NIRI: from proposal planning to images for science grade photometry

Cecilia Fariña, FCAG - CONICET - OGA

Outline

About IR

- IR basic data
- IR astronomy
- The Earth's atmosphere at IR wavelengths

The Scientific project

- NGC 604 a quick presentation
- NIRI instrument description
- The observing proposal

The data

- Raw images: main characteristics
- The reduction process

Personal conclusions

IR basic

- Infrared radiation (IR):

  the wavelength range is defined somewhere between 0.75 – 350 μm.

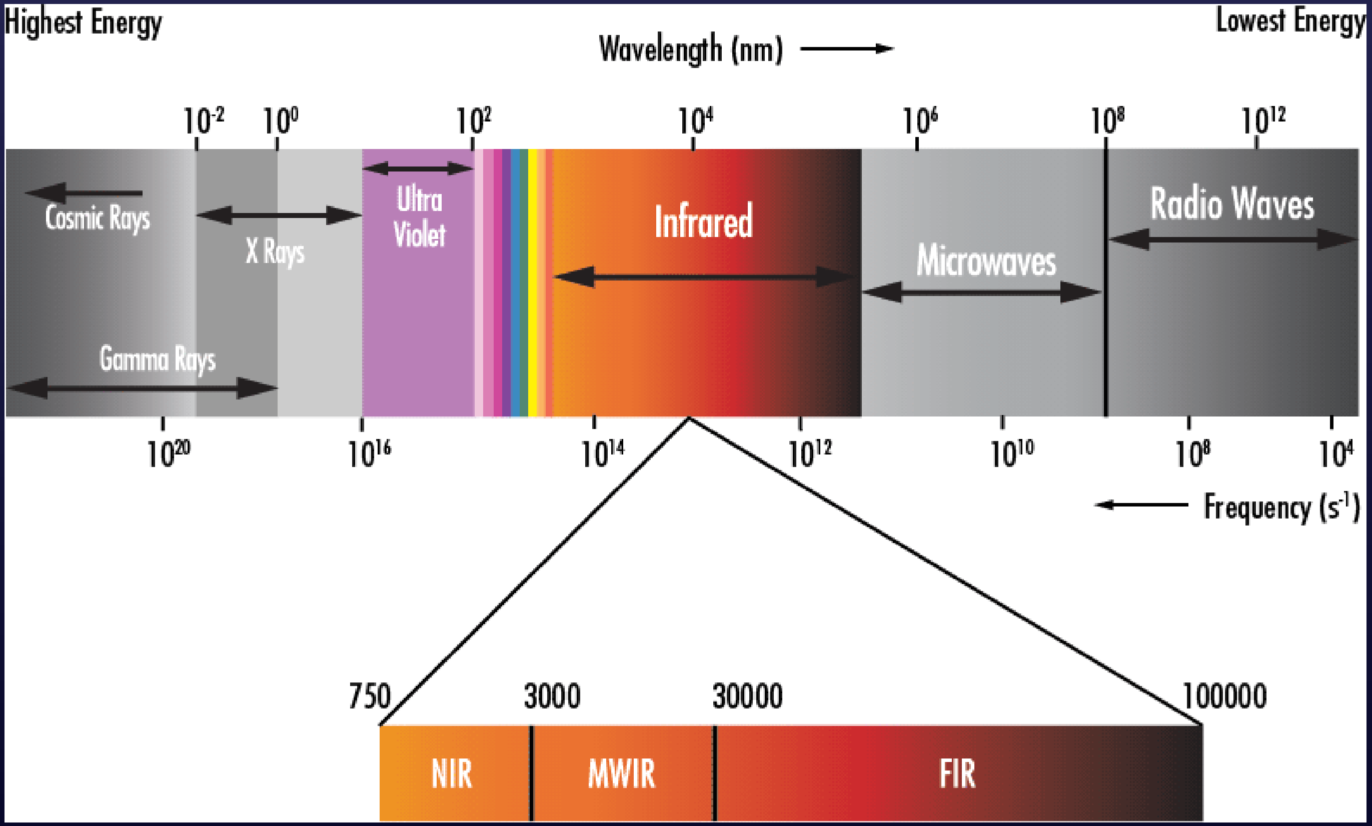
- IR radiation can be divided into 3 ranges:

  NIR : ~ 0.75 – 5 μm

  MID : ~ 5 – 25 μm

  FIR : ~ 25 – 350 μm

- sub-mm: 350 – 1000 μm

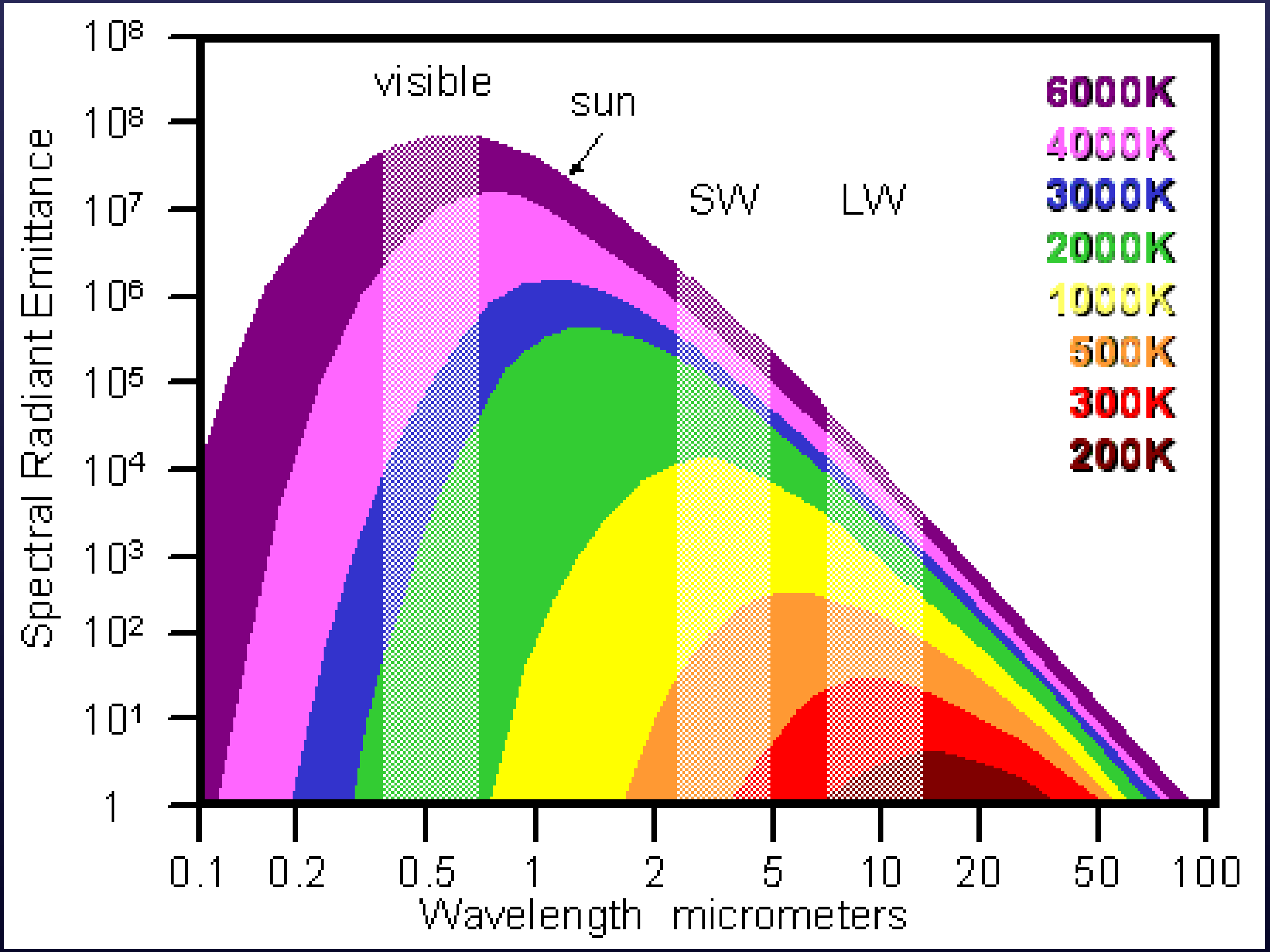


http://www.edmundoptics.com/technical-support/optics/optics-101-level-1-theoretical-foundations/

IR basic

The primary source of infrared radiation is heat or thermal radiation: radiation produced by the motion of atoms and molecules in an object. The higher the temperature, the more the atoms and molecules move and the more infrared radiation they produce.

Any object which has a temperature (i.e. anything above absolute zero) radiates in the infrared.

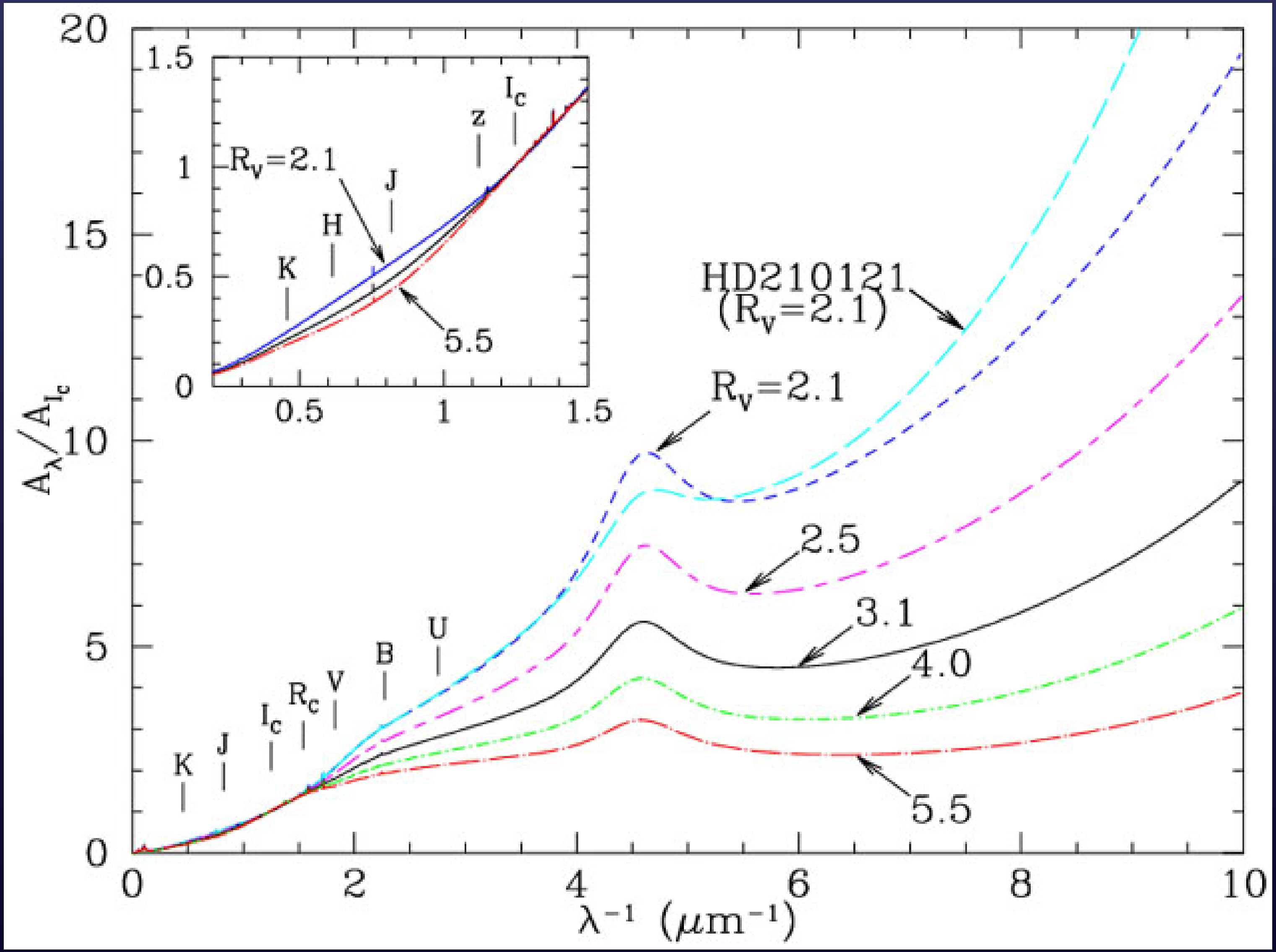


http://www.infraredtraining.com/ir_primer.asp

IR and the interstellar dust

At NIR wavelengths the radiation is less affected by interstellar dust extinction (scattering + absorption)

$A_V \sim 0.1x\ A_K$



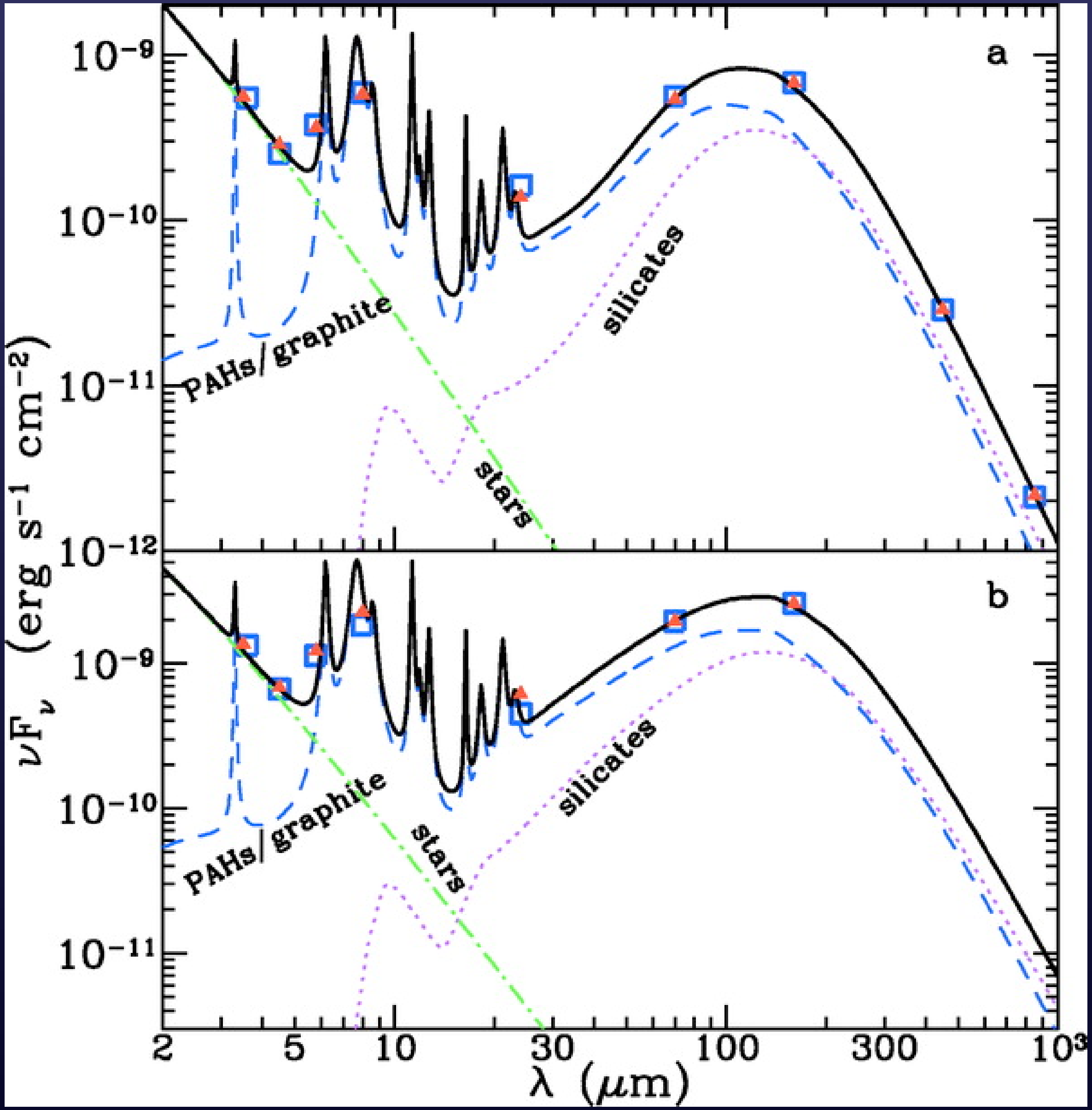
http://ned.ipac.caltech.edu/level5/March04/Draine/Draine3.html

IR and the interstellar dust

At the 5-20 μm MIR spectrum of galaxies is generally dominated by broad emission features arising from large molecules, PAHs.

Underlying these features is the stellar continuum at short wavelengths and hot dust emission.

