# Technology behind the future science goal: the infrared instrument for JWST


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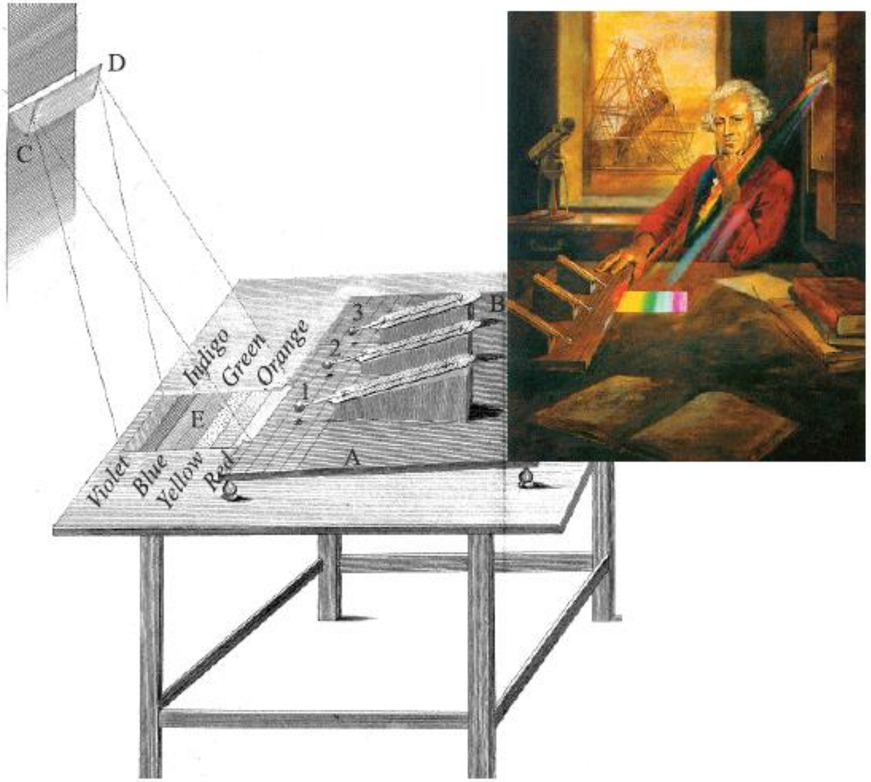
# Content

- Introduction to Infrared science
- Instruments
- Summary

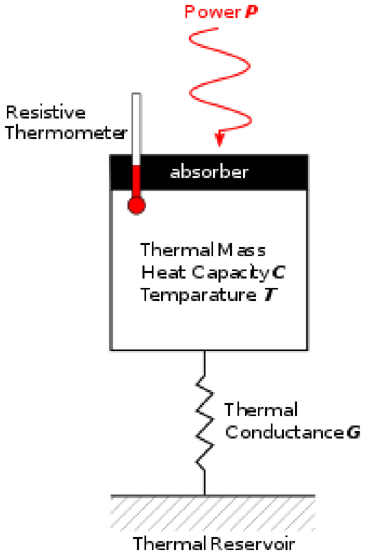
# Introduction Part

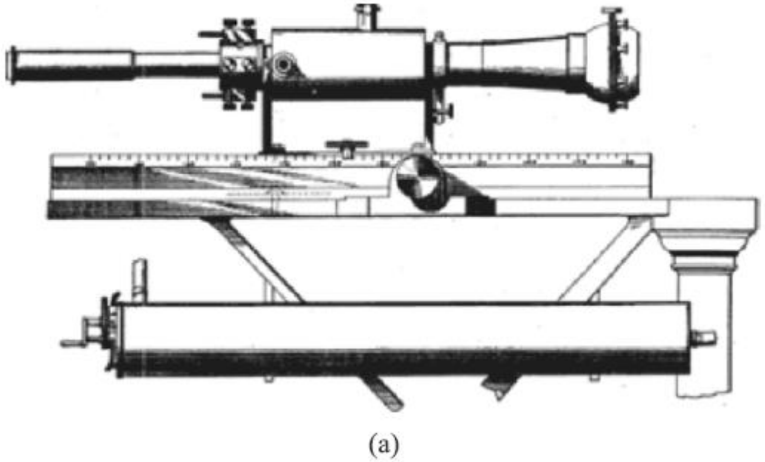
# History of Detector




Infrared light (Herschel, 1800)

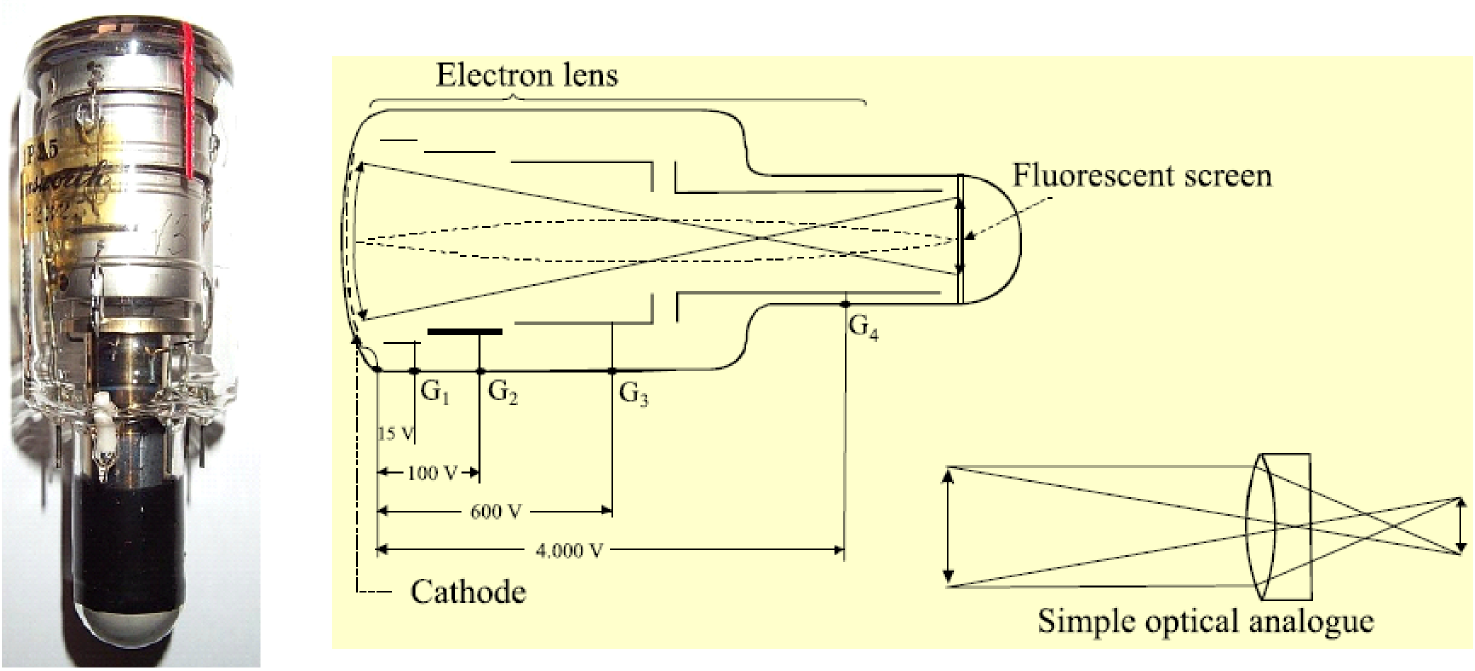

Thermopiles detector (Nobili, 1830)




Bolometer (Langley, 1880)

