The Visible and InfraRed Hyperspectral Imaging Spectrometer (VIRHIS): a study for EJSM

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VIRHIS Team

What is VIRHIS

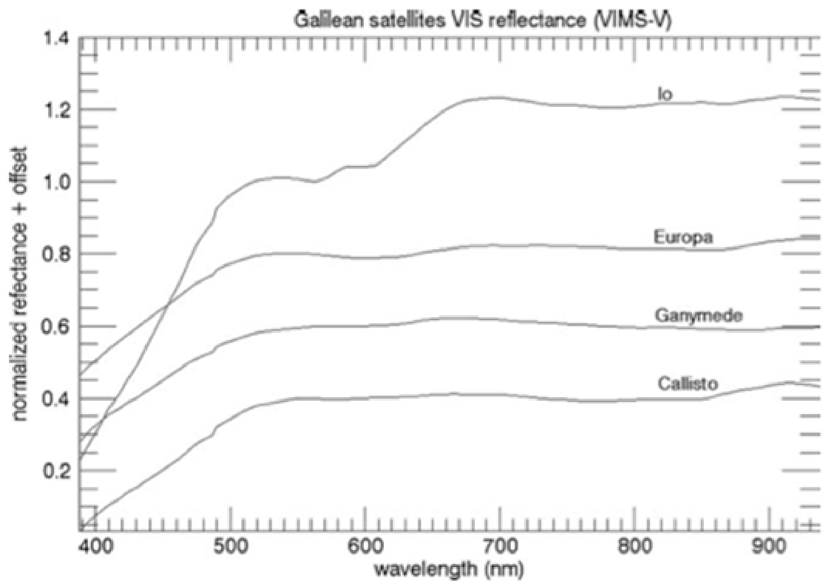
- ***VIRHIS*** is a performing imaging spectrometer for JGO-EJSM, operating in the 0.4-5.2 µm spectral range (or beyond), perfectly suitable to study the Galilean satellites and the Jupiter atmosphere
- A delta study is also planned for a similar instrument on board JEO-EJSM
- ***The VIRHIS study proposal is in response to the ESA DOI EJSM issued on March 26 2009***

Scientific objectives for Jovian satellites

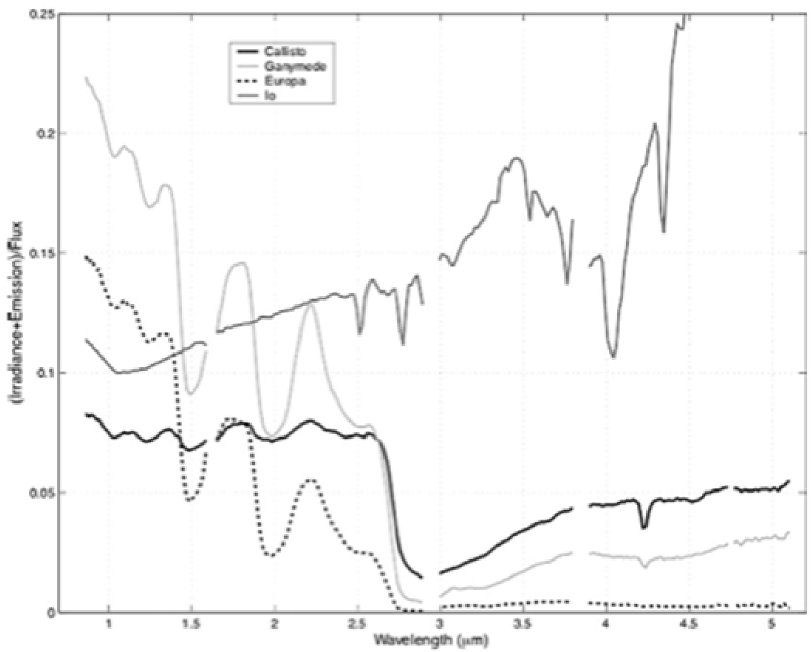
Study the Jovian satellites system and their connection to the population of minor bodies in the Solar System

- Measurement at high resolution (< 1 km/pixel) of surface icy, non-icy, mineral, organic and inorganic chemical composition
- Determination of the relation between composition and geological processes
- Measurement of volatiles and indicators for life
- Search for sites of recent geological activity
- Identification of tectonic, cryovolcanic and impact features
- Determination of interesting sites for future landing mission
- Mapping surface alterations due to radiation environment
- Monitoring O_2 exosphere on Ganymede with limb scans
- Monitoring Io's volcanic and thermal activity on day and night sides
- Observations of the irregular satellites and Jupiter's rings system
- Comparative study of the Galilean satellites

Jovian satellites VIS-NIR spectroscopy



Cassini/VIMS - McCord et al., Icarus 172, 2004

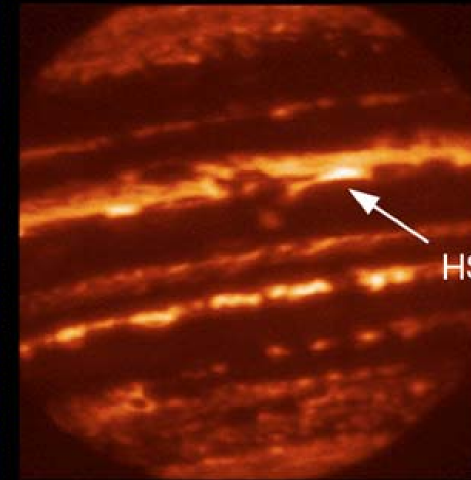


Element	Diagnostic bands (μm)
H_2O	Crystalline: 1.04, 1.25, 1.5, 1.65, 2.05, 3.0; 3.1 triple Fresnel peak Amorphous: 1.04, 1.25, 1.5, 2.00, 3.0; 3.1 single Fresnel peak continuum @ 3.6 indicator for grain sizes 1.65 band indicator for ice temperature visible slopes indicators for ice contamination
SO_2	2.54, 2.80, 2.92, 4.07
H_2SO_4	1.2, 2.4
H_2S-S_2O frosts	3.75, 3.85, 4.0
H_2O_2	~3.50
C-H	1.73, 3.40
S-H	~3.88
$C\equiv N$	2.42, 4.35, 4.90
CO_2	2.02, 2.70, 2.78, 4.25
CO2	1.56, 2.34, 4.68
Tholins	4.57, visible slopes
O_2	0.577, 0.628
O_3	~0.260
Hydrated minerals	1.40, 1.95
PAH	3,28

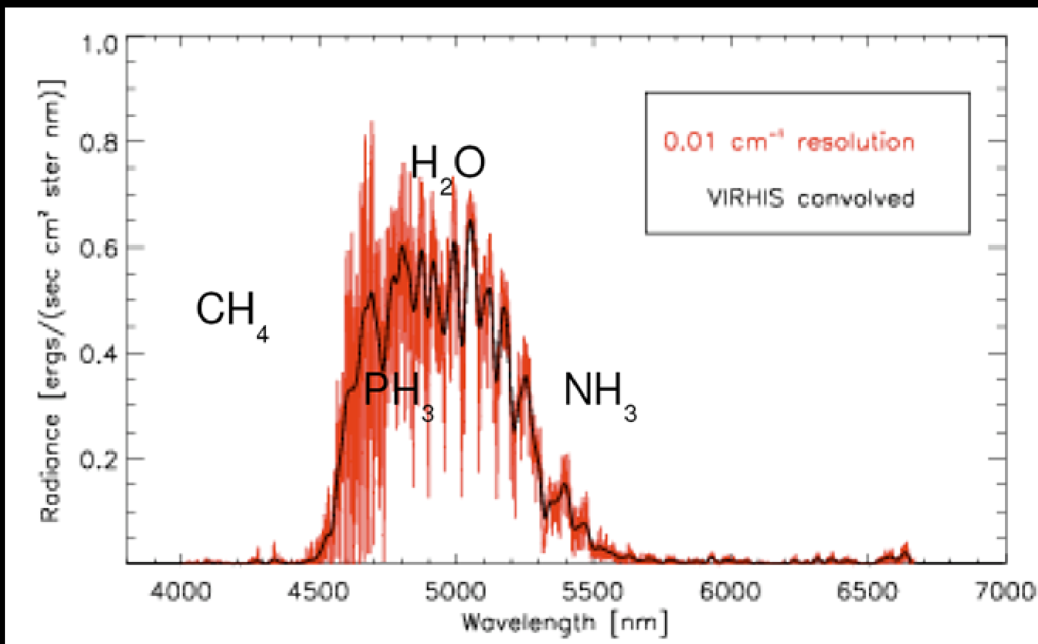
Scientific objectives for Jupiter

- **Study the stratospheric and thermospheric structure, global circulation dynamics and composition**
- Determination of the general circulation and composition of the atmosphere
- Observation of the auroral emissions (mainly due to H_3^+)
- Determination of the origin of water in the stratosphere; its latitudinal distribution and role in chemistry and dynamics
- Monitoring clouds and thermal hot spots
- Characterization of the nature of the hydrocarbon chemistry
- Determination of the the composition of the primordial material from which Jupiter formed
- Characterization of the strength of the vertical mixing in the stratosphere

Jovian atmosphere VIS-NIR spectroscopy: 5 µm window and hot spots



4.85 µm



Hot spots are regions of anomalous high emission at 5 µm (methane transparency window):

- Thinner cloud deck allows radiation from deeper (warmer) troposphere to escape
- Observed more often in northern edge of the Equatorial Zone
- Dynamical nature still controversial
- Galileo Entry Probe (GEP) provided in situ measurements of hot spot conditions

5 µm windows transparency windows of methane encompasses spectral features of:

- Water (main oxygen bringing molecule)
- Ammonia (main nitrogen bringing molecule)
- Phosphine (disequilibrium molecule)
- and many others....