NGC 7331 Spectrum: Observations and Model (top:interior, botton: the entired galaxy)



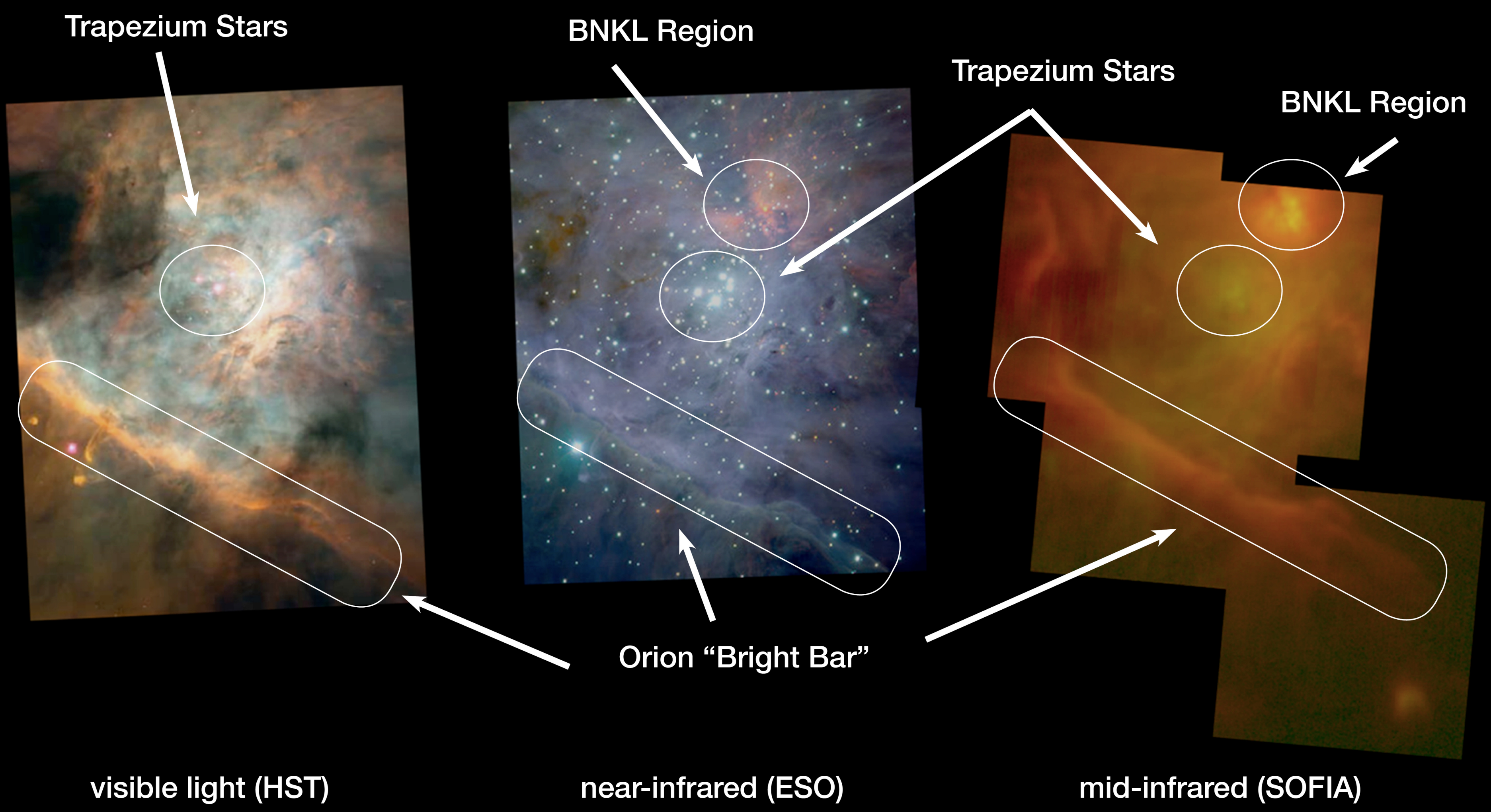
IR Emission and Dust Models
B.T. Draine, Princeton Univ.
http://aramis.obspm.fr/DUSTY04/talks/draine.pdf

What can be observed at IR?

IR is especially useful to study:

- Cold objects: planets, BDs, etc.
- Areas with clouds of gas and dust (YSOs, Galactic Center, circumstellar discs, SNRs, evolved star, etc).
- The early universe.

M42 is a star-forming region at visible, NIR and MIR

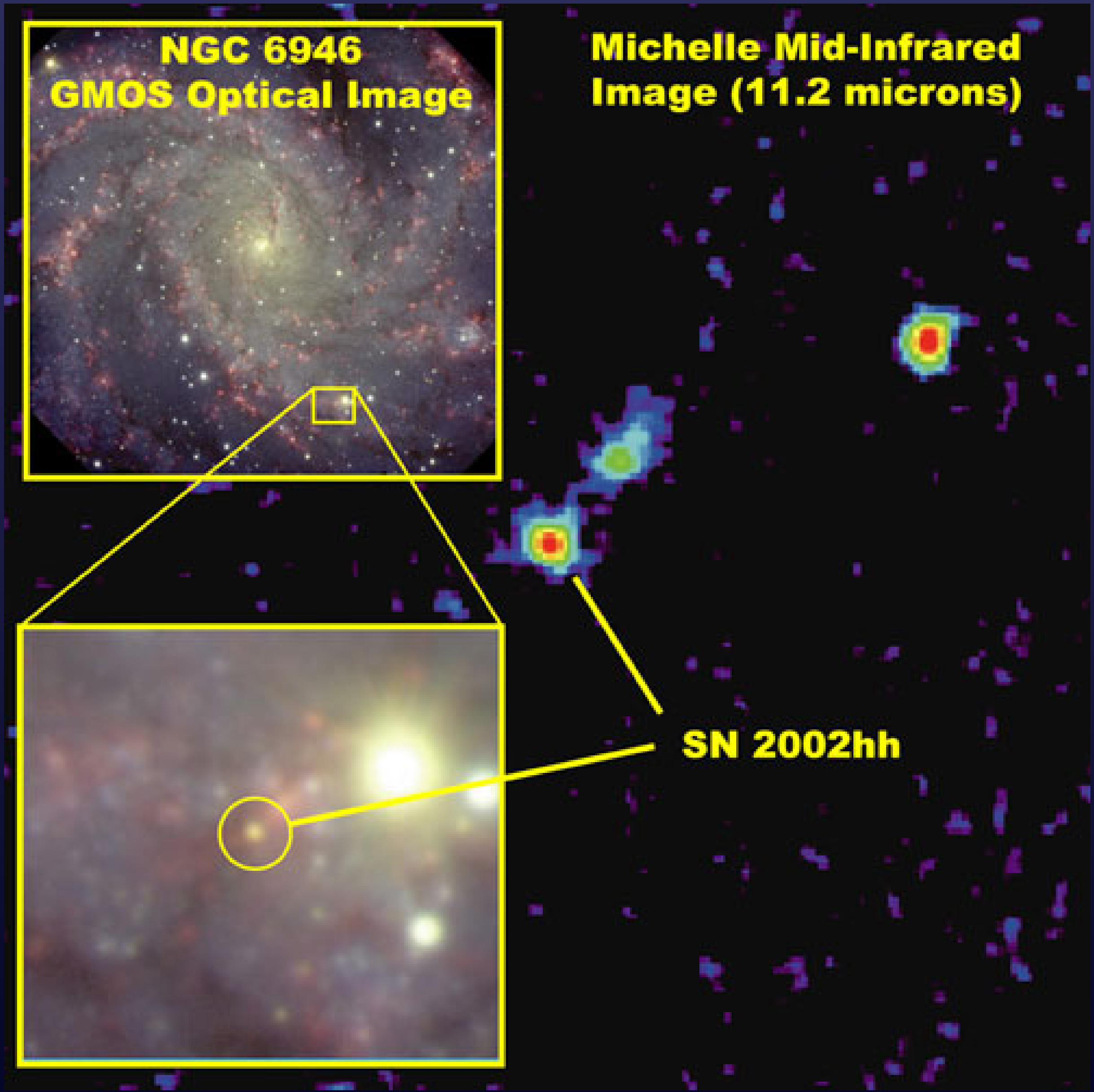


http://www.sofia.usra.edu/Gallery/science/SCI2011_0003.html

Dust in SN remnant 2002 hh at MIR

Newly formed dust in supernovae ejecta is detectable at mid-infrared wavelengths. MIR is particularly suitable to trace the onset of dust formation in supernovae, and to determine the amount of dust formed.

Supernova remnant 2002 hh in NGC 6946 at 5.5 Mpc



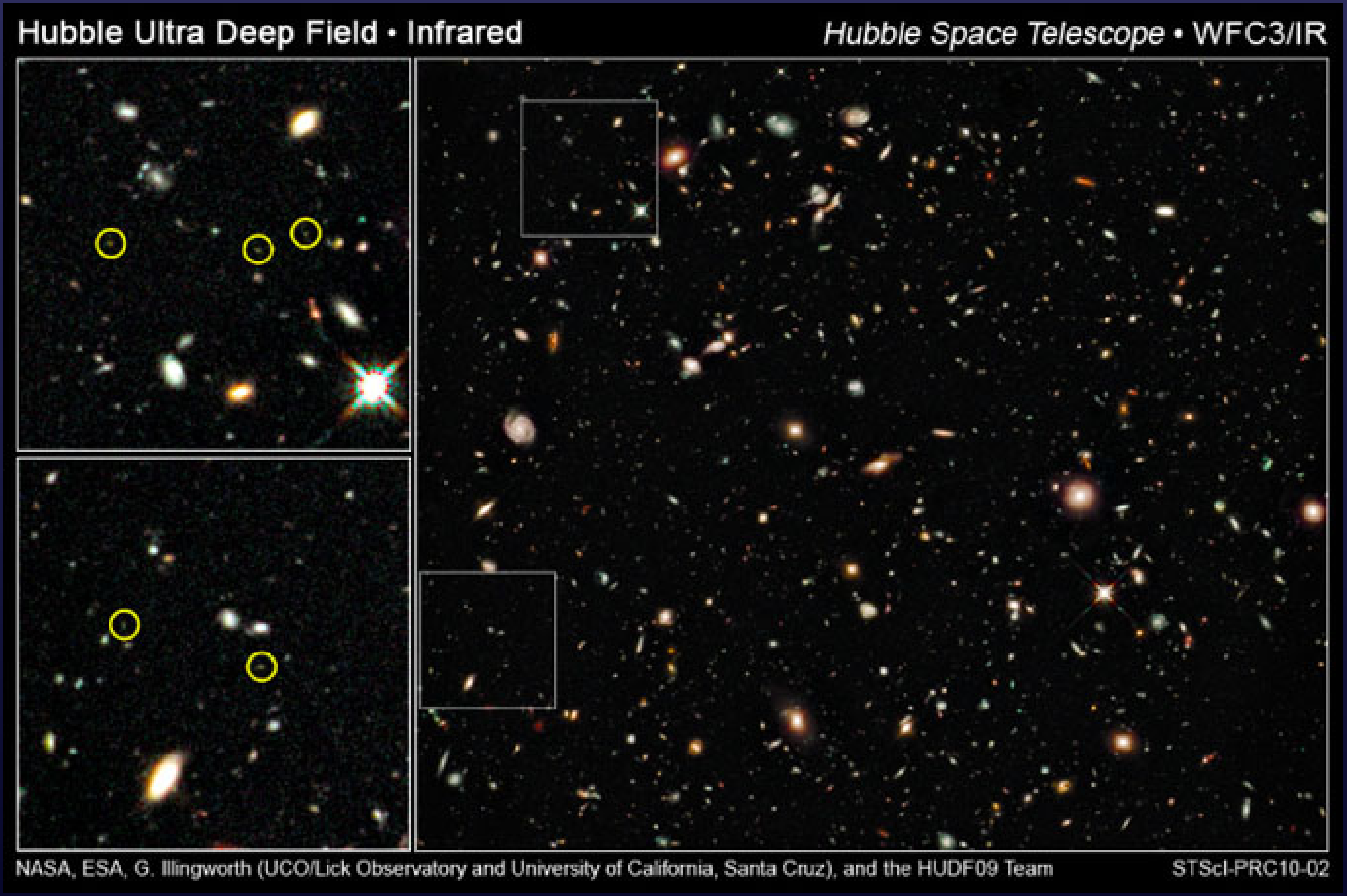
http://www.gemini.edu/node/137

The early universe at NIR

Early galaxies in HST's deepest view of the Universe.

Image was taken with the WFC3/IR camera.

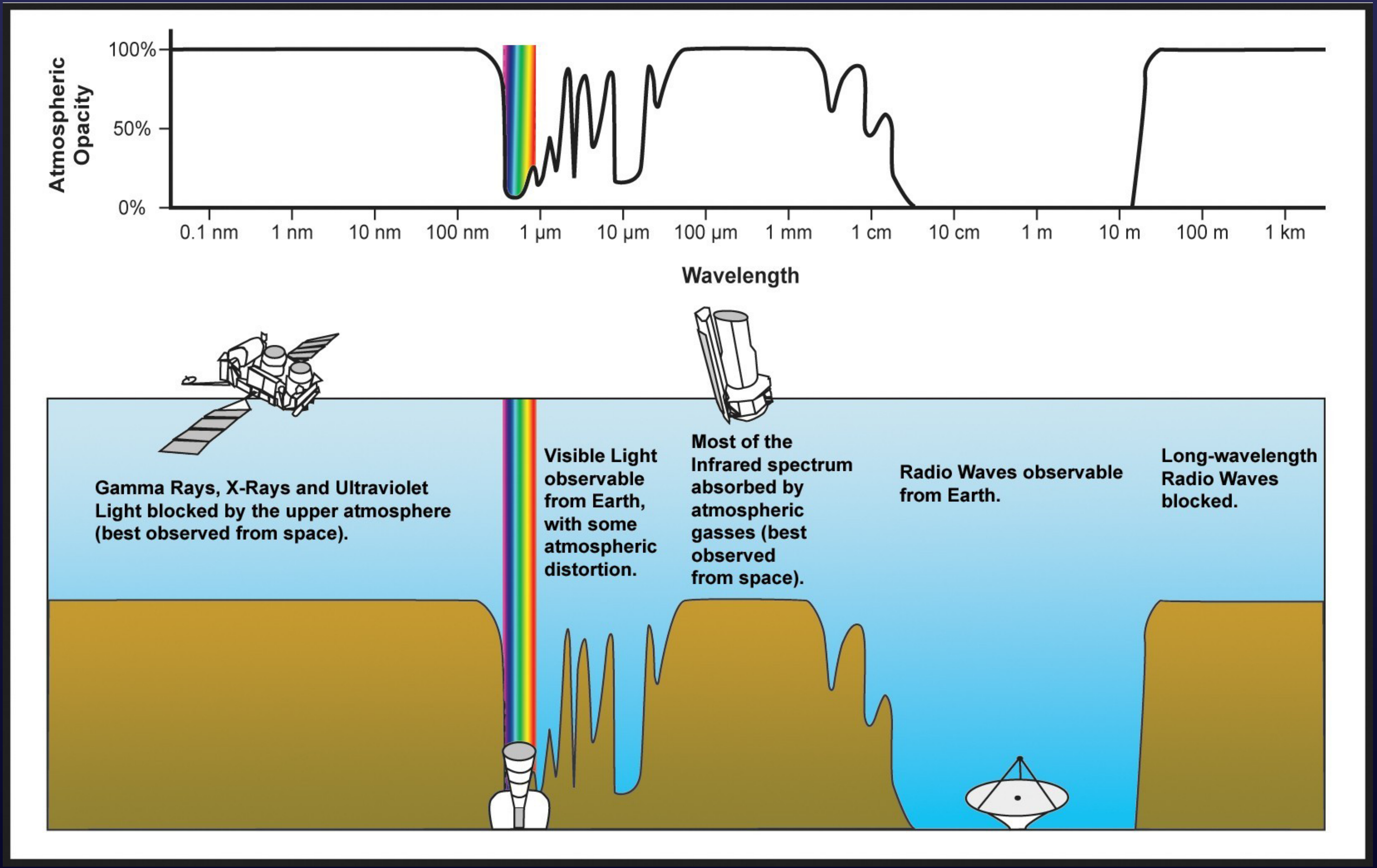
The positions of galaxies at z ~ 7-8 are indicated by the circles in the zooms on the left-hand side.



http://ned.ipac.caltech.edu/level5/March11/Bromm/Bromm3.html

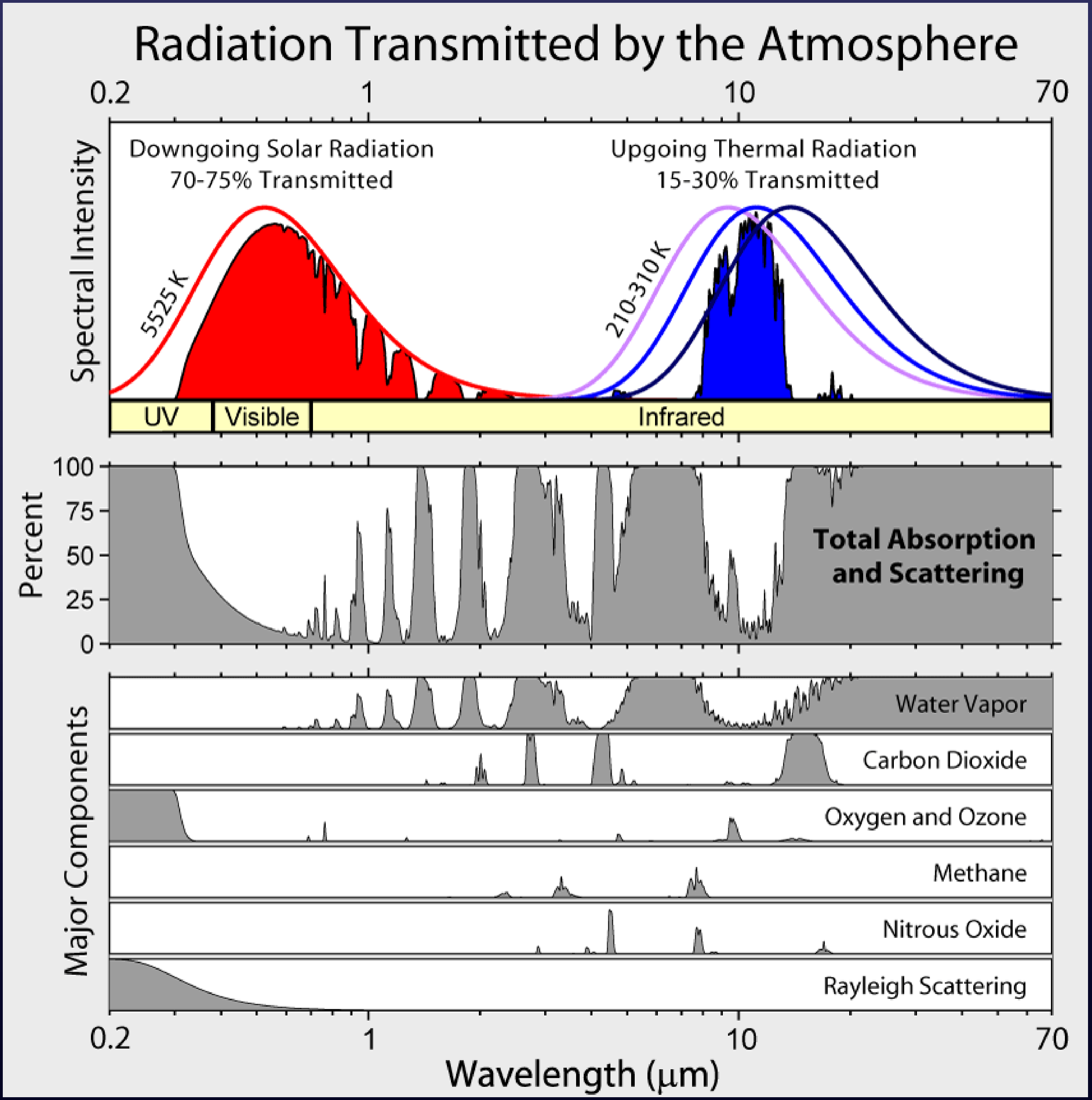
The Earth's Atmosphere at IR wavelengths

