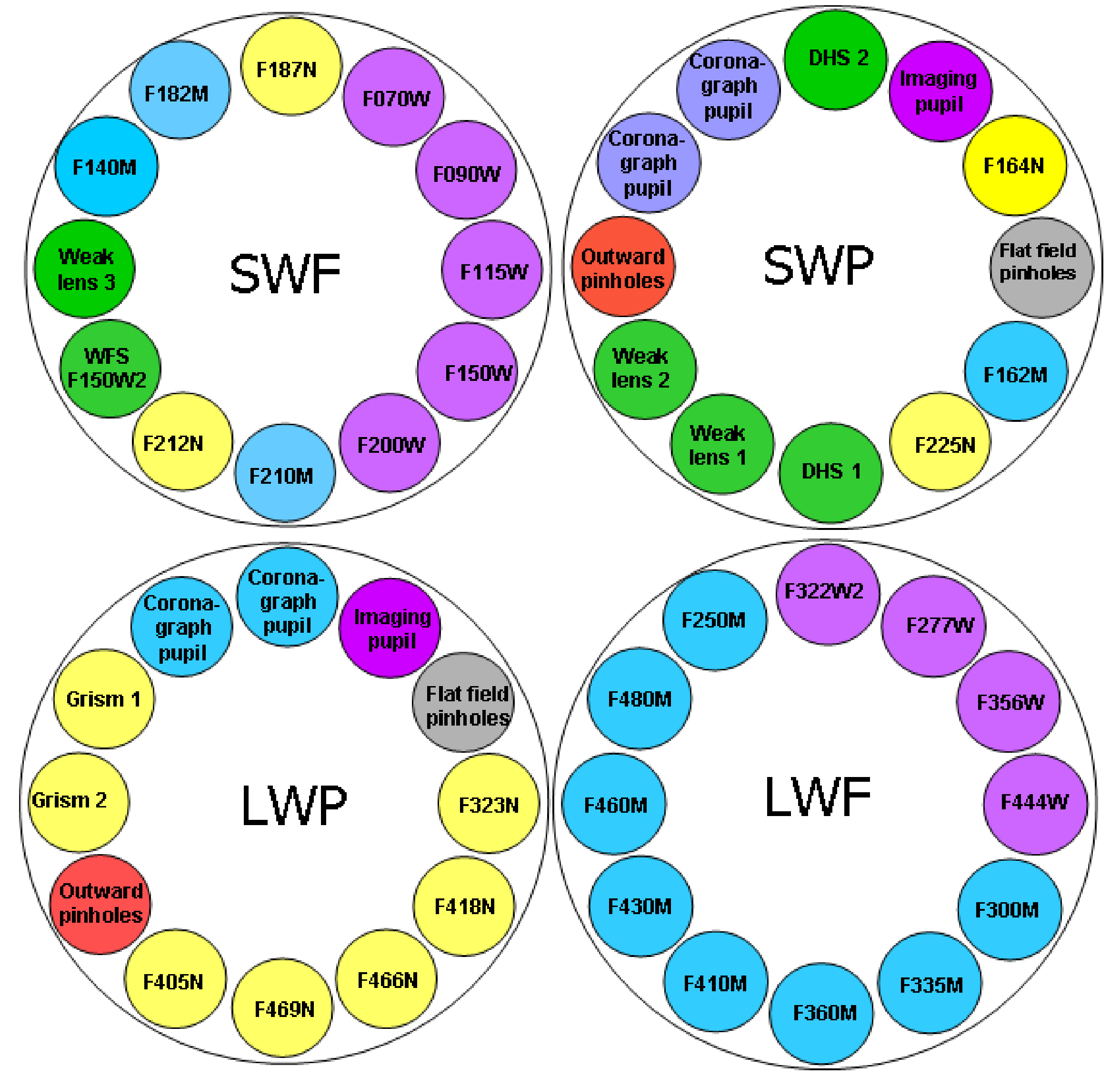


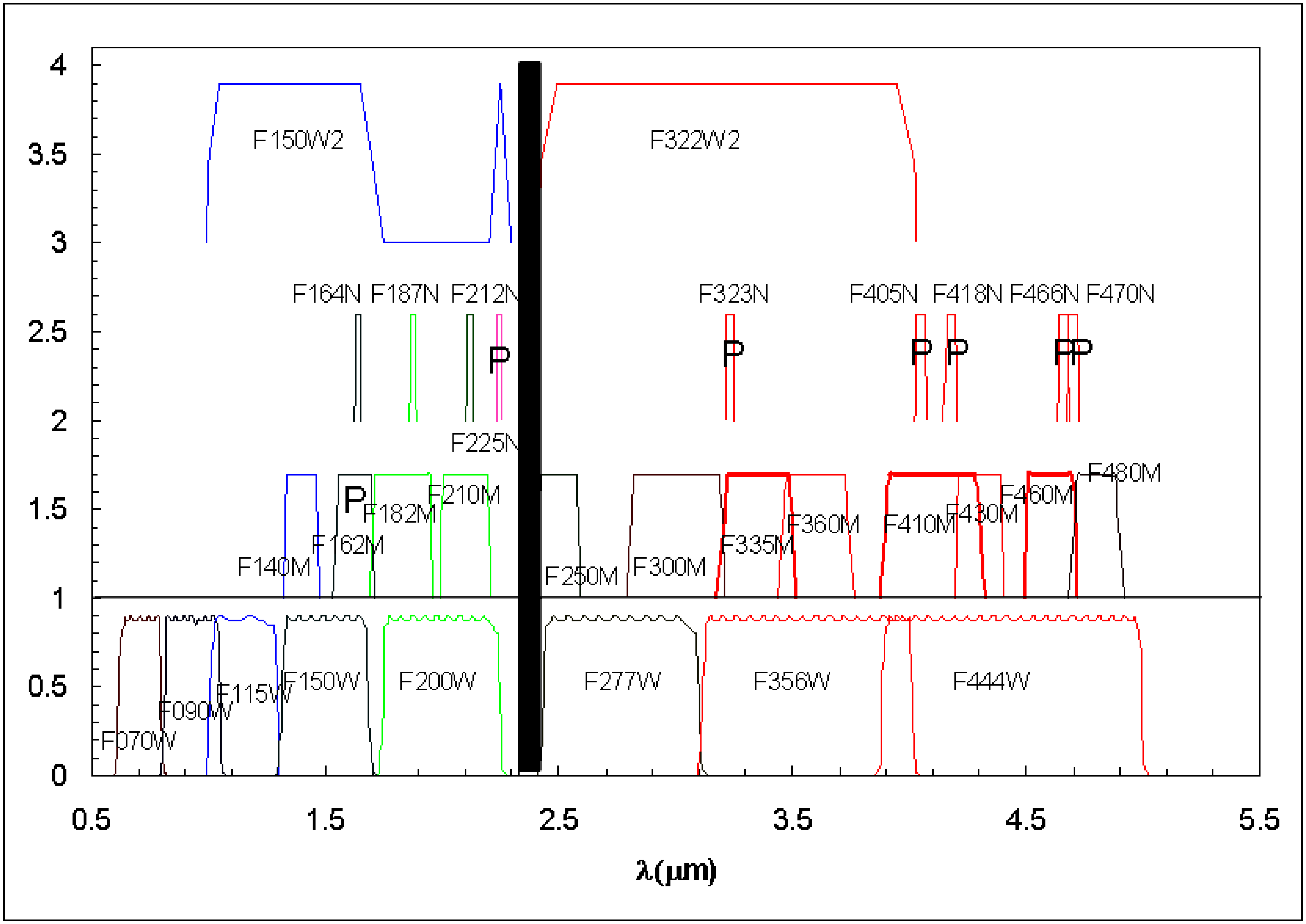
Current FOV Layout



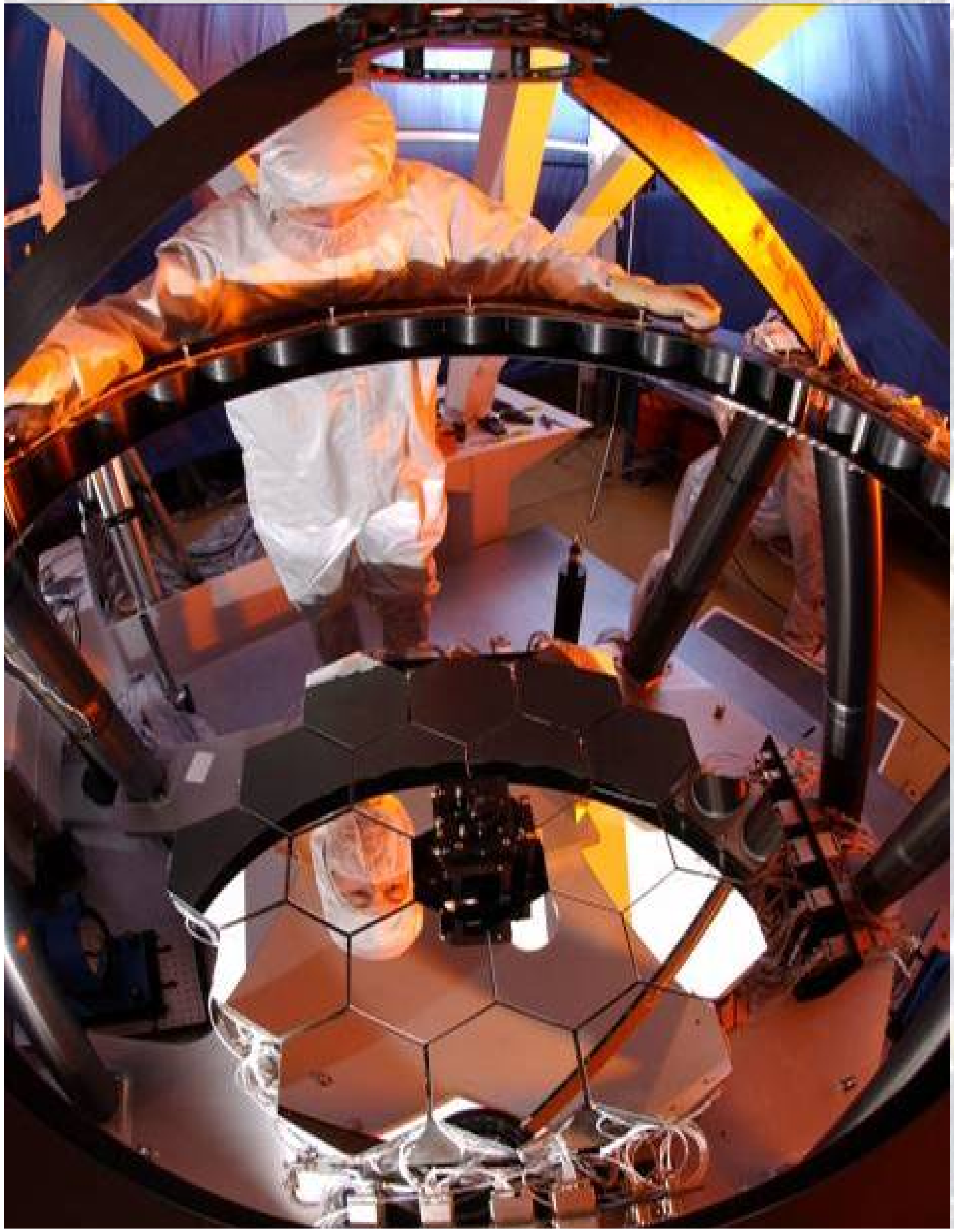
Shared focal plane = parallel observing possible

NIRCam Filters




4
3.5
3
2.5
2
1.5
1
0.5
0
F150W2
F322W2
F164N
F187N
F212N
F225N
F323N
F405N
F418N
F466N
F470N
P
P
P
P
P
P
F140M
F162M
F182M
F210M
F250M
F300M
F335M
F360M
F410M
F430M
F460M
F480M
F070W
F090W
F115W
F150W
F200W
F277W
F356W
F444W
0.5
1.5
2.5
3.5
4.5
5.5
λ(μm)

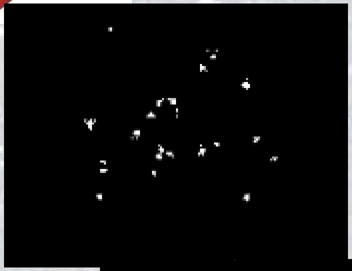
Wavefront Sensing and Control

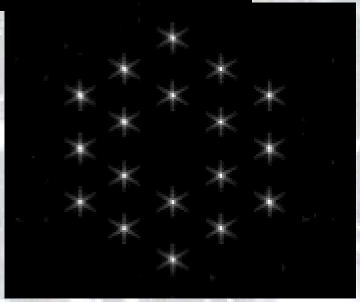


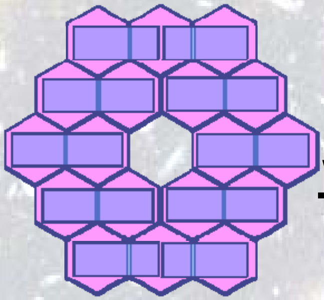
- Any telescope larger than ~3.8-meters must deploy on-orbit and hence needs an optical control system.
- Because most materials (and especially Be) have low coefficients of thermal expansion at 35K and because the L2 thermal environment is benign, wavefront updates should be needed only every two weeks.
- All steps in the process including initial capture and alignment have been tested.

The Testbed Telescope at Ball Aerospace – 1/6 scale model of JWST.

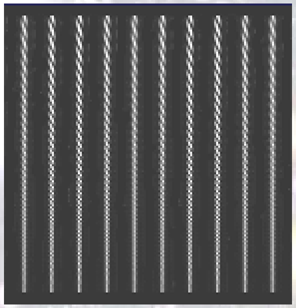
Initial Capture and Alignment

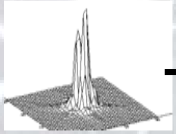

First Light


After segment capture

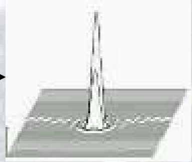

DHS at pupil

Coarse phasing w/DHS →


Spectra recorded by NIRCam


After coarse phasing

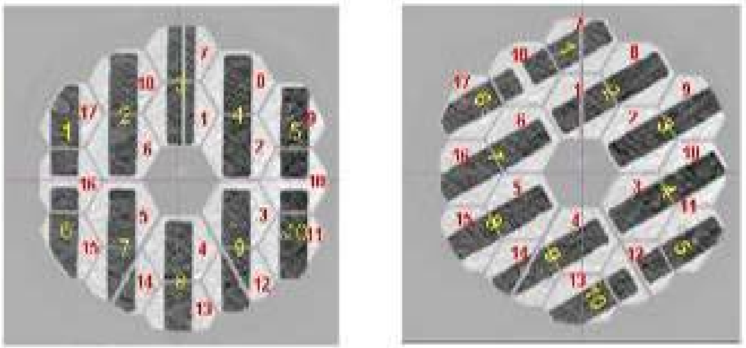
Fine phasing →

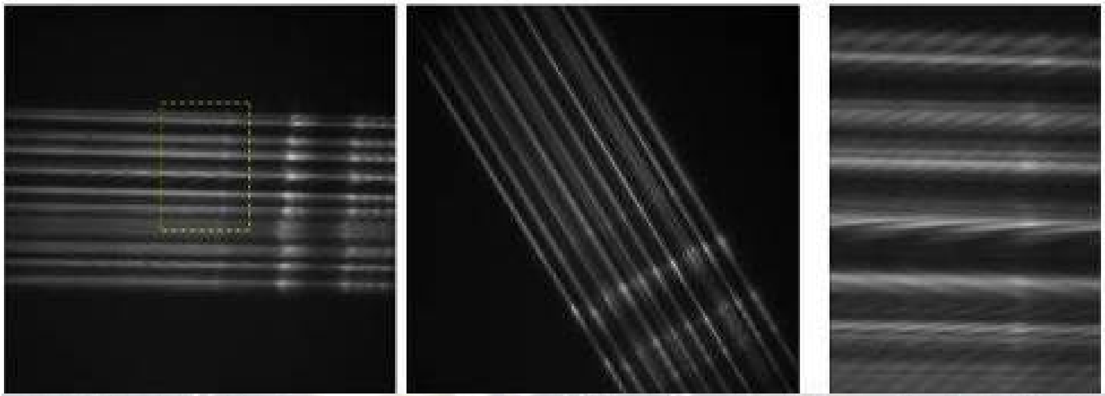

Fully aligned

- Telescope focus sweep
- Segment ID and Search
- Image array
- Global alignment
- Image stacking
- Coarse phasing
- Fine phasing
- Multi-field fine phasing.

- NIRCam provides the imaging data needed for wavefront sensing.
- Two grisms have been added to the long wavelength channel to extend the segment capture range during coarse phasing and to provide an alternative to the Dispersed Hartmann Sensor (DHS)
- Entire wavefront sensing and control process demonstrated using prototypes on the Keck telescope and on the Ball Testbed Telescope.

