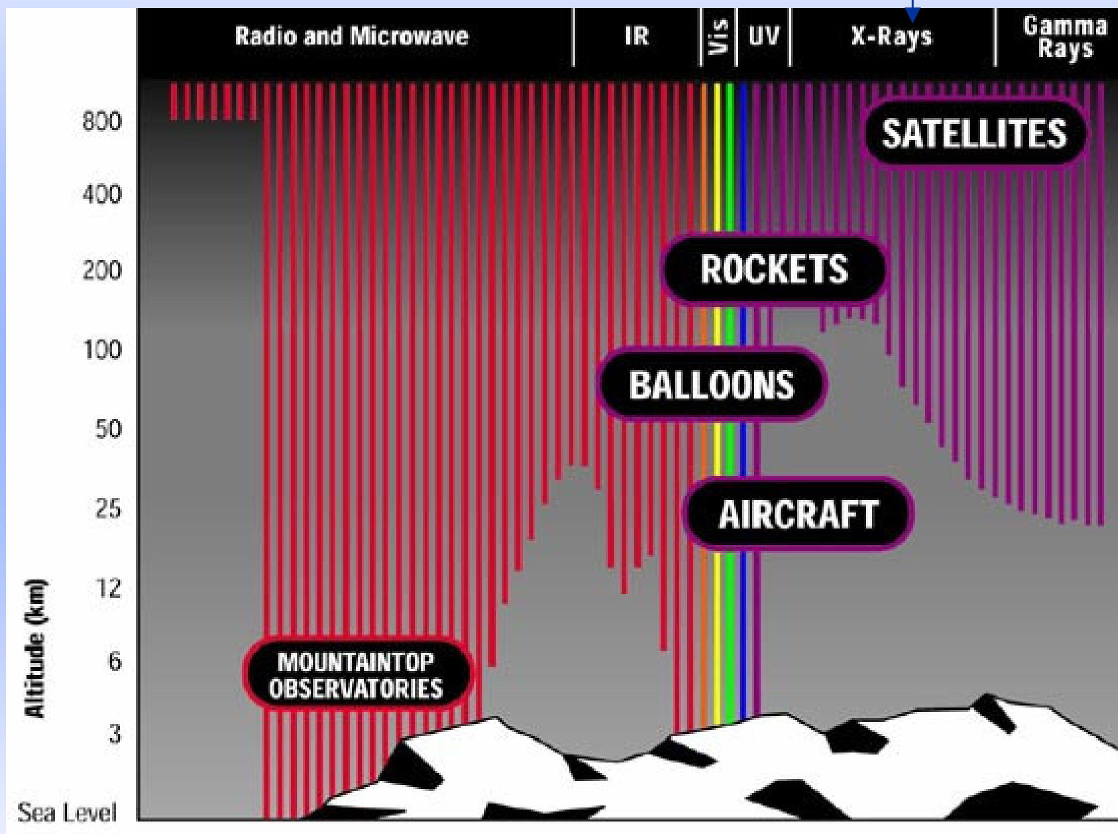
# World Space Observatory (WSO/UV)


M.Uslenghi

# Outline

- Why an UV mission?
- WSO/UV overview
  - Telescope
  - Focal plane instruments
- The imaging camera unit

# UV light




Earth's atmosphere is opaque below ~ 320 nm

Observations only from space



M.Uslenghi, IASF-MI

# UV instrumentation issues

- Optical materials: limited choices for good transmissions or reflectivities; challenge greater for shorter wavelengths.
- Cleanliness and contamination control are critical because many materials are UV-opaque
- UV designs similar to optical-band, but fewer surfaces preferred, due to the lower efficiency
- Filters:
  - require excellent long-wave blocking (not so easy …): astronomical sources typically emit $10^6$-$10^8$ more photon in optical than in UV
  - require good blocking of strong geocoronal, skyglow emission lines (Lyman-alpha 1216 Å, O I 1302 Å)
- Detectors with low efficiency (and often with high effeiciency in the optical, see the prev. point)

# Ultraviolet Astronomy

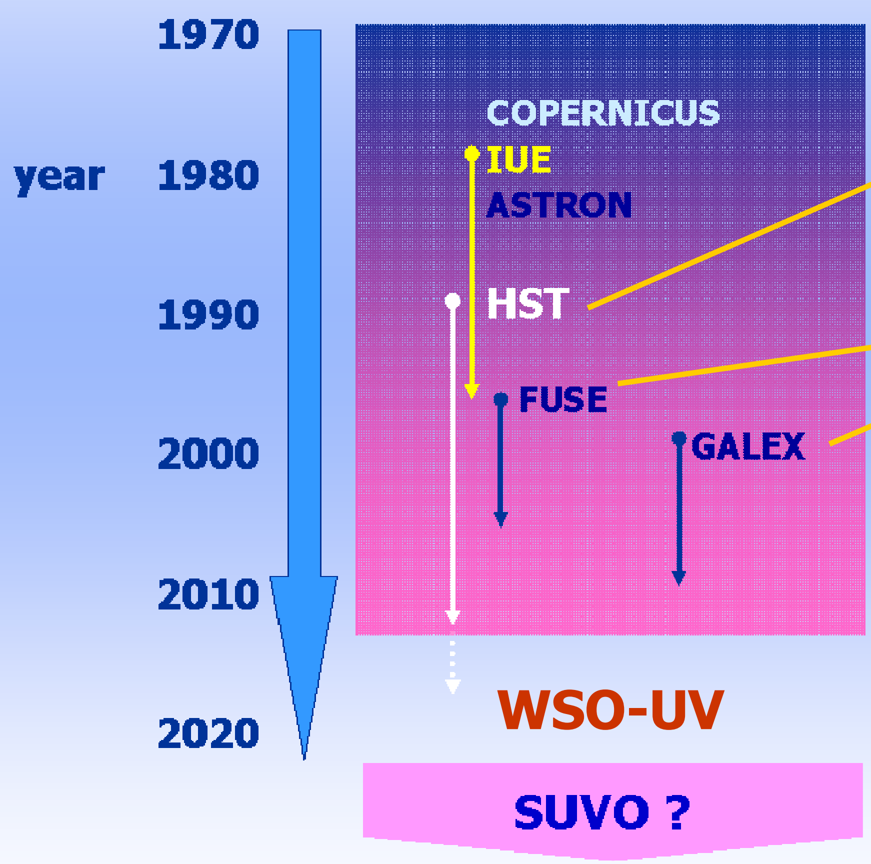
- UV spectroscopic and imaging capabilities are a fundamental tool to study plasmas at temperatures in the 3,000-300,000 K range
- Most resonance transitions from ions, atoms, and also molecules ($H_2$, CO, OH, CS, $CO_2^+$, $CO_2$) of astrophysical significance are in the ultraviolet wavelength domain.

↓

- UV provides very sensitive tools:
  - to trace the distribution of (baryonic) matter in the Universe,
  - to diagnose the chemical composition, physical properties and kinematics of astronomical objects of all types.