Most of the IR light reaching the Earth is absorbed by the water vapor and carbon dioxide in the Earth's atmosphere. Only in a few narrow wavelength ranges, can infrared light make it through (at least partially) to ground based telescopes.



http://www.ipac.caltech.edu/outreach/Edu/Windows/irwindows.html

The Earth's Atmosphere absorption



http://en.wikipedia.org/wiki/File:Atmospheric_Transmission.png

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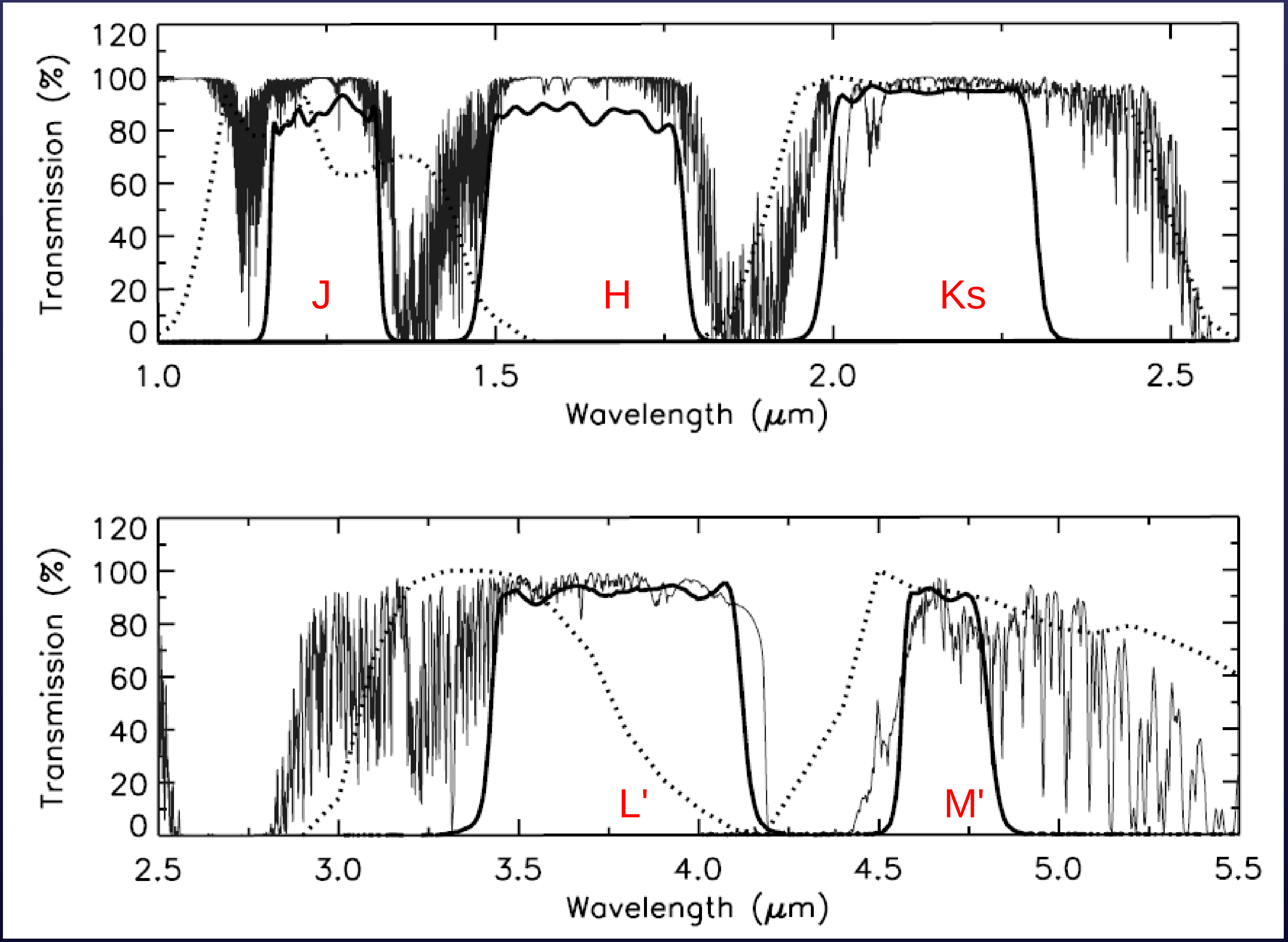
The Earth's Atmosphere absorption

The atmospheric windows define the IR pass-bands.

Comparison of Johnson (1965) filters (dotted lines) with MKO-NIR J, H, Ks, L′, M′ filters (solid lines). The atmospheric transmission for MKO with 1 mm precipitable water and an airmass of 1.0 is shown for comparison.

Tokunaga & Vacca 2007



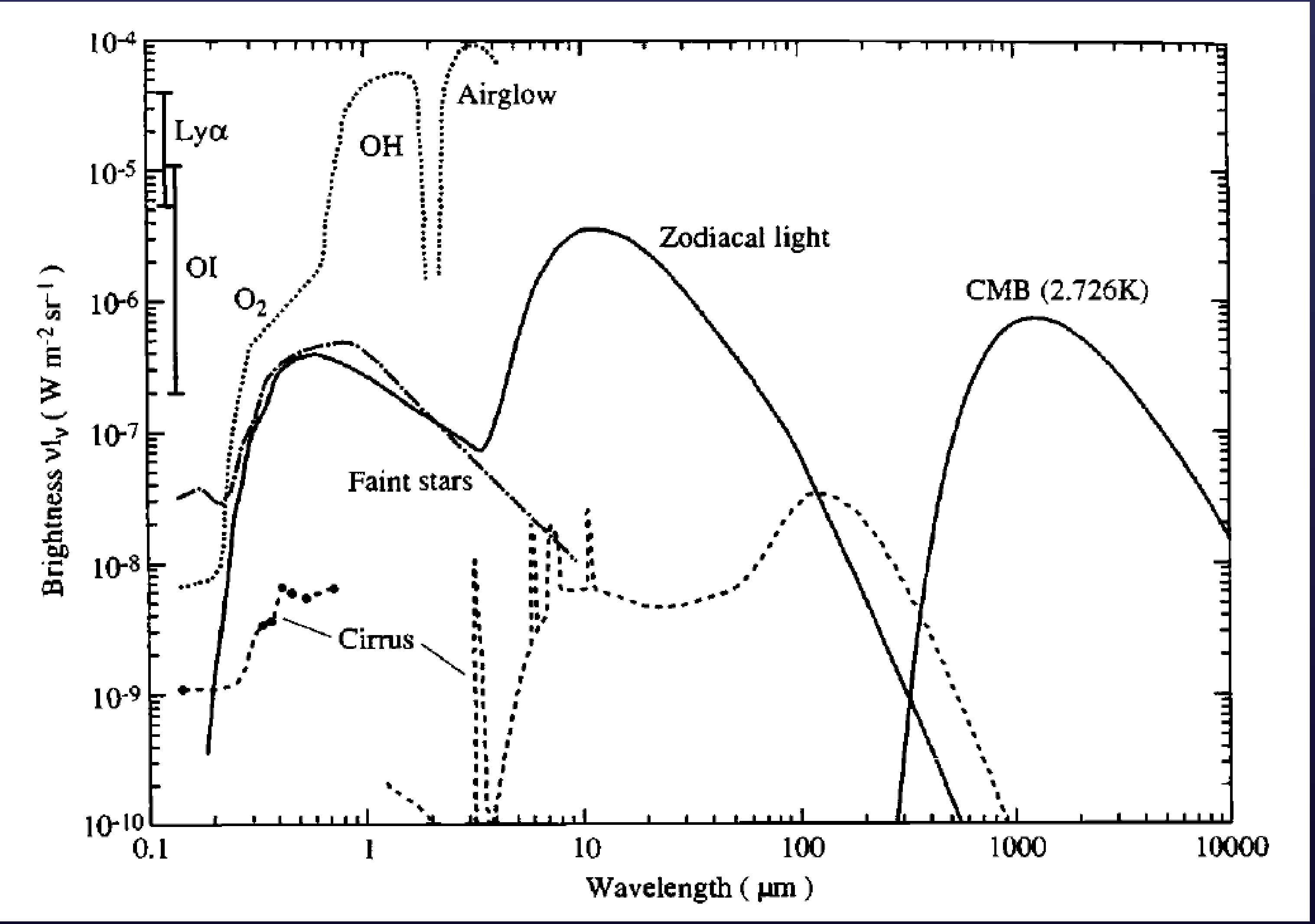
Atmospheric and extraterrestrial background sources

The atmosphere itself radiates strongly in the IR (particularly in the NIR: the hydroxyl radical, and airglow).

Other sources:

- Interstellar dust
- Zodiacal light
- Cosmic background radiation

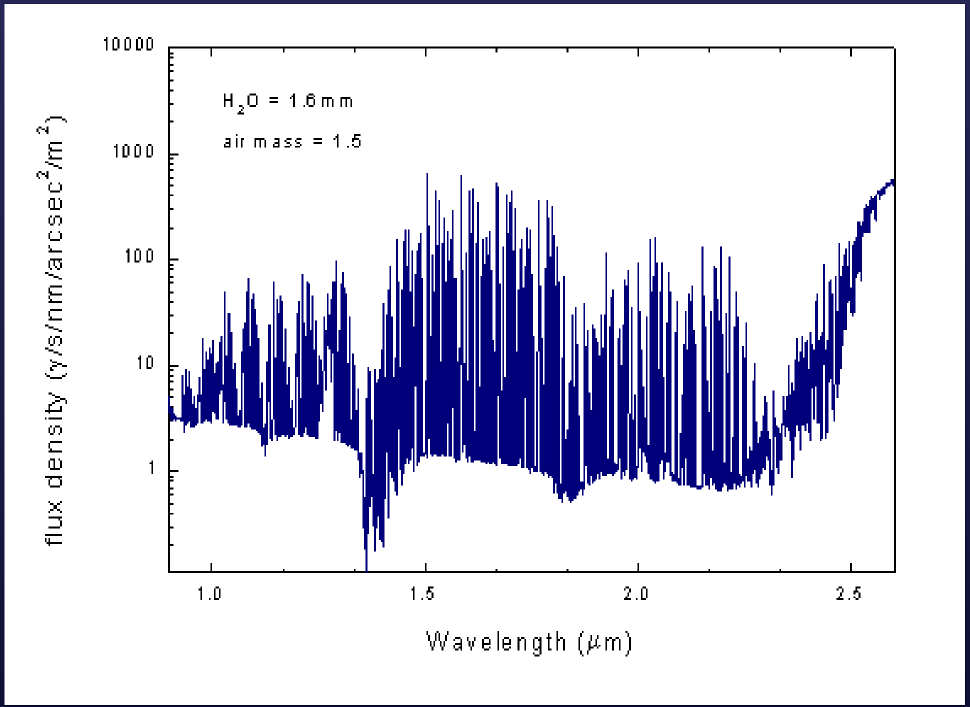
I. S. Glass – Handbook of IR Astronomy



The Earth's Atmosphere emission at NIR & MIR

The IR Integration Time Calculators Gemini employ model high resolution sky emission spectra.

The NIR (1-2.5 µm) sky background is dominated by many narrow hydroxyl (OH) emission lines. A few other species (e.g. molecular oxygen at 1.27µm) also contribute, as do H2O lines at the long wavelength end of the K window.



http://www.gemini.edu/sciops/telescopes-and-sites/observing-condition-constraints/ir-background-spectra#Mid-IR

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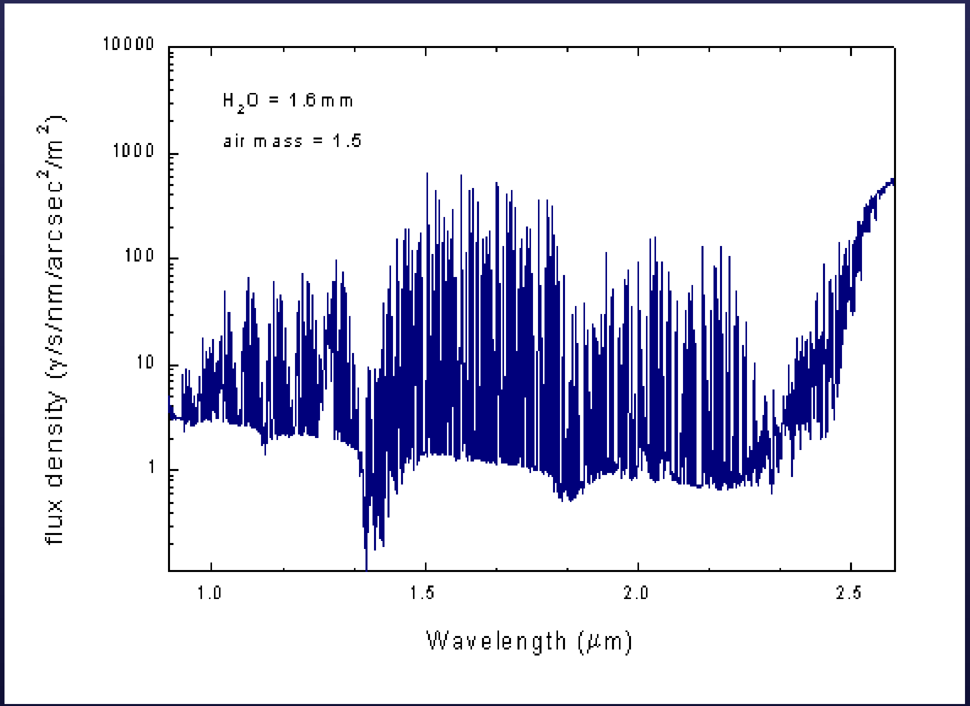
During the night OH lines vary in brightness (timescale: 5-15 min, amplitude of 5-10%) as atmospheric wave phenomena change the local density of species.

The strength of the OH lines also exhibits a steady decline for the first 1-2 hrs after sunset.



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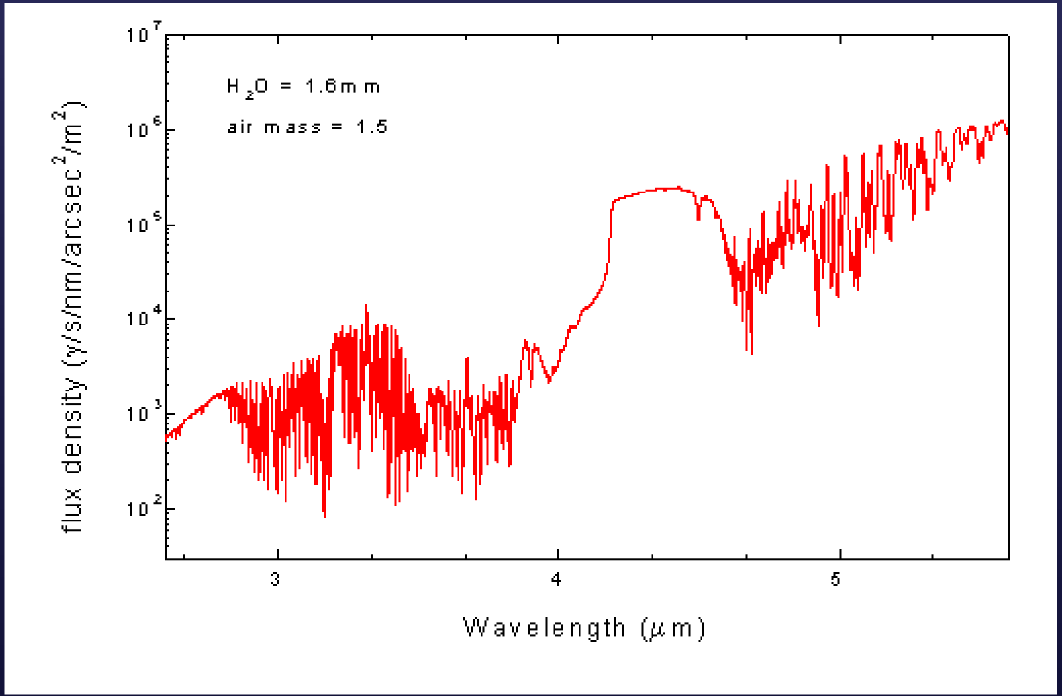
The NIR (3-5 µm) sky background is due primarily to thermal emission from the atmosphere. The transmission (and therefore the emission) varies with atmospheric water vapour content and airmass.