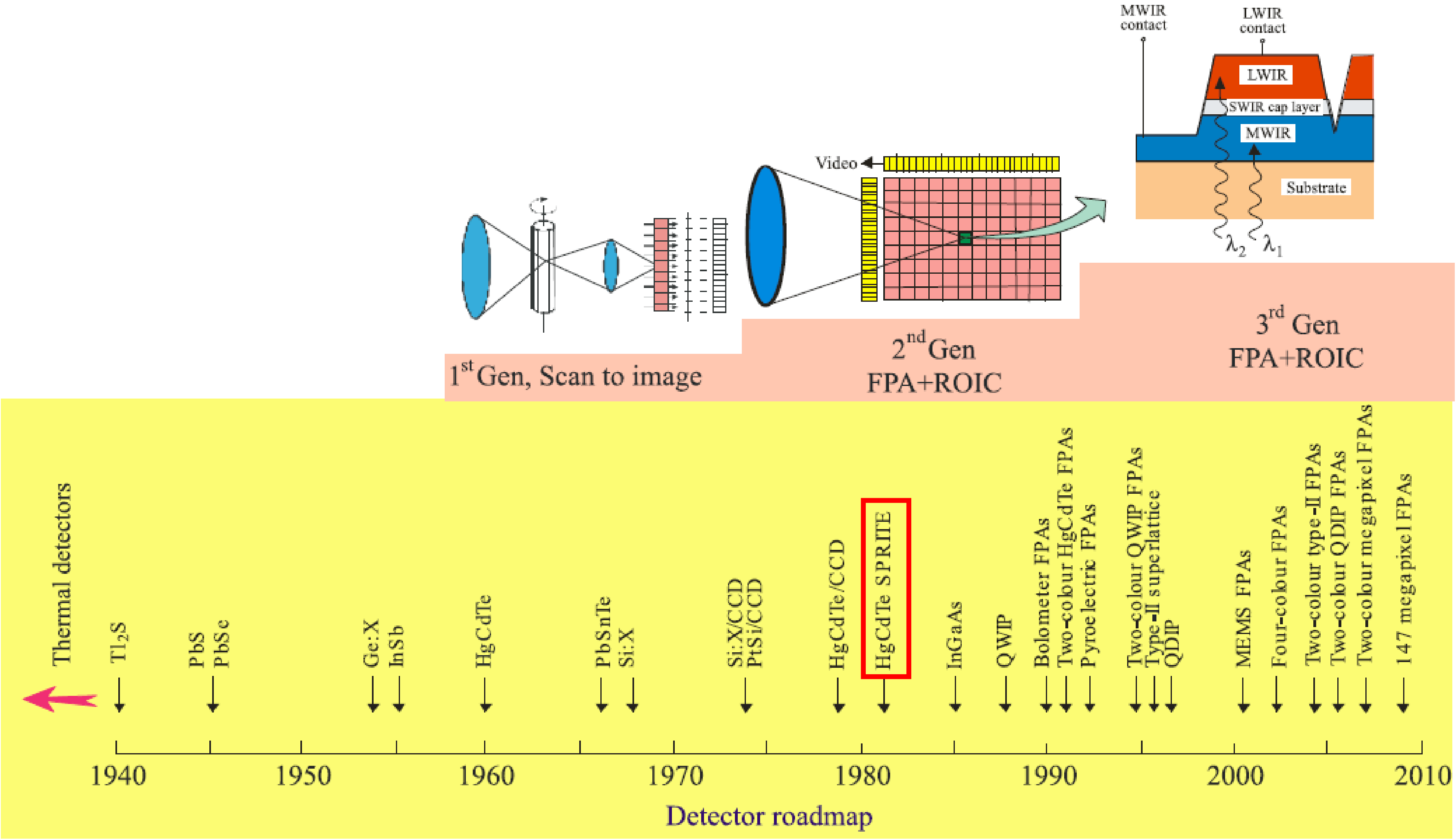
# PE effect detector




(a) (b)

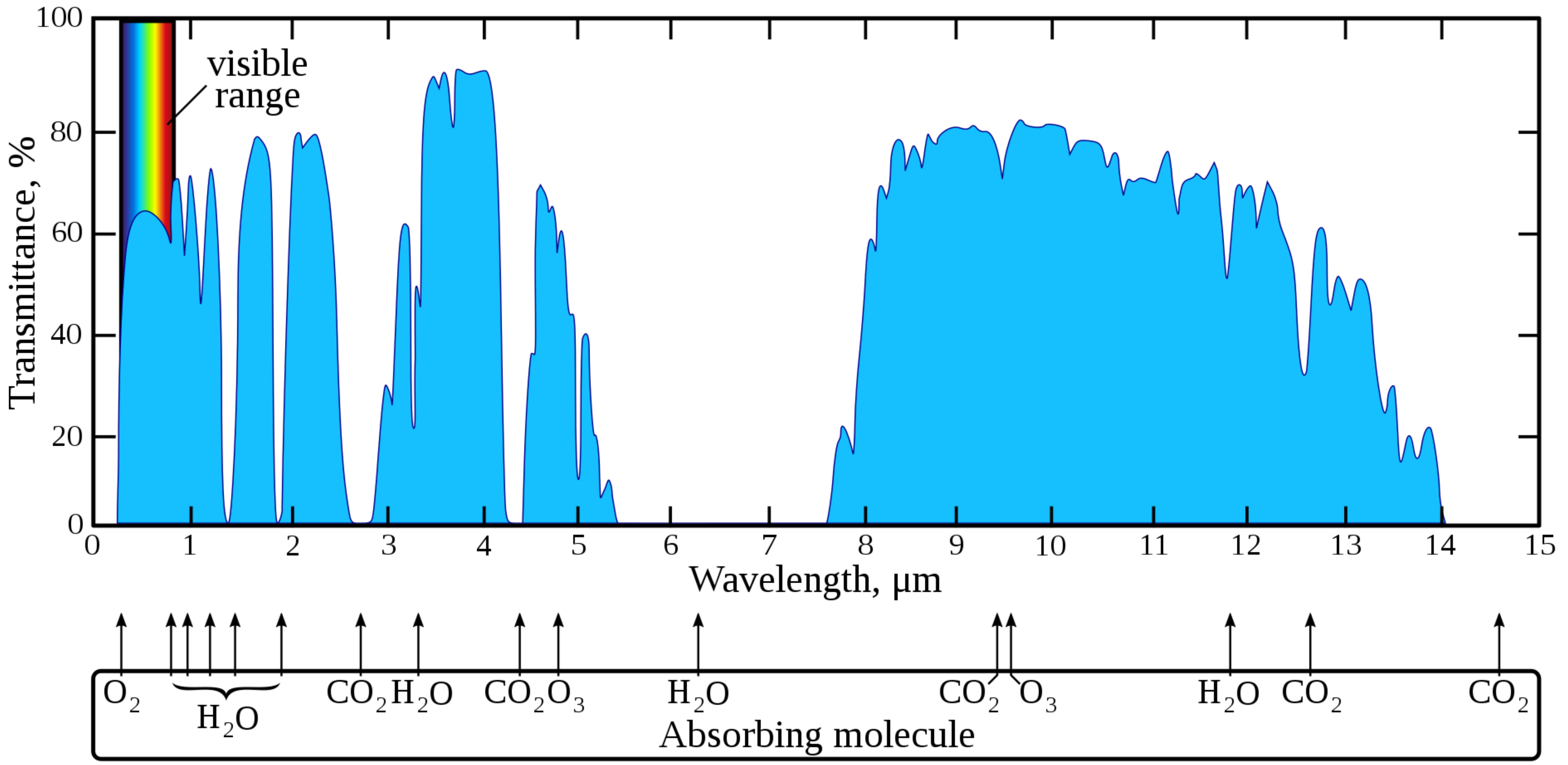
Photocathode (RCA, 1942)

# History of PE detector

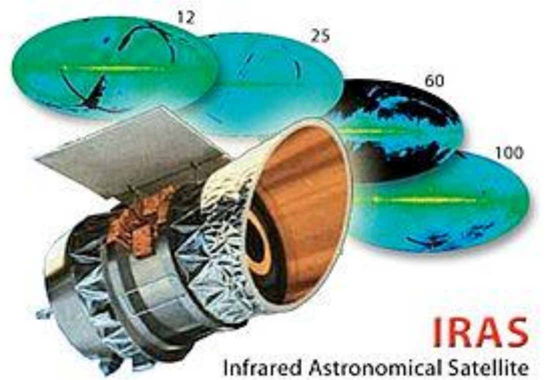



"All physical phenomena in the range of about 0.1–1eV will be proposed for IR detectors"

# Absorption on Ground

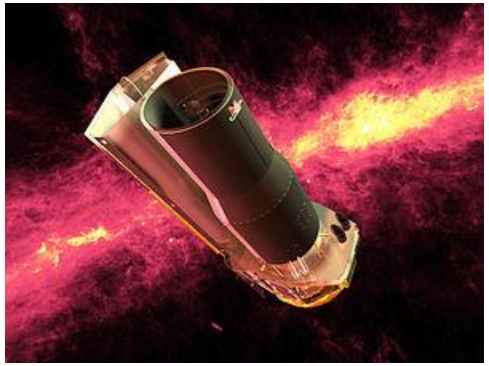


# Space IR Telescope

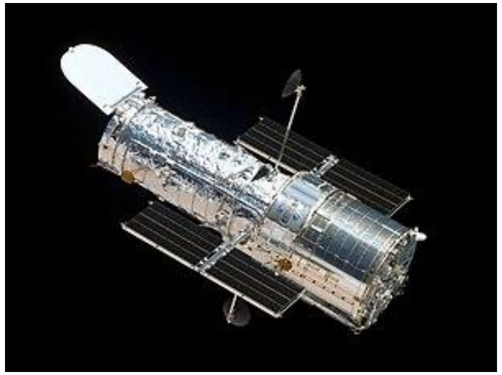



IRAS (1983)

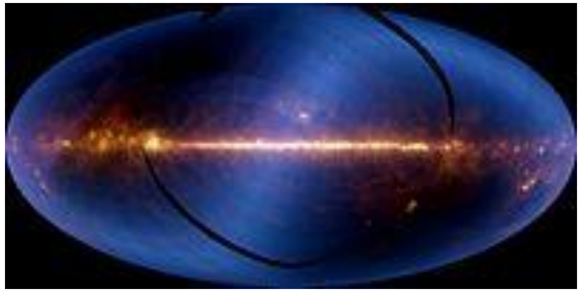
ISO (1995)

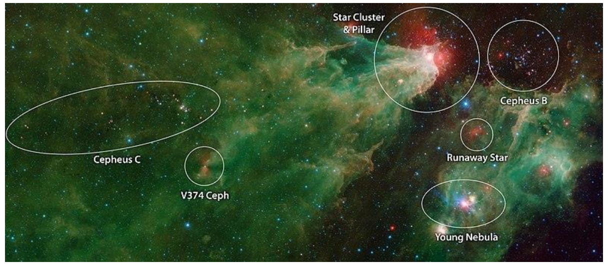


Spitzer (2003)