**“UV astronomy gives *Highest density* (bits per unit wavelength) of astrophysical information on stars and gas “**

# Astronomical UV facilities




| Facility (lifetime) | Type of Instrument | Spectral Range (nm) | Field of view (arcsec) | Spectral Resolution R | Spatial Resolution |
|---|---|---|---|---|---|
| HST (1990-2013 ??) | Imaging-ACS(HRC) | 200-1100 | 26x29 | Broad band filters (FWHM ~ 40nm) | 0."027 pix$^{-1}$ |
| | Imaging-ACS(SBC) | 115-170 | 31x35 | Continuum filters | 0."032 pix$^{-1}$ |
| | Spectroscopy-ACS | 115-390 | Grism | 100 | |
| | *Spectroscopy-COS* | 115-320 | | 2000 - 24000 | |
| FUSE (1999-2010 ??) | Spectroscopy | 90.5-118.7 | | 20000 | |
| GALEX (2003-early 2007 ??) | Imaging | 135-300 | All-sky | Two broad bands: NUV(180-300) and FUV(135-180) | 3"-5" |
| | Spectroscopy | 135-300 | (grism) | 100 | |

Access to UV is becoming problematic. Even with a full success of the 4° servicing mission (→ Hi-res spectroscopy in classical UV), it is unlikely that HST will remain operative after 2012-2013

NASA & ESA do not have plans for a new UV mission → not before 2020-2025

# Future?

- High scientific value projects ongoing with HST and GALEX; some of them needs extended temporal coverage (e.g. variability, proper motions)

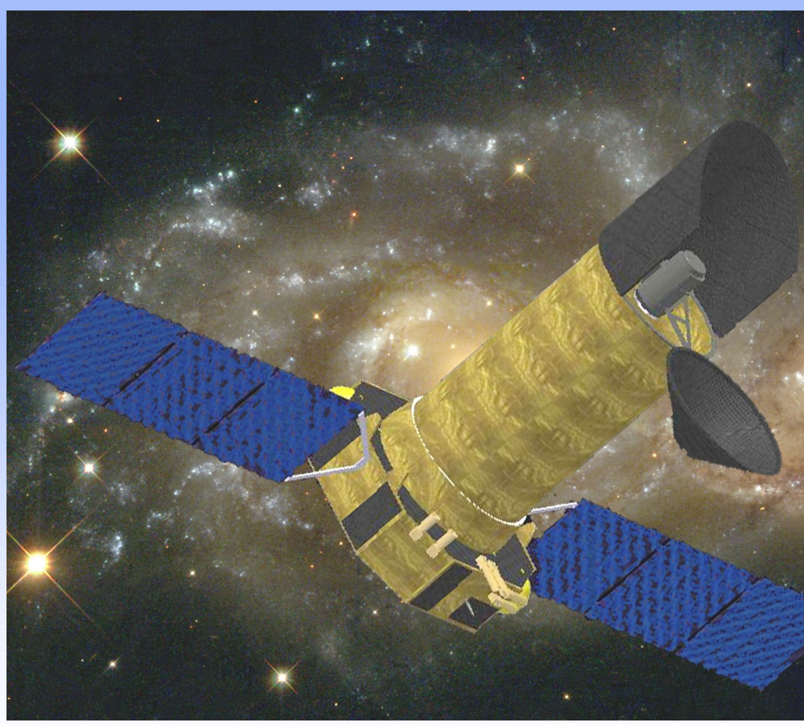
- No UV high angular resolution counterparts for JWST and ground-based next generation 30m+(NIR+ AO/MCAO) telescopes.

# WSO-UV

## World Space Observatory / Ultraviolet Project

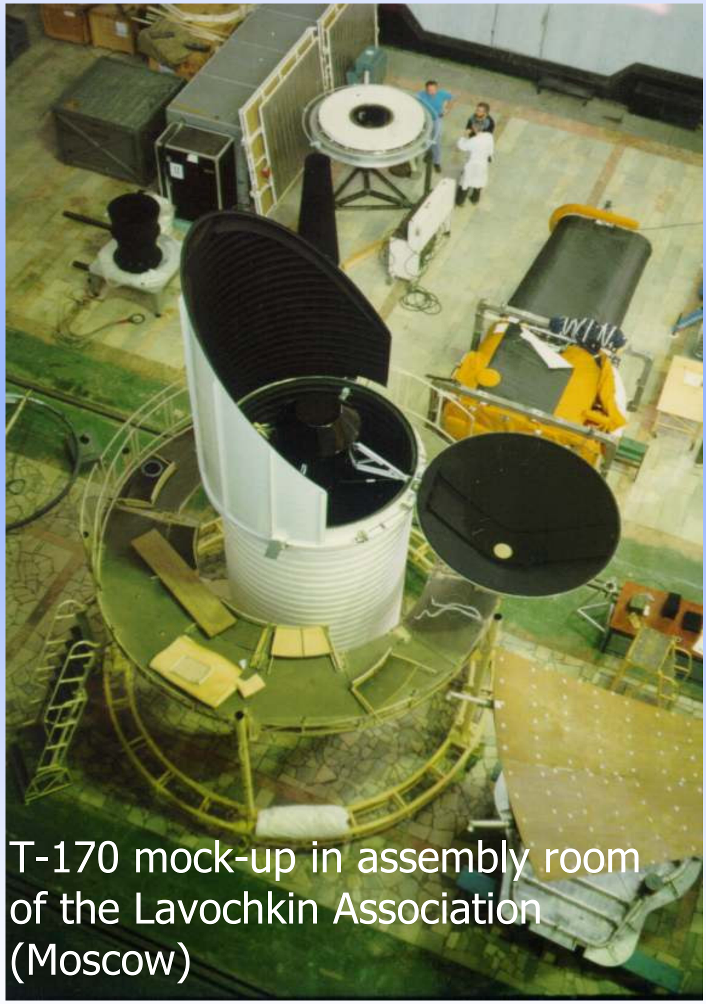
**Objective:**

**Provide spectroscopy and imaging access to the UV (110 - 300 nm) sky.**



| | |
|---|---|
| **Launch date:** | 2012 |
| **Duration:** | 5 years (+5years) |
| **Orbit**: | Circular/geosyncrhronous<br>~35,800 Km<br>51.8° orbit inclination |
| **Telescope:** | T-170M *(Russia)* |
| **Platform:** | Navigator *(Russia)* |
| **Launcher**: | Zenith + Fregat *(Russia)* |
| **GS:** | *Russia, Spain (contributions from Italy, China, Ukraine, South Africa … are being considered)* |
| **Focal Plane Instruments**: | Hirdes (Germany)<br>LSS (China, UK)<br>FCU (Italy) |

