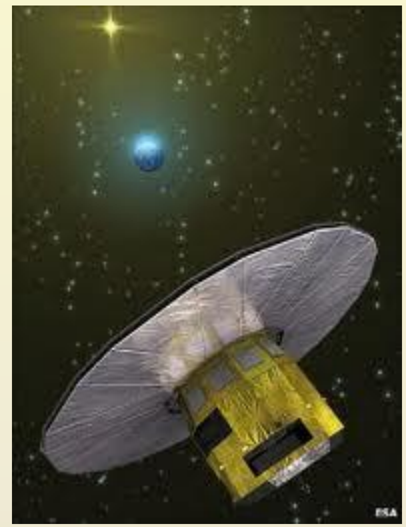
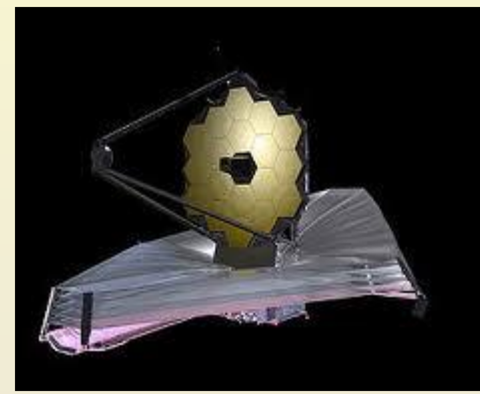
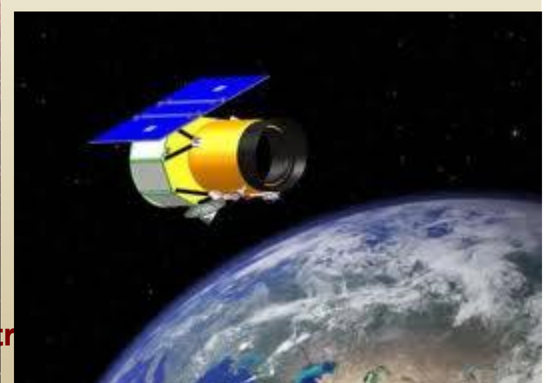
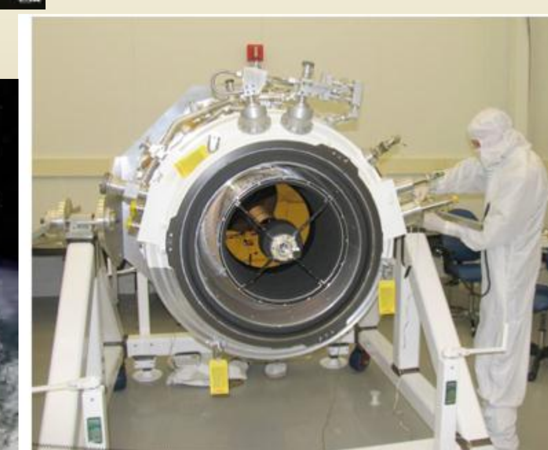
Tema 4: telescopios espaciales

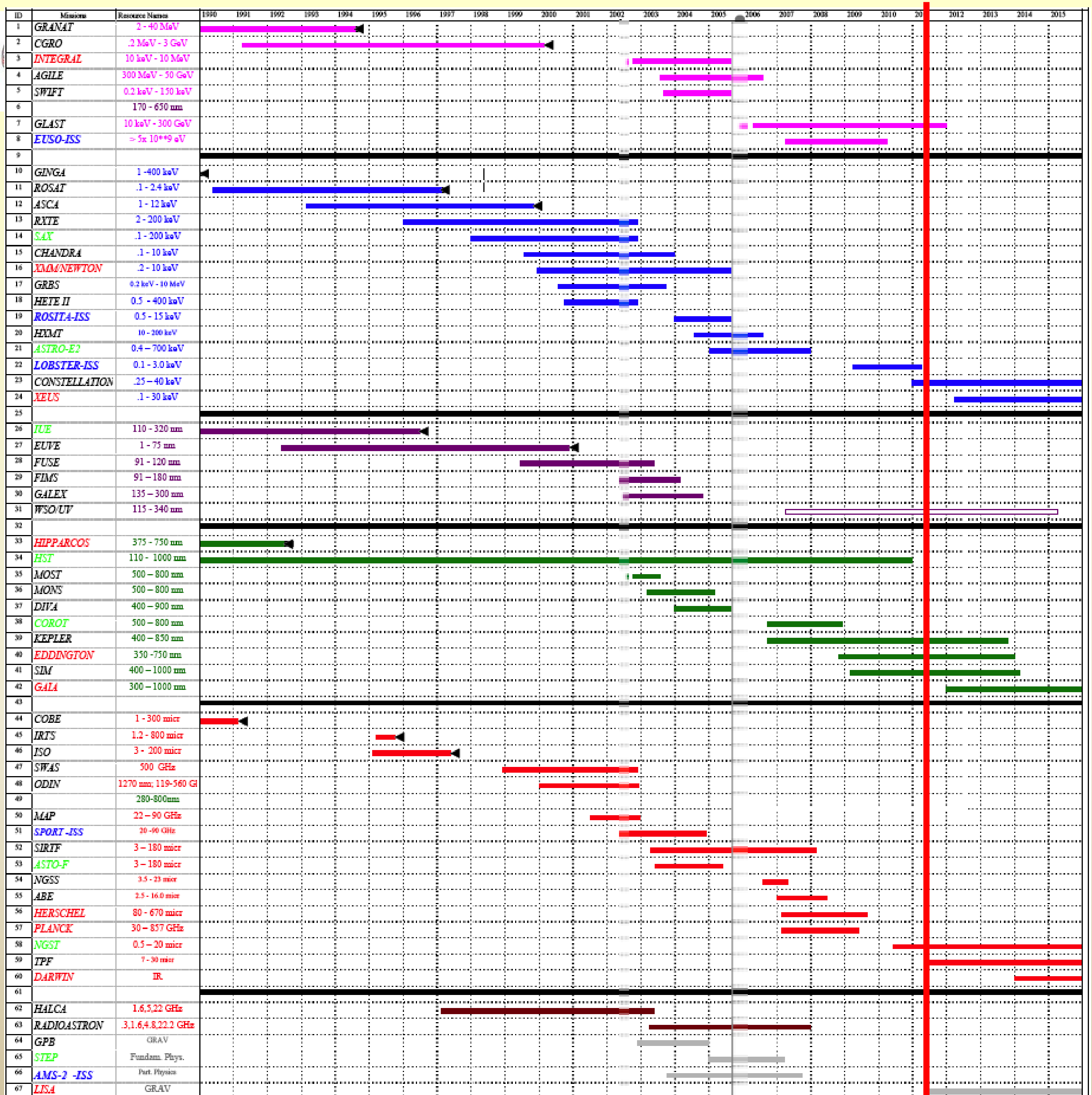






(material compilado por A. Gil de Paz, J. Zamorano, J. Gallego, P.G. Pérez-González)



Past/Present/Future Space Observatories:

Scheme (1/3)

Covering the basics:

- **Why observing from Space?**

Image quality, low bckg., transparency *vs.* *Costs & risks*

HST

- **Description of the Observatory**
- **Preparing a *HST* proposal:**
  - ***Constraints, APT, etc.***
- **Using Archival Data: MAST**

Scheme (2/3)

GALEX

- **Description of the Observatory**
- **Preparing a GALEX proposal**
- **Bright-star and background limitations**
- **Using Archival Data**

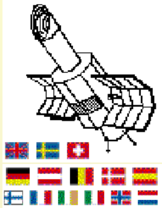
Spitzer and WISE

Herschel

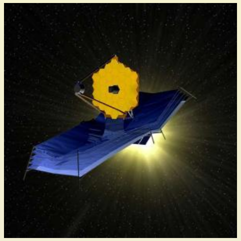
- **Description of the Observatories**
- **Preparing proposals: *Using Spot / Hspot***
- **Constraints, pipeline, & latents**
- **Using the Spitzer Archive: *Leopard/SHA***

Scheme (3/3)

Past: • **Using IUE, IRAS, ISO data**

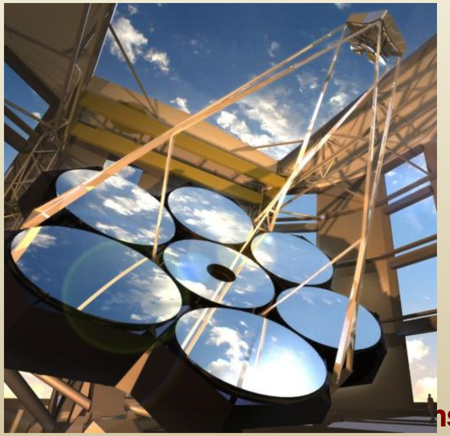


Future: • **James Webb Space Telescope (JWST), Gaia, SPICA, WSO-UV, ...**

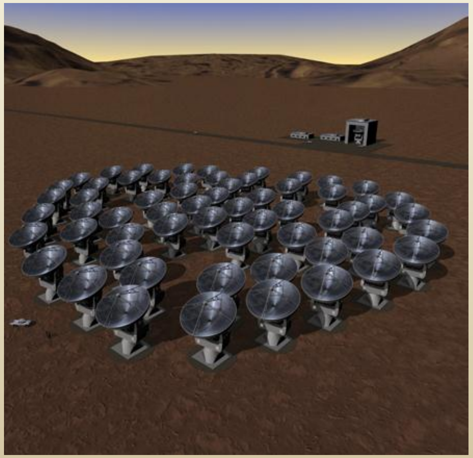


Synergy with ground based data:

• ***HST - Keck/VLT***



• ***JWST-ALMA***

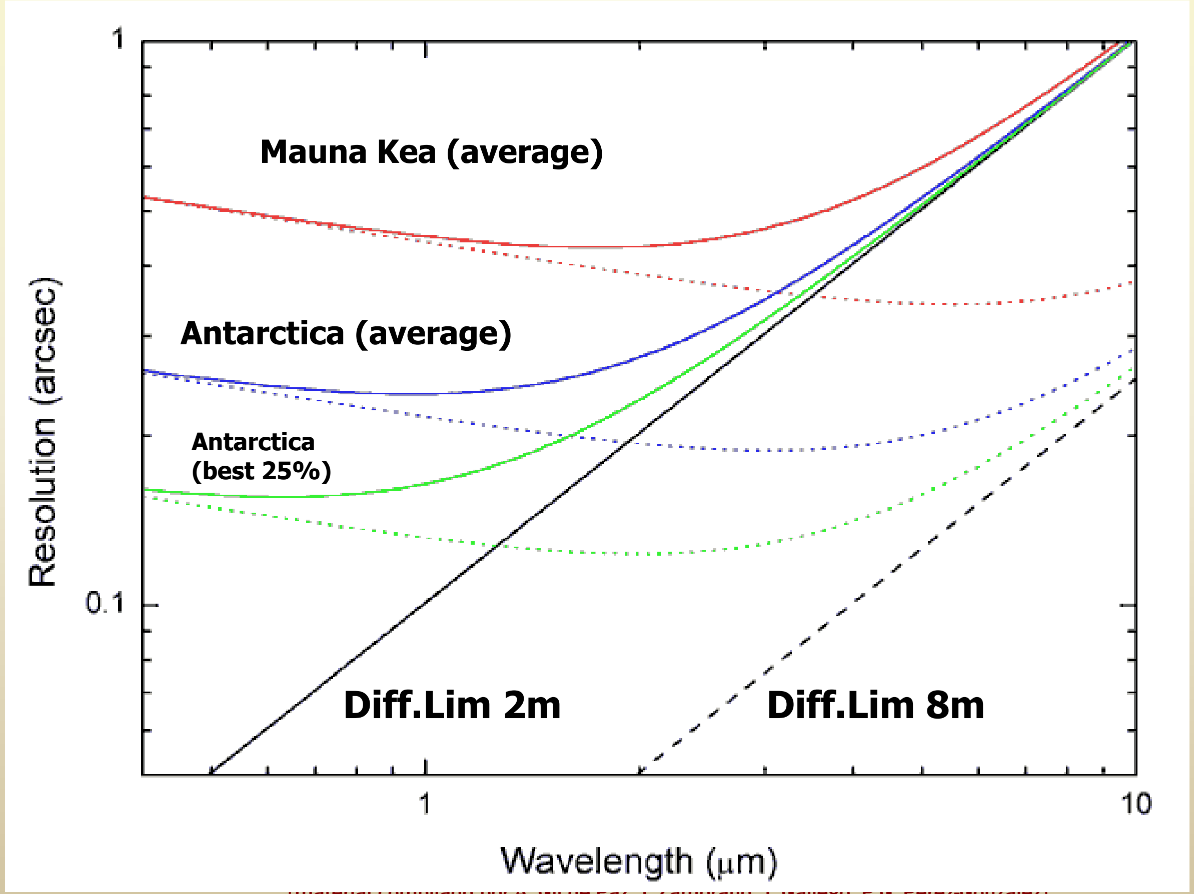


Space Astronomy: Why?

No atmosphere

• Better image quality (no atmospheric *seeing*)

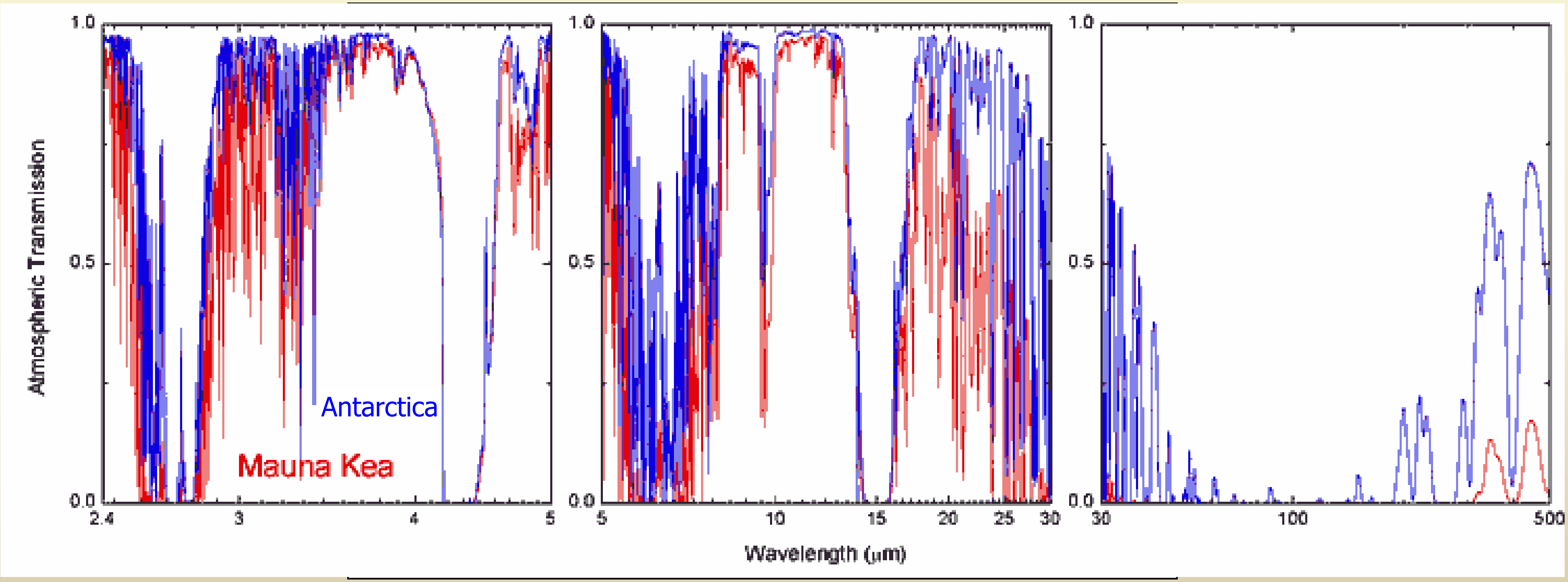
$FWHM_{seeing} \sim\lambda^{-0.2}$; Diffraction limit = λ/D



Space Astronomy: Why?

<u>No atmosphere</u>

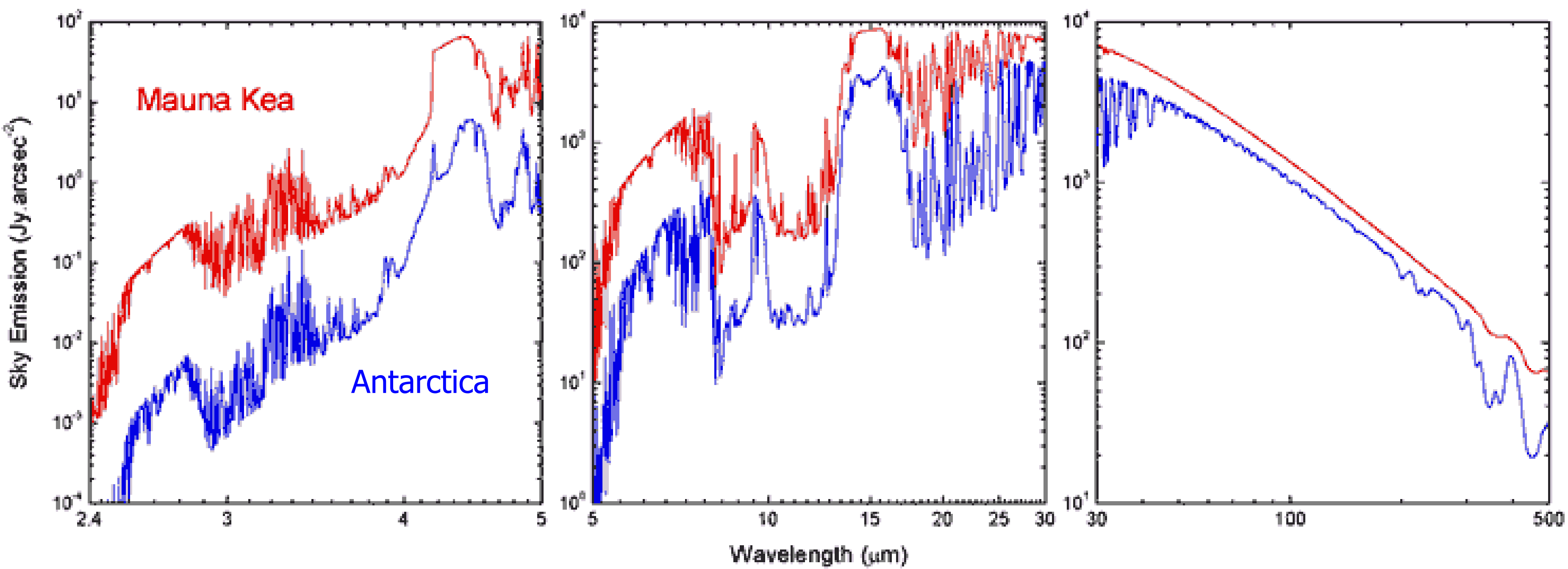
- Better transparency & no cloudy nights



Space Astronomy: Why?

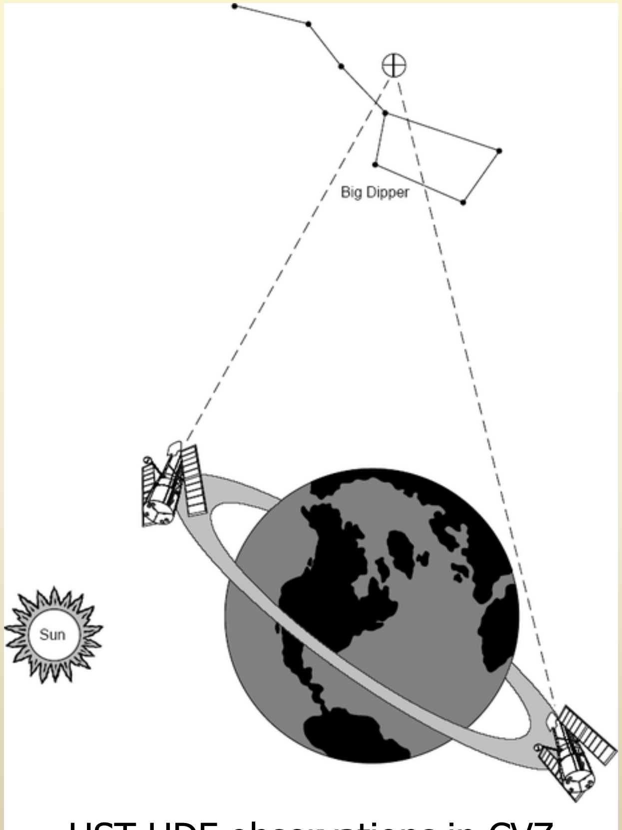
No atmosphere

- Less (scattered and thermal) background

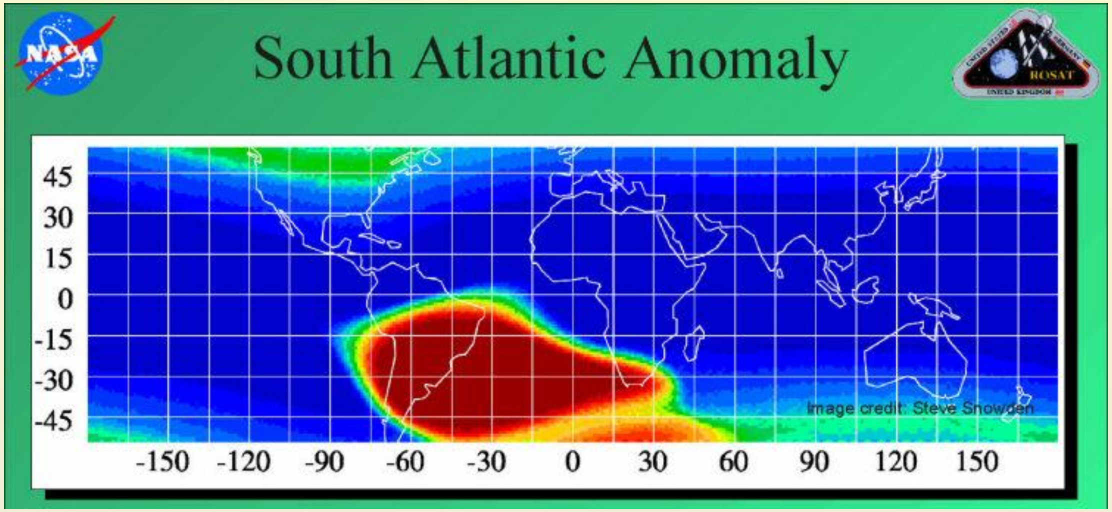


Space Astronomy: Why?

Existence of Continuous Viewing Zones (CVZ)



HST HDF observations in CVZ



In high orbits (Earth-trailing, L2)

- Longer lasting (& fixed) CVZ
- Lower thermal background from Earth
- No South Atlantic Anomaly passages

Space Astronomy: Why?