Hotspots potentially provide a mean to probe the deeper atmosphere:

- Retrieval of 'bulk' mixing ratios for main element bringing molecules =>
- Constraints on the formation scenario of the planet
- Constraints on cloud properties and planet's radiative budget
- Detection of disequilibrium species, tracers for deep convective motion

VIRHIS study team

- The VIRHIS study team is a ***consortium*** of scientists and engineers from the following international institutes:

- INAF-IASF Rome, Italy *(instrument study proposal leader)*
- INAF-IFSI Rome, Italy
- Physics department, Università del Salento, Lecce, Italy
- IAS (Institut d'Astrophysique Spatiale), Centre universitaire d'Orsay, France
- Bear Fight Center, WA, United States
- DLR Institute of Planetary Research, Berlin, Germany
- Dpto. Física Aplicada, Universidad del Pais Vasco, Bilbao, Spain
- Engineering department, Università di Padova, Italy
- GALILEO AVIONICA, Campi Bisenzio, Florence, Italy
- NASA/JPL, Pasadena, CA, United States
- Institut für Planetologie, Münster, Germany
- LESIA, Observatoire de Paris/Meudon, France
- Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany
- NASA/GSFC, Greenbelt, MD, United States
- Southwest Research Institute, San Antonio, TX, United States
- University of Oxford, Clarendon Laboratory, Oxford, United Kingdom

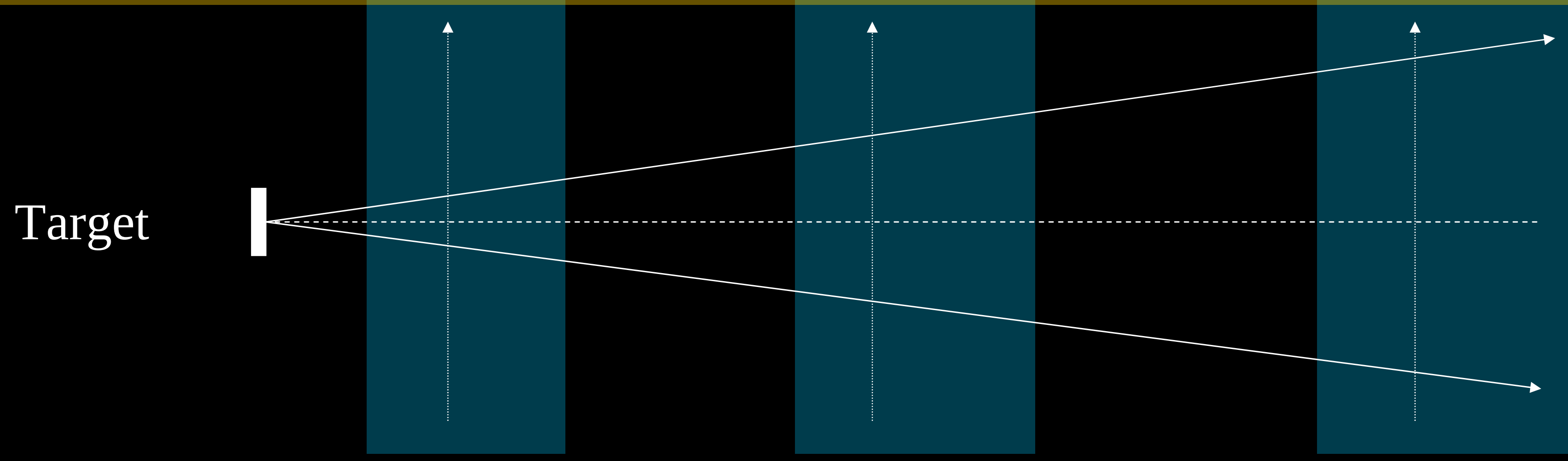
VIRHIS characteristics summary

Requirements

OPTICS	Design	Three mirror anastigmatic telescope, with scanning mirror (TBC)
	min IFOV	125 μrad (JGO) – 250 μrad (JEO)
	FOV	3.4° (JGO) – 9.17° (JEO)
	Aperture	34 mm - 60 mm
	Focal length	192 mm
	f/#	5.6 - 3.2
SPECTROMETER	Design	Offner spectrometer, with convex grating (TBC)
	Spectral range	0.4÷2.2 μm – 2.0÷5.2 μm (with possible extension above 5.2 μm)
	Spectral sampling	2.8 nm/band - 5.0 nm/band (JGO) 5.0 nm/band - 10.0 nm/band (JEO)
	$\lambda/\Delta\lambda$	143÷786 – 400÷1040 (JGO) 80÷440 – 200÷520 (JEO)
	Order sorting filters	LVF (TBC)
	Operative temperature	< 150 K (TBC)
DETECTORS	Technology	HgCdTe with HgCdZn substrate removed, CMOS multiplexer HgCdTe, CMOS multiplexer
	Format and pixel pitch	640×480, 27 μm (TBC)
	Full well capacity	2Me$^-$
	Operative temperature	180±10 K - 70±10 K (TBC)
RESOURCES	Mass	17 kg (OH, PEM, ME); harness not included (JGO) 20 kg (OH, PEM, ME); harness and radiation shielding not included (JEO)
	Power	20 W (average)

VIRHIS on ground spot size

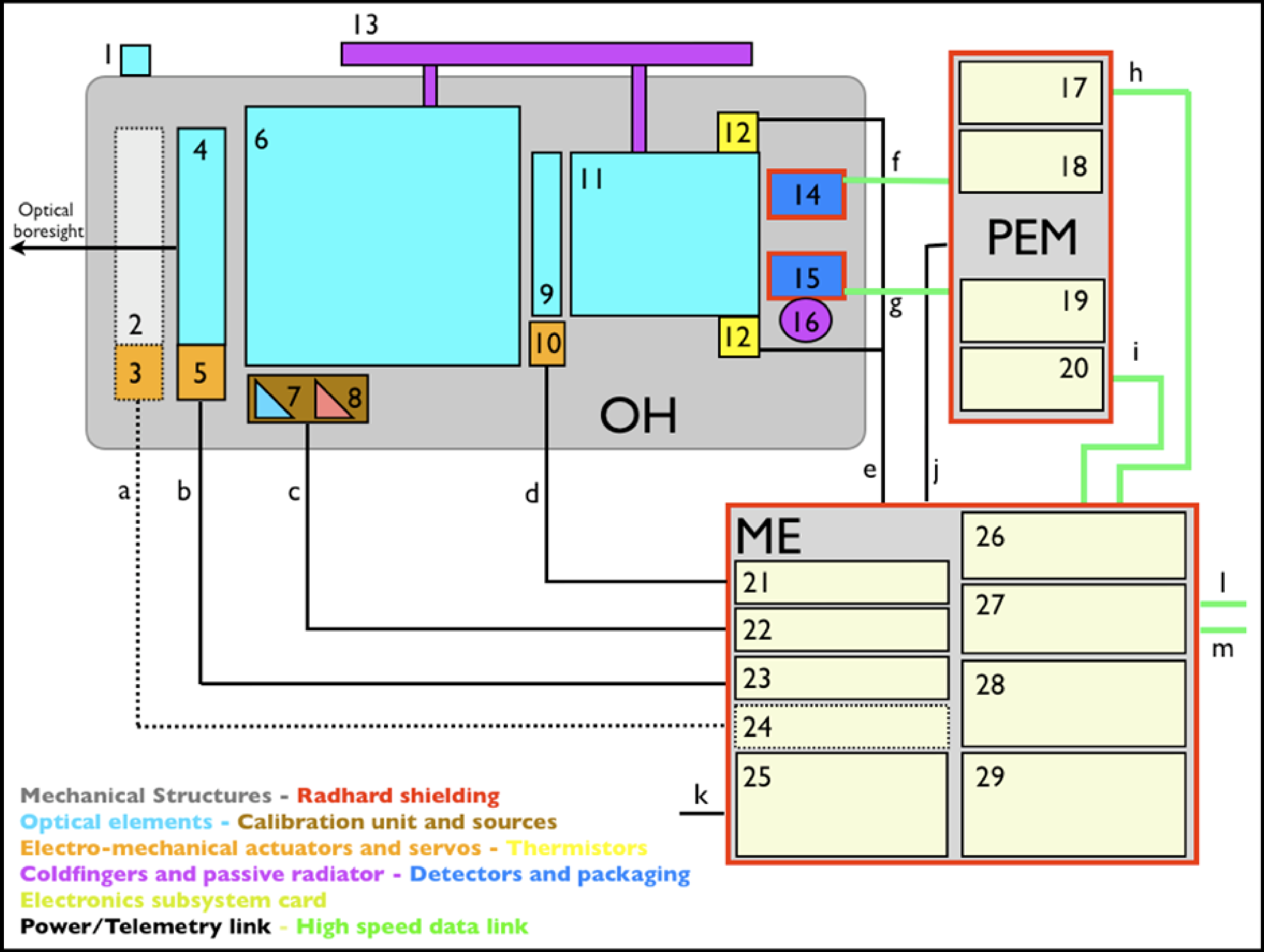
Slant distance	200 km	10000 km	20000 km
Full FOV	12 km	600 km	1200 km
Nominal (x4)	100 m	5 km	10 km
High res	25 m	1.25 km	2.5 km



