Exoplanet Characterization with NIRSpec

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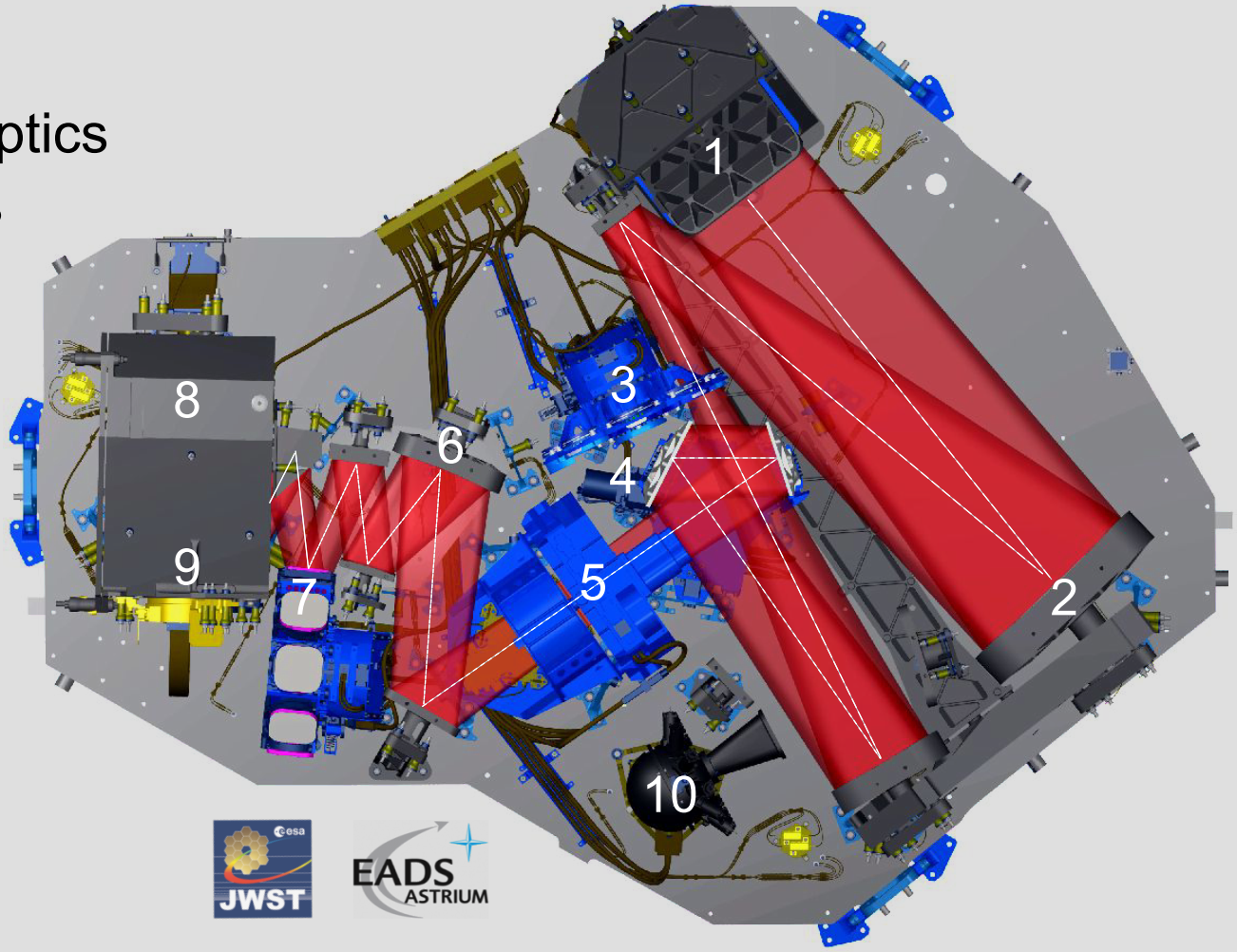
1. Coupling optics
2. Fore optics
3. Filters
4. Focus
5. Apertures
6. Collimator
7. Gratings
8. Camera
9. Detectors
10. Lamps