Downs

Higher risks

- Not 100% launch and deploy successful rates (e.g. HETE, Abrixas, ASTRO-E, WIRE)
- Telescope & instruments never tested under exact working conditions (e.g. HST).
- Difficult to repair if something fails. Impossible for satellites in high orbits.

Limited lifetime

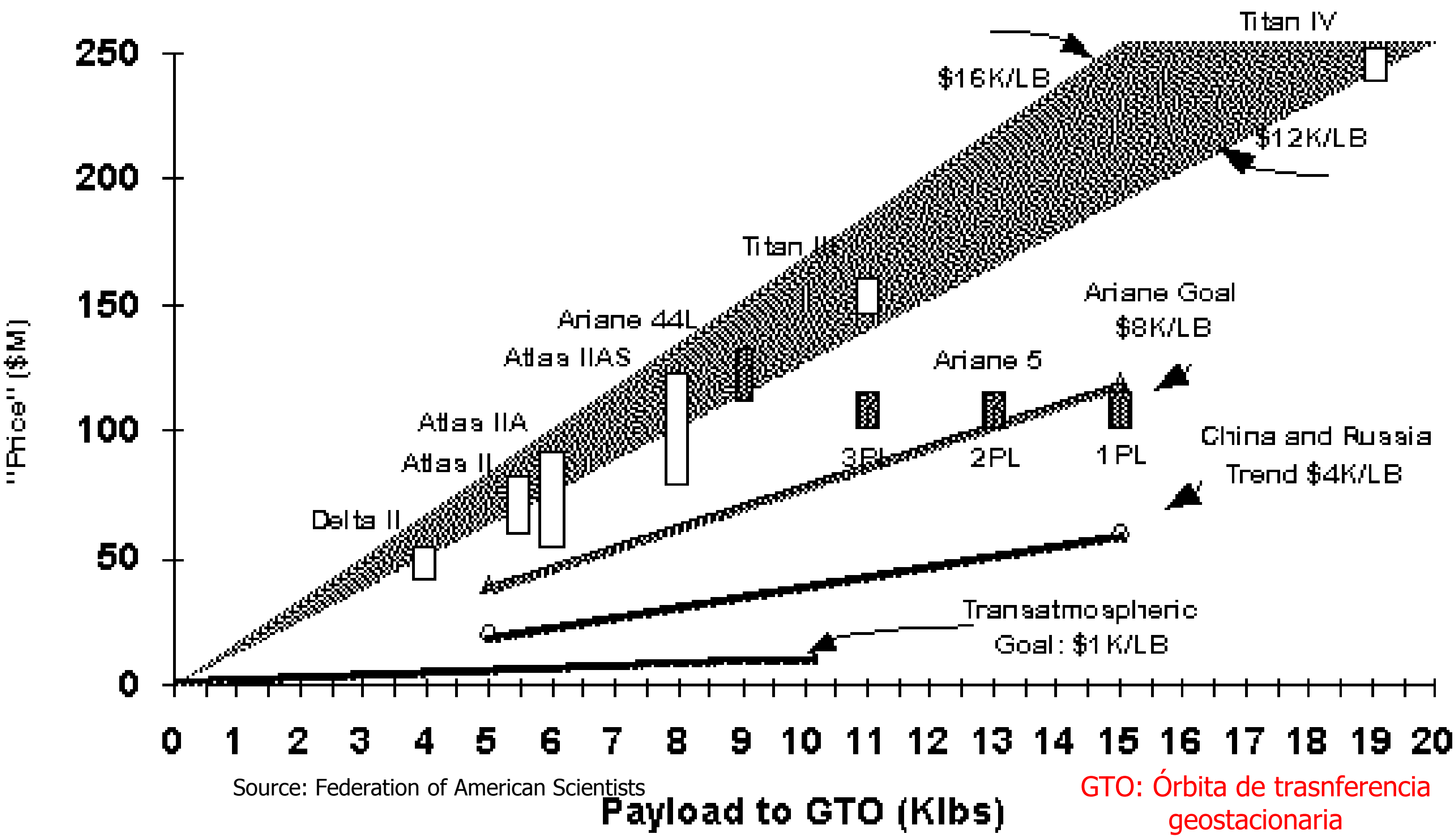
- Instrument consumables (cooling: NICMOS, ISO, *Spitzer, HSO*)
- Propellant (to compensate for atmospheric drag -Compton GRO- or angular momentum build up –JWST-)
- Gyros (despite redundant systems).

Space Astronomy: Why?

Downs

Higher costs

- For both telescope & instruments plus launch cost.
- Example: All four VLTs cost ~1/7 HST.



Source: Federation of American Scientists

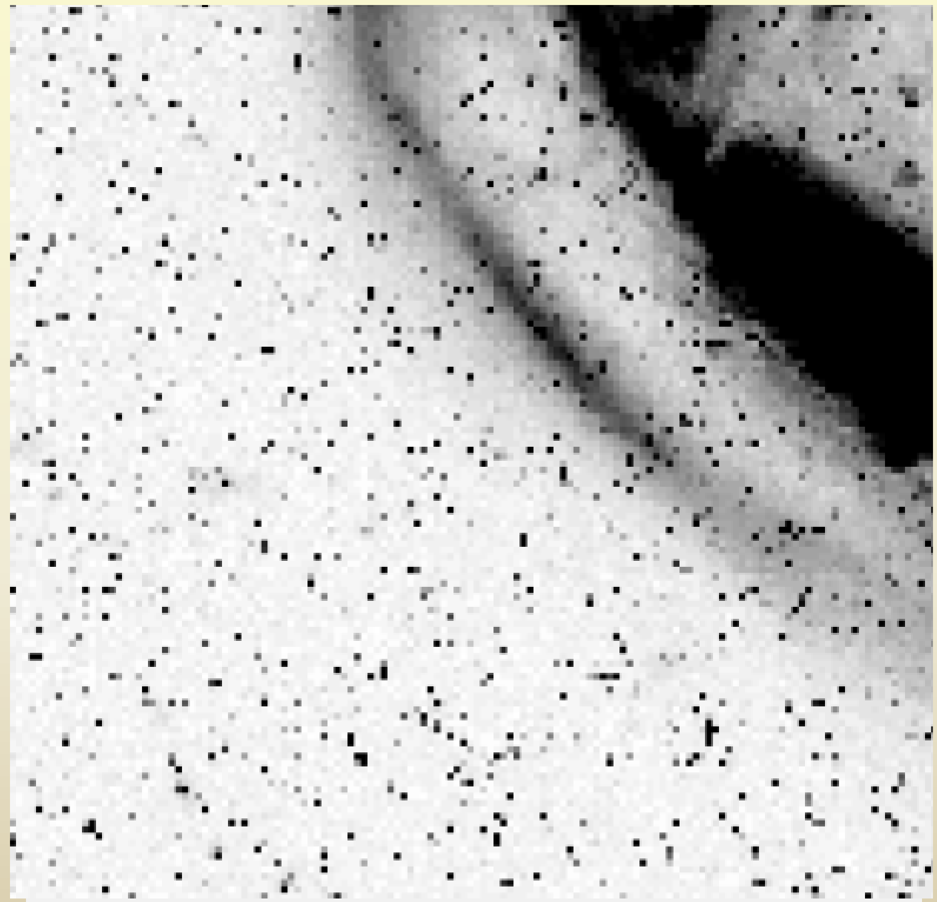
GTO: Órbita de trasnferencia geostacionaria

Space Astronomy: Why?

Downs

Higher rates of high-energy particles:

- Cosmic-rays events in HST detectors are several times higher than in the ground (1.5-3% ACS/WFC pixels affected in 1000s).
- This situation is worse in high orbits (5%-10% pixels expected to be affected in a JWST 1000s exposure) where there is no protection by the Van Allen belts.



Single 600s-long HST ACS/WFC raw image

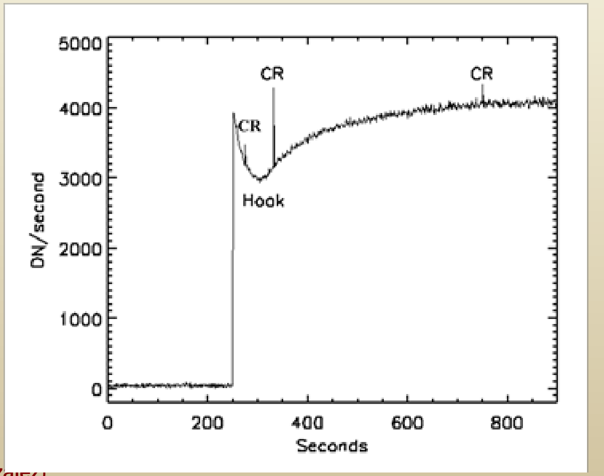
Space Astronomy: Specifics

These <u>Ups and downs</u> determine the specifics of the analysis methods used in Space Astronomy:

- High-spatial res. & Diff. Lim. images: PSF phot. (HST, *Spitzer*)
- Low background: Highly Poissonian statistics (HST & GALEX)
- High cosmic-rays rates: (HST CR-SPLIT)

Specifics of the instrumentation used in Space Observatories exploring new windows (UV, FIR):

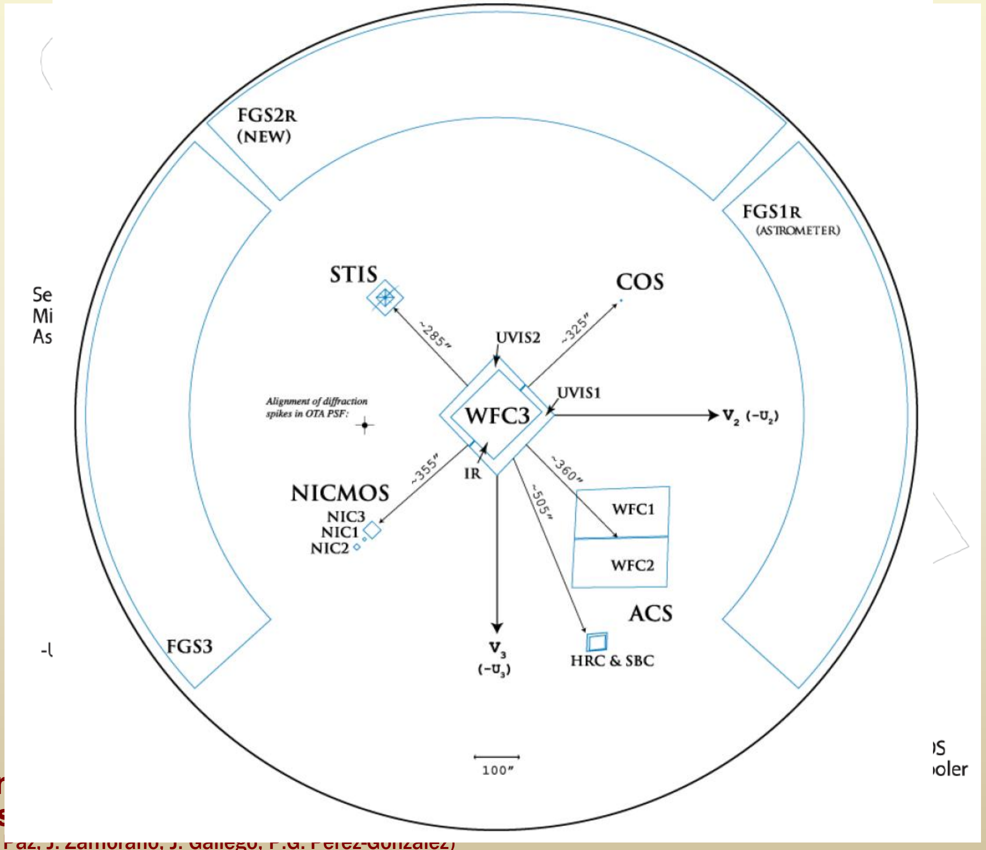
- Count-rate, color, and position-dependent PSF (GALEX & MIPS)
- Multiple time constant response (MIPS 70 & 160um photoconduct.)
- Confusion limits (GALEX & MIPS)



NASA's Hubble Space Telescope - HST

Hubble Space Telescope

- 2.5-m telescope in a low orbit (600 km) deployed in 1990.
- Functioning “legacy” instruments: ACS, STIS, NICMOS
- Replaced instruments: FOC, FOS, GHRS, WF/PC, WFPC2
- Last generation instruments (2009): COS, WFC3

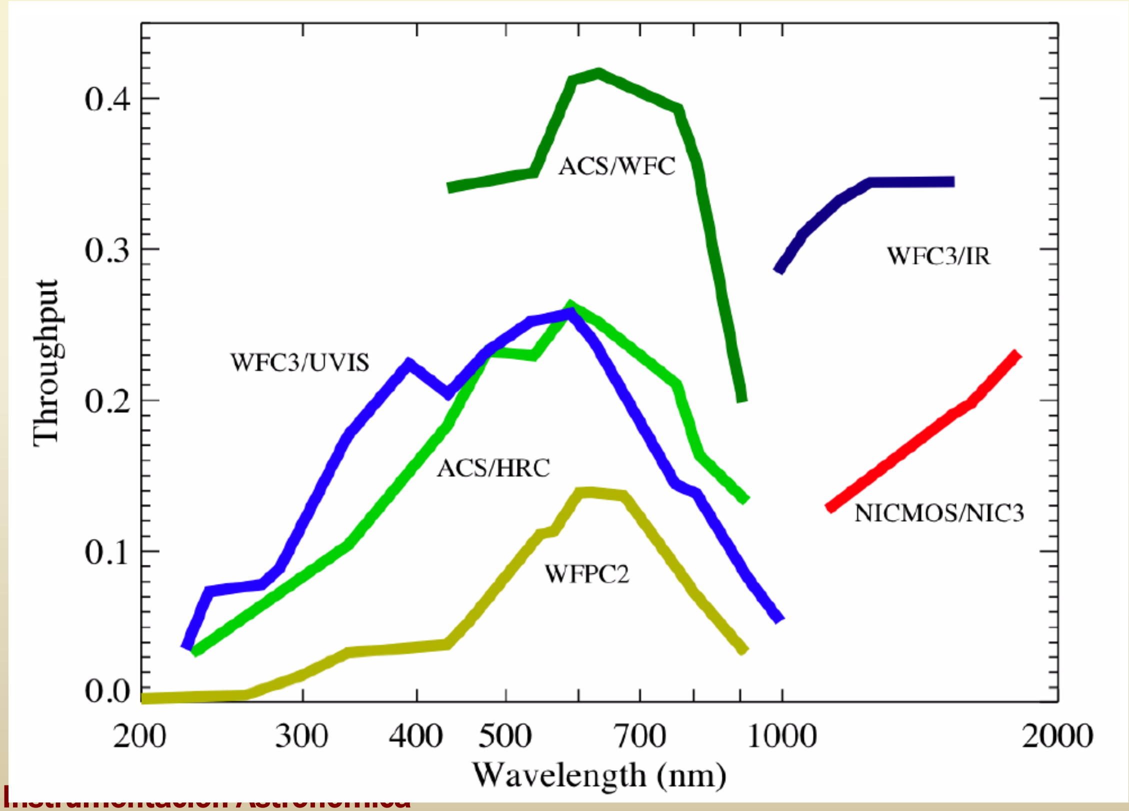


HST Instruments

Newest instruments: (Installed in 2009 - SM4)

COS (Cosmic Origins Spectrograph): Low and medium-resolution spectrograph in the UV range (1150-3200 AA).

WFC3 (Wide Field Camera 3): Imaging from 0.2-1.7 microns. It replaced the aging WFPC2. Some redundancy with ACS.



HST Instruments

UV imaging:

	WFC3/UVIS	ACS/HRC	STIS/NUV-MAMA
FOV Area (arcsec2)	162" x 162" (26183)	29" x 26" (754)	25" x 25" (625)
Broadband Throughput @ 230, 330 nm	0.07, 0.18	0.05, 0.10	0.026, 0.002
Pixel Scale (arcsec)	0.040	0.027	0.025
Number of Pixels	4k x 4k	1k x 1k	1k x 1k
Read Noise (e-)	3	4.7	None
Dark Current	1.0×10^{-4} (e-/pix/s)	5.8×10^{-3} (e-/pix/s)	1.4×10^{-3} (cnt/pix/s)
Number of Filters	13 10 full-field 3 quad	6 3 full-field 3 UV polarizers[1]	9 8 full-field (inc. 2 ND), 1 quad ND

HST Instruments

Optical imaging:

	WFC3/UVIS	ACS/WFC	ACS/HRC
FOV Area (arcsec2)	162" x 162" (26183)	202" x 202" (40804)	29" x 26" (754)
Broadband Throughput[1] @ V, I, z	0.26, 0.14, 0.08	0.41, 0.36, 0.20	0.23, 0.16, 0.13
Pixel Scale (arcsec)	0.040	0.049	0.027
Number of Pixels	4k x 4k	4k x 4k	1k x 1k
Read Noise (e-)	3	5	4.7
Dark current	1.0×10^{-4} (e-/pix/s)	2.6×10^{-3} (e-/pix/s)	5.8×10^{-3} (cnt/pix/s)
Number of Filters	49 32 full-field 17 quad	27 12 full-field 15 ramp	21[2] 13 full-field, 3 polarizers 5 ramp

HST Instruments

Near-infrared imaging:

	WFC3/IR	NIC3	NIC2	NIC1
FOV Area (arcsec2)	123" x 136" (16728)	51" x 51" (2601)	19" x 19" (361)	11" x 11" (121)
Broadband Throughput @ 1.1, 1.6 μm	0.29, 0.33	0.13, 0.20	0.14, 0.20	0.12, 0.18
Wavelength Range	0.9- 1.7 μm	0.8 - 2.5 μm	0.8 - 2.5 μm	0.8 - 1.8 μm
Pixel Scale (arcsec)	0.13	0.200	0.075	0.043
Number of Pixels	1k x 1k	256 x 256	256 x 256	256 x 256
Read Noise (e-)	16	29	26	26
Number of Filters	15	16	19 16 standard, 3 polarizers	19 16 standard, 3 polarizers

HST Instruments

UV spectroscopy:

		COS/FUV	COS/NUV	STIS/FUV	STIS/NUV
Spectral Coverage (Å)		1150 - 1775 (M) 1230 - 2050 (L)	1700 - 3200	1150 - 1700	1600 - 3100
Effective Area (cm^2) @ 1300Å (FUV), 2500Å (NUV)		2800 (M) 2400 (L)	900 (M) 750 (L)	400 (M) 1700 (L)	350 (M) 900 (L)
Resolving Power $R = \lambda/d\lambda$	H	N/A	N/A	114,000	114,000
	M	20,000 - 24,000	16,000 - 24,000	10,000 - 46,000	10,000 - 30,000
	L	2400 - 3500	1500 - 2800	1000	500
Number of Pixels Along Dispersion		32768	1024	1024 (2048)	1024 (2048)
Background (cts/s/resel)		4.3×10^{-5}	1.9×10^{-3}	350×10^{-5}	17×10^{-3}
Background Equivalent Flux (ergs/cm^2/s/Å)		$(0.5 - 8) \times 10^{-18}$	$(1.3 - 3.8) \times 10^{-16}$	20×10^{-18}	13×10^{-16}

Optical spectroscopy: STIS (COS does not cover the optical)

Proposing for HST – Cycle 20

Feasibility:

- Reasonable number of orbits (compared with the expected scientific return and number of people involved). Use ETC.
- The assumptions for determining the number of orbits are well justified and the overheads are properly accounted for.

Need for HST:

- *HST* (and only *HST*) can address this particular science topic.
- Available in the MAST archive? If so, justify additional time.

Flexibility:

- Long & frequent visibility windows and no unnecessary timing or orientation constraints.

Proposing for HST: Constraints

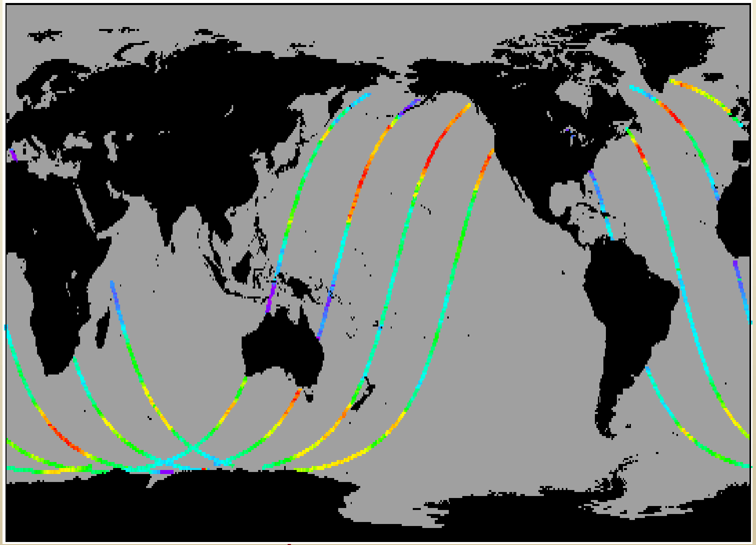
- ***Orbit:*** 96 min long. Most objects partially occulted by the Earth (up to 44 min/orbit). CVZ within 24º the orbital poles.

  (Note: CVZ should not be requested for background-limited broad-band imaging or observations with timing constraints, special orientation requirements, or ToO)

- ***SAA:*** although precession cycle is 56 days (so objects can be in the CVZ for many days in a row), the SAA limits the longest continuous observation to 5-6 orbits.

- ***Pointing constraints:*** within 60º of the Sun, 20º of the Earth and 9.5º of the Moon. Additional constraints for the ACS/SBC MAMA detector apply.

- ***Other constraints:*** Between 2005 and 2009 (SM4) HST in 2-gyros mode.