The MIR (5-25µm) sky background behaves similarly to the 3-5µm background, but is much more intense.



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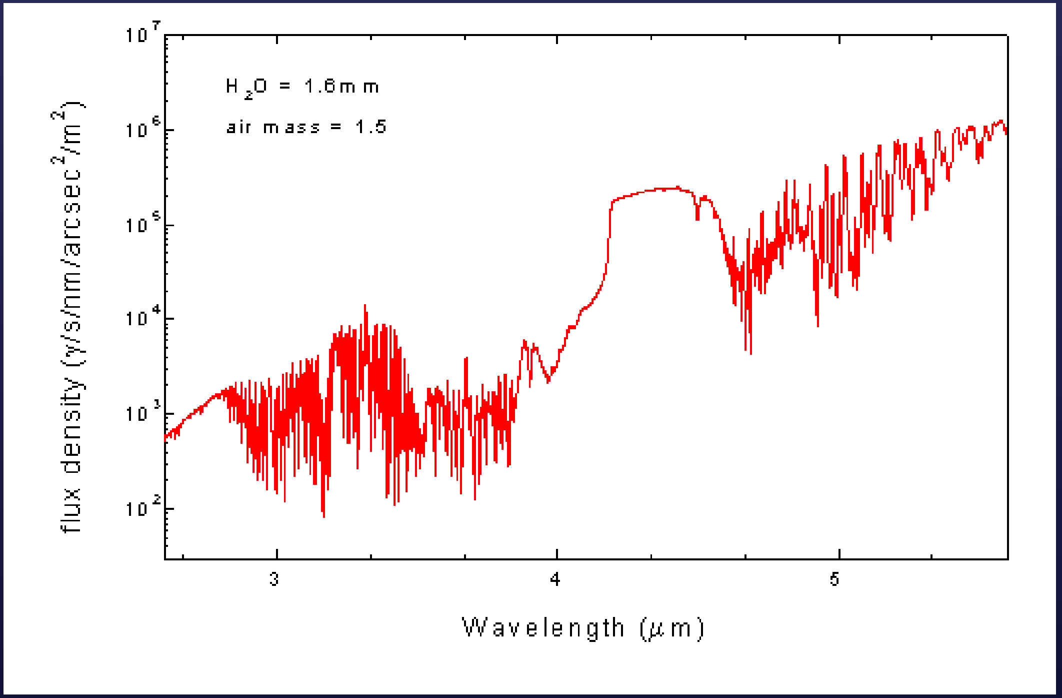


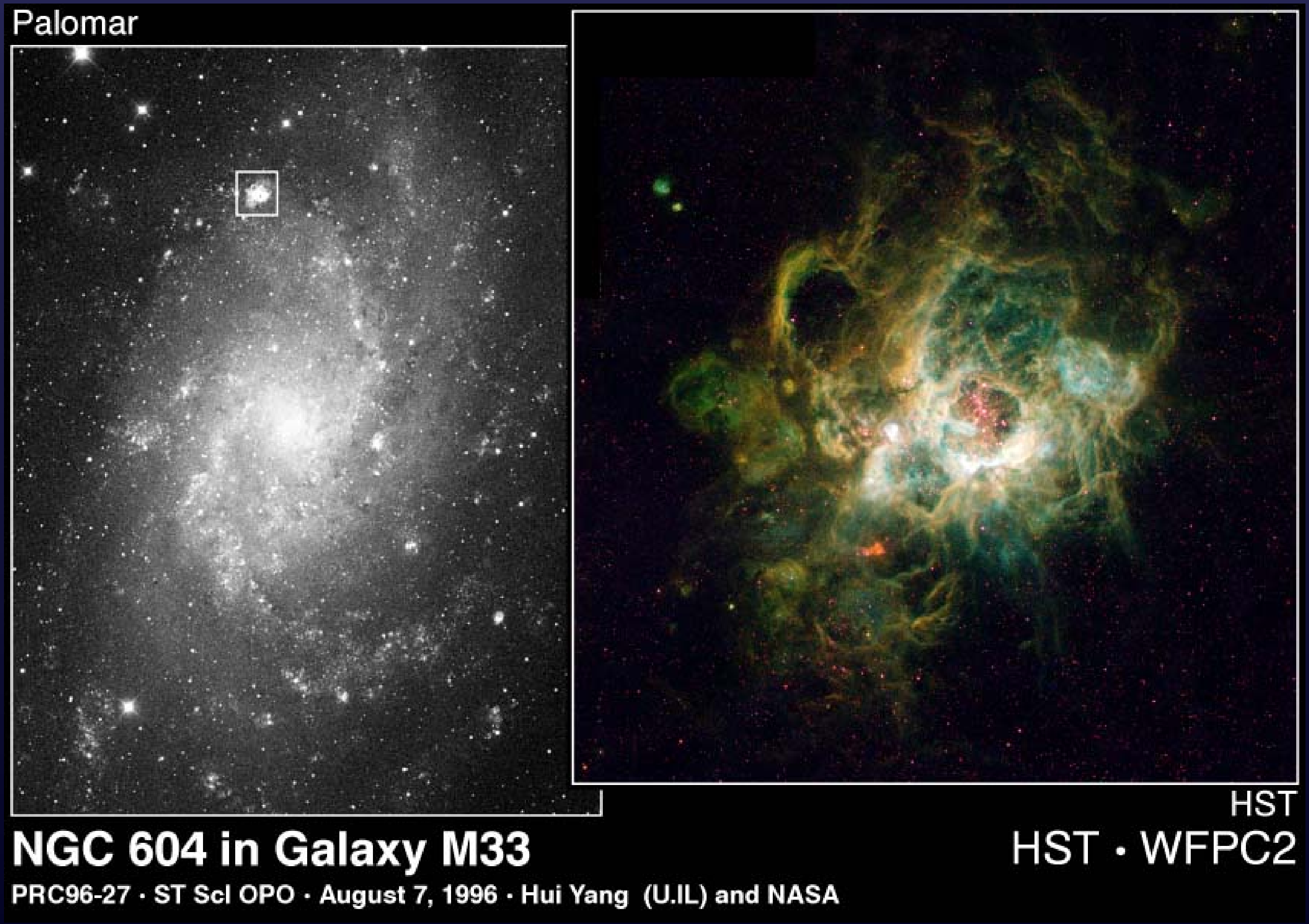
Moonlight, is not included, but it can be the dominant background source, especially in the J band when the moon is bright and and the target is close to the moon.

http://www.gemini.edu/sciops/telescopes-and-sites/observing-condition-constraints/ir-background-spectra#Mid-IR

NIR imaging: from observation planning to data reduction

Scientific Case:

Perform a photometric study focused on the detection and first characterization of 'individual sources' candidates to massive young stellar objects (MYSOs), that belong to the NGC 604 newest generation of massive stars.



http://messier.obspm.fr/more/m033_n604.html

NGC 604: Basic data

- Giant HII region (GHR) (the 2nd. most luminous in the LG after 30 Dor).

Hunter+, 1996; Delgado & Pérez,2000; Maíz-Apellániz+,2000,2004; Barbá+, 2009; Terlevich+, 1996; Drissen+, 2008

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- Located in M33, at 840 kpc Freedman+, 2001

  (~18 times the distance to 30 Dor, 1" = 4.1 pc)

  Allows global structure studies as well as the observation and study of individual resolved objects.

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- Evolved stellar population: WR, RSG candidates, a LBV, a possible SNR.
- Estimated central cluster age: 2.5-5 x 10^6 yrs.

Hunter+, 1996; Delgado & Pérez,2000; Maíz-Apellániz+,2000,2004; Barbá+, 2009; Terlevich+, 1996; Drissen+, 2008

The instrument: NIRI – Gemini North

NIRI: Near InfraRed Imager and Spectrometer

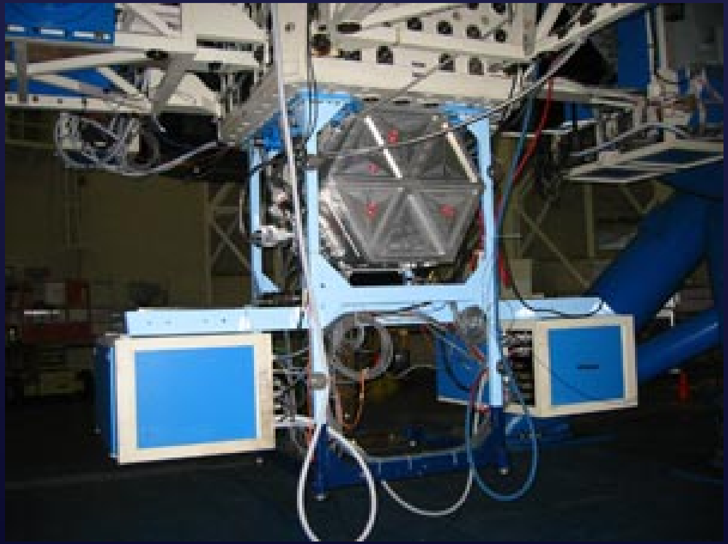
(Gemini- North)

- Imaging and spectroscopy in the 1-5 micron.
- NIRI's detector is a 1024 x 1024 ALADDIN InSb array.
- Cameras, imaging mode plate scales & FoV:

Pixel Scales and Field of View[1]

Camera	Pixel dimension (arc sec)	Field of View (arc sec)
f/6	0.1171	119.9 x 119.9
f/14	0.0499	51.1 x 51.1
f/32	0.0219	22.4 x 22.4

[1]For full (1024 x 1024 array)



- The Gemini facility adaptive optics (AO) system, ALTAIR, is available for use with NIRI at f/14 or f/32.

http://www.gemini.edu/sciops/instruments/niri/

NIRI's detector properties

Gemini Observatory: Exploring The Universe From Both Hemispheres

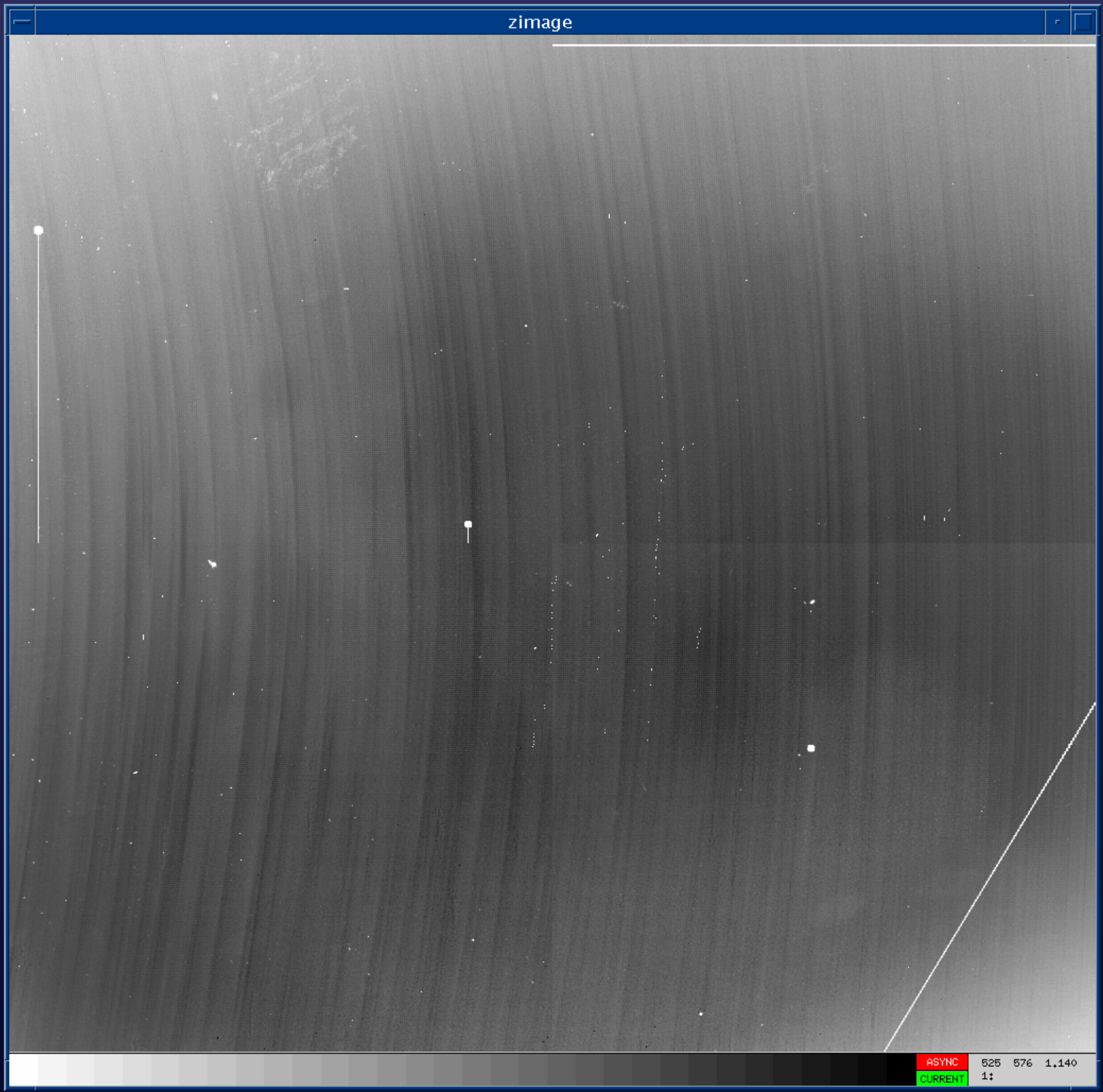
Detector Array

Change page style: Wide

The basic properties of NIRI's array are given here, as well as the problems that occasionally affect the quality of the raw data.

Array	Aladdin InSb (Hughes SBRC)
Pixel format	1024x1024 27-micron pixels
Spectral Response	1 to 5.5 microns
Dark Current	0.25 e-/s/pix
Dark Background	0.5 e-/s/pix
Read Noise (low background mode)	10 e-/pix
Read Noise (medium background mode)	35 e-/pix
Read Noise (high background mode)	70 e-/pix
Gain	12.3 e-/ADU
Well depth (near-IR)	200,000 e-
Well depth (thermal-IR)	280,000 e-
Quantum efficiency	about 90%
Flat field uniformity*	+/-18% (VIEW)
Flat field repeatability*	+/-0.3%; (show me)
Residual image retention	0.5-1% of a bright (saturated) source in the next frame
Centered Sub-array dimensions	768x768, 512x512, 256x256 pixels

The array’s cosmetics



The most evident array features:

- Two groups of bad pix. (top left).
- Diagonal crack (lower right).
- A few locations with dead pixels.
- The total number of bad working pixels of 0.1% of the total array’s pixels.
- The vertical arc pattern is the dominant pattern in the flat field image. It is present in all raw images. It was originated in the array’s fabrication process.

NIRI: Imaging mode

NIRI contains two filter wheels and a pupil mask wheel with room for about 25 broad and narrow-band filters.