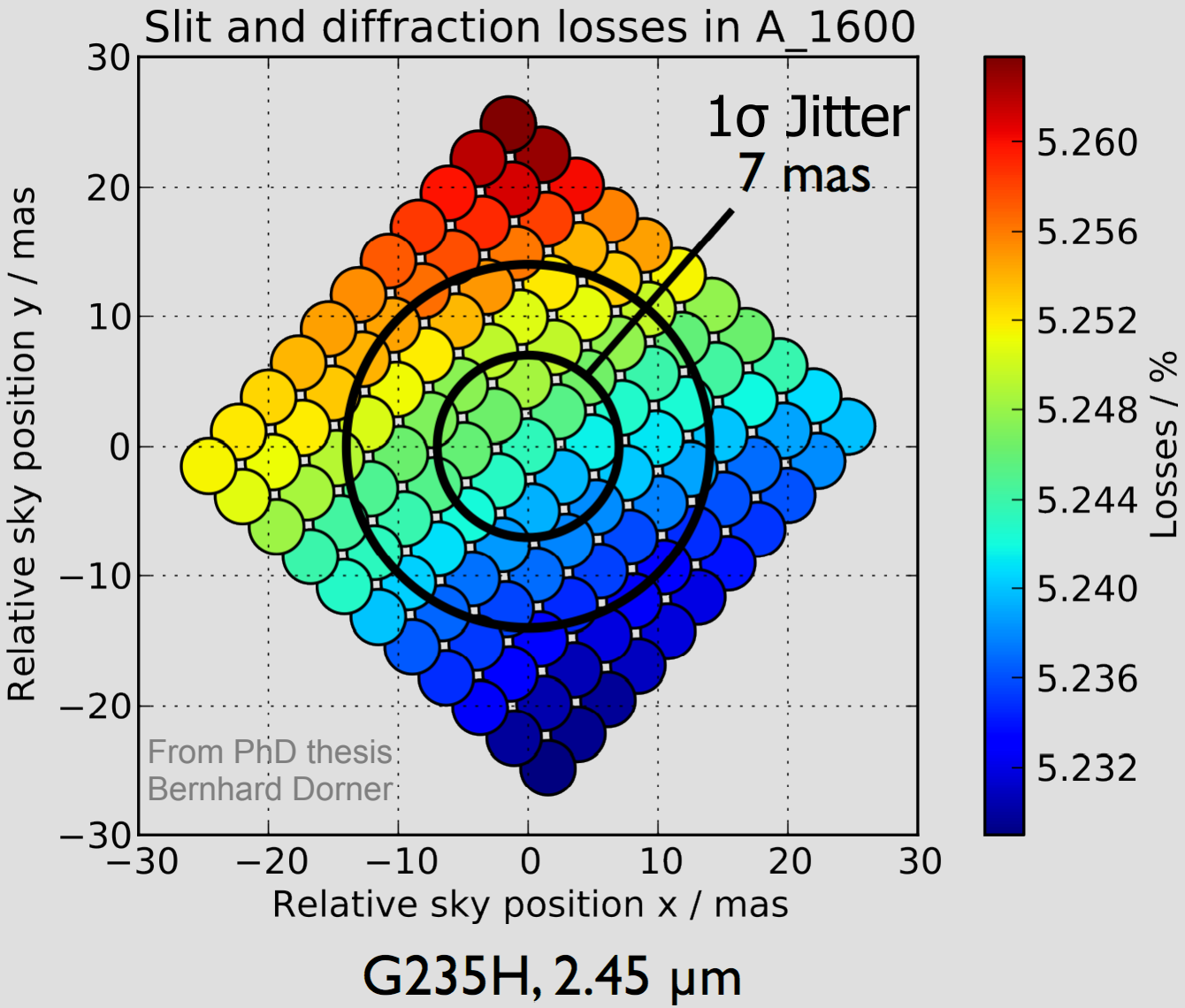


NIRSpec Apertures

Aperture	Spectral	Spatial
S1600	**1.6”**	**1.6”**
S400	0.4”	3.65”
S200	0.2”	3.2”
IFU	36 x 0.1”	3.6”
MSA	2 x 95”	2 x 87”