# Telescope T-170

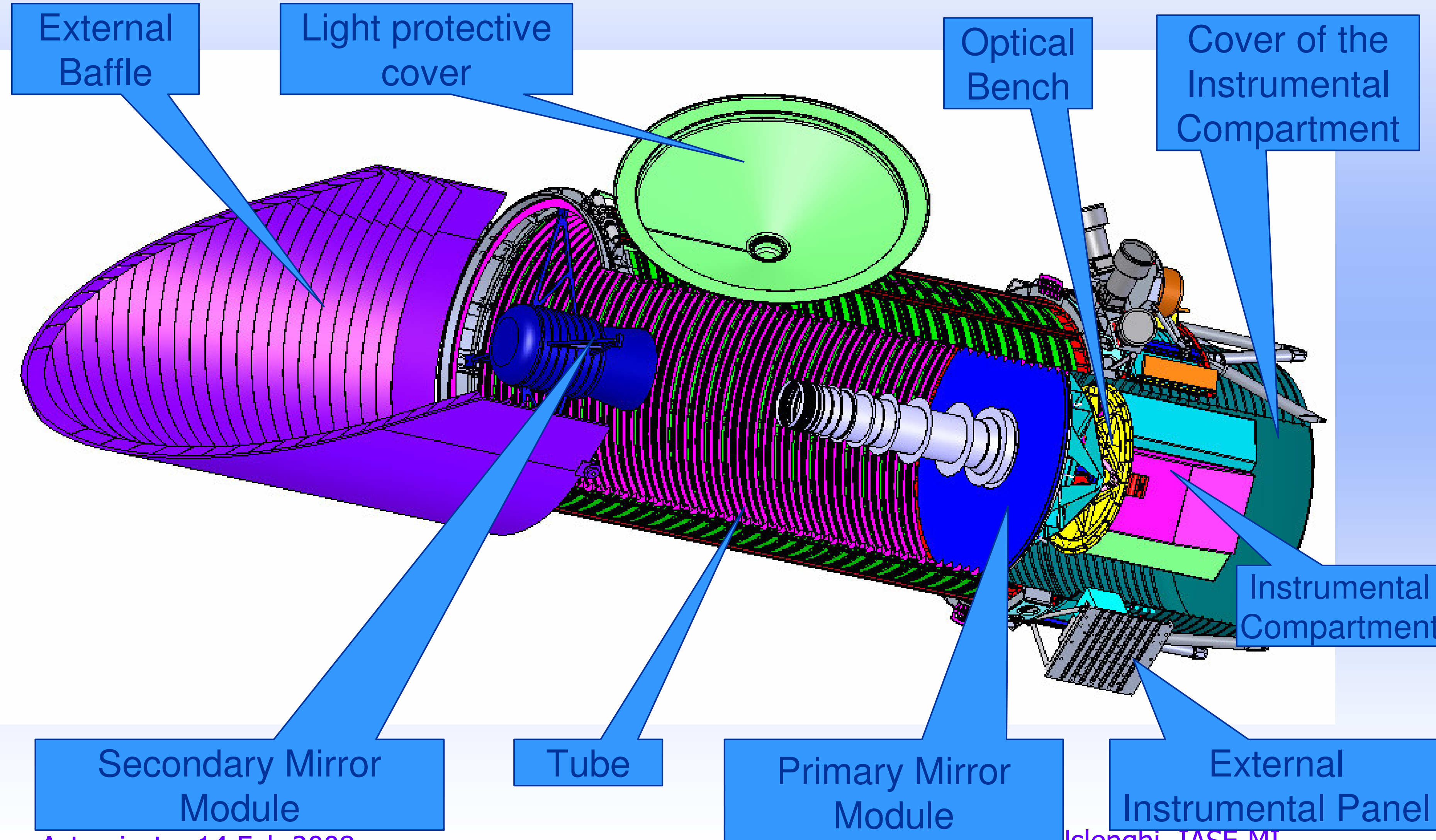

T-170 mock-up in assembly room of the Lavochkin Association (Moscow)

The WSO/UV telescope (T-170M) is a new version of the T-170 telescope designed in Russia by Lavochkin Association for Spectrum-UV mission.

| | |
|---|---|
| **Optical System** | Ritchey-Chretien aplanat |
| **Aperture diameter** | 1700 mm |
| **Telescope f-number** | 10.0 |
| **FOV** | 30' (150 mm in diameter) |
| **Wavelength range** | 100-310 nm (+visible) |
| **Primary Wavelength** | 200 nm |
| **Optical quality** | Diffraction optics at the FOV center |
| **Mass** | 1570 kg (1600 with adapter truss) |
| **Size** | 5.67x2.30 m (transport)<br>8.43x2.3 m (operational) |

WSO - UV

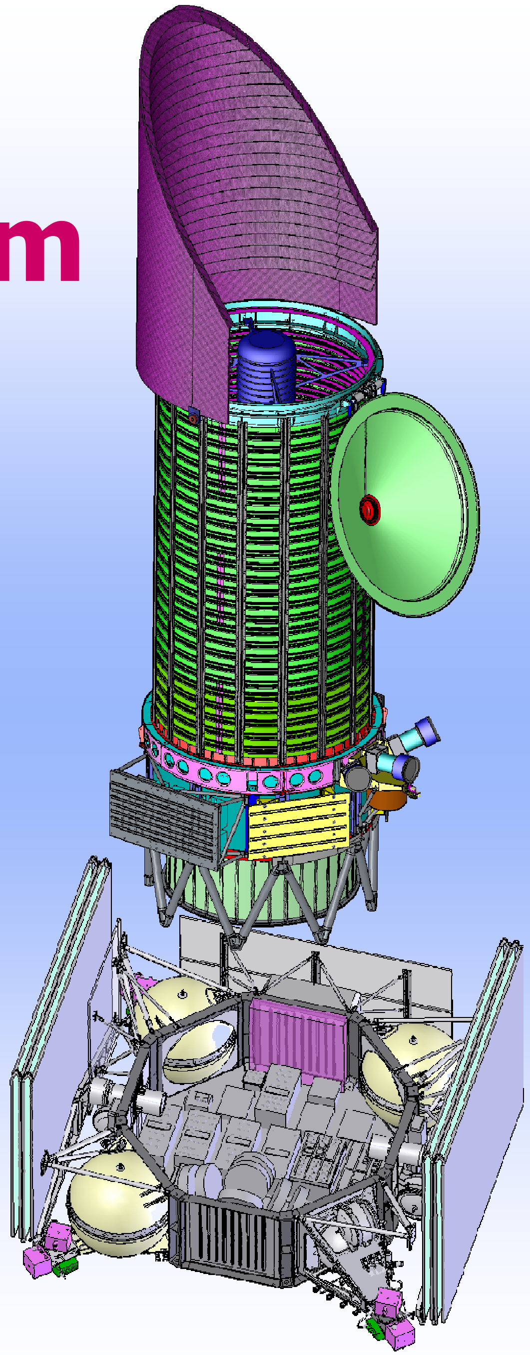
# T-170M Telescope



# The *Navigator* platform

- The WSO-UV bus is the "Navigator" service module used for other Russian projects: e.g. "Electro" and "Radioastron" that will fly before WSO-UV, and Spectrum X-gamma which will follow WSO-UV.

- The "Navigator" of WSO-UV requires adaptation of radio complex, antenna-feeder system and software of on-board control system in terms of precision telescope pointing.

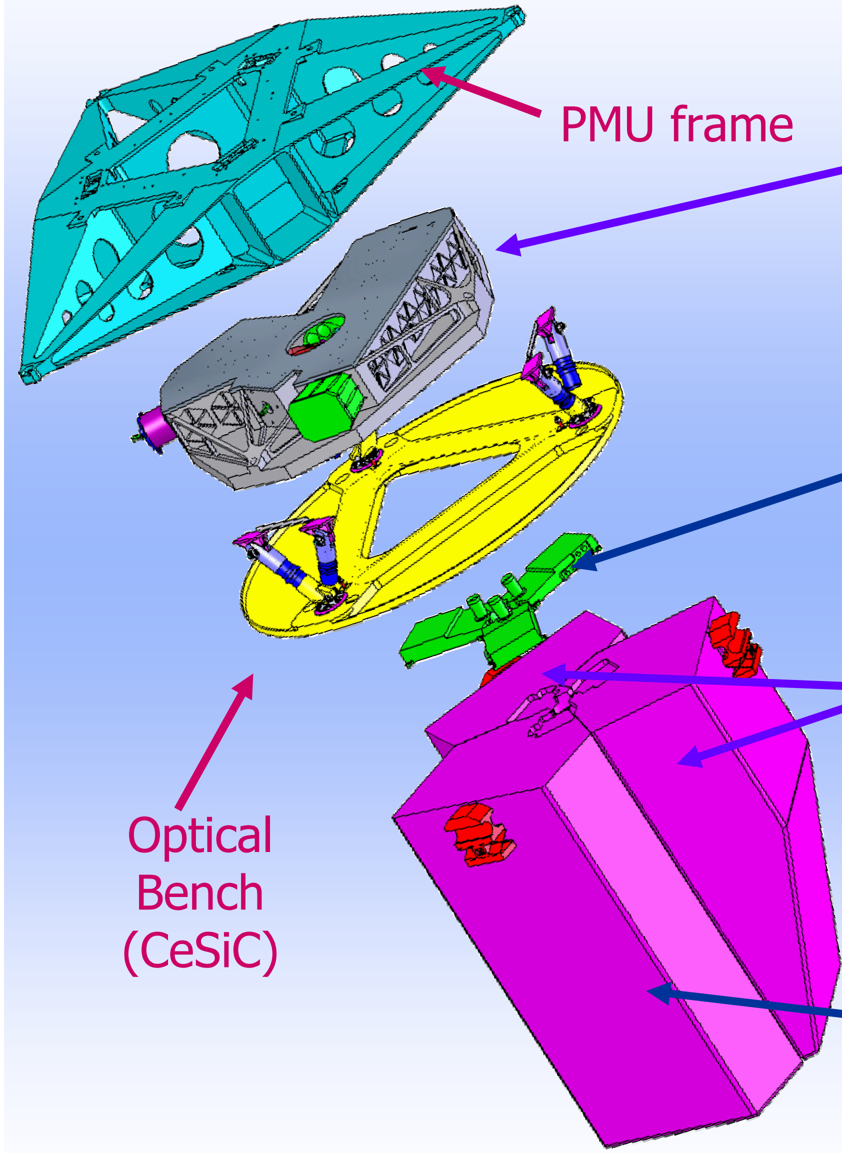


# WSO-UV Payload

Focal plane instruments will provide:

- High resolution UV spectroscopy **HIRDES**
- Long slit low resolution spectroscopy **LSS**
- Deep UV and high resolution optical imaging **FCU**

# Scientific Instrument Compartment




**FCU**: 3-channel Imager:

**FUV, NUV, UVO**

***FGS***: Fine Guidance System (3 sensors 1kx1k)

**HIRDES**: high-res echelle spectrographs:

**UVES** (178-320nm)

**VUVES** (102-180nm)

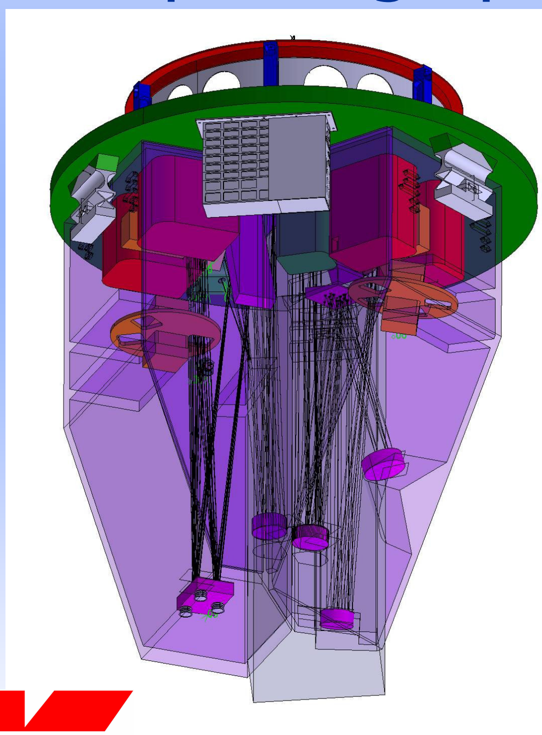
**LSS**: 102- 320 nm, low-res long slit spectrograph

# WSO-UV Hi-Res Spectrograph

## **HIRDES** (High Resolution Double Echelle Spectrograph)

**R ≥ 55,000** echelle spectrographs

| | **UVES** | **VUVES** |
|---|---|---|
| Wavelength coverage | 178-320nm | 102-180nm |
| Limiting mag (SNR=10 in 10h) | 18 | 16 |
| Detectors | MCP | MCP |



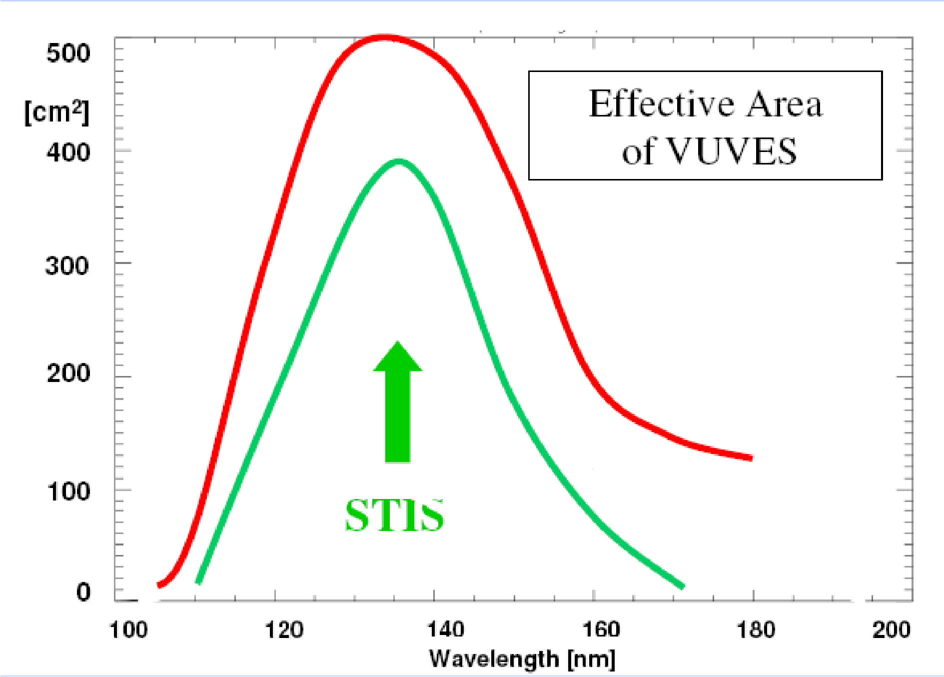
**Funding Agency:** DLR
**Science Contractor:** Universität Tübingen, Institut für Astronomie und Astrophysik
**Industry Contractor:** Kayser Threde
**Principal Investigator:** Prof. Dr. Klaus Werner
**Instrument Scientist:** Dr. Norbert Kappelmann

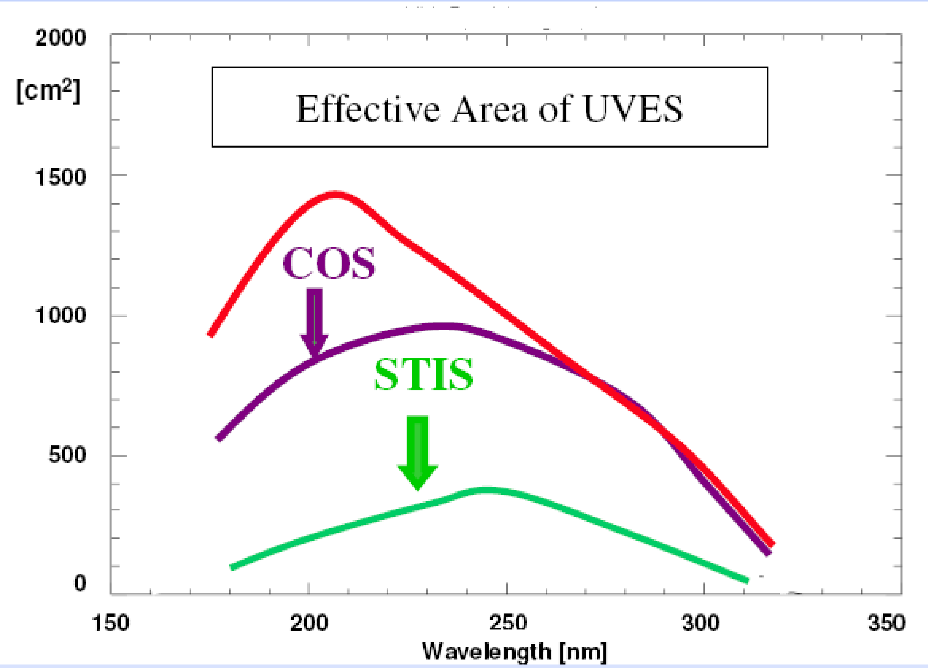
KAYSER-THREDE

**STATUS:** ***B1 completed***

# HIRDES effective area

Spectral resolution of HIRDES (UVES & VUVES, R~50,000) is similar to HST-STIS, but higher than HST-COS (R~20,000)




Sensitivity is comparable with COS (lower in FUV, higher in NUV) and definetly better than STIS

ETC available at http://astro.uni-tuebingen.de/groups/wso_uv/exptime_calc.shtml

# WSO-UV Low-Res Spectrograph

## LSS (Long Slit Spectrograph)

**Funding Agency:** CNAS
**Science Contractor:** National Astronomical Observatories of China Academy of Science (NAOC)
**Industry Contractor:** to be selected
**Principal Investigator:** Prof. Gang Zhao

| Parameter | Requirements |
|---|---|
| Wavelength coverage<br>– FUV channel<br>– NUV channel | 102~190 nm (1 or 2 subchannels)<br>190~320 nm |
| Width of slit | 1″ ≈ 82 μm |
| Length of slit | 75″ ≈ 6.2 mm |
| Spectral resolution | 1500~2500 |
| Spatial resolution | 0.5″~1″ |
| Detectors | MCPs |