Coarse Phasing with the Dispersed Hartmann Sensor

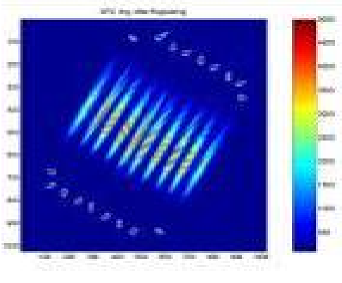




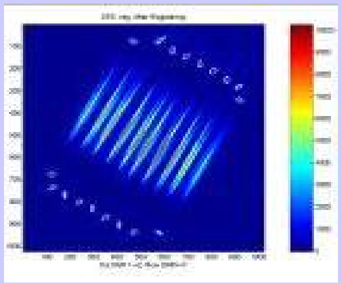
DHS is collection of grisms and wedges that are placed in the NIRCam pupil wheel.

Every segment pair is covered by one grism so coarse phasing consists of measuring spectra to determine the offset in the focus direction between segments.

Process is robust even if a segment is missing.



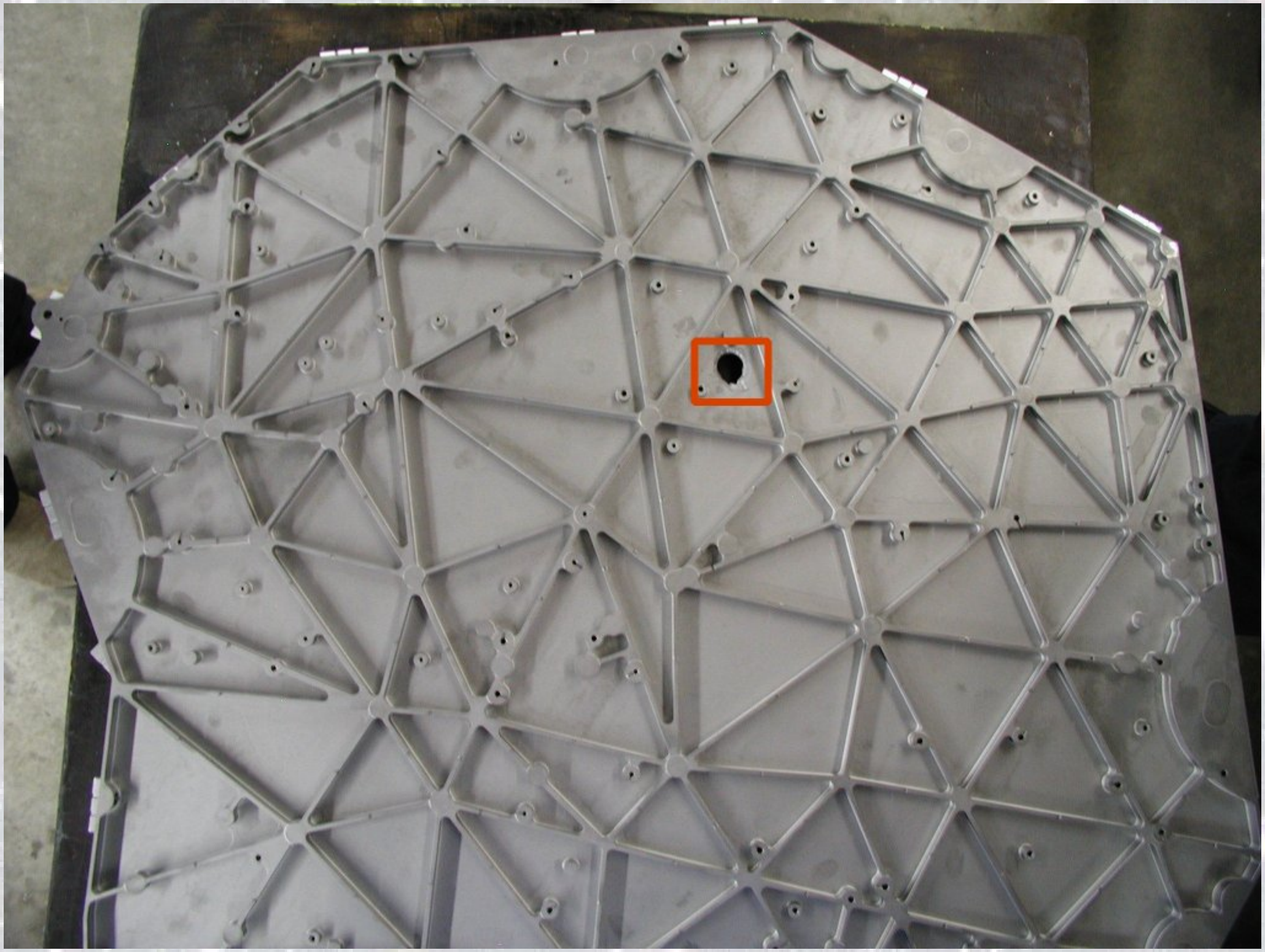
Initial errors
Max piston error=19 μm
Rms=5 microns



After correction
Max piston error=0.66 μm
Rms=0.18 microns

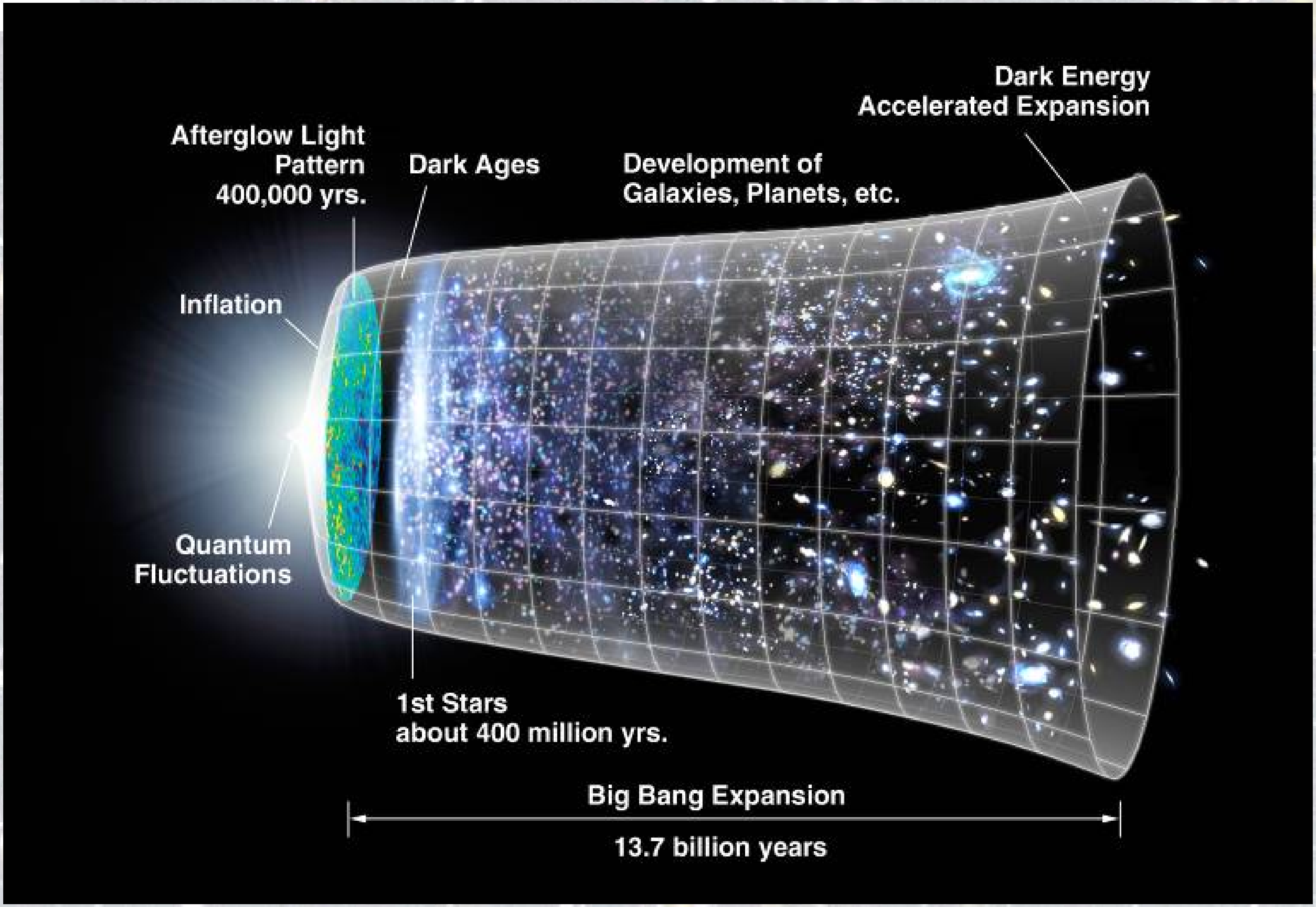
A prototype DHS was tested on Keck.

Why Being PI Isn't Fun!



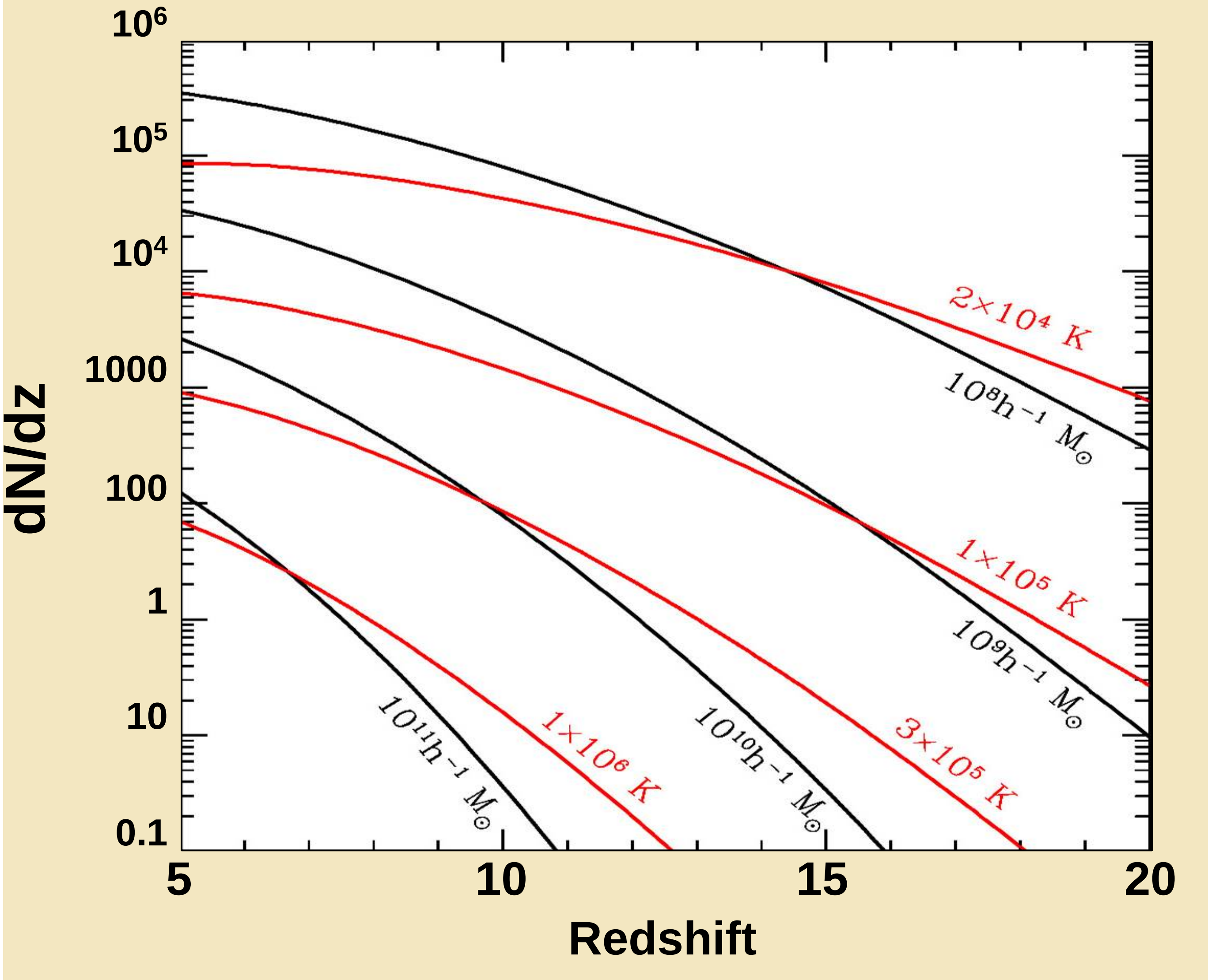
Because there is no one to pass the buck to!

Schematic of Galaxy Development



How to Search for “First Light”?

- When did the first objects form – what redshift range should be searched?
- What are the characteristics of the first sources?
  - Which were most important: black holes or stars?
  - Should we base our assumptions on Super Star Clusters or dwarf galaxies or ….
  - Will the IMF be different?
  - What will be most detectable?

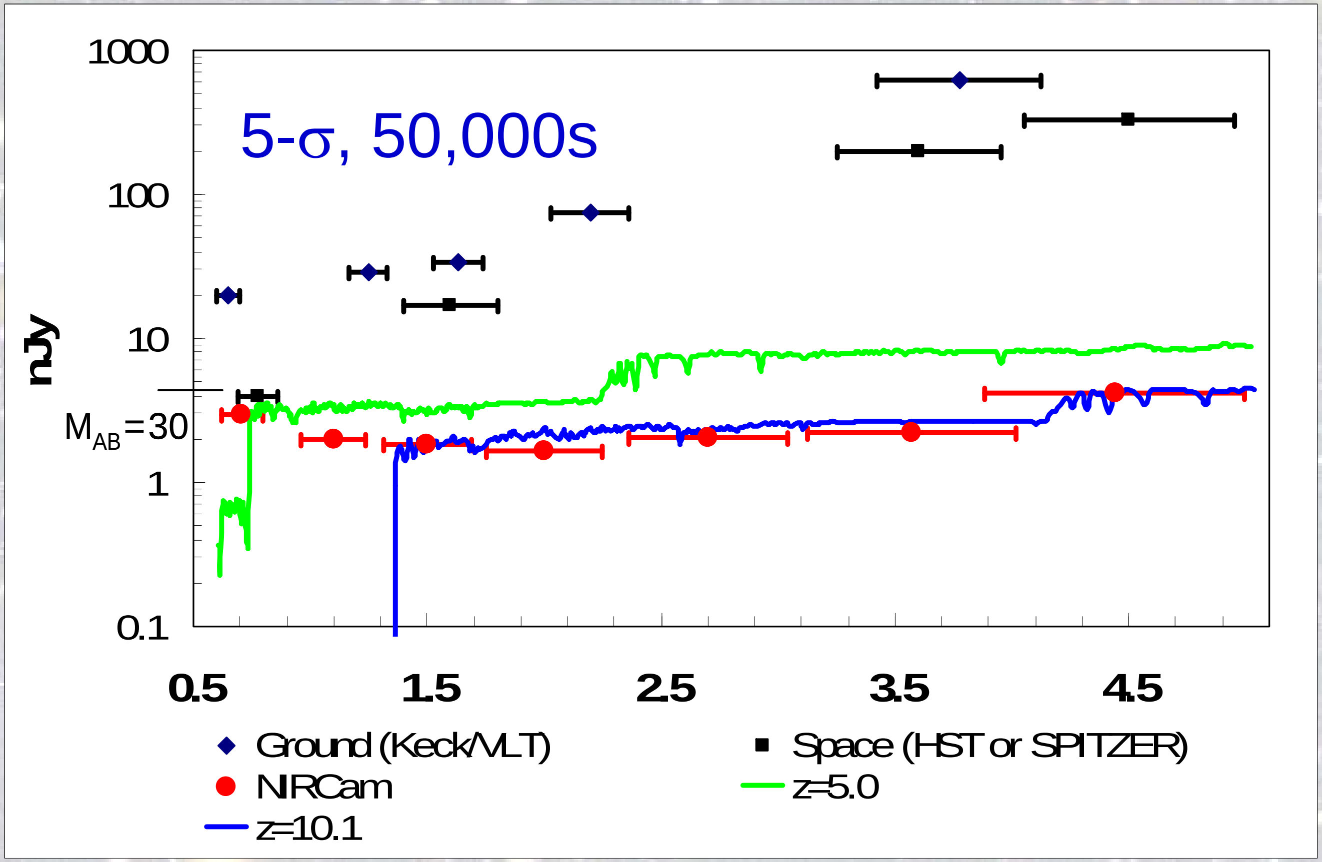


Search for “first light” objects is bound to be successful given the numbers of large dark matter haloes.