The **S1600** aperture was designed for exoplanet observations

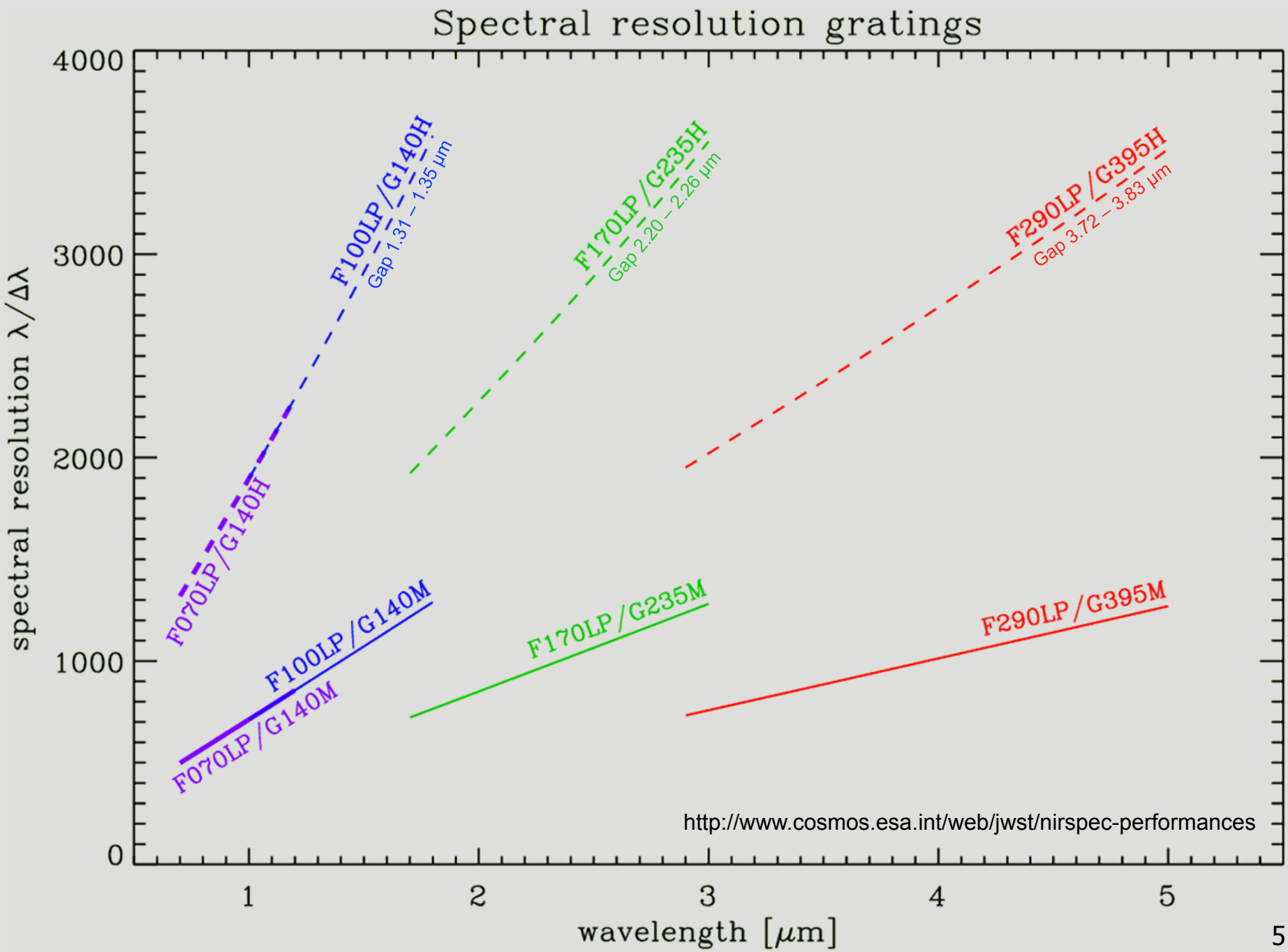
Noise Due to Jitter

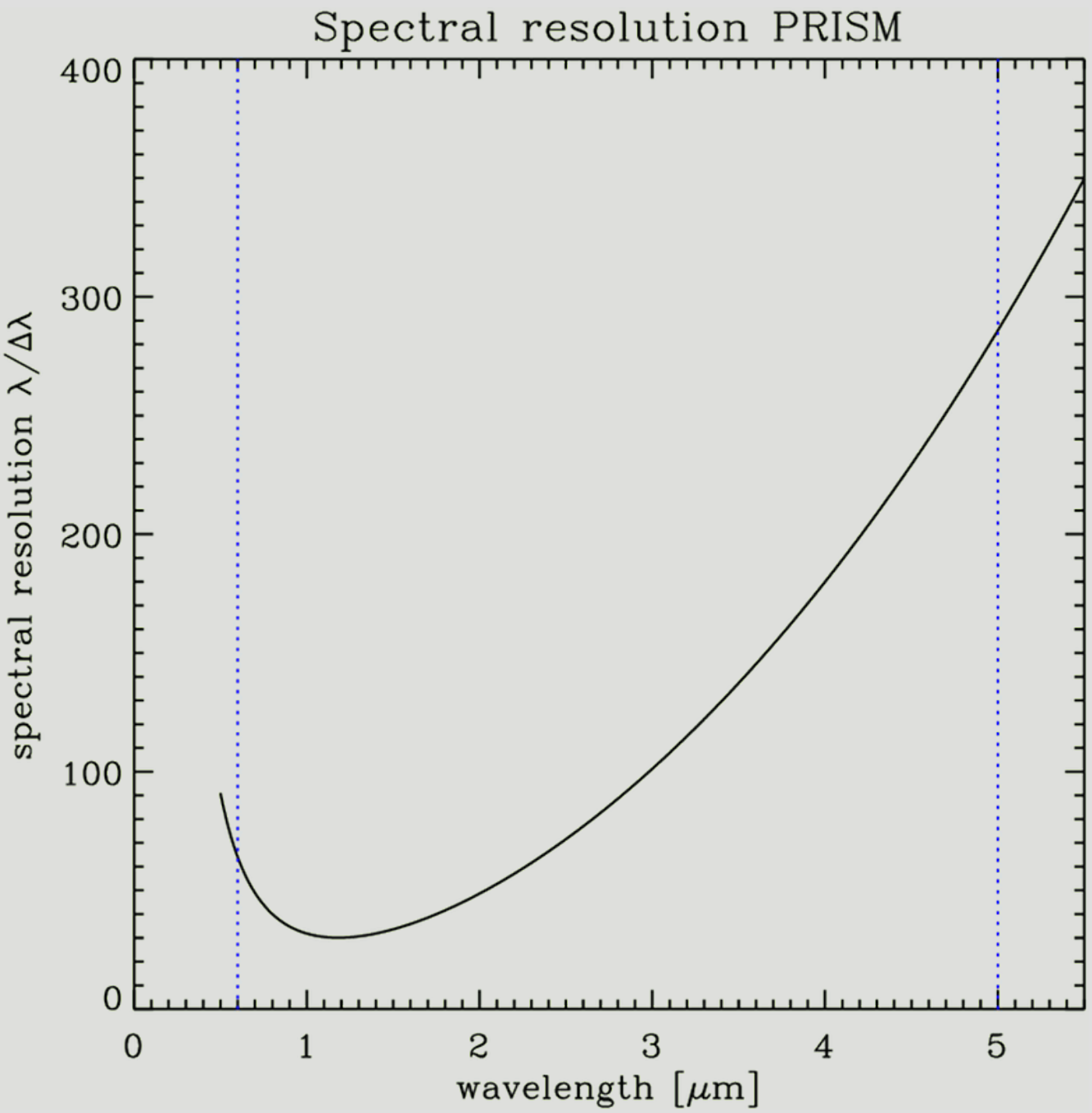


Jitter of **7 mas** causes relative noise of **4 x 10^{-5}**

NIRSpec Optical Configurations

Grating	Filter	Wavelengths	Resolution	
PRISM	CLEAR	0.6 – 5.0	30 – 300	“100”
G140M	F070LP	0.7 – 1.2	500 – 850	
	F100LP	1.0 – 1.8	700 – 1300	“1000”
G235M	F170LP	1.7 – 3.0		
G395M	F290LP	2.9 – 5.0		
G140H	F070LP	0.7 – 1.2	1300 – 2300	
	F100LP	1.0 – 1.8	1900 – 3600	“2700”
G235H	F170LP	1.7 – 3.0		
G395H	F290LP	2.9 – 5.0		