**STATUS:** ***Phase A completed. Phase B1 end in March 2008***

# WSO-UV Imagers

## FCU

### Field Camera Unit

**Funding Agency:** ASI
**Science Contractor:** Istituto Nazionale di Astrofisica (INAF)
**Industries involved:** Galileo Avionica, Thales Alcatel Alenia Space
**Principal Investigator:** Dr. Isabella Pagano
**Project Manager**: Dr. Salvatore Scuderi (INAF CT)

**STATUS:** ***Phase B1 completed***

# WSO-UV imagers guidelines

- Large wavelength coverage (115-700nm)
- Large field of view
- High spatial resolution; mandatory to:
  - Morphological studies (e.g. planets, planetary nebulae, star formation regions, external galaxies)
  - High accuracy stellar photometry
  - High accuracy stellar astrometry
  - Resolve stars in crowded fields (e.g. in star clusters, external galaxies, star formation in AGNs)

# FCU main parameters

| Camera | Parameter | Specifications |
|---|---|---|
| FUV | Wavelength Range | 115-190 nm |
| | Field of View | 6.6′x6.6′ (2kx2k) |
| | Scale | 0.2″/pix |
| | Pixel size | 20μm |

No f-number change

→Optimize efficiency

| | | |
|---|---|---|
| NUV | Wavelength Range | 150-280 nm |
| | Field of View | 1′x1′ (2kx2k) |
| | Scale | 0.03″/pix |
| | Pixel size | 20μm |

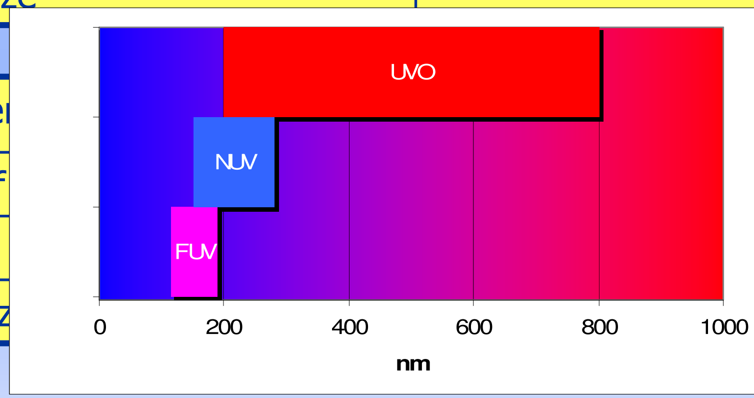
| | | |
|---|---|---|
| UVO | Wavelength Range | 200-700 nm |
| | Field of View | 4.7′x4.7′ (4kx4k) |
| | Scale | 0.07″/pix |
| | Pixel size | 15μm |

# FCU main parameters

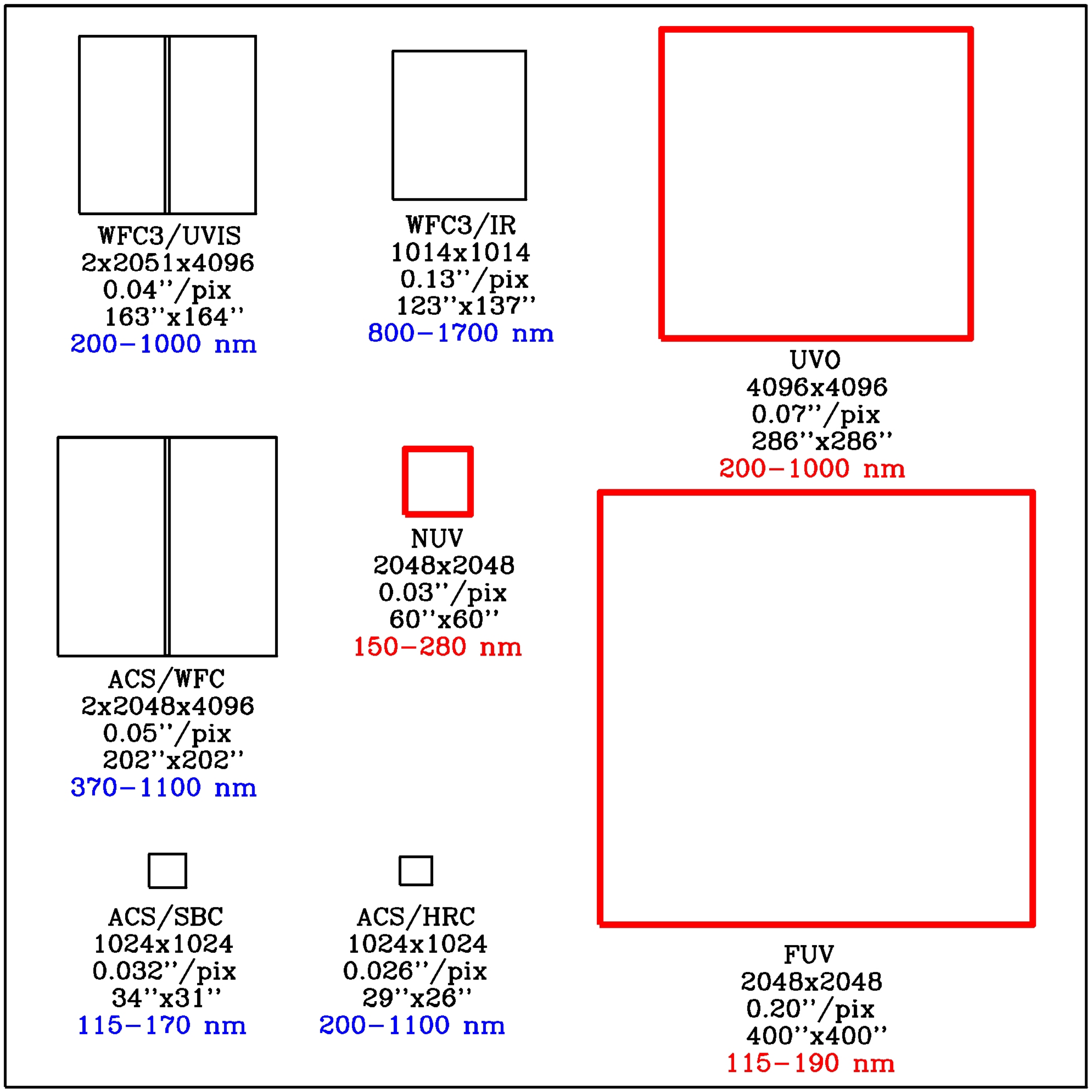
| Camera | Parameter | Specifications |
|---|---|---|
| **FUV** | Wavelength Range | 115-190 nm |
| | Field of View | 6.6′x6.6′ (2kx2k) |
| | Scale | 0.2″/pix |
| | Pixel size | 20µm |
| **NUV** | Wavele | 0-280 nm |
| | Field of | 1′ (2kx2k) |
| | Scale | .03″/pix |
| | Pixel siz | 20µm |
| **UVO** | Wavelength Range | 200-700 nm |
| | Field of View | 4.7′x4.7′ (4kx4k) |
| | Scale | 0.07″/pix |
| | Pixel size | 15µm |