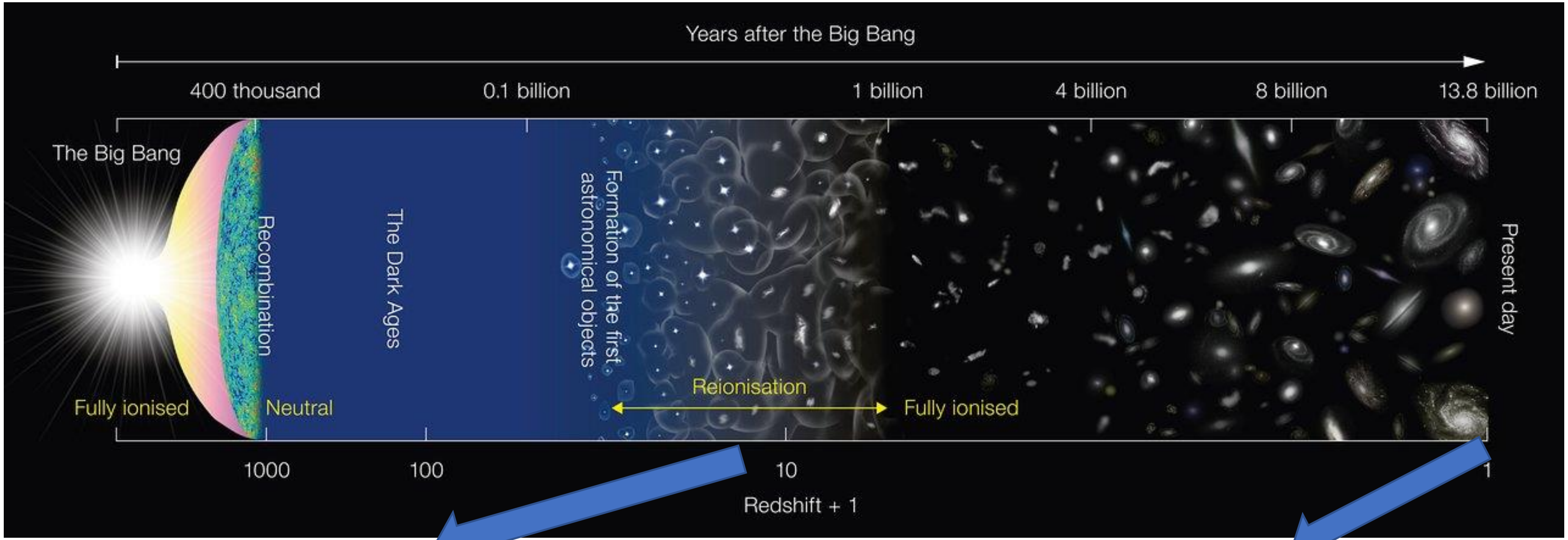
HST (1990)



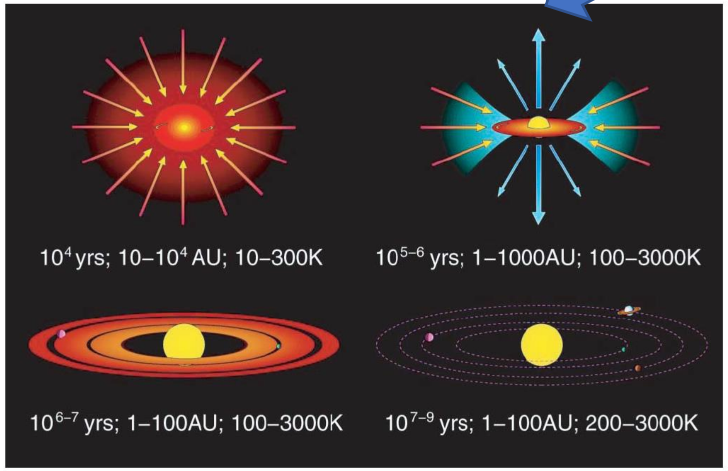



| Name | IRAS | ISO | Spitzer | HST |
|---|---|---|---|---|
| Working year | 0.83 | 3 | 17 | >30 |
| Wavelength($\mu m$) | 5-100 | 2.5-240 | 3-160 | 0.8-2.4 |

# Targets of JWST



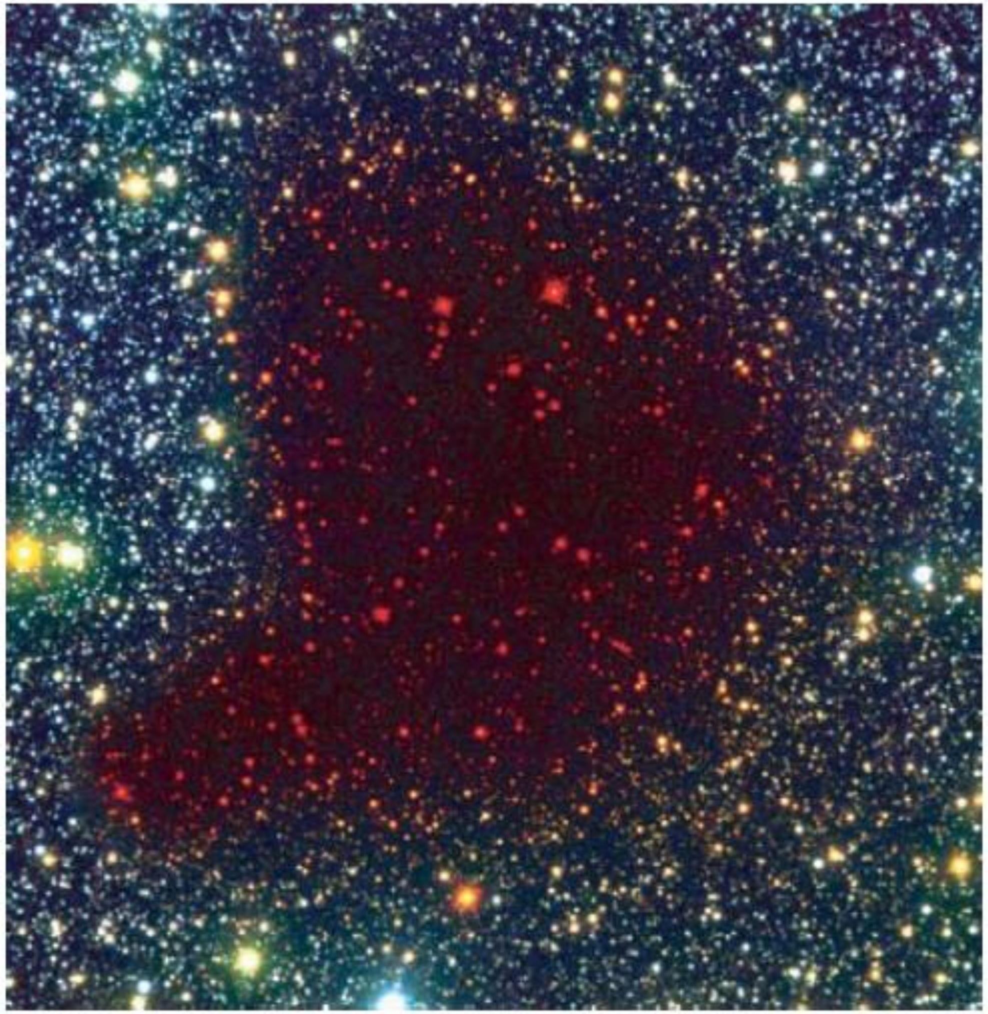

z~11




Star formation

# Image in IR

B,V,I band



B,I and $K_S$ band

# Instrument Part

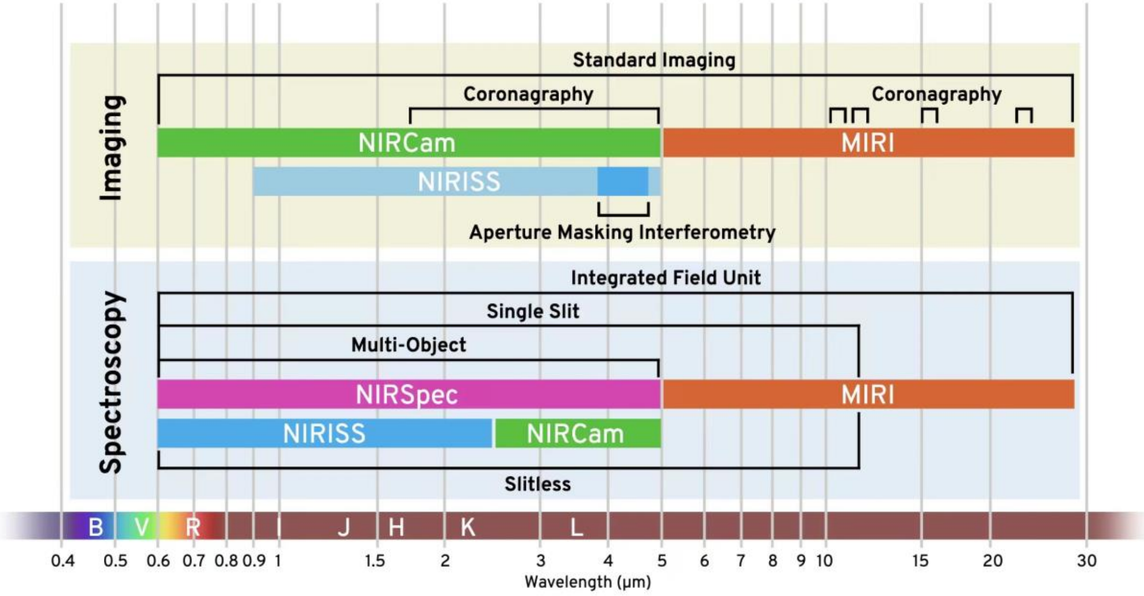
Chen Naihui

# Scientific Instruments

| | Classical Imaging | High Contrast Imaging | Spectroscopy |
|---|---|---|---|
| NIRCam | FoV: 4x2.2'x2.2'<br>27 bands, λ: 0.6-5μm<br>pixel size 0.032", 0.065" | 5 Coronagraphic Masks<br>and 2 Pupils for each arm | Slitless, R~2000, λ: 2.4-5μm |
| NIRSpec | | | - 5 Fixed slits, one large<br>- Multi-Object Spectroscopy<br>- IFU<br>λ: 0.6-5μm, R~100,1000, 2700 |
| NIRISS | FoV: 2.2'x2.2'<br>7 bands, λ: 0.9-5μm<br>pixel size 0.065" | Aperture Masking Interferometry<br>λ: 3.8-4.8μm | - Slitless Wide-field<br>R~150, λ: 1-2.5μm<br>- Slitless Single-Object<br>R~700, λ: 0.6-2.5μm |
| MIRI | FoV: 1.25'x1.88'<br>9 bands, λ: 5-27.5μm<br>pixel size 0.1" | 4 Coronagraphs, λ: 10.6-23μm<br>(3 4QPM, 1 Lyot) | - Slitless/Slit, R~100, λ: 5-12μm<br>- IFU, R~3000, λ: 5.0-28μm |

