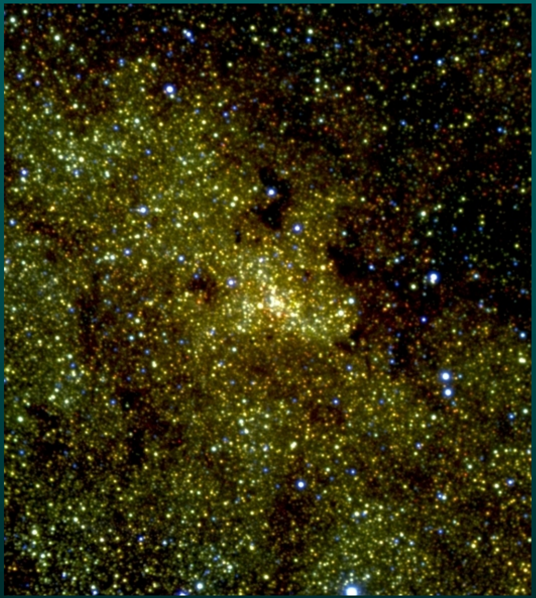
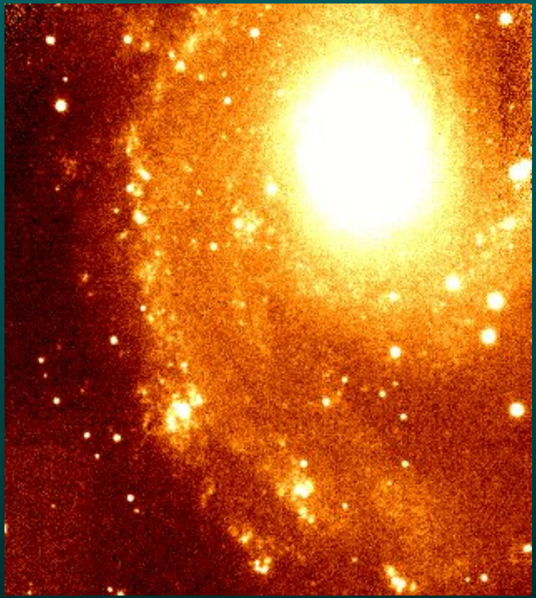
Observing in the NIR



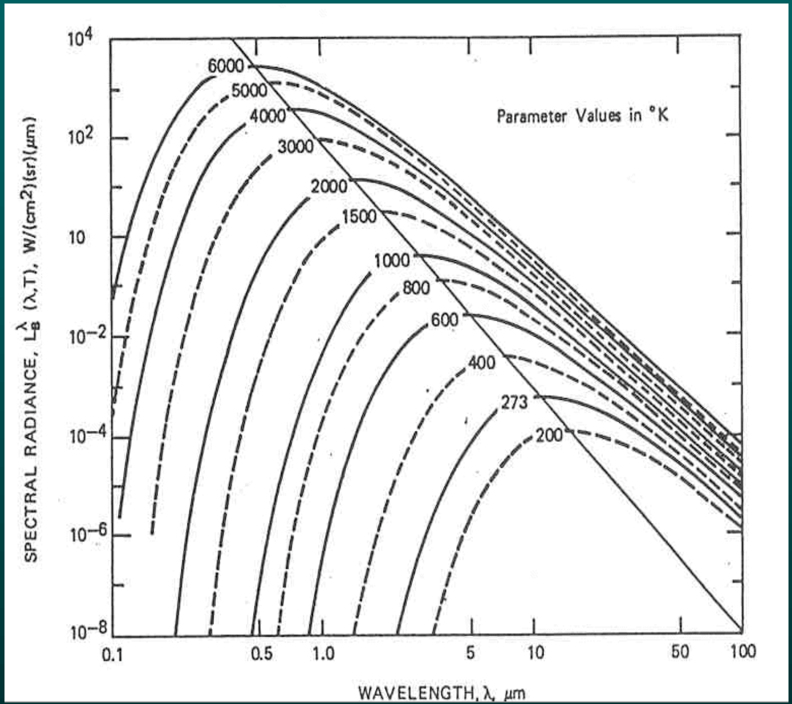


Rubén Díaz - 9/2017
(presented by Gonzalo Díaz)

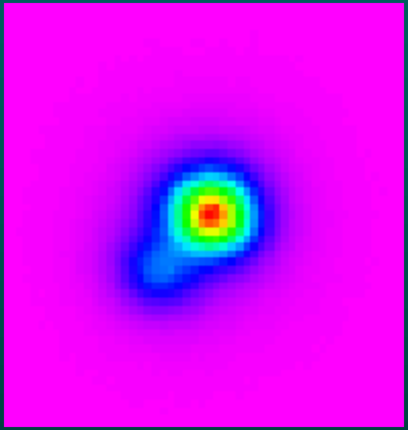
Contents

- Why use the NIR?
- Challenges of the NIR.
- Detectors.
- Observing strategies and calibrations.

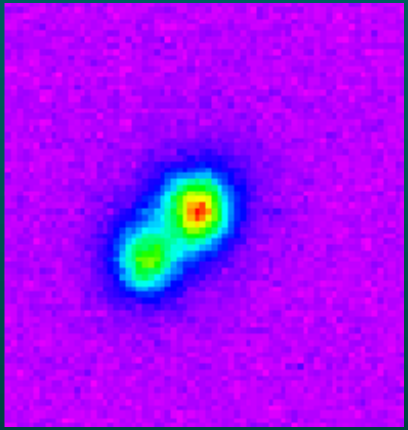
Why use the NIR



Some cool objects emit more light in the NIR



GMOS-S,
z band

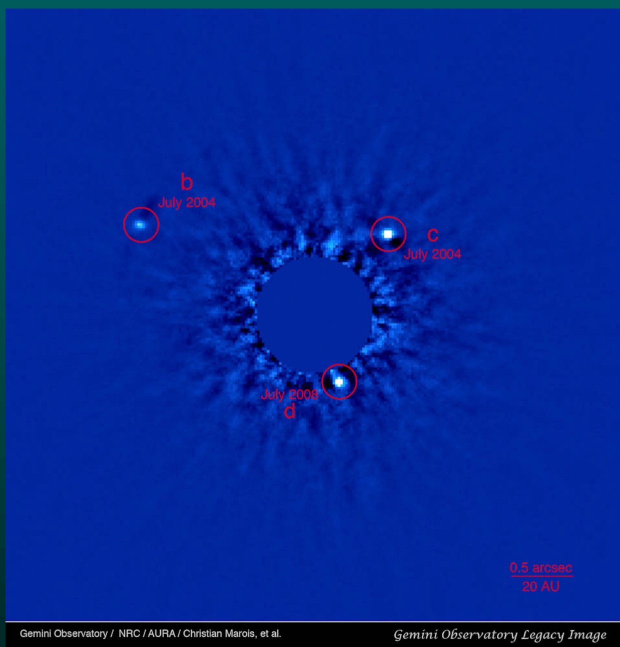


Phoenix,
J band
(a brown dwarf)

Temperature Range	Objects
740 a (3000-5200)	Red dwarfs, red giants. Little dust emission.
(92.5-140) a 740	Planets and small bodies. Dust heated by starlight. Protoplanetary disks.
(10.6-18.5) a (92.5-140)	Cool dust. Galaxies central regions. Molecular clouds.