No f-number change

→Optimize efficiency

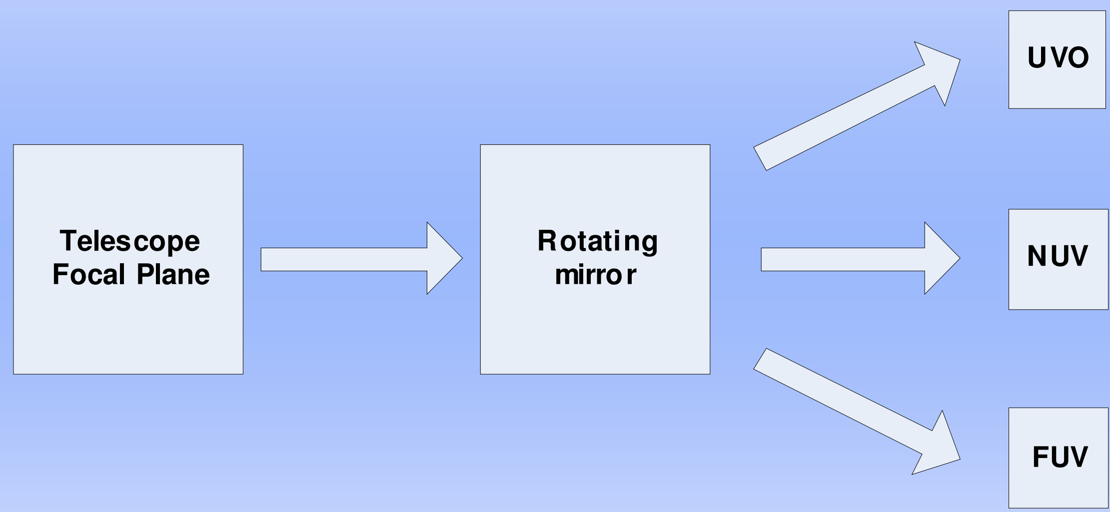


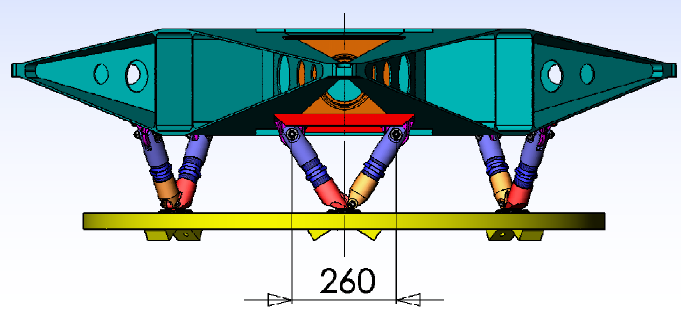
# FCU vs. ACS/WFC3



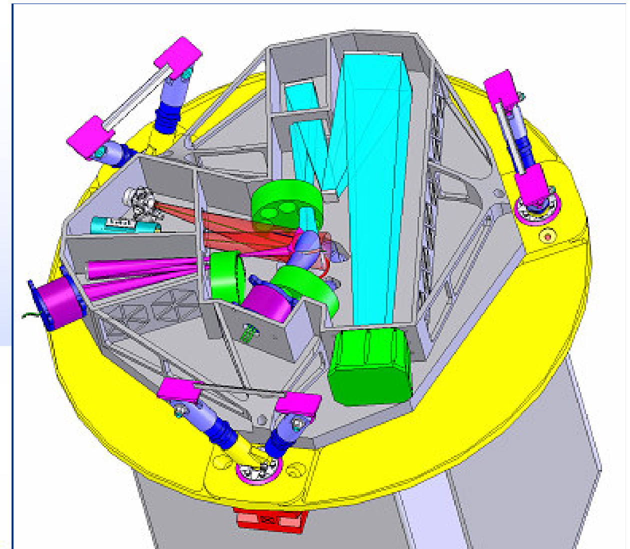

- **UVO**: 2 times larger field of view than ACS, and 3 times larger than WFC3/UVIS; high angular resolution (diffraction limit @500nm). Undersampled, but sampling as for ACS and WFC3
- **FUV:** same field as UVO; Much larger than the ACS/SBC field of view, (lower angular resolution, but still OK for many surveys)
- **NUV:** high angular resolution similar to ACS/SBC + ACS/HRC, but four times larger field of view than ACS/SBC + ACS/HRC; unique spectropolarimetry facilities.

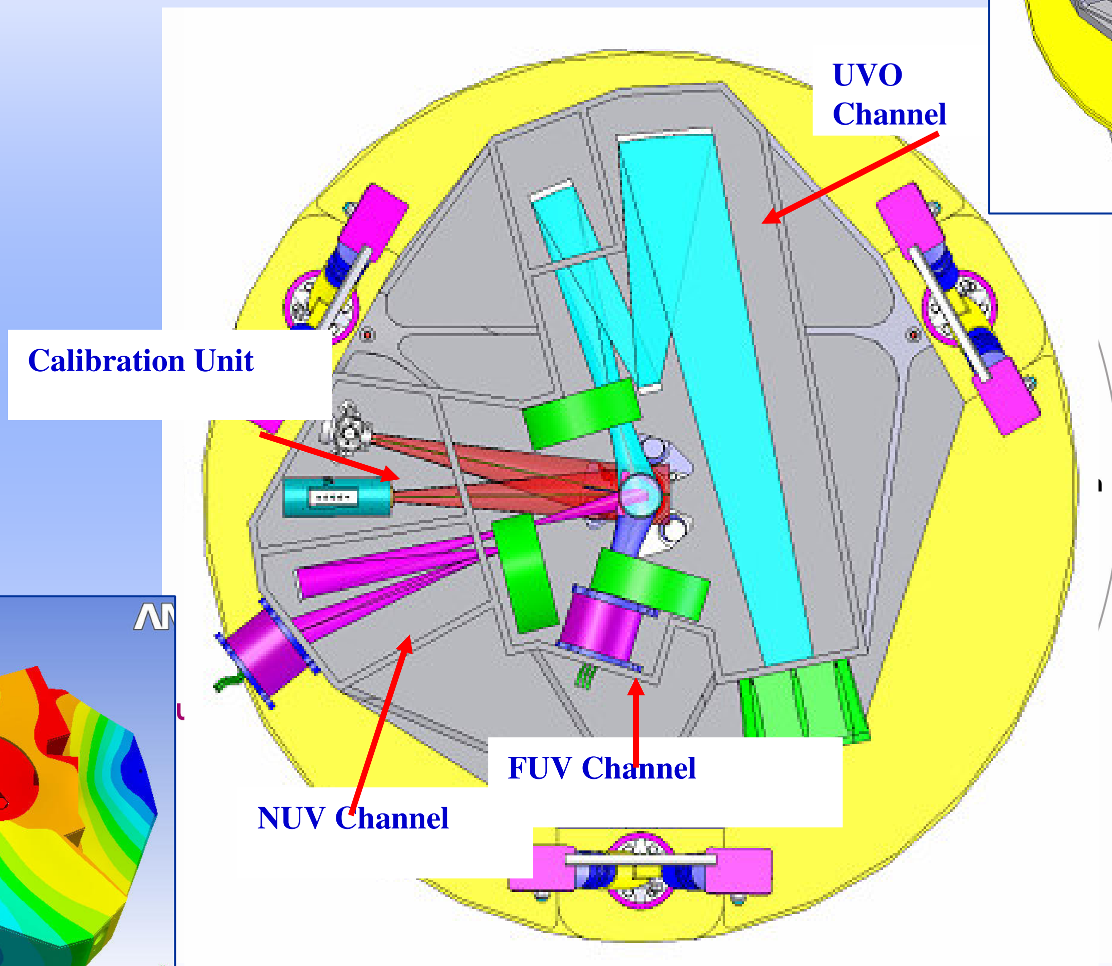
# FCU Layout

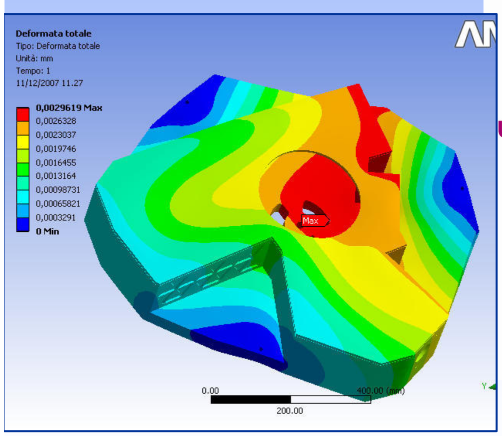


# FCU Layout




UVO
Channel
Calibration Unit
NUV Channel
FUV Channel


Deformata totale
Tipo: Deformata totale
Unità: mm
Tempo: 1
11/12/2007 11.27
0,0029619 Max
0,0026328
0,0023037
0,0019746
0,0016455
0,0013164
0,00098731
0,00065821
0,0003291
0 Min
0.00
200.00
400.00 (mm)