Filter Name	Central Wavelength (microns)	Coverage (microns or dl/l)	Gemini ID	Transmission Curve (click for graph)	Numerical Transmission Data	Currently In Dewar?
Broad-band filters						
Y[1]	1.02	0.97-1.07	G0241	yes	warm	yes
J	1.25	1.15-1.33	G0202	yes	warm	yes
H	1.65	1.49-1.78	G0203	yes	warm	yes
H-K notch	-	1.45-1.76;1.93-2.29	G0236	yes	warm	no
K	2.20	2.03-2.36	G0204	yes	warm	yes
K(short)	2.15	1.99-2.30	G0205	yes	warm	yes
K(prime)	2.12	1.95-2.30	G0206	yes	warm	yes
L(prime)	3.78	3.43-4.13	G0207	yes	warm	yes
M(prime)	4.68	4.55-4.79	G0208	yes	warm	yes

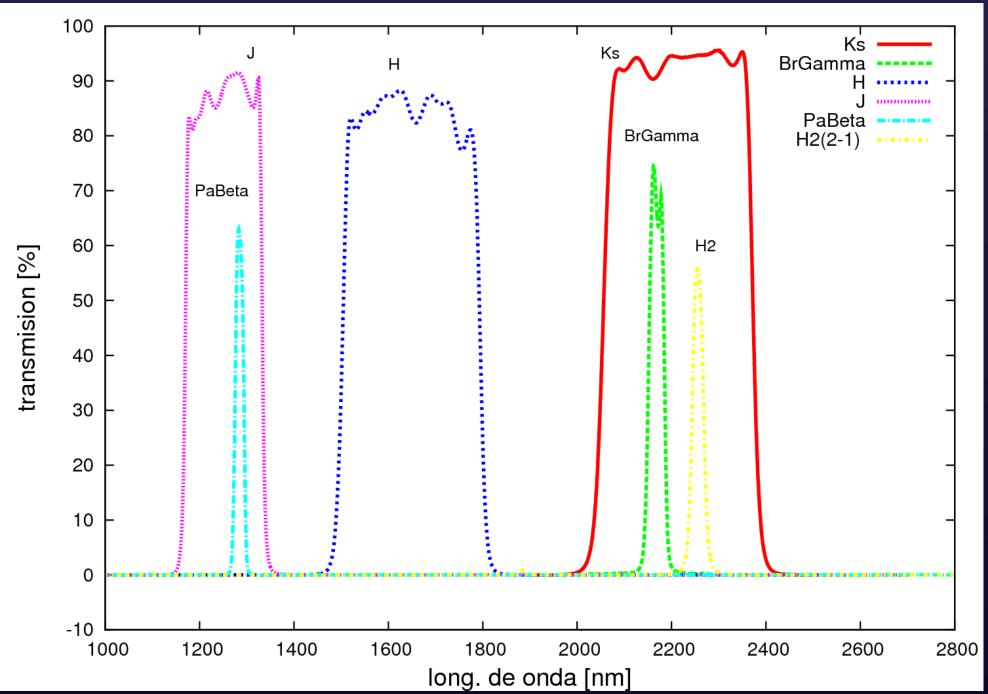
Filter Name	Central Wavelength (microns)	Coverage (microns or dl/l)	Gemini ID	Transmission Curve (click for graph)	Numerical Transmission Data	Currently In Dewar?
Line and feature (narrow-band) filters						
J-continuum[1]	1.065	0.8%	G0239	yes	warm	no
HeI	1.083	1.5%	G0234	yes	warm	yes
Pa(gamma)	1.094	1.5%	G0240	yes	warm	no
J-continuum[1]	1.122	0.8%	G0235	no	cold	yes
J-continuum[1]	1.207	1.5%	G0232	yes	warm	yes
Pa(beta)[1]	1.282	1.5%	G0221	yes	warm cold	no
H-continuum[1]	1.570	1.5%	G0214	yes	warm cold	yes
CH4 (short)[1]	1.58	6.5%	G0228	yes	warm cold	yes
CH4 (long)[1]	1.69	6.5%	G0229	yes	warm cold	yes
[FeII][1]	1.644	1.5%	G0215	yes	warm cold	yes
H2O ice	2.045	8.31%	G0242	yes	warm	yes
HeI (2p2s)[2]	2.059	1.5%	G0233	yes	warm	yes
K-continuum	2.0975	1.31%	G0217	yes	warm cold	yes
H2 1-0 S(1)[3]	2.1239	1.23%	G0216	yes	warm cold	yes
Br(gamma)	2.1686	1.36%	G0218	yes	warm cold	yes
H2 2-1 S(1)	2.2465	1.34%	G0220	yes	warm cold	no
K-continuum	2.2718	1.55%	G0219	yes	warm cold	no
CH4 ice	2.275	6.59%	G0243	yes	warm	yes
CO 2-0 (bh)	2.289	1.22%	G0225	yes	warm cold	no
H2O ice	3.050	5%	G0230	yes	warm	no
hydrocarbon	3.295	1.5%	G0231	yes	warm	yes
Br(alpha) cont	3.990	3.95-4.02	G0237	yes	warm	yes
Br(alpha)	4.052	4.02-4.09	G0238	yes	warm	no
PK-50 blocker	N/A	0.8-2.6	G0201	yes	warm	yes

The observing proposal

- The images were acquired with NIRI, in its imaging mode, without adaptive optics.
- The proposal was awarded 6.3 hours on Band-1 (queue mode) for 2004B, and observed in 2005B semester (GN-2005B-Q-3, PI: Guillermo Bosch).
- Images in broad-band (J, H, and Ks filters) and narrow-band (BrG, PaB, and H2 filters).

Camera	Pxs. scale (arcsec)	FOV (arcsec)
f/6	**0.117**	**119.9 x 119.9**
f/14	0.050	51.1 x 51.1
f/32	0.022	22.4 x 22.4

The images were acquired under excellent seeing conditions: Ks FWHM ~ 0.35''



The image set

Image set per filter:

Included in NIR Baseline Calibrations.

- Darks → taken as daytime calibrations (not during the night). Short darks (~1s) are taken daily for all instruments to assess readnoise and identify bad pixels.

- Flats-on
- Flats-off

→ taken the morning after the science observations to allow for correction of thermal emission, dark current, and hot pixels.

Gemini Facility Calibration Unit (GCAL) is available on each Gemini telescope, providing continuum and line emission light sources for wavelength and flat-field calibrations.

- Standard star (for each filter) One photometric standard for every 2 hours of science integration.

Remind:

All calibrations, baseline or additional, must be specified by the PI in the Phase II definition.
Baseline calibrations are not charged to the program.

The image set

Image set per filter:

- Science Field
- Sky Field

Filter (λ mic)	Night	# sky	# field	Exp. time (s)
J (1.25)	08/09/05	17	15	120.0
H (1.65)	11/09/05	17	16	60.0
Ks (2.20)	08/09/05	17	14	40.0
Paβ (1.28)	07/09/05	9	8	225.0
Brγ (2.17)	26/12/05	9	8	225.0
H_2 (2-1, 2.25)	07-11/09/05	9-4	8-4	225.0

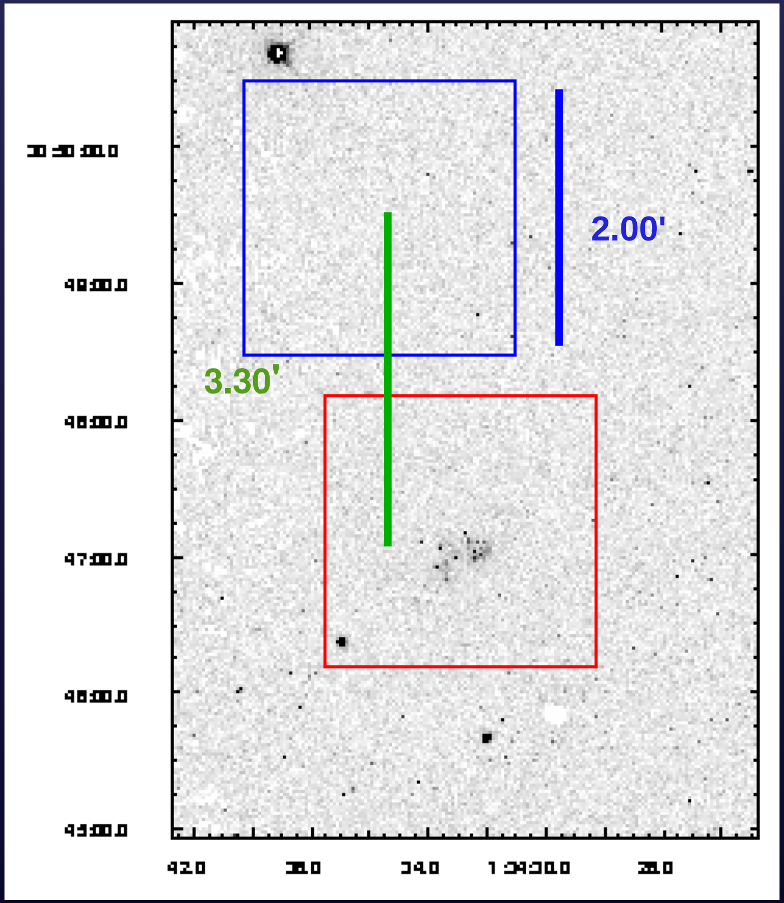
The sky background is strong and variable on short time scales in the NIR range. If the science target is extended or very crowded, additional sky frames must be acquired. Dithers on the sky should be large enough to remove point sources when making sky images.

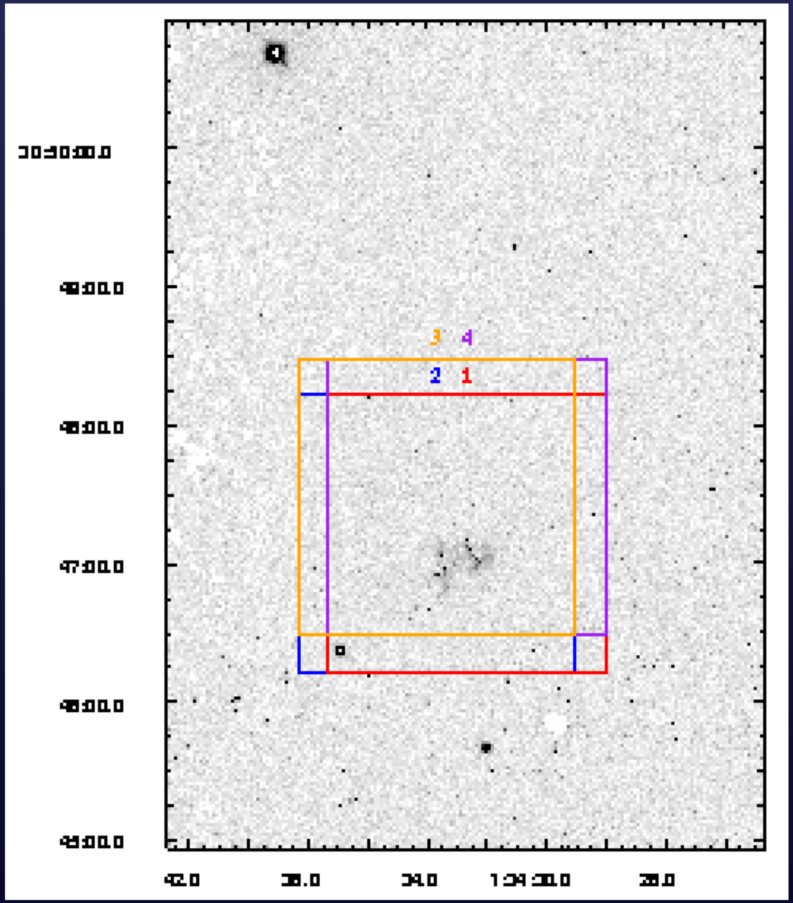
Dithering: make small displacements between images of the same field to achieve a better correction of bad pixels and other artifacts when the images are combined. (out case the dither was 85 pixels.)

The observing sequence

For the broad-band images:

1s - 2f - 2s - 2f - 4s - 2f - 2s - 4f - 2s - 2f - 4s - 2f - 2s - 2f

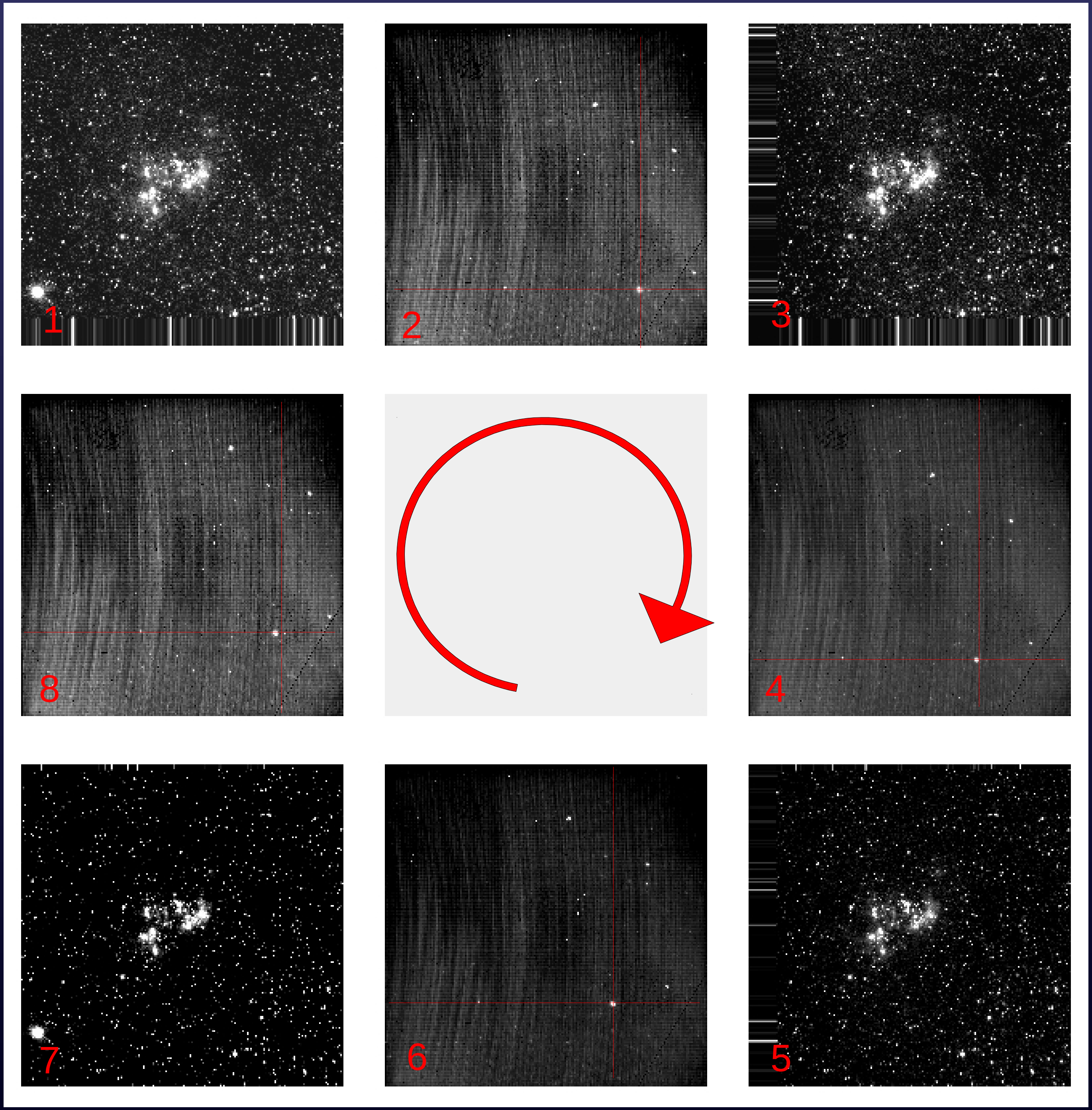




The observing sequence

Dithering sequence

4 positions with a displacement of ~ 10" to clean bad pixels and other artifacts)



NGC 604 field

RA: 01:34:32.35
Dec: +30:47:04.00

Sky field

RA: 01:34:35.70
Dec:+30:49:08.00

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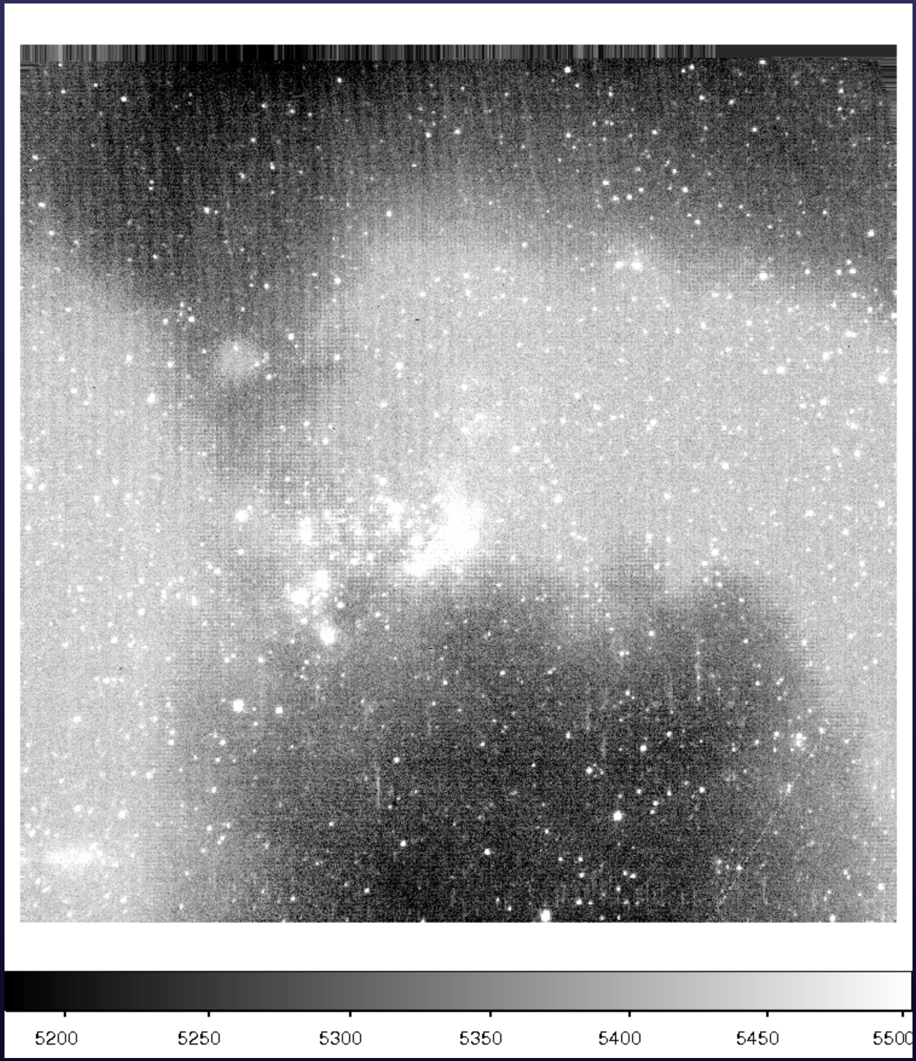
The first frame image dark current pattern

The array is read at the beginning and at the end of the exposure and the difference is recorded.

The first frame problem arises because the NIRI array is not continuously reset when idle.

