Sinergies with space missions

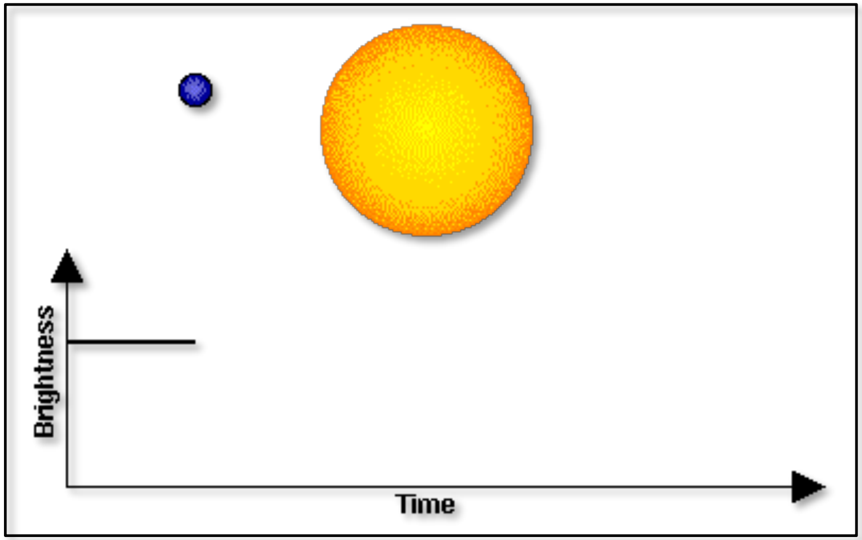
CHEOPS
JWST
~~PLATO~~

D. Barrado

EXCELENCIA MARÍA DE MAEZTU

Planet characterization

SPACE
Transit Method

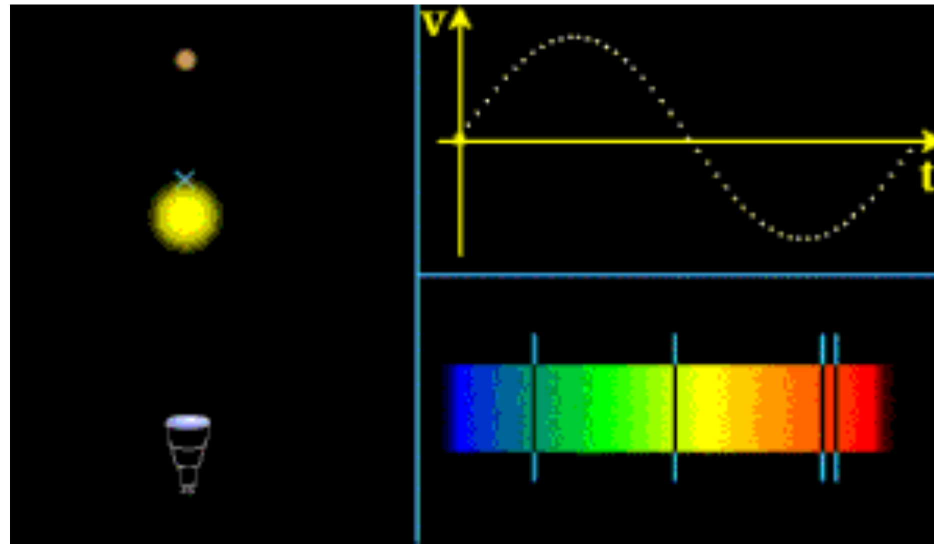


→ Orbital parameters

→ Orbital inclination, ***i***

→ Planet radius

CARMENES
Radial velocity method



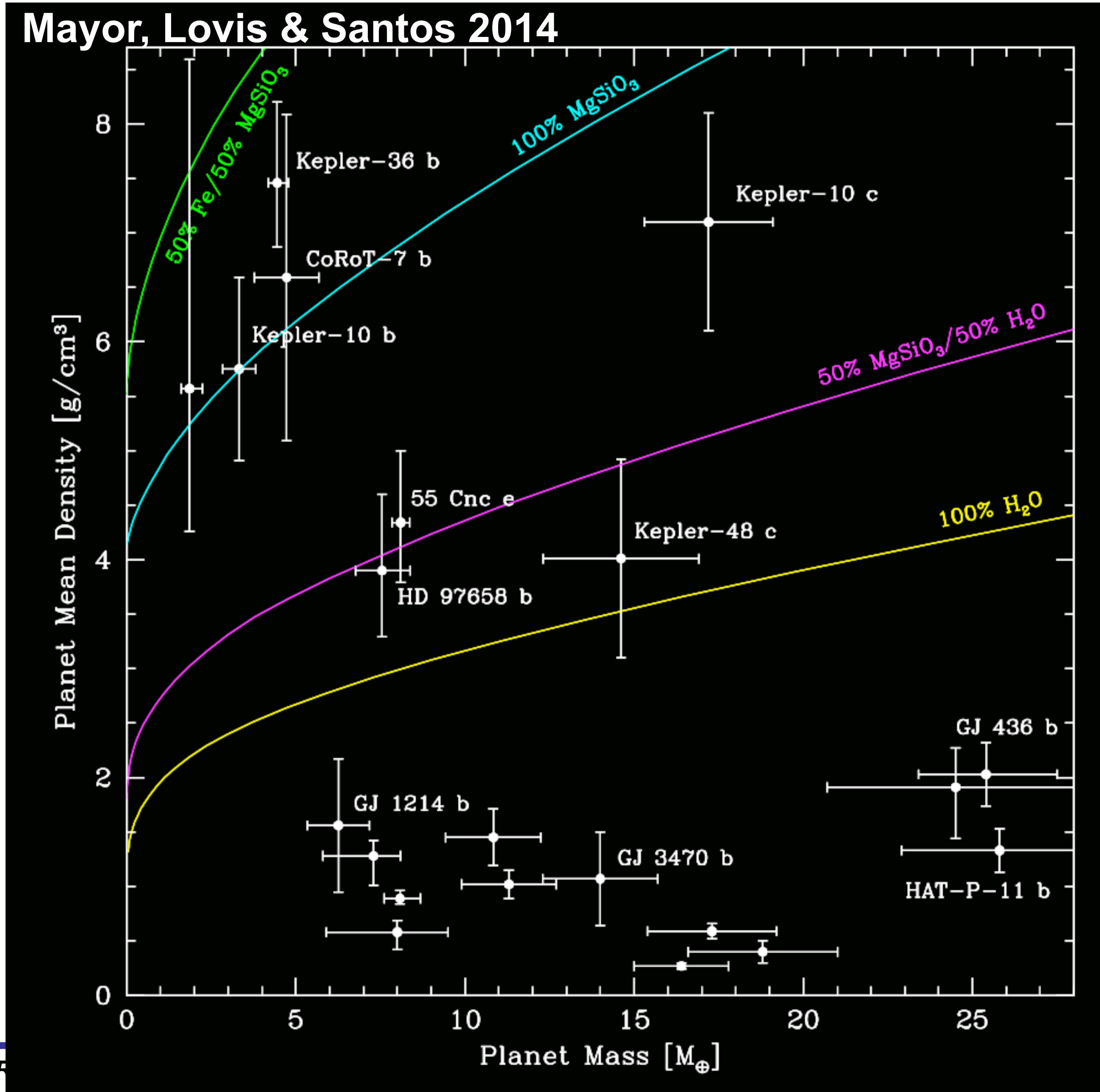
→ Orbital parameters

→ Minimum planet mass, ***m* sin *i***