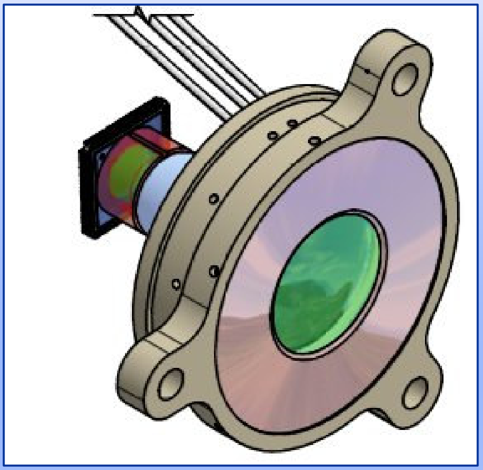
# FCU Detectors

**FUV & NUV Channel:** **Solar blind,**
(identical, except for the photocathode)
MCP-based, photon counting detectors, in sealed configuration

Format: 2kx2k (40mm)

Read-out system: CCD

Photocathodes: CsI (FUV), CsTe (NUV)



**OUV Channel:** CCD

Format: 4kx4k (61mm)

Pixel size: 15 μm

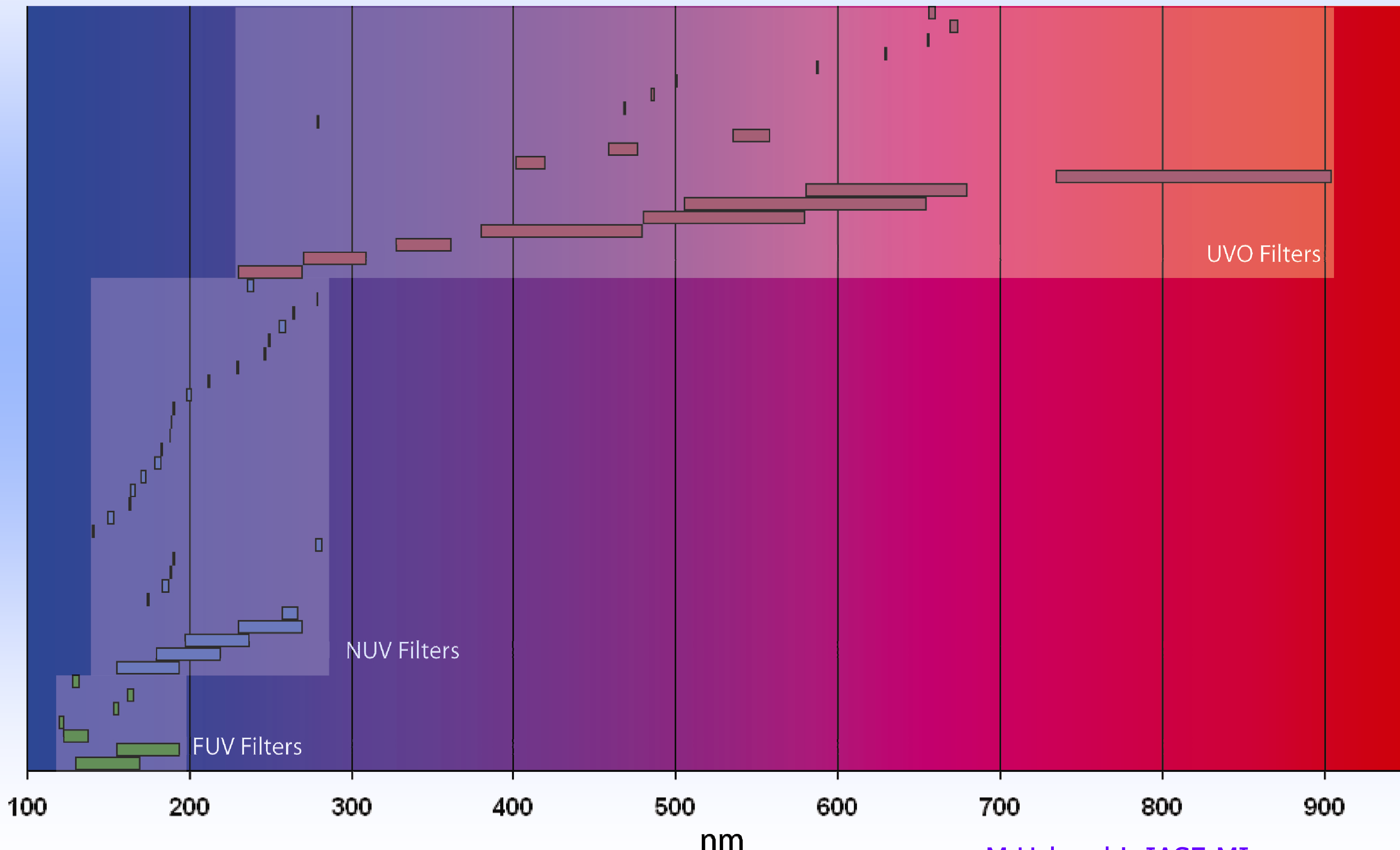
Back illuminated

MPP

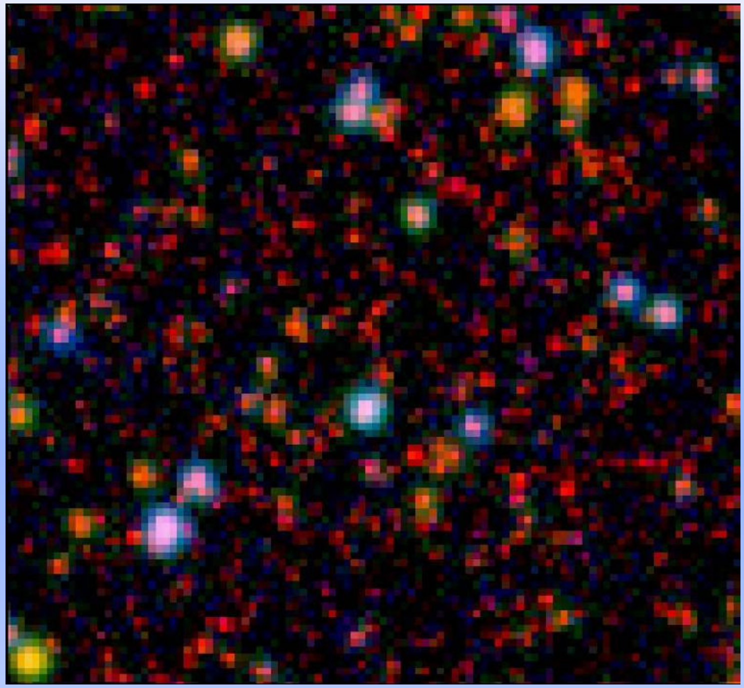
# Operating Modes

- Optical Mode
  - Imaging (FUV, NUV, UVO channel)
  - Polarimetry (NUV, UVO)
  - Slitless spectroscopy (FUV, NUV, UVO channel)
  - Slitless spectropolarimetry (NUV channel)
- High Time Resolution Mode
  - Time Tag (FUV, NUV)
  - Windowing (FUV, NUV, UVO)
- Calibration Mode