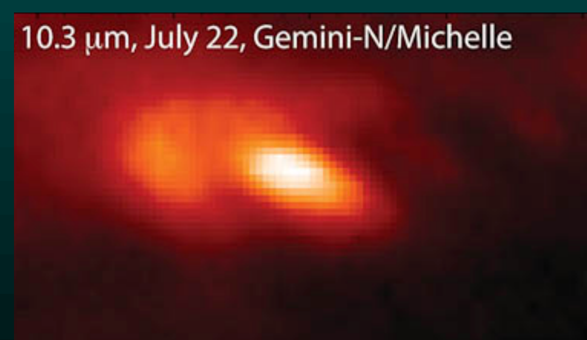
Why use the NIR

Some cool objects emit more light in the NIR



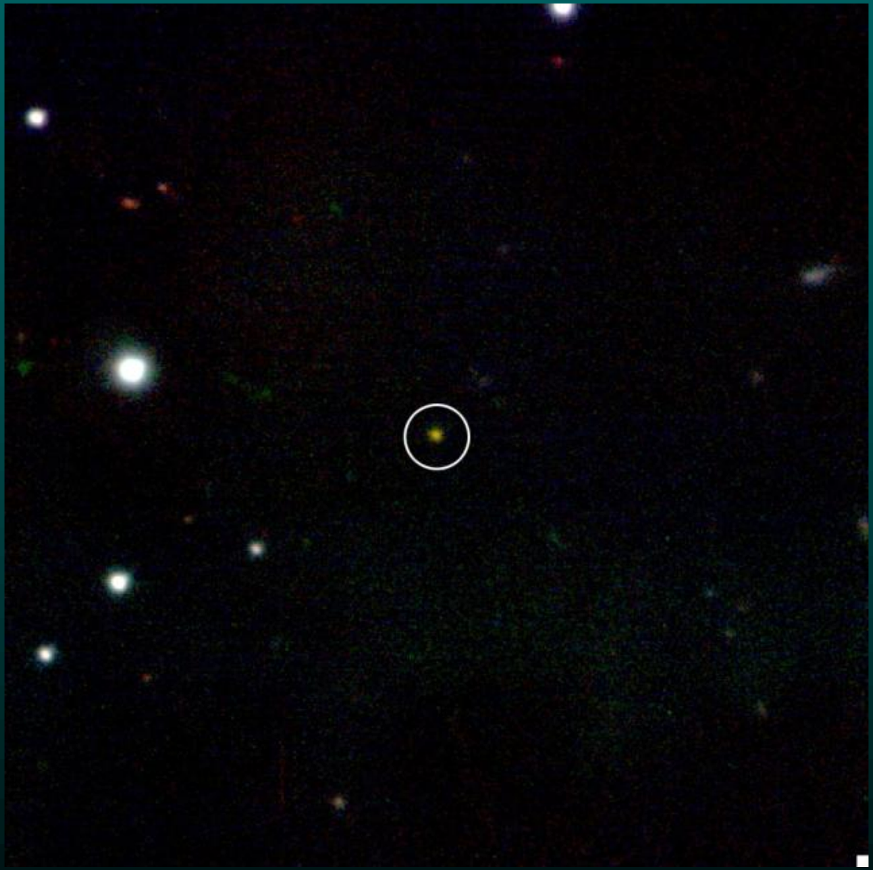
NIRI coronography

NIRI + Altair, K' band



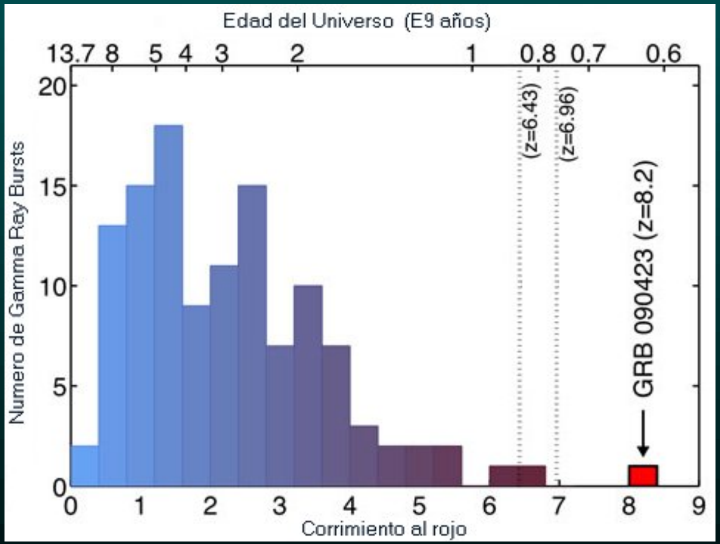
Michelle, 8.7 y 9.7 μm

Why use the NIR



NIRI, JHK

Redshifted spectral features

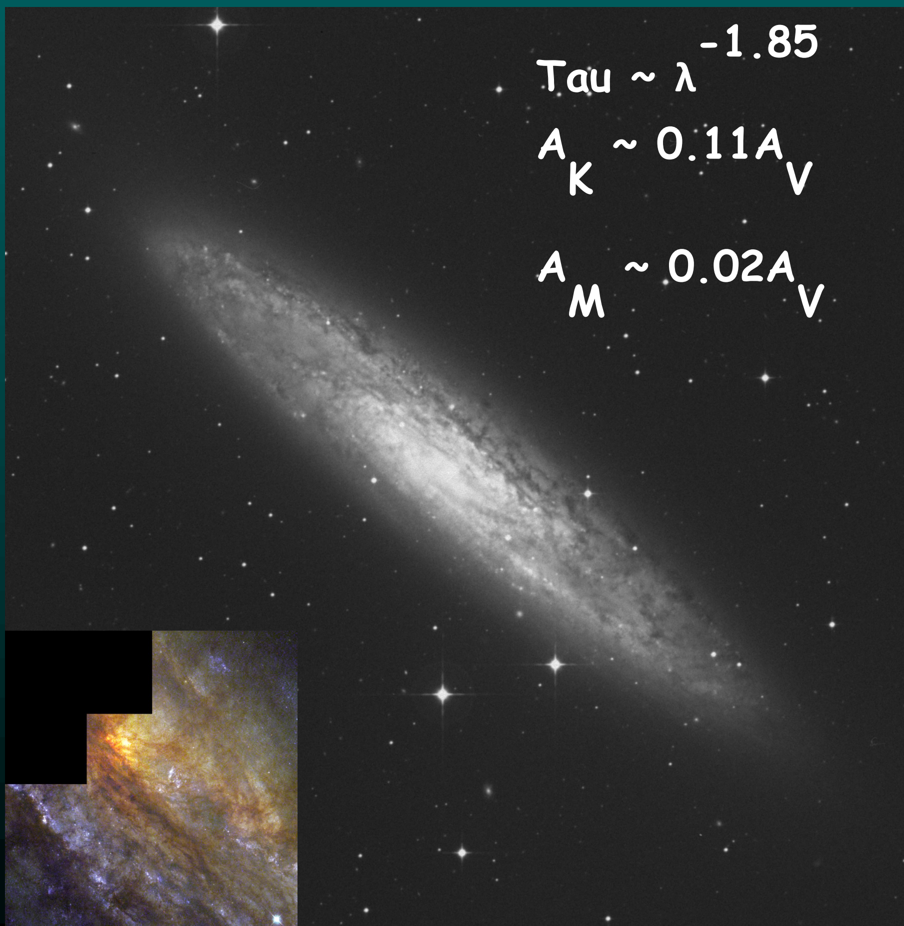


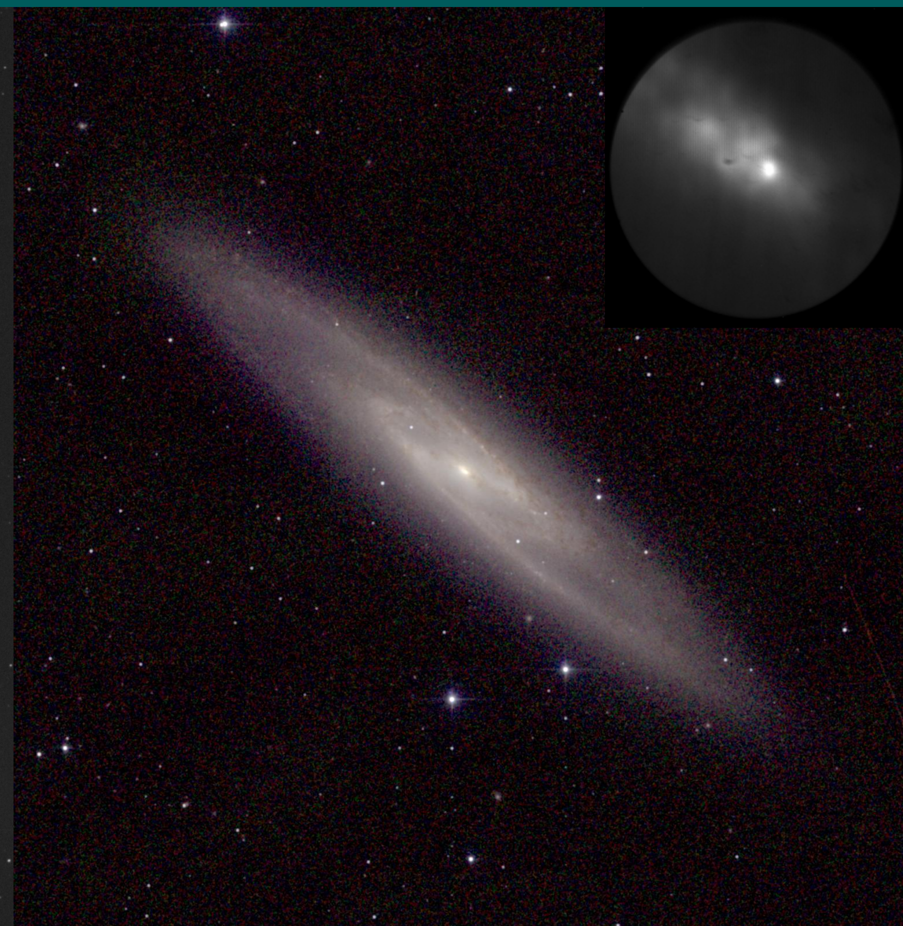
GEMINI OBSERVATORY

Why use the NIR

Reduced Extinction

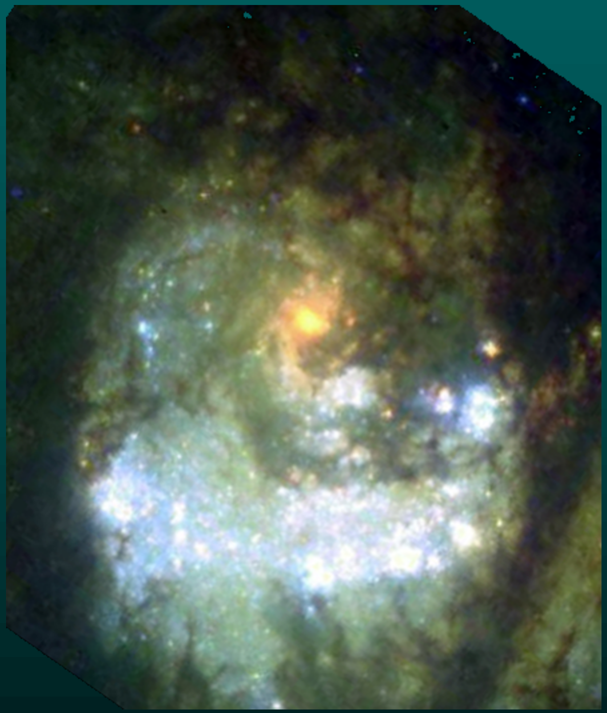
Phoenix, K band



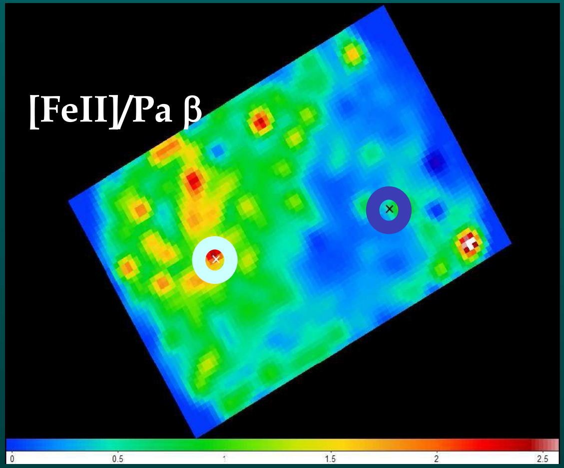


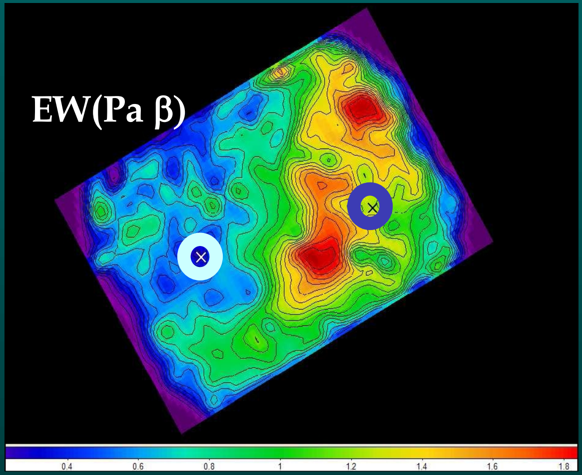
Why use the NIR