True planet mass and mean density

Atmospheric studies

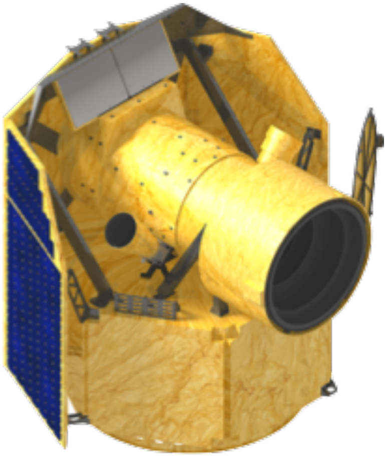
Mass-density diagram



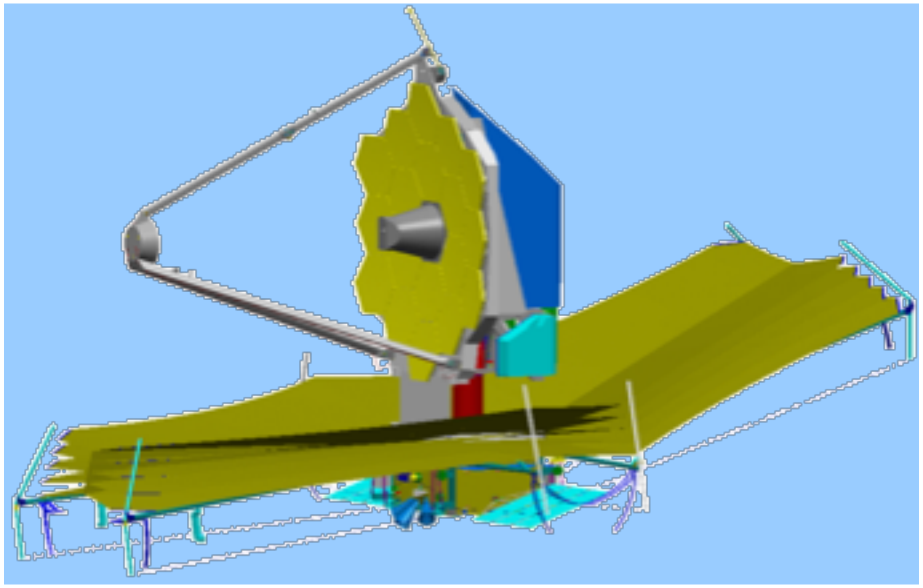
Targets: Bright stars

Better knowledge of the stars
Better knowledge of the planets

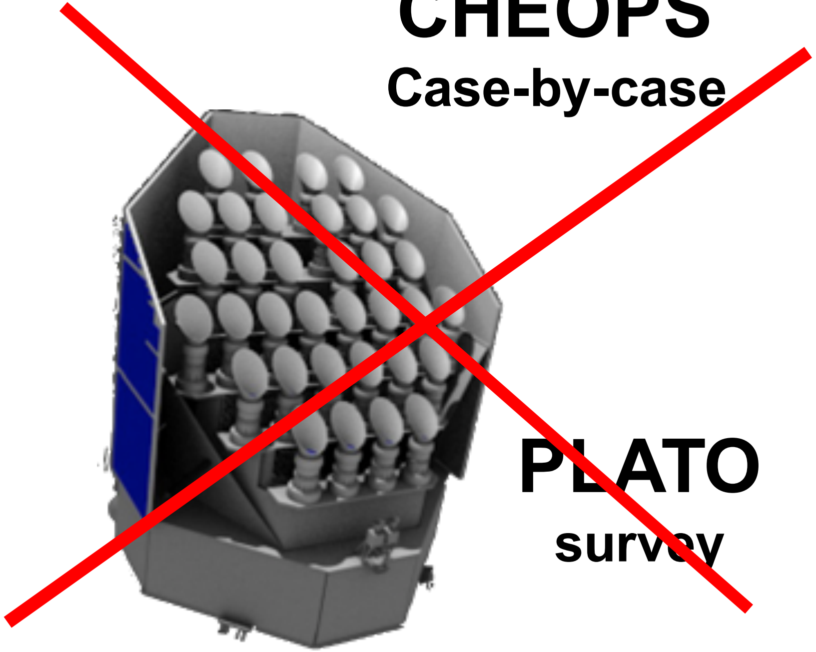
TESS
survey



CHEOPS
Case-by-case



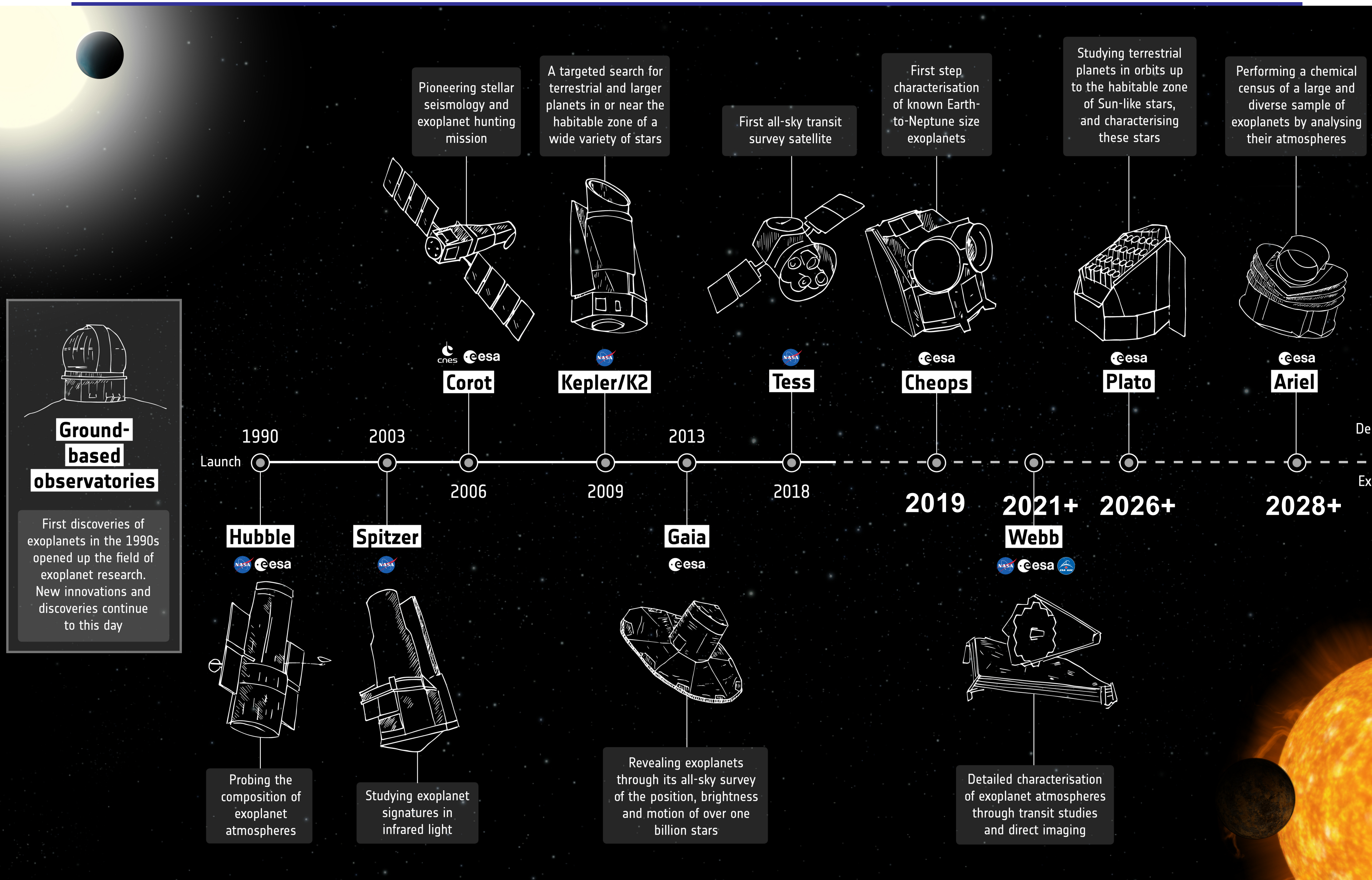
JWST
Case-by-case



~~**PLATO**~~
~~**survey**~~

EXCELENCIA
MARÍA
DE MAEZTU

Space missions: time-line



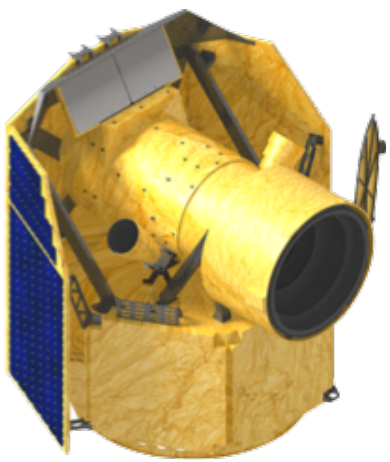
CHEOPS

CHEOPS science goals

What *CHEOPS* will do:

➡ **Perform 1st-step characterisation of super-earths & neptunes** ***by measuring accurate radii & bulk densities for such planets orbiting bright stars***

➡ **Provide golden targets for future atmospheric characterisation** ***by finding the planets most amenable***



How *CHEOPS* will do it:

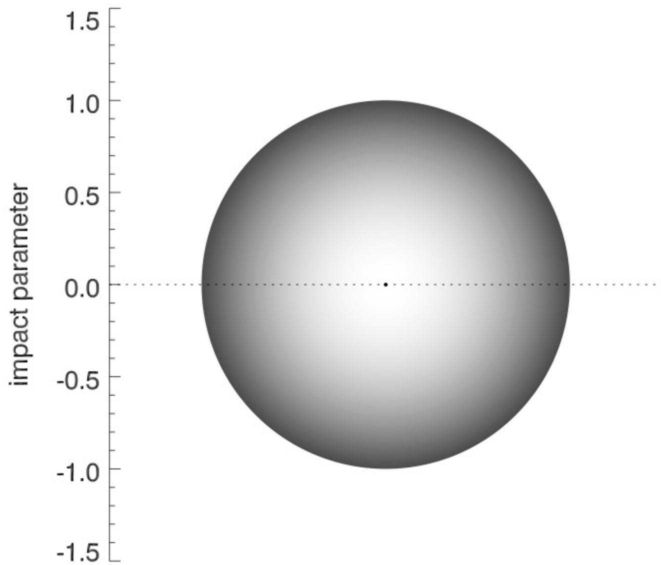
➡ **High-precision photometry**

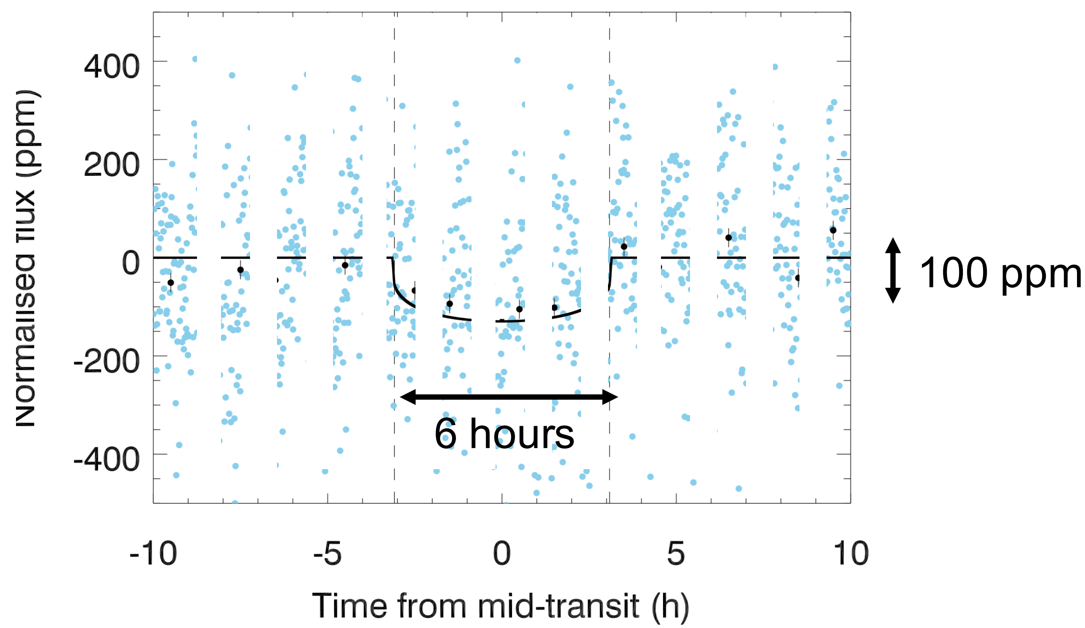
➡ **Achieve a photometric precision similar to *Kepler***

➡ **Observing brighter stars anywhere**

Photometric precision

Detection of super-earths transiting bright stars (6<*V*<9)



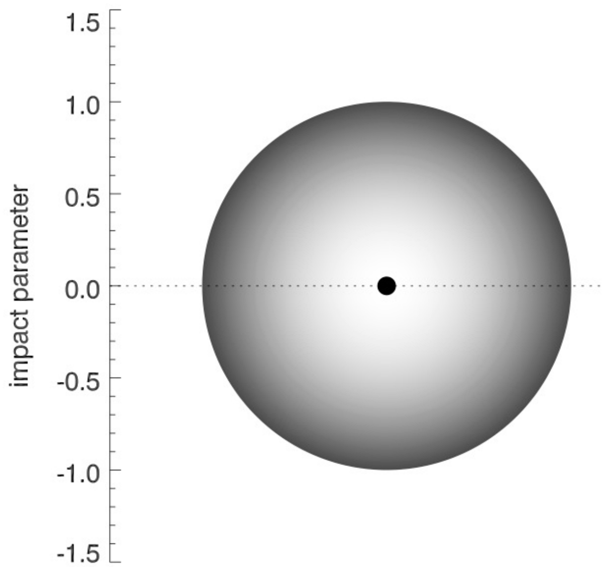


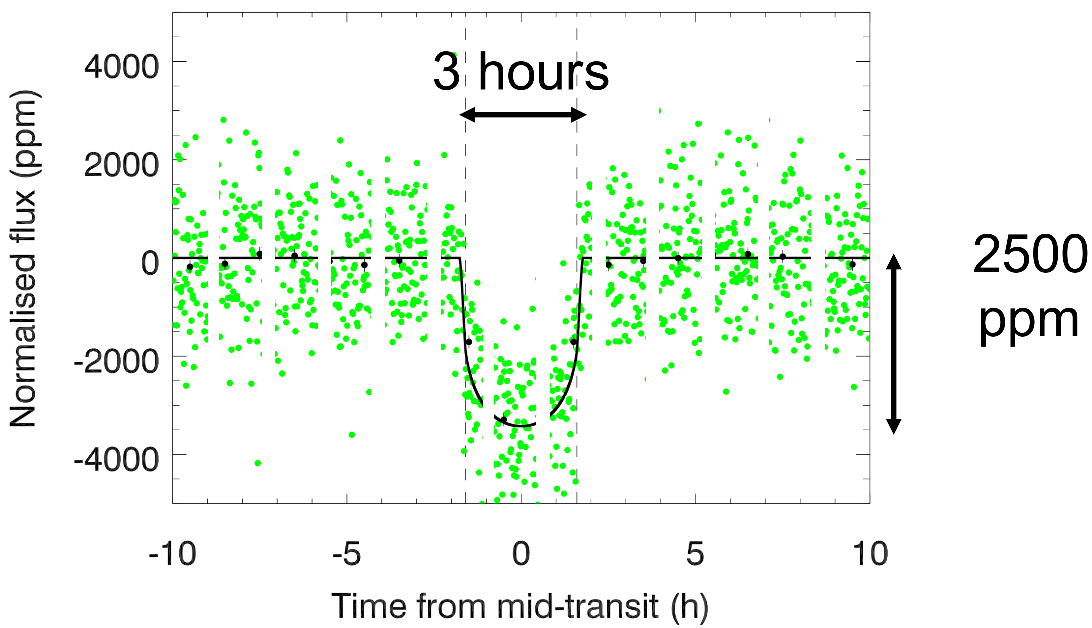
Bulk density to 30%
➡ radius to 10%
➡ transit depth to 20%
➡ *S/N*$_{\text{transit}}$ = 5

➡ 20 ppm accuracy over 6 hours for G-type stars with *V* < 9 (tolerating 50% interruptions)

Photometric precision

Characterisation of neptune transit light curves (9<*V*<12)





Best possible parameters
- ➡ **radius to R★**
- ➡ **transit depth to <5%**
- ➡ ***S/N*transit = 30**

➡85 ppm accuracy over 3 hours for K-type stars with *V* < 12 (tolerating 20% interruptions)

JWST

The JWST Mission

Themes:

- First Light (after the Big Bang)
- Assembly of Galaxies
- Birth of Stars and Protoplanetary Systems
- Planetary Systems and the Origins of Life

JWST will offer:

- Imaging from **0.6 to 28 micron**.
- Coronagraphic imaging from 0.6 to 28 micron.
- Spectro-coronagraphy at R=100 from 1.2 to 5 micron.
- Low resolution spectroscopy from 0.6 to 10 micron.
- Medium resolution spectroscopy from 1 to 28 micron with multi-object capability between 1 and 5 mm and integral field capability over the whole range.