Spectral resolution gratings
spectral resolution λ/Δλ
wavelength [μm]
F100LP/G140H
Gap 1.31 – 1.35 μm
F170LP/G235H
Gap 2.20 – 2.26 μm
F290LP/G395H
Gap 3.72 – 3.83 μm
F070LP/G140H
F100LP/G140M
F070LP/G140M
F170LP/G235M
F290LP/G395M
http://www.cosmos.esa.int/web/jwst/nirspec-performances



http://www.cosmos.esa.int/web/jwst/nirspec-performances

Example of High-Resolution Model Spectra

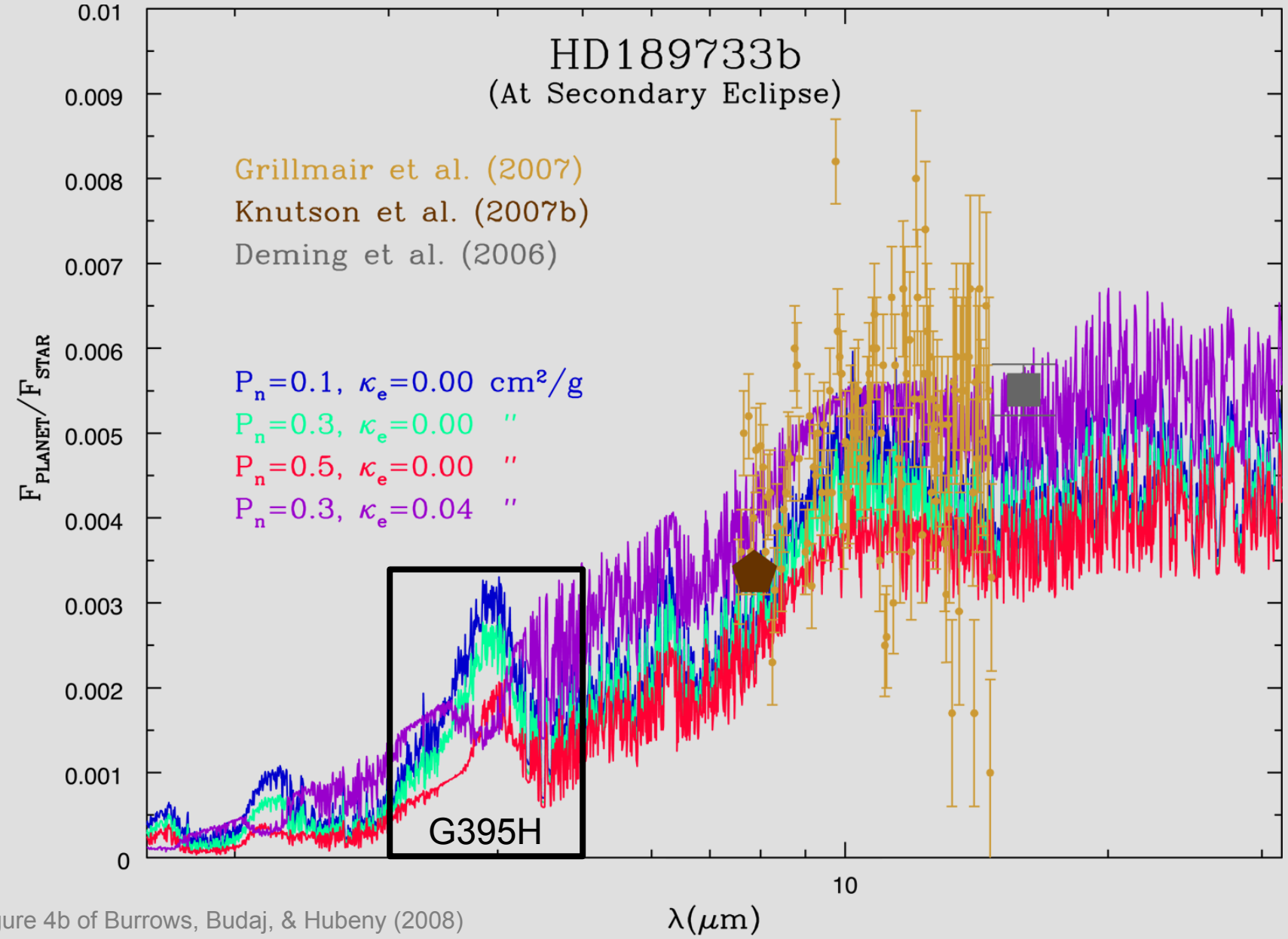
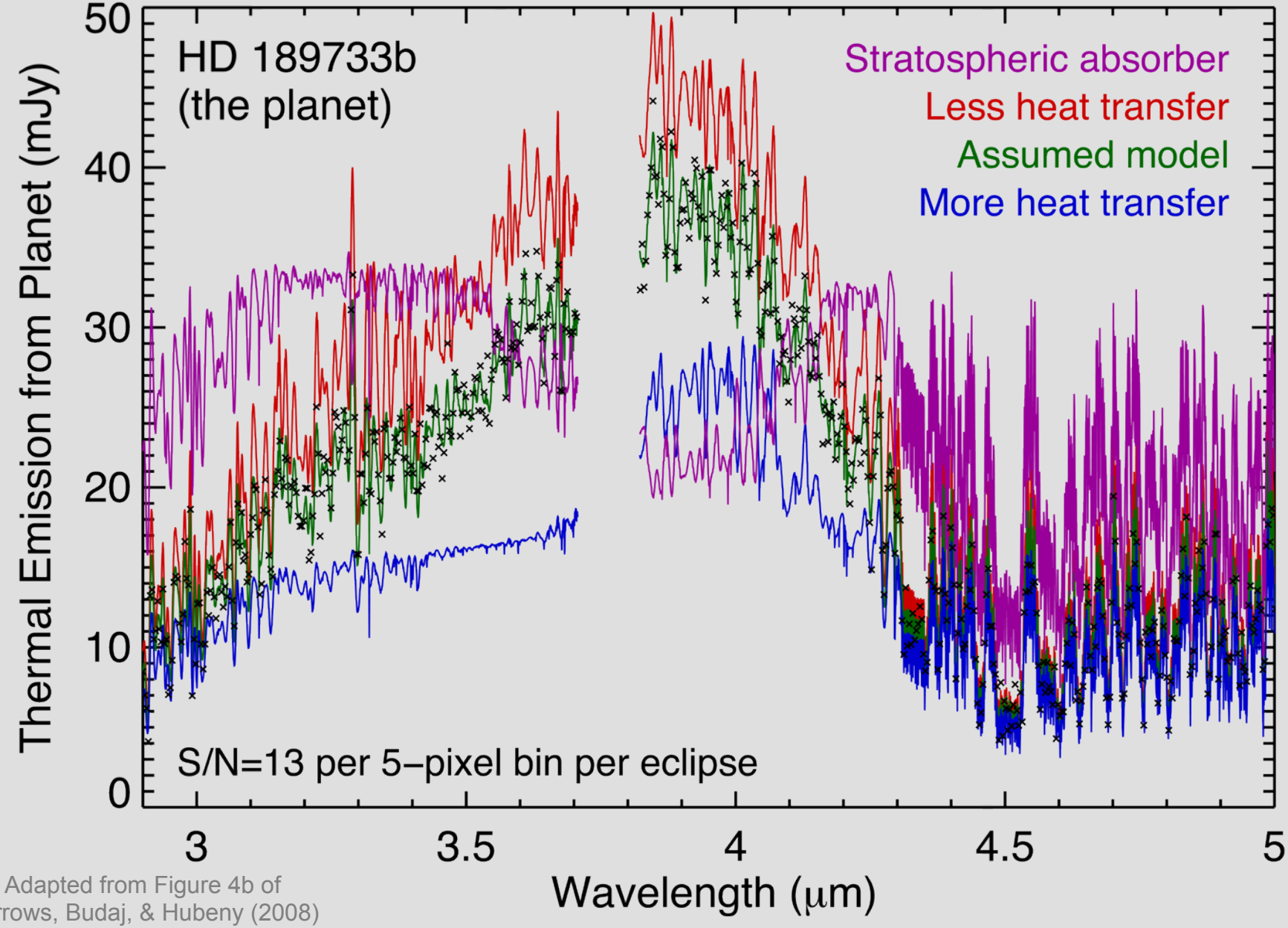