HST Phase I: APT

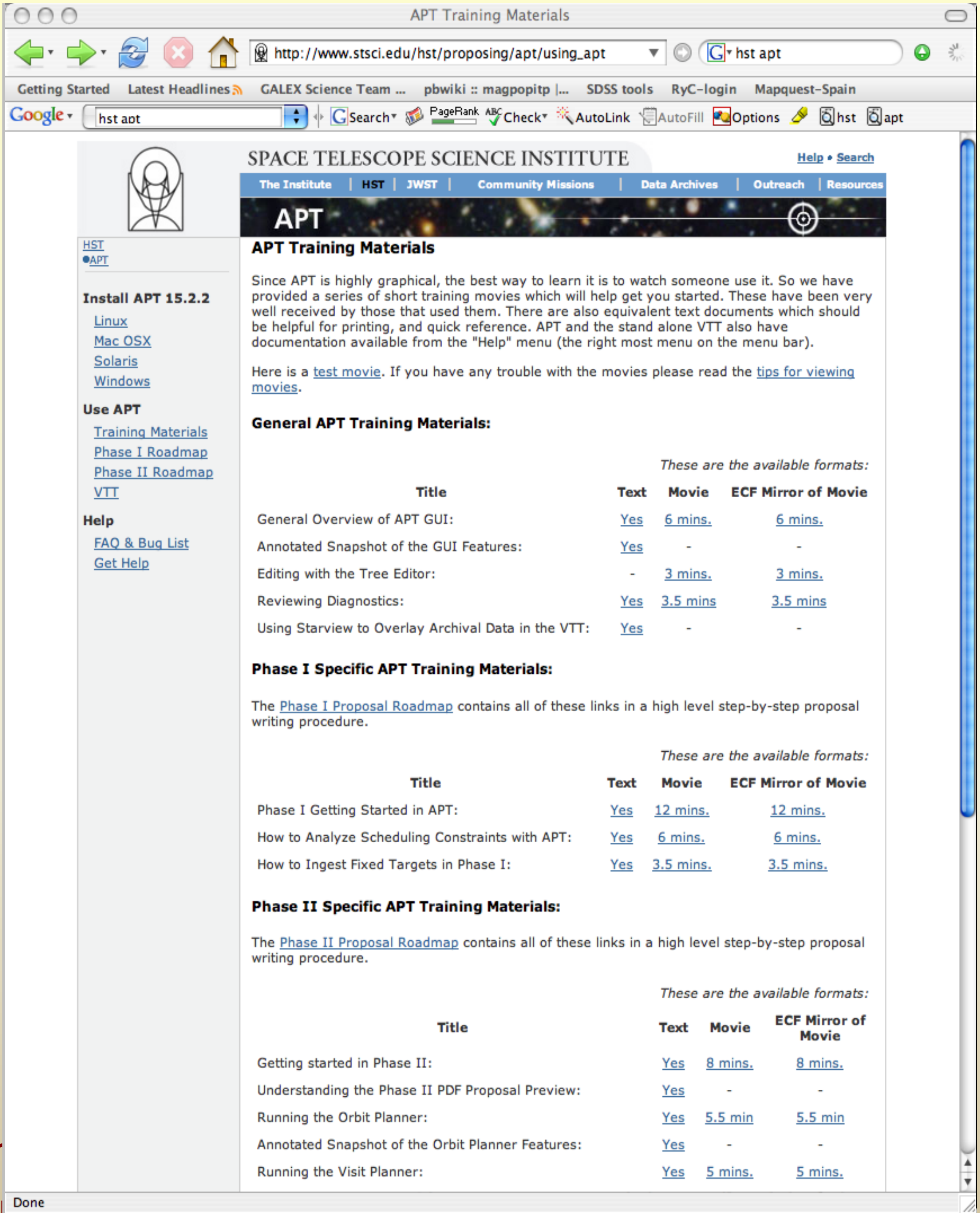
First steps:

- *Documentation:* Call for Proposals, HST Primer, and relevant instrument (ACS, NICMOS, WFC3 ...) handbook.

- Get Scientific Justification LaTeX/Word/PDF template

- *Software:* Proposer Tool + Visualizer (APT: Astronomer's proposal Tool)

(See APT training materials!)



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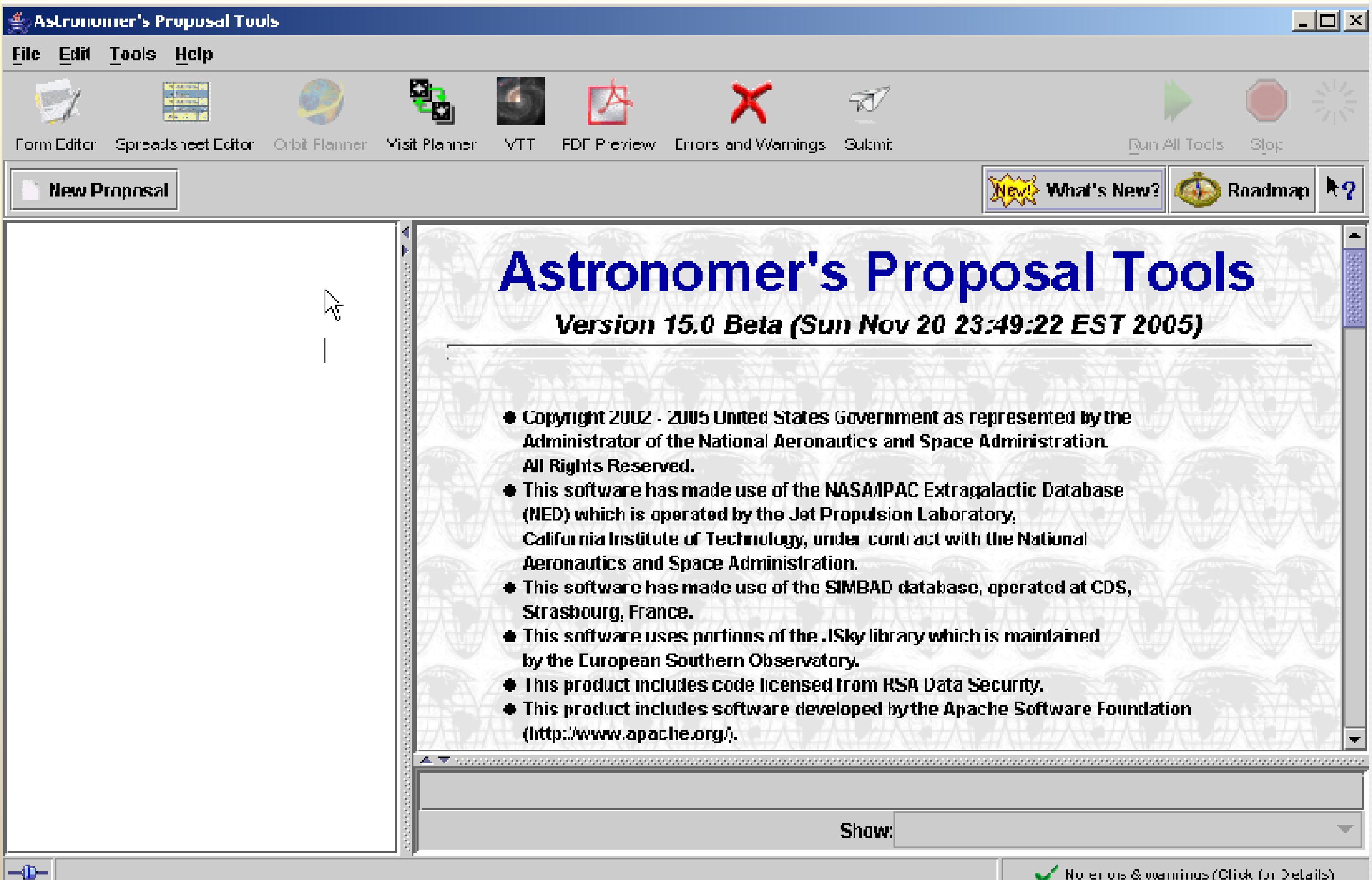
HST Phase I: APT



HST archive: MAST (Multimission Archive at STScI

- Images can be retrieved from MAST or using *Starview* or Aladin Sky Atlas (includ. in APT).

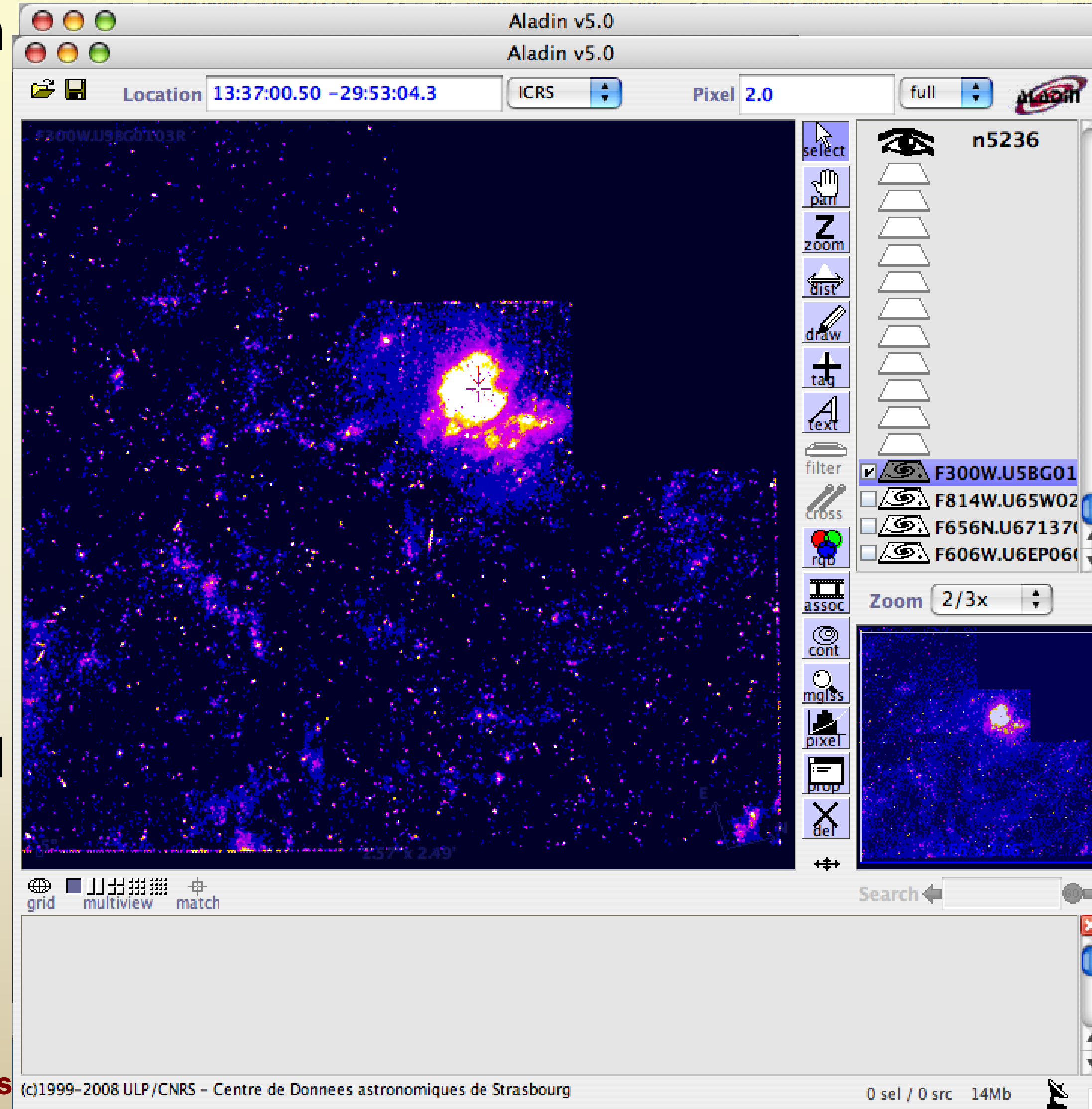
- Data formats (see the instruments data handbooks):

  Multiextension FITS: Science, data quality and error arrays

- Extensions: RAW, FIT, CRJ, DRZ (ACS & STIS), _raw, _ima, _cal, _mos (NICMOS), _d0f, _c0f (WFPC2)

- WFPC2 associations: 27000 combined WFPC2 images created from associations of 90000 individual WFPC2 frames.

- Images are VO complaint.



NASA's Galaxy Evolution Explorer - GALEX

Galaxy Evolution Explorer

Satellite:

- Developed by Orbital Science Corporation, launched by Pegasus-XL on April 28th 2003
- Circular orbit, altitude: 700 km, inclination: 29º, period: 98 min

Telescope: M1=50cm; M2=22cm, Richey-Chrétien design

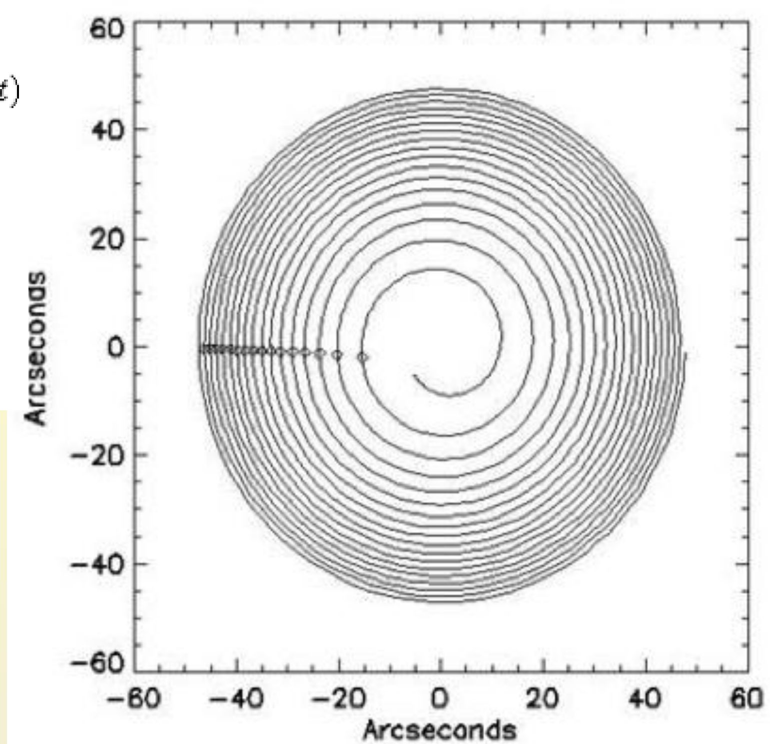
Instrument (SODA):

- Simultaneous imaging in two UV bands (FUV & NUV; ~1500 & 2200 Å)
- Circular FOV of 1.2º in diameter. FWHM~5" at a scale of 1.5"/pixel

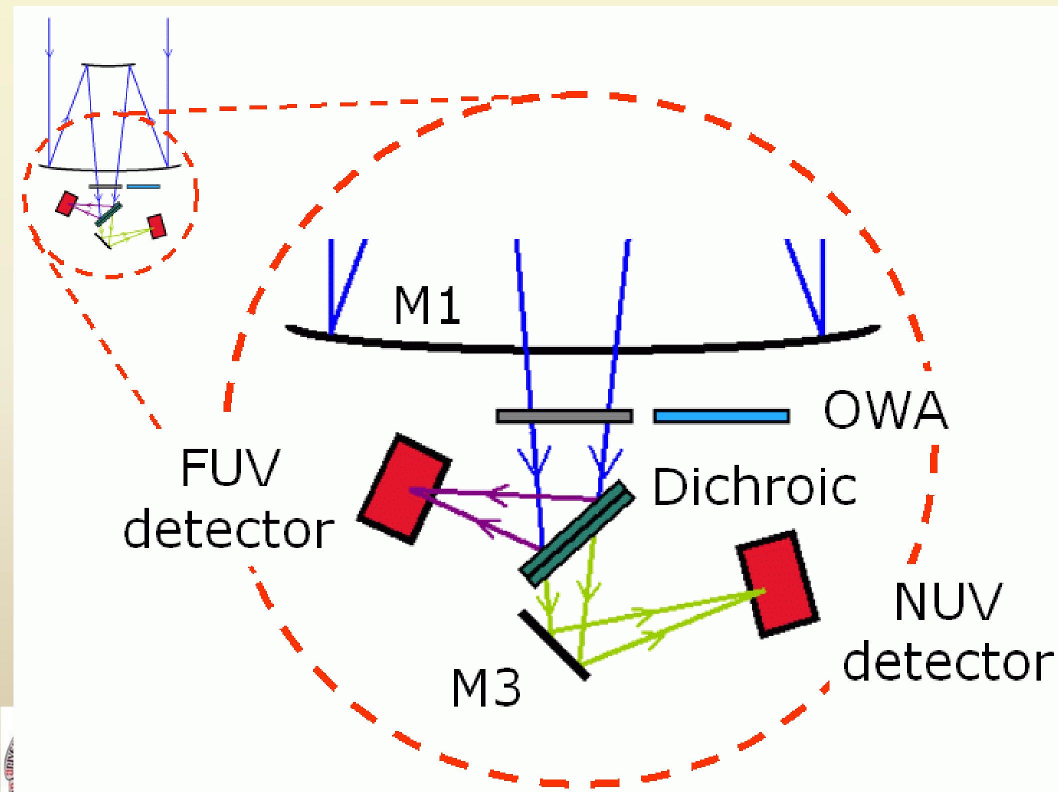
Mission: Limited by funding.

GALEX

$$\omega_x = K_1 t^n \omega \sin(\omega t) + K_2 \omega \cos(\omega t)$$
$$\omega_y = -K_1 t^n \omega \cos(\omega t) + K_2 \omega \sin(\omega t)$$
$$\omega_z = 0$$
$$K_1 = 2.2442 \ rad$$
$$K_2 = 0.1000 \ rad$$
$$n = 0.40$$
$$\omega = 0.05236 \ rad/s$$

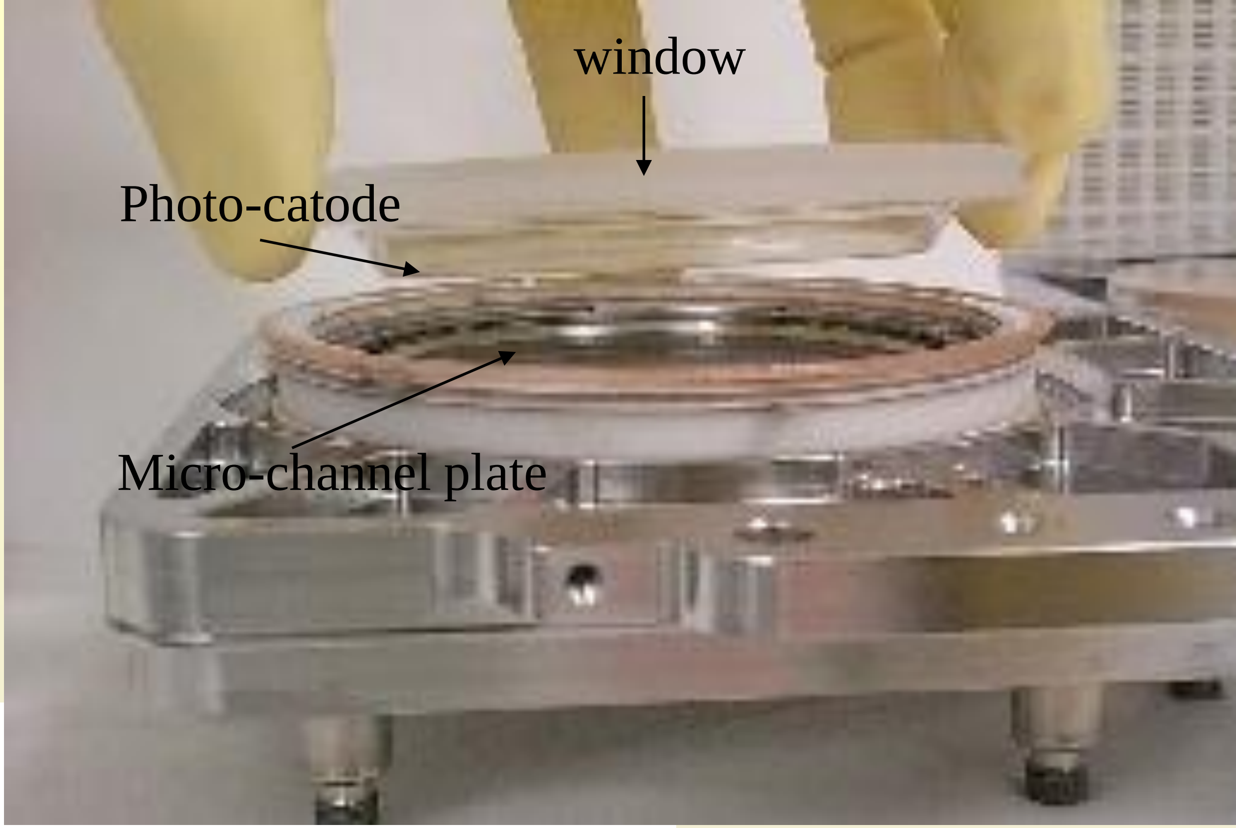


Observing strategy:
avoids saturation and preserves detector fatigue



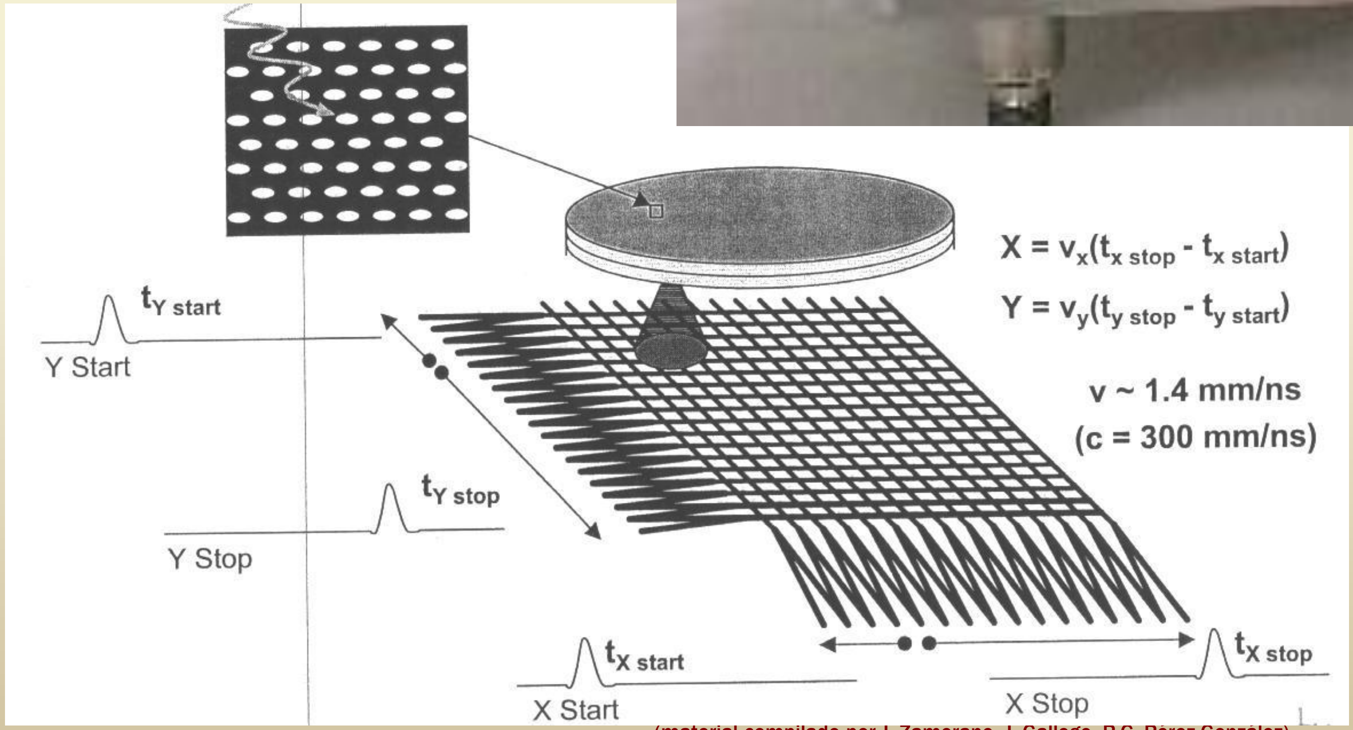
- GALEX moves in a dither spiral pattern of 1′ amplitude during the observation.
- Initial telemetry data plus bright-stars tracks in the field (1.2º in diameter) are used for trajectory reconstruction.