LAUNCH: no sooner March 2021

INSTRUMENTS

(FGS)/NIRISS.- Short (1.2-2.4 micron) and long (2.5-5 micron) wavelength channels. *The instantaneous observed bandpass will be R~ 100 with a limiting sensitivity of Mag(AB)=25 at S/N=10 in 10,000 seconds*. Coronagraphic capabilities.

NIRCam.- Short (0.6-2.3micron) and long (2.4-5.0micron) wavelength. Coronograph. *Sensitivity: The NIRCam limiting sensitivity to point sources with S/N=10 in 10,000 seconds is Mag(AB)=28.69 in F110W and Mag(AB)=28.86 in F200W.*

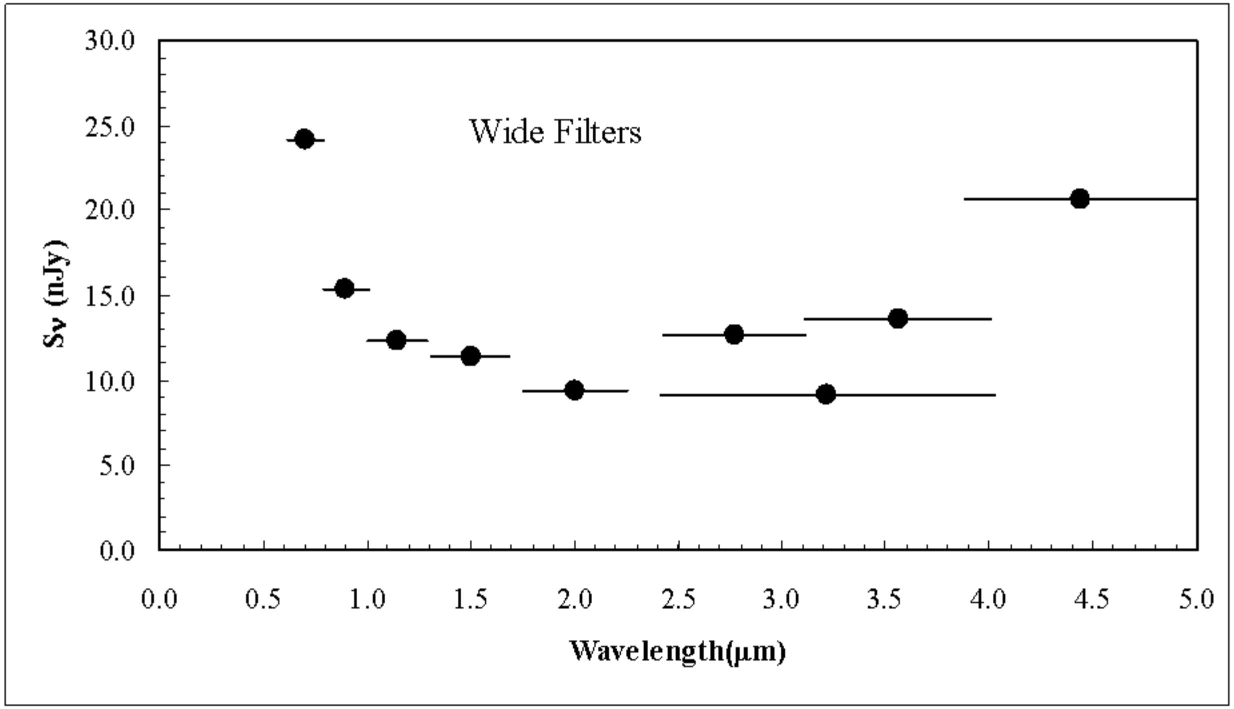
NIRSpec.- Near infrared multi-object dispersive spectrograph capable of simultaneously observing more than 100 sources over a 3x3arcmin FOV. *Sensitivity: 10,000 sec, point source, 3 micron, S/N=10 Mag(AB)=26.2. For emission lines at R=1000, 2 micron, 100,000 seconds is flux limit =* 5.2×10^{-19} *erg* cm^{-2} s^{-1}.

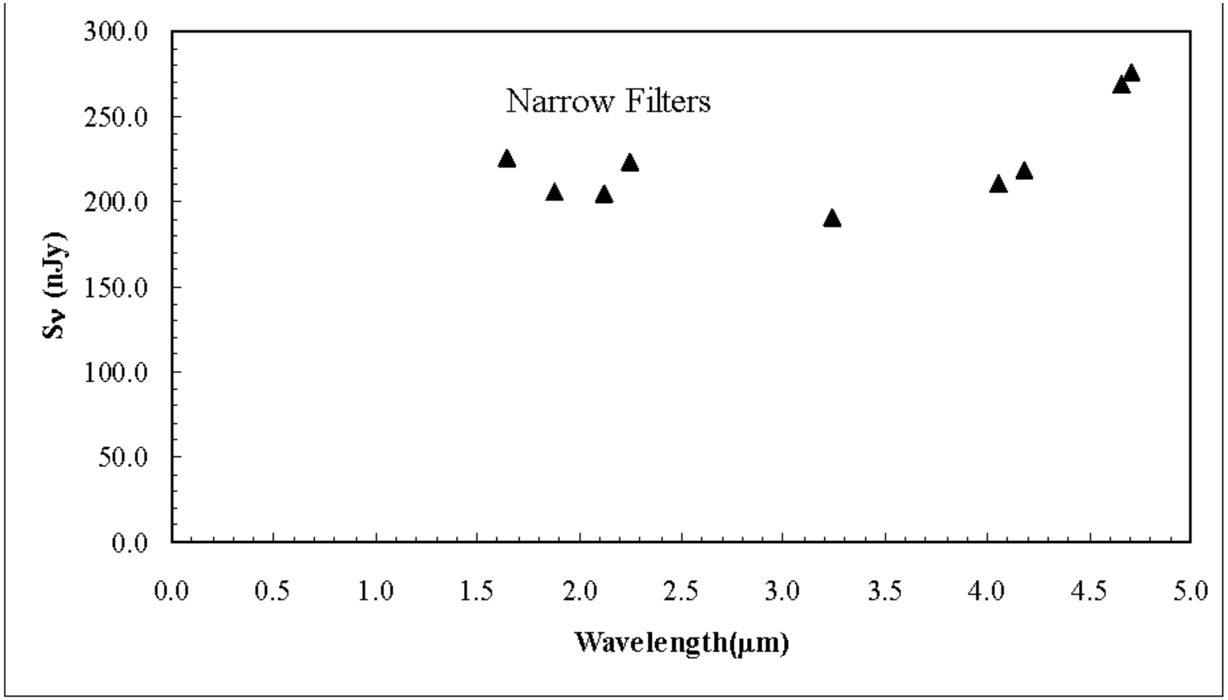
MIRI.- Imaging and spectroscopic measurements over the wavelength range 5-27micron. Sensitivity: *Limiting sensitivity in imaging at 10 and 20* micron *(S/N=10, 10,000 sec) are, respectively, Mag(AB)=24.53 and Mag(AB)=22.15. The limiting flux in 10,000 seconds for a resolving power of R=2400 and at 9.2*micron *is* 3.4×10^{-18} *erg* cm^{-2} s^{-1}.