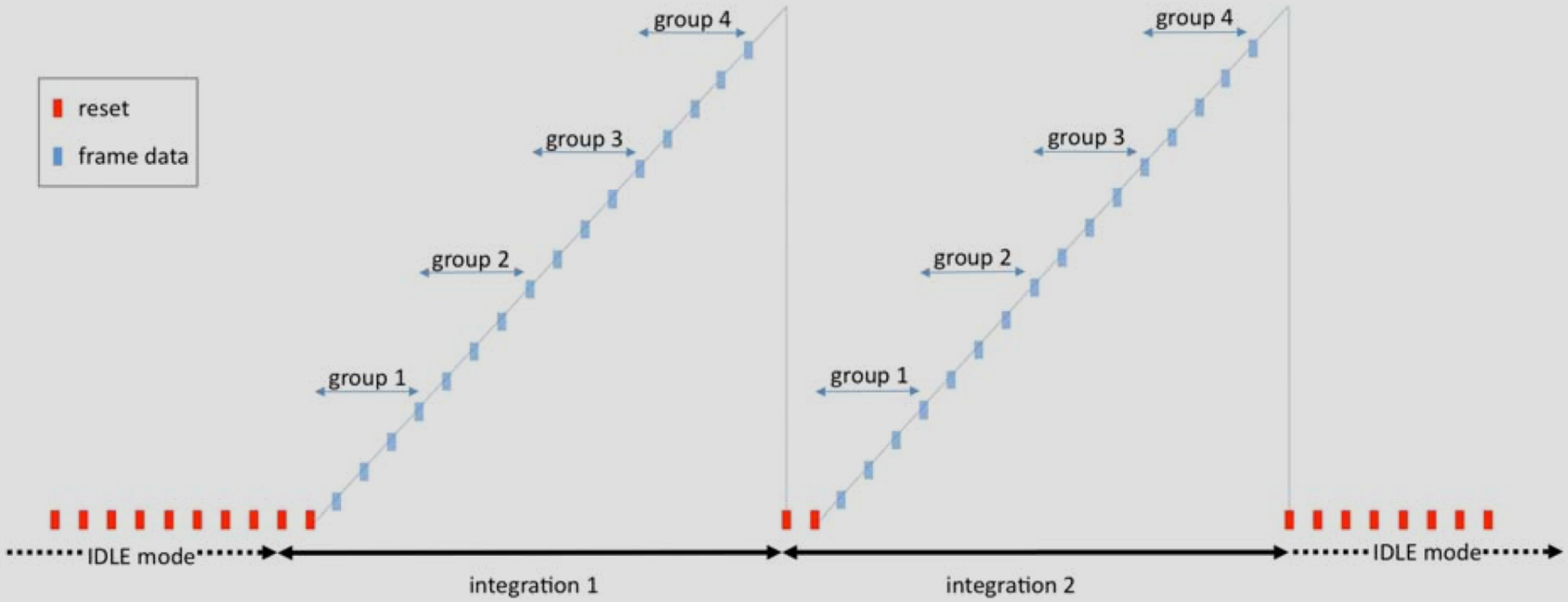
Figure 4b of Burrows, Budaj, & Hubeny (2008)

Thermal Emission from a Hot Jupiter



Adapted from Figure 4b of
Burrows, Budaj, & Hubeny (2008)