GALEX



GALEX single instrument: SODA

- Micro-channel plate detectors with crossed delay-line anodes.



- Resolution (PSF) is determined by image reconstruction and time resolution.

GALEX Surveys

SURVEY	Area [deg]	Length [Month]	Expos [ksec]	m lim	log #Gals	Volu me	<z>	Comments
All-sky (AIS)	>35000	4	0.1	20.5	7	1.5	0.2	
Medium Imaging (MIS)	1000	2	1.5	23	6.5	~1	0.6	SDSS, 2dF overlap
Deep Imaging (DIS)	80	4	30	25	7	~1	0.85	NDWS, Swire
Ultra-Deep Im. (UDIS)	4	1	200	26	5.5	0.05	0.9	HDF-N, CDF
Nearby Galaxy (NGS)	200	0.5	1.5	27.5 μ	2.5	---	0.01	Spitzer ROC
Guest Investigator	---	4	---	---	---	---	---	Now over

GALEX: Constraints

- Observations are carried out only on the night-side of the orbit.
- GALEX cannot observe close to the sun (avoidance angle 85^o), earth limb, moon (40^o), planets (2^o).
- GALEX detectors saturate and might be potentially damaged by UV-bright stars (FUV=5000 counts/s; NUV=30000 c/s) that are commonly encountered on the Galactic plane, SMC, and LMC.
- GALEX detectors will also saturate and possibly be damaged by over-bright fields with (a) too many moderately UV-bright stars or (b) high backgrounds (FUV=15000 c/s; NUV=50000 c/s).

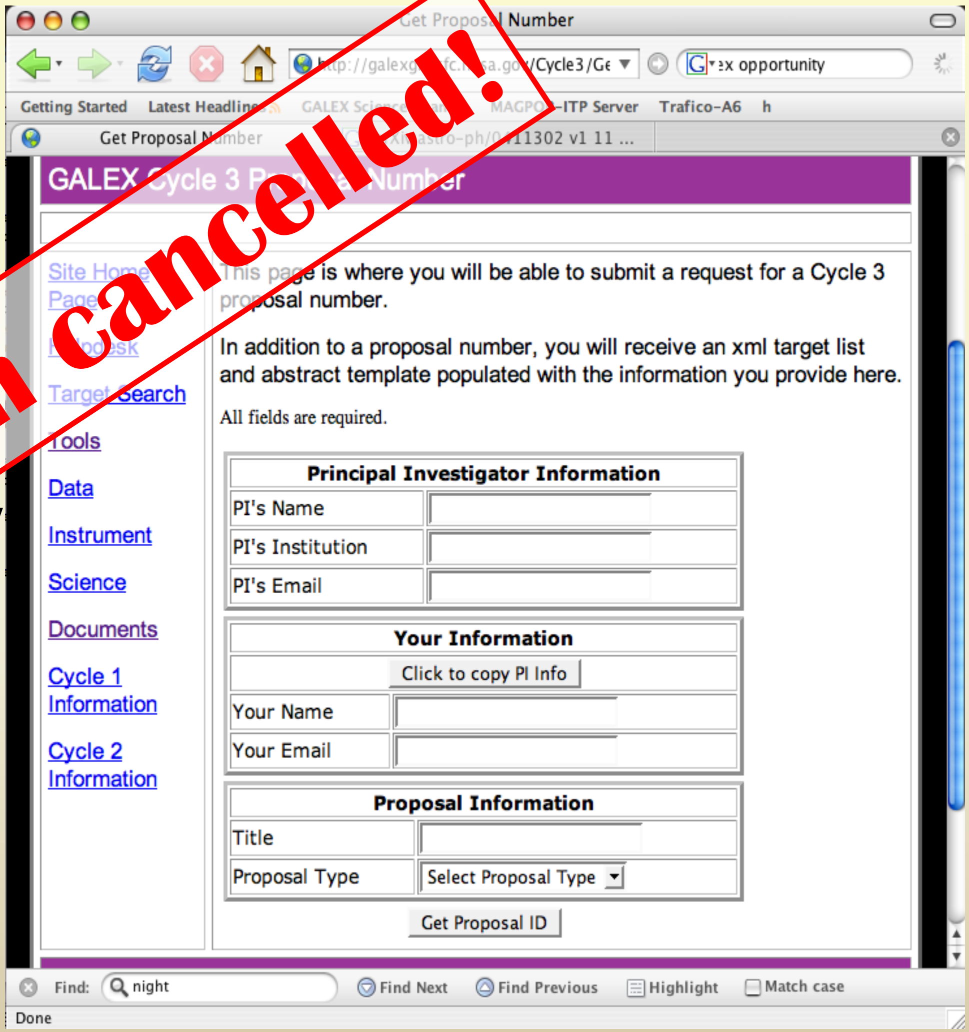
These constraints limit the objects observable (~80% of the sky available) and the observing epoch for a given target to 1 month or so.

- Since 2009 the FUV channel is not functioning.

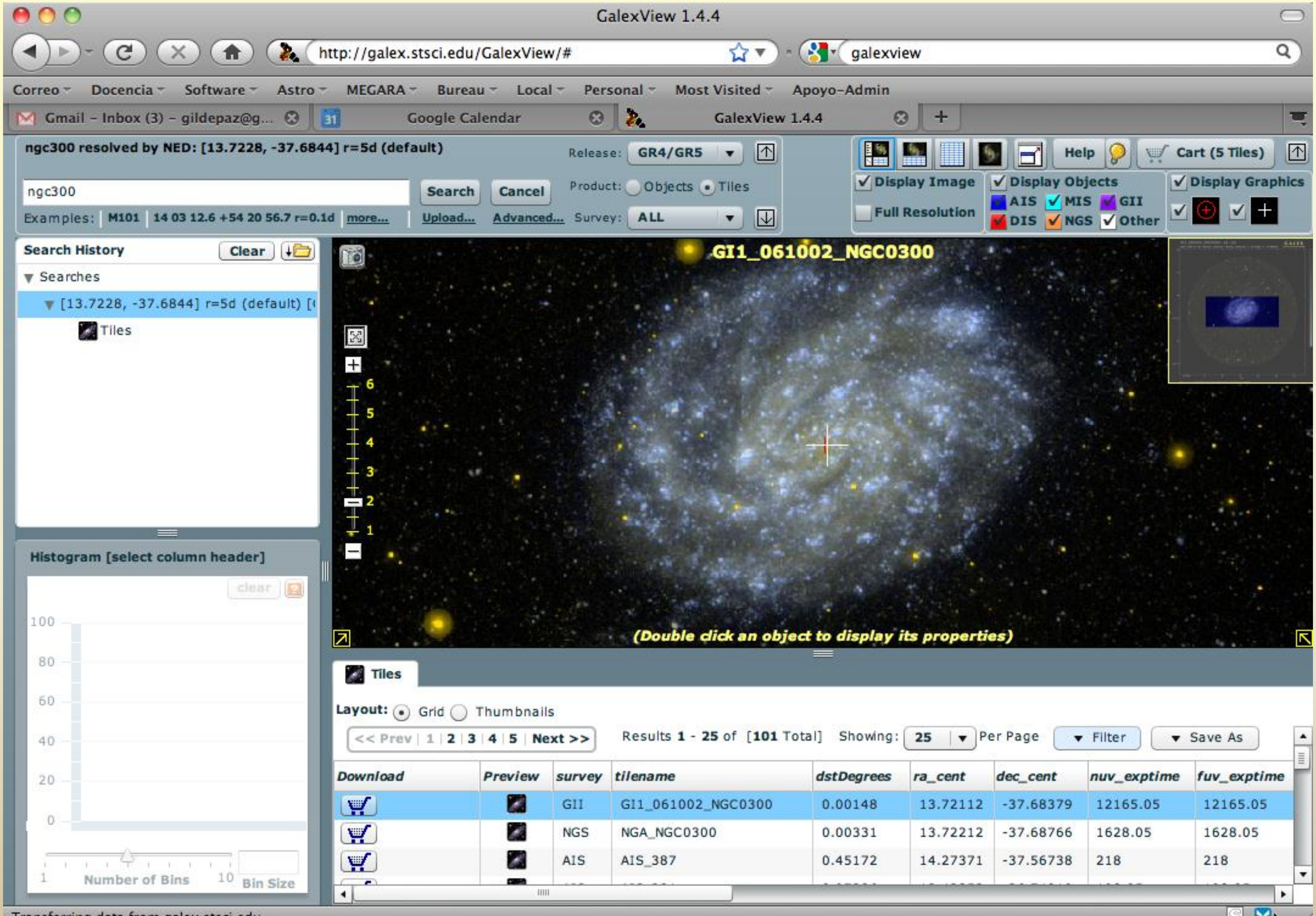
Proposing for GALEX

- Submit Notice of Intent to NASA 1.5 months in advance
- Get a proposal number from the GALEX GI program (GSFC).
- Get LaTeX/Word template for Scientific Justification (Cycle 5)
- Do the targets pass the safety tests? *Try moving the field center!*
- Are they already in the GALEX MAST archive, or are they part of the planned PI-science *(check PI targets)*?
- Generate XML file of targets.

GI program cancelled!



GALEX Archive (Galexview)



(material compilado por A. Gil de Paz, J. Zamorano, J. Gallego, P.G. Pérez-González)

GALEX Archive: Products

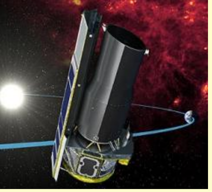
Data products:

Catalogs		*NUV, FUV, and merged catalogs*
-[n or f]d-cat.fits	FITS binary table	Sextractor catalogs for images. Table of objects extracted by GALEX reduction pipeline. The table contains positions, flux, magnitude, and major/minor axes.
-[n or f]d-[f or n]cat.fits	FITS binary table	NUV (FUV) extractions using FUV (NUV) positions; the latter are taken from the FUV (NUV) source catalog "fd-cat.fits" ("nd-cat.fits").
-xd-mcat.fits	FITS binary table	Merged source catalog. Band-merged table of extracted objects. Contains all objects contained in "[n or f]d-cat.fits" matched to the best candidate. The table contains positions, flux, magnitude, and major/minor axes. By definition, it contains all data from the two single-band catalogs.

(you can use ds9 for the images and fv for the catalogs)

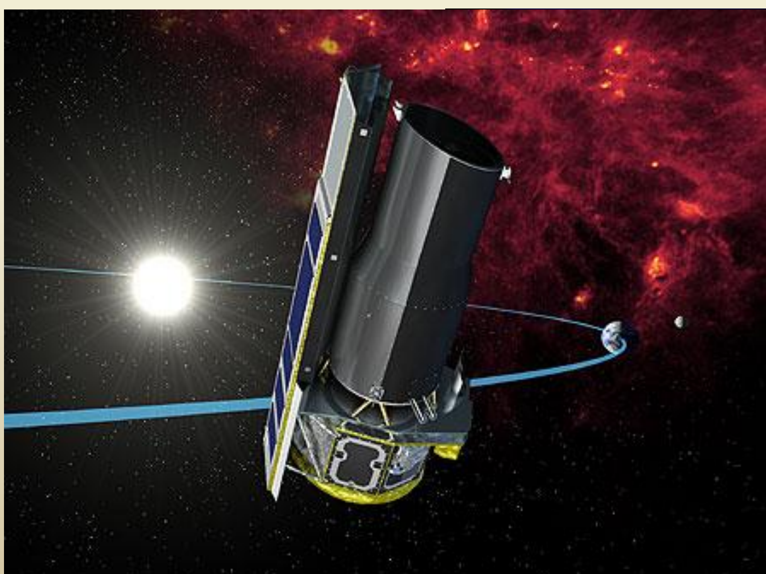
Latest release (aug10): GR6 (AIS~30k tiles, MIS~3500 tiles, NGS~500 tiles, DIS~340 tiles, GI~1300 tiles)

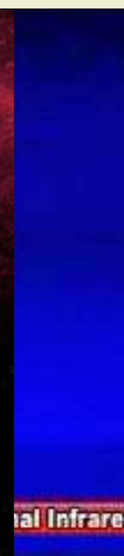
NASA's Spitzer Space Telescope - Spitzer

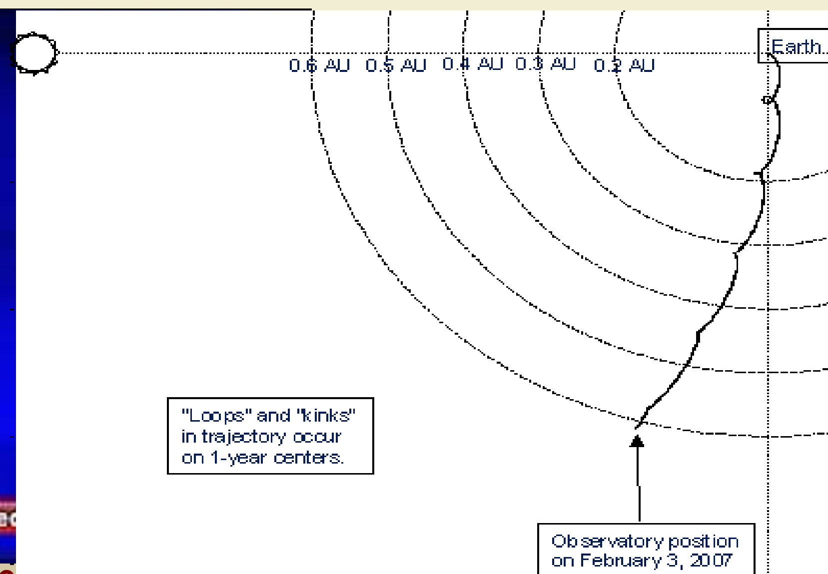


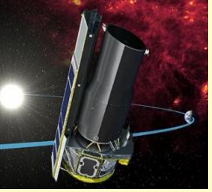
Spitzer Space Telescope

- The Spitzer Space Telescope is NASA's 4th Great Observatory
- It carries an 85-cm telescope and three cryogenically-cooled science instruments: IRAC, IRS, MIPS
- Spitzer was launched on a Delta rocket into an Earth-trailing heliocentric orbit on August 2003. Spitzer cryogenic lifetime requirement was 2.5 yrs, although it finally reached 5 yrs.

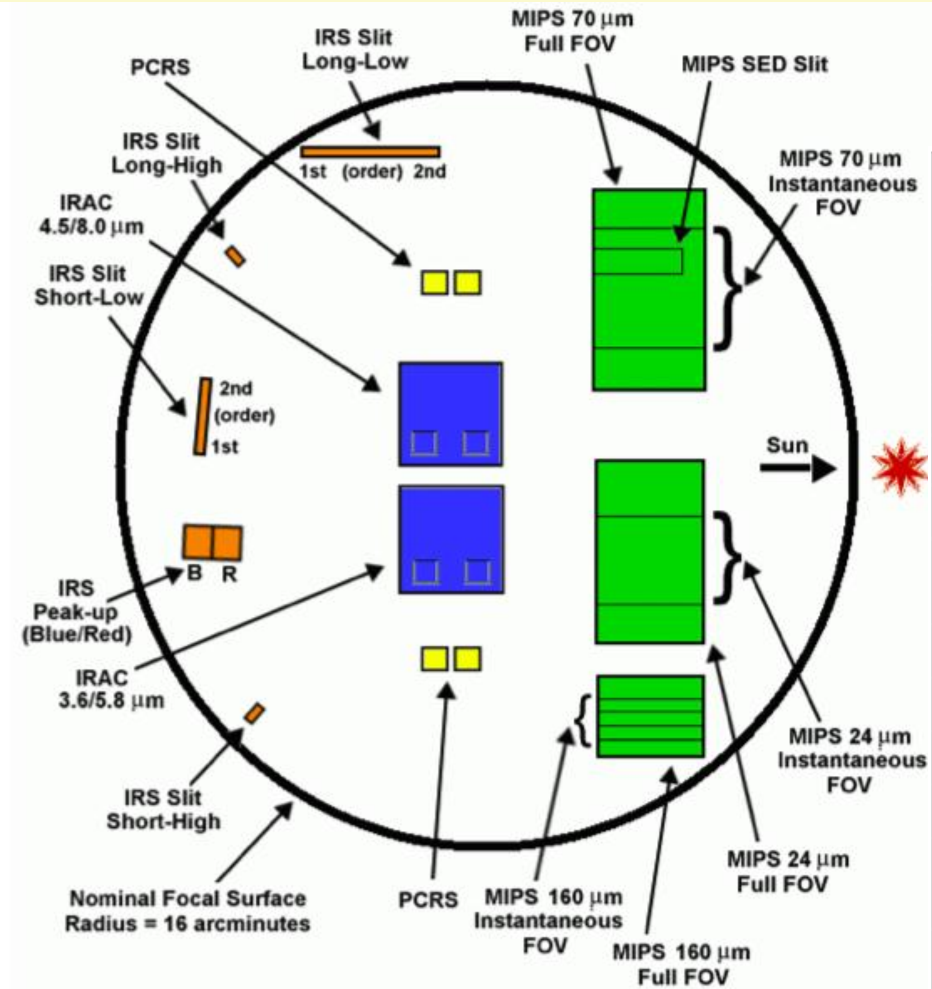




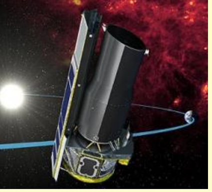




Spitzer Instruments



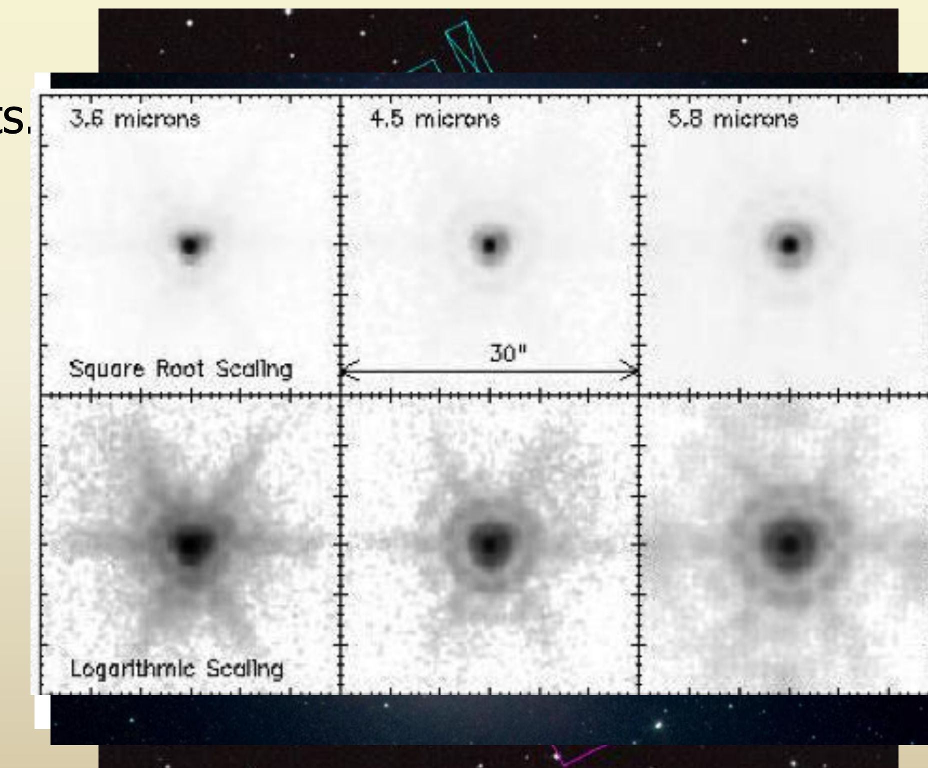
	λ (μm)	Array Type	λ/Δλ	Field of View	Pixel Size (arcsec)
IRAC	3.6	InSb	4.7	5.21′×5.21′	1.2
	4.5	InSb	4.4	5.18′×5.18′	1.2
	5.8	Si:As(IBC)	4.0	5.21′×5.21′	1.2
	8.0	Si:As(IBC)	2.8	5.21′×5.21′	1.2
IRS	5.2–14.5	Si:As(IBC)	60–127	3.7″×57″	1.8
	13.5–18.5 18.5–26	Si:As(IBC) Peak-Up [5]	~3	1′×1.2′	1.8
	9.9–19.6	Si:As(IBC)	~600	4.7″×11.3″	2.3
	14.0–38.0	Si:Sb(IBC)	57–126	10.6″×168″	5.1
	18.7–37.2	Si:Sb(IBC)	~600	11.1″×22.3″	4.5
MI PS	24	Si:As(IBC)	5	5.4′×5.4′	2.55
	70	Ge:Ga	4	2.7′×1.4′ 5.2′×2.6′	5.20 9.98
	55-95 [8]	Ge:Ga	15–25	0.32′×3.8′	10.1
	160	Ge:Ga (Stressed)	5	0.53′×5.33′	16×18

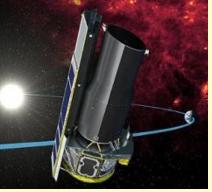


Spitzer Instruments: IRAC

- IRAC allows simultaneous imaging in four NIR-MIR bands: 3.6, 4.5, 5.8, 8.0 um with a FOV of 5.2'x5.2'. Each two arrays are pointing to the same position in the sky.

- Light in the IRAC1 & IRAC2 bands (3.6 & 4.5 um) are mostly due to stellar photospheric emission of MS stars & giants.
- IRAC3 & IRAC4 have contribution from PAH features.
- The PSF of the images ranges between 1.7-2" (*Spitzer* is diffraction limited at a wavelength of 5.4 μm).
- Observations in the the first 2 channels are the only current capabilities of Spitzer.