JWST: instruments

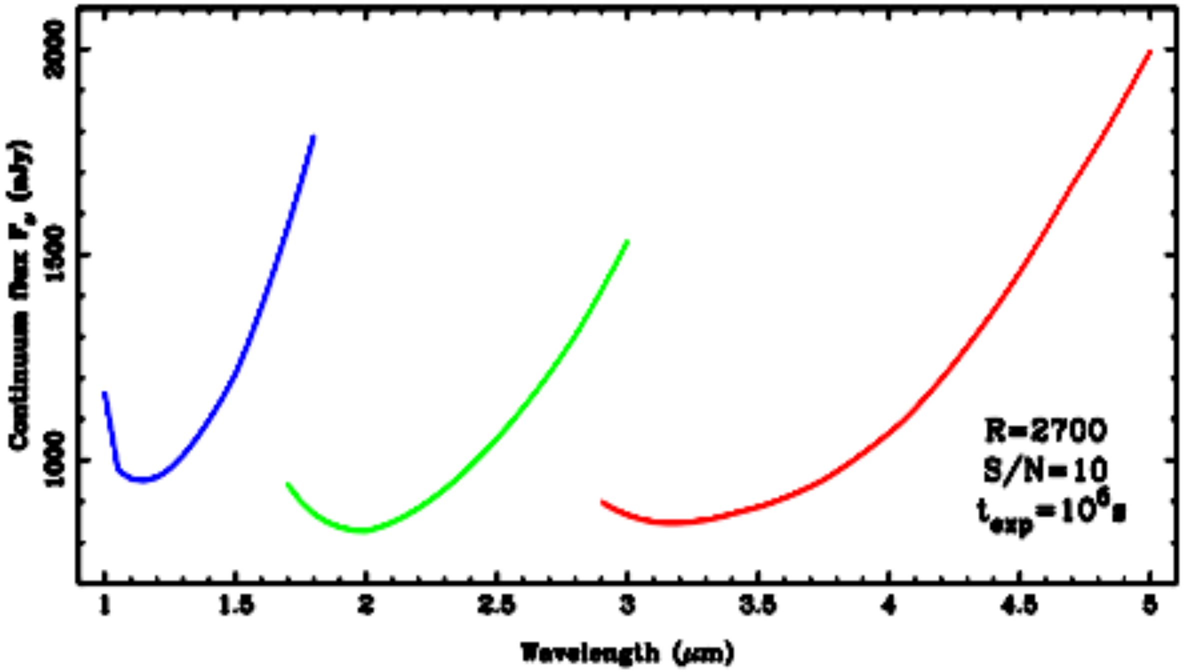
Instrument	Wavelength (μm)	Optical Elements	FPA	Plate Scale (milliarcsec/ pixel)	Field of View
NIRCam (Short Wave)	0.6 - 2.3	fixed filters (R~4, R~10, R~100), coronagraphic spots	Two 2×2 mosaics of 2048x2048 arrays	32	2.2′×4.4′
NIRCam (Long Wave)[1]	2.4 - 5.0	fixed filters (R~4, R~10, R~100), coronagraphic spots	Two 2048×2048 arrays	65	2.2′×4.4′
NIRSpec (prism, R=100)	0.6 - 5.0	transmissive slit mask: 4x384x175 micro-shutter array, 250 (spectral) by500 (spatial) milliarcsec; fixed slits 200 or 300 mas wide by 4″long	Two 2048×2048 arrays	100	3.4′×3.1′
NIRSpec (grating, R=1000)	1.0-5.0				
NIRSpec (IFU, R=3000)	1.0-5.0	integral field unit			3.0″×3.0″
MIRI (imaging)	5 - 27	broad-band filters, coronagraphic spots & phase masks	1024×1024	110	1.4′×1.9′ (26″×26″ coronographic)
MIRI (prism spectroscopy)	5 - 10	R ~ 100			
MIRI (spectroscopy)	5 - 27	integral field spectrograph (R~3000) in 4 bands	Two 1024×1024 arrays	200-470	3.6″×3.6″ to 7.5″×7.5″
Short-wavelength FGS-TF	1.2 - 2.4	Order-blocking filters+etalon (R~100)	2048×2048	68	2.3′×2.3′
Long-wavelength FGS-TF[2]	2.5 - 5.0	Order-blocking filters+etalon (R~100)	2048×2048	68	2.3′×2.3′