0.6-5μm

5-28μm

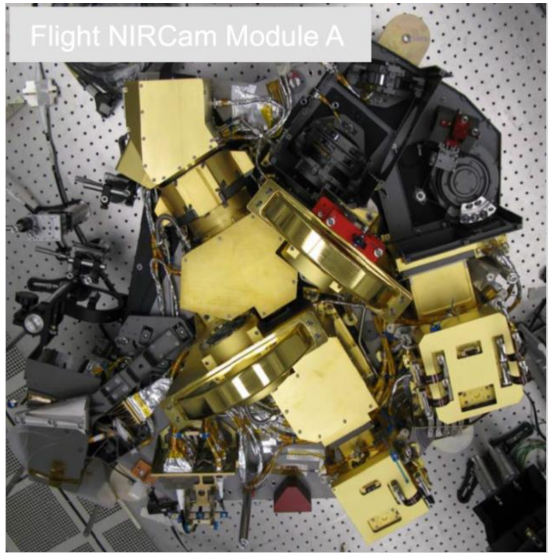


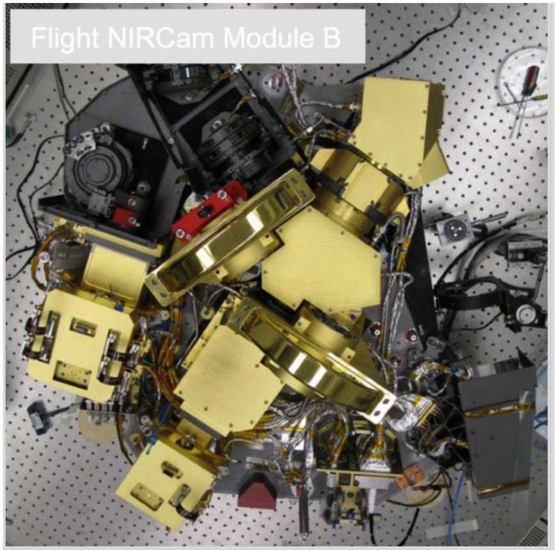

Observing modes of scientific instruments

# Standard imaging mode of NIRCam

# NIRCam

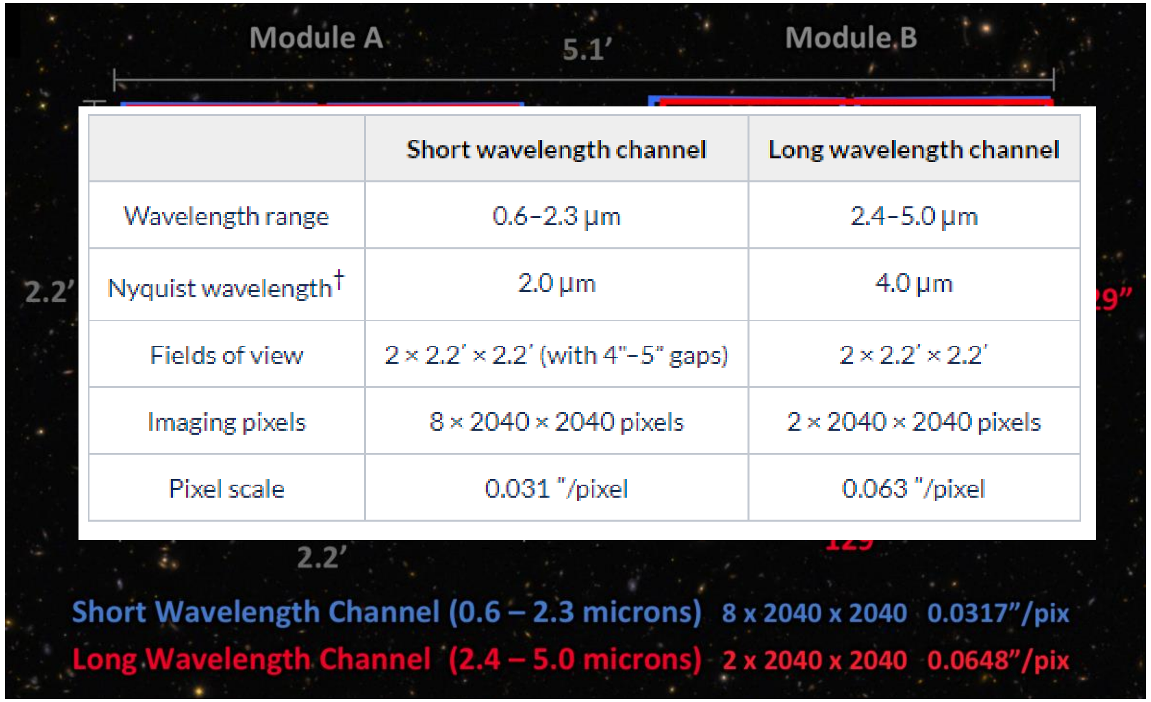
| Observing mode | Wavelength coverage (μm) | Field of view§ | Pixel scale (arcsec/pix) | Notes |
|---|---|---|---|---|
| Imaging | 0.6–2.3 | 2 × 132" × 132" (44" and 5" gaps) | 0.031 | FWHM 2 pix at 2.0 μm |
| | 2.4–5.0 | 2 × 129" × 129" (48" gap) | 0.063 | FWHM 2 pix at 4.0 μm |
| Coronagraphic imaging | 1.8–2.2<br>2.8–5.0 | 20" × 20" | 0.031<br>0.063 | |
| Wide field slitless spectroscopy | 2.4–5.0 | 2 × 129" × 129" | 0.063 | R ~ 1,600 at 4 μm |
| Time-series imaging | 0.6–2.3<br>2.4–5.0 | 129" × 129"<br>132" × 132" | 0.031<br>0.063 | |
| Grism time series | 2.4–5.0 | 129" × 129" | 0.063 | R ~ 1,600 at 4 μm |




Photos of two modules

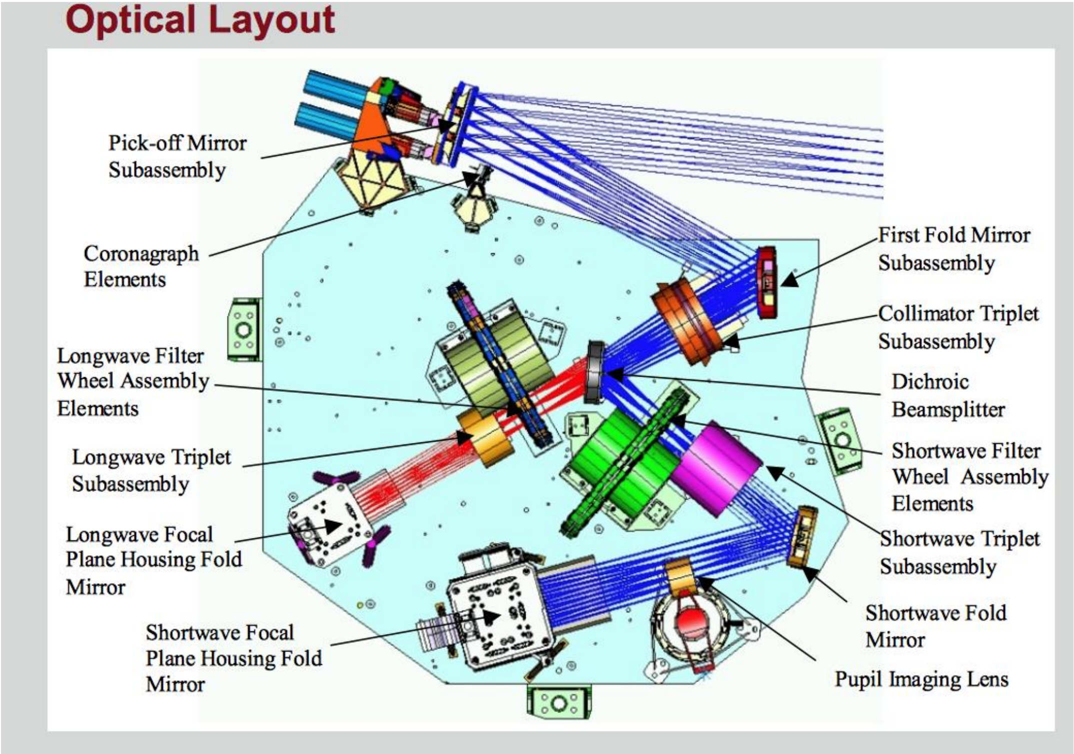
# Two wave length channels



| | Short wavelength channel | Long wavelength channel |
|---|---|---|
| Wavelength range | 0.6–2.3 μm | 2.4–5.0 μm |
| Nyquist wavelength† | 2.0 μm | 4.0 μm |
| Fields of view | 2 × 2.2′ × 2.2′ (with 4"–5" gaps) | 2 × 2.2′ × 2.2′ |
| Imaging pixels | 8 × 2040 × 2040 pixels | 2 × 2040 × 2040 pixels |
| Pixel scale | 0.031 ″/pixel | 0.063 ″/pixel |