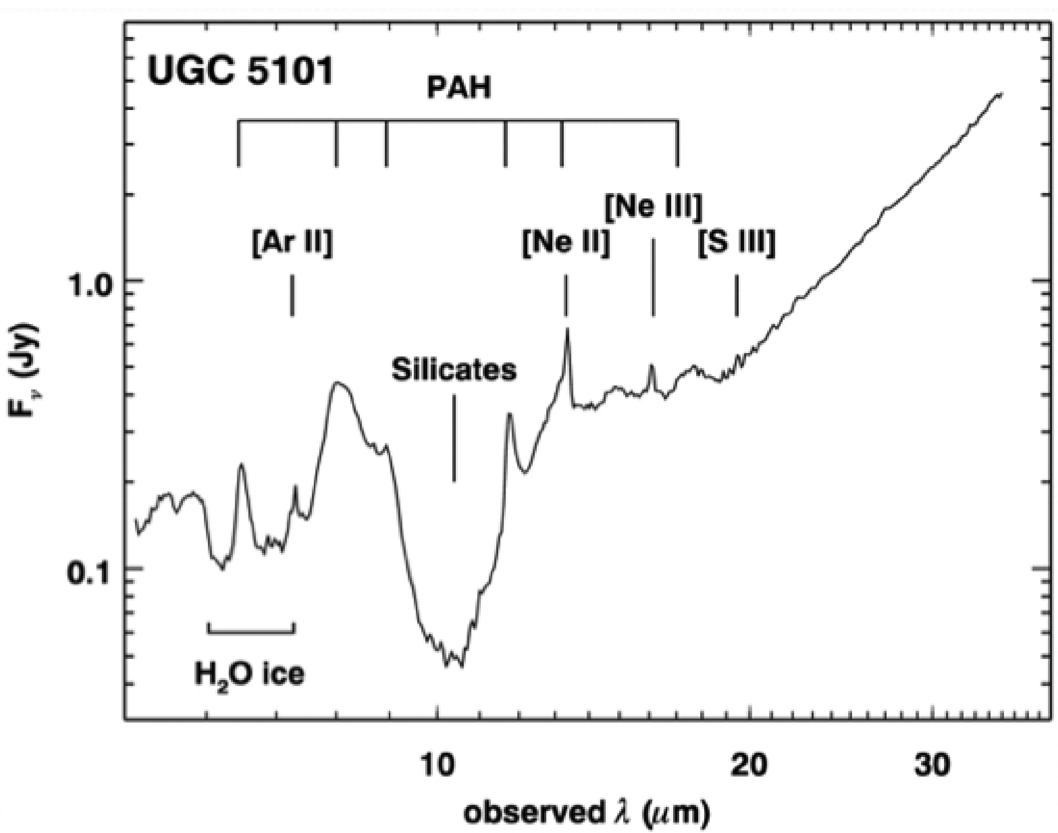


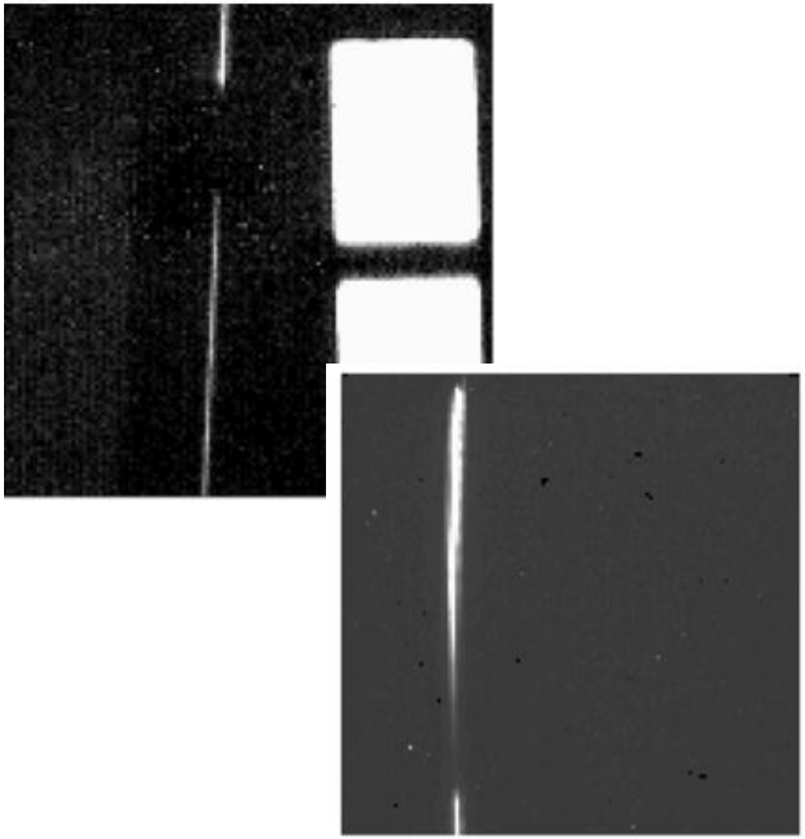


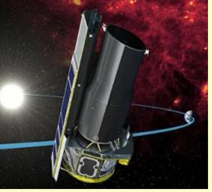
Spitzer Instruments: IRS

- IRS provides low (R~60-120 between 5-38 um) and moderate resolution (R~600 over 10-37 um) spectroscopy.

- Peak-up also used for imaging (13-19 um & 19-26 um).

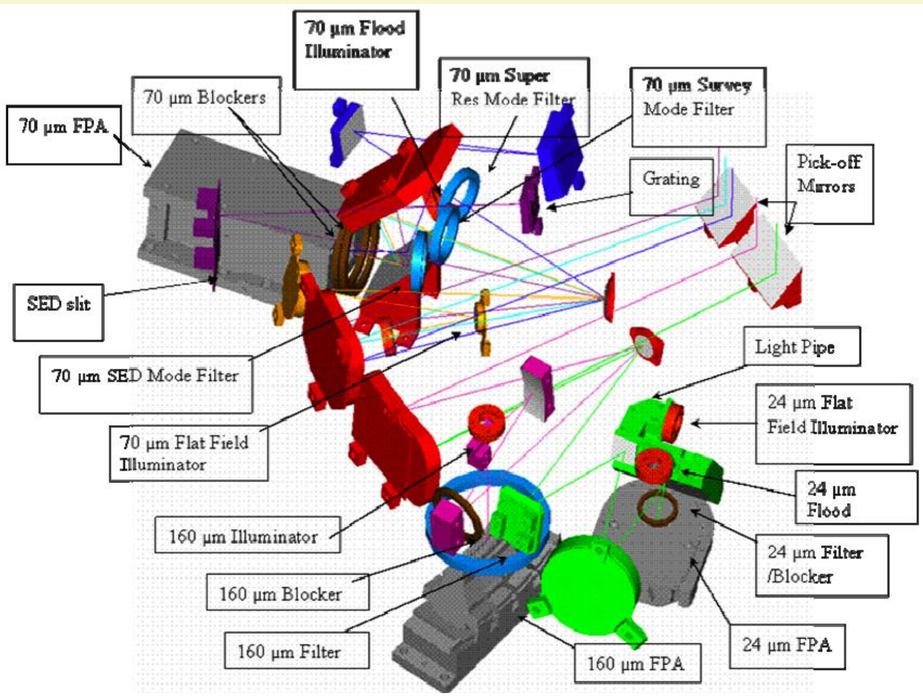






Spitzer Instruments: MIPS

- MIPS provides imaging at 24, 70, and 160 um and low resolution (R = 15 - 25) spectroscopy between 55 and 95 um.



- MIPS observing modes: photometry, super-resolution (sub-pixel sampling dithering), scan mapping, SED spectroscopy, and Total Power mode.

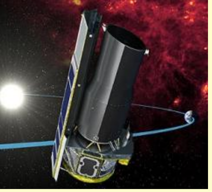
- Emission in MIPS bands arising from dust at different temperatures/sizes.

MIPS Instantaneous Fields of View:

24 µm	5.4×5.4 arcminutes
70 µm	5.25×2.6 or 2.6×1.3 arcminutes
160 µm	0.53×5.33 arcminutes (effective)
SED Slit	3.8×0.32 arcminutes

The MIPS Detector Arrays:

24 µm	Si:As (IBC) 128x128 pixels; 2.55" 4.7 µm bandwidth
70 µm	Ge:Ga 32x32 pixels; 4.99" or 9.84" 19 µm bandwidth SED R = 15 – 25 (9.84" pixels)
160 µm	Stressed Ge:Ga 2x20 pixels; 16.0" 35 µm bandwidth



Proposing for Spitzer

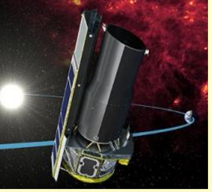
• Documentation: Call for Proposals (Cycle 8-WS), Observers Manual, Instruments Data Handbook.

Checklist:

• Targets: Check both the latest *Reserved Observations Catalog* and the *Spitzer* archive. Justify additional time on already observed objects. Determine visibility windows using SPOT (timing constraints allowed).

• Exposure: Estimate required exposure time for the IR background of your object and the instrument expected sensitivity (use PET, *Performance Estimation Tool*).

• **<u>Submit:</u>** Cover sheet, Scientific and Technical justifications (PDF), and AORs (*Astronomical Observation Requests*). All should be submitted through SPOT.

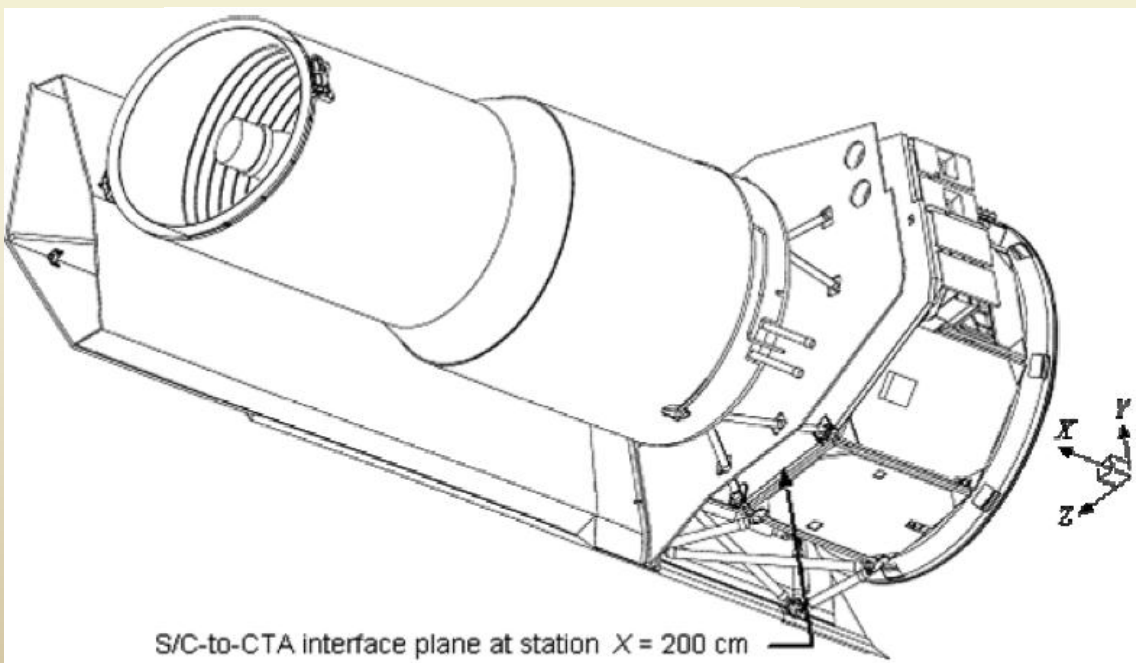


Proposing for Spitzer: Constraints

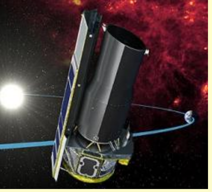
• **Spitzer is currently in the warm-Spitzer phase**: Only IRAC1 (3.6 μm) and IRAC2 (4.5 μm) observations can now be requested.

• **Pointing constraints:** The angle with the Sun must be >82.5º and <120º.

• At any given time, the center of the sunshade (X-Z plane) is kept within ±2º of the Sun. Observations must be designed with this lack of roll control in mind. This affects IRS observations but also IRAC & MIPS mapping.

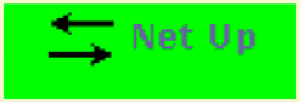


• **Bright limits:** By default the visibility windows are calculated to exclude regions of time when the positions of the Earth, Moon, Jupiter, Saturn, bright asteroids (only solar system objects).

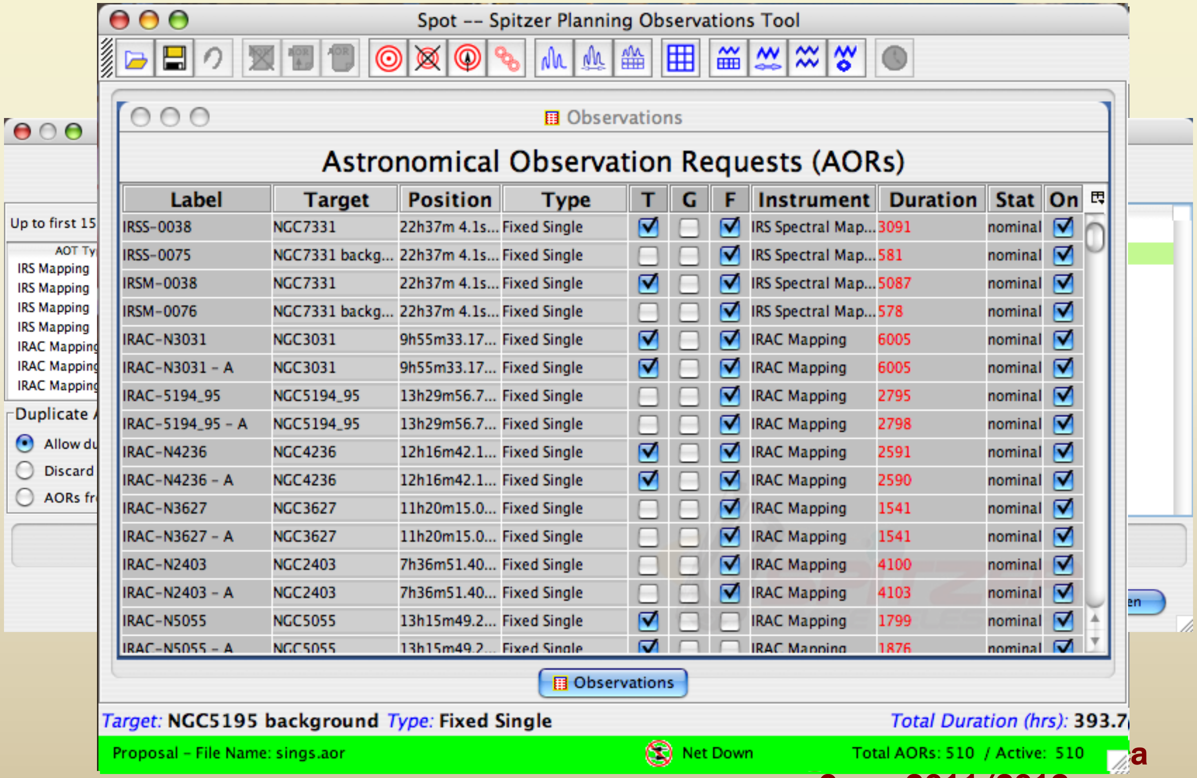


Proposing for Spitzer: SPOT

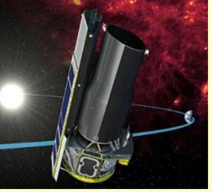
- SPOT is available for Solaris, Windows, Linux, & Mac OS X as part of the *Spitzer-Pride* software.
- Most SPOT features require network connectivity



- Use example AORs or download previous programs' AORs.

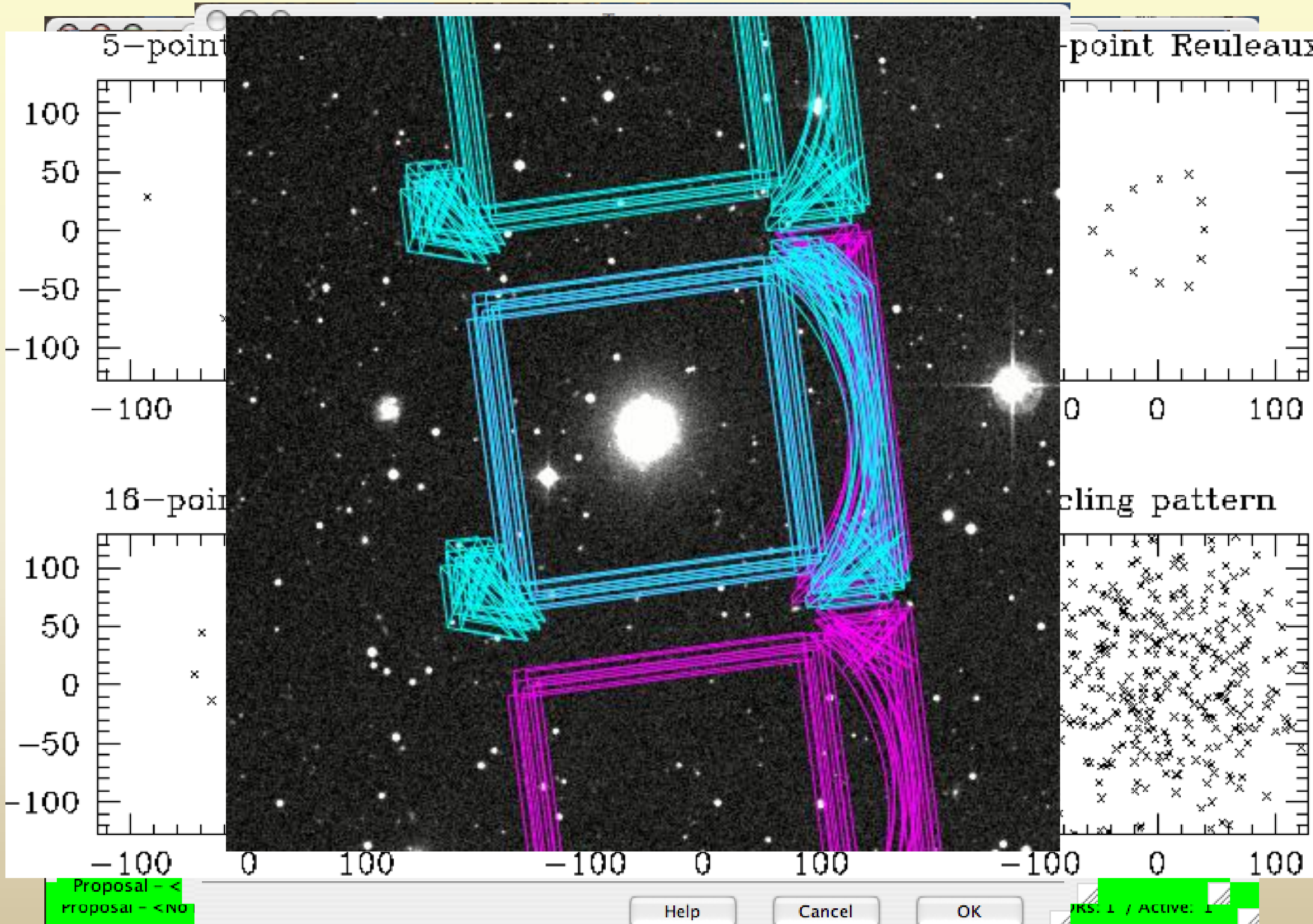


- Get program IDs from *Spitzer's* webpage.
- *Observing Time Estimate* reports: AOR duration (*wall-clock* time: slew & settle time plus on-source time). Maximum AOR duration: 3h for IRS and MIPS, and 6h for IRAC.