The number of dark matter haloes per NIRCam field and redshift interval. Black curves are lines of constant mass, red lines indicate lines of constant virial temperature

High Sensitivity is Paramount

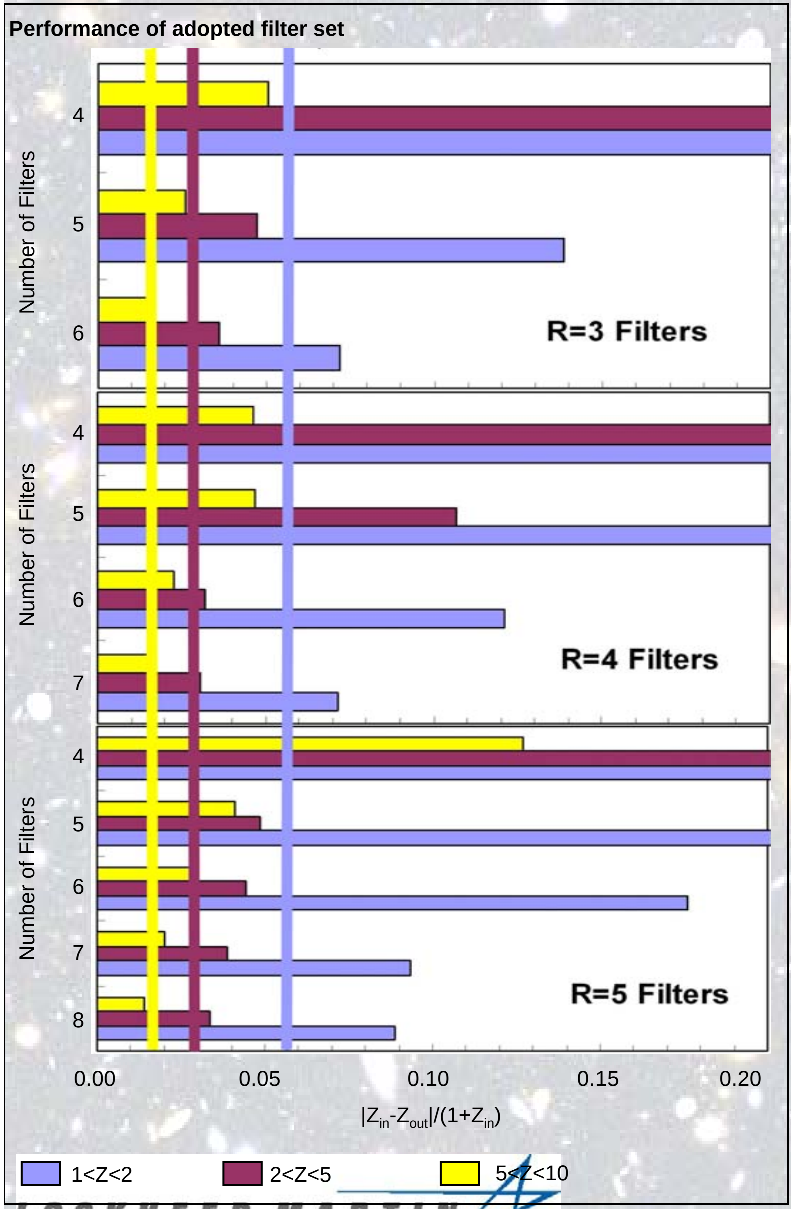
- NIRCam sensitivity is crucial for detecting “first light” objects
- At 3-5μm, NIRCam can detect objects 100x fainter than Spitzer opening up new survey possibilities



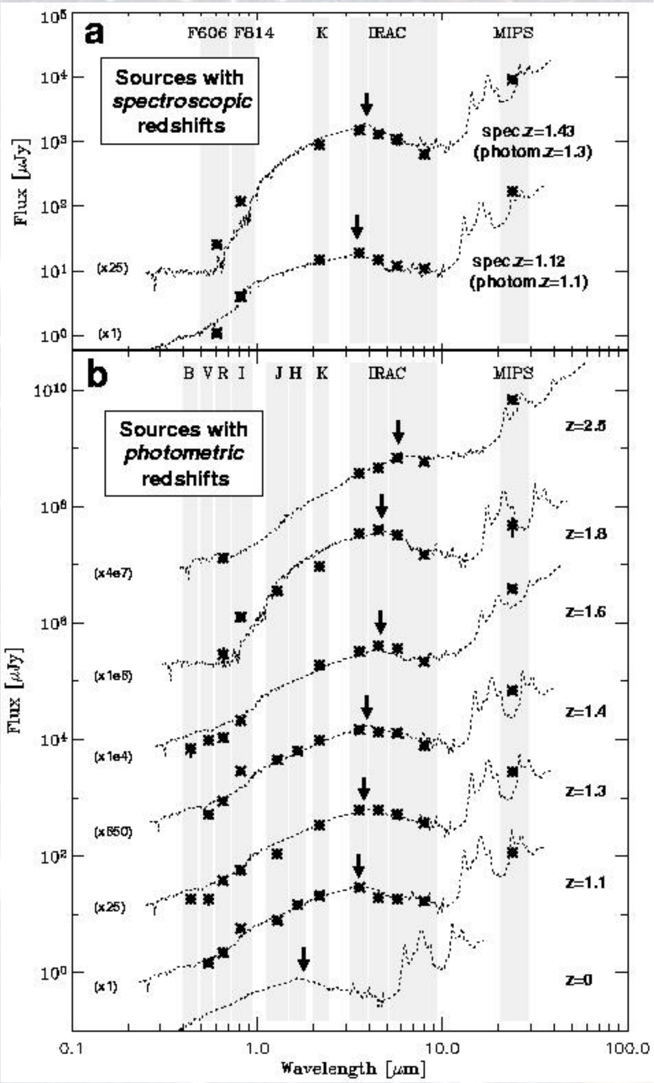
The z=10 galaxy has a mass of $4x10^8M_{Sun}$ while the mass of the z=5 galaxy is $4x10^9M_{Sun}$.

Above assumes 50,000 sec/filter with 2x time on longest wavelength

Photometric Redshifts Important


Performance of adopted filter set

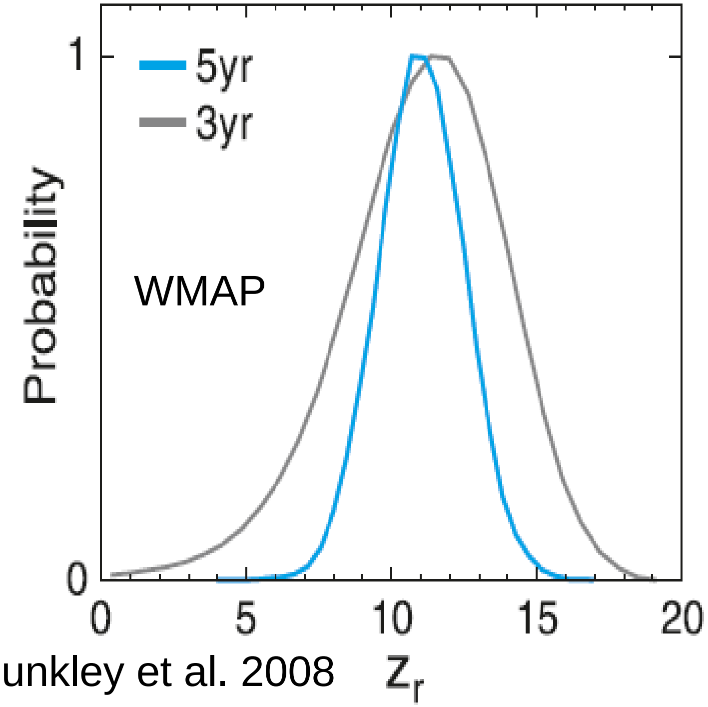
NIRCam will detect objects too faint for spectroscopy and will rely on photometric redshifts for statistical studies. The large number of broad filters in NIRCam have been optimized for this task as illustrated by the simulation results shown at the left. Right: Spitzer data demonstate that galaxy SEDs have sufficient structure for phot-zs.



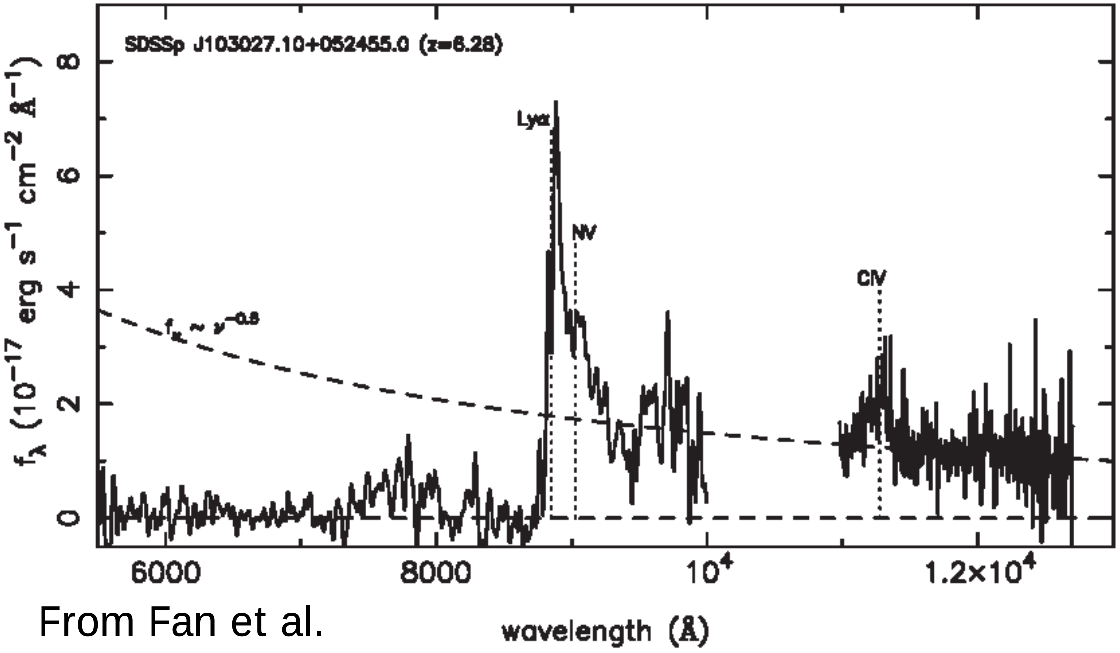
Le Floc'h et al. 2004, ApJS

WMAP & QSO Results

- Year 5 WMAP release has reduced the uncertainties in the electron optical depth so the epoch of reionization is constrained to z~11.0 ± 1.4, equivalent to ~350Myr after Big Bang.
- Spectra of SDSS z~6 QSOs show hints that Universe was reionized at only somewhat higher z than 6.5.
- Need to search from z~7 to z~15



Dunkley et al. 2008

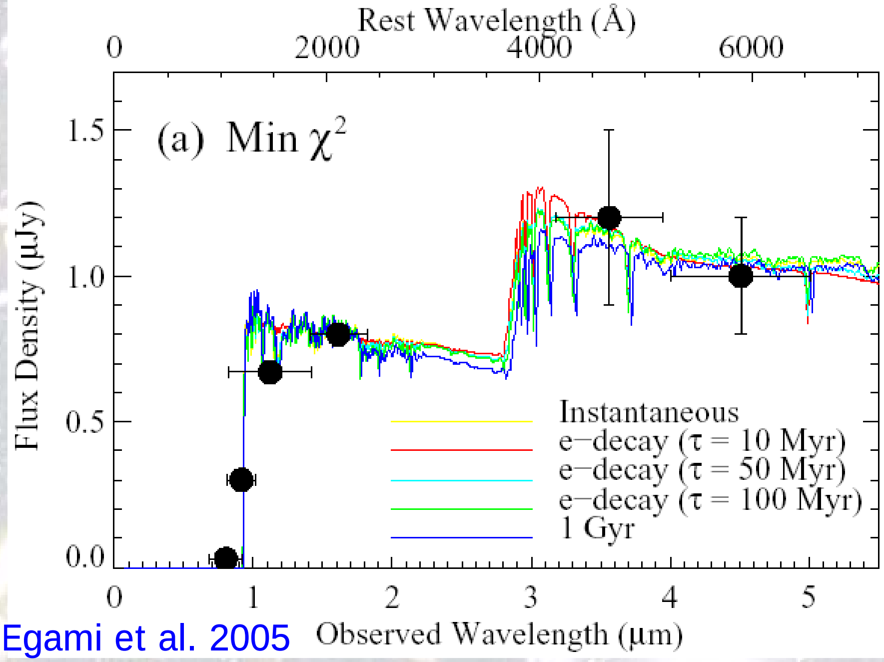


From Fan et al.

Spitzer Contributions

- The star formation rate as a function of z is much better known.
- Stellar mass assembly rate can be characterized for the first time.
- Spitzer is showing us that galaxies at z~7 formed stars as much as 200-400 million years earlier (around z~10)

➔ Epoch of first star formation now seem likely to have been around z~10-15 from combining Spitzer and WMAP results.

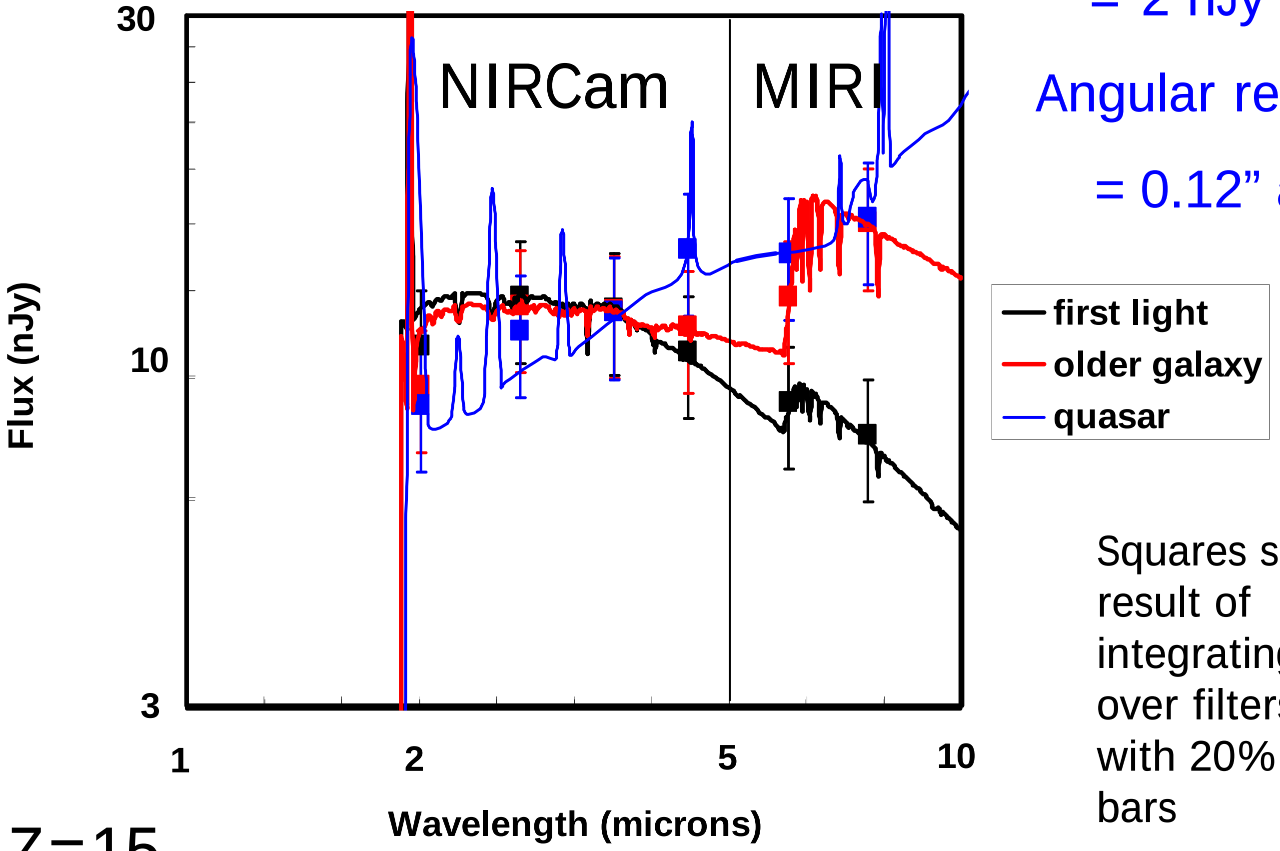


Egami et al. 2005

Imagine such a galaxy at 2x the redshift => z~14
- roles of NICMOS and IRAC correspond to NIRCam and MIRI on JWST.

Important to note that a number of similar galaxies have now been found by many observers

NIRCam & MIRI Provide Robust Discriminators



Z=15

Sensitivity:

5-σ in 50,000 sec

= 2 nJy at 3.6μm.