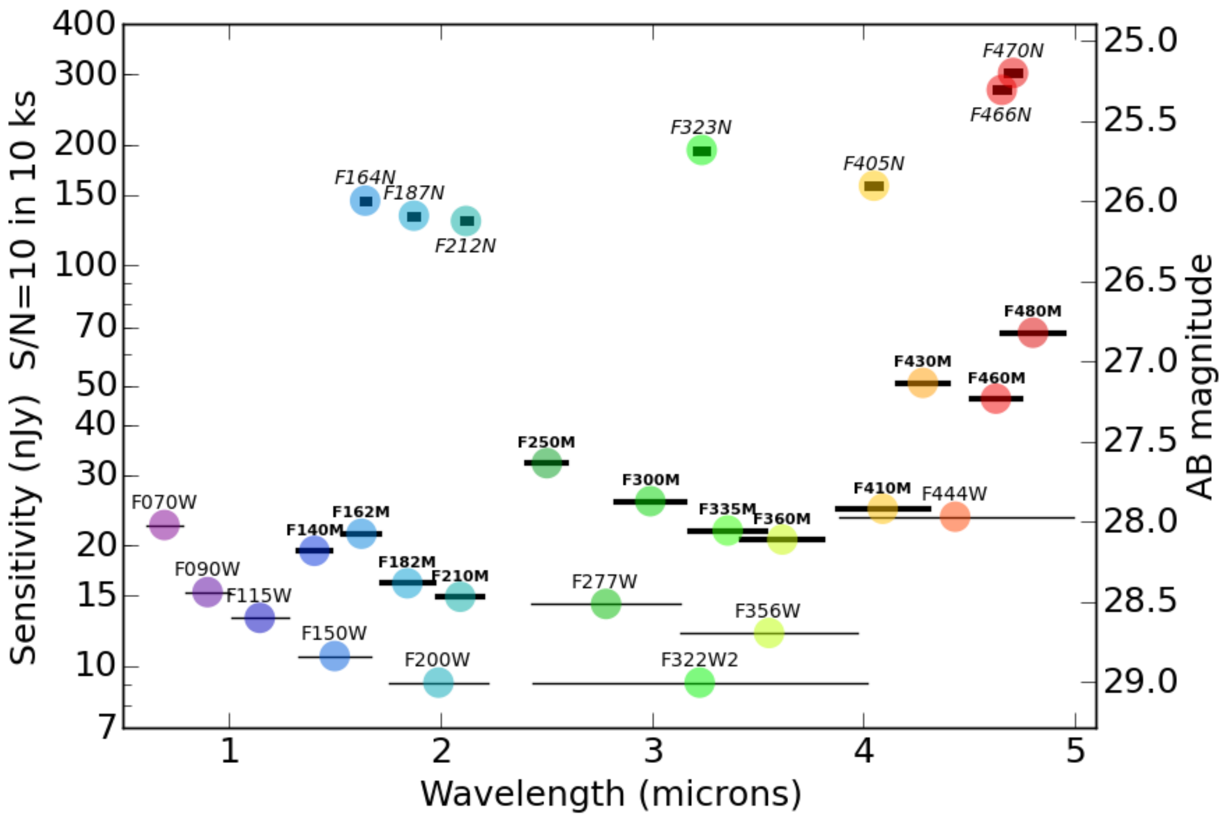


Projected detector plane




Optical layout

# Filters

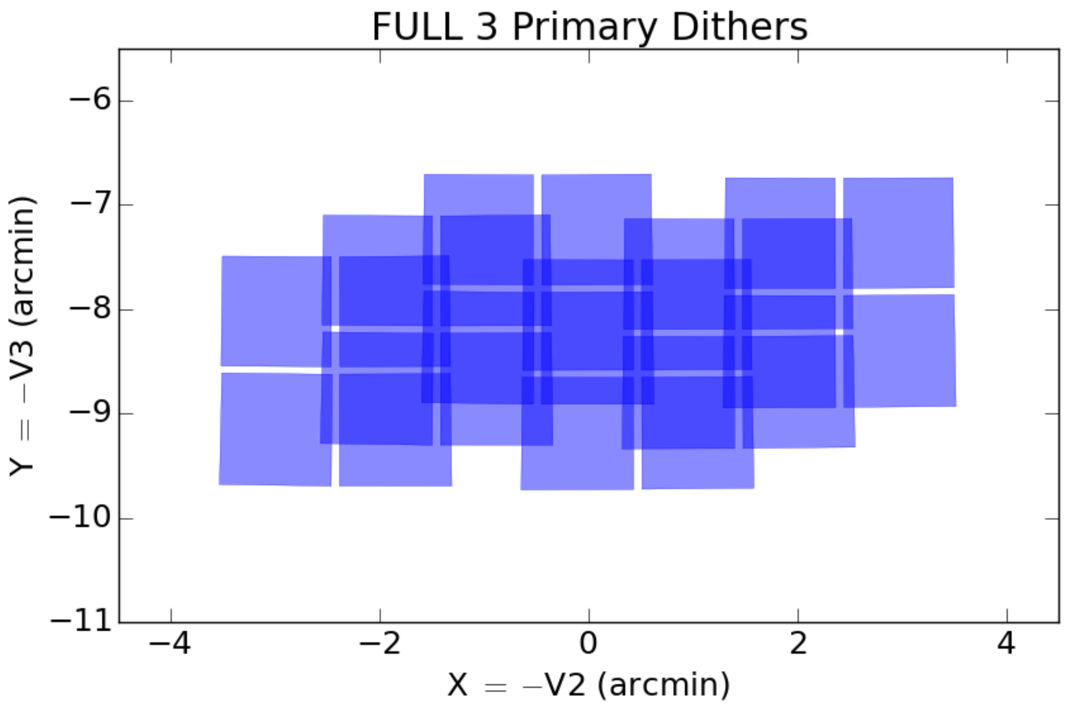


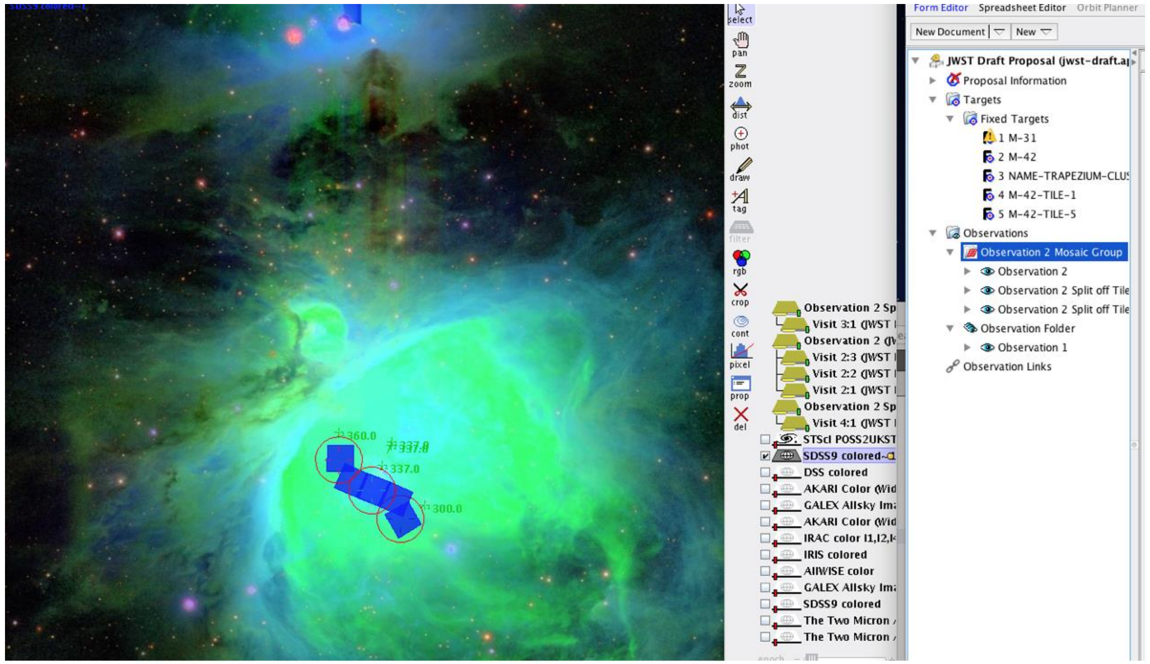

Sensitivity for different filters.

| Filter (module-average) | Pivot* λ (μm) | BW† Δλ (μm) | Effective‡ response | Blue§ $\lambda_-$ (μm) | Red¶ $\lambda_+$ (μm) | Use |
|---|---|---|---|---|---|---|
| F070W | 0.704 | 0.132 | 0.200 | 0.621 | 0.781 | General purpose |
| F090W | 0.902 | 0.194 | 0.292 | 0.795 | 1.005 | General purpose |
| F115W | 1.154 | 0.225 | 0.325 | 1.013 | 1.282 | General purpose |
| F140M | 1.405 | 0.142 | 0.397 | 1.331 | 1.479 | Cool stars, H2O, CH4 |
| F150W | 1.501 | 0.318 | 0.422 | 1.331 | 1.668 | General purpose |
| F162M | 1.627 | 0.168 | 0.416 | 1.542 | 1.713 | Cool Stars, off-band for H2O |
| F164N | 1.645 | 0.020 | 0.355 | 1.635 | 1.653 | [FeII] |
| F150W2 | 1.659 | 1.175 | 0.415 | 1.008 | 2.334 | Blocking filter for F162M, F164N, and DHS |
| F182M | 1.845 | 0.237 | 0.454 | 1.722 | 1.968 | Cool stars, H2O, CH4 |
| F187N | 1.874 | 0.024 | 0.374 | 1.863 | 1.884 | Pa-alpha |
| F200W | 1.989 | 0.457 | 0.472 | 1.755 | 2.226 | General purpose |
| F210M | 2.095 | 0.206 | 0.461 | 1.992 | 2.201 | H2O, CH4 |
| F212N | 2.121 | 0.027 | 0.394 | 2.109 | 2.134 | H2 |

Characteristics of filters for short wavelength channel.