When starting exposures after a change in program, target, or offset sequence, the background or dark current level is different, probably due to image persistence after saturating the array (NIRI has no shutter).

Hence, the first exposure of each new sequence will show poor background subtraction and should be rejected.

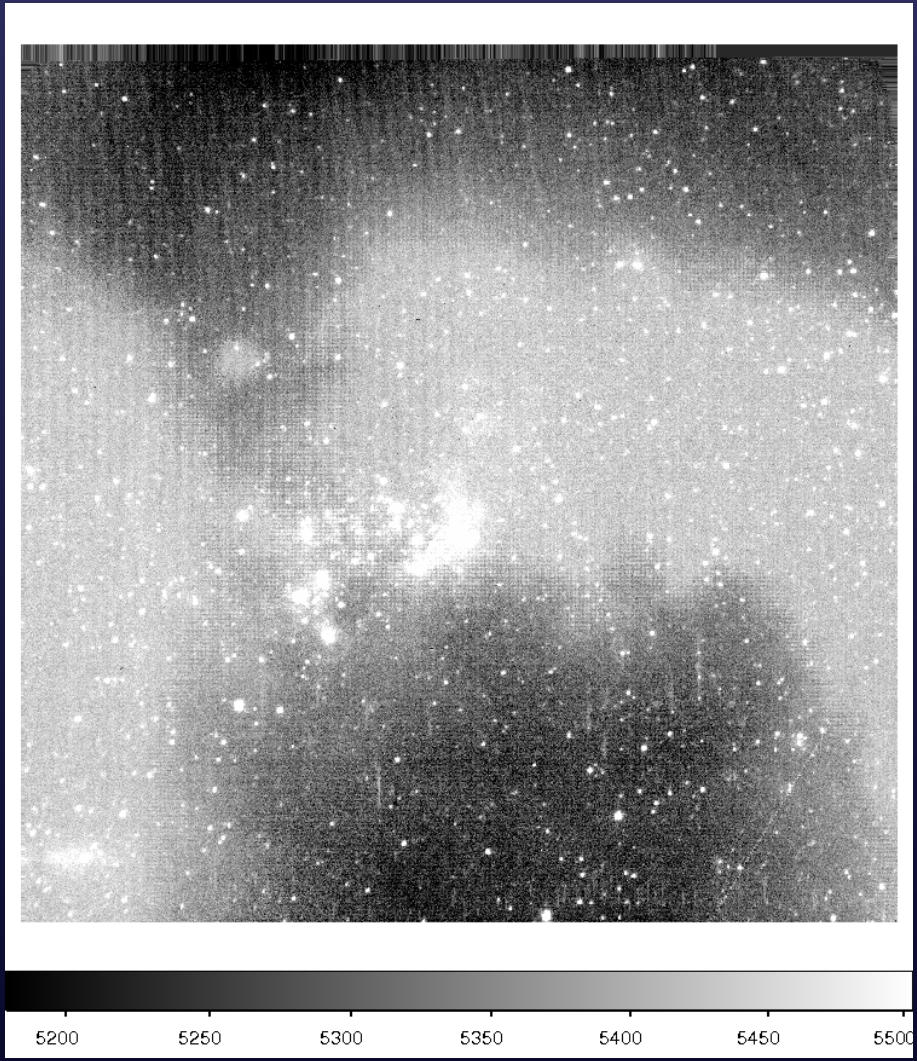


The first frame image dark current pattern

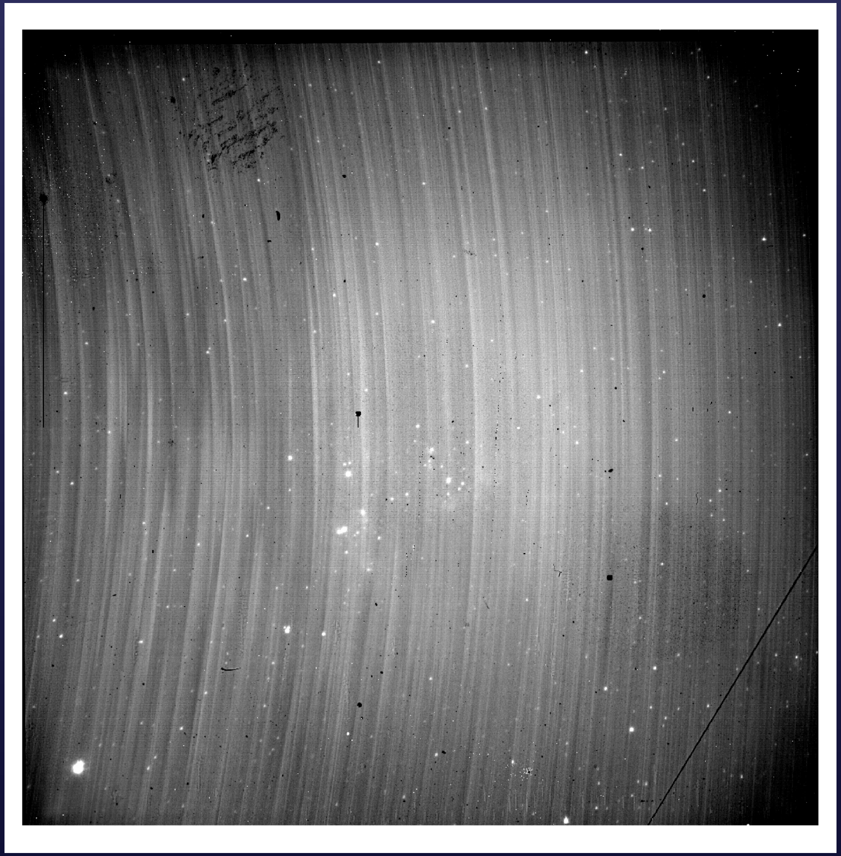
WARNING !!!

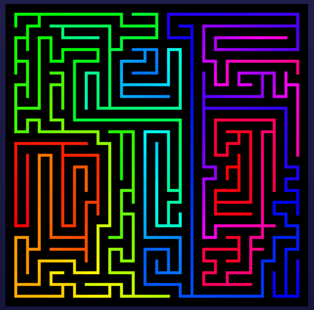
These bad first images ARE included in the distributed data, so care should be taken to review and reject them from all sequences (science, flats and darks) as necessary.

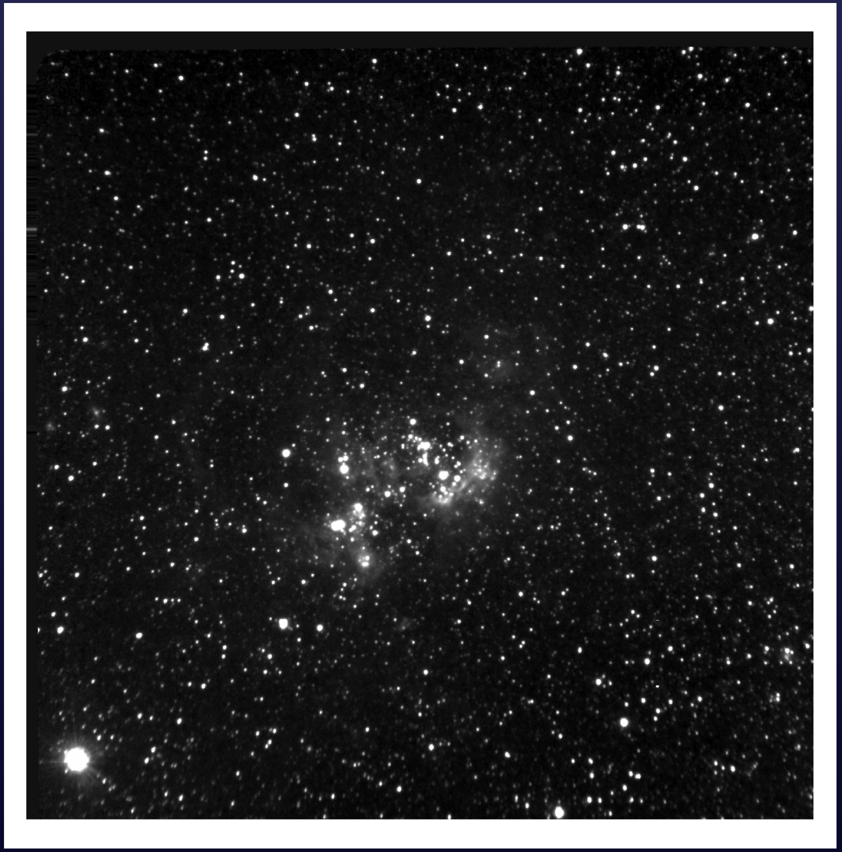
One should add an additional step at the beginning of each sequence (or repeat the first position at the end of the dither sequence).



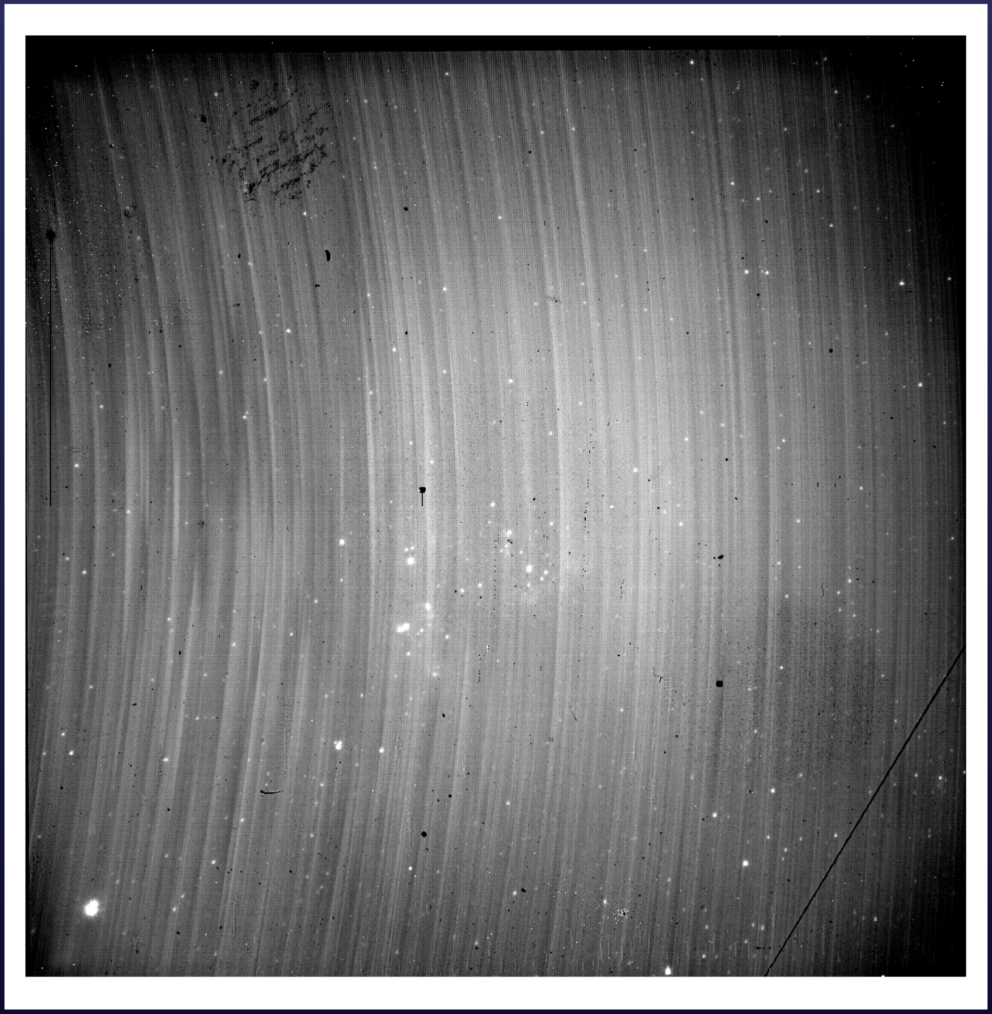
The path from the raw images to science images







The field raw image



Raw NIRI images are dominated by the the pixel sensitivity variations.

Common features:

• Small-scale curved "stripes" running vertically, resulting from the manufacture of the array.

• A circular pattern of ripples resembling a thumbprint in the upper left quadrant.

•Three small regions of bad pixels, about 10 pixels across, two of which have a partially bad column below them. Dither patterns should be large enough to guarantee that these pixels can be corrected.

• A few hundred hot pixels (mostly in the upper left corner)

• A prominent crack in the array substrate (bad pixels in the lower right-hand corner).

• An overall large-scale bright region in the center of the array with darker regions top and bottom

• Offsets in overall sensitivity at the quadrant boundaries

NIRI data reduction: Basic steps

Phyton routines:

1) Vertical striping correction

2) Non-linearity correction

IRAF gemini.niri package routines:

3) Nprepare

4) Nisky

5) Niflat

6) Nireduce

7) Imcoadd

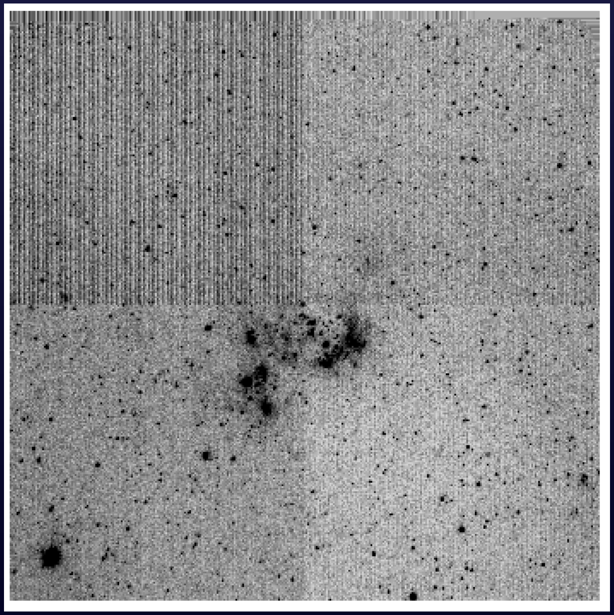
1) Vertical Stripping correction: CLEANIR

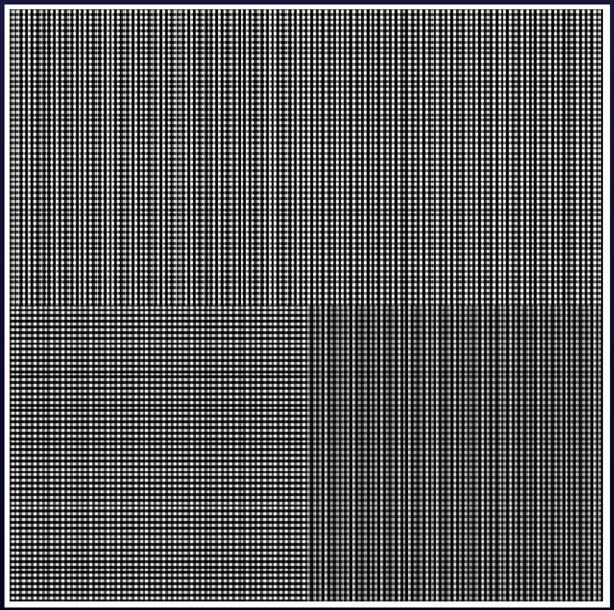
The ALADDIN Array Controler, GNAAC, in NIRI sometimes superimposes a pattern noise of vertical striping, horizontal banding and offset in the bias values between the four quadrants on the data.

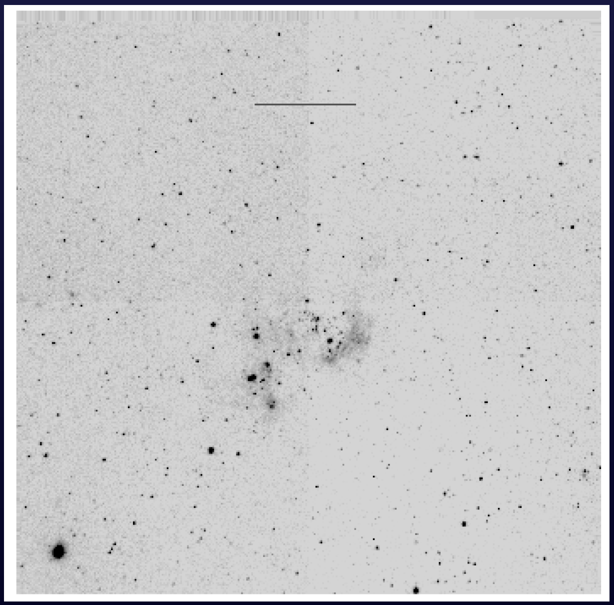
CLEANIR is a Python routine created for cleaning IR data from NIRI & GNIRS.