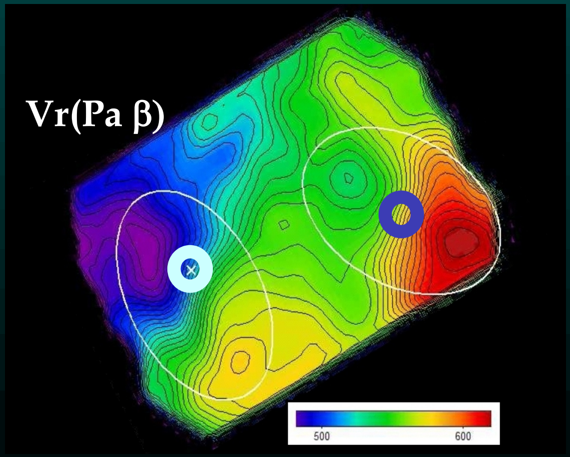
Reduced Extinction

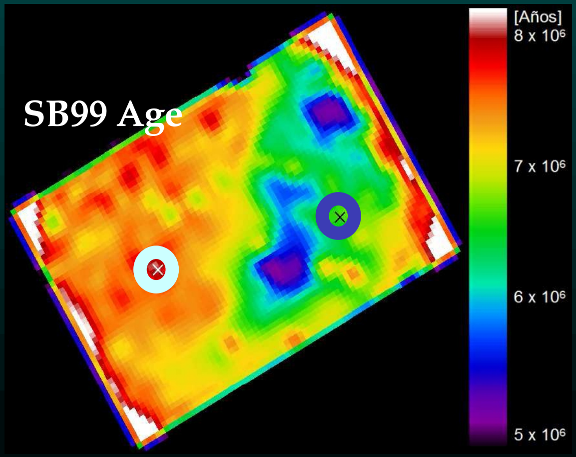


CIRPASS, J band



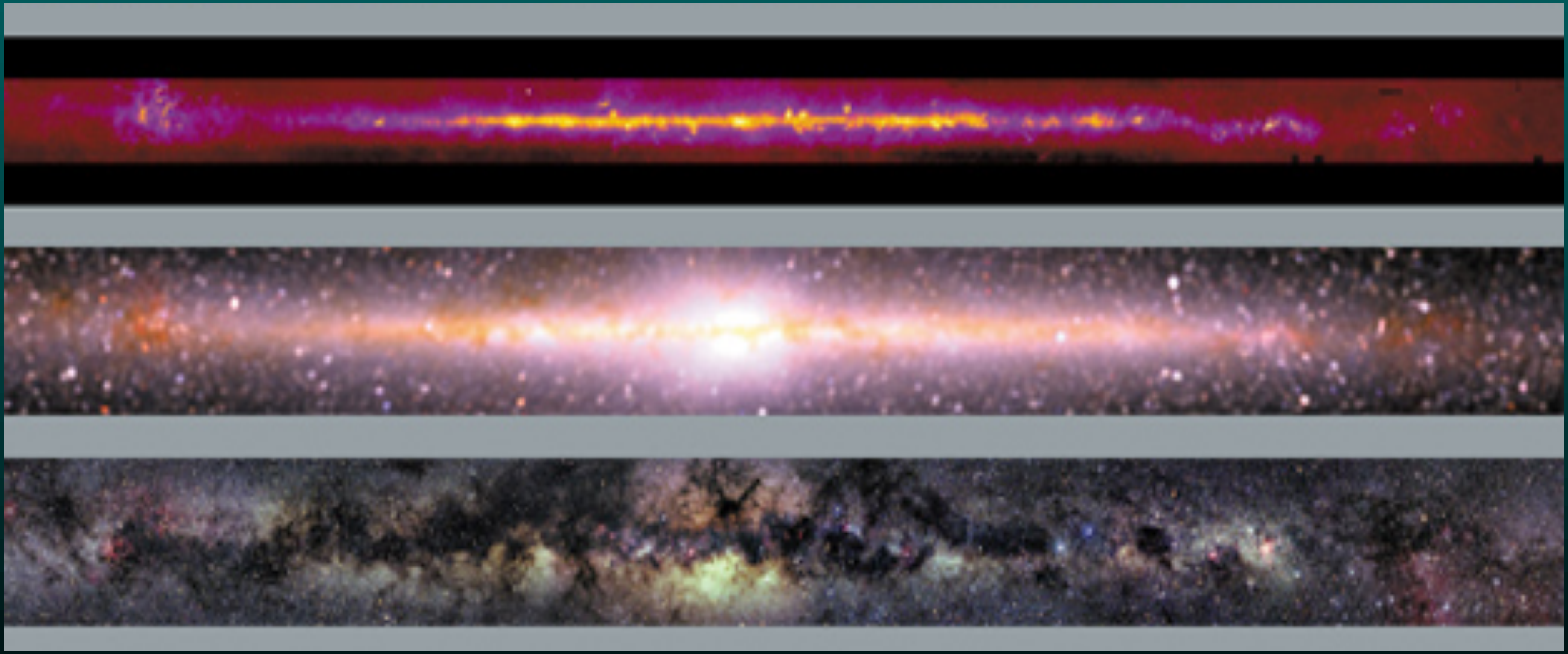






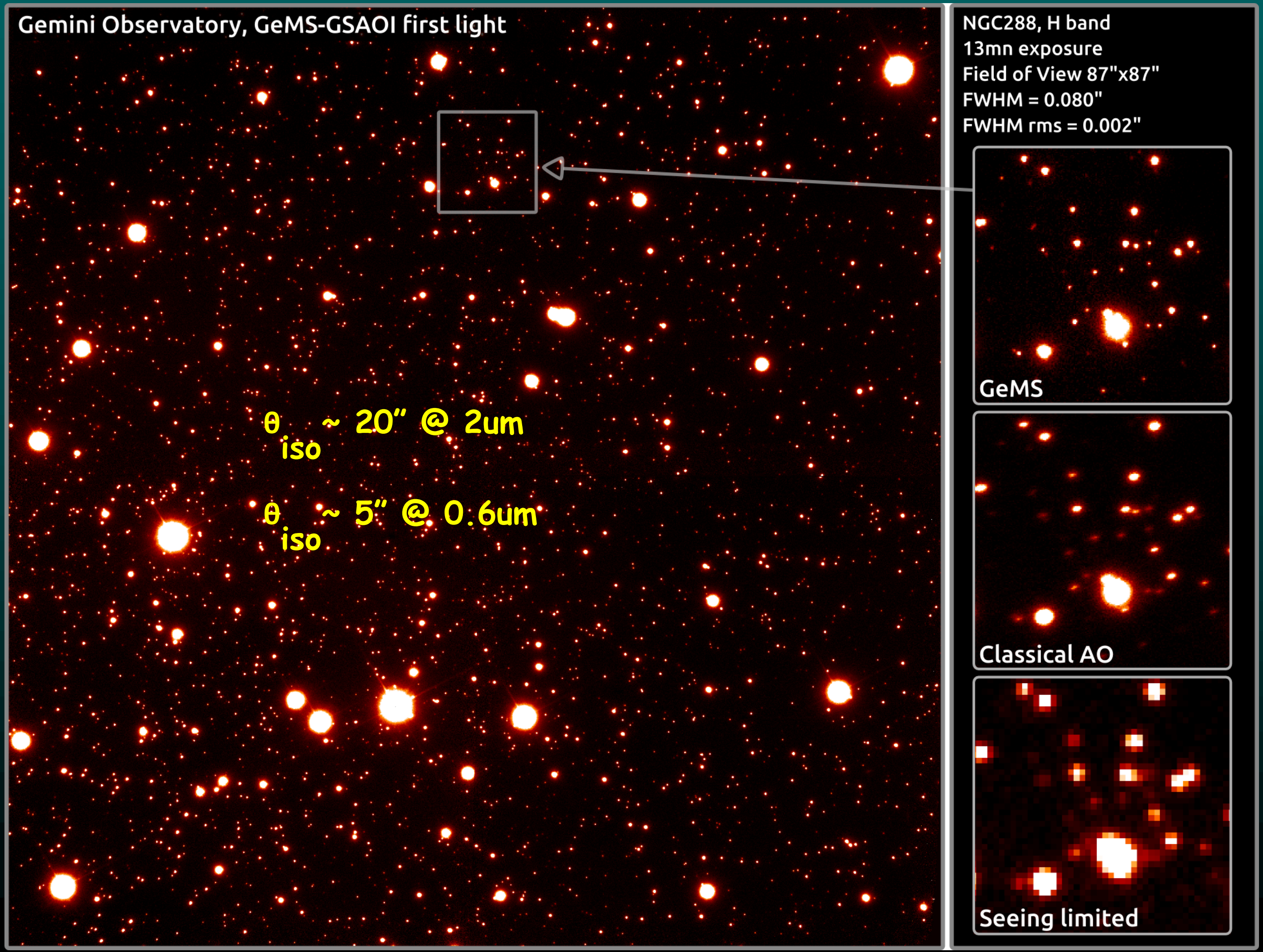
Why use the NIR

Reduced Extinction



Why use the NIR

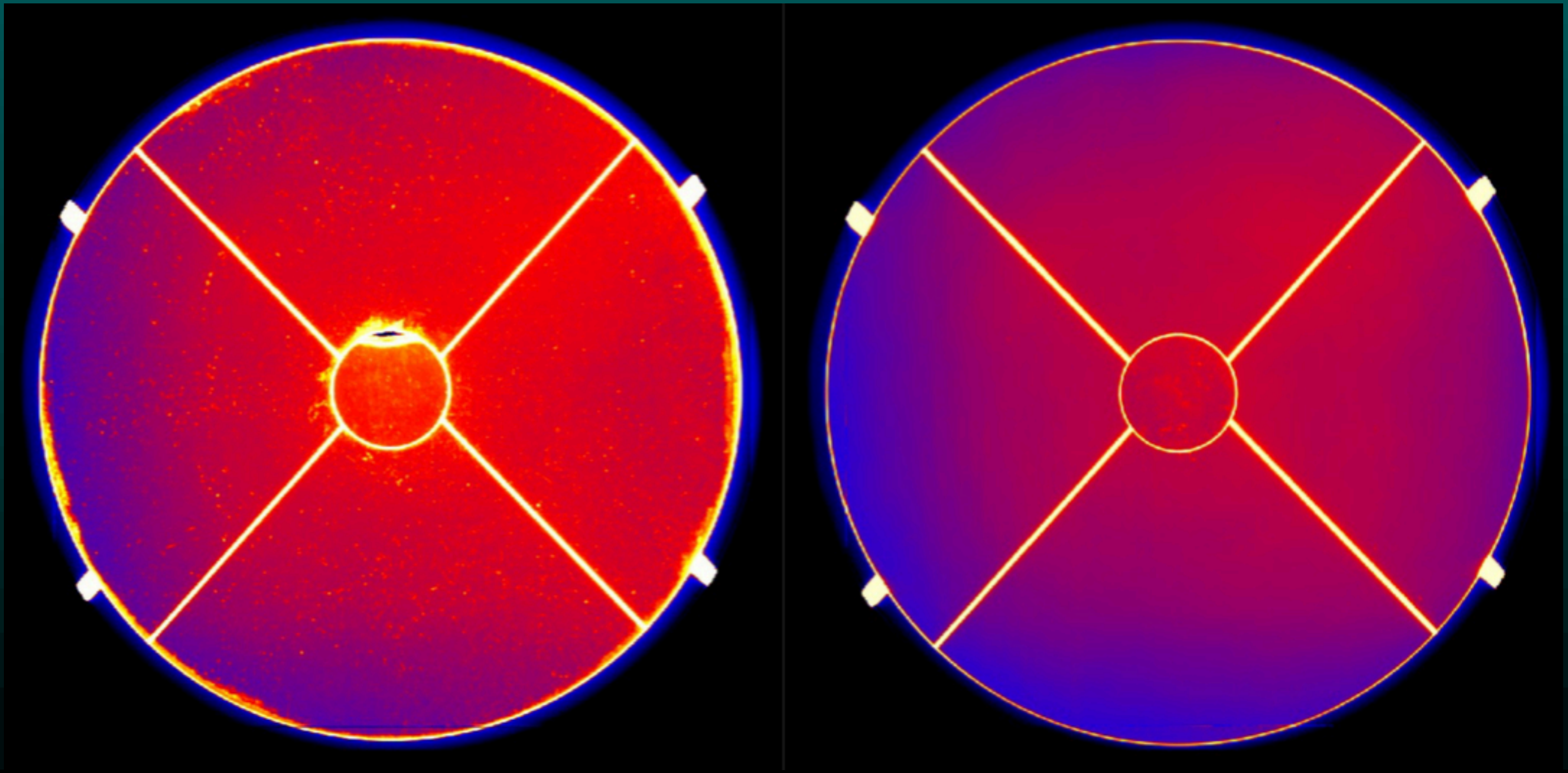
Enhanced AO performance



Challenges of the NIR

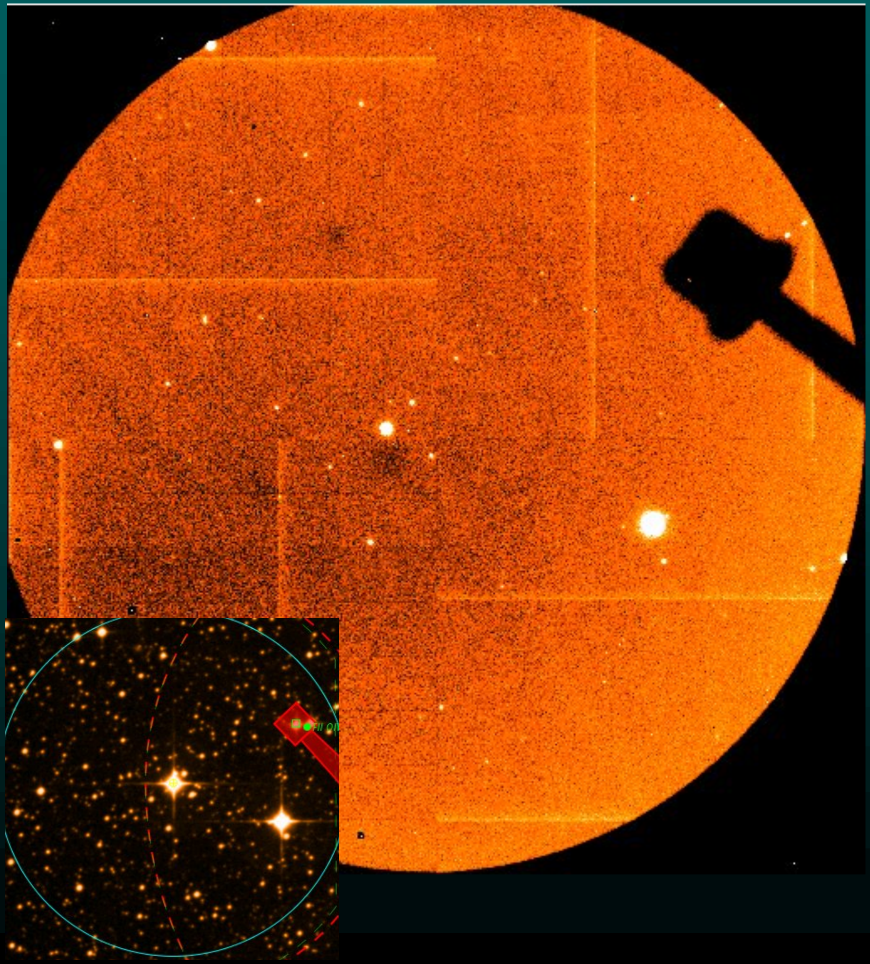
Background (emission from anything warm in the beam)

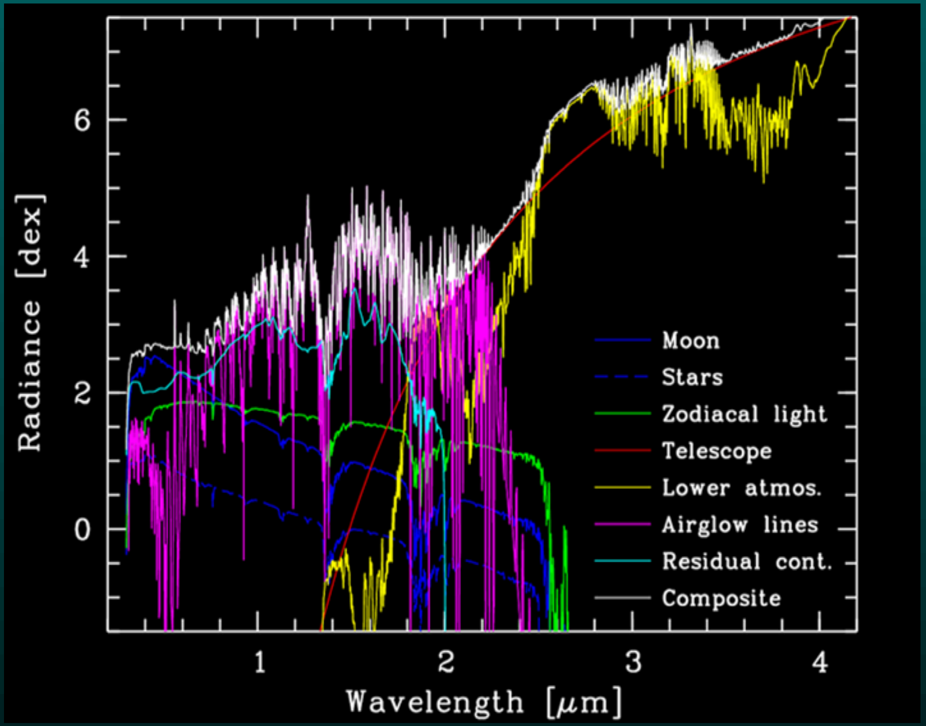
Optics: M1, M2, sci-fold | M2 support | Atmosphere



Challenges of the NIR

High background, specially in H and K.