Block Diagram of VIRHIS

Instrument subsystems:
1. Alignment reference cubic mirror;
2. Optical head cover (Optional);
3. Cover mechanism (Optional);
4. Scan mirror;
5. Scan mirror mechanism;
6. Telescope;
7. Internal calibration unit, VIS-NIR reference source;
8. Internal calibration unit, IR source;
9. Slit with motorized shutter;
10. Shutter mechanism;
11. Spectrometer;
12. Heaters (for annealing and surviving);
13. Passive radiator, coupled to the OH structure;
14. VIS-NIR FPA, with radhard shield;
15. IR FPA, with radhard shield;
16. IR FPA coldfinger (S/C provided);
17. High speed I/O interface for data downlink to ME, VIS-NIR channel;
18. FPGA controller, VIS-NIR channel;
19. FPGA controller, IR channel;
20. High speed I/O interface for data downlink to ME, IR channel;
21. Shutter mechanism controller card;
22. Internal calibration unit controller card;
23. Scan mirror mechanism controller card;
24. Cover mechanism controller card (Optional);
25. Power supply;
26. High speed I/O interface for data downlink from PEM, VIS-NIR and IR channels;
27. High speed I/O interface for data downlink to S/C bus, VIS-NIR and IR channels;
28. Data compressor; 29. DPU, including mass memory.

Instrument links:
a. Cover mechanism to ME, power and telemetry;
b. Scan mirror mechanism to ME, power and telemetry;
c. Internal calibration unit to ME, power;
d. Shutter mechanism to ME, power and telemetry;
e. Heaters to ME and S/C bus, power and temperature readings;
f. VIS-NIR FPA to PEM, high speed analog datalink;
g. IR FPA to PEM, high speed analog datalink;
h. PEM to ME, high speed digital datalink for VIS-NIR channel;
i. PEM to ME, high speed digital datalink for IR channel;
j. ME to PEM, power line;
k. S/C bus to ME, power line;
l. ME to S/C bus, high speed digital datalink for VIS-NIR channel;
m. ME to S/C bus, high speed digital datalink for IR channel.



VIRHIS Team meetings

- December 10 2009 : meeting #1 in Rome (after pre-assessment)
- February 17-18 2010 : meeting #2 in Paris (progress)
- Around May (TBD) : meeting #3 in MPS-Lindau (progress)

Main tasks

- **Radiometric model** (parameterization running)
- **Optics** (analysis on the preliminary architecture running)
- **Thermal model** (preliminary sensitivity analysis running)
- **Main Electronics and Power Supply** (running)
- **IR detector and its proximity electronics** (running)
- **VIS-NIR detector and its proximity electronics** (running)
- **In flight calibration tools** (awaiting a first preliminary analysis on the optical configuration)
- Radiation and Planetary Protection (active)

Optics architecture

- Two configurations are currently under study:

- Offner with convex or plane grating
- Double compact spectrometers with double or single slit sharing a unique telescope

Preliminary results from the thermal model sensitivity analysis

Radiator surface assumption = 0.15 m^2 as starting point, but actual area is TBC

Radiator partially embedded (obscured), PCBZ - white paint coated

Radiator temperature variation between no input flux case (deep space) and Ganymede, Jupiter or Sun fluxes cases (worst condition):

- Ganymede flux contribution (worst case) => ΔT = 6 K
- Jupiter flux contribution (worst case) => ΔT = 3 K
- Sun flux contribution (worst case) => **ΔT = 14 K**

Radiator not embedded, PCBZ - white paint coated

Radiator temperature variation between no input flux case (deep space) and Sun flux case (worst condition):

- Sun flux contribution (worst case) => **ΔT = 12 K**

Radiator not embedded, OSR coated

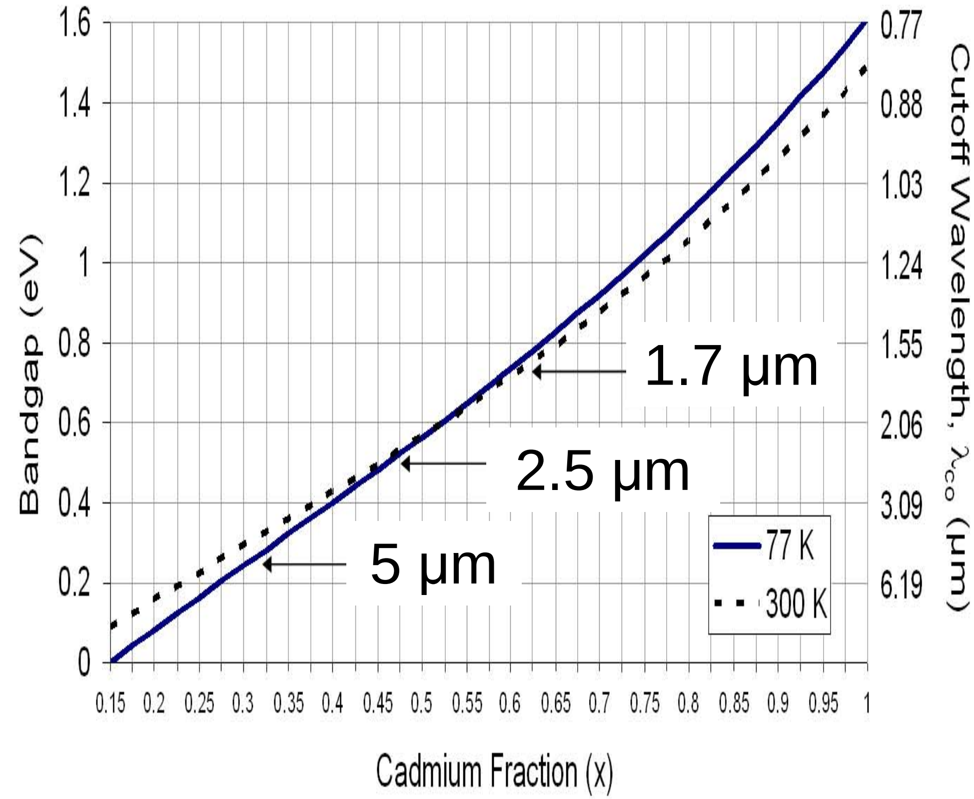
Radiator temperature variation between no input flux case (deep space) and Sun flux case (worst condition):