Angular resolution

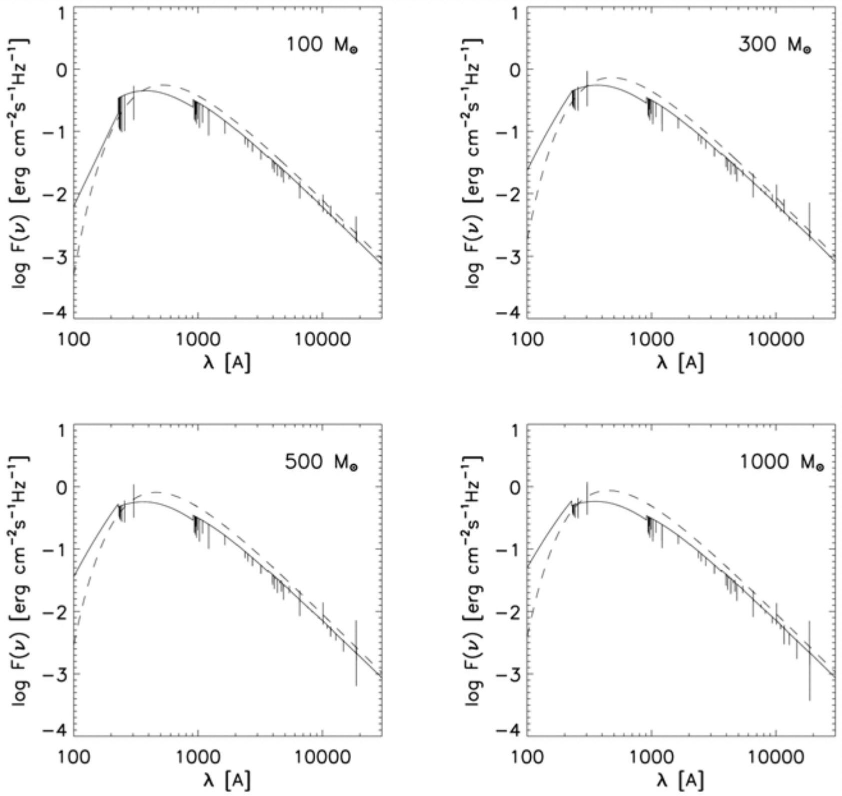
= 0.12” at 4μm.

Squares show result of integrating over filters with 20% error bars

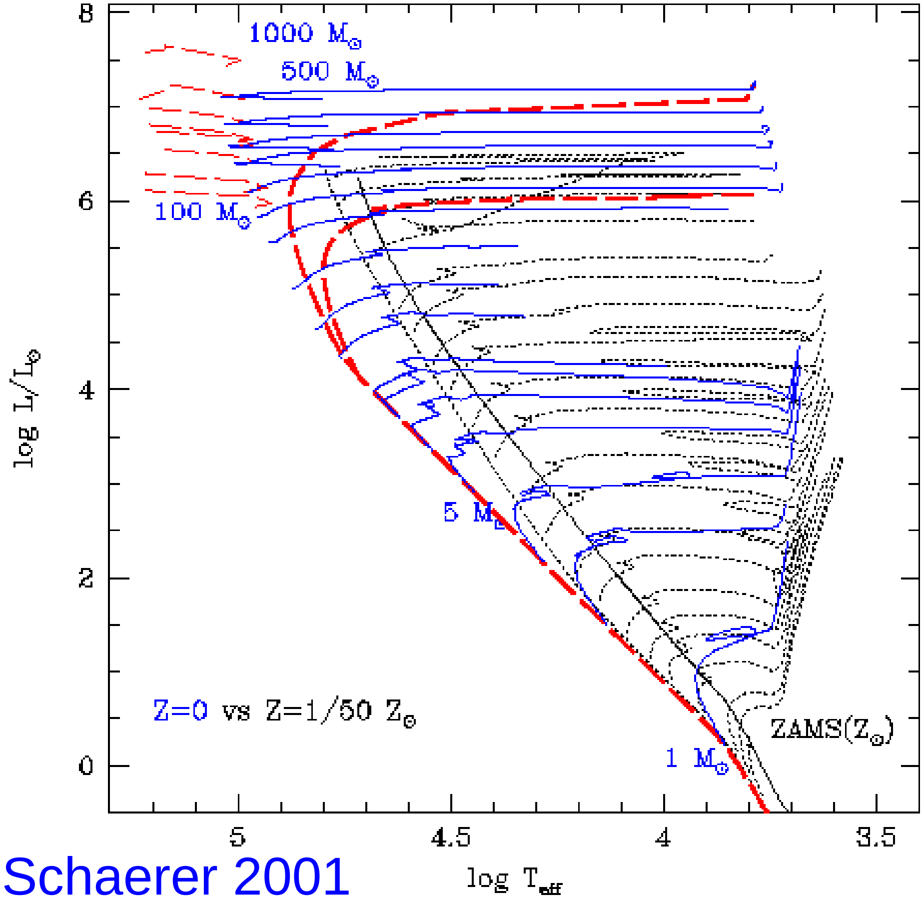
Possible Characteristics of First Stars

- Pop III stars may extend up to much higher masses
- IMF may be tilted towards high mass stars

But not even JWST could detect a single one of these stars except as a supernova.



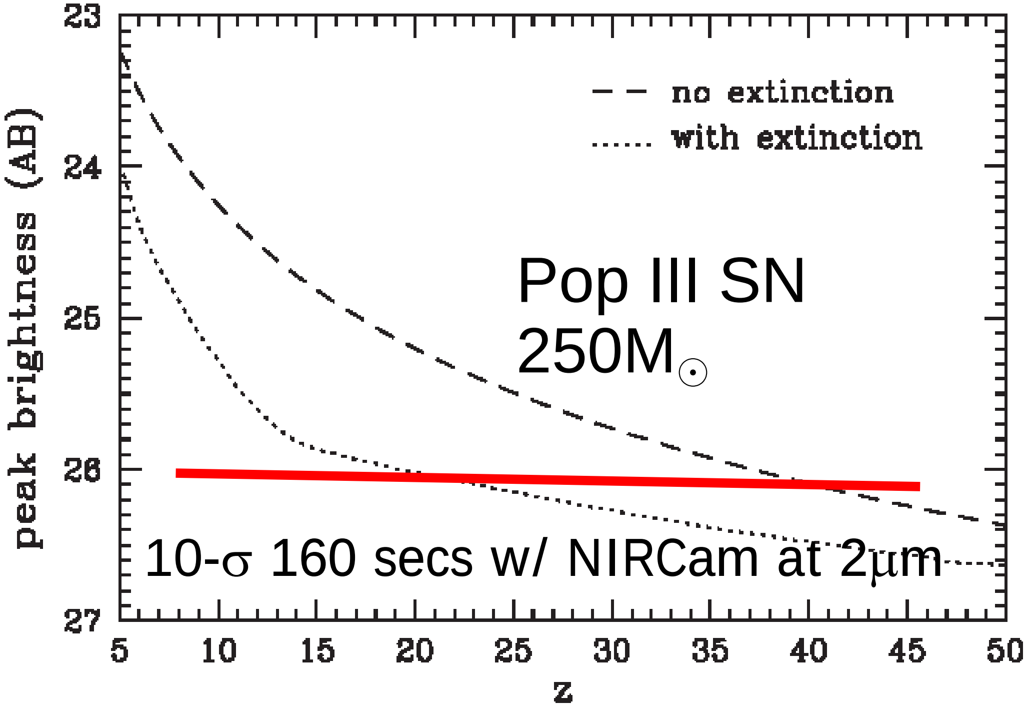
Bromm et al. 2001



Schaerer 2001

Pop III SN Detectable?

- Supernovae -- detectable but too rare?

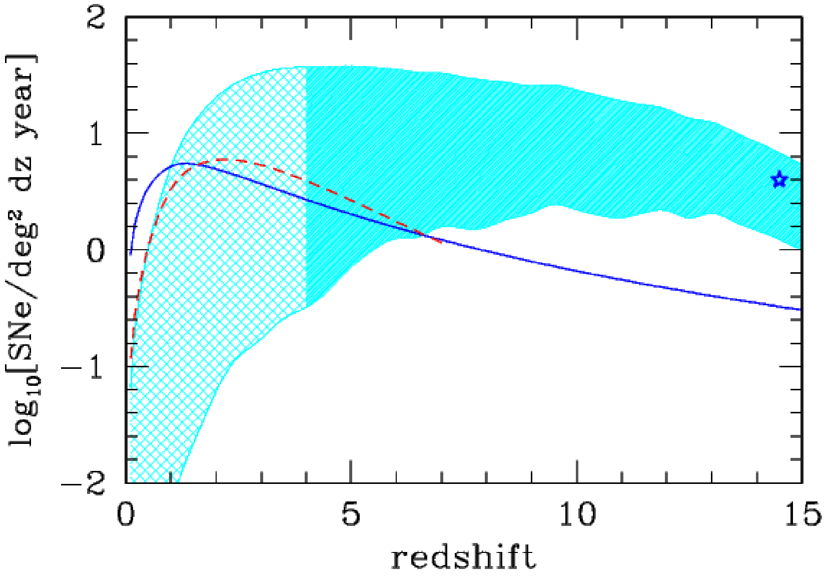


Pop III SN 250M$_{\odot}$

10-σ 160 secs w/ NIRCam at 2μm

Weinmann & Lilly 2005 ApJ 624 526

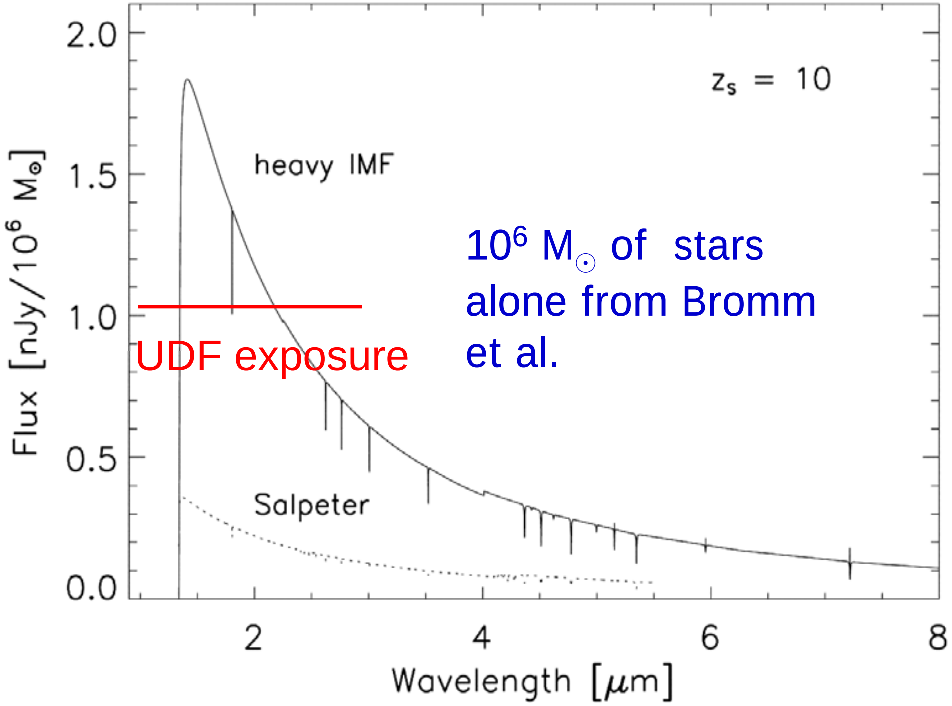
SN with M=175M$_{\odot}$ will be 25 times fainter and would require more time to detect.



Scannapieco 2006

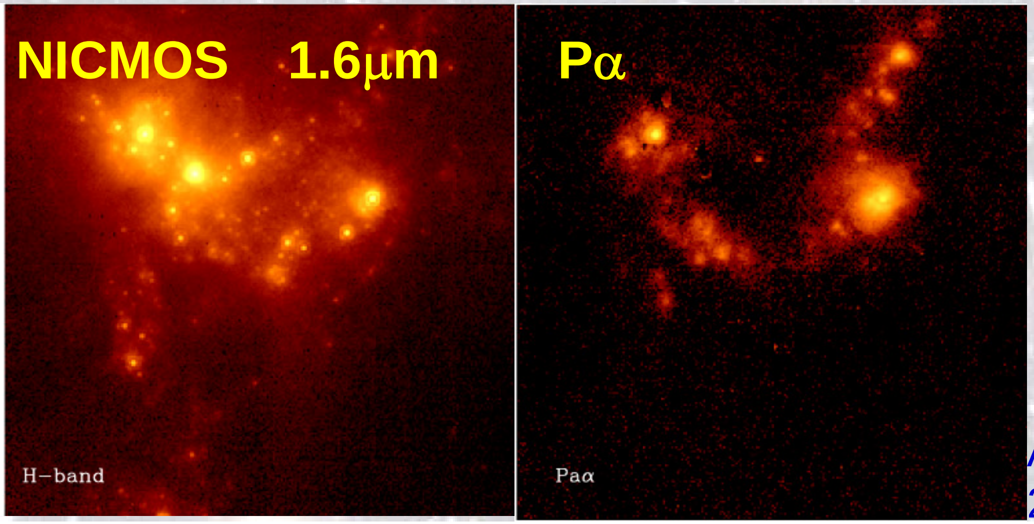
Unfortunately NIRCam's FOV is only 2.69x10^{-3} sq. deg so need to image ~360 fields to be sure of getting 1 z=10 SN.

Super Star Clusters Good First Light Candidates

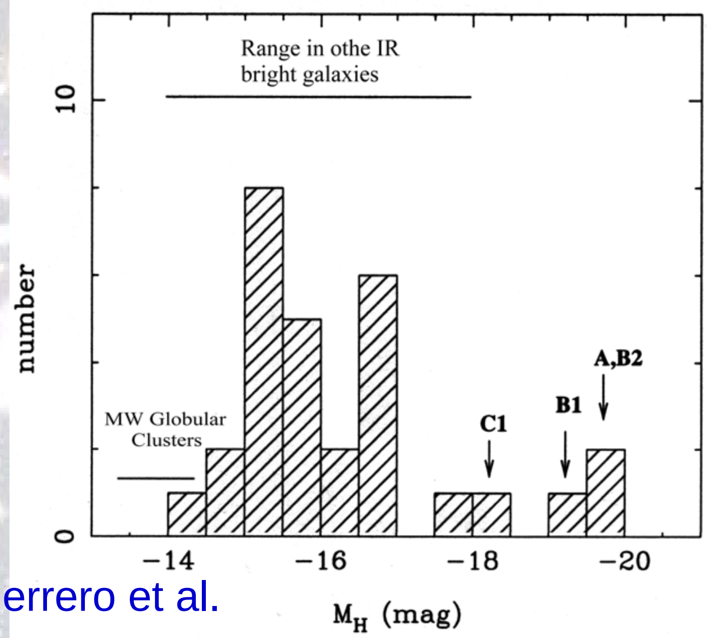


10^6 $M_\odot$ of stars alone from Bromm et al.

Super star clusters analogous to what's been found in galaxies like the Antennae or Arp 299 would be detectable at z=10 – larger clusters with M=10^7 $M_\odot$ will be readily detectable in a deep survey which spends 14 hours/filter.