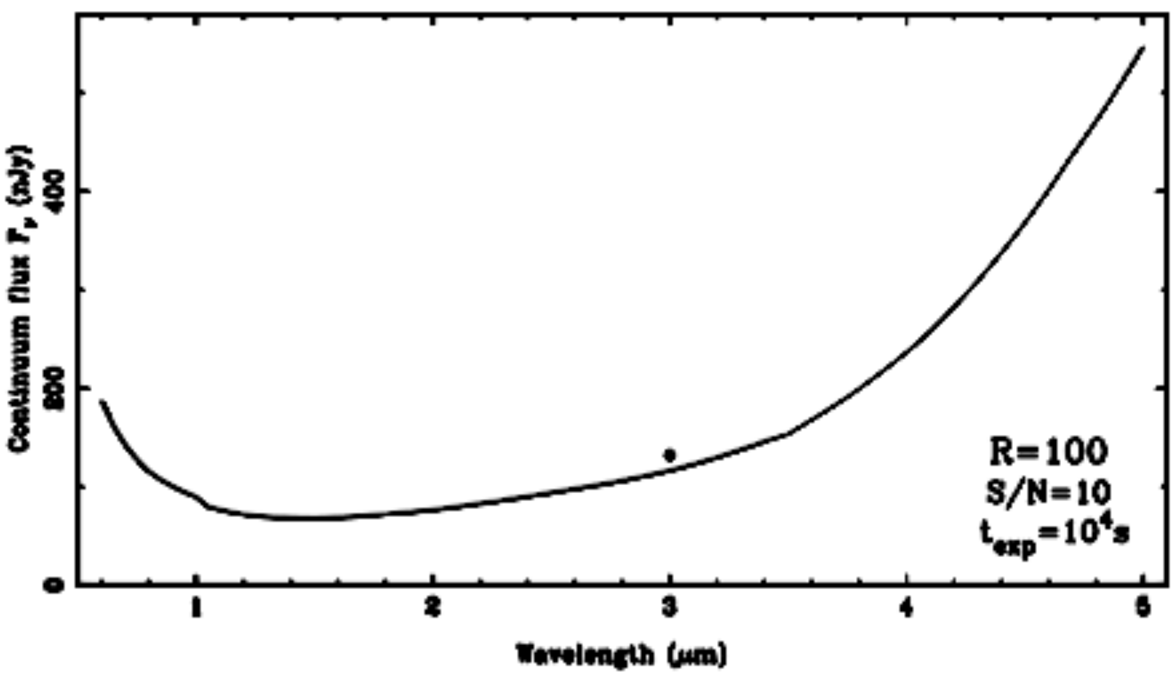
NIRCam sensitivity





NIRSpect sensitivities





MIRI sensitivity

The MIRI science team has provided the following tables for the MIRI photometric and spectrograph sensitivities. All estimates assume a low zodiacal background (important below 10 microns), a point source, and 10 sigma measurement after 10,000s.

MIRI Camera

Lambda (Microns)	Flux (microJansky)
5.6	0.2
7.7	0.28
10	0.7
11.3	1.7
12.8	1.4
15	1.8
18	4.3
21	8.6
25.5	28

Low resolution spectroscopy
(5-10 microns)

3 microJy at 7.5 microns

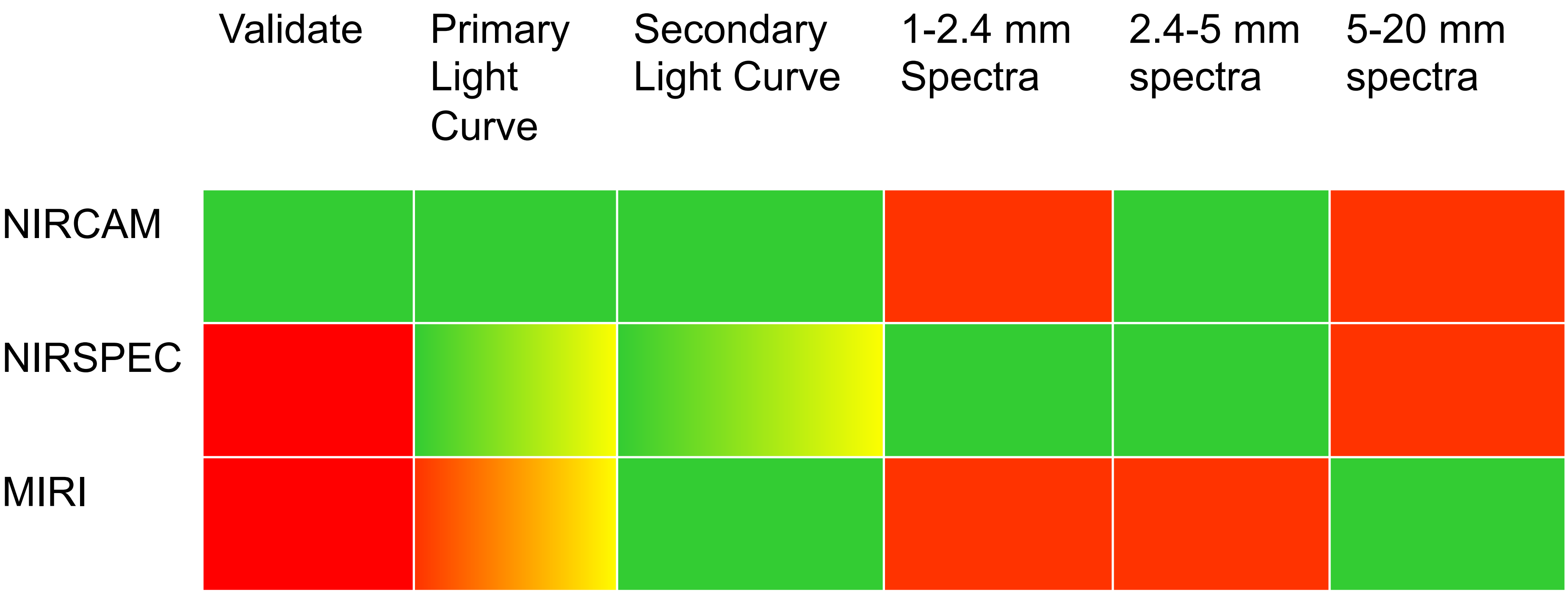
Medium resolution spectroscopy
(IFU, 10,000s per setting)

Lambda (Microns)	Line Flux (W/m^2)	Fnu (Jy)
6.4	7.00E-21	4.6E-5
9.2	1.00E-20	9.5E-5
14.5	1.20E-20	1.81E-4
22.5	6.00E-20	1.03E-3