The pattern spatial profile is well known (eight columns wide) its intensity varies from one exposure to another and, within an individual image, it is different among the four image quadrants. Hence, the correction must be applied to all images, included calibration image.

http://www.gemini.edu/sciops/instruments/niri/data-format-and-reduction/cleanir

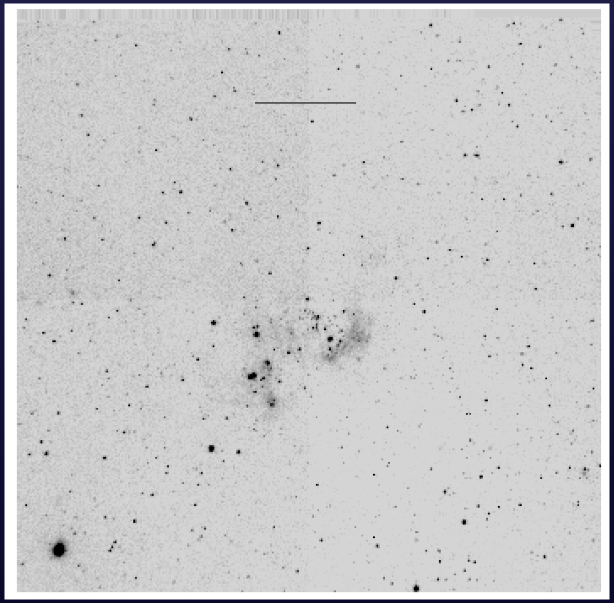


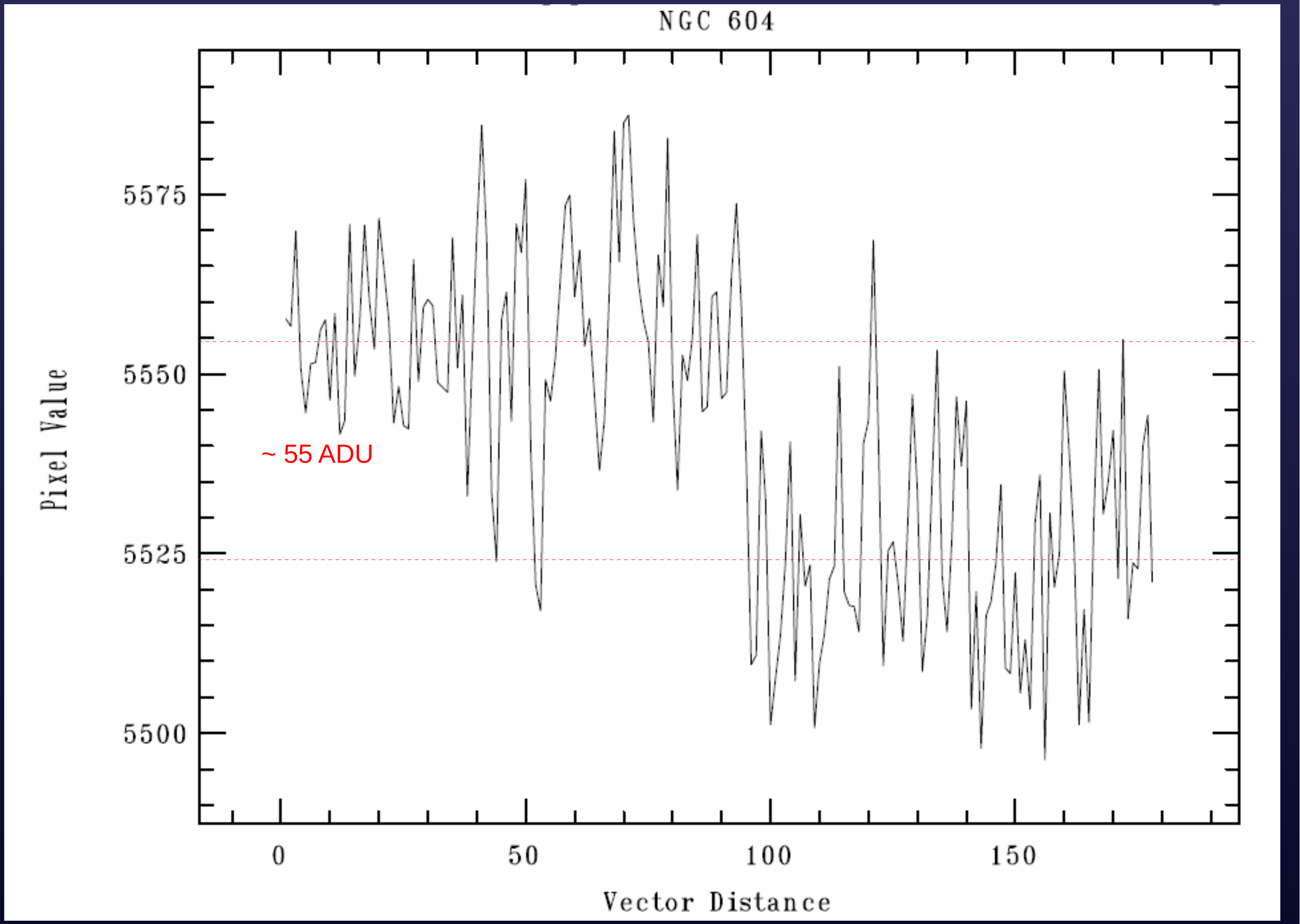




1) Vertical Stripping correction: CLEANIR

The script not always properly corrects the background level.





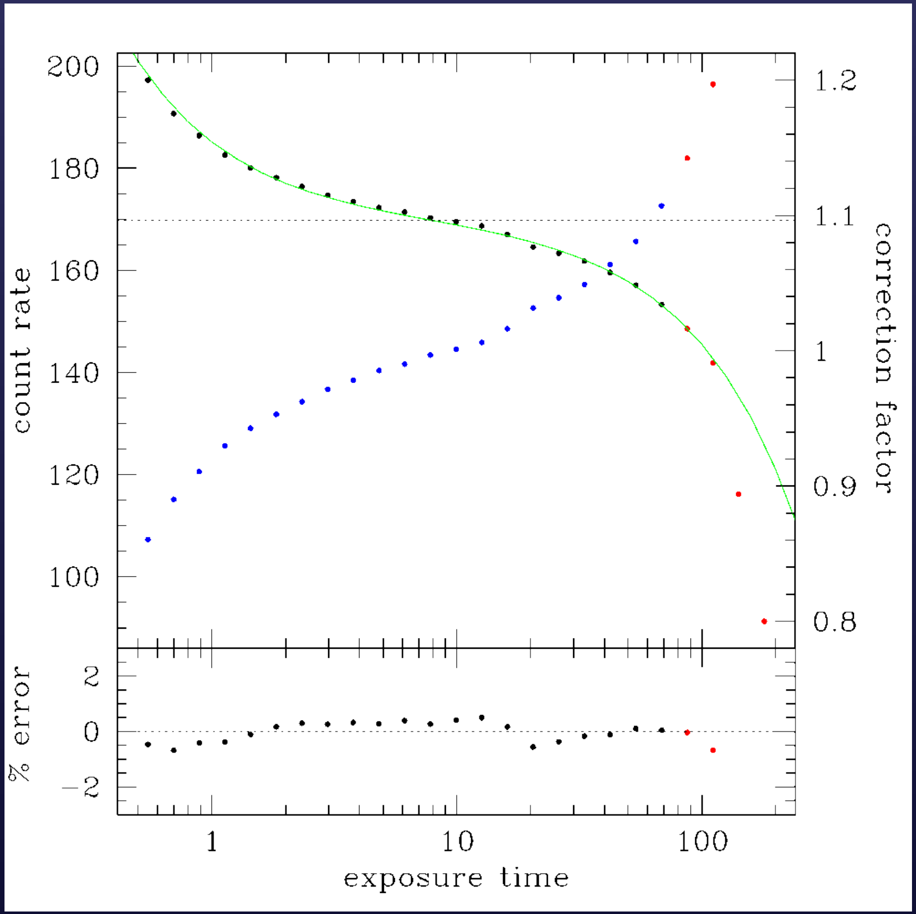
2) Non-linearity correction: NIRLIN

NIRI's detector response depends on the exposure time, the count rates, the read out mode, the bias level and the position within the detector.

NIRLIN is a Python routine that calculates and applies a per-pixel linearity correction and it should be used to linearize all science data.

The non-linearity correction is important at the extremes of very low exposure times (< 1.0 s) and near the full well detector limit (>10000 ADU).

The correction is effective up to 12000 ADU.



Non-linearity correction coefficients (blue dots, and scale at the right side) that should be applied to a constant brightness source, according to the exposure time and hence the count rate (scales at the bottom and left side, respectively). The count rate is the green line fit (the residuals of this fit are shown at the bottom panel).

2) Non-linearity correction: NIRLIN

NIRLIN - NIR LINearization

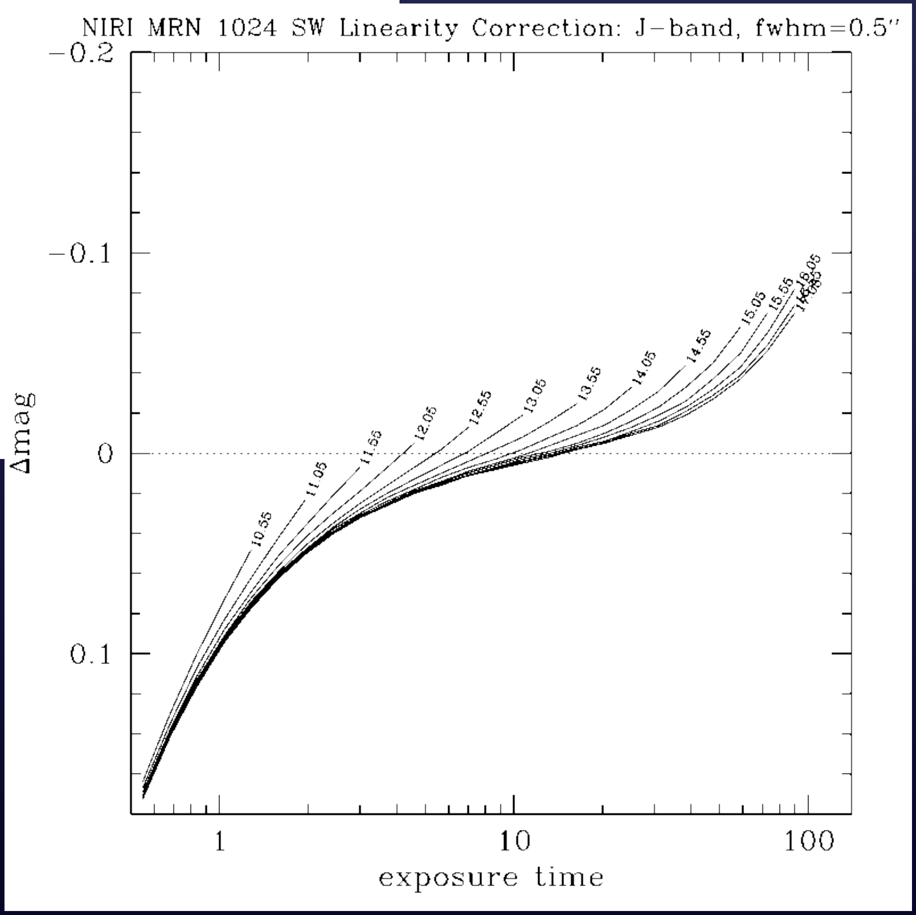
BETA VERSION

INTRODUCTION:

NIRLIN should be used to linearize all science data. This version uses three coefficients to correct for non-linearity in the NIRI detector: an exposure time correction, a counts squared term and a counts cubed term. These coefficents are dependent on the read mode and detector ROI. We have currently derived coefficients for the following configurations:

Read Mode	ROI	Well Depth	dt	c2	c3
Low RN	1024	shallow	1.266	7.39e-06	1.94e-10
Medium RN	1024	shallow	0.094	3.43e-06	4.81e-10
Medium RN	256	shallow	0.0103	6.82e-06	2.13e-10
High RN	1024	shallow	0.0097	3.04e-06	4.64e-10
High RN	1024	deep	0.0077	3.58e-06	1.82e-10

Note: We have not yet quantified the effect of linearizing flat fields.



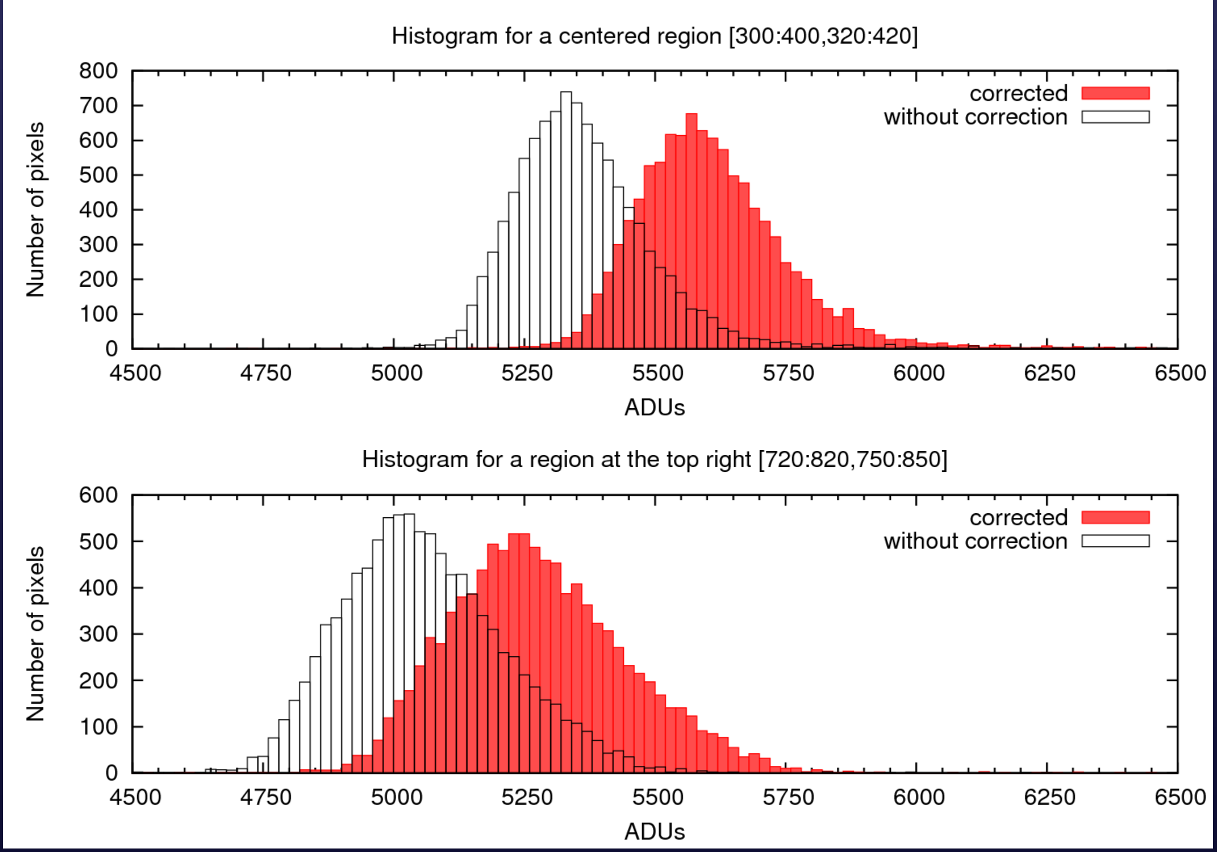
http://staff.gemini.edu/~astephens/niri/nirlin/

2) Non-linearity correction: NIRLIN

Histograms to compare the pixel values distribution before (black lines) and after (red) the non-linearity correction was applied.

The panels show the sample of two different sections of 101×101 pixels, from a raw Ks image.

Top panel: at the frame center
Bottom panel: at the top right corner of the frame.



Reduction process: IRAF tasks at gemini.niri package

After the vertical stripping (CLEANIR) and non-linearity (NIRLIN) image corrections the reduction procedure continues making use of IRAF routines in the gemini.niri package.

3) NPREPARE

All data must be run through NPREPARE before further processing.
NPREPARE generates variance and data quality frames for raw NIRI images.
NPREPARE adds a few header keywords:

EXPTIME:	total exposure time (adding all coadds)
GAIN:	gain (e-/ADU)
RDNOISE:	read noise (e-)
SATURATI:	saturation level (ADU)
NONLINEA:	the level at which the data start to be non-linear (ADU)
BIAS:	the array bias voltage.

These header keywords are used by other scripts in the NIRI package.
NPREPARE refers to a data file named nprepare.dat that contains vital information for adding these header keywords.

http://www.gemini.edu/sciops/data/IRAFdoc/niriinfo.html,
http://www.gemini.edu/sciops/instruments/niri/data-format-and-reduction/data-primer
IRAF help pages of each task.

```
File   Edit
AMSTART =                1.048 / Airmass at start of exposure
AMEND   =                1.047 / Airmass at end of exposure
CTYPE1  = 'RA---TAN'           / the coordinate type for the first axis
CRPIX1  =     425.651373538341 / x-coordinate of reference pixel
CRVAL1  =     23.6410357420452 / first axis value at ref pixel
CTYPE2  = 'DEC--TAN'           / the coordinate type for the second axis
CRPIX2  =       512.0656945715 / y-coordinate of reference pixel
CRVAL2  =     30.7858525019719 / second axis value at ref pixel
CD1_1   = -3.2263463742995E-05 / partial of first axis coord w.r.t. x
CD1_2   = -1.91085146821504E-06 / partial of first axis coord w.r.t. y
CD2_1   = -1.97888114227432E-06 / partial of second axis coord w.r.t. x
CD2_2   = 3.22463598385252E-05 / partial of second axis coord w.r.t. y
MJD_OBS =     53624.4833829836 / Mean Julian day of observation
INTEGRIT= 'OK      '           / Observation status (OK|STOP|ABORT)
FRAME   = 'FK5     '           / Target coordinate system
RELEASE = '2007-03-11        ' / End of proprietary period YYYY-MM-DD
HISTORY Cleaned with nirinoise.py 2010.06.20 15:09:44
HISTORY Linearized by nirlin.py 2010.06.20 19:55:20
NEXTEND =                    3 / Number of extensions
RDNOISE =                 41.2 / Estimated read noise (electrons)
GAIN    =                12.30 / Gain (electrons/ADU)
BIASVOLT=               -0.585 / Array bias voltage (V)
SATURATI=                16371 / Saturation level in ADU
NONLINEA=            11493.132 / Non-linear regime in ADU
FILTER  = 'H                 ' / Filter name combined from all 3 wheels
PUPILMSK= 'pupil38           ' / Name of pupil mask
PIXSCALE=              0.11630 / Pixel scale in arcsec/pixel
GEM-TLM = 'Sun Aug 15 19:43:10 CDT 2010' / Last modification with GEMINI
PREPARE = 'NPREPARE at Sun Aug 15 18:40:00 CDT 2010' / Prepared for further proc
BPMFILE = 'none              ' / Input bad pixel mask file
NRESIDUA= 'Sun Aug 15 19:35:00 CDT 2010' / Time stamp for NRESIDUAL
INPUTDQ1= 'nflcN20050911S0072[DQ]' / Additional included DQ plane
NIREDUCE= 'Sun Aug 15 19:43:10 CDT 2010' / Time stamp for NIREDUCE
SKYIMAGE= 'bnlcN20050911S0074_sky' / Sky image subtracted from raw data
SKYSCALE=      1.0163727347382 / Scale factor by which sky was scaled
FLATIMAG= 'ncN20050911S0345_flat' / Flat field image used
SKYCONST=             6898.758 / Constant added after sky image subtraction
IMCOFIX = 'done    '           / Imcoadd: fixpix using DQ
```

Reduction process: IRAF tasks at gemini.niri package

NRESIDUAL - Flag saturated pixels in the DQ planes of subsequent exposures.