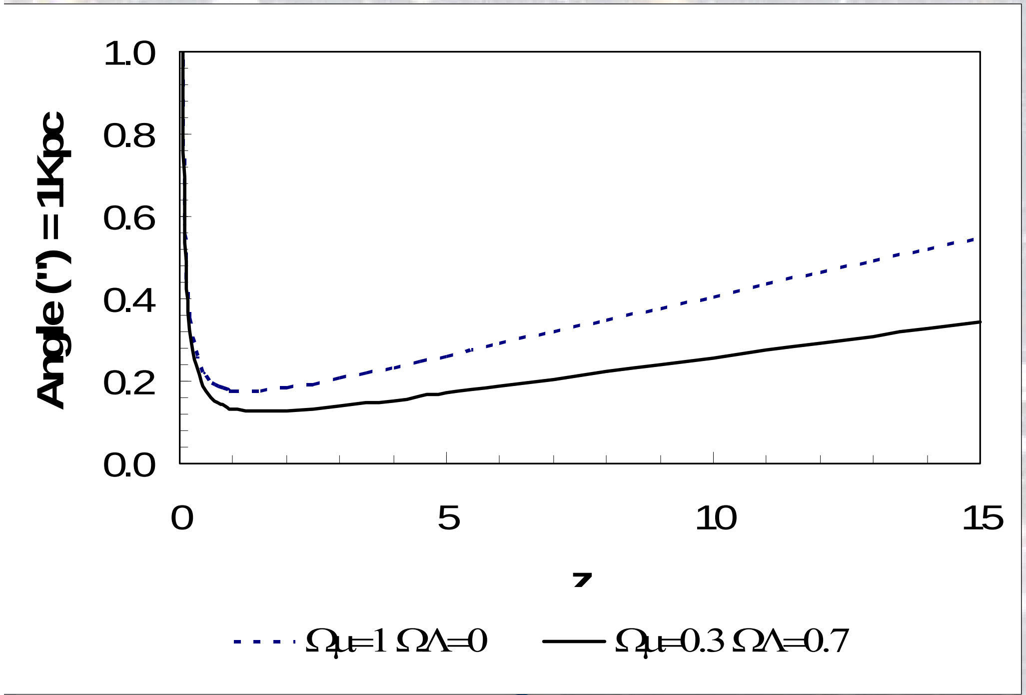
NGC 3690 =Arp 299

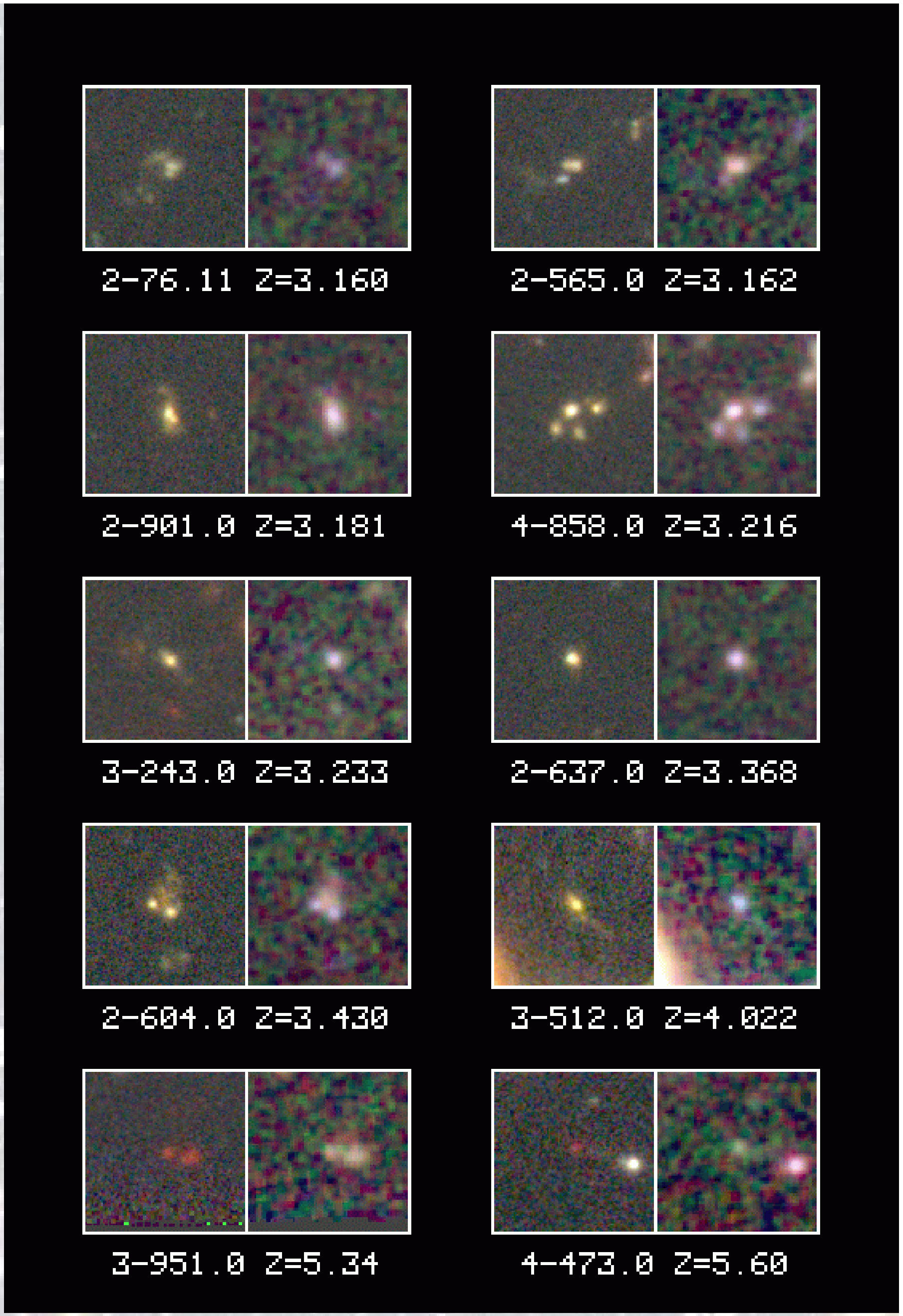


Alonso-Herrero et al. 2000

Galaxy Assembly: Merger History

Diffraction Limit for JWST at 2µm is 0.06” ==> adequate for resolving galaxy scale lengths, morphologies



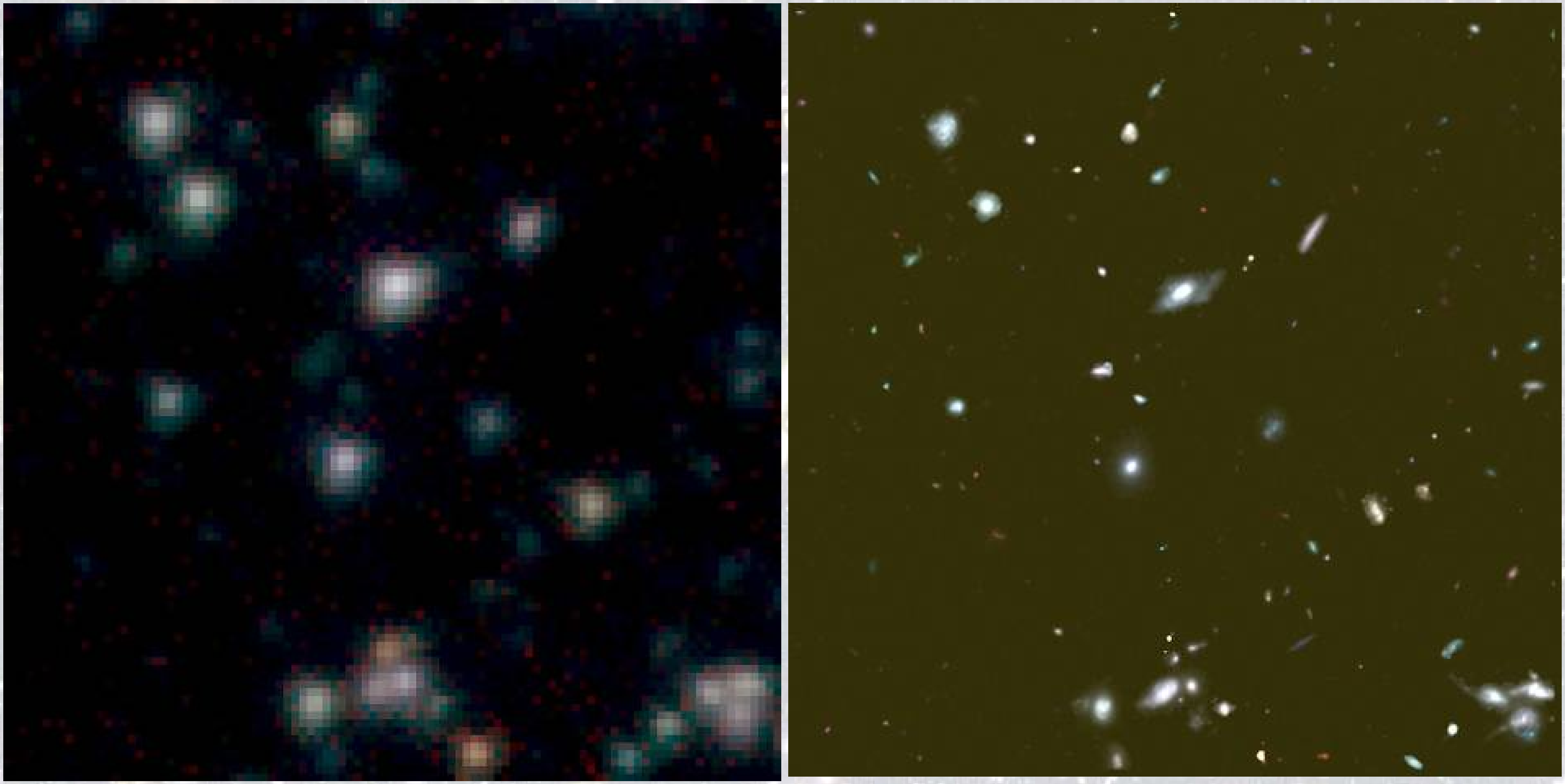


Restframe UV (left), Visible (right)

Windhorst et al.

JWST-Spitzer Image Comparison

1'x1' region in the UDF – 3.5 to 5.8 μm



Spitzer, 25 hour per band (GOODS collaboration)

JWST, 1000s per band (simulated)

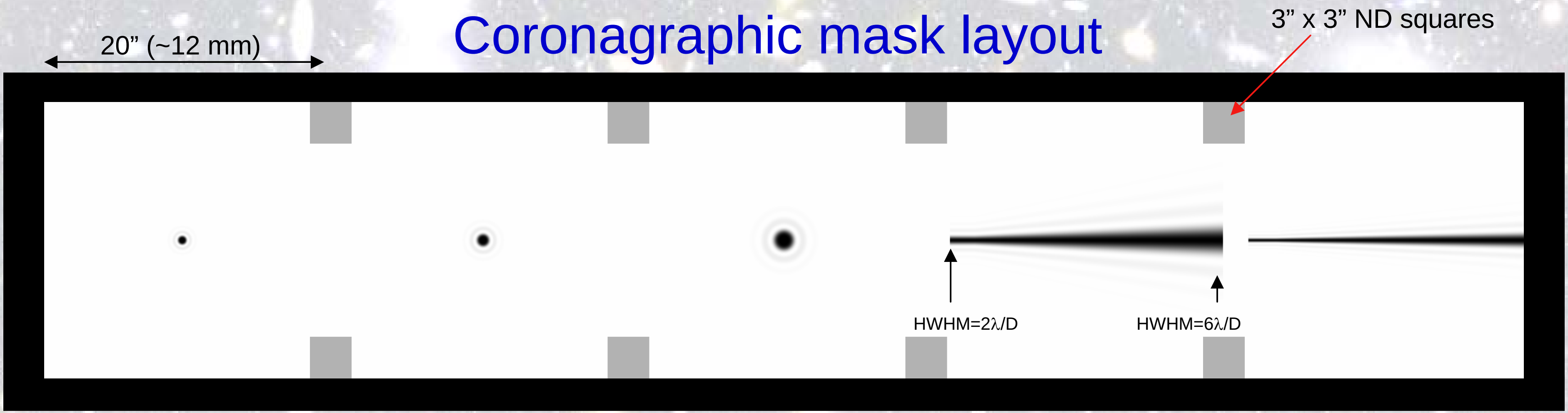
Courtesy of M. Stiavelli

NIRCam at z=0: Observing Planets

Two different observing strategies:

- Direct imaging using coronagraphy
  - ➢ Optimized for λ ≈ 4.5 μm imaging
- Use long wavelength grisms or short wavelength defocussing lenses to observe transits

Coronagraphic mask layout



FWHM = 0.40” (6λ/D @ 2.1 μm)

FWHM = 0.64” (6λ/D @ 3.35 μm)

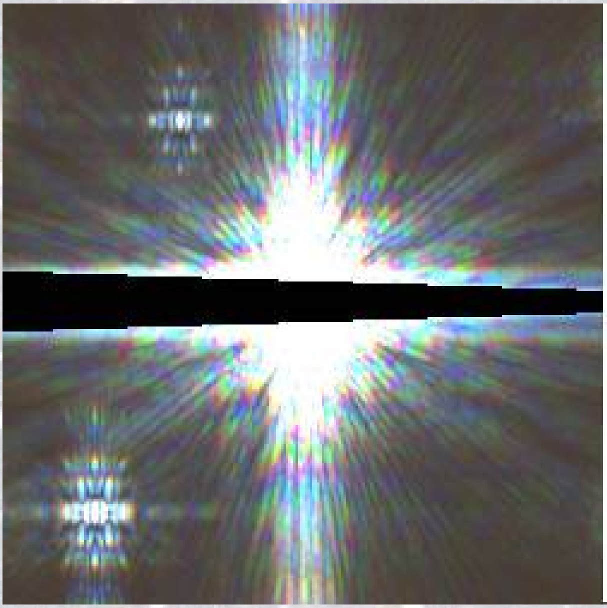
FWHM = 0.82” (6λ/D @ 4.3 μm)

FWHM_c = 0.58” (4λ/D @ 4.6 μm)

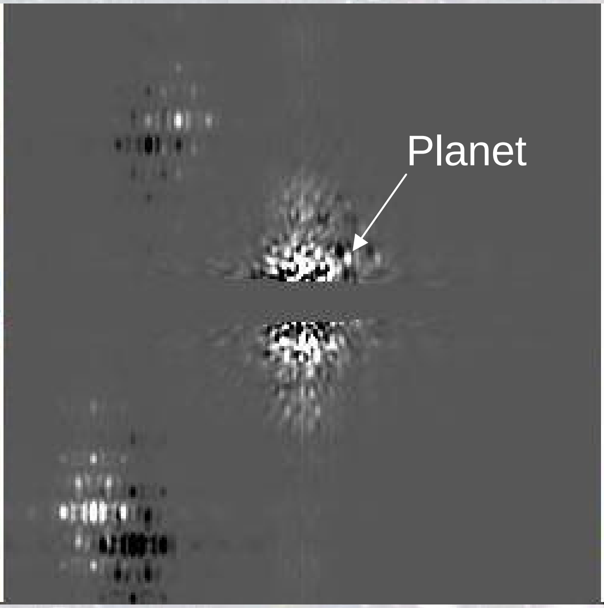
FWHM_c = 0.27” (4λ/D @ 2.1 μm)

Simulated Planet Observations

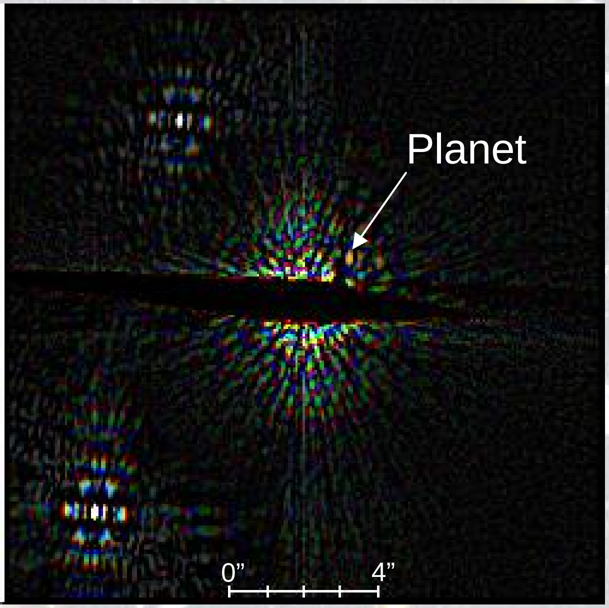
Multi-filter
Combined, Unsubtracted



F460M
Orient 1 – Orient 2 (10º)