- Sun flux contribution (worst case) => **ΔT = 6 K**

Detector

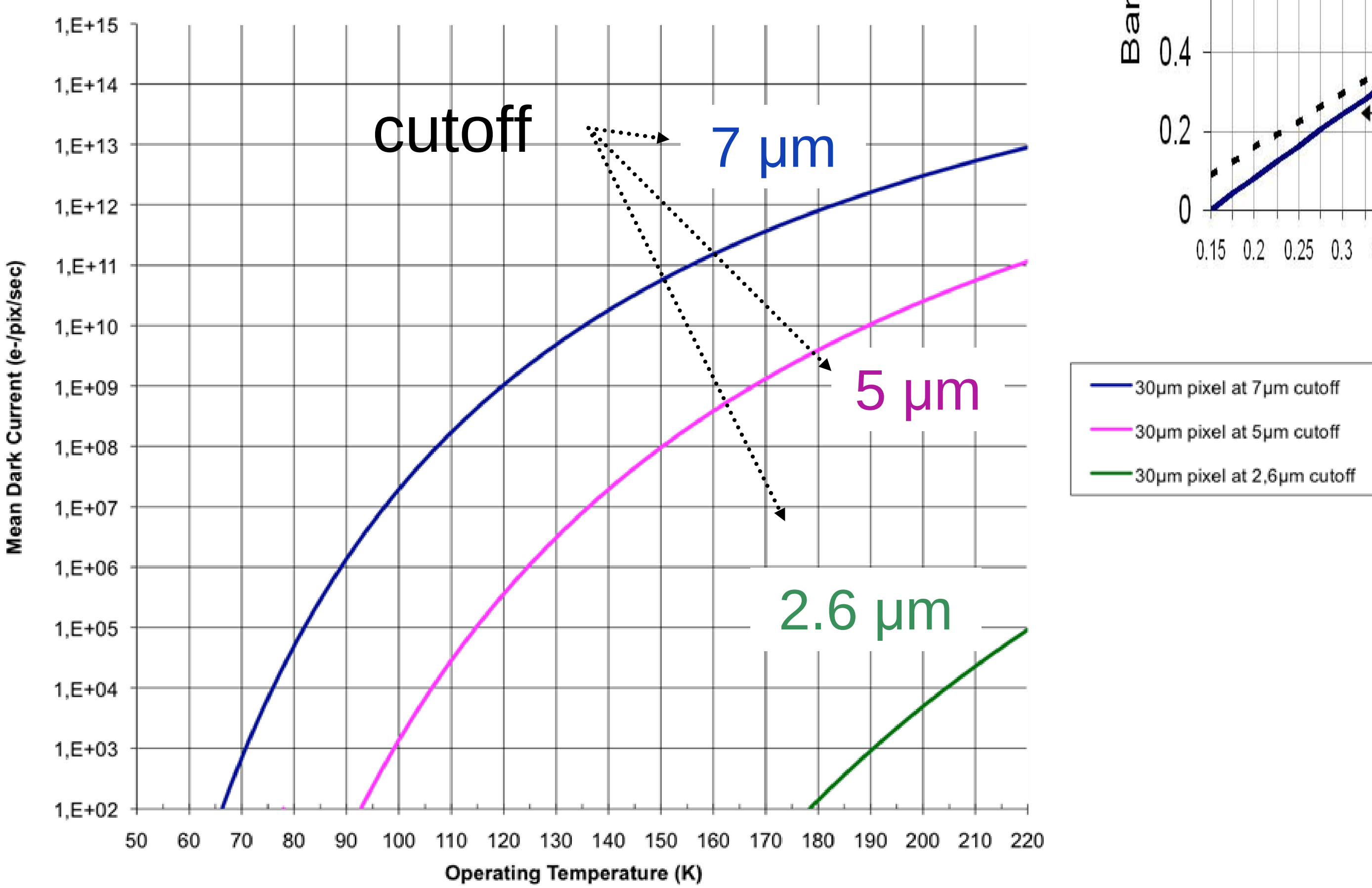
HgCdTe tecnology can cover the full range of VIRHIS

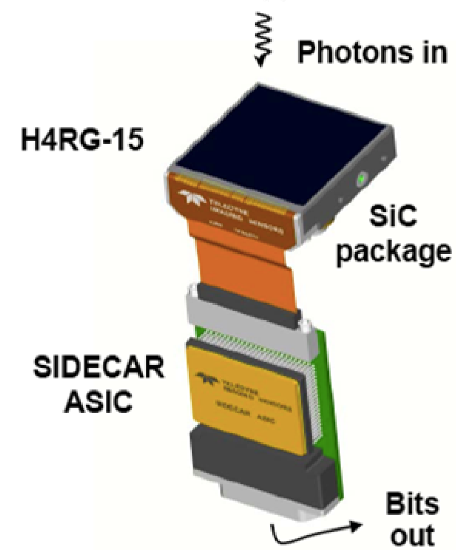
Bandgap dependence on $Hg_{1-x}Cd_x$ mixture and temperature (Hansen et al. 1982)



Dark current

HgCdTe Dark current vs temperature from Teledyne Rule 07





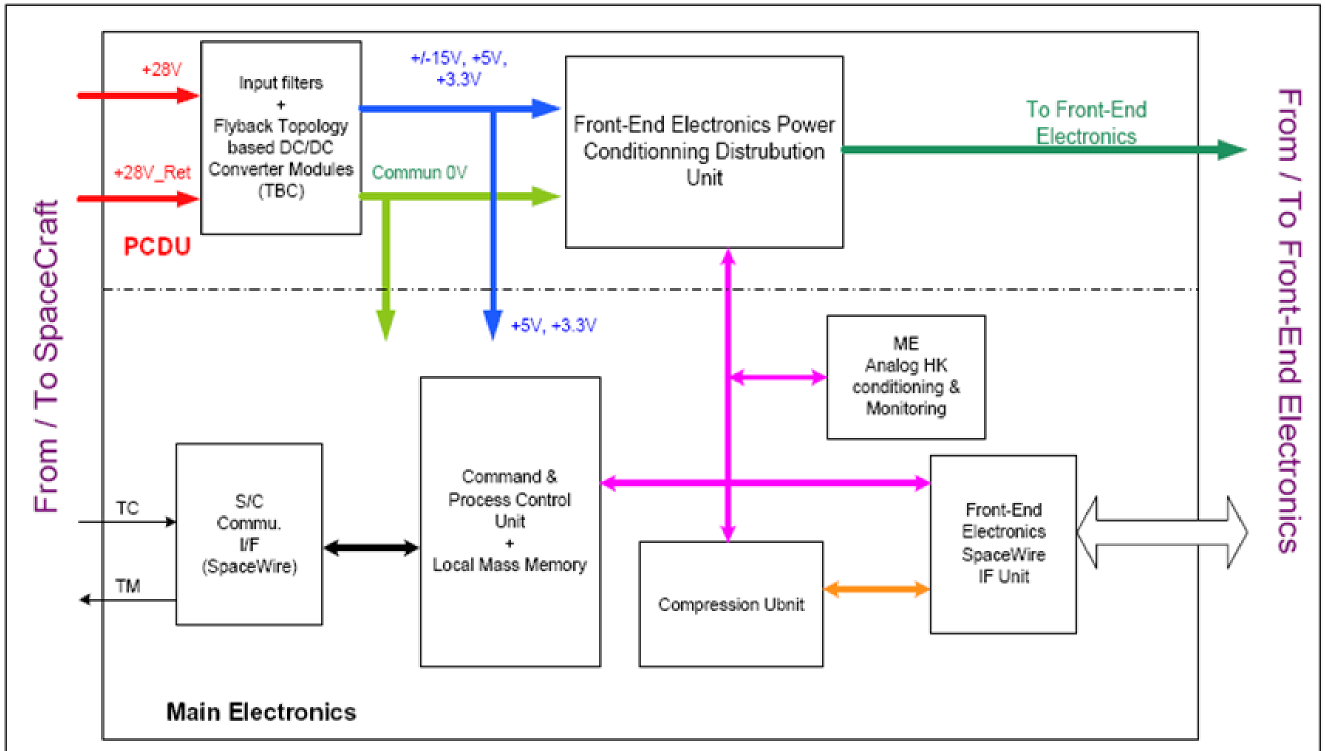
Main electronics functional block diagram

- Interface satellite (Power Conditioning and Distribution Unit)

- Command and process control unit (TC/TM)

- Interface with the IFEs

- Data compression



Main Electronics Functional Block Diagram

Flexibility

- VIRHIS can potentially provide a lot of data (and also a lot of science)
- The mission datarate/volume resources limitation is a driver to consider an high level of flexibility for the instrument - this is not an issue but a great advantage for the different phases of the mission -