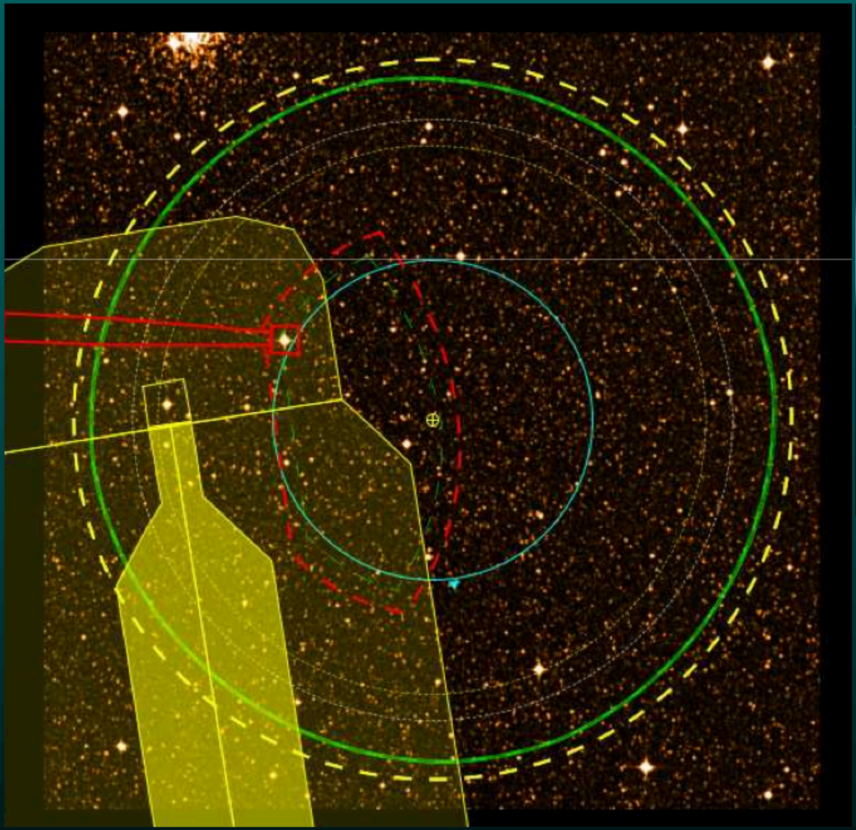


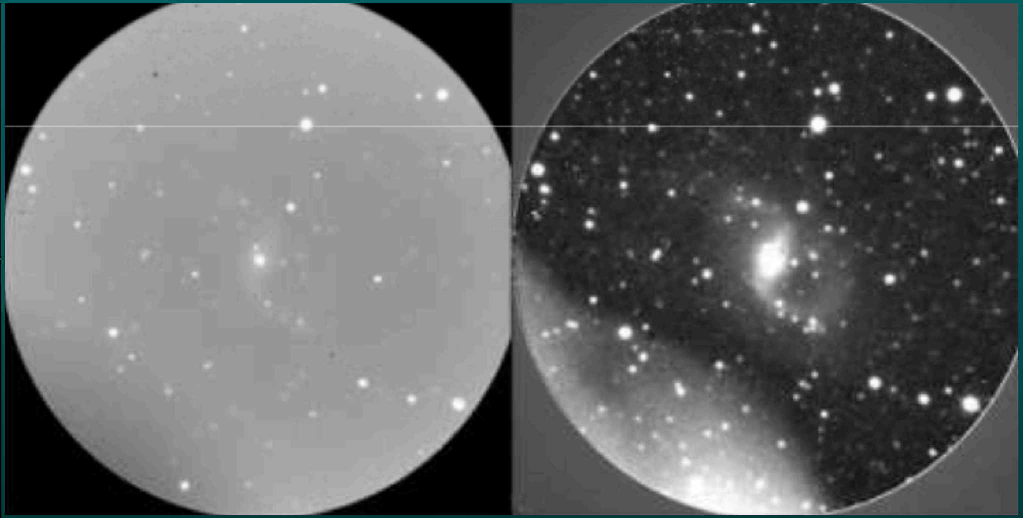


Important: half of the useful dynamical range is used in only 15 seconds of H or Ks imaging with F2

>>> It is easy to saturate

Challenges of the NIR

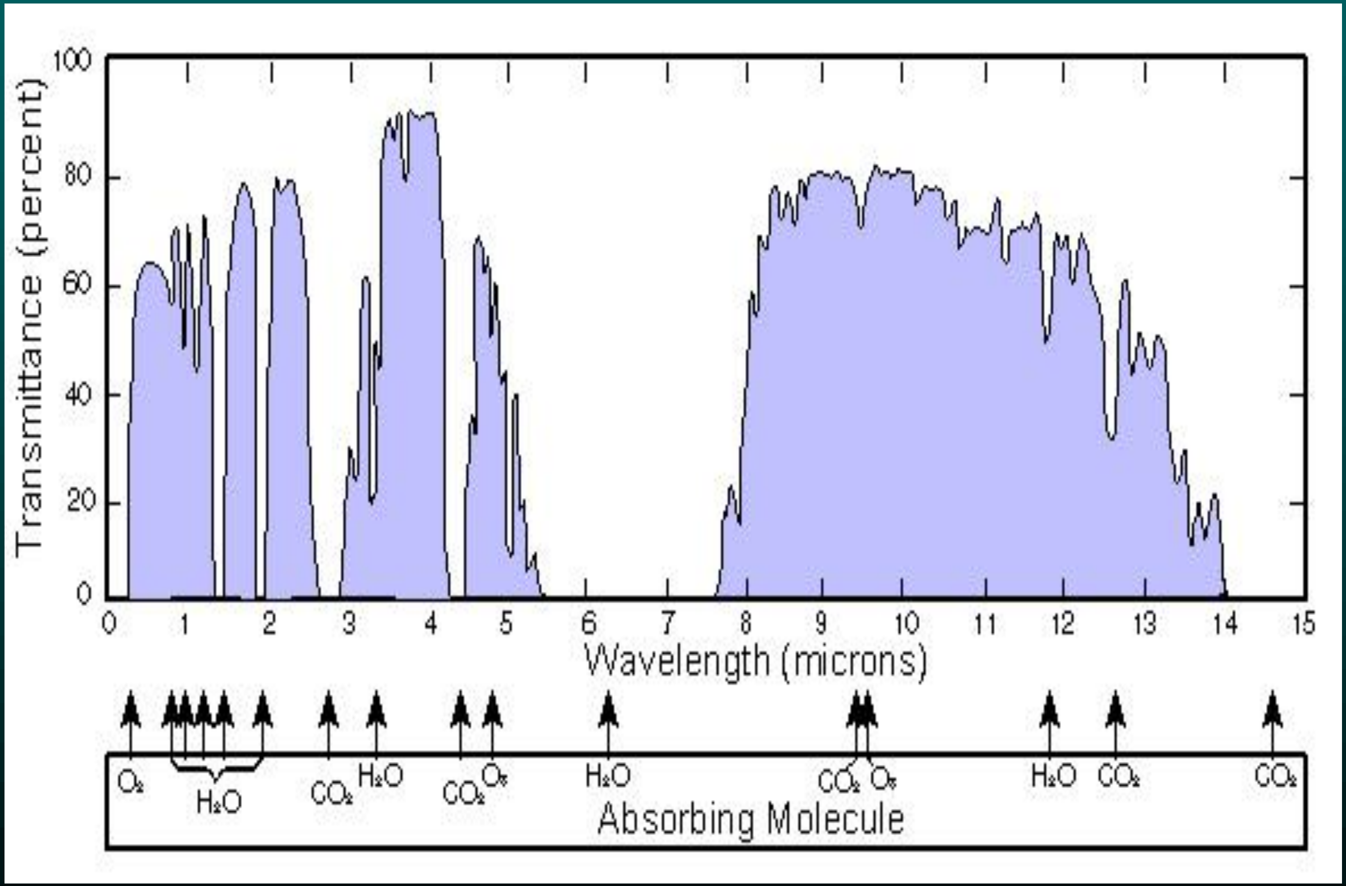




At J & H bands, the PWFS2 produces vignetting.

At K band, it increases the thermal background.

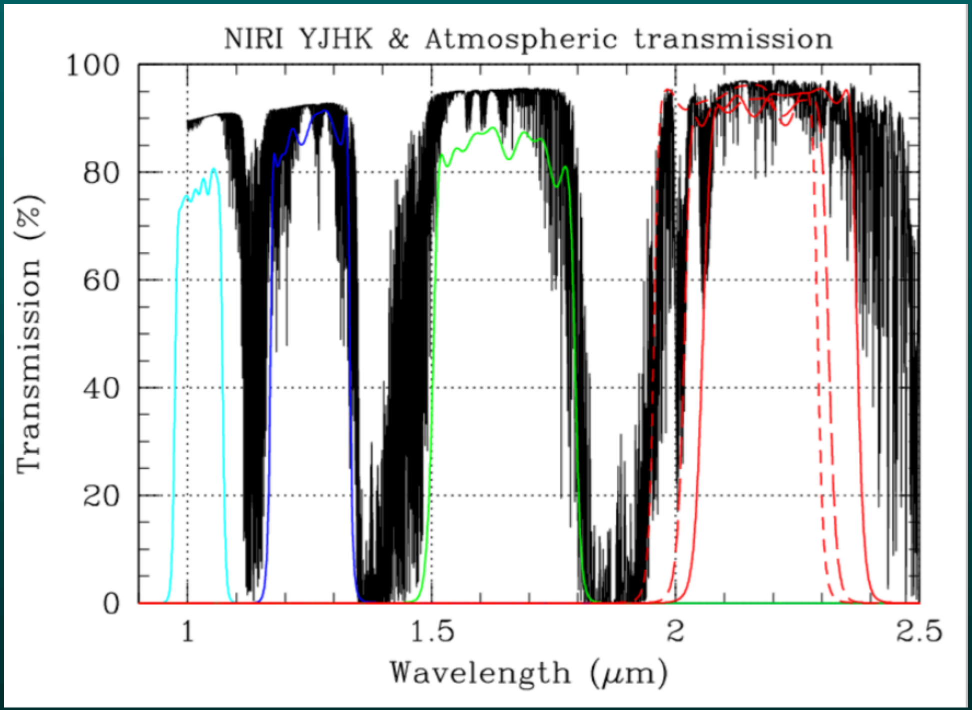
Challenges of the NIR

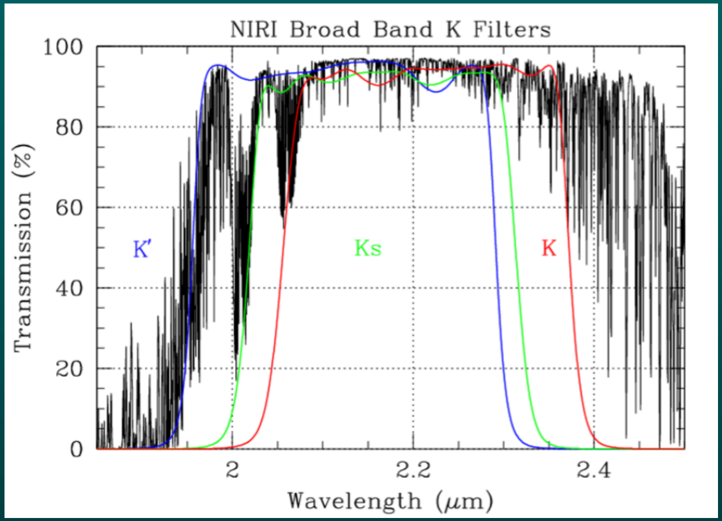


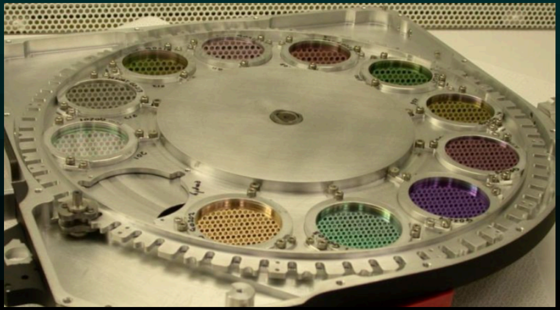
Atmospheric windows

λ Range	Filter
1.1 – 1.4 μm	J
1.5 – 1.8 μm	H
2.0 – 2.4 μm	K
3.0 – 4.0 μm	L
4.6 – 5.0 μm	M
7.5 – 14.5 μm	N
17 – 25 μm	Q

Challenges of the NIR







Variations of the K-filter

Ks & K' have shorter λ cutoff to reduce terrestrial and telescope thermal background.