# Observation Strategies




Dithering

- Fill image gaps.
- Compensate bad pixels

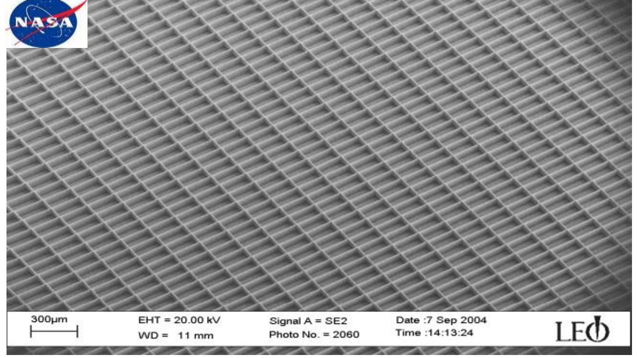
…

Mosaic

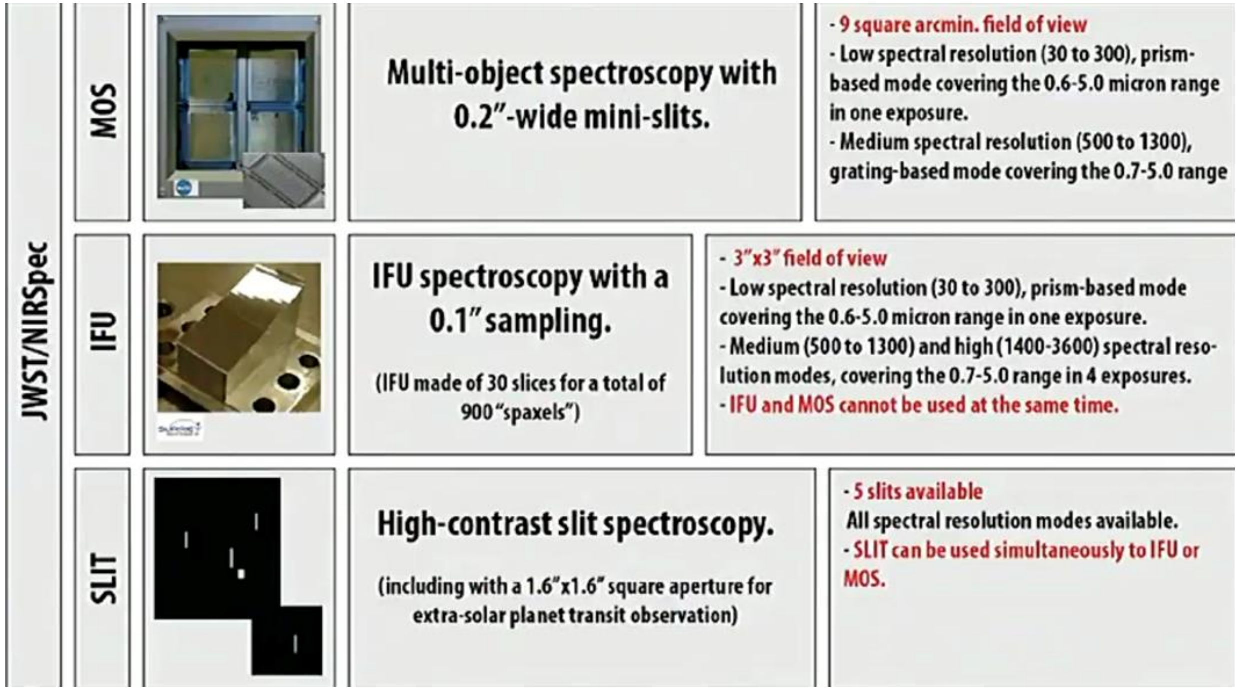
- See large sky regions

# MOS mode of NIRSpec

# Multi-object spectroscopy

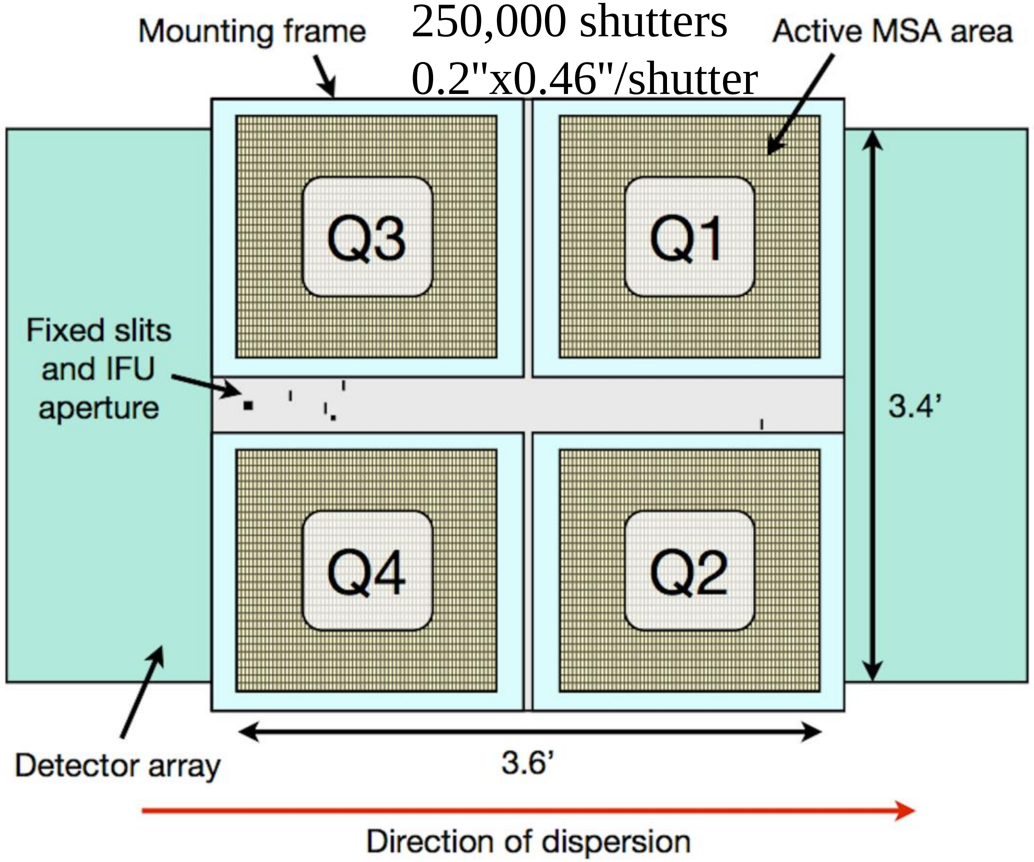



250,000 shutters
0.2"x0.46"/shutter



| JWST/NIRSpec | | | |
|---|---|---|---|
| MOS | Multi-object spectroscopy with 0.2"-wide mini-slits. | | - 9 square arcmin. field of view<br>- Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure.<br>- Medium spectral resolution (500 to 1300), grating-based mode covering the 0.7-5.0 range |
| IFU | IFU spectroscopy with a 0.1" sampling.<br>(IFU made of 30 slices for a total of 900 "spaxels") | | - 3"x3" field of view<br>- Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure.<br>- Medium (500 to 1300) and high (1400-3600) spectral resolution modes, covering the 0.7-5.0 range in 4 exposures.<br>- IFU and MOS cannot be used at the same time. |
| SLIT | High-contrast slit spectroscopy.<br>(including with a 1.6"x1.6" square aperture for extra-solar planet transit observation) | | - 5 slits available<br>All spectral resolution modes available.<br>- SLIT can be used simultaneously to IFU or MOS. |