Unfeasible for global mapping

Feasible, but not the best option

Fully feasible for global mapping

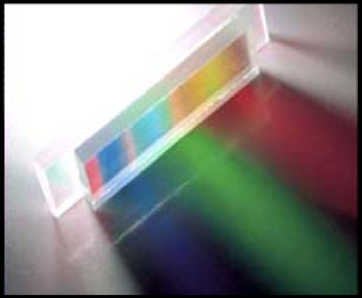
Survey GEO
Compression factor f(compr) = 2
Acquisition only on the dayside and only if texp>tdwell>1 s
Total downlink data < f*37 Gbit
Spectral channels: 512 (2 * 256)

Binn	f(rand)	N(orb)	Delta t	Coverage (days)	(Cov red)	Data vol (Gbit)	Downlink vol (Gbit)	Mem resid (Gbit)
4x4	<0.5	110	53.8	0.75105	1.98240	0.3622E+02	0.7227E+02	0.8352E-01
4x4	<0.25	162	79.7	0.79153	2.49902	0.2777E+02	0.5538E+02	0.8079E-01
4x4	<0.125	162	79.7	0.72868	2.04344	0.1367E+02	0.2727E+02	0.4036E-01
2x2	<0.5	70	34.1	0.51874	1.10166	0.1609E+03	0.7227E+02	0.1277E+03
2x2	<0.25	72	35.1	0.50543	1.06575	0.8469E+02	0.7227E+02	0.4972E+02
2x2	<0.125	77	37.7	0.46851	0.95609	0.4522E+02	0.7227E+02	0.9304E+01
8x8	1.0	162	79.7	0.82632	2.99672	0.1529E+02	0.3046E+02	0.5920E-01
4x4	1.0	72	35.1	0.57162	1.27883	0.4884E+02	0.7227E+02	0.1301E+02
2x2	1.0	70	34.1	0.30272	0.54296	0.1609E+03	0.7227E+02	0.1277E+03
1x1	1.0	70	34.1	0.08215	0.12524	0.1609E+03	0.7227E+02	0.1278E+03

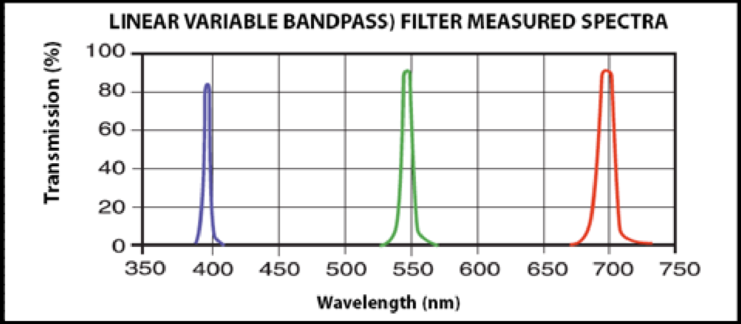
Survey GCO
Compression factor f(compr) = 6
Acquisition only on the dayside and only if texp > tdwell > 0.01 s
Total downlink data < f*18 Gbit
Spectral channels: 640 (full IR focal plane)

Binn	f(rand)	N(orb)	Delta t	Coverage (days)	(Cov red)	Data vol (Gbit)	Downlink vol (Gbit)	Mem resid (Gbit)
8x8	1.0	206	22.3	0.01125	0.01239	0.1425E+03	0.1055E+03	0.1280E+03
8x8	<0.25	206	22.3	0.01130	0.01252	0.1426E+03	0.1055E+03	0.1280E+03
8x8	<0.025	206	22.3	0.00201	0.00204	0.2469E+02	0.1055E+03	0.7279E+01

Technological Development Activity on Linear Variable Filters

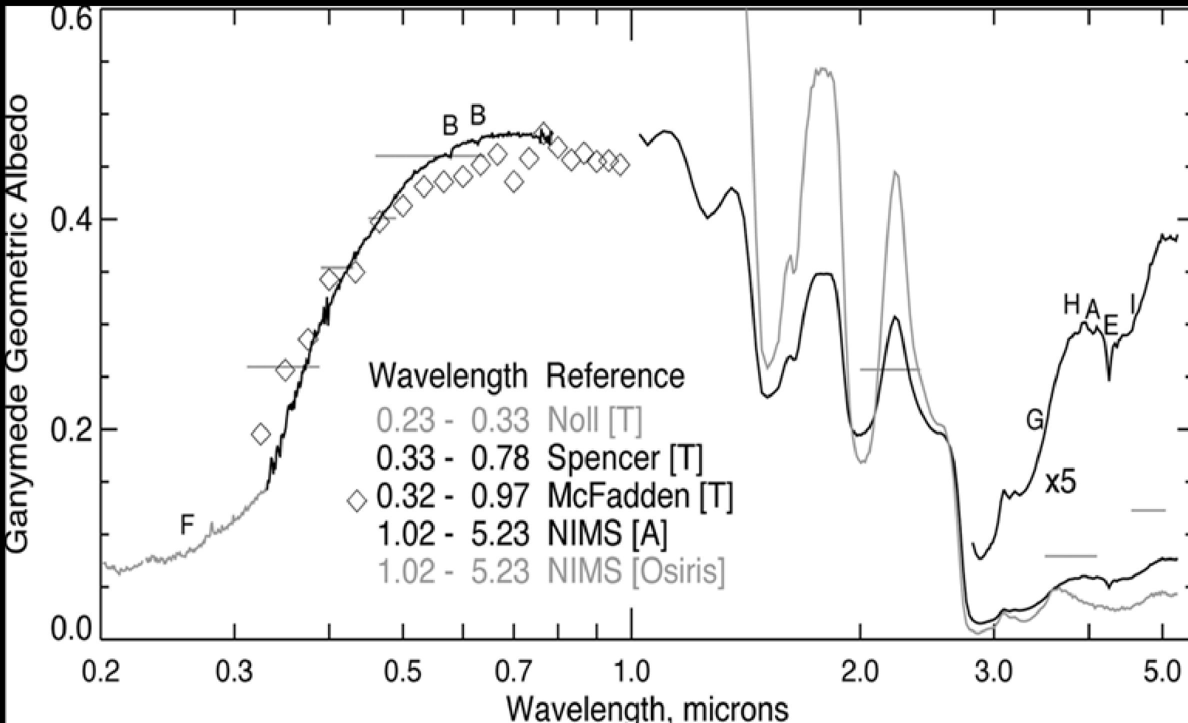


- A TDA on LVF has been proposed
- The proposal is under evaluation



Rationale for a wavelength extension above **5.2 μm** (delta study)

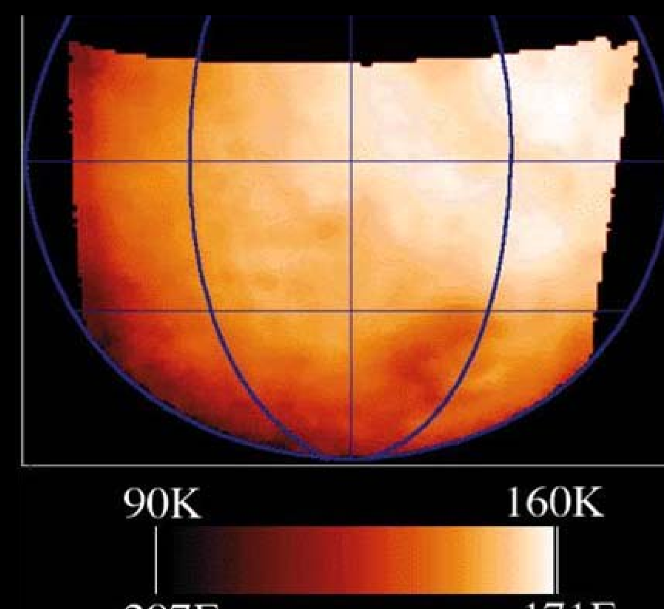
Ganymede



Ganymede geometrical albedo

???