K' has shorter cut-on to take advantage of low WV (and reduced H2O absorption) on MK.

Challenges of the NIR

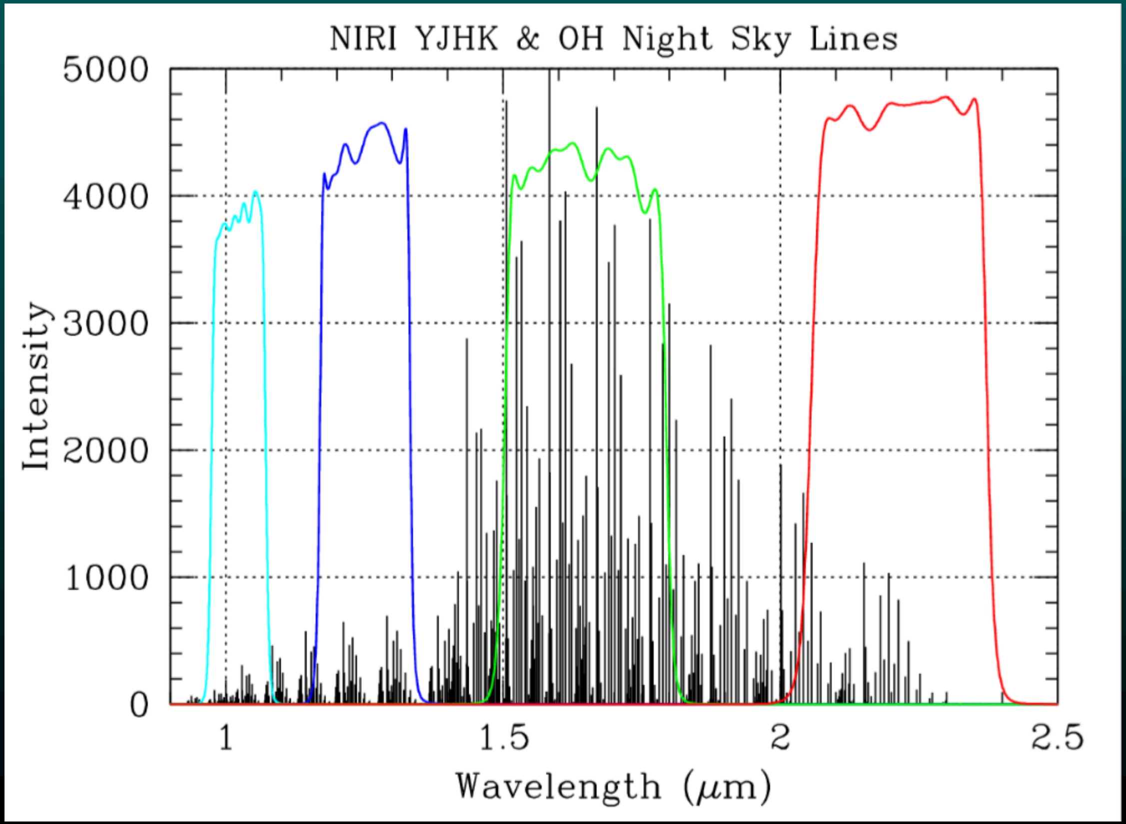
OH airglow strong source of background

From OH- @ 85-100 km in Earth's atmosphere

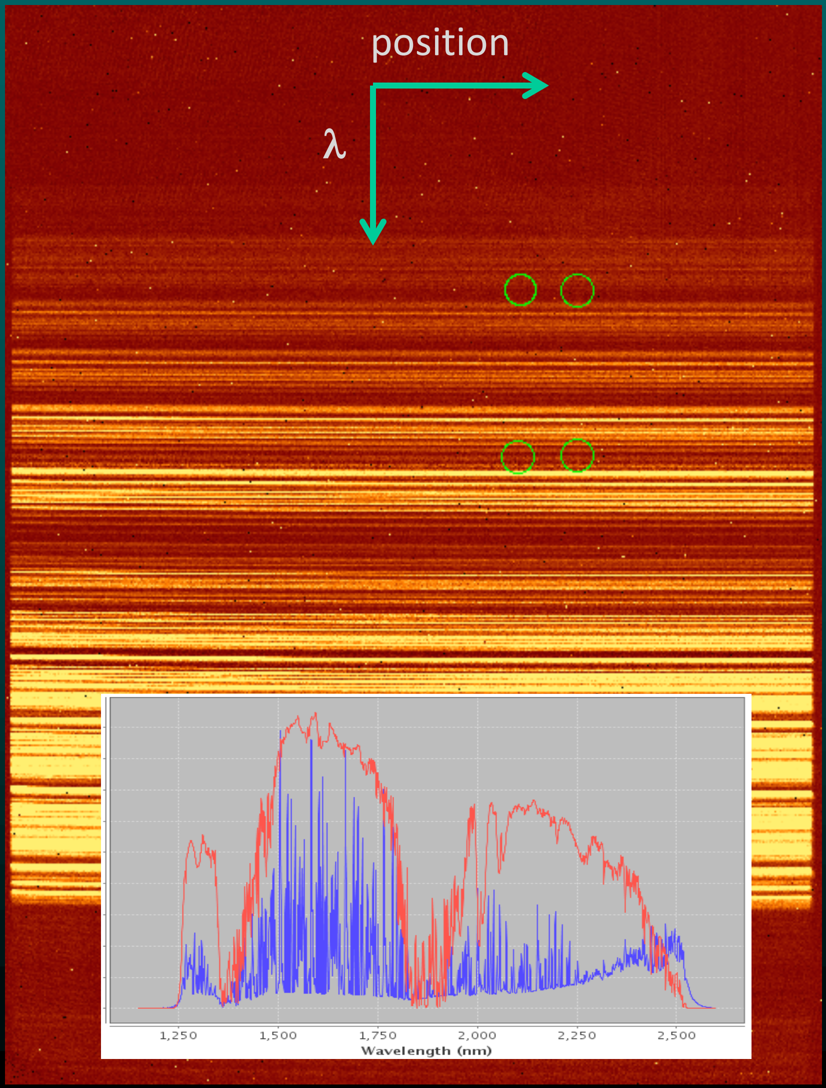
Spatially variable; ~10 km

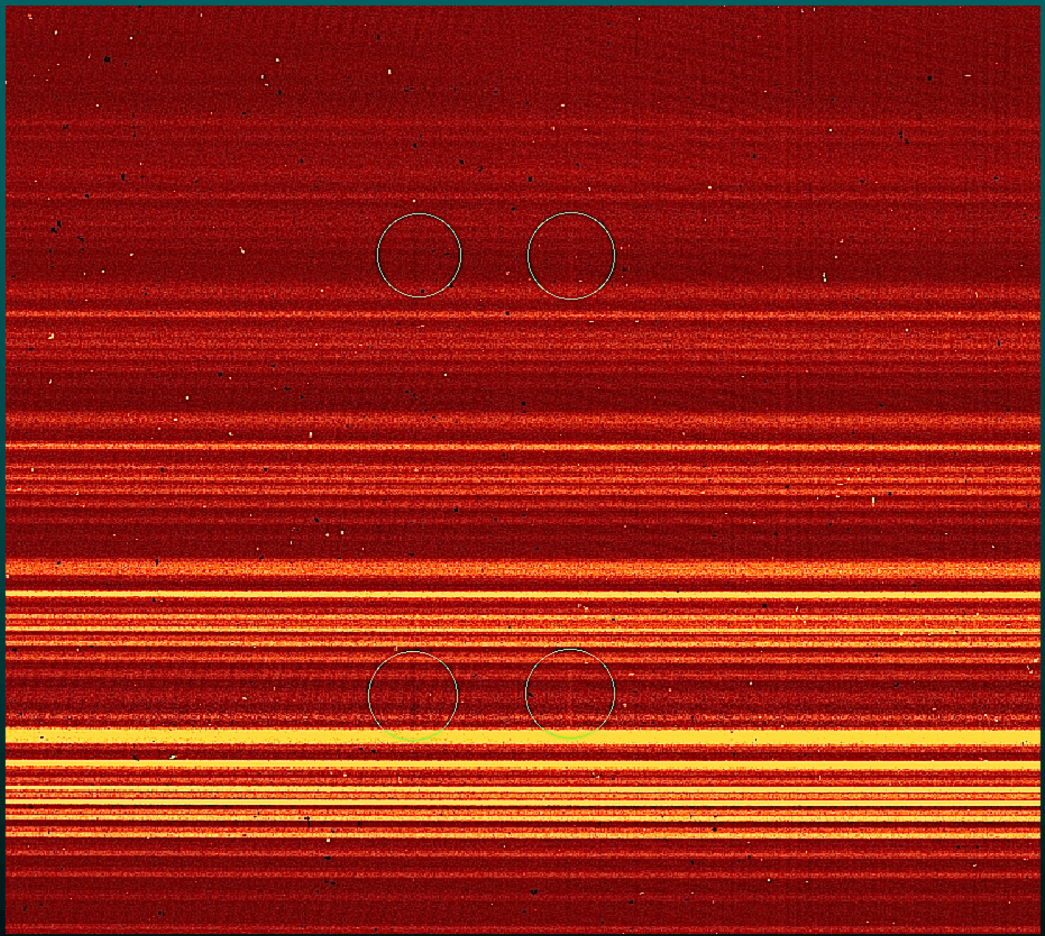
Temporally variable

10% in ~5-15 min



Challenges of the NIR

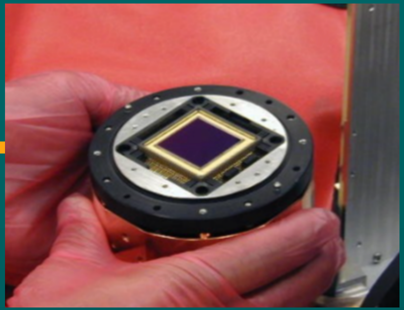




Y dwarf candidate, H ~ 20.5
Raw spectra combined 10 min. per node

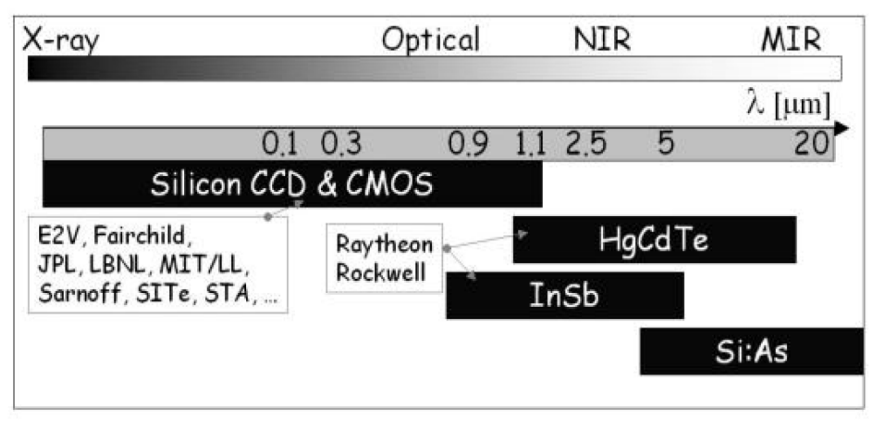
GEMINI OBSERVATORY

Detectors



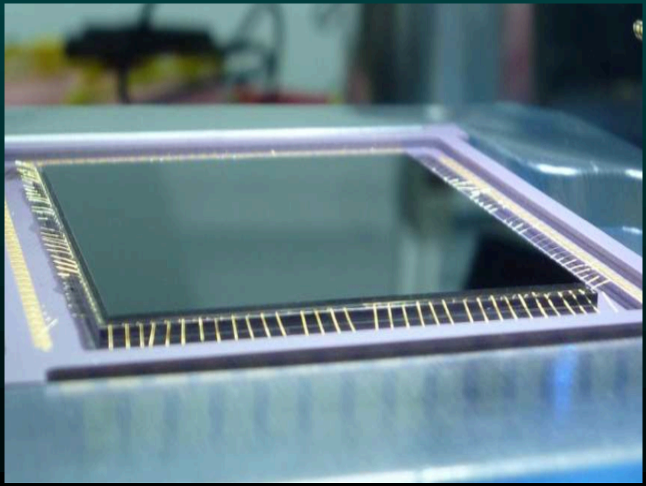
Indium Gallium Arsenide (InGaAs)
Indium Antimonide (InSb)

Sensitivity: 0.8 – 5.5 um
Wide wavelength coverage
Need strict thermal radiation control
1024 aka "Aladdin"
NIRI & GNIRS



Mercury Cadmium Telluride (HgCdTe)
1024 aka "Hawaii" 2048 aka "Hawaii-2"
NIFS, Flamingos-2, GSAOI, GPI

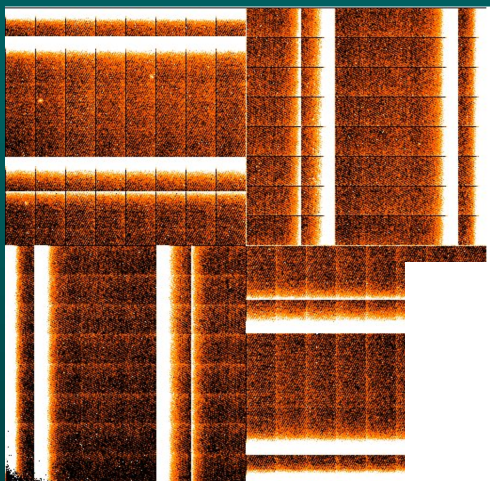
32 outputs, pre-amplifiers & A-D converters
Split into 4 quadrants.
Voltages are read and digitized
(twice in the simplest read "correlated double sampling").
The voltage difference gives the number of electrons collected.
The error in determining the number of electrons is the "read noise".