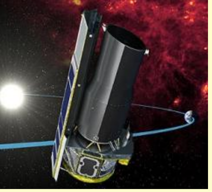


Proposing for Spitzer: SPOT

Starting from scratch:



(material compilado por A. Gil de Paz, J. Zamorano, J. Gallego, P.G. Pérez-González)



Spitzer Archive: Leopard

- Leopard was part of *Spitzer*-Pride softw
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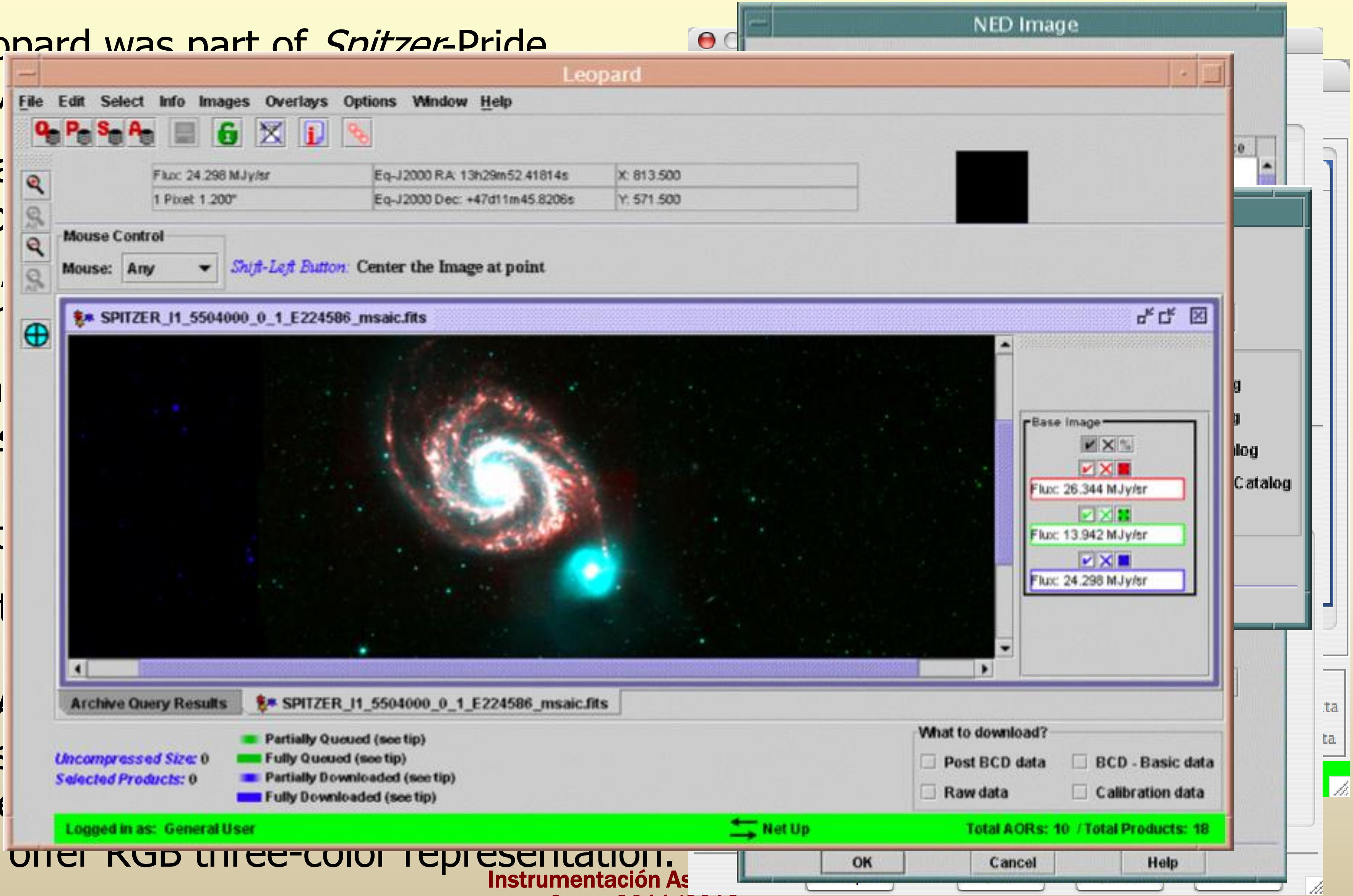
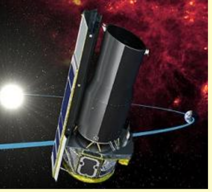
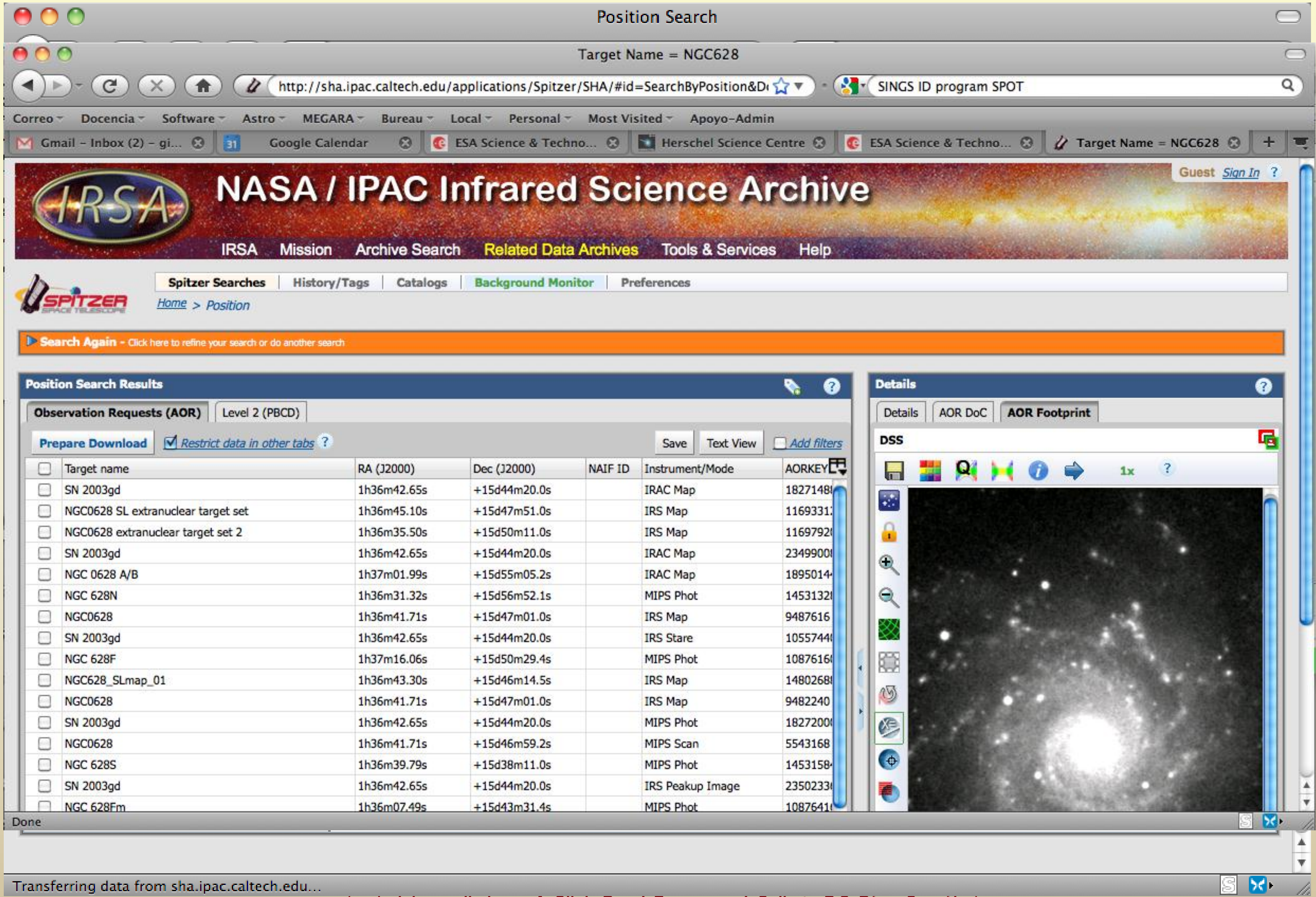
- On *regis* dow or st
- Wit and (2MA grids targe also offer RGB three-color representation.





Spitzer Heritage Archive

Since Nov.4th Leopard has been replaced by the
"Spitzer Heritage Archive" (SHA)



(material compilado por A. Gil de Paz, J. Zamorano, J. Gallego, P.G. Pérez-González)

NASA's WISE Small Explorer

Wide-field Infrared Survey Explorer

Science Objectives

WISE will provide an all-sky survey from 3 to 25 μm with 500,000 times the sensitivity of COBE/DIRBE and hundreds of times that of IRAS. The survey will help search for the origins of planets, stars, and galaxies and create an infrared atlas whose legacy will endure for decades.

Science Payload

The WISE instrument is a four-channel imager which operates in a single mode, taking overlapping snapshots of the sky. It includes:

- A 40-cm telescope and reimaging optics.
- A scan mirror to stabilize the line-of-sight while the spacecraft scans the sky.
- A 47 arcminute field of view.
- HgCdTe and Si:As 1024^2 detector arrays at 3.4, 4.6, 12, and 22 μm with a plate scale of 2.75"/pixel.
- A resolution of 6" (12" at 22 μm).
- A two-stage solid-hydrogen cryostat with an expected 10-month lifetime, to cool focal planes and optics.

Mission Overview

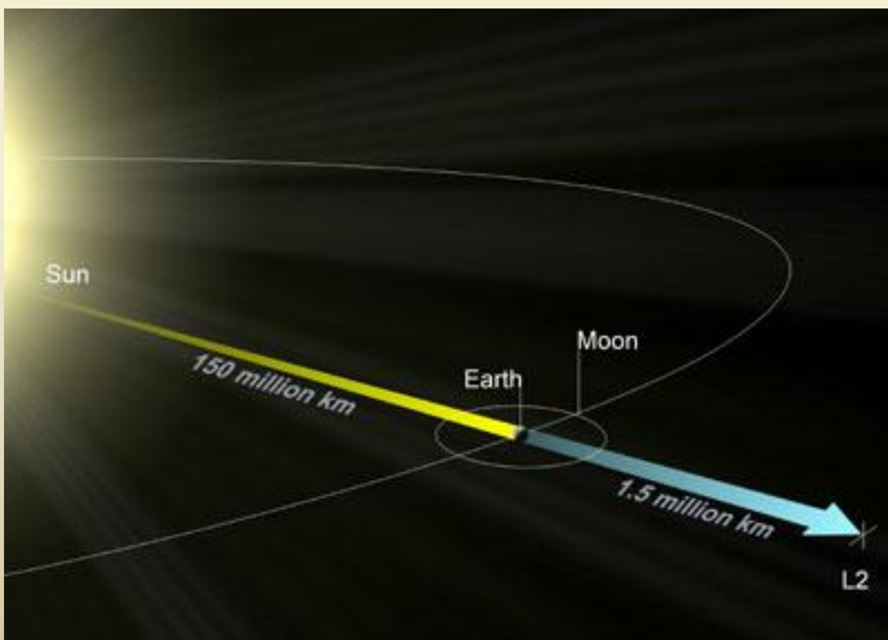
Launch: 2009 Dec. 14 at 6:09am PST

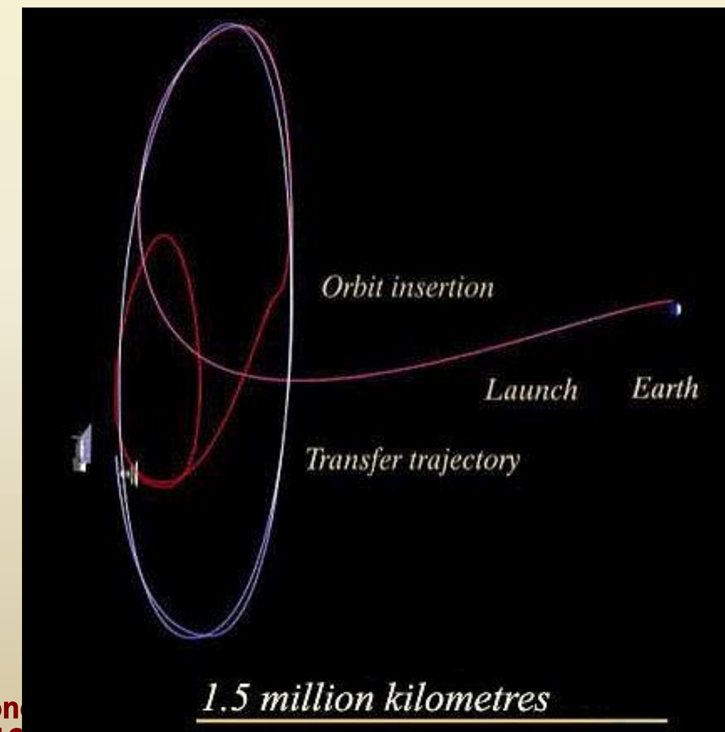
- Direct injection launch on a Delta II rocket into a circular, 525-km, Sun-synchronous orbit.
- 6-month survey of entire sky following a 1-month checkout, with estimated cryogen lifetime allowing 3 additional months of survey.

ESA's
Herschel Space Observatory

Herschel Space Observatory

- The Herschel Space Observatory is a 3.5-m radiatively cooled (~80 K) telescope observing in the far-infrared and sub-millimeter.
- Herschel (& Planck) was launched on May 19th 2009 (Ariane V).
- It orbits the L2 Sun-Earth-Moon Lagrange point. The mission will have 3 yr of routine operations.





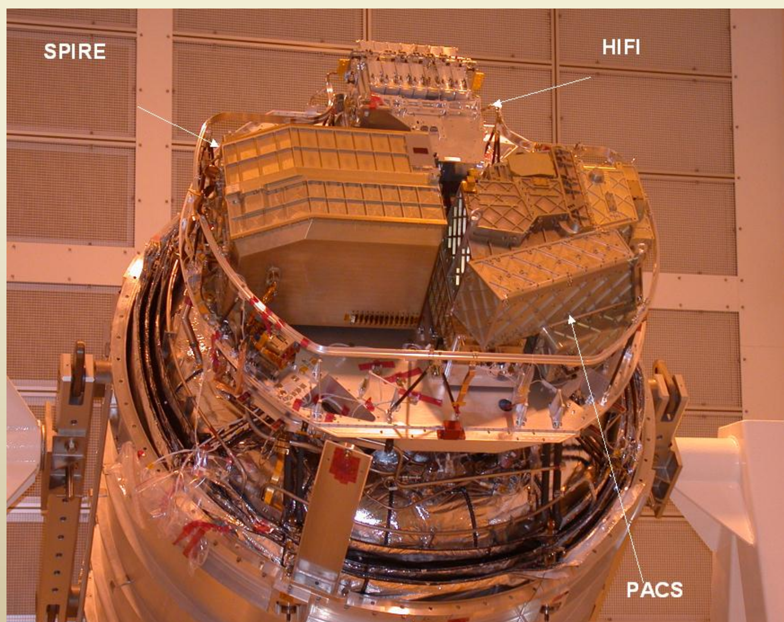
Herschel Space Observatory

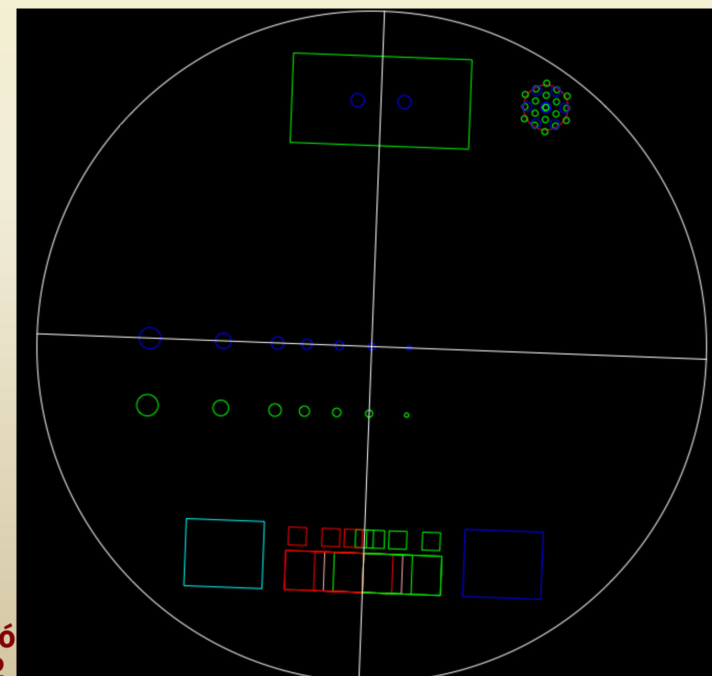
Instruments:

• **PACS** (Photoconductor Array Camera and Spectrometer): Simultaneous imager at 70 or 100 and 160 μm plus an IFS

• **SPIRE** (Spectral and Photometric Imaging REceiver): Simultaneous photometer at 250, 350, & 500 μm plus a FTS

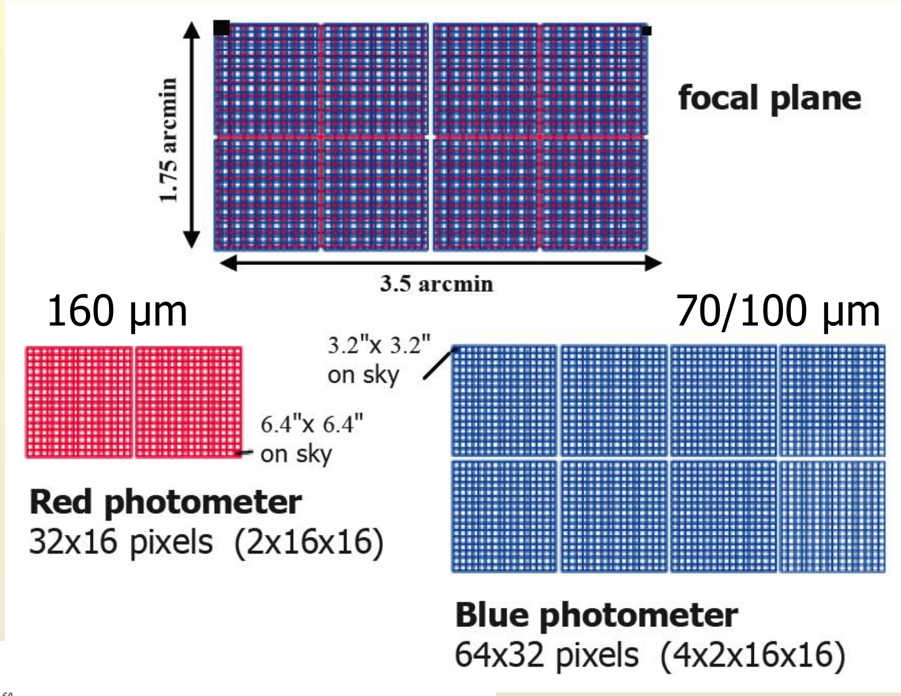
• **HIFI** (Heterodyne Instrument for FIrst): Submillemeter high-resol. heterodyne spectrometer

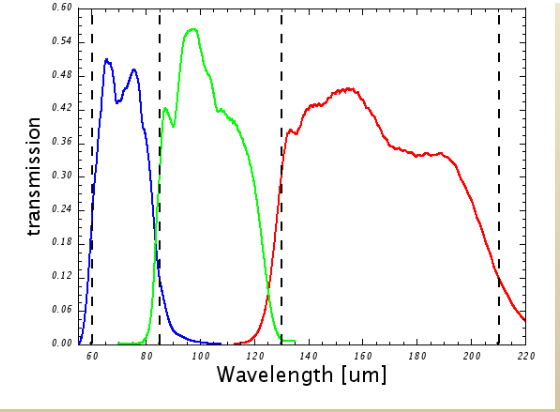




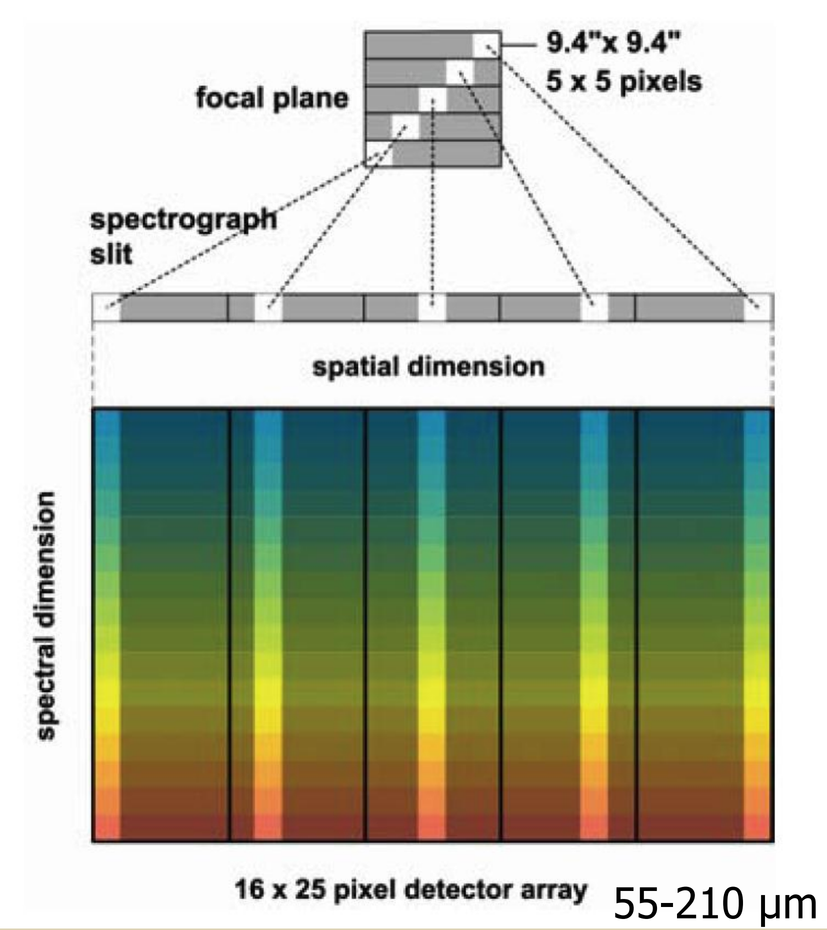
Herschel Space Observatory

PACS (Photoconductor Array Camera and Spectrometer)





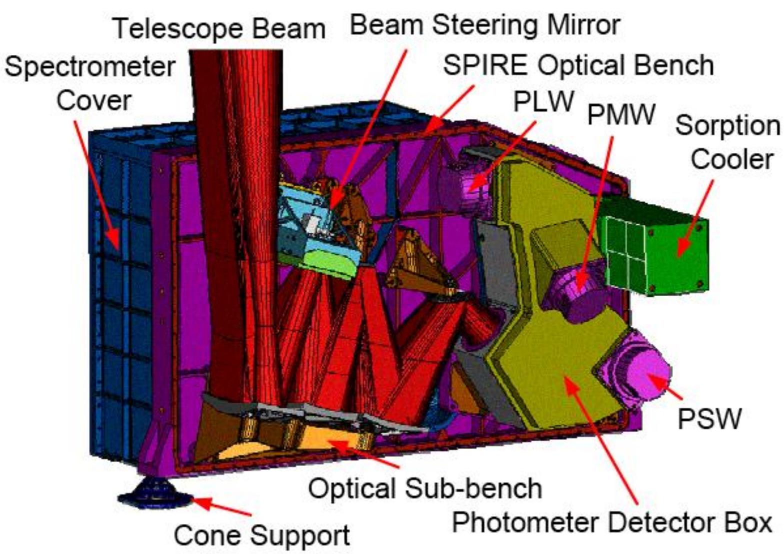
Photometer

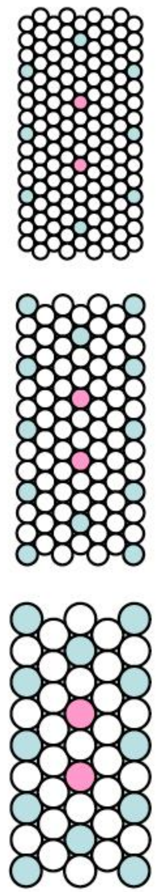


Integral Field Spectrometer

Herschel Space Observatory

SPIRE (Spectral and Photometric Imaging REceiver)





Imaging Photometer

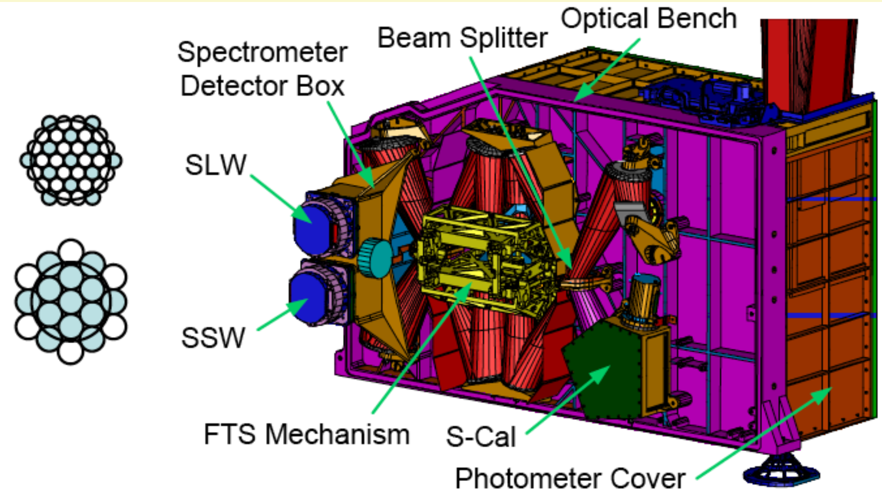
Simultaneous observation in 3 bands

139, 88, and 43 pixels

Wavelengths: 250, 350, 500 µm

$\lambda/\Delta\lambda \sim 3$

FOV 4' x 8', beams (18", 25", 36")