Image persistence is small in NIRI's array, but saturated or nearly saturated images will leave a ghost in one or two subsequent frames. The persistence of a very bright source is typically 0.5 to 1% in the next frame and less than 0.1% by the third frame.

When there are saturated or nearly-saturated objects in a frame, image persistence in the array leaves a faint residual that can be confused with a real object in subsequent images. NRESIDUAL takes the DQ planes from the images taken immediately prior to an image and combines them, allowing the effects of saturation to be followed in subsequent exposures.

This task is not needed if there are no saturated or non-linear pixels in the exposures.

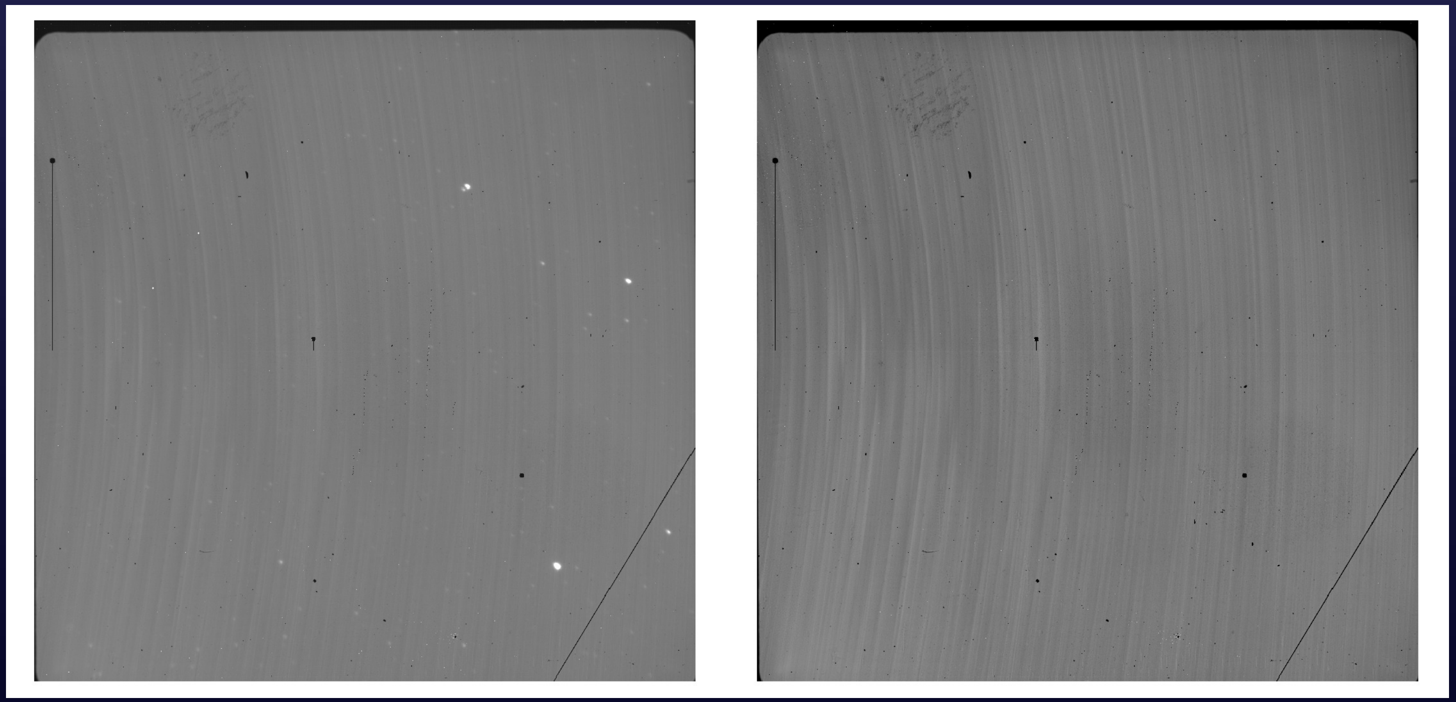
Reduction process: IRAF tasks at gemini.niri package

4) NISKY - Derive sky image, includes masking of objects.

NISKY constructs a sky image from a list of input images. It calls NIFASTSKY to generate a simple median sky image, which it uses to reduce the input sky images.

A flat field is generated by normalizing this quick sky image. The input images, sky subtracted and flattened, are then used to identify objects and create an object mask.

OBJMASKS is then run to identify all objects in the field.



Reduction process: IRAF tasks at gemini.niri package

5) NIFLAT – derives a flat field image and the bad pixel mask.

The normalized flat field is created by combining the ‘lamp on’ images and subtracting from it an image created by combining ‘lamp off’ images to account for the thermal component of the flat field.

The short darks (1.0-2.0 seconds darks) are used to identify the bad pixels within the frame to create the bad pixel mask.

The method used to combine the images was ‘average’.

All the important information regarding niflat’s parameters used is stored in the resulting flat field image header.

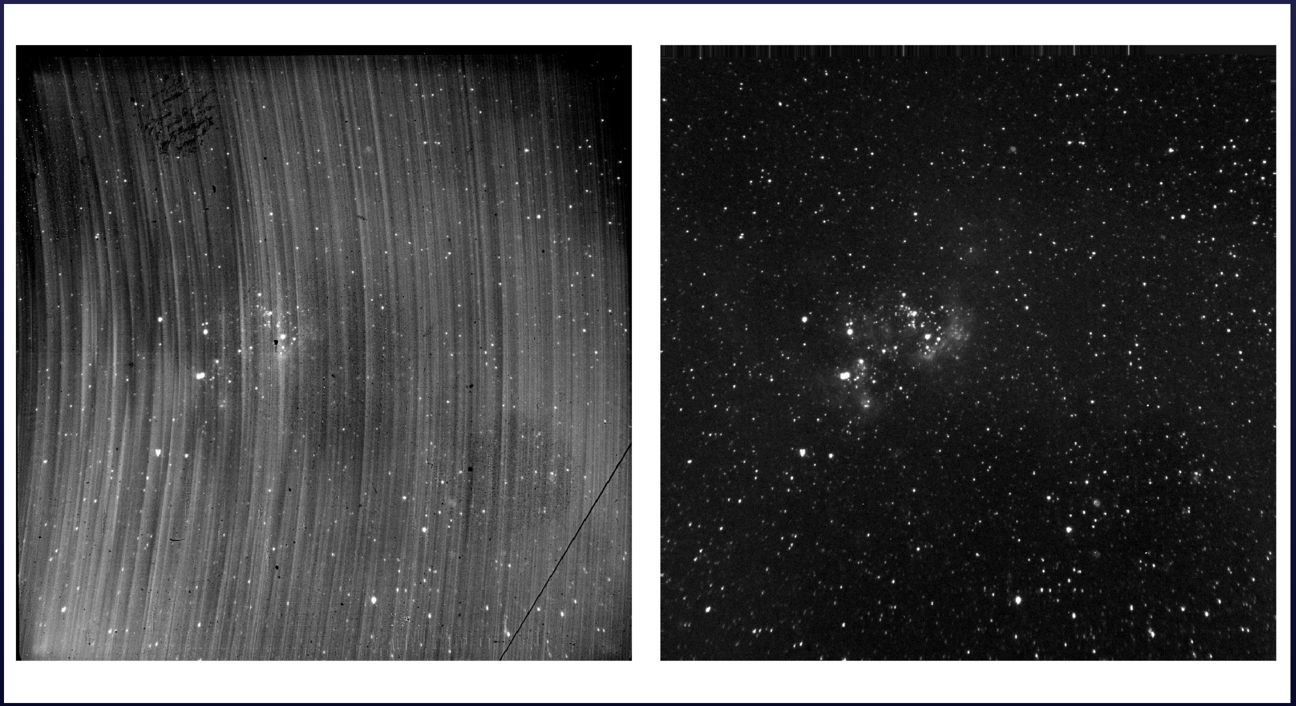
Reduction process: IRAF tasks at gemini.niri package

6) NIREDUCE - operates algebraically with the science images using the sky image for the sky subtraction and the normalized flat field to divide the images.

All science data must be run through NIREDUCE.

This task restores the sky level to the original level (to maintain the noise characteristics of the image) by adding the median of the sky image.

Updates the DQ and VAR planes for each image.
The VAR frame contains the definitive measure of the noise in each pixel.
The DQ frame is generated by combining the DQ frames of all the relevant input images hence, the resulting DQ frame contains all the flags that were present in the input images.



Reduction process: IRAF tasks at gemini.niri package

7) IMCOADD - Used to generate the final image (in which the photometric analysis will be performed) by combining all the reduced science images.

i) Derives the geometrical transformation between the images to register several images of the same field (calling geomap and geotran tasks).

ii) Constructs the average image cleaning it for cosmic ray events (with the imcombine task).

Reduction process: IRAF tasks at gemini.niri package

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A very important point to start with is that imcoadd operates over a list of science images to combine, taking the FIRST image in the list as a reference for several issues, from geometry to scale magnitude references. For this reason, the first image in the list must be the best available. In the case of images taken with the dithering technique the final image will also have the same field as the first image in the list.

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IMCOADD is modular in design and each step has a flag in the parameter file related to it.

1. Find the objects in the reference image (the first in the list of images) using DAOFIND: fl_find+
2. Derive the transformations using GEOMAP: fl_map+
3. Transform the images using GEOTRAN: fl_trn+
4. Derive the median image using IMCOMBINE: fl_med+
5. Derive the average image cleaned for cosmic-ray-events, using IMCOMBINE: fl_add+
6. Derive the average uncleaned image using IMCOMBINE: fl_avg+

Reduction process: IRAF tasks at gemini.niri package

The (many) output images after running IMCOADD are for each image:

(1) [image]_pos: a coordinate file with approximate objects positions.

(2) [image]_cen: a coordinate file with objects positions derived using apphot-center with [image] pos as the input file.

(3) [image]_trn: a position input file for geomap. The entry in database will also be called [image] trn. The file is made from [reference] cen and [image] cen. This files come from the alignment procedure.

(4) [image]_trn_mag: is a file with photometric information used for scaling of the intensity of the images.

(5) [image]_badpix.pl: is the derived bad pixel mask for each image.

Reduction process: IRAF tasks at gemini.niri package

For the reference image (which is the first image in the list) the outputs are

(1) [reference]_cen: a coordinate file for the reference image, with positions derived using apphot-center with [reference] pos as the input file. This file comes from the alignment procedure.

(2) [reference]_mag.tab: this file contains all the photometric information used for scaling the intensity of the images.

(3) [reference] med.fits: is the derived median image.

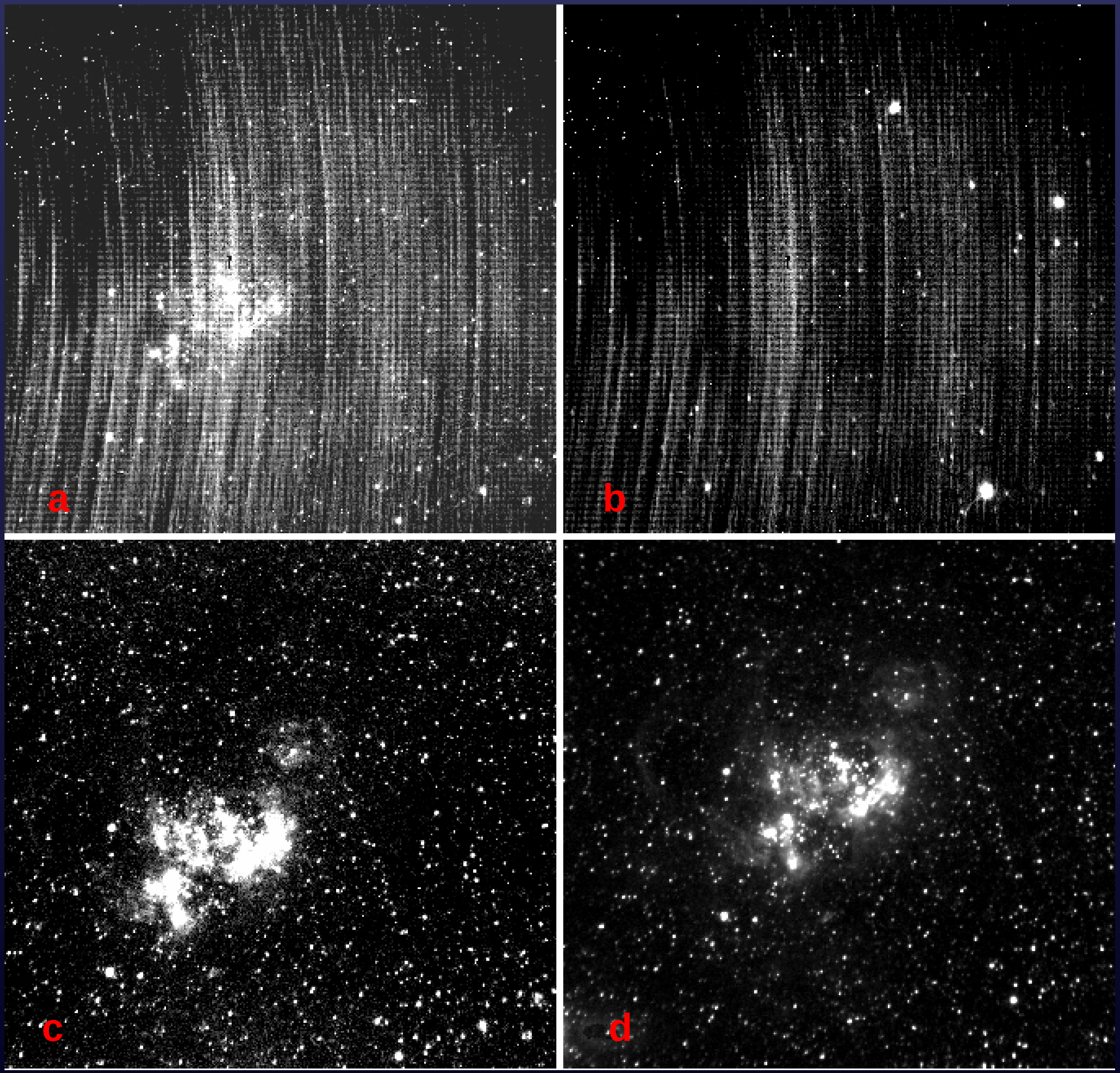
(4) [reference]_badpix.pl: is the derived bad pixel mask for reference image.

(5) [reference]_avg.fits: is the uncleaned cosmic-ray average image. This image should not be used for photometry.

(6) [reference]_add.fits: is the cosmic-ray cleaned average image. This is the image that must be used for science photometry.

- The [reference] add.fits is a MEF file with a complete header information on frame [0], but it has lost the VAR and DQ planes. Nevertheless, the information in the DQ is not completely lost since the DQ planes of all the images were used to generate the bad pix mask images for all the images.

From raw images to science images: synthesis



Example: Filter J
a) NGC 604 filed (raw image)
b) Sky frame
c) NGC604 field
(flats, sky, darks)
d) NGC 604 final images

Cecilia Fariña

A few personal recommendations

1) Before planning the observations read carefully the reduction procedures.

2) Read all the instrument web pages (and more than once).

3) Examine every raw image before starting with the reduction procedure.

4) Examine the images after running tasks (checking the background levels, possible artifacts, etc).

5) Examine headers' keywords values before/after running tasks.

6) Have an idea about the values (e.g. which is the medium readout noise?, how it should change after combining images?)

7) Never let pass “warnings” without carefully reading them...they always have a consequence...

8) If you are not happy by the result try an alternative way to obtain images (e.g. generate a flat field by hand and compare the resulting images).

9) Do not let IRAF (or any program) work alone, check the parameters, adapt them, try different things than the cookbooks.

10) Take some time to play with your images … it might take time but is the best way to learn, to know the data and to trust your results.

Bibliography/References

- http://www.gemini.edu/
- http://iraf.noao.edu/docs/docmain.html
- IRAF help pages
- Handbook of infrared Astronomy – I. S. Glass – Cambridge University Press
- Other researches with experience :)

Thank you !!!