Ganymede temperature map (Galileo radiometer)

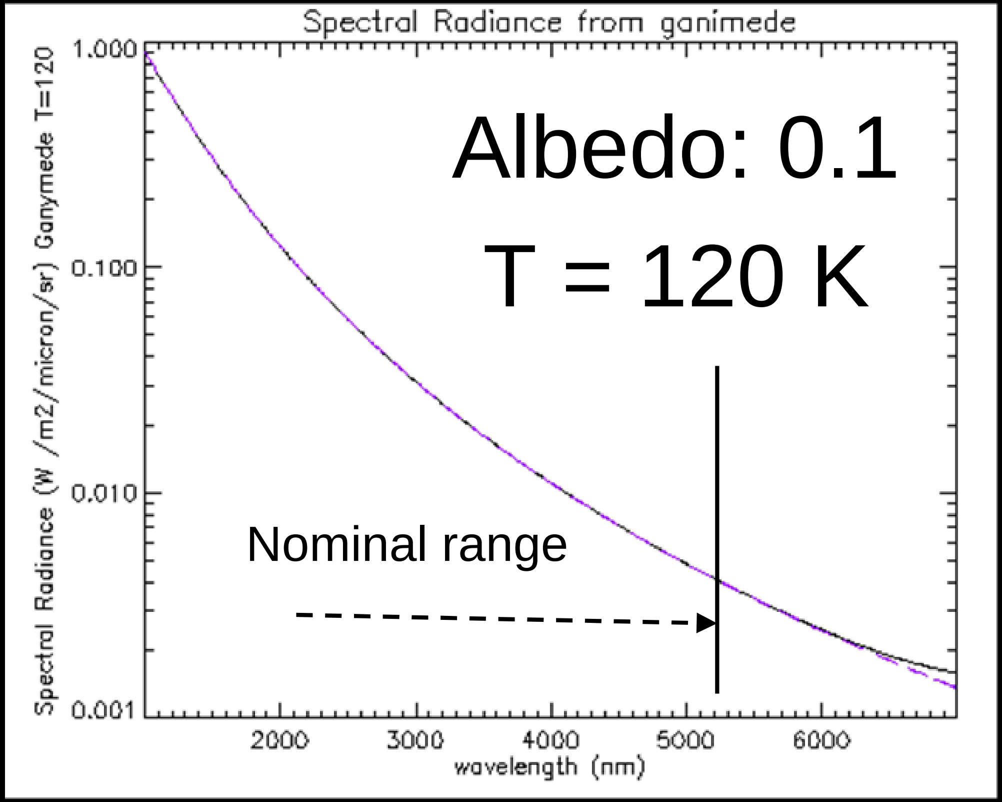


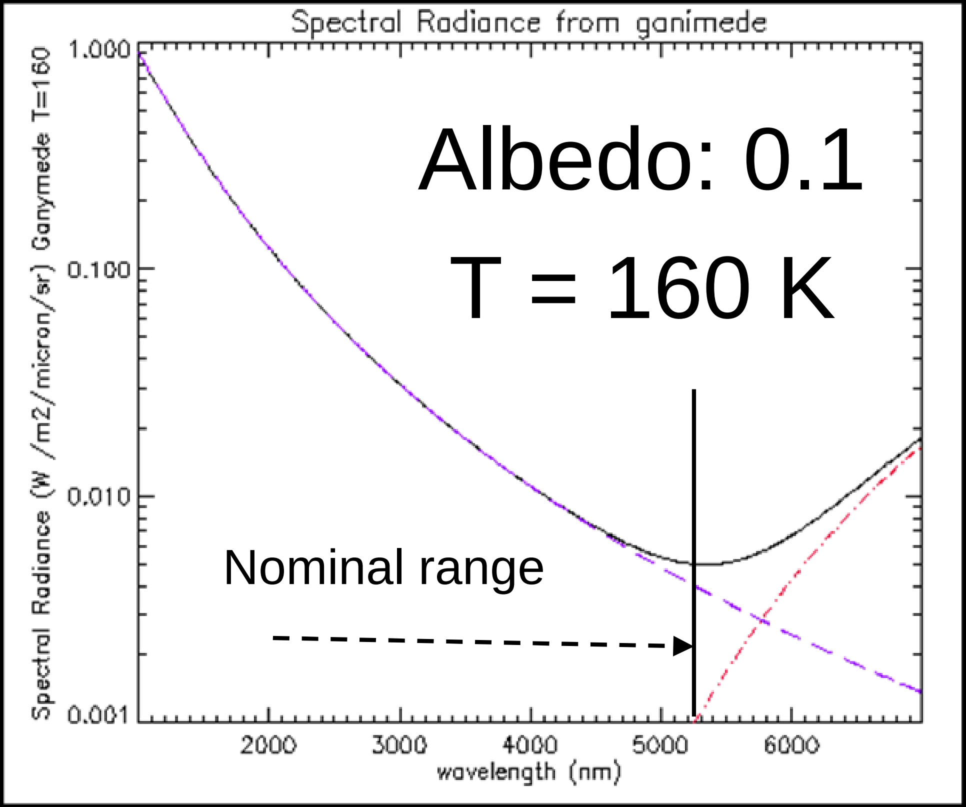
Ganymede

Continuum spectral radiance rough estimation

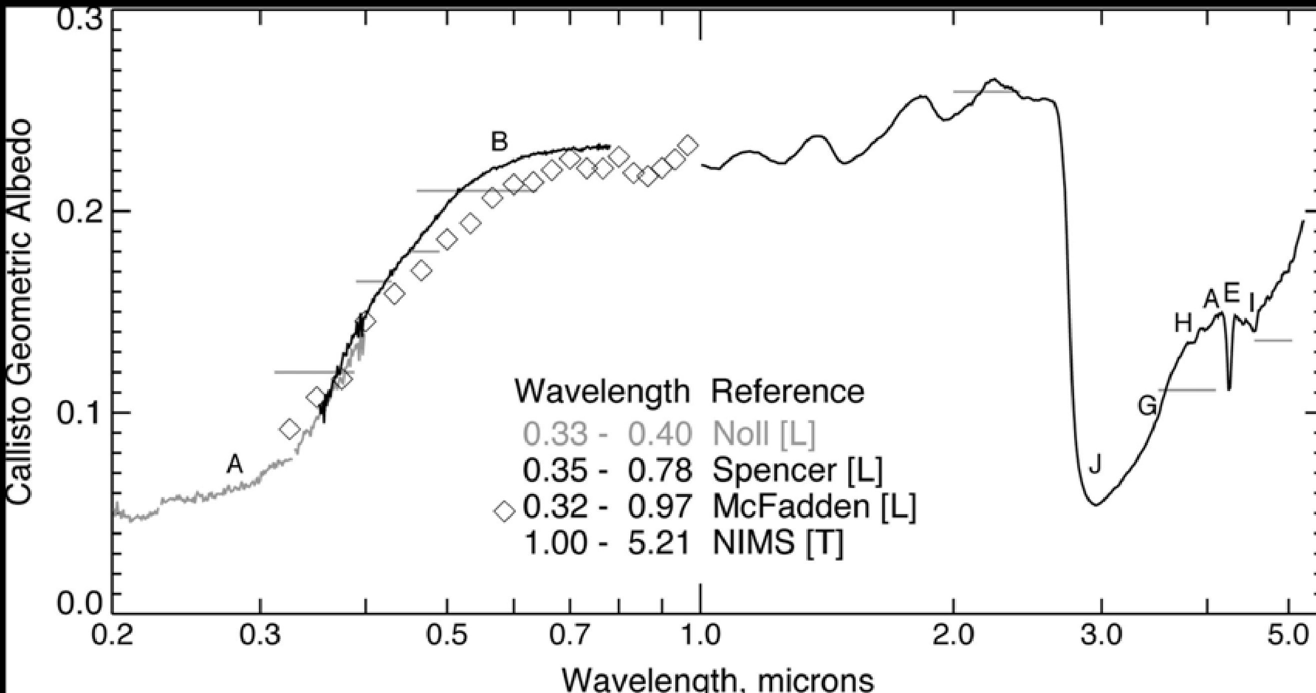
Albedo: 0.1

Different Temperature





Callisto



???