Imaging Fourier Transform Spectrometer

Simultaneous imaging observation of the whole spectral band

37 and 19 pixels

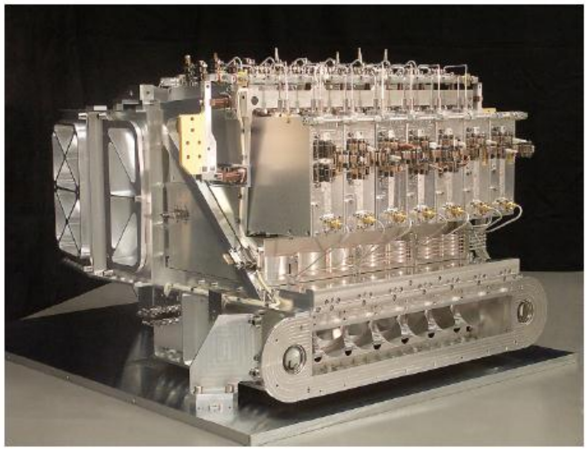
Wavelength Range: 194-672 µm

$\lambda/\Delta\lambda$ = 1289-372 , 206-60, 52-15 (variable)

FOV circular 2.6' diameter, beams 16", 34"

Herschel Space Observatory

HIFI (Heterodyne Instrument for FIrst)



General Features

Broad Coverage of the FIR and Sub-mm

Instantaneous IF Bandwidth of 4 GHz in Bands 1-5, and 2.4 GHz in Bands 6 and 7

Resolving Power $\nu/\delta\nu$ up to 10^7, or <0.1 km/s

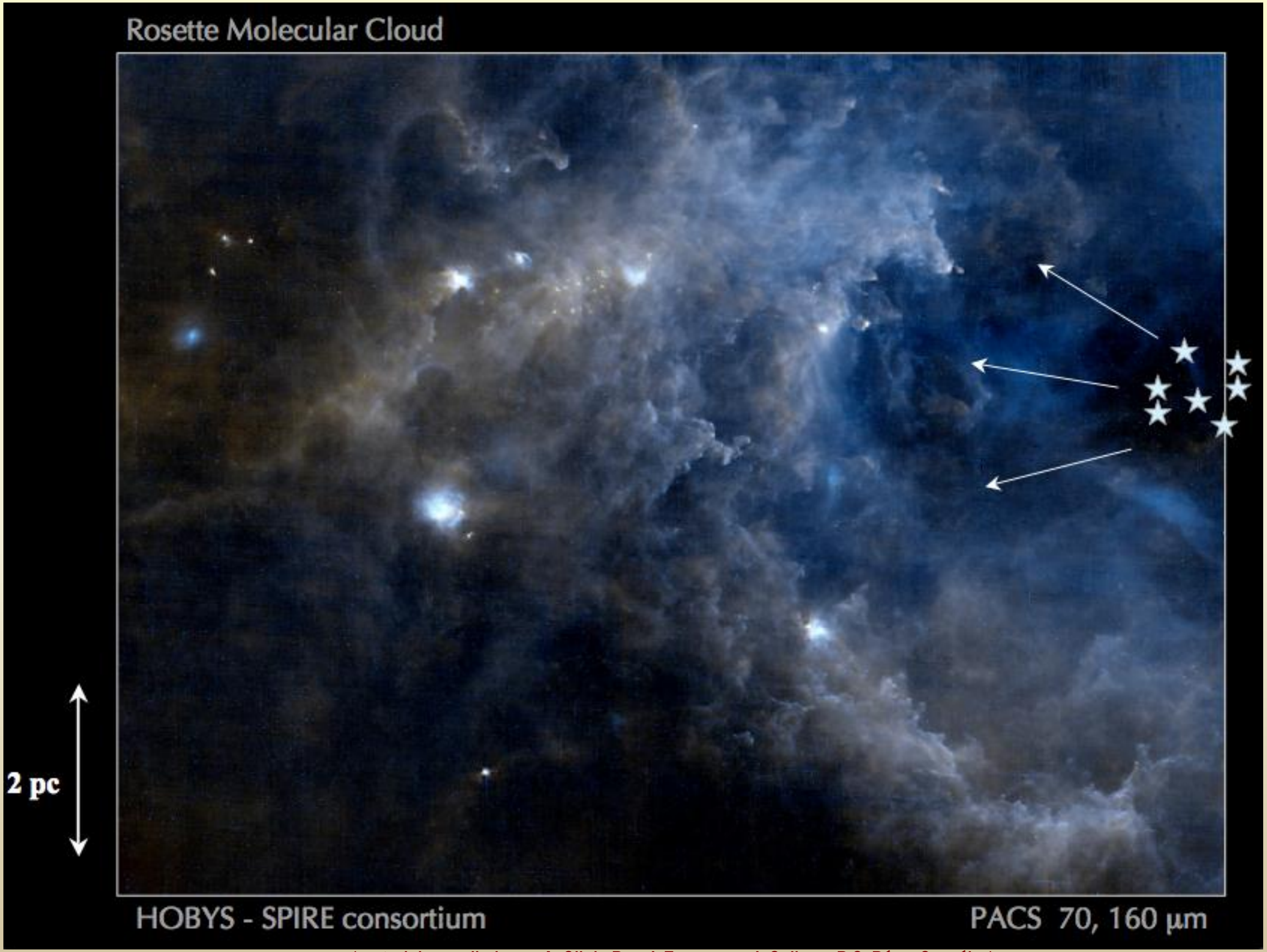
Diffraction-limited (11 – 42 arcsec) beam

Seven bands utilizing low-noise SIS and HEB Mixers.

	SIS Technology					HEB Technology	
GHz:	480 → 634	634 → 799	799 → 959	959 → 1108	1108 → 1250	1440 → 1684	1684 → 1916
HIFI Bands	1	2	3	4	5	6	7
μm:	625 → 473	473 → 375	375 → 313	313 → 271	271 → 240	208 → 178	178 → 157

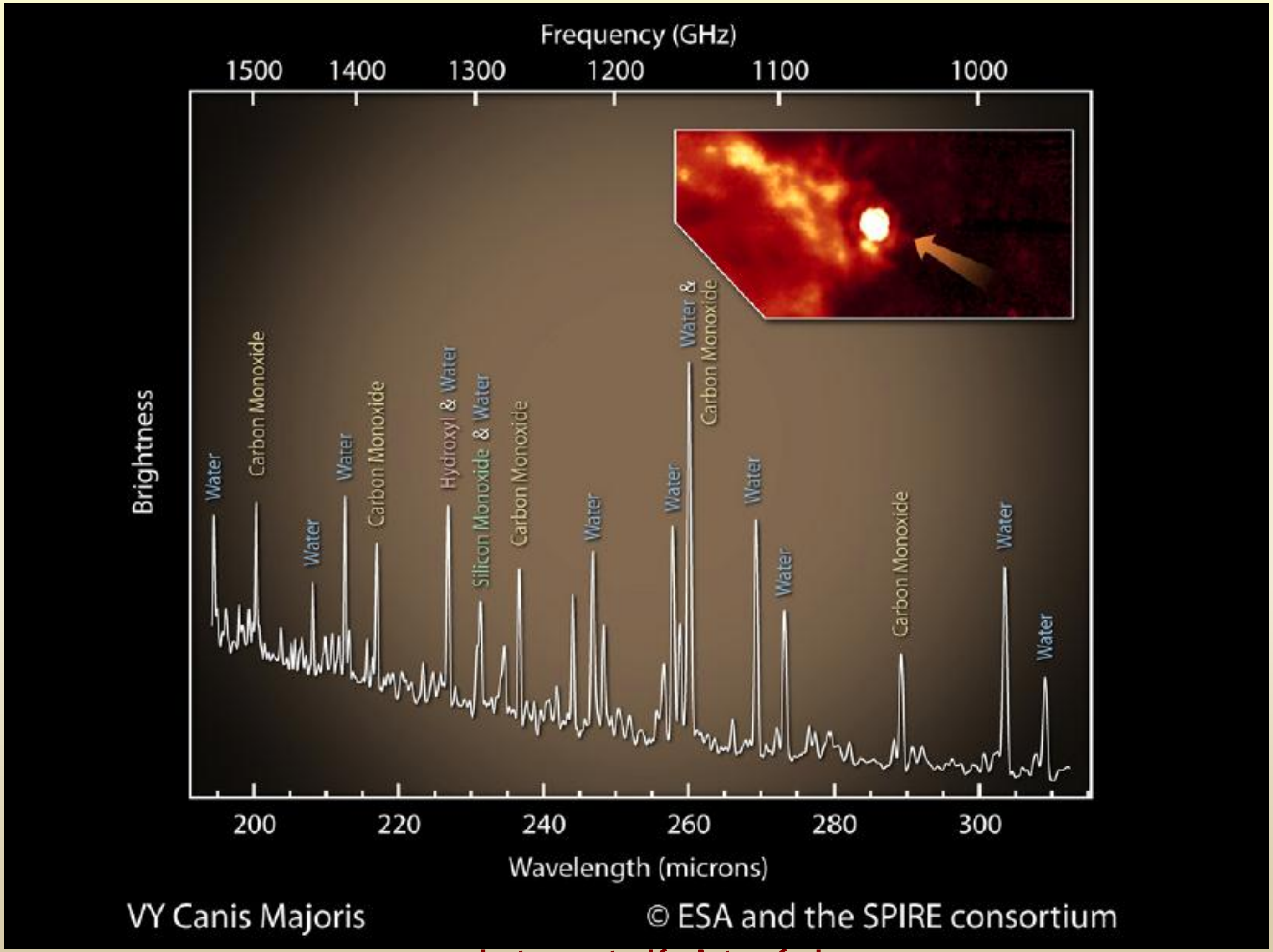
Herschel Space Observatory

Highlights from Herschel ...



Herschel Space Observatory

Highlights from Herschel …

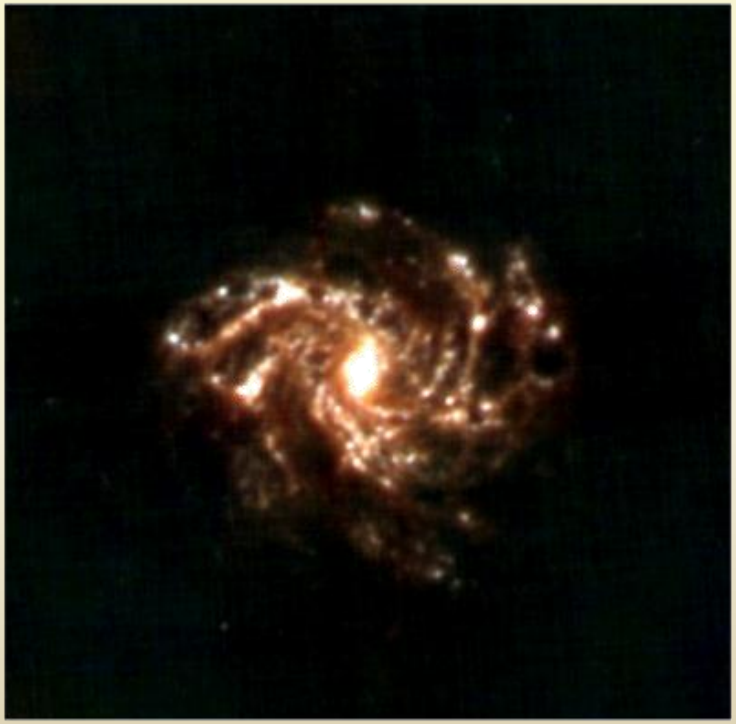


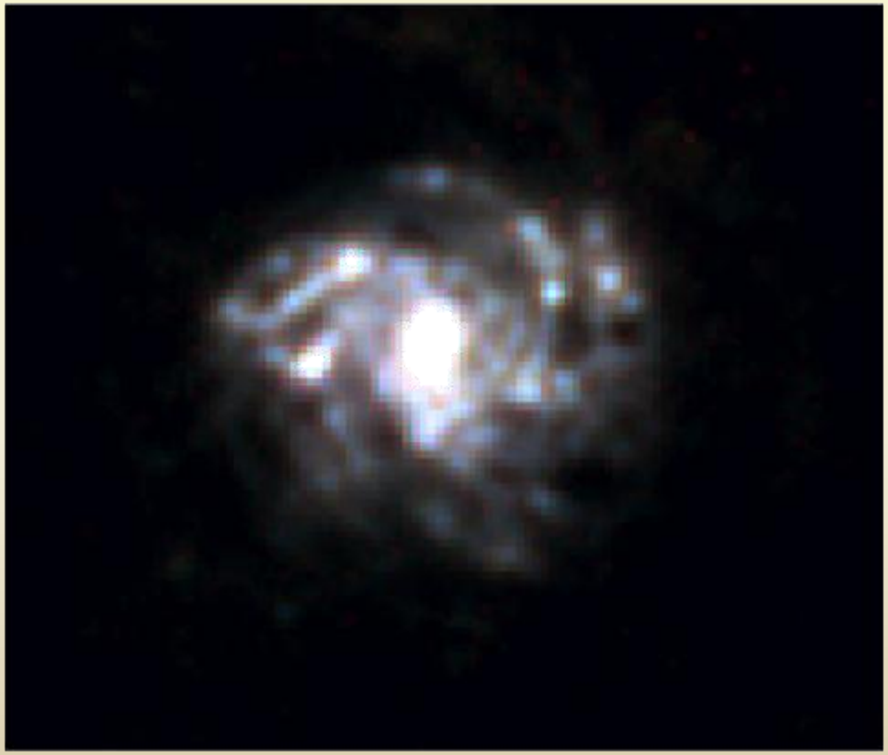
Herschel Space Observatory

Highlights from Herschel …

NGC6946

SABcd
D=6.8 Mpc



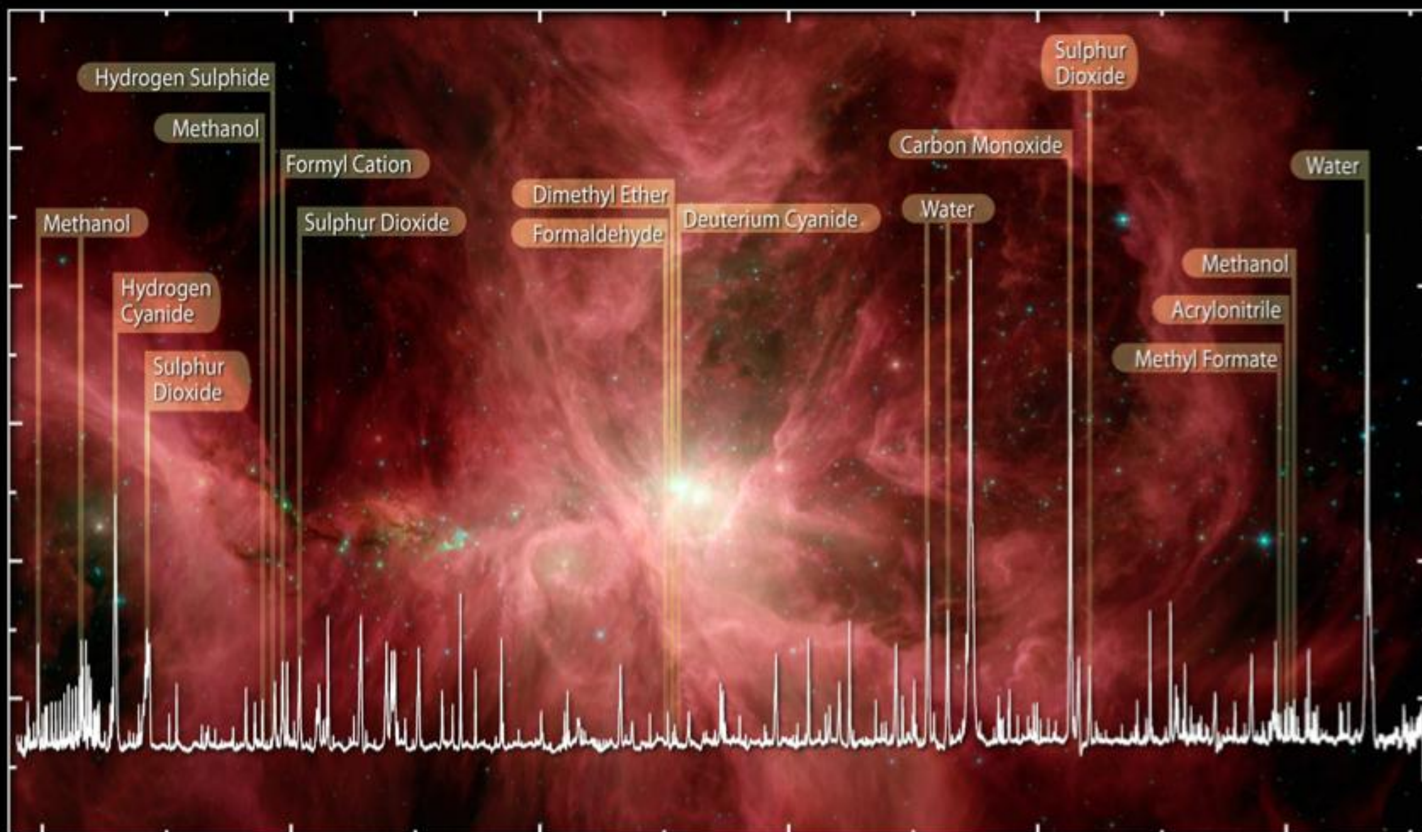


PACS 70/100/160

SPIRE 250/350/500

Herschel Space Observatory

Highlights from Herschel …

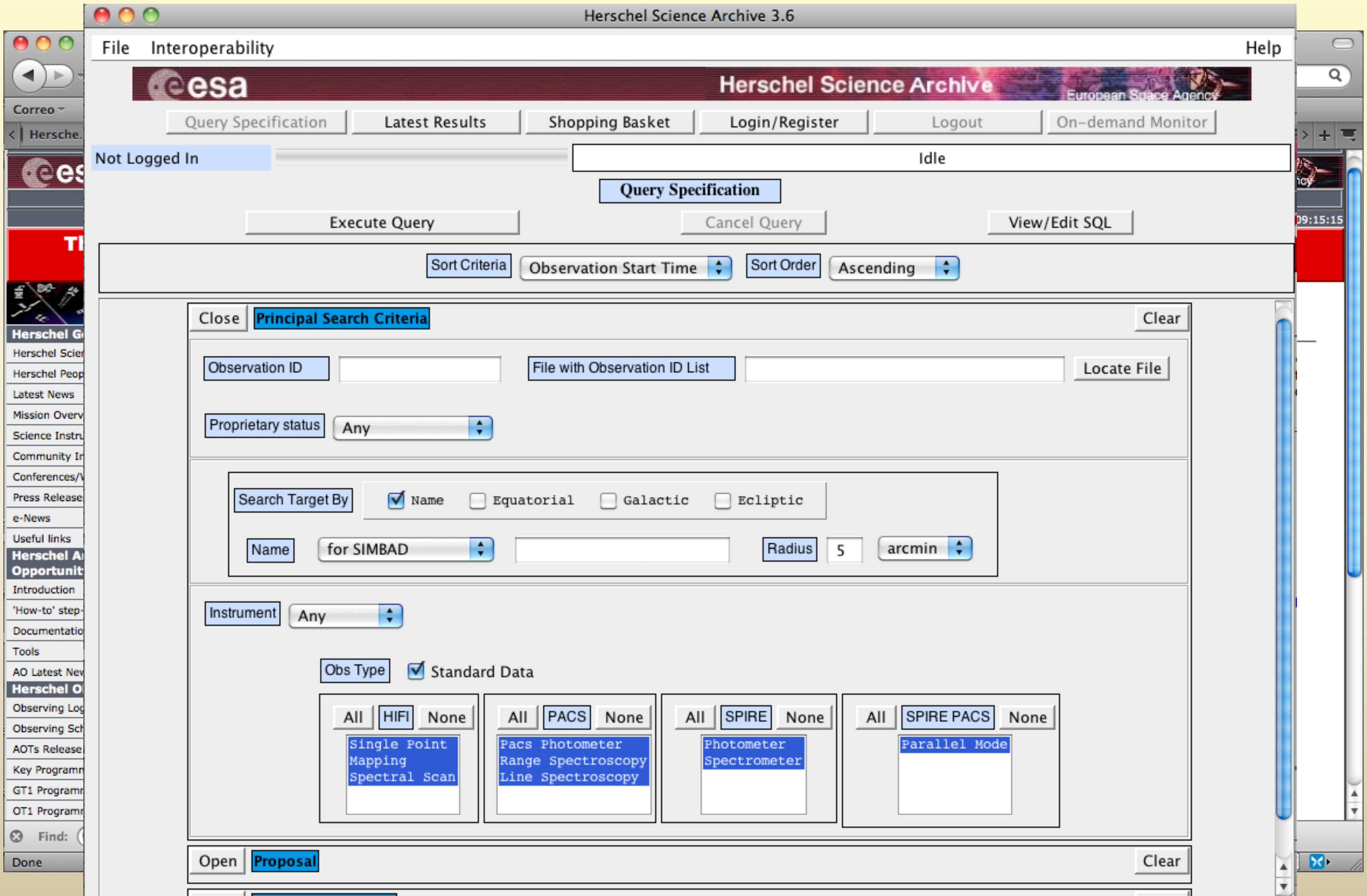


HIFI Spectrum of Water and Organics in the Orion Nebula

© ESA, HEXOS and the HIFI consortium
E. Bergin

Herschel Space Observatory

Herschel Science Archive @ ESAC



Herschel Space Observatory

Proposing for Herschel – Not possible anymore

After 3-5 months of commissioning and 5-6 months of science demonstration phase routine science operations started:

36 months in total - *20,000 hours of science observing time*:

32% Guaranteed time programmes (GT)

68% Open Time programs (OT):

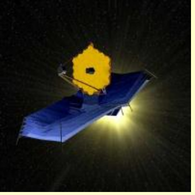
40% in one call for Key Programmes (Oct 07)

60% in two calls for Regular Programmes (<100h)

Tool of use: Herschel-SPOT, aka **HSPOT**

Check first the Herschel's **Reserved Observations List** !!