Spectrometer: l Ranges, R, Sampling and fov

WAVELENGTH CHANNEL:		1	2	3	4
λ-limits (μm):		5.86–7.74	7.43–11.84	11.44-18.20	17.53-28.75
		λ-range (μm) $R_{spectral}$	λ-range (μm) $R_{spectral}$	λ-range (μm) $R_{spectral}$	λ-range (μm) $R_{spectral}$
Exp. A	$\Delta\lambda$:	4.86–5.81	7..43-8.88	11.44-13.64	17.53-21.16
	R:	2450-3710	2480-3690	2510-3730	2070-2490
Exp. B	$\Delta\lambda$:	5.61-6.71	8.59-10.26	13.22-15.76	20.43-24.66
	R:	2450-3710	2480-3690	2510-3730	2070-2490
Exp. C	$\Delta\lambda$:	6.48-7.74	9.91-11.84	15.27-18.20	23.82-28.75
	R:	2450-3710	2480-3690	2510-3730	2070-2490
IFU main parameters					
slice width (arcsec):		0.176	0.277	0.387	0.645
slice length (arcsec):		3.70	4.51	6.13	7.74
number of IFU slices:		21	17	16	12

Transits Follow-up



See JWST White paper s by Clampin et al (2007), Seager (2008)

Taken from C. Beichman

Setups for transits

SI	λ (μm)	Spectral Resolution (λ/δλ)	FOV	Mode	Comments	Application
NIRCam	0.6 - 2.3 2.4 - 5.0	4, 10, 100 4, 10, 100	2 x (2.2' x 2.2') 2 x (2.2' x 2.2')	Imaging Imaging	Photometric Imaging	High precision light curves of transits from photometry of point source images. Wavelength coverage permits photometric monitoring of primary or secondary eclipses.
NIRCam	0.6 – 2.3	4, 10, 100	2 x (2.2' x 2.2')	Phase diversity imaging	Defocusing of images to 57 or 114 pixel diameters	High precision light curves of transits associated with bright objects which need to be defocused to avoid saturation within the minimum integration time
NIRCam	2.4 – 5.0	2000	2 x (2.2' x 2.2')	Long-λ Grism	Backup capability for WFSC. Used with F277W, F322W, F356W, F410M or F444W	Emission spectroscopy of hot gas giant transiting planets
NIRSpec	1.0 – 5.0	100, 1000, 2700	0.1" x 2.0", 0.2" x 3.5", 0.4"x 4.0"	Spectroscopy	Fixed long slits	Low and intermediate resolution transmission and emission spectroscopy of transiting planets.
NIRSpec	0.7 - 5.0	2700	3" x 3"	Spectroscopy	Integral Field Unit	Intermediate resolution, transmission and emission spectroscopy of transiting planets.
MIRI	5 – 29	4-6	1.9' x 1.4'	Imaging	Photometric Imaging	
MIRI	5 - 11	100	5" x 0.2"	Spectroscopy	Fixed Slit or Slitless	Light curves of transits from photometry of point source images.
MIRI	5.9 – 7.7 7.4 – 11.8 11.4 – 18.2 17.5 – 28.8	3000 3000 3000 3000	3.7" x 3.7" 4.7" x 4.5" 6.2"x 6.1" 7.1"x7.7"	Spectroscopy	Integral field unit	Intermediate resolution, emission spectroscopy of transiting planets.
TFI	1.6 – 2.5	100	2.2' x 2.2'	Imaging	Selectable central λ	High precision light curves of transits from photometry of point source images. Wavelength coverage permits photometric monitoring of primary eclipses.
TFI	3.2 – 4.9	100	2.2' x 2.2'	Imaging	Selectable central λ	High precision light curves of transits from photometry of point source images. Wavelength coverage permits photometric monitoring of secondary eclipses.

Clampin 2008

Programas JWST GTO y ERS

Direct Imaging and Spectroscopy

1184 *Survey of Nearby Young M Stars,* J. Schlieder et al. 1
1188 *Direct Spectroscopy of Non-transiting Exoplanets,* K. Hodapp et al. 2, 3
1193 *Coronagraphic Imaging of Young Planets and Debris Disks,* C. Beichman et al. 1,2
1194 *Characterization of the HR 8799 Planetary System,* C. Beichman et al. 1,2
1195 *Coronagraphic Imaging of Young Planets,* C. Beichman et al. 1
1200 *Architecture of Directly-imaged Planetary Systems,* J. Rameau et al. 4
1241 *Coronagraphic Imaging of Exoplanets (ERS),* M. Ressler et al. 2
1270 *Characterizing the TWA 27 System,* S. Birkmann et al. 2,3
1274 *Extrasolar Planet Science with JWST,* J. Lunine et al. 1
1275 *Spectroscopic characterization of PSO J318,* P.-O. Lagage et al. 2,3
1276 *Spectroscopic Observations of WD 0806-661B,* P.-O. Lagage et al. 1,2,3
1277 *Coronographic Observations of Young Exoplanets and Spectroscopic Observations of ROSS 458 Abc,* P.-O. Lagage et al. 2,3
1278 *Spectroscopic Observations of Brown Dwarfs,* P.-O. Lagage et al. 2
1292 *ROSS 458 Abc,* J. Lunine et al., 3
1412 *Characterizing 51 Eridani Exoplanetary System,* M. Perrin et al. 1
1386 *High Contrast Imaging of Exoplanets* (ERS), S. Hinkley et al. 1,2,3,4

1=NIRCam; 2=MIRI; 3= NIRSPEC; 4=NIRISS

Todo sobre el JWST

Nada ha cambiado desde el 2015, salvo que para MIRI podemos usar el MRS + imagen simultaneamente

ESAC 2016 JWST Workshop
https://www.cosmos.esa.int/web/jwst-2016-esac/

Presentaciones y vídeo:

- **Imaging Mode**
- **Multi Object Spectroscopy**
- **Single Object Spectroscopy and Time Series Spectroscopy**
- **Coronagraphy and Moving Targets**
- **Integral Field Spectroscopy**
- **Science Parallels, Tools and Pipeline. Demonstrations**

CARMENES

- Entre el final de JWST (2021+5+5 => 2031)
- PLATO (2026)
- La explotación de Gaia continuará
- EUCLID 2024
- Calar Alto es análogo a cualquier otro observatorio (Carlos Eiroa *dixit* y yo lo subscribo)
- Rapidez de la respuesta y profesionalidad
- CARMENES es **indispensable** ahora para **casos científicos muy variados** y los seguirá siendo durante muchos años más, junto a Calar Alto
- Intensidad del esfuerzo (número de noches)
- **Estudios atmosféricos** de manera cuasi-simultánea
- Science-ready products?
- Amplia base de datos