Multi-filter
Combined, Subtracted

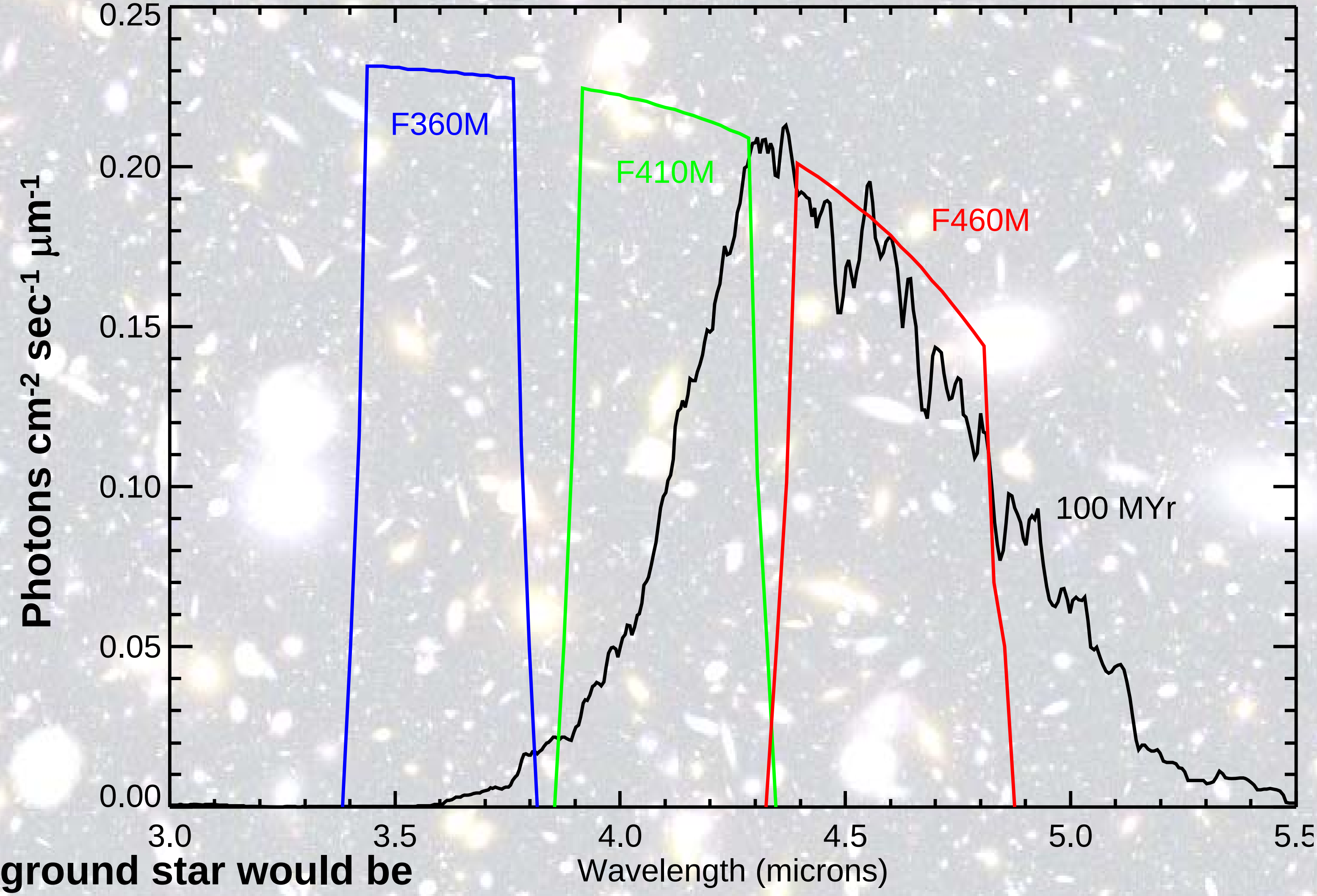


Red = F460M
Green = F410M
Blue = F360M

1 Gyr-old M0V star @ 4 pc
2 M_{Jup} planet @ 7 AU
5000 sec / filter / orientation

Simulation by J. Krist

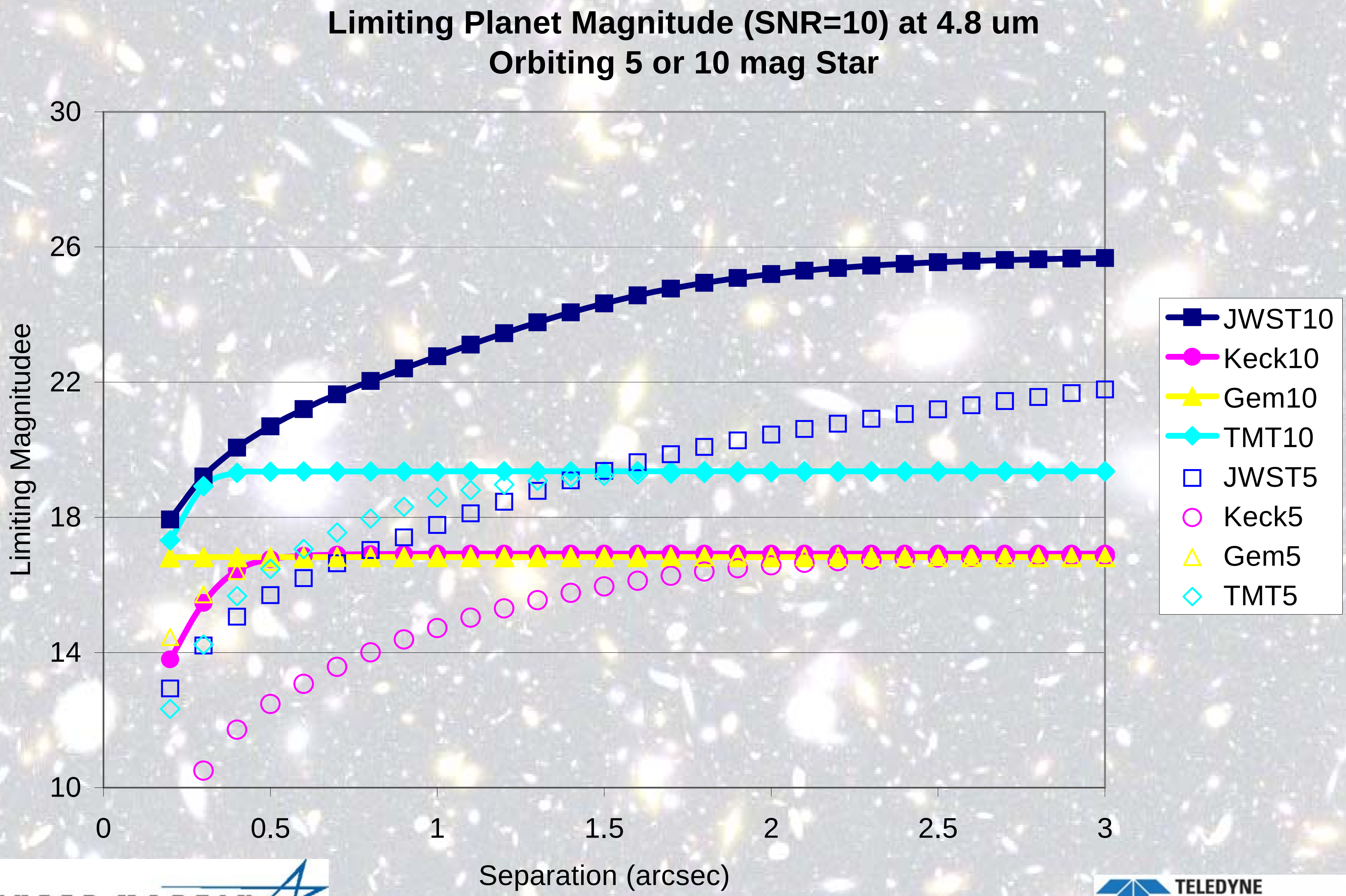
100 Myr-Old, 2 M_{Jup} Planet



A background star would be brightest at F360M.

Spectrum from Burrows, Sudarsky, & Lunine (2003)

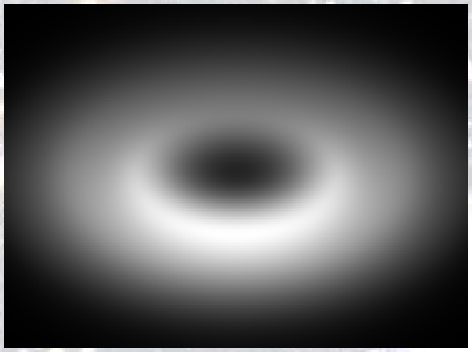
JWST Dominates at 4.8 µm

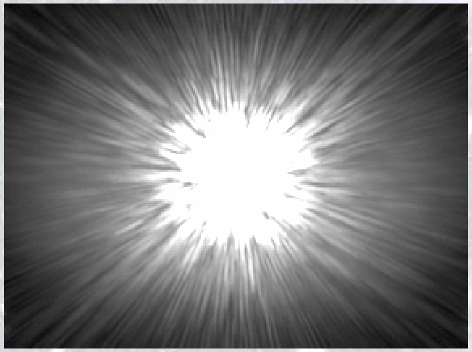


F200W Disk Imaging

A0V star @ 100 pc, r=0.4” spot occulter

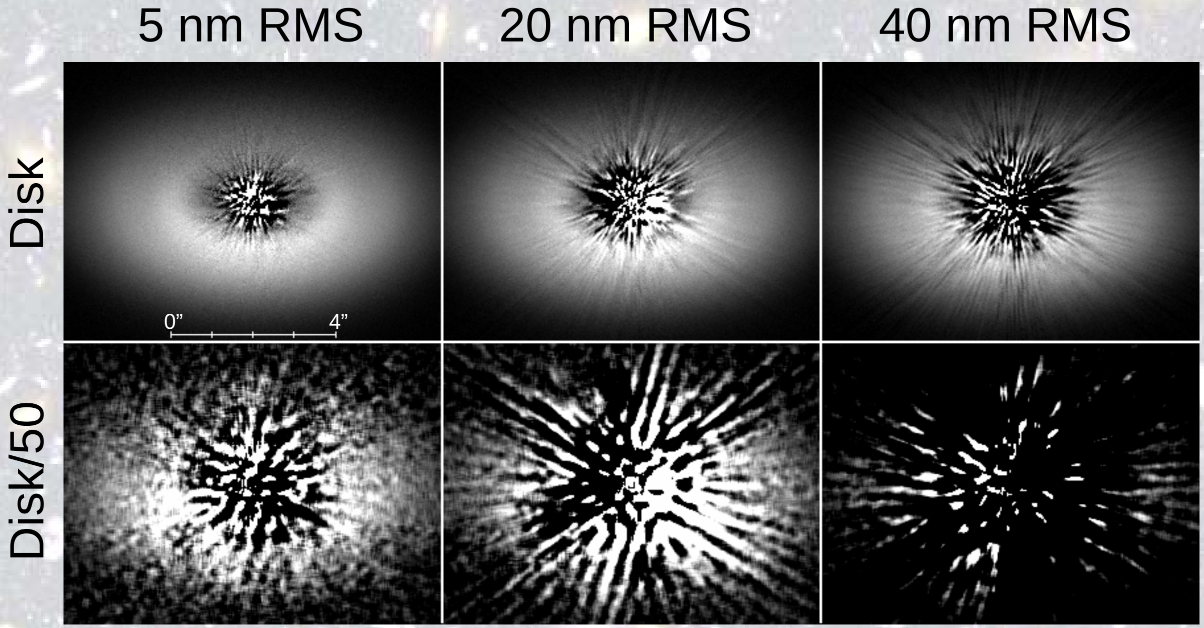
Disk Model





Disk Model + Coronagraph

After subtraction of a similarly imaged A1V reference PSF star with the given amount of wavefront error change



Disk is ~3x Beta Pic optical depth

Precision Light Curves

- Large collecting area
  - 45 × Spitzer, Kepler
  - 350 × CoRoT
- Increased SNR ($\propto D$), faster observations ($\propto D^2$)
- Very precise light curves for primary eclipses
  - Albedo, rings, moons, TTVs, etc.
  - Ingress & egress curves for temp map (Rauscher et al)
- Thermal mapping (secondary transit/full light curves) for heat redistribution, rotation, phase effects

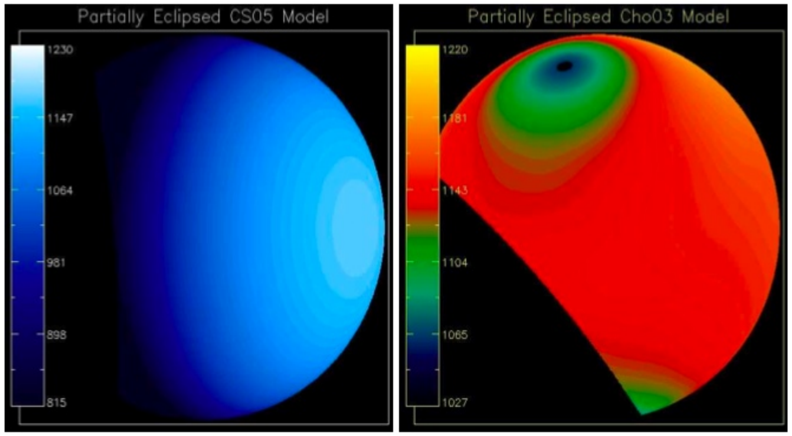
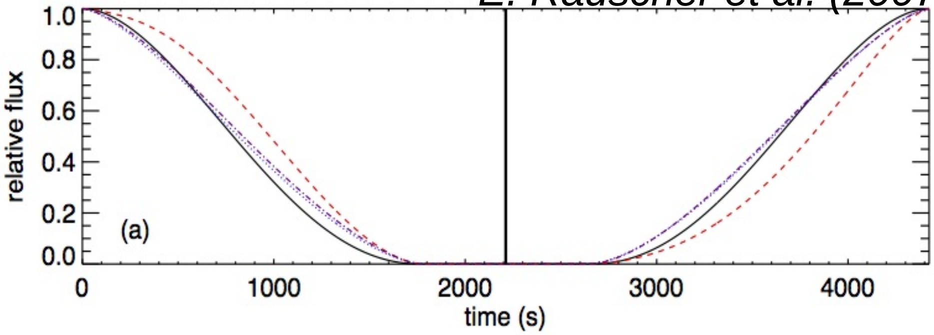


Fig. 1.— Partially eclipsed temperature maps in a CS05-like model of TrES-1 (*left*) and a Cho03-like model of HD189733b (*right*). The color-temperature scale (in K) is shown on the left of each panel. Notice how the different system geometries affect the orientation and shape of the eclipsing stellar limb, and consequently the detailed shape of the ingress/egress curves.

E. Rauscher et al. (2007)



Spectroscopic Observations (2-5 μm)

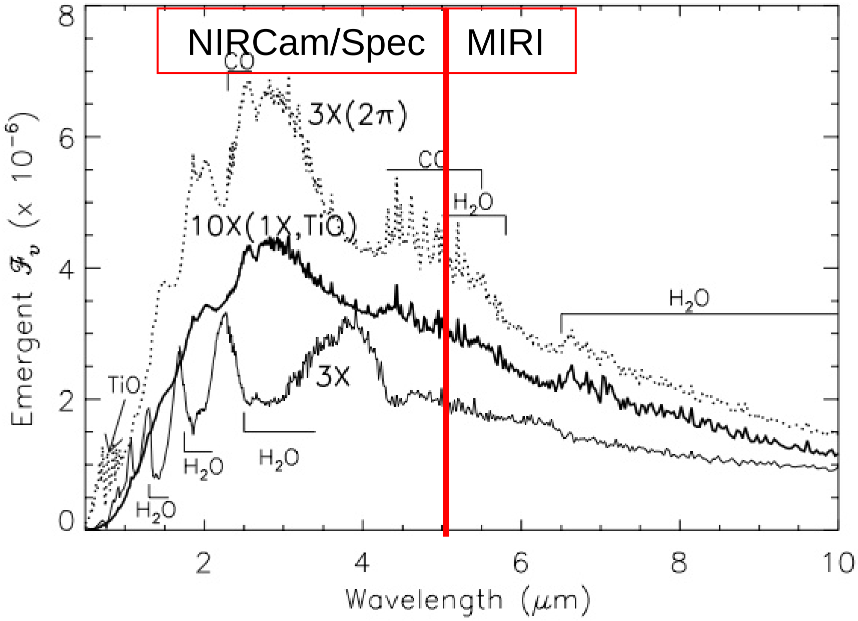
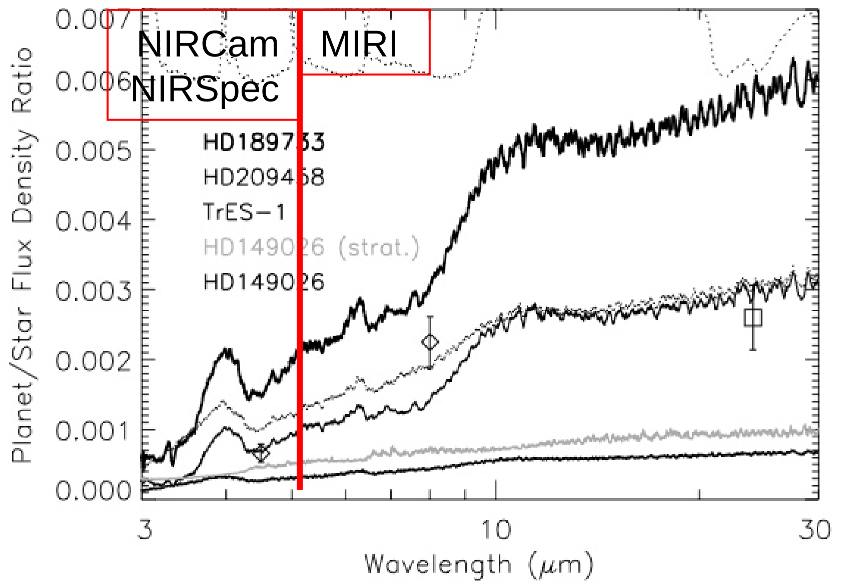
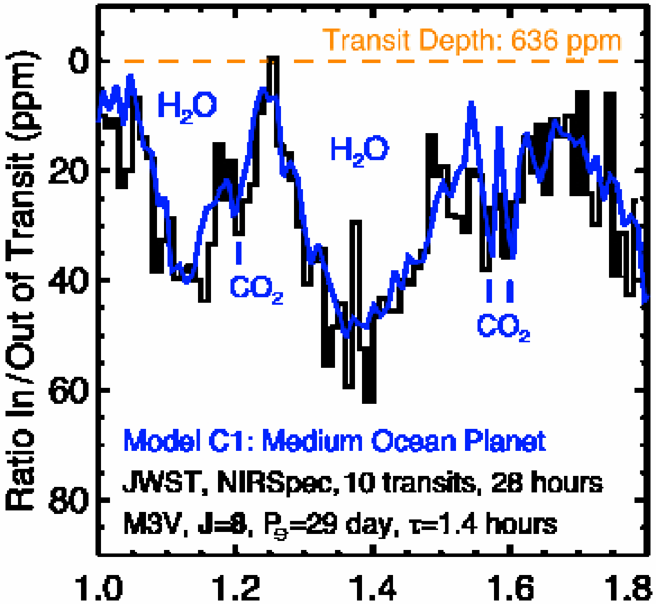


FIG. 3.—Emergent infrared spectra for HD 149026b at [M/H] = 0.5 (labeled 3×), [M/H] = 1.0 with TiO/VO reduced to solar [labeled 10×(1×,TiO)], and [M/H] = 0.5 with 2π sr reradiation (labeled 3×2π). The flux is in ergs s^{-1} cm^{-2}



Spitzer photometry of a nur
209458b) compared with th
642, 295).