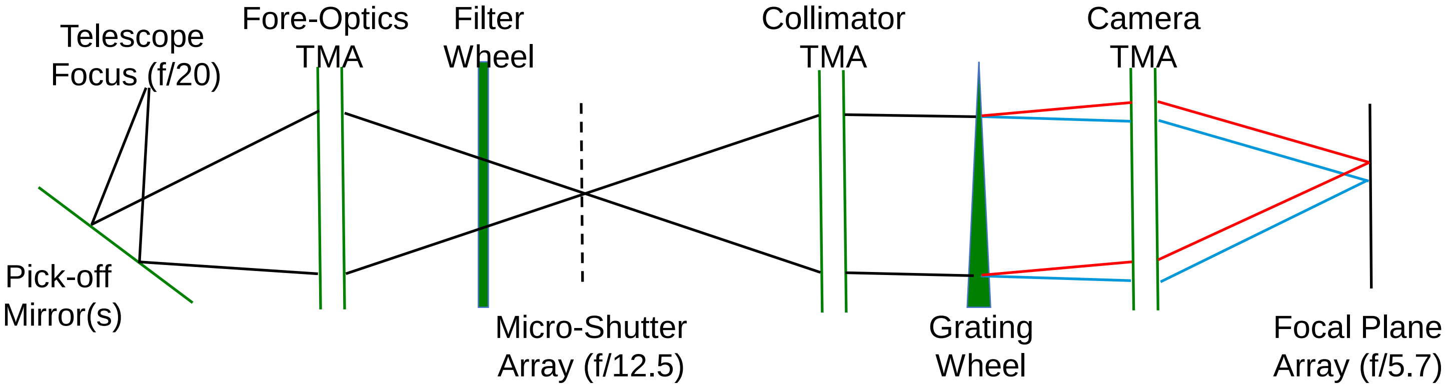
Spectrograph modes of NIRSpec

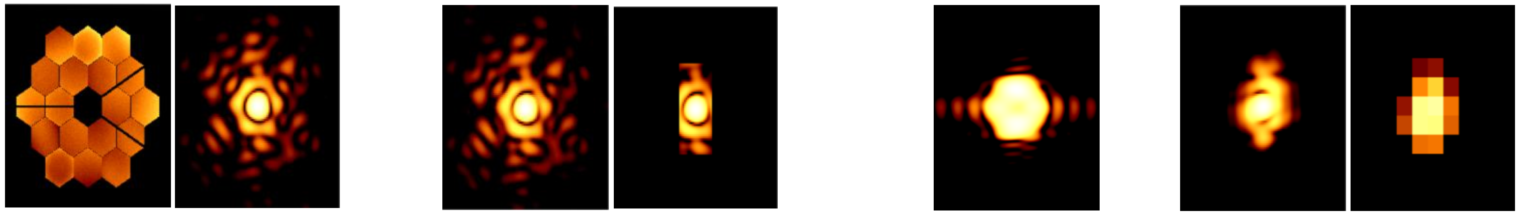


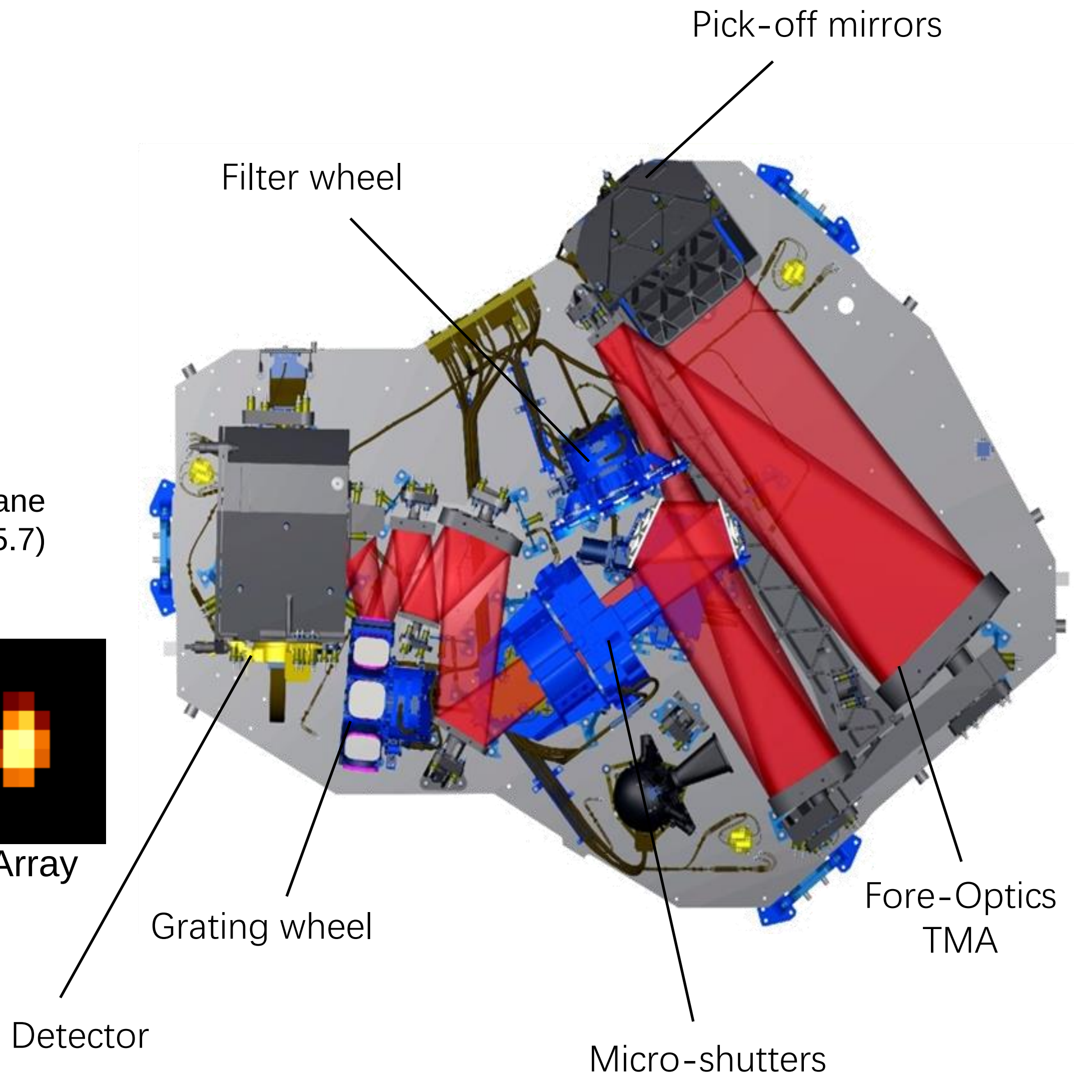

NIRSpec

Most novel and complex subsystem of NIRSpec

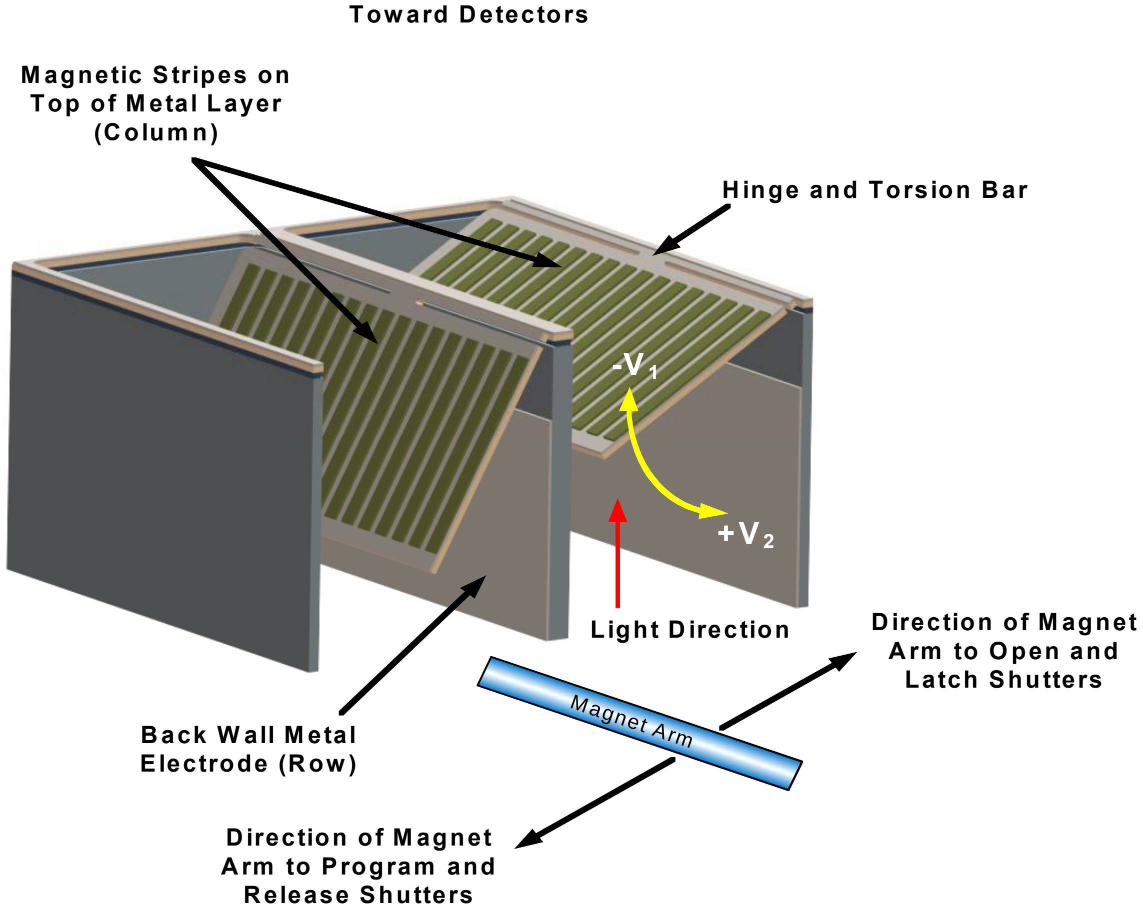
# Optical layout

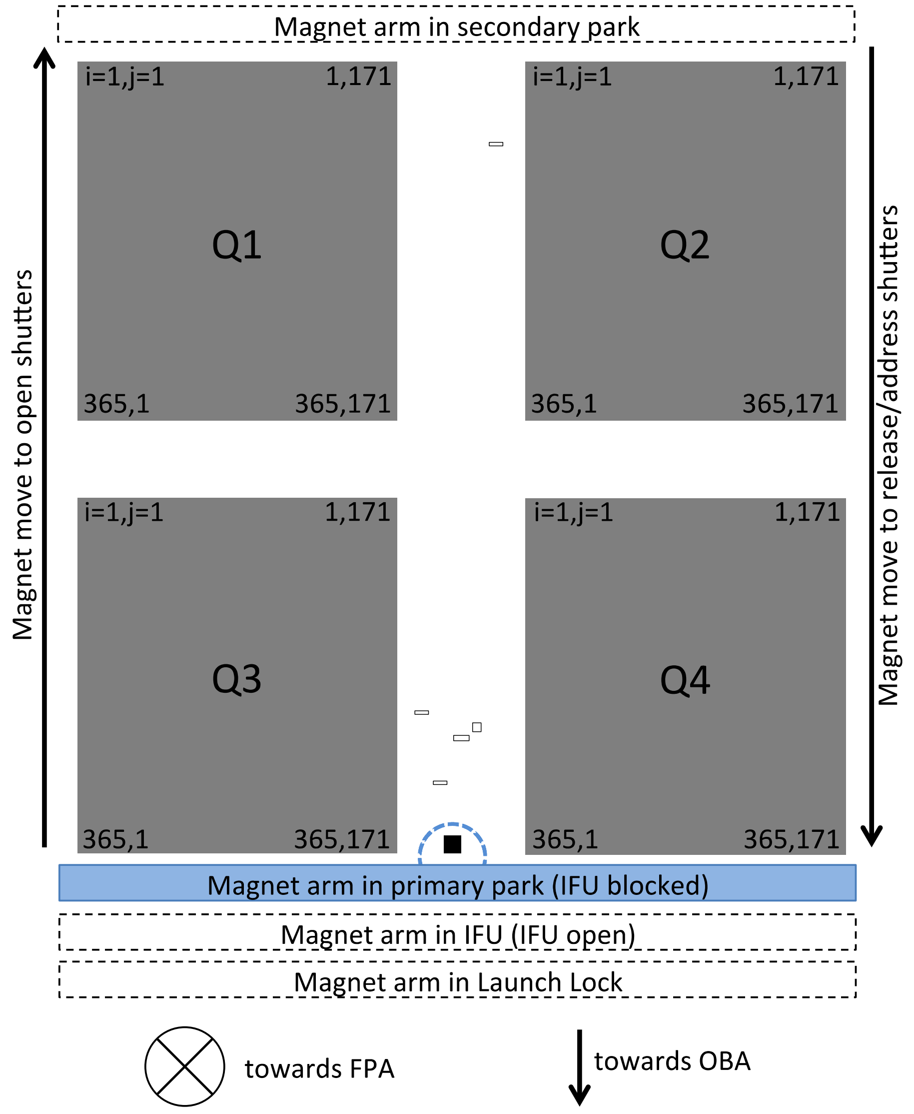




Telescope Focus Slit Mask Pupil at Disperser Detector Array

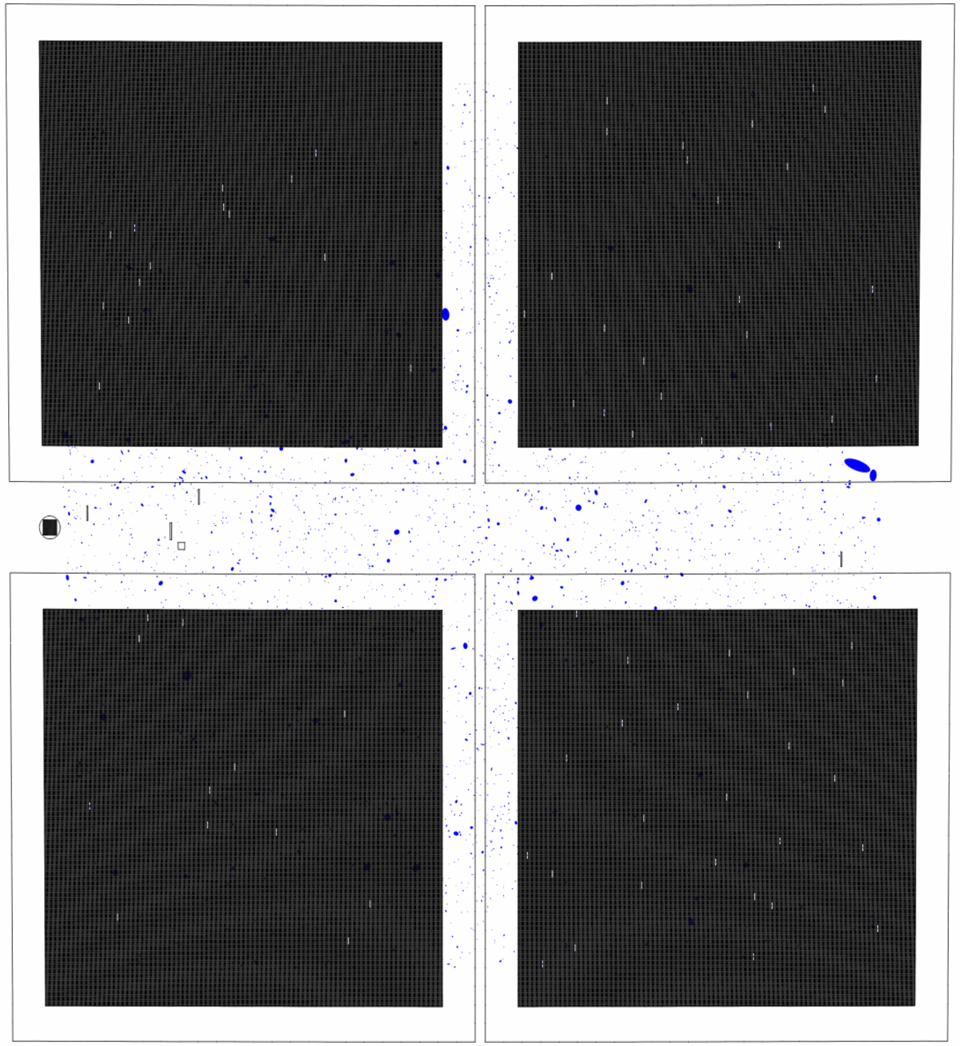