Misiones futuras /
Future Space Observatories

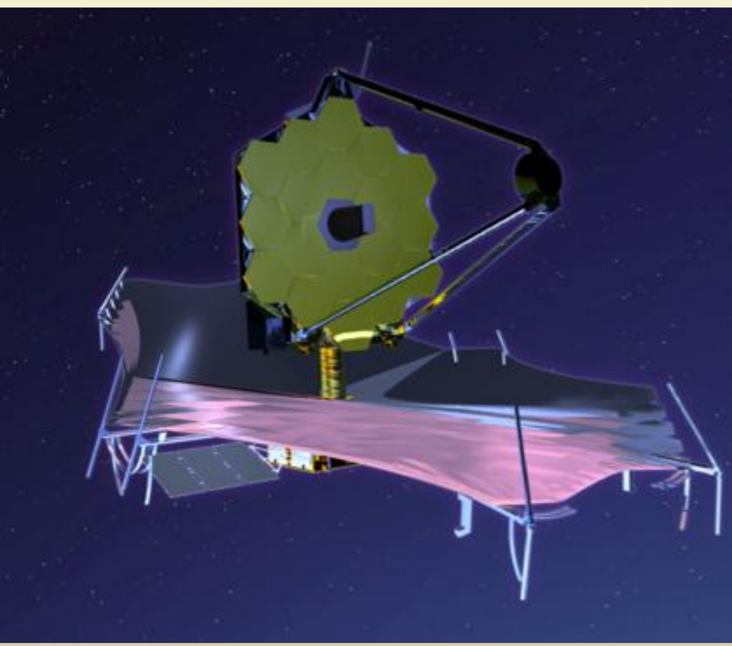


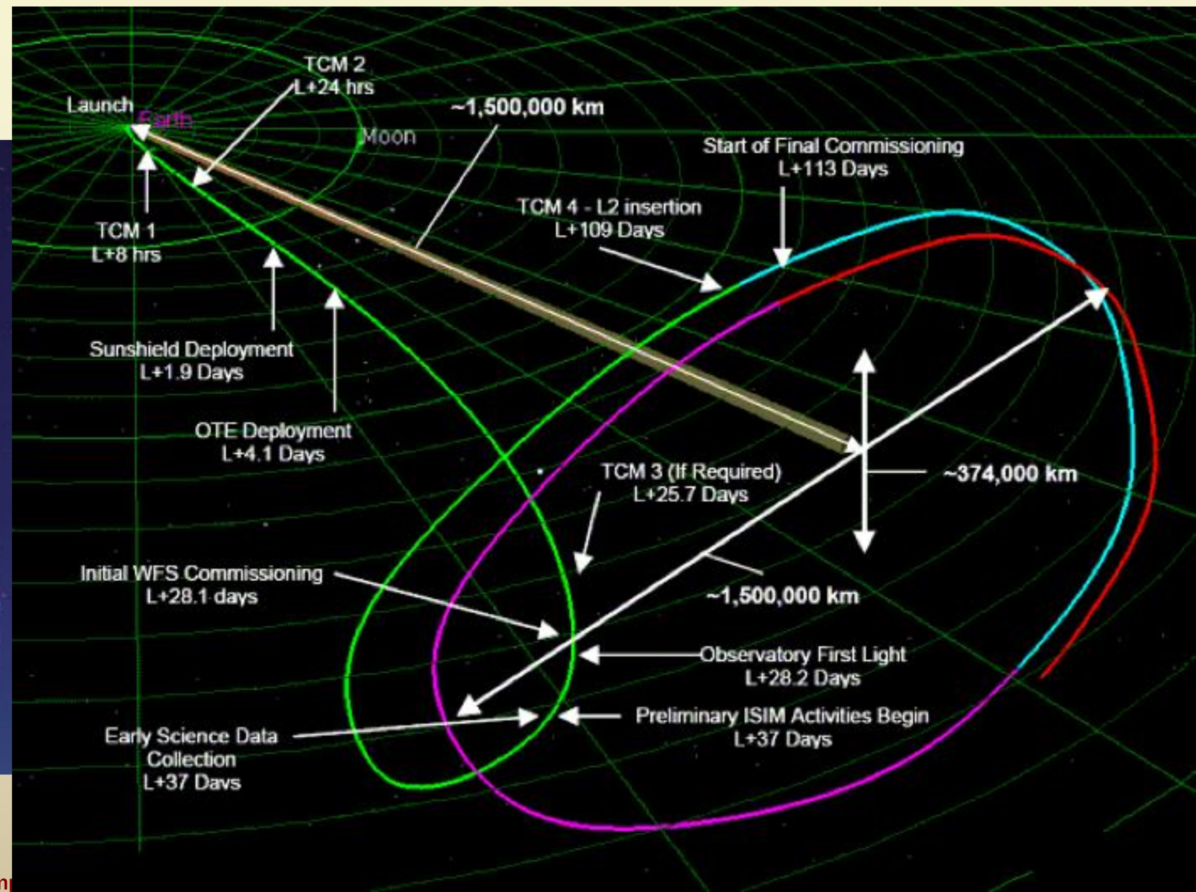
Future missions: JWST

James Webb Space Telescope: Summary

• Developed by an industrial consortium under NASA's supervision in collaboration with ESA (mostly for instrument development).

• High orbit around the L2 Sun-Earth Lagrange point. Launch ~2018 by an Ariane V rocket.





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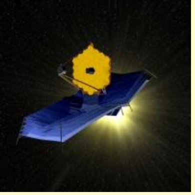


JWST: Instruments

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′

Other Future Missions

WSO-UV (World Space Observatory - UV, formerly Spectrum UV):

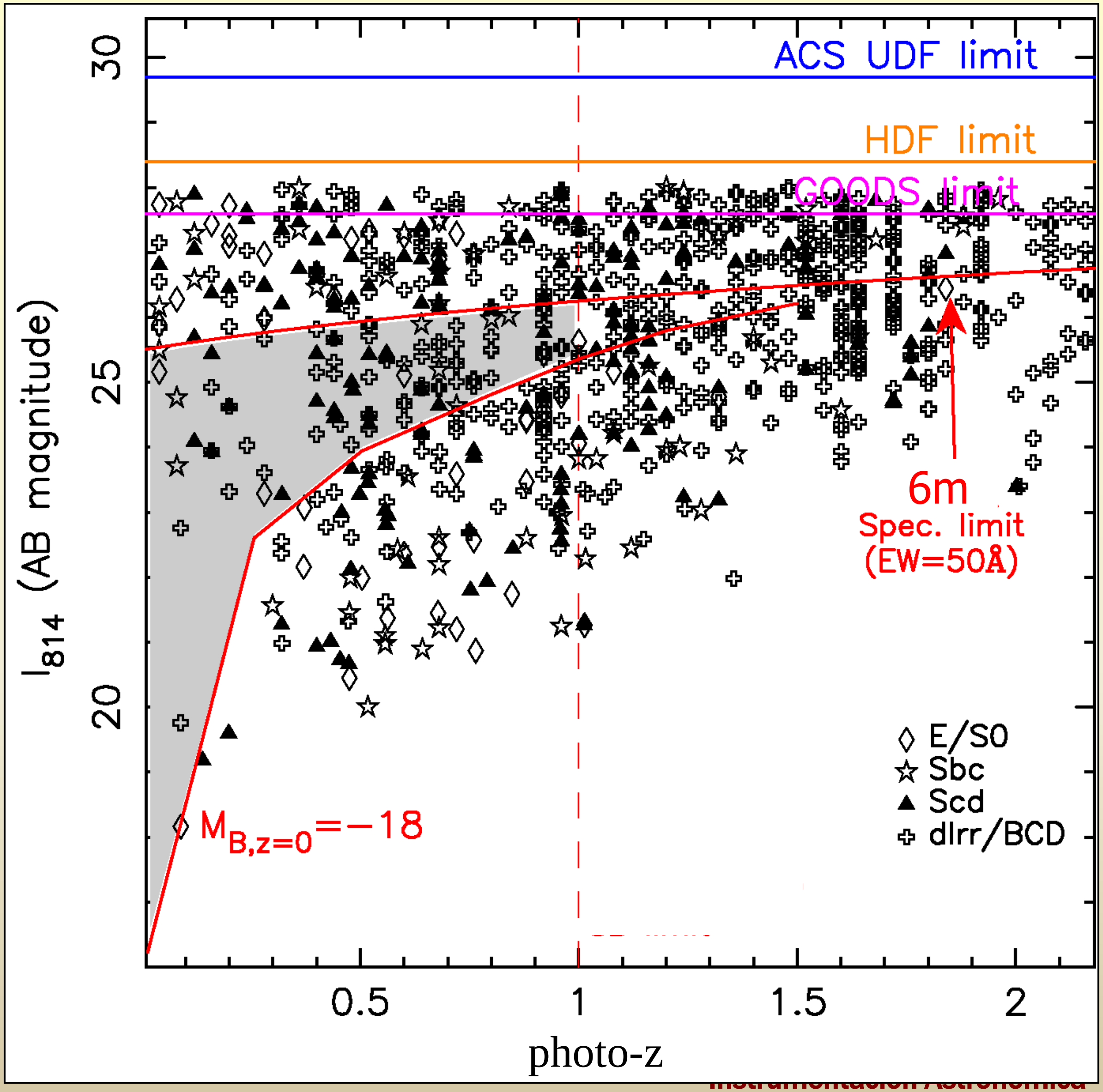
- 1.7m UV-optimized telescope working in the range between 120-500 nm.
  The instrumentation includes:
  - *ISSIS: Deep UV and diffraction-limited opt. imager and slitless spec (led by UCM).*
  - *Long-slit low-resolution (R~200) UV spectrograph.*
  - *High-resolution (echelle) spectrograph (R~55,000) in the range 1000-3100 Angst.*
- Being built by a consortium of Russian, German, Chinese, & Spanish institutions.
- Scheduled to be launched in 2014.

Gaia (formerly *Global Astrometric Interferometer for Astrophysics*)

- Dual telescope (primary mirror shown above) on a common focal plane.
- Focal plane: 106 CCDs (0.5mx1m).
- Objectives:
  - *Measure the positions of ~10^9 stars in our MW & Local Group gals. (accuracy ~20 µas).*
  - *Perform spectral and photometric measurements of all objects.*
  - *Derive space velocities of the Galaxy's stars using the stellar distances and motions -> 3D structural map of the MW.*
- ESA mission to be launched in 2013.

Sinergia con observaciones desde tierra / Sinergy with ground-based Astronomy

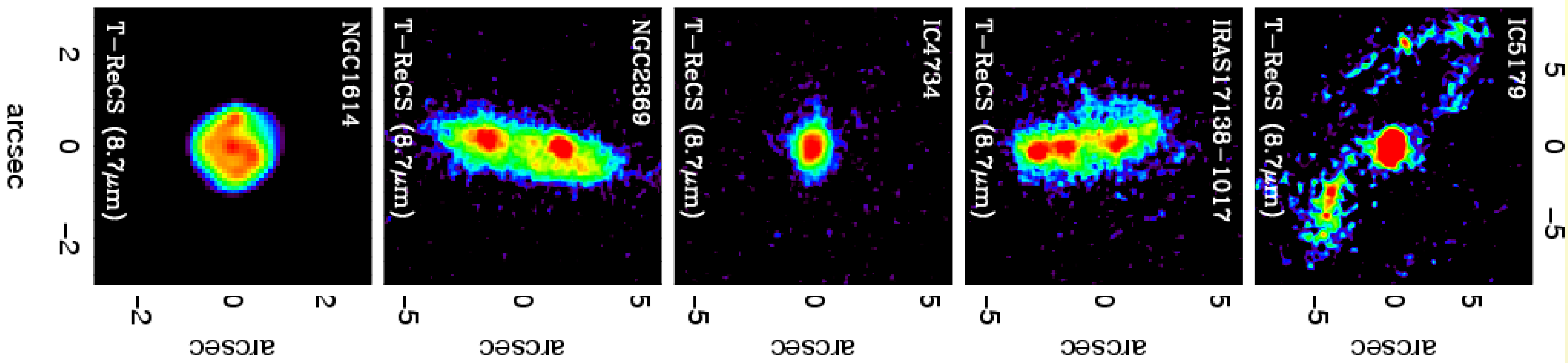
Synergy with ground-based astronomy



Cosmological redshift surveys (HST-Keck/VLT):

- *HST* is not optimized for measuring redshifts of faint distant galaxies *(just a 2.5m!)*
- Redshifts have traditionally come from 8-10m telescopes such as Keck, VLT, Gemini…
- Unfortunately, most sources in deep imaging surveys with HST (HDF, UDF) are well beyond the spectroscopic limit (I_{AB}~26).

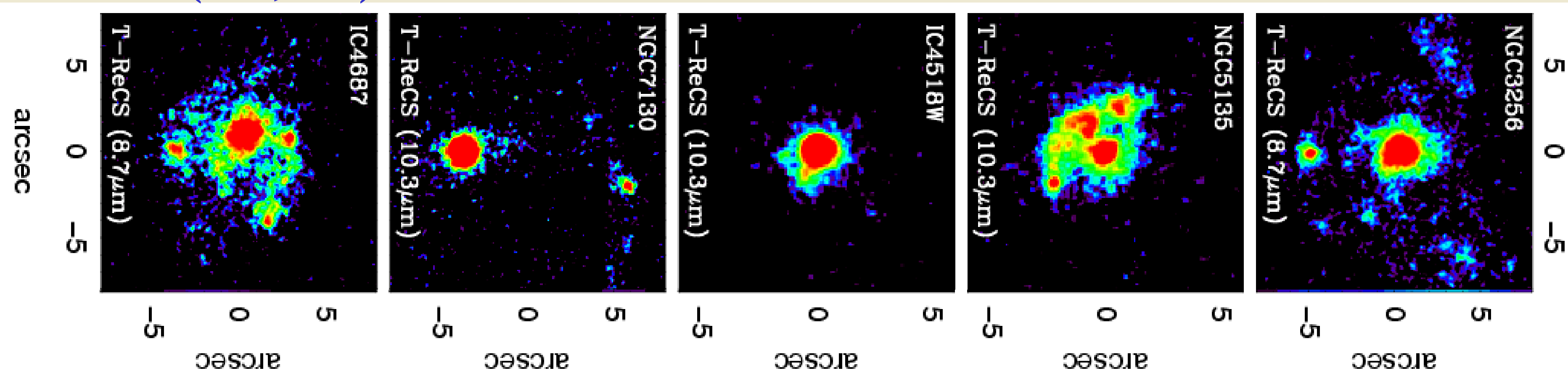
Objective of new 30-m class telescopes (TMT, GMT, E-ELT)

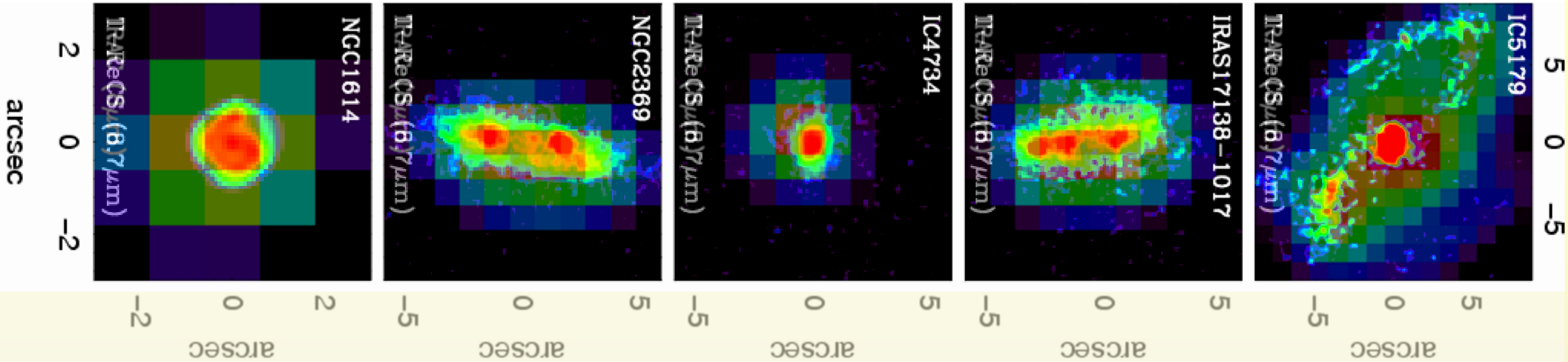


Mid-IR imaging: space (Spitzer/IRAC) vs. ground (Gemini/T-ReCS) observations

Díaz-Santos (2009, PhD)

Credit: Almudena Alonso-Herrero

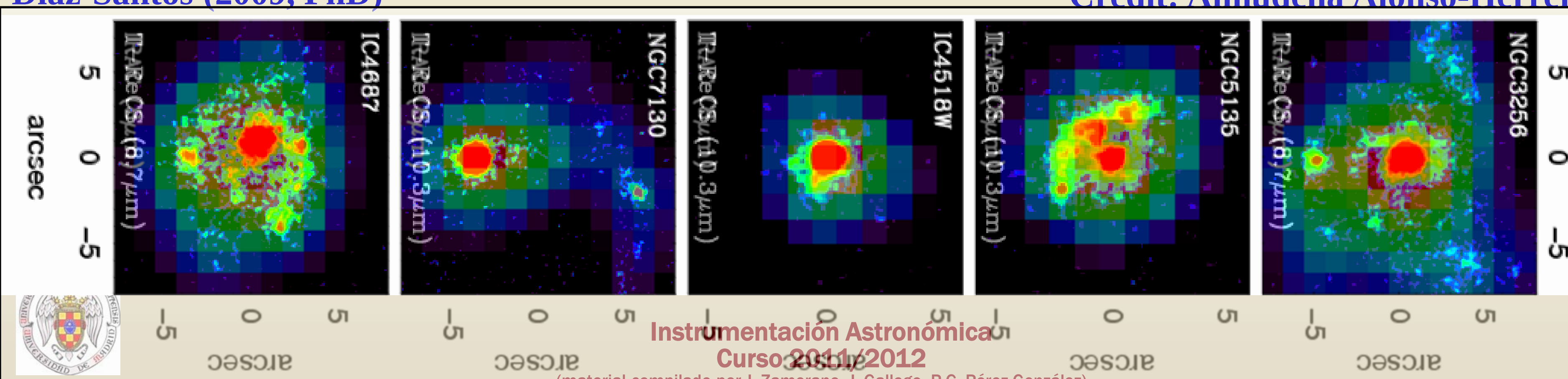




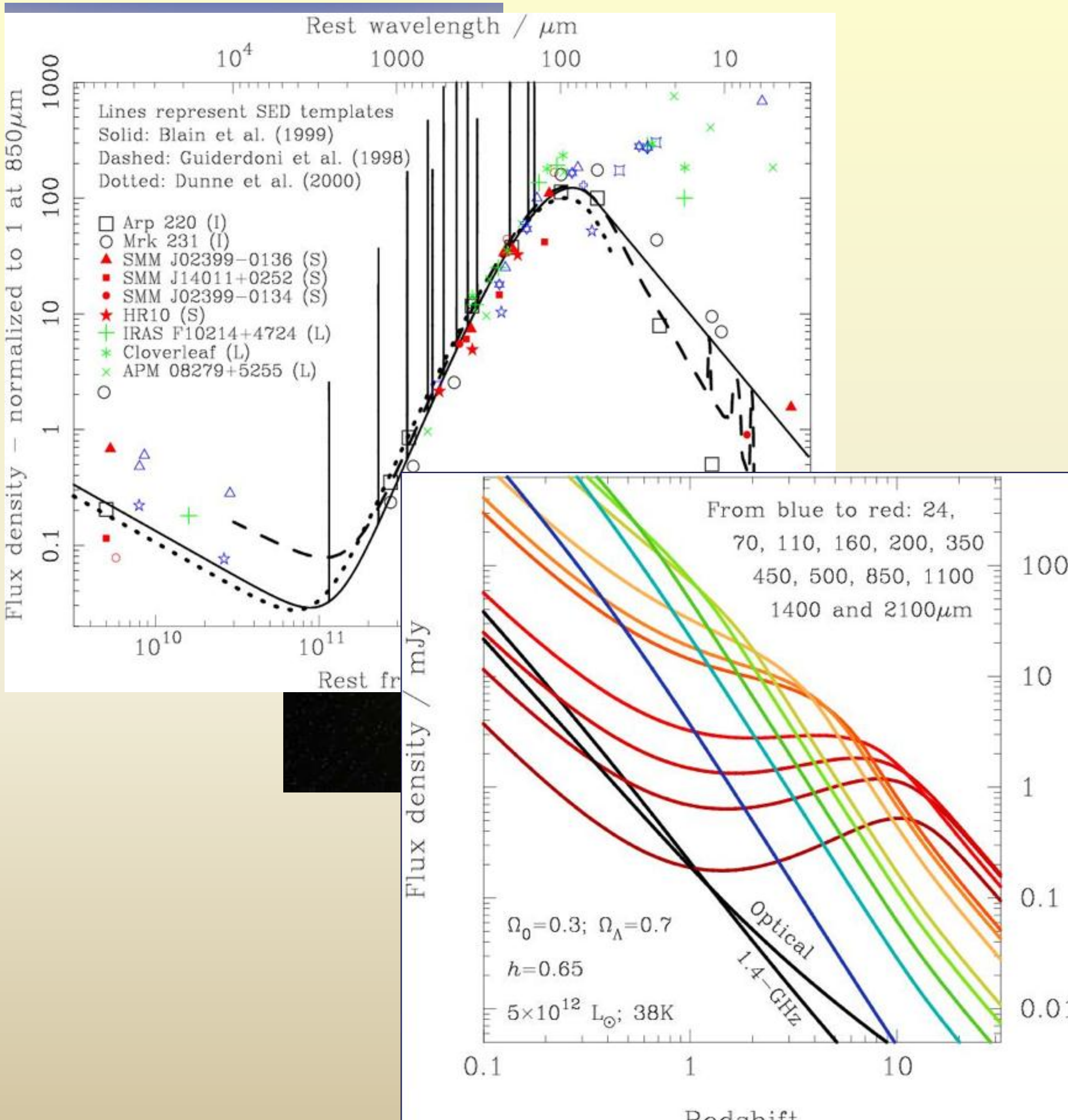
- Only with high spatial resolution can constituent parts of AGN & host galaxy be investigated and de-blended
- Resolution at distance of 30Mpc
  - **Spitzer = 450pc (galactic star forming rings, etc.)**
  - **GTC/CanariCam = 45 pc (nuclear dominated)**

Díaz-Santos (2009, PhD)

Credit: Almudena Alonso-Herrero



Synergy with ground-based astronomy



Future surveys (JWST-ALMA-30m synergy):

- ALMA will provide an unprecedented sample of very distant galaxies thanks to the negative K-correction.
- Targeted JWST programs will allow deriving rest-frame optical properties with superb resolution.
- 30m-class telescopes should provide redshifts for ALMA sources with faint molecular (CO) or [CII] 158 μm line emission.

(material compilado por A. Gil de Paz, J. Zamorano, J. Gallego, P.G. Pérez-González)

Resumen de contenidos

- ¿Por qué se lanzan telescopios espaciales? Sinergías con telescopios de tierra.
- Principales telescopios espaciales (más allá del UV), características, instrumentos,…
- Típicos programas de preparación de propuestas.
- Archivos de misiones.
- Futuras misiones espaciales.