- 0.65 - 5 μm spectra with R~50-100 (NIRSpec prism and NIRCam grism) diagnostic of composition and temperature
  - ➢ Transmission spectra of primary eclipses
  - ➢ Emission spectra of hot planets



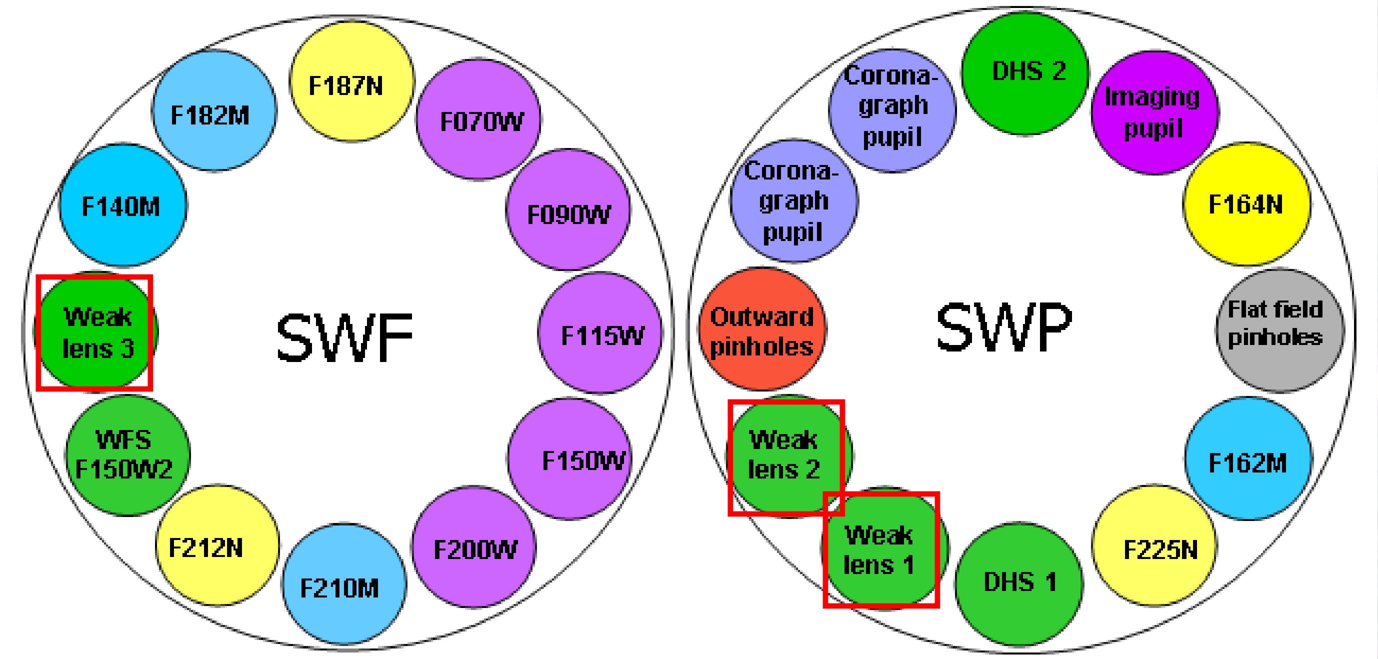
J. Valenti

NIRCam Opportunities

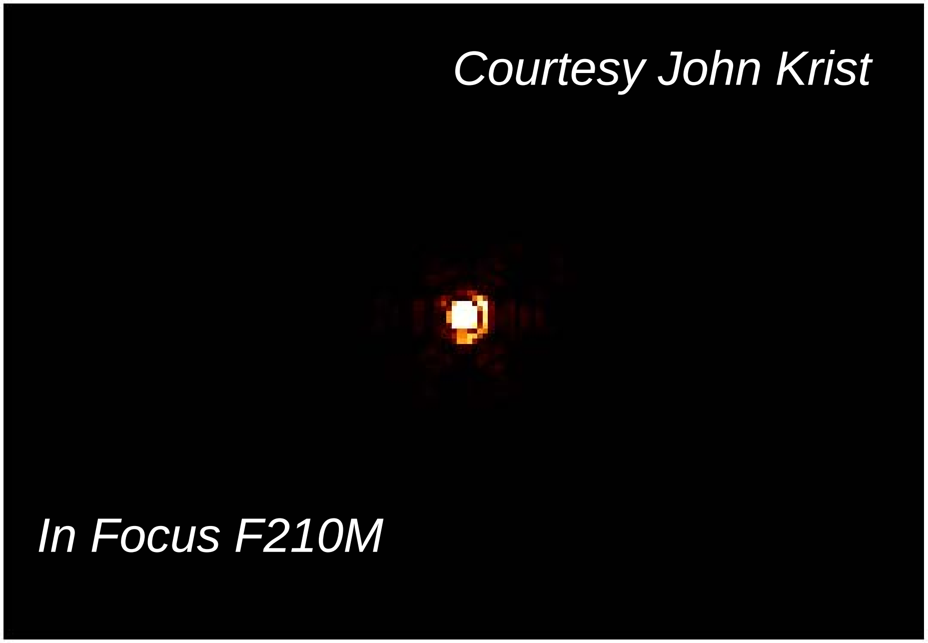
- Primary and secondary transit or hot Jupiter light curves with high precision using defocused images (1-2.4 μm) and *slitless* grisms (2.4-5.0 μm).
  - Short and long-lam data obtained simultaneously
  - Spectroscopy at R~ 500-2,000 at 2.5-5.0 μm where exoplanets have important spectral features.
- NIRCam may be preferred for many transit observations:
  - Immunity to initial pointing and subsequent drifts
  - High photon efficiency and stability due to *no slit losses*
  - Simultaneous long and short lam observations
  - Monitor pointing and some drifts using other arm of NIRCam

Transits With NIRCAM

- Lenses introduce 4,8,12 λ of defocus to spread light over many hundreds of pixels compared with 25 pixels when in-focus
  - Reduce flat-field errors for bright stars 5<K<10 mag
  - Max defocus is 12λ and is limited to F212N ($\lambda/\Delta\lambda$=100)
  - 8λ of defous with variety of filters, incl F150W2 ($\lambda/\Delta\lambda$=1.5!)
- Ultra-high precision data for bright transits
- *Earth transit* of K~10 mag star will have SNR=20-30 in 6.5 hours
- Diffused images (weak lenses) or spectrally dispersed images (grism) reduce brightness/pixel by >5 mag. K=3-5 mag stars not saturated.

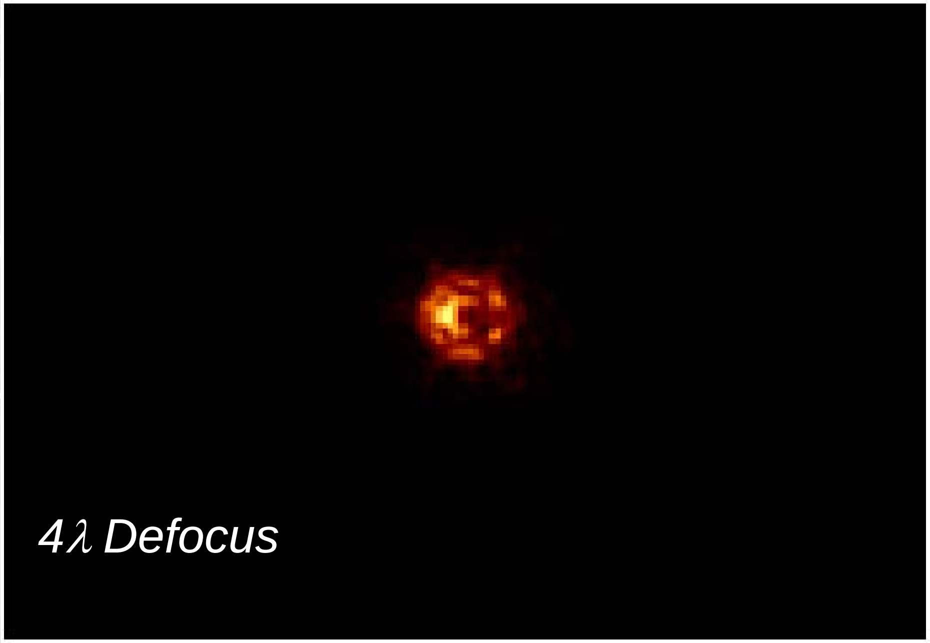


NIRCAM F212N w/ Weak Lenses

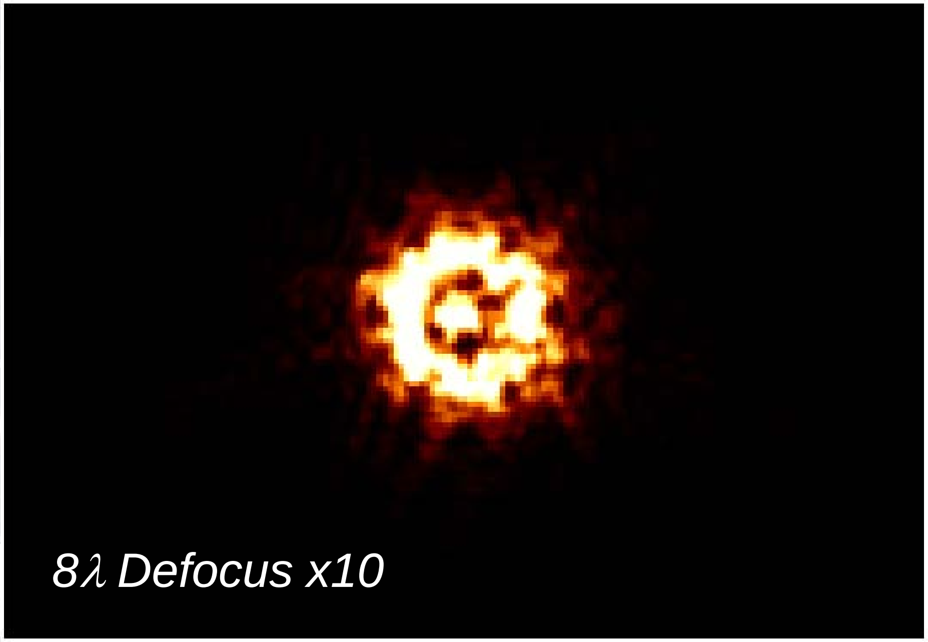


Courtesy John Krist

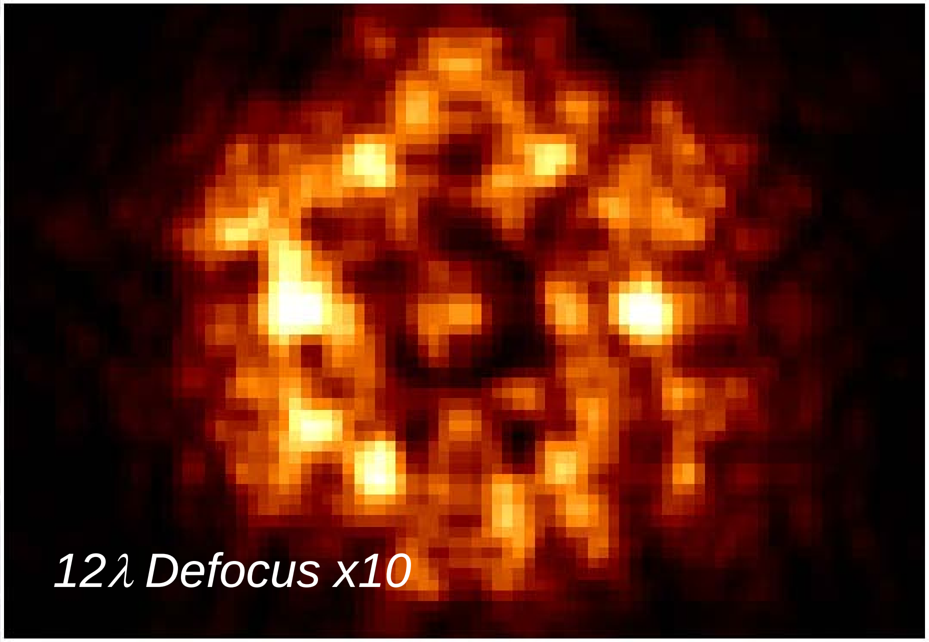
In Focus F210M



4λ Defocus



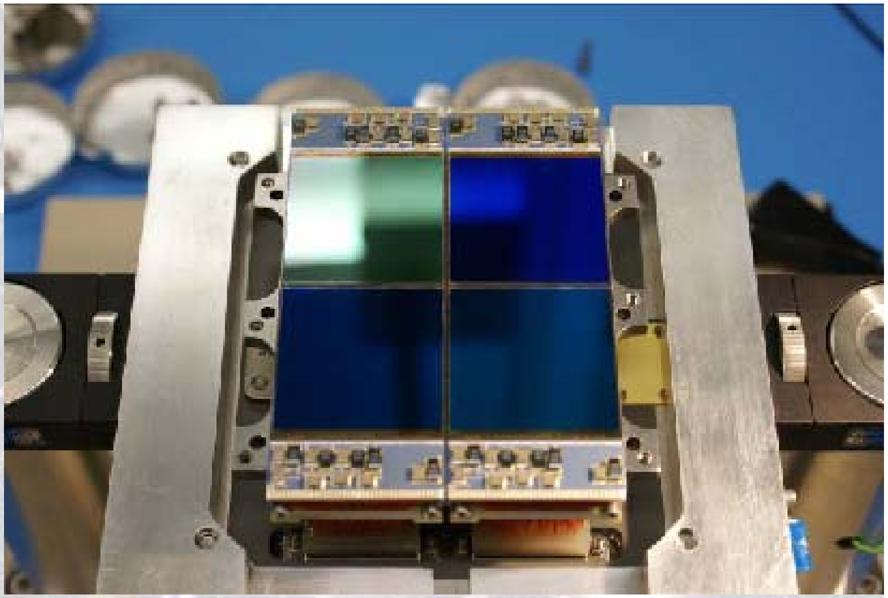
8λ Defocus x10

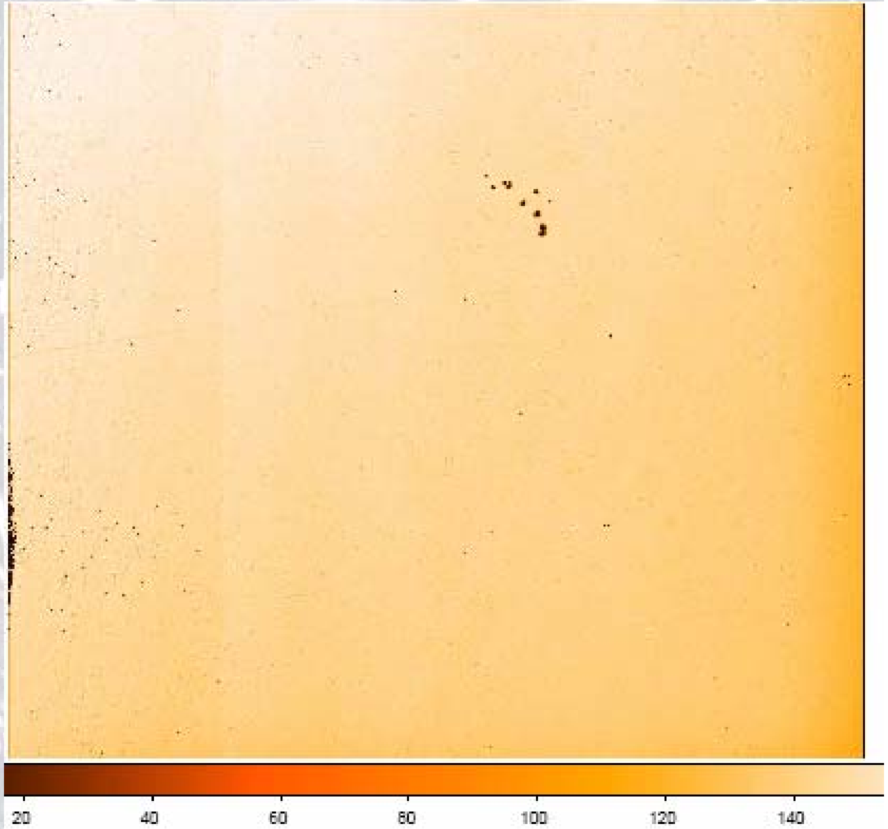


12λ Defocus x10

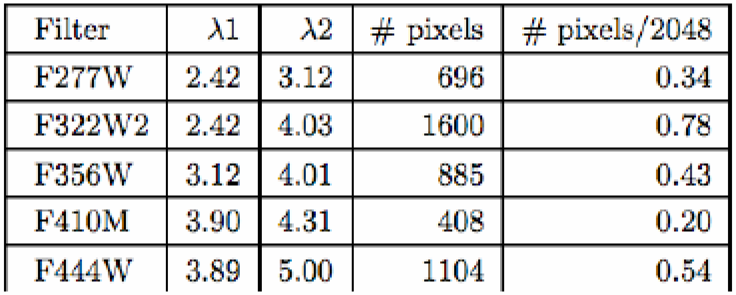
Initial Flat Field Detector Test

- Experiments underway at UofA to make high precision flat field measurements and test removal of detector drifts (“red noise”)
- Initial tests suggest flat field error of $\leq 2.5\times10^{-4}$ over 0.5 hr.
- Tests with hundreds of full well frames will be used to understand stability of detectors for transit measurements





Long-λ GRISM Spectroscopy



Filter	λ1	λ2	# pixels	# pixels/2048
F277W	2.42	3.12	696	0.34
F322W2	2.42	4.03	1600	0.78
F356W	3.12	4.01	885	0.43
F410M	3.90	4.31	408	0.20
F444W	3.89	5.00	1104	0.54

- Grism provides R~2,000 spectra
  - ➢ Spectra improve saturation limit and reduce flat field error
  - ➢ No slit losses → immune to pointing drifts
- Average over few 10^3 pixels for precision mapping
- Average over few 10^2 pixels for R~50-100 spectra

- *Spectra of (Hot) Jupiters at R~500*
- *Super Earth spectrum SNR ~ 6 in 4hr, R=20*

SNR for Primary Transit of G 2V Star. R = 500; τ= 1,000 sec; T_{planet} = 1500K

Jupiter	*M (mag)* [**]			*Earth*	*M (mag)*	
Flat/mag	5	10	15	*Flat/mag*	5	10
1.0E-06	88.32	8.83	0.82	1.0E-06	0.74	0.07
1.0E-05	87.65	8.82	0.82	1.0E-05	0.73	0.07
1.0E-04	55.37	8.76	0.82	1.0E-04	0.46	0.07
1.0E-03	7.08	5.54	0.81	1.0E-03	0.06	0.05

SNR for Secondary Transit of G 2V Star. R = 500; τ=1,000 sec; T_{planet} = 1500K

Jupiter	*M (mag)*			*Earth*	*M (mag)*	
Flat/mag	5	10	15	*Flat/mag*	5	10
1.0E-06	9.12	0.91	0.09	1.0E-06	0.08	0.01
1.0E-05	9.05	0.91	0.09	1.0E-05	0.08	0.01
1.0E-04	5.71	0.90	0.09	1.0E-04	0.05	0.01
1.0E-03	0.73	0.57	0.09	1.0E-03	0.01	0.00

*Obtained by binning ~8 spectral channels. [**]Johnson magnitudes.