# Work Principle

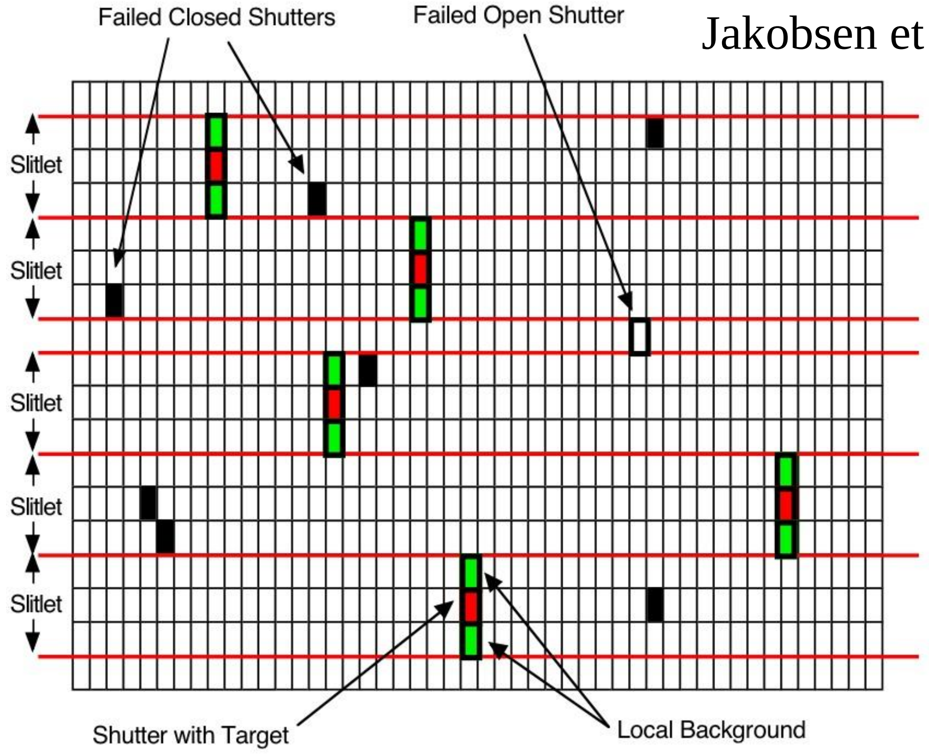


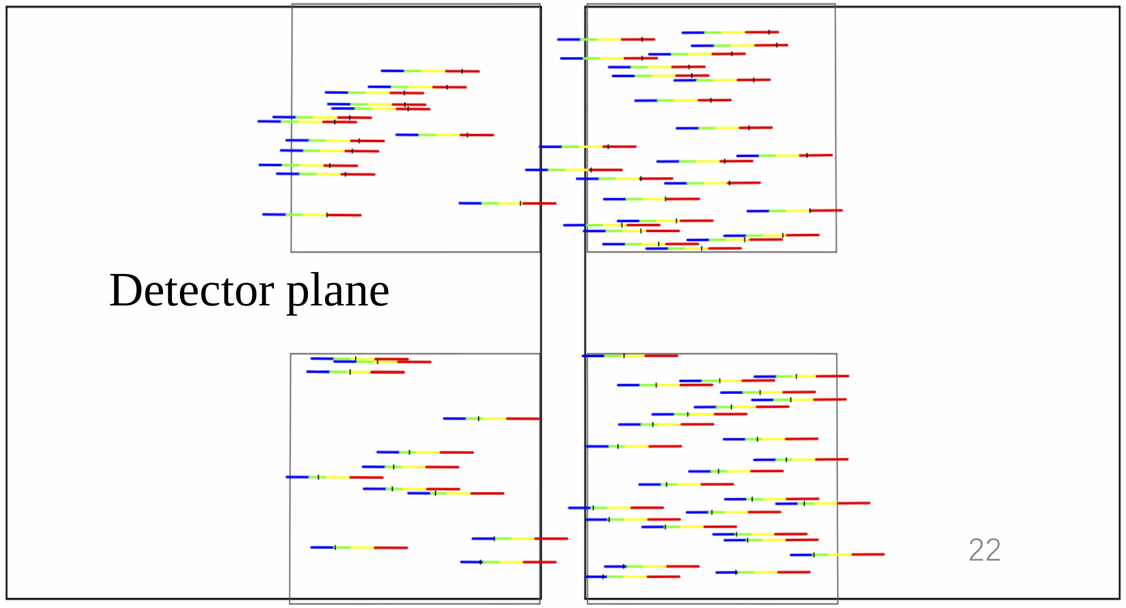



# Example



Jakobsen et al. 2021



# Summary

- IR detection has a long history and those detectors using PE effect give us more chance in IR astronomy.
- The IR band will let JWST to see more.
- NIRCam provides a variety of filters for different purposes.
- MOS mode of NIRSpec give us the ability to see hundreds of faint objects in a single exposure.