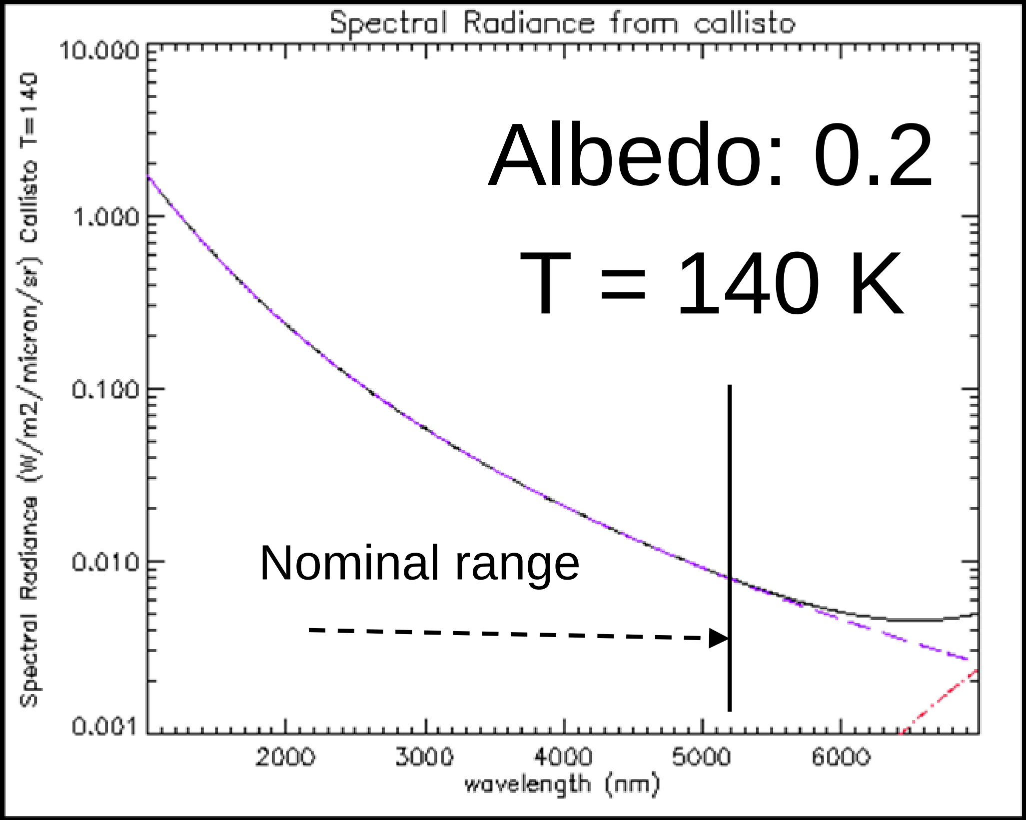
Callisto geometrical albedo

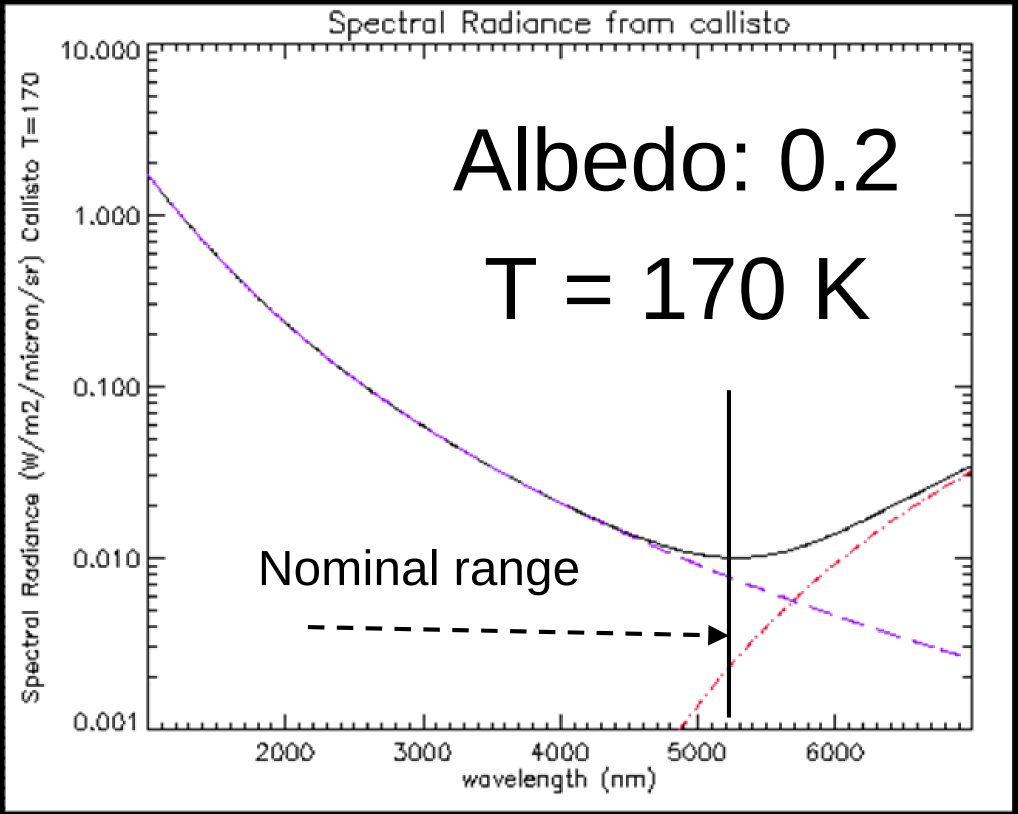
Callisto

Continuum spectral radiance rough estimation

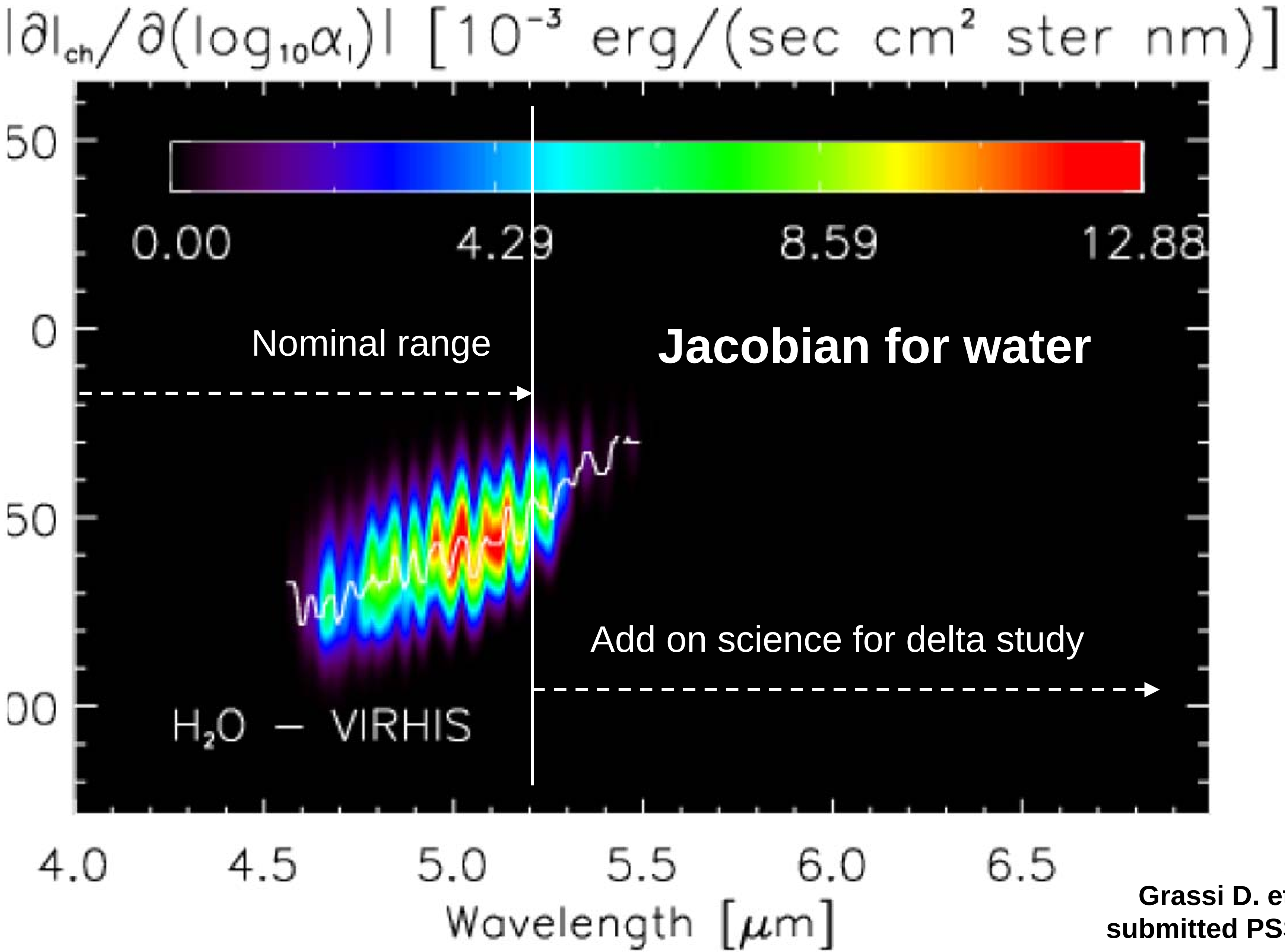
Albedo: 0.2

Different Temperature



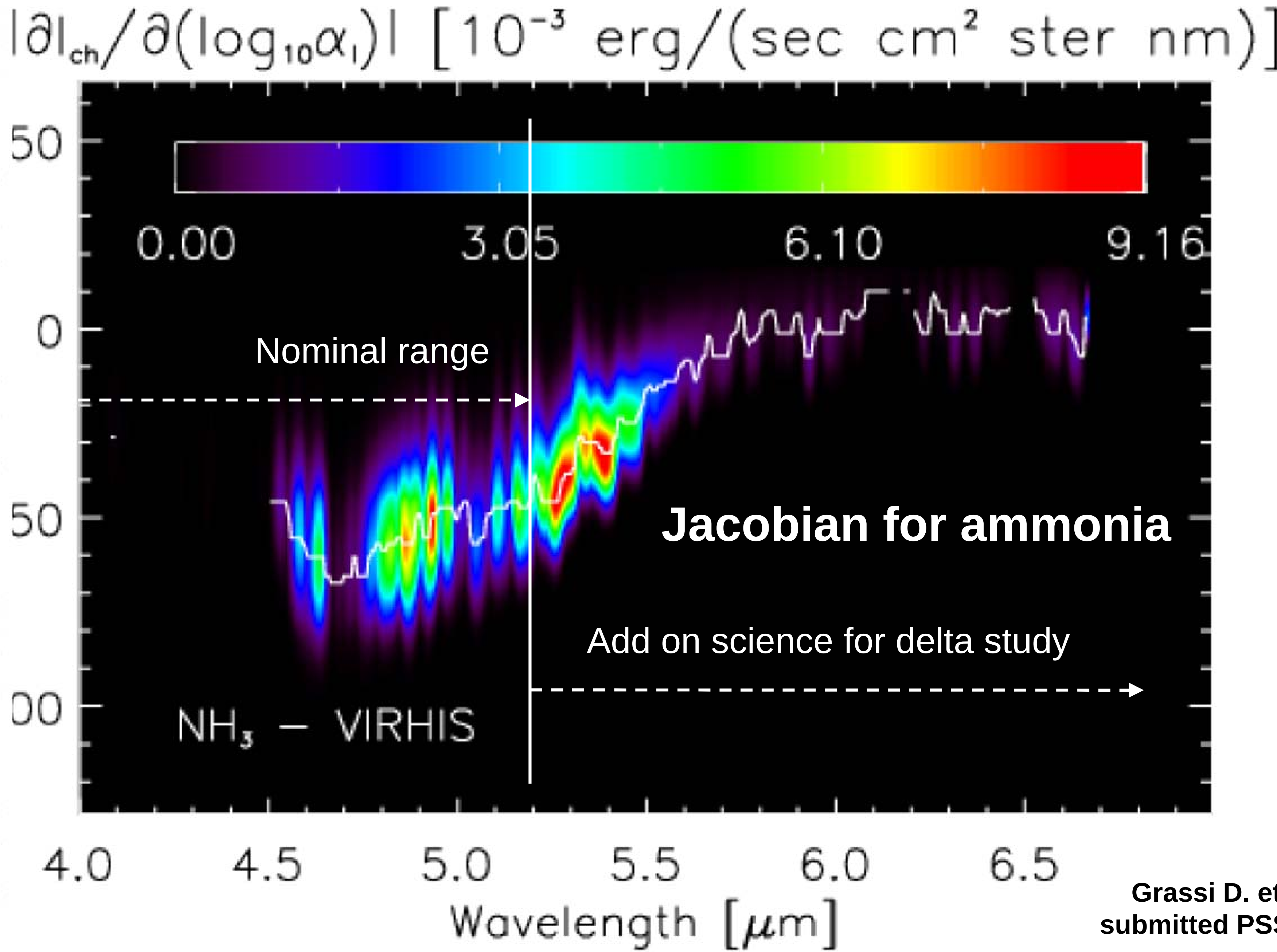


Jupiter



Grassi D. et al., submitted PSS 2009

Jupiter



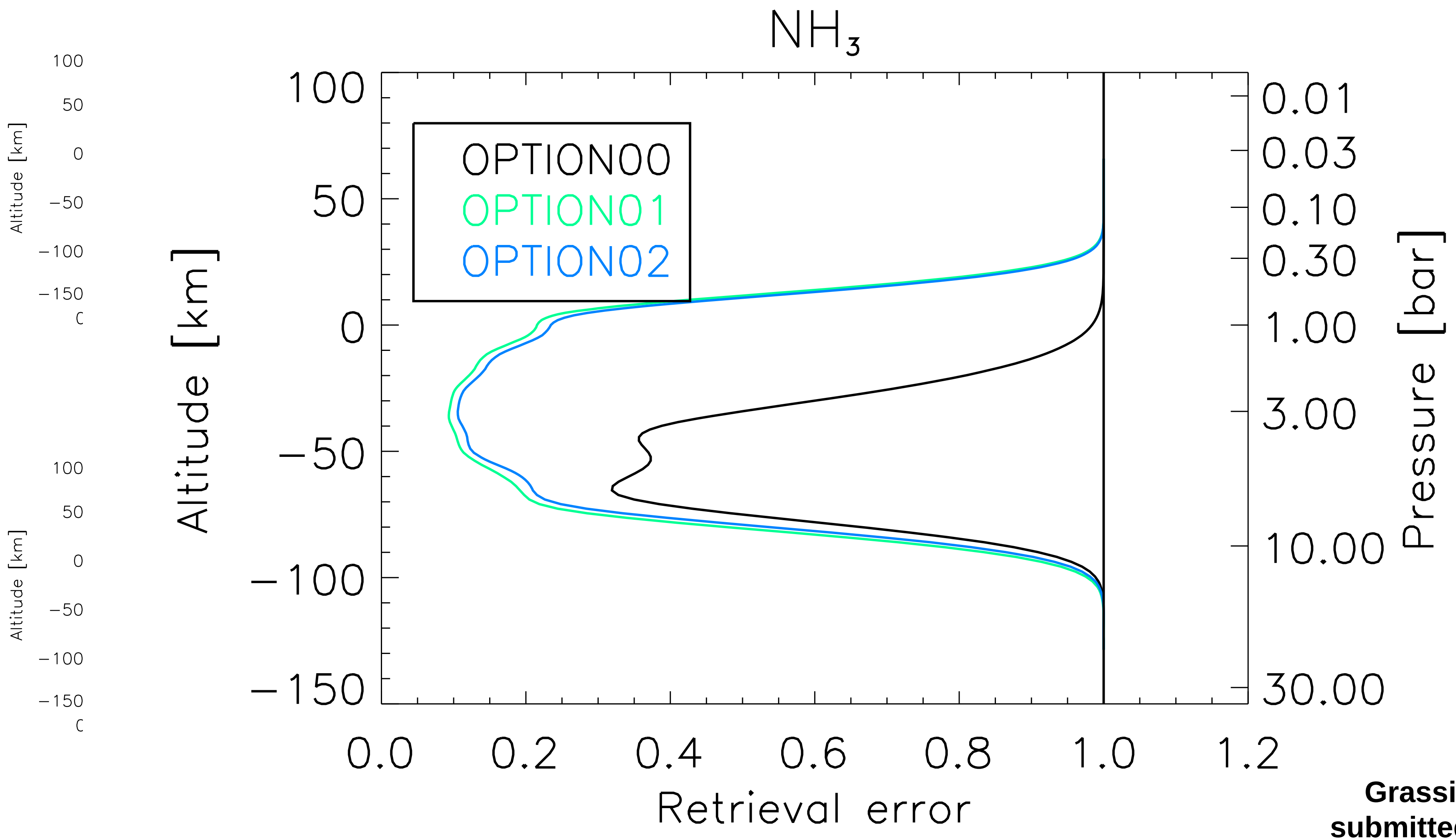
Grassi D. et al., submitted PSS 2009

Improvement of retrieval capability for Jupiter in case of extension up to 6 microns

OPTION00 = JUNO-JIRAM-like (range up to **5.01 um**, spectral sampling **9 nm**)

OPTION01 = Best option for VIRHIS (range up to **6. um**, spectral sampling **5 nm**)

OPTION02 = 2nd option for VIRHIS (range up to **6. um**, spectral sampling **7 nm**)



Grassi D. et al., submitted PSS 2009

Summary

- VIRHIS study is on going, now entering the phase with an higher level of details
- Funding of the study is not yet available, formal procedure is on going with ASI, CNES and DLR
- No stopping point is identified til now
- A more tight interaction or exchange of information between instrument study and science definition teams is very desirable in order to optimize the efforts on both sides