Grism Observations of M Stars @ 4.6 μm

SNR for Primary Transit of M3 V Star. R = 500; τ= 1,000 sec; T_{planet} = 1500K

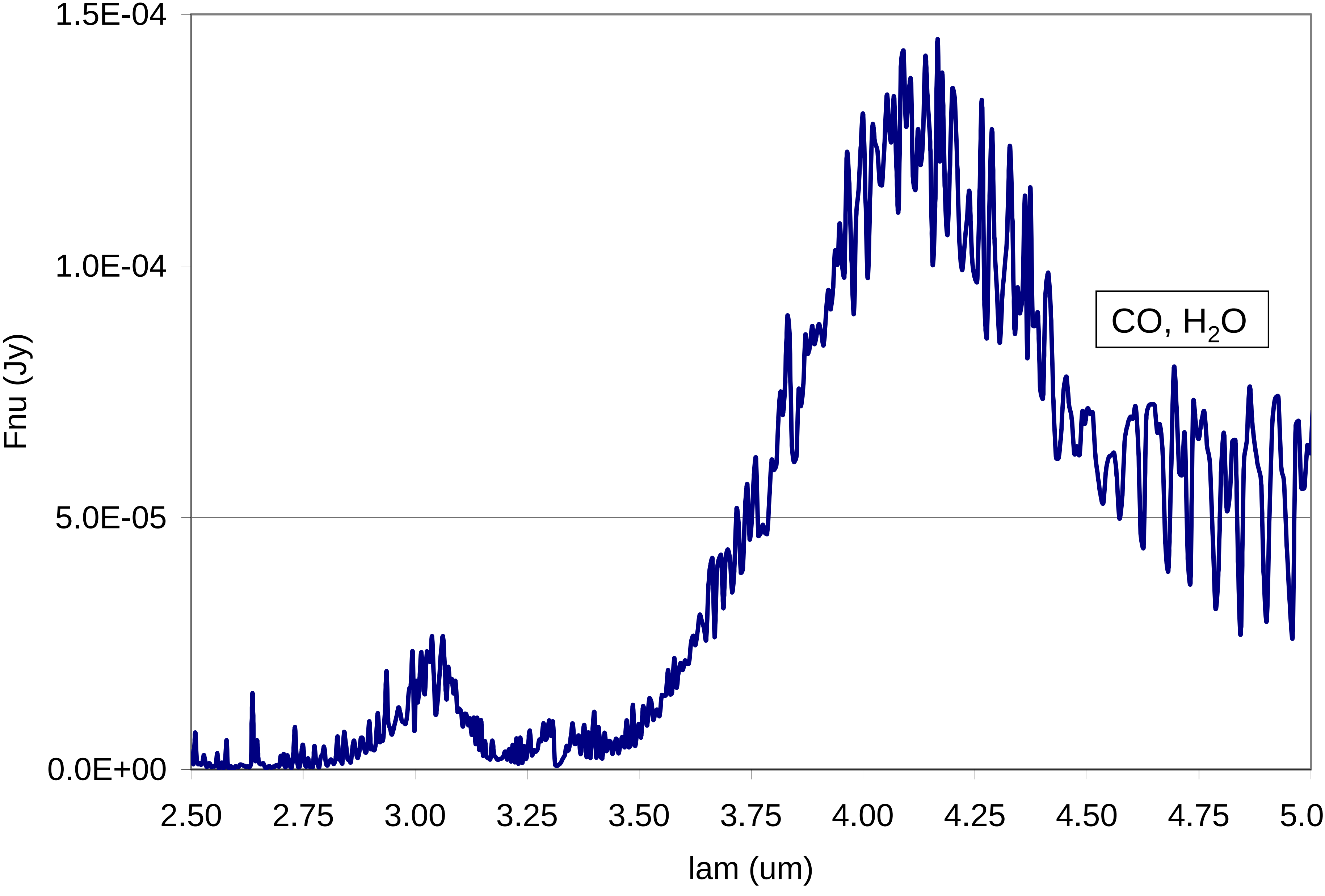
Jupiter	*M (mag)*			*Earth*	*M (mag)*	
Flat/mag	5	10	15	*Flat/mag*	5	10
1.0E-06	355.97	35.60	3.56	1.0E-06	2.96	0.30
1.0E-05	353.32	35.60	3.56	1.0E-05	2.94	0.30
1.0E-04	224.16	35.33	3.56	1.0E-04	1.85	0.29
1.0E-03	28.76	22.42	3.53	1.0E-03	0.24	0.19

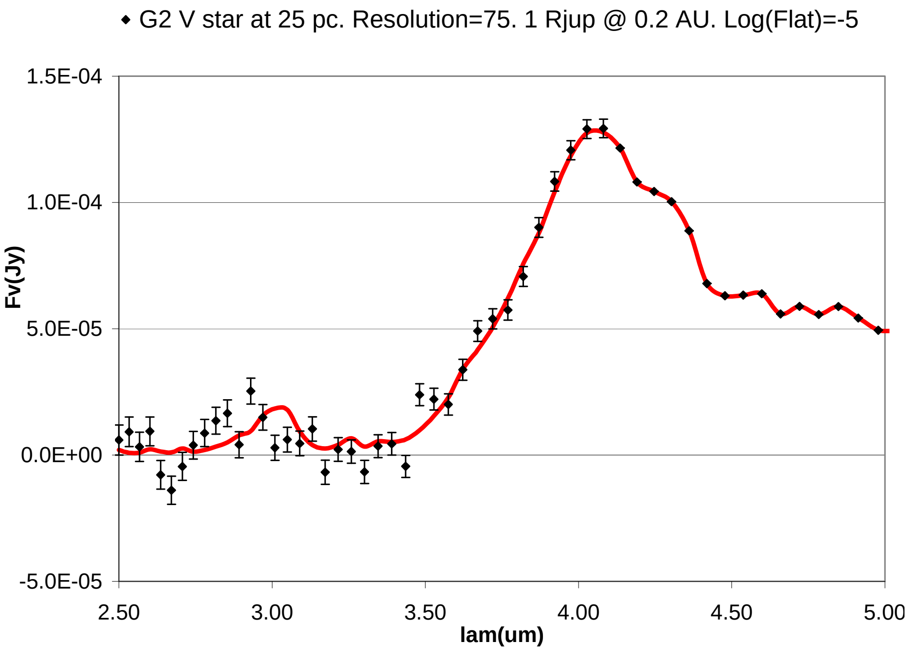
SNR for Secondary Eclipse of M3 V Star. R = 500; τ= 1,000 sec; T_{planet} = 1500K

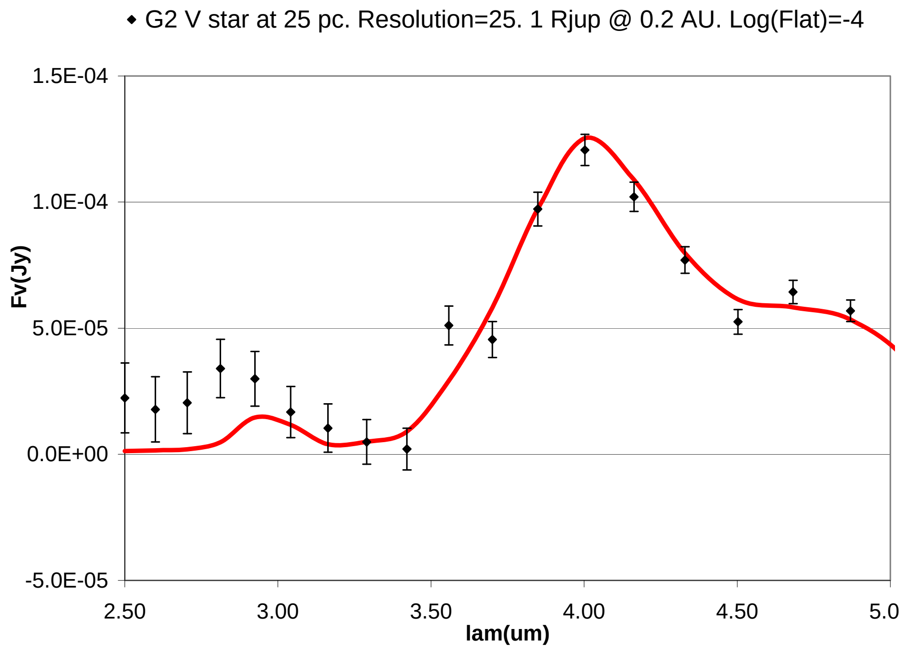
Jupiter	*M (mag)*			*Earth*	*M (mag)*	
Flat/mag	5	10	15	*Flat/mag*	5	10
1.0E-06	88.45	8.85	0.88	1.0E-06	0.75	0.07
1.0E-05	87.77	8.84	0.88	1.0E-05	0.74	0.07
1.0E-04	55.28	8.78	0.88	1.0E-04	0.47	0.07
1.0E-03	7.06	5.53	0.88	1.0E-03	0.06	0.05

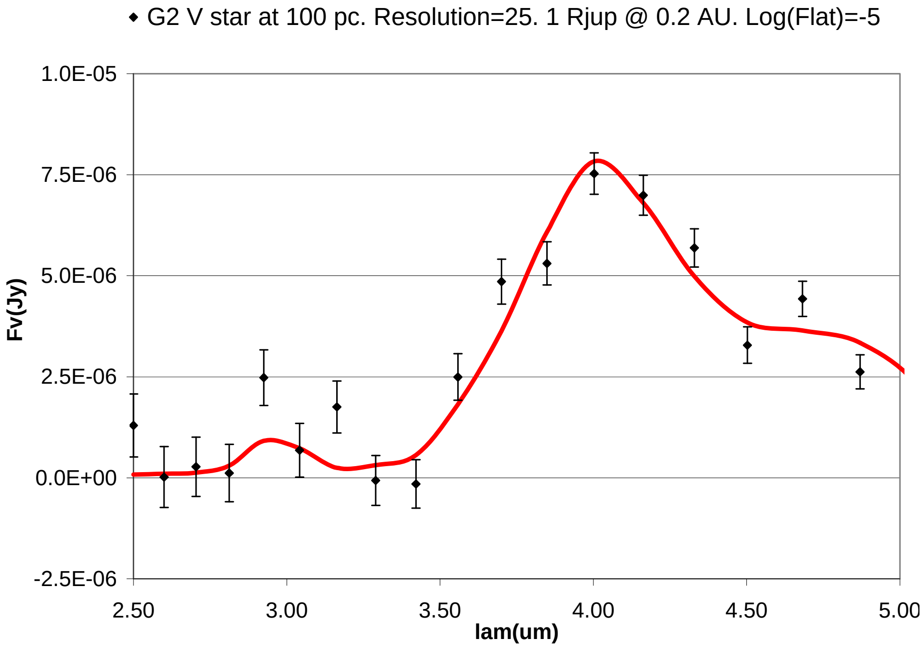
- High S/N R=500 spectra of a Jupiter around M2-3V stars can be observed via secondary eclipse.
- Secondary transits of Hot Earths around M5V stars could be detected at low SNR in R~50 spectra in ~10^4 sec.

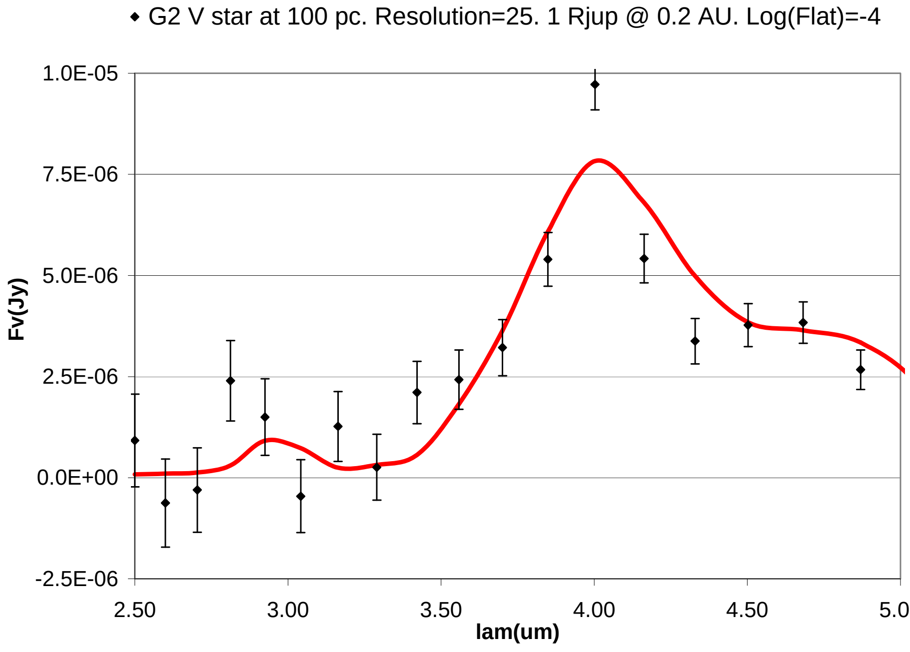
Jupiter at 0.2 AU from G2 Star (Burrows et al)




◆ G2 V star at 25 pc. Resolution=75. 1 Rjup @ 0.2 AU. Log(Flat)=-5
1.5E-04
1.0E-04
5.0E-05
0.0E+00
-5.0E-05
Fv(Jy)
2.50
3.00
3.50
4.00
4.50
5.00
lam(um)


◆ G2 V star at 25 pc. Resolution=25. 1 Rjup @ 0.2 AU. Log(Flat)=-4
1.5E-04
1.0E-04
5.0E-05
0.0E+00
-5.0E-05
Fv(Jy)
2.50
3.00
3.50
4.00
4.50
5.00
lam(um)


◆ G2 V star at 100 pc. Resolution=25. 1 Rjup @ 0.2 AU. Log(Flat)=-5
1.0E-05
7.5E-06
5.0E-06
2.5E-06
0.0E+00
-2.5E-06
Fv(Jy)
2.50
3.00
3.50
4.00
4.50
5.00
lam(um)


◆ G2 V star at 100 pc. Resolution=25. 1 Rjup @ 0.2 AU. Log(Flat)=-4
1.0E-05
7.5E-06
5.0E-06
2.5E-06
0.0E+00
-2.5E-06
Fv(Jy)
2.50
3.00
3.50
4.00
4.50
5.00
lam(um)

Summary

- NIRCam will be a versatile instrument capable of detecting “First Light” galaxies
- Recent additions to NIRCam such as long wavelength slitless grisms make it also capable of definitive planet studies
- NIRCam will contribute to many topics
- Both NIRCam and the entire JWST Project are making great progress towards a 2013 launch