Integrations and Exposures



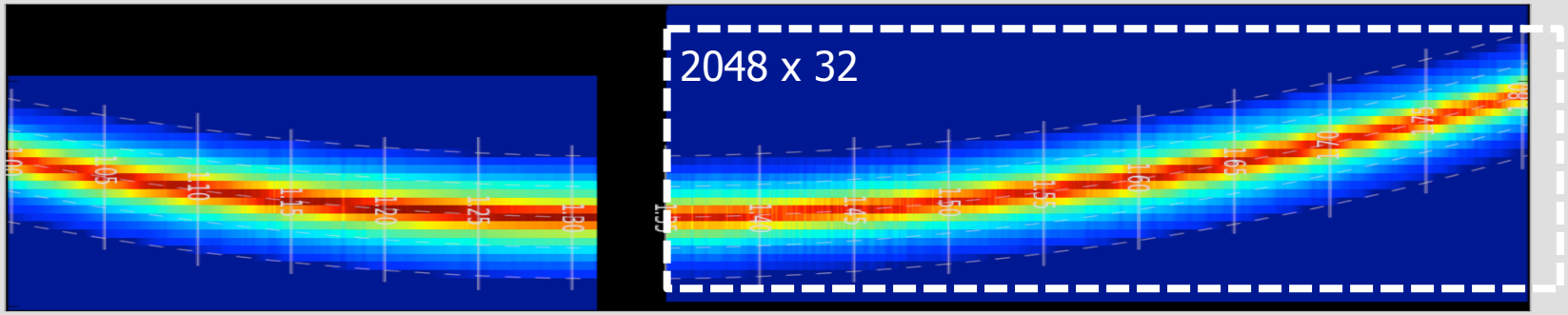
- An “exposure” is a sequence of integrations.
- An “integration” is a sequence of groups, sampled up-the-ramp
- One or more resets between integrations, but no other overheads
- Currently using pixel-by-pixel resets, but row-by-row possible

Subarrays

NX	NY	Frame time (s)	Notes
2048	512	10.74	Full frame, 4 amps
2048	256	5.49	All slits
2048	64	1.56	S200, S400 slits
2048	32	0.90	S1600 aperture
1024	32	0.45	Half wavelength coverage
512	32	0.23	Prism, no reference pixels

Frame time = 10 μs x (NY+12) x (NX+1) / nAmp

- Spectra are curved on detector, so NY=16 is not useful



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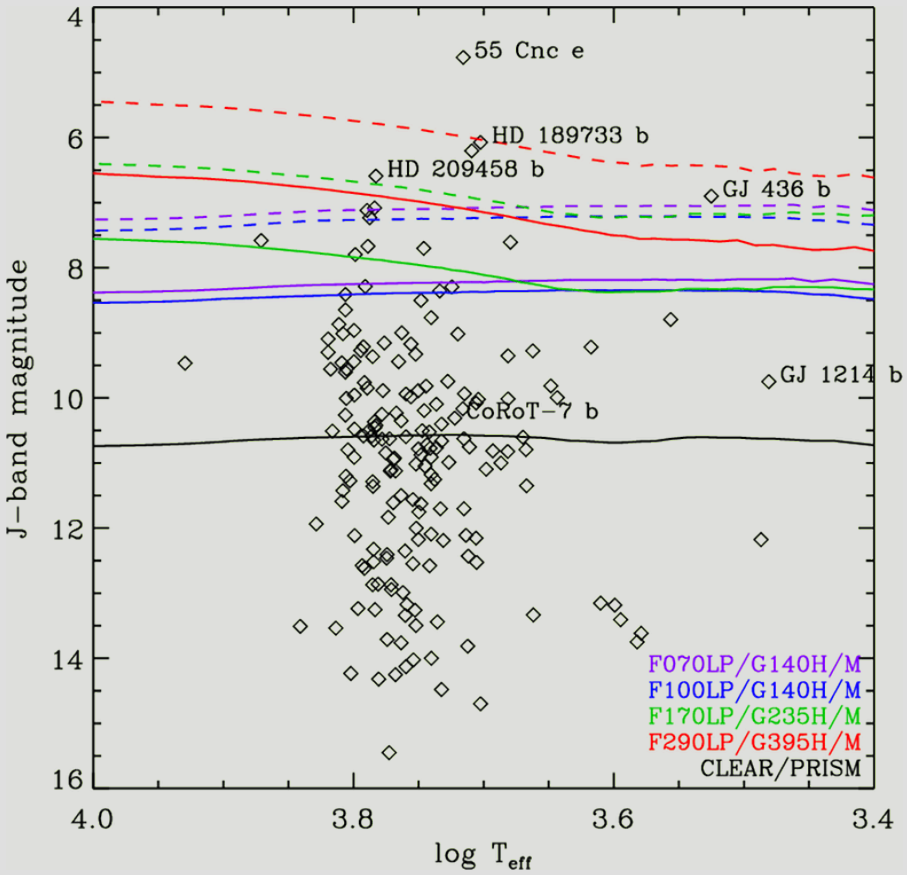
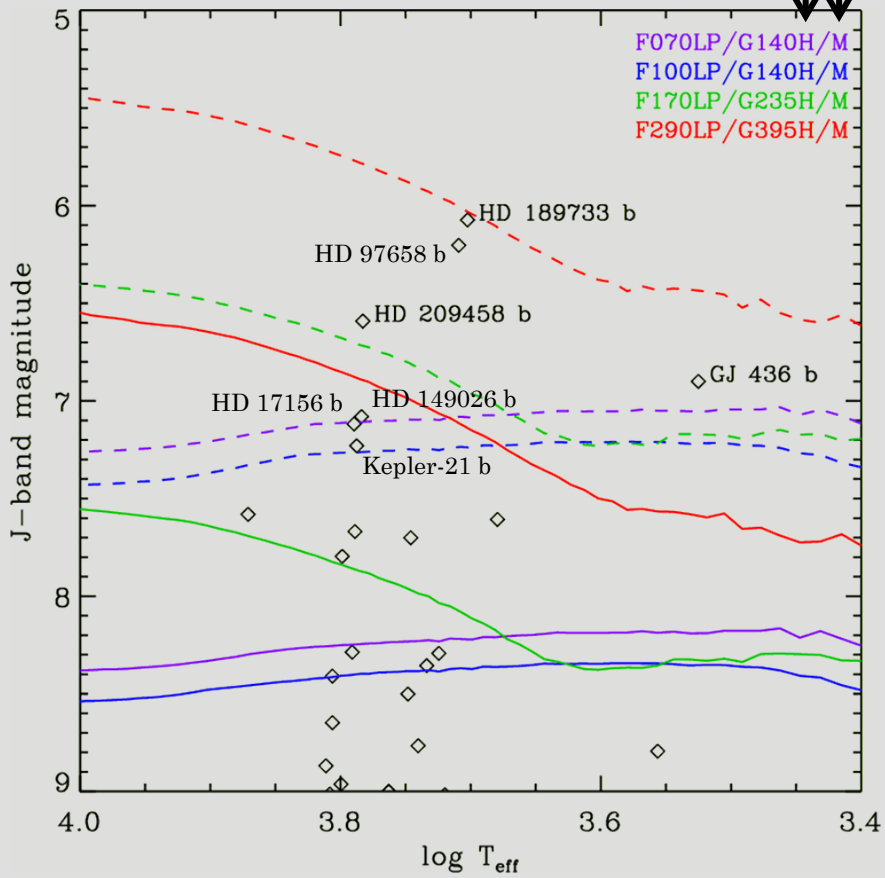
- Spectra are curved on detector, so NY=16 is not useful
- Frame time affects bright limit by 1 to 3.5 magnitudes
- Charge accumulates for at least 2 frame times (reset, read, read)
- Subarray size has at most 30% effect on data volume