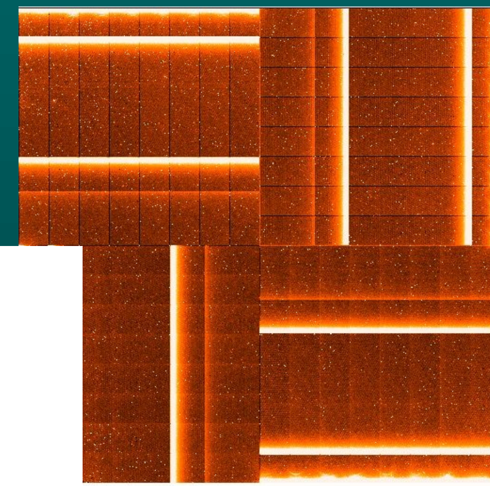
We now have a H4RG available for an instrument upgrade.

Detectors

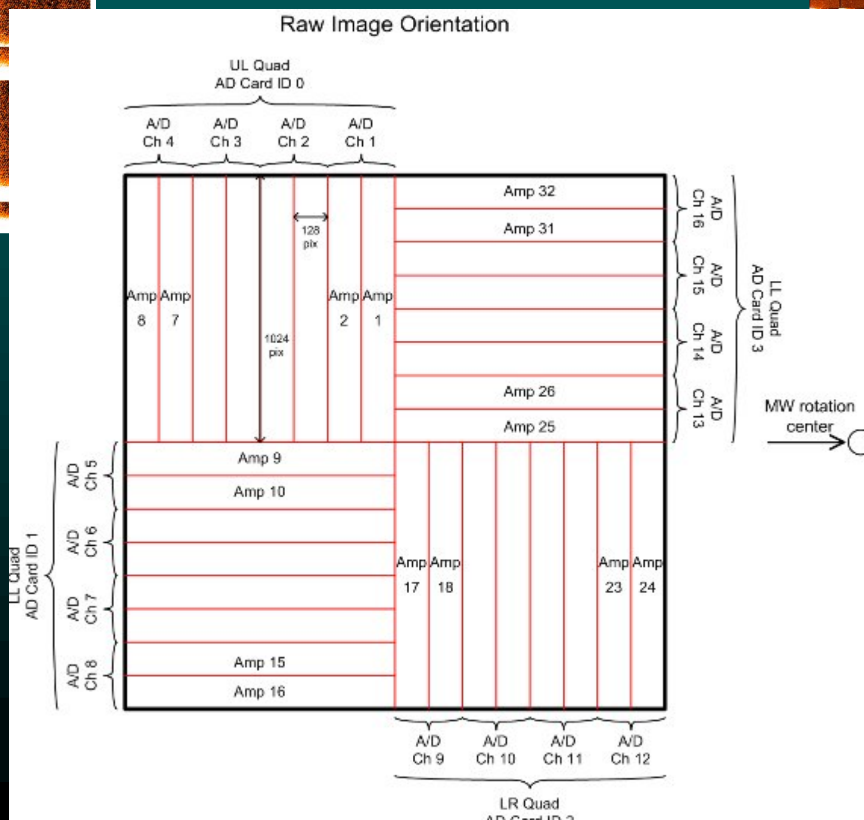
F2 darks



3 seconds CDS

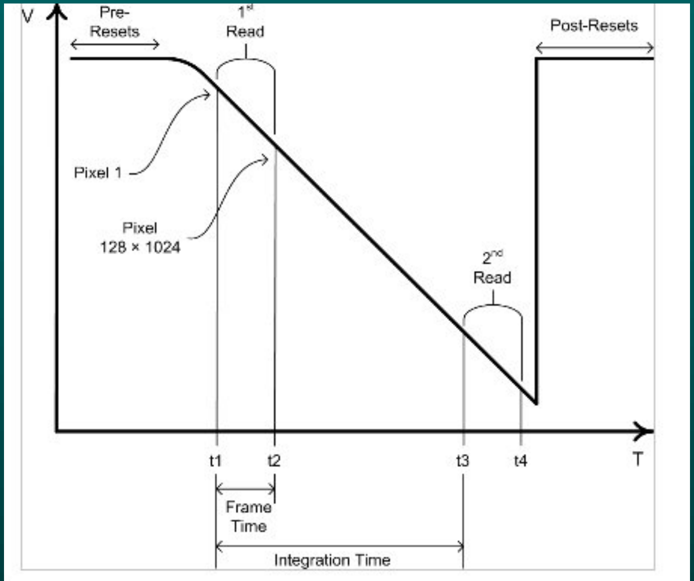


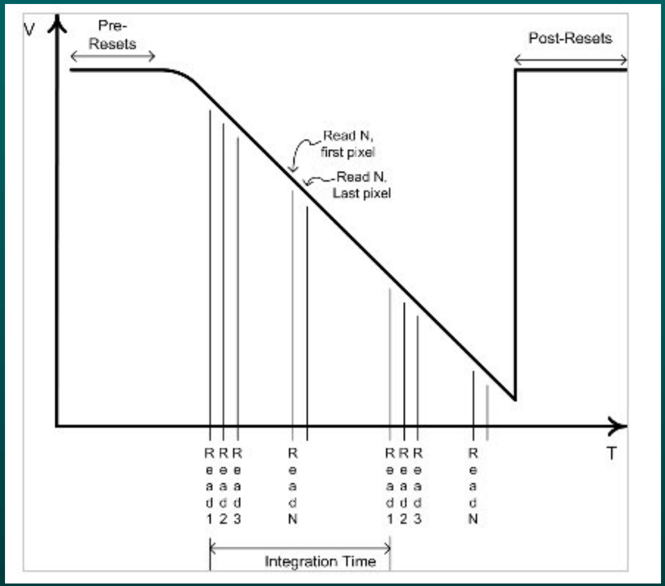
120 seconds CDS



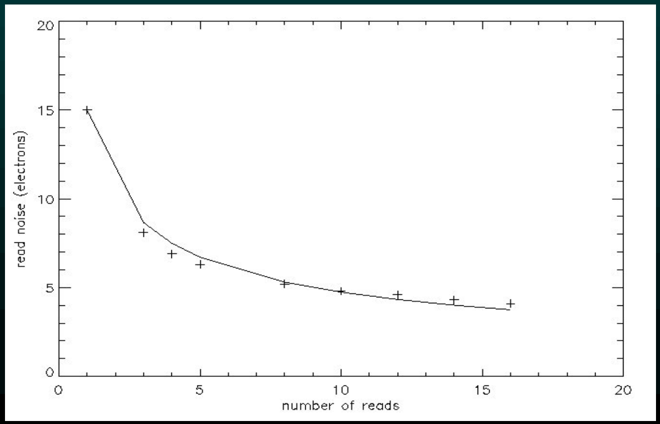
Amplifiers thermal glow

Detectors





CDS = First_read - Second_read
or
MDS = Sum of First_Reads – Sum Second_Reads

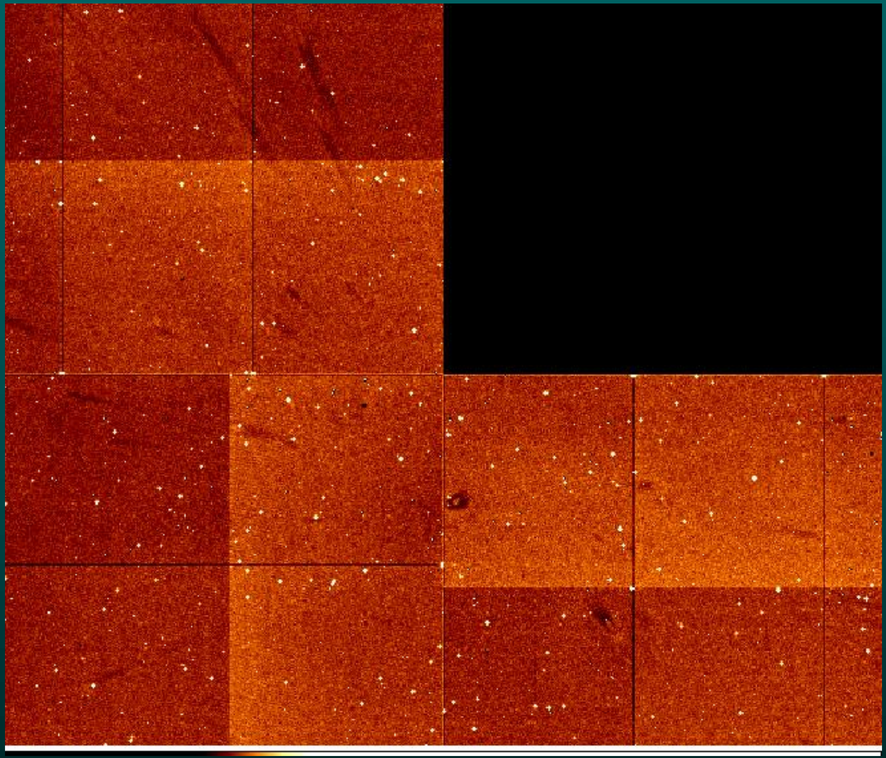


Readout noise decreases with the number of reads ($n^{-1/2}$)

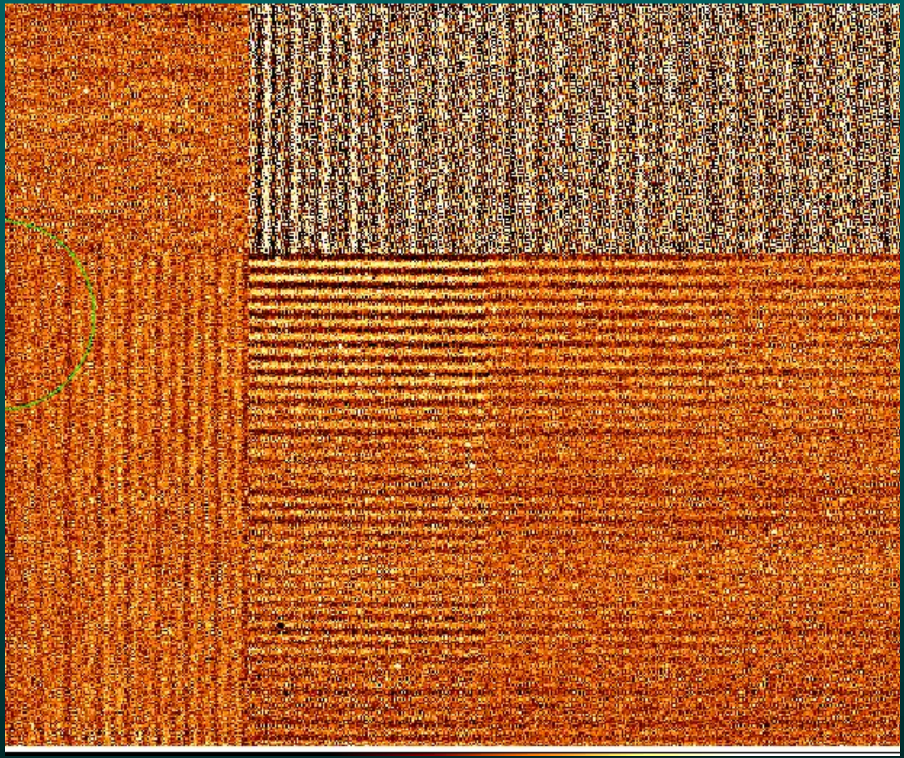
Photoelectron charge is not displaced, voltage is read.

Exposures cannot be aborted. It may require controller reboot.

Detectors



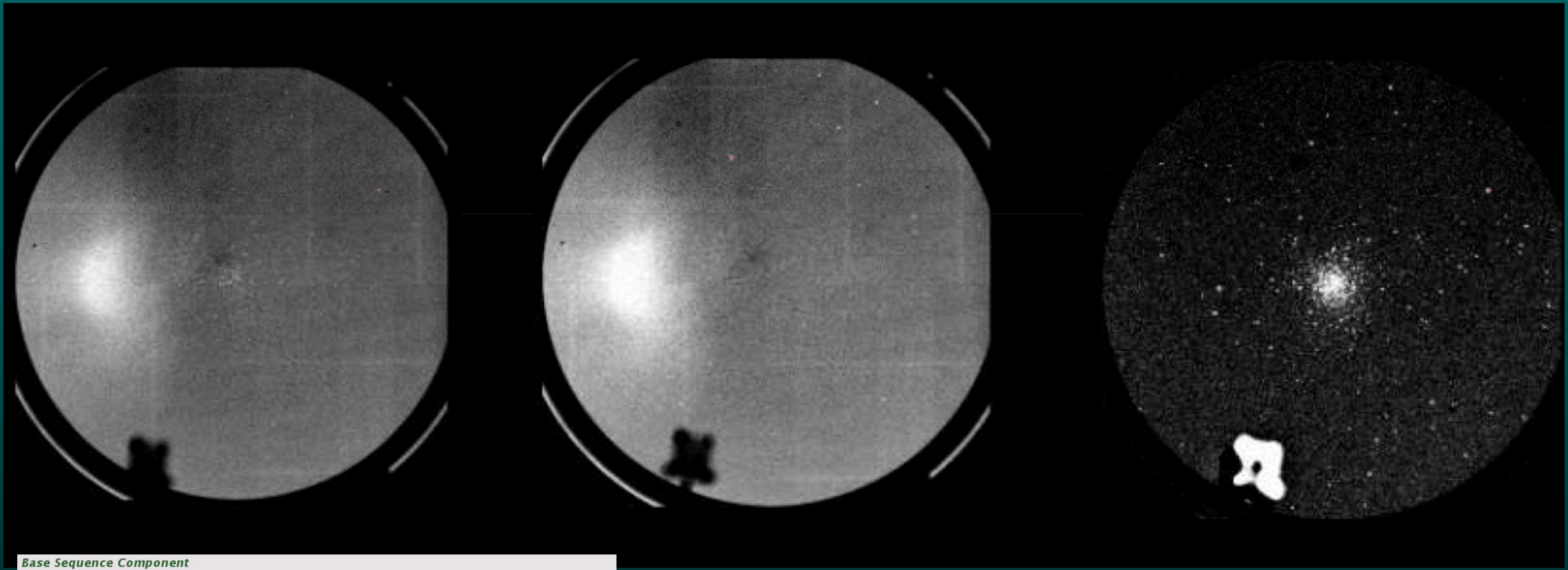
Cosmetic “splash pattern” (was removable)



50 Hz pick-up noise (removed from the electronics)

Hawaii-2 detectors

Observing strategies



Base Sequence Component

This component contains the sequence of operations that generates the observation science data.

Title: Sequence

Sequence | Timeline

Data Label	Class	P	Q	Exposure Time	Filter	Observing Wavelength	Guide With OIWFS
GS-F2-RECOM13-RUN-3-224-103	Science	-10.0	10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-104	Science	10.0	-10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-105	Science	-10.0	-10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-106	Science	270.0	270.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-107	Science	300.0	300.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-108	Science	240.0	300.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-109	Science	300.0	240.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-110	Science	240.0	240.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-111	Science	0.0	0.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-112	Science	10.0	10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-113	Science	-10.0	10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-114	Science	10.0	-10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-115	Science	-10.0	-10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-116	Science	270.0	270.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-117	Science	300.0	300.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-118	Science	240.0	300.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-119	Science	300.0	240.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-120	Science	240.0	240.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-121	Science	0.0	0.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-122	Science	10.0	10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-123	Science	-10.0	10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-124	Science	10.0	-10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-125	Science	-10.0	-10.0	10.0	K-short (2.15 um)	2.15	guide
GS-F2-RECOM13-RUN-3-224-126	Science	270.0	270.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-127	Science	300.0	300.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-128	Science	240.0	300.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-129	Science	300.0	240.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-130	Science	240.0	240.0	10.0	K-short (2.15 um)	2.15	freeze
GS-F2-RECOM13-RUN-3-224-131	Science	0.0	0.0	10.0	K-short (2.15 um)	2.15	guide

Static Configuration

```
--> ndi S20130717S0306 sky=S20130717S0311
Image = adata@S20130717S0306
Instrument = F2
Setting saturation value to 25,000 ADU
Subtracting S20130717S0306 - S20130717S0311
Image has 1 coadd.  Pixels with >25000 ADU marked in red.
Obs-ID = GS-F2-RECOM13-RUN-3-224
Target = "NGC 7006"
Local time of image = 05:15:03.1
Exposure time = 10.0 sec  x  1 coadd
Airmass = 1.79
Filters = Ks_G0804 + Open
Decker = Open
Grism = Open
Running imexamine with ACS...
```

In the NIR, overheads are large, sky subtraction in extended object imaging implies overhead larger than actual on-source time.

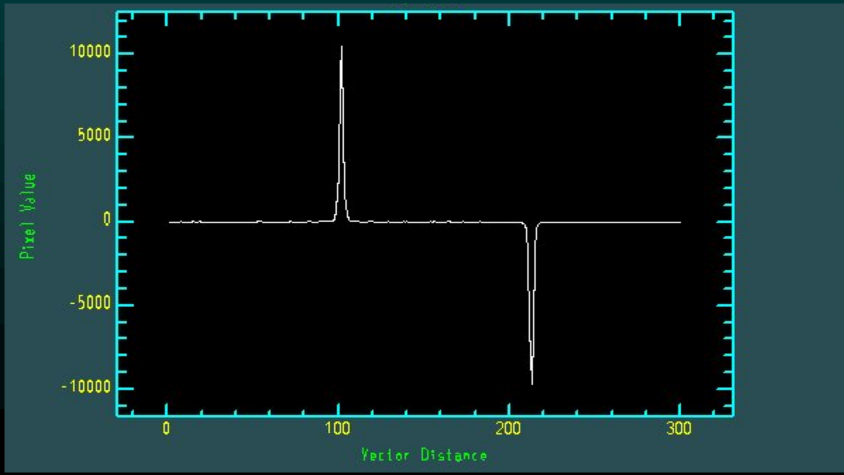
Observing strategies

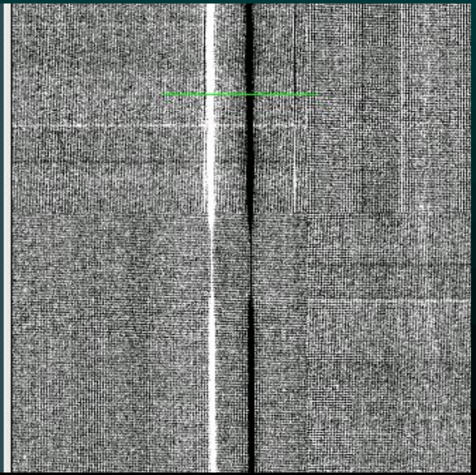
Often the sky is brighter than the science target.
Need to subtract a "sky frame" of equal exposure time.
2 methods of measuring sky contribution:

- Dither telescope with offsets > size of objects
- Offset telescope to empty field

Sky frame includes dark current contribution (and the many detector defects).
The sky brightness is changing with time.
Required measurement frequency is a function of wavelength.
Generally want a sky frame every ~5-10 minutes.

For spectroscopy nodding along the slit is used:



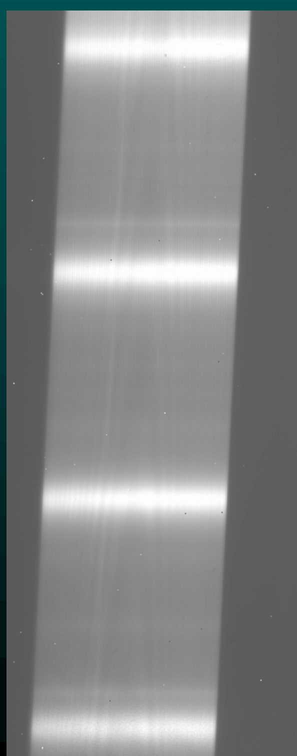


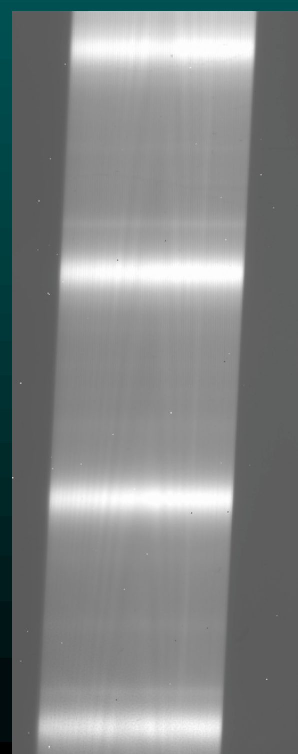
At the NIR observing conditions vary a lot and quickly. Check expected signal using the ITC and be conservative.

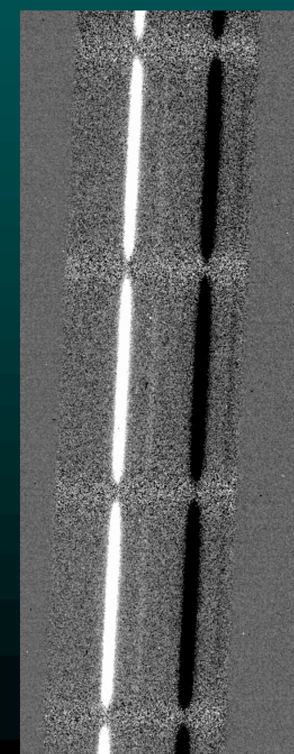
Observing strategies

Example: High resolution spectrum in M band (Phoenix)

Nod A - Nod B = Difrerencial spectrum



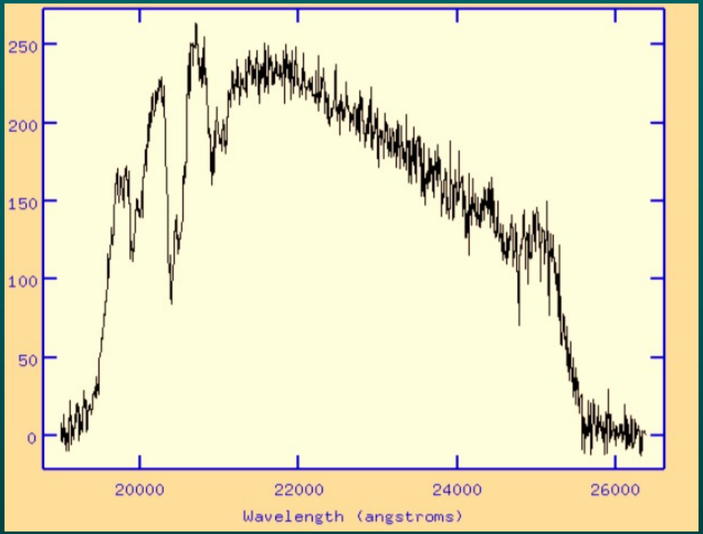


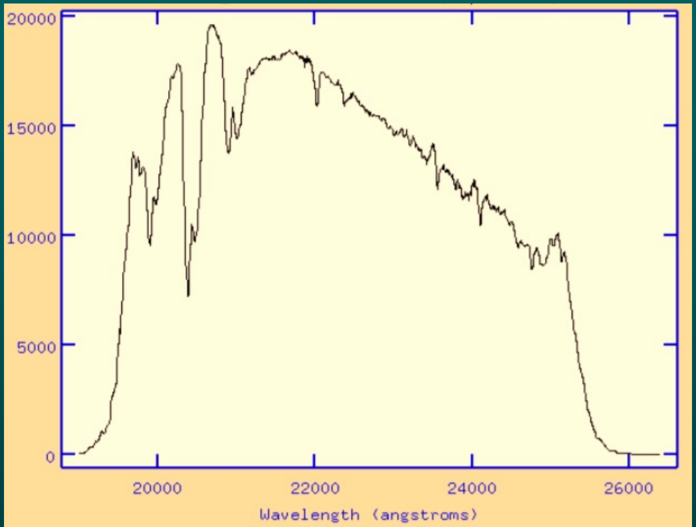


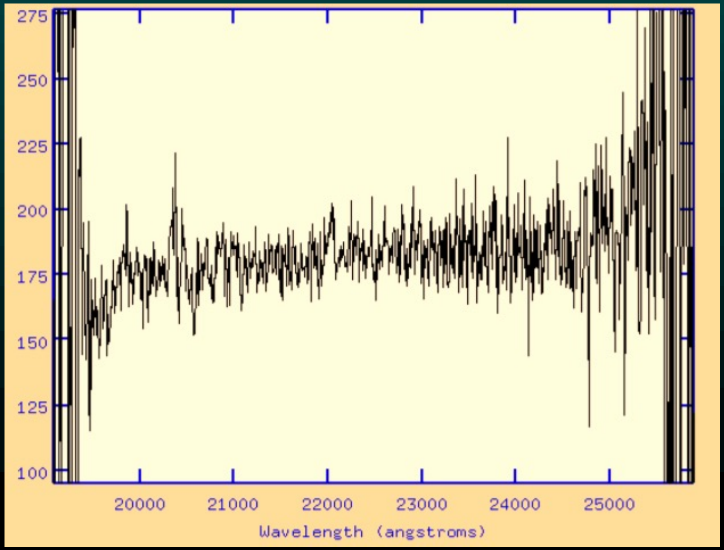
Calibrations

Calibration	Frequency
Imaging flats	Daytime program calibration
Imaging photometric standard	If requested and prepared at the OT program
Imaging darks	On a periodic basis (unless requested)
Spectroscopic GCAL flat & arc	On-sky, one set per configuration
Telluric star	One each 1.5-2 hours on sky
Spectrophotometric standard	If requested and prepared at the OT program
Spectroscopic darks	On a periodic basis (unless requested)