Bright Limits versus J Band Magnitude

http://www.cosmos.esa.int/web/jwst/exoplanets

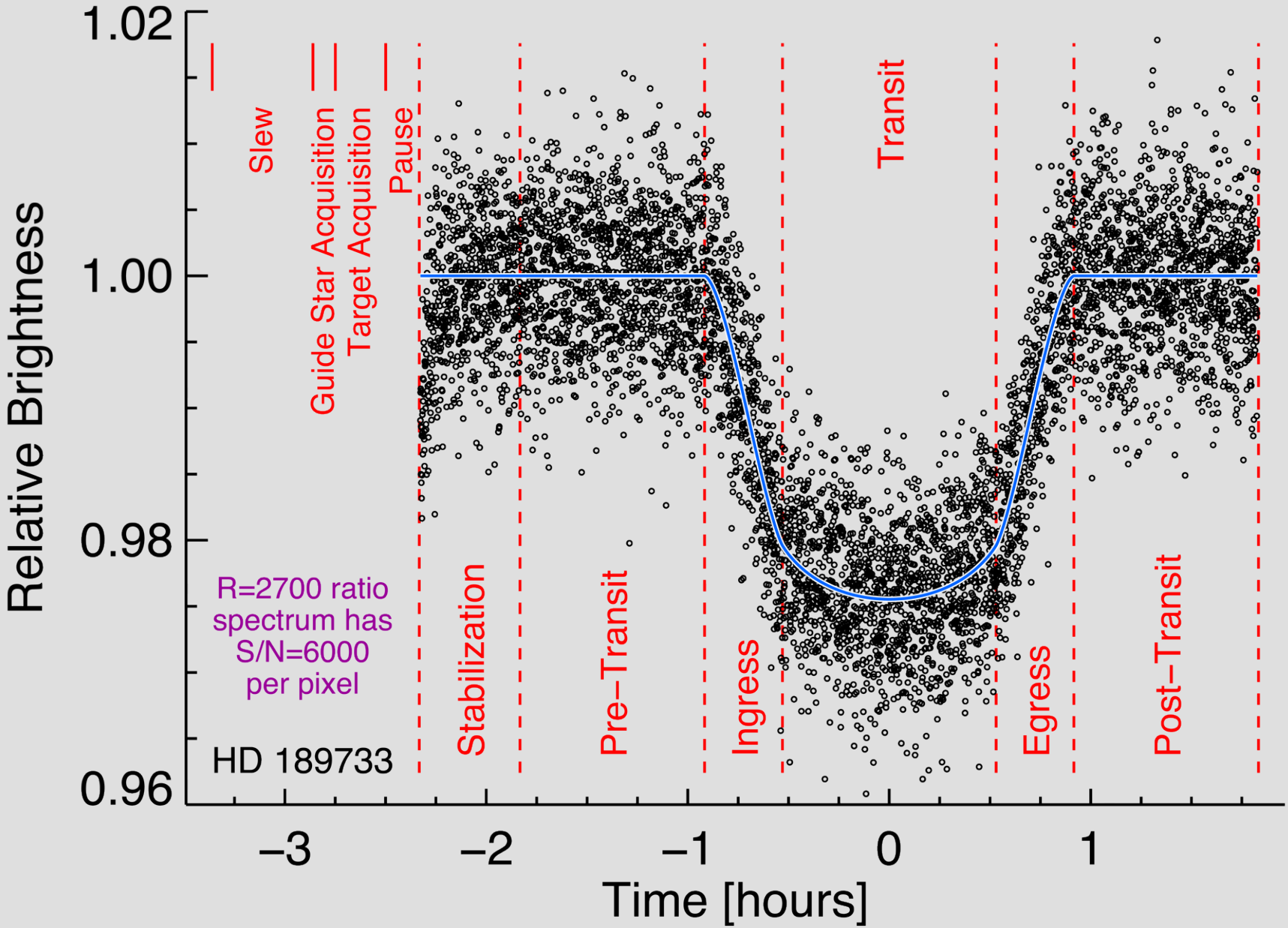


Dashed
Solid

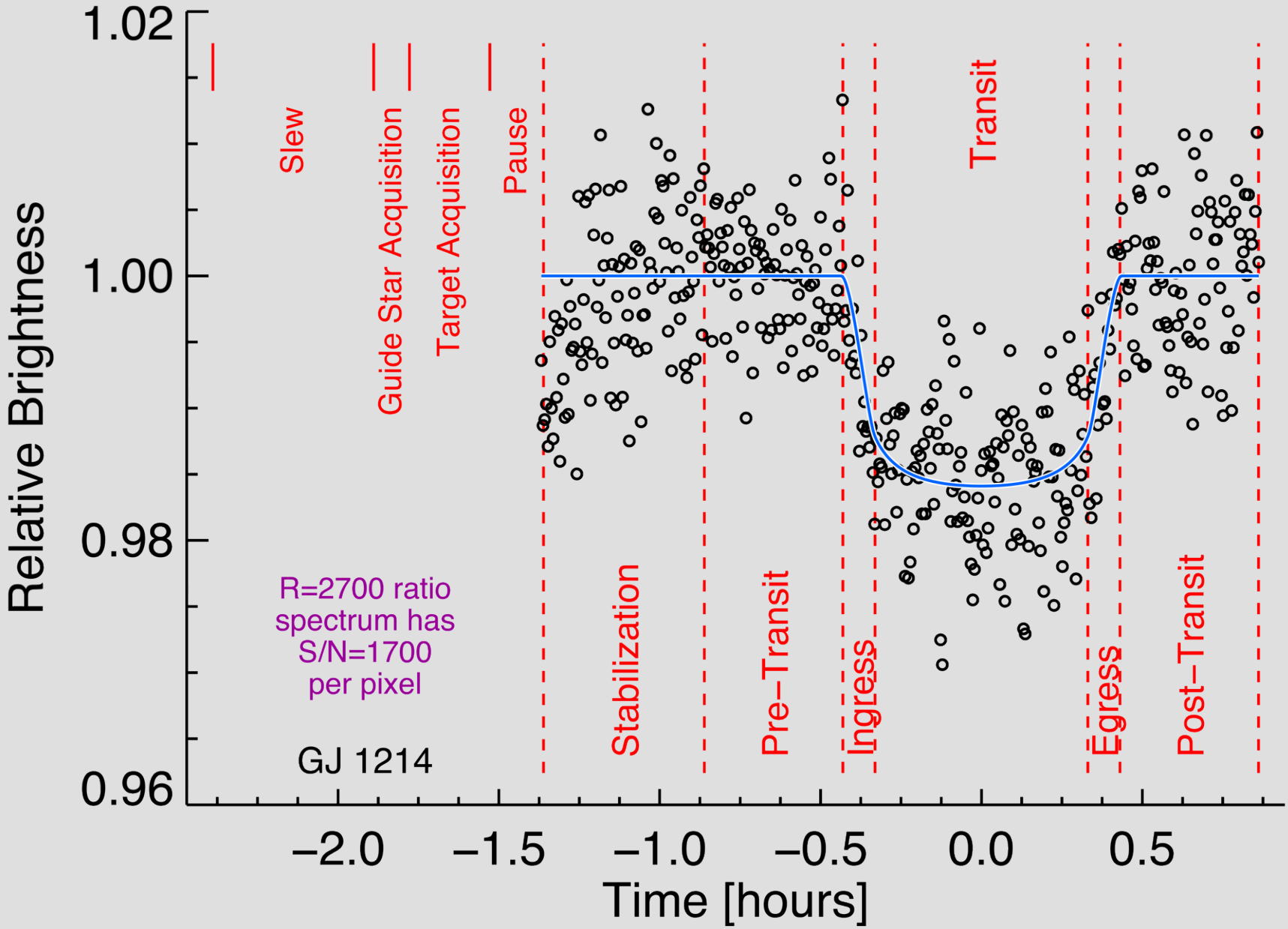


- 2048 x 32 subarray for gratings, 512 x 32 subarray for prism
- Assumes full well of 77,000 electrons
- Plotted limits are 5% fainter than prediction based on ground tests

Timeline of a Transit Observation



GJ 1214


Relative Brightness
1.02
1.00
0.98
0.96
Slew
Guide Star Acquisition
Target Acquisition
Pause
Stabilization
Pre−Transit
Ingress
Transit
Egress
Post−Transit
R=2700 ratio spectrum has S/N=1700 per pixel
GJ 1214
−2.0
−1.5
−1.0
−0.5
0.0
0.5
Time [hours]

Disturbances

- Target drift during exposure
  - Drift required to be at most 0.01 arcsec (0.1 pixel) in 3 hours
  - Mainly a roll error, which moves target perpendicular to dispersion
- Repoint high-gain antenna
  - Every 3 hours, 0.1 arcsec amplitude, 1 minute duration
  - Continue integration sequence, discard bad data during analysis
- Break long time series into separate exposures
  - Every 65535 integrations (12 hours for prism, 49 hours for gratings)
  - Commanding overhead (15 seconds), thermal and electrical transients
- Break long time series into separate visits
  - Maximum visit duration is nominally 1 day to allow momentum dump
  - Require new acquisitions: guide star (6 minutes), target (12 minutes)
  - Spectrum jumps on detector because grating wheel does not repeat