Calibrations



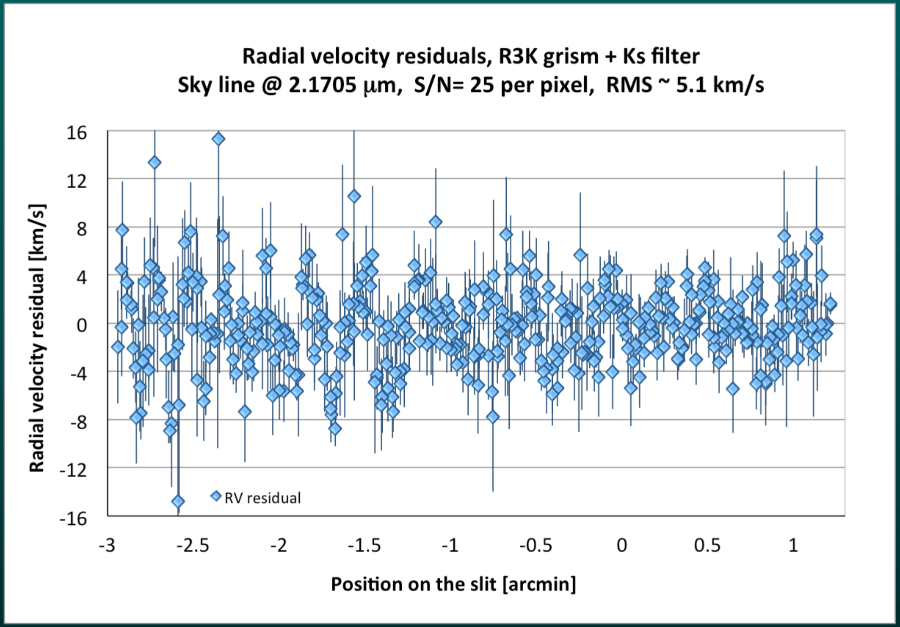


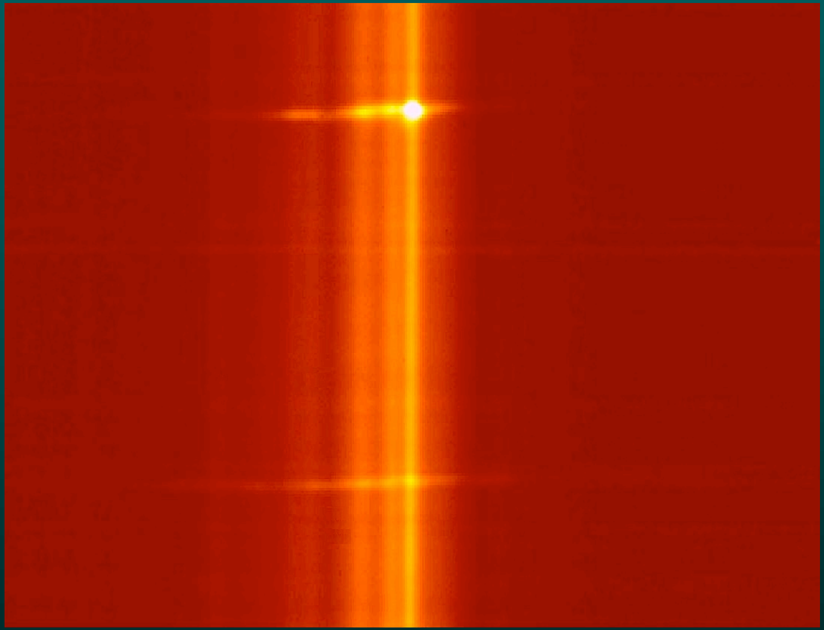


Telluric standard.

Used to derive an atmospheric transmission curve made from the observation and a library model of the telluric standard.

Calibrations





Good radial velocity precision is achievable due to the use of sky emission lines as reference.

Galaxy nucleus spectrum, note the difference between ionized and molecular gas, respect to the sky emission lines.

Typical performance

Band	F2	NIRI	MOIRCS
Y	22.2		24.6
J	23.5	23.5	24.0
H	22.7	22.5	23.2
Ks	22.8	22.6	22.8

S/N~5 in 1 hour on-source, conditions IQ70, CC50.

Total transmission typical to NIR instruments:

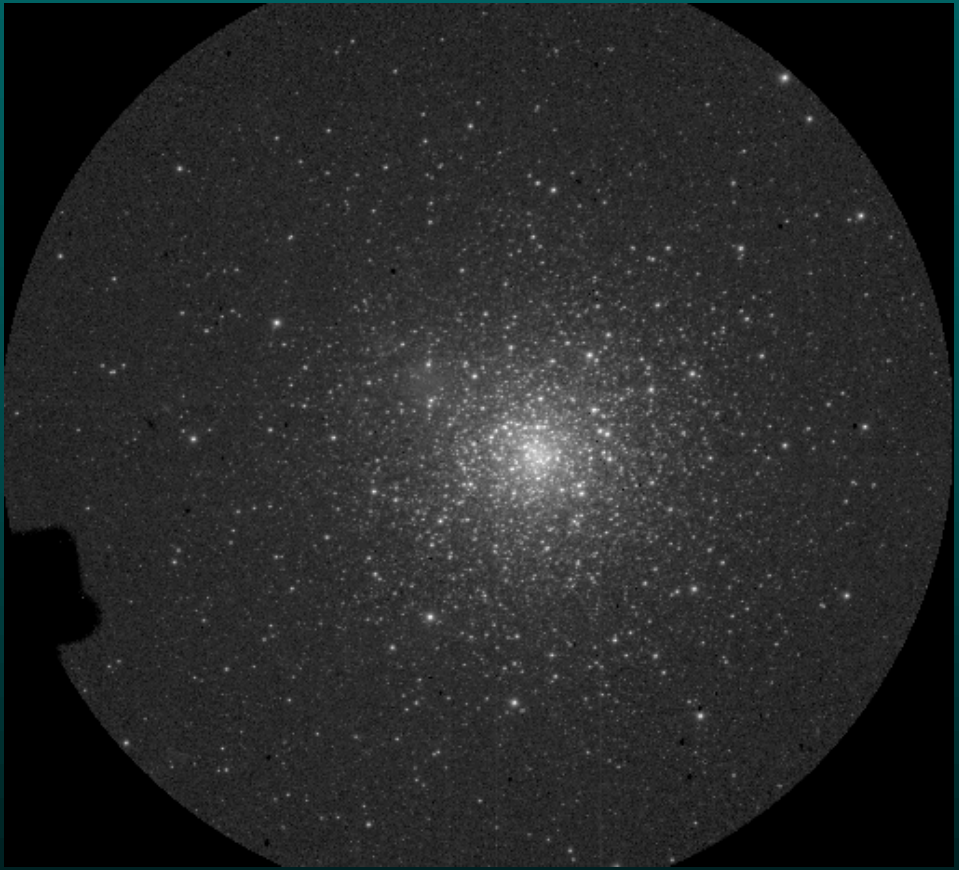
~30% in *J*, ~45% in *H*, y ~50% in *Ks*.

In spectroscopy mode:

~20% en *JH*, ~35% en *HK*.

S/N~5 in 1h spectra:

18.4 *J*, 18.6 *H*, 17.6 *Ks* (IQ70, CC50).



NGC 1851, F2, Y band.
FWHM = 2.1±0.2 pixels = 0.38”,
e = 0.08±0.03 across the 6’ FOV.

Questions?

GEMINI OBSERVATORY

Thanks!

F2, JHKs
reduced by Mischa

GEMINI OBSERVATORY

Appendix – Imaging calibrations

BASELINE CALIBRATION:

- Flat fields: For each on-sky imaging observation we provide GCAL flats which should be taken within the same week (preferably at the end of the night). The purpose of the GCAL flats is to correct the pixel-to-pixel response variations, which are quite stable. The only requirement is that the illumination is smooth and that the peak counts are below 23k ADUs.

  These are separated sequences located in the same program.

  Flat fields are always taken in CDS mode (single read = 'bright object' configuration).

- Darks: the dark current level is low and stable enough to allow the darks to be taken on a weekly basis. On Fridays the daytime SOS runs a script that checks all the exposure time / readmode pairs used in the week, and constructs a sequence that has to be run on the weekends.

  On each Monday, the SOS has to assure that these darks were taken and are all passed. Otherwise has to prioritize taking (or repeating) the sequence soon.

Appendix – Spectroscopy calibrations

DURING THE OBSERVATION:

- Direct image of the focal plane unit. This one, taken during the acquisition, not only is used for registering the slit position, it is also a check of the slit width, extension and uniformity.

- GCAL flat field frame: without moving the grism, a flat field is taken. It serves to trace the position of the spectrum and to correct the pixel to pixel (or row to row) response variations. One flat is enough for most purposes (because in the spectra the noise is dominated by the source itself). If more than one flat is requested then it is charged to the program.
  As usual, check that the flat count peak does not reach the non-linear level of the detector, and that it has enough signal. I.e., the peak level should be within 5k-23k ADUs.

- Arc frame: it is also taken on the spot, for every spectroscopic sequence before moving the grism. In order to allow enough lines to have good signal, usually one or two Ar lines are saturated. That's fine.

- Sky spectra: nodding the object along the slit in timescales lower than the sky variation (120-300 seconds) is the only alternative to apply complex atmospheric line emission models. The nod length depends on the extent of the object, can be to a different position on the sky if the object is very extended.

Appendix – Spectroscopy calibrations

TELLURIC STANDARDS:

- Spectra: For each 1.5 h of observation we provide a telluric standard star observation, in the same configurations as the science spectra. This one should be chosen by the PI (in order to avoid that some stellar absorption lines are located just on a precious portion of the spectrum. For most of the applications these are ~A0V stars (mostly featureless except for the Paschen/Bracket series H lines). We provide a good sample in the OT library. It has to be taken at approximately the same airmass (within ~0.2 airmass difference).

  Check that spectrum peak is within the linear range (5-23k ADUs for F2).

- All telluric observations should be taken with an arc and a flat.

- Spectrophotometric calibration. Is provided by the telluric itself after slit losses correction. The telluric standard magnitudes are well known, these combined with the stellar atmosphere model spectrum allow to achieve 10% accuracy in spectrophotometric calibration. If more precision is needed, then a flux standard chosen by the PI has to be observed before and after, and will be charged to the program. Both science target and standards have to be observed with the widest slit (8-pixel), under conditions IQ70/CC50.

- Darks: the dark current level is low and stable enough to allow the darks to be taken on a weekly basis. On Fridays the daytime SOS runs a script that checks all the exposure time / readmode pairs used in the week, and constructs a sequence that has to be run on the weekends.

Appendix – Spectroscopy calibrations

BASELINE CALIBRATIONS:

- Darks: the dark current level is low and stable enough to allow the darks to be taken on a weekly basis. As said before, on Fridays the daytime SOS runs a script that checks all the exposure time / readmode pairs used in the week, and constructs a sequence that has to be run on the weekends.

  The sky frames themselves also provide a better way to subtract the dark.

- No other baseline calibrations for spectroscopy.

- Transmission function along the slit: this can be determined from the sky emission across the slit. For most purposes only the central 40 arcsec of the slit are used, therefore the GCAL flat field of the on-sky sequence is enough. Transmission is flat in the central 2 arcminutes of the slit within a 1% variation.

Remember that each 2 hours the target has to be re-acquired on the slit, this means moving the grism wheel and therefore the next science sequence has to be provided with new arc and flat.

Atmospheric dispersion is relatively low at NIR and for most of the purposes observing at the parallactic angle is not required, however some programs may require it if they use 2-pixel slit and good spectrophotometric accuracy, specially at low airmasses.

Appendix – Mid-IR

Example: T-ReCS Q band observation

"Chop & nod" technique.

Usually a few Hz chopping.

2 Nods/min.

Detector reading each 20 ms.