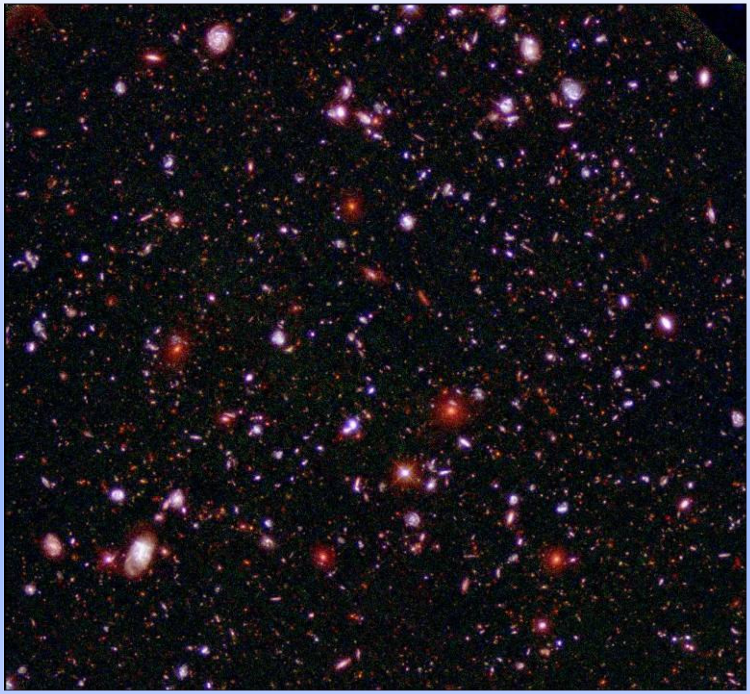
# Filters


UVO Filters
NUV Filters
FUV Filters
100
200
300
400
500
600
700
800
900
nm

# Hubble Deep Field UV counterpart



Part of the UDF: the blue and green channels are GALEX FUV (~1500A, ~75Ks) and GALEX NUV (~2000A, ~76 Ks), the red channel is the VIMOS@VLT deep imaging (~36000Ks) in band U. Most of the red "noise" are objects detected in ground based U band, but not detected in GALEX data. The size of the image is 2'x2'.



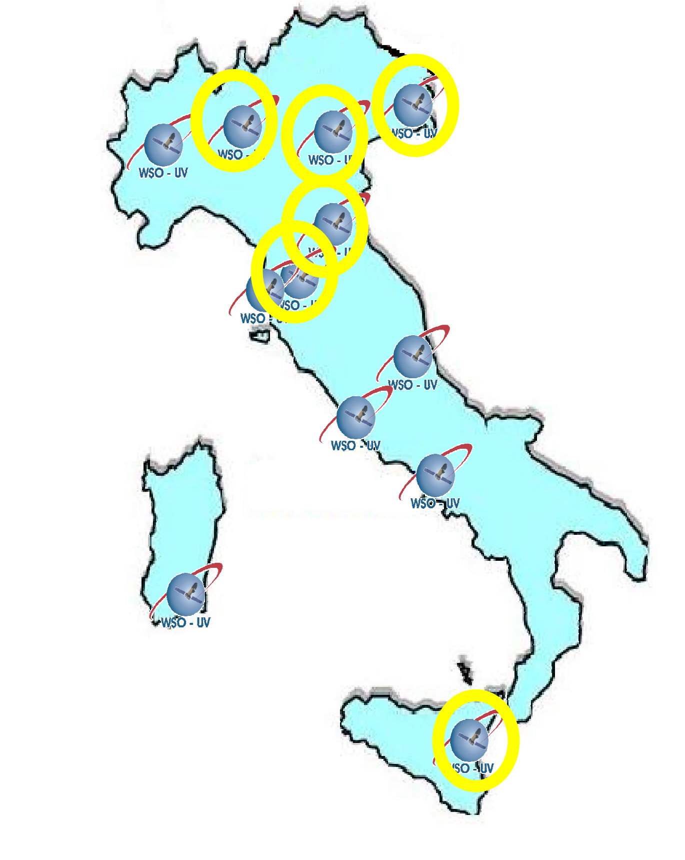
Simulation of the same field: the blue and green channels are WSO-FUV and WSO-NUV respectively, while the red is U band image.



M.Uslenghi, IASF-MI

# WSO-UV in Italy

- **INAF**
  - Catania Obs., Napoli Obs., Padova Obs., Milano IASF, Bologna IASF & Obs., Torino Obs., Trieste Obs., Cagliari Obs., Teramo Obs., Roma IASF.
- **Universities**
  - DASS Firenze, Dip. Astr. Padova, Dip. Astr. Univ. Bologna, Univ. Pisa
- **Industrial support**
  - Galileo Avionica, Thales Alenia Space Italy (MI)



# Technical Team

- Isabella Pagano (chair) - INAF-OA Catania
- Andrea Bulgarelli - INAF-IASF Bologna
- Domitilla de Martino - INAF-OA Capodimonte, Napoli
- Giacinto de Paris - INAF Sede Centrale
- Mauro Fiorini - INAF-IASF Milano (resp. Electronics)
- Lisa Gambicorti - Dip. di Astronomia e Scienza dello Spazio - Università di Firenze
- Alessandro Gherardi - Dip. di Astronomia e Scienza dello Spazio - Università di Firenze
- Fulvio Gianotti - INAF-IASF Bologna
- Demetrio Magrin - INAF-OA Padova
- Matteo Munari - INAF-OA Catania
- Emanuele Pace - Dip. di Astronomia e Scienza dello Spazio - Università di Firenze (resp. NUV camera)
- Maurizio Pancrazzi - Dip. di Astronomia e Scienza dello Spazio - Università di Firenze
- Giampaolo Piotto - Dip. di Astronomia - Università di Padova (science team chair)
- Cristian Pontoni - INAF-OA Catania (resp. Mechanics)
- Daniela Recupero - INAF-OA Catania
- Salvo Scuderi - INAF-OA Catania (system eng & resp. UVO camera)
- Massimo Trifoglio - INAF-IASF Bologna (resp. GSE)
- Michela Uslenghi - INAF-IASF Milano (resp. FUV camera)
- Sandro Villanova - Dip. di Astronomia - Università di Padova

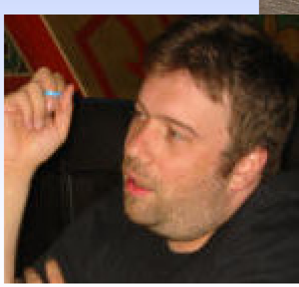
# Science Team

- Giampaolo Piotto (chair) - Uni Padova
- Francesca Bacciotti - INAF-OA Arcetri, Firenze
- Luigi Bedin - STScI-ESA
- Enzo Brocato - INAF-OA Teramo
- Lucio Buson - INAF-OA Padova
- Carla Cacciari - INAF-OA Bologna
- Alessandro Capetti - INAF-OA Torino
- Angelo Cassatella - INAF-IFSI Roma
- Riccardo Claudi - INAF-OA Padova
- Domitilla De Martino - INAF-OA Capodimonte, Napoli
- Francesco Ferraro - Dip. di Astronomia - Uni Bologna
- Simone Marchi - Dip. di Astronomia – Uni Padova
- Giacomo Mulas - INAF-OA Cagliari
- Mario Nonino - INAF-OA Trieste
- Emanuele Pace - Uni Firenze
- Isabella Pagano - INAF-OA Catania
- Elena Pian - INAF-OA Trieste
- Salvatore Scuderi - INAF-OA Catania
- Steve Shore – Uni Pisa
- Massimo Turatto - INAF-OA Padova
- Michela Uslenghi - INAF-IASF Milano

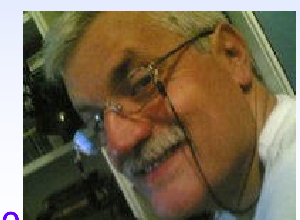
**Scientific interests**

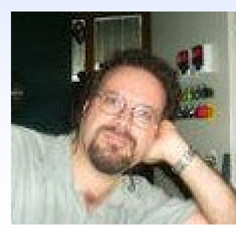
- Planetary Science
- Extrasolar planets
- Intergalactic Media
- Cool Stars & Stellar magnetic activity
- Accretion and Outflow processes
- Stellar Populations in star clusters
- Stellar Populations in nearby galaxies
- SNe
- Galaxies and Active Galactic Nuclei
- Gamma-ray bursts
- The local Universe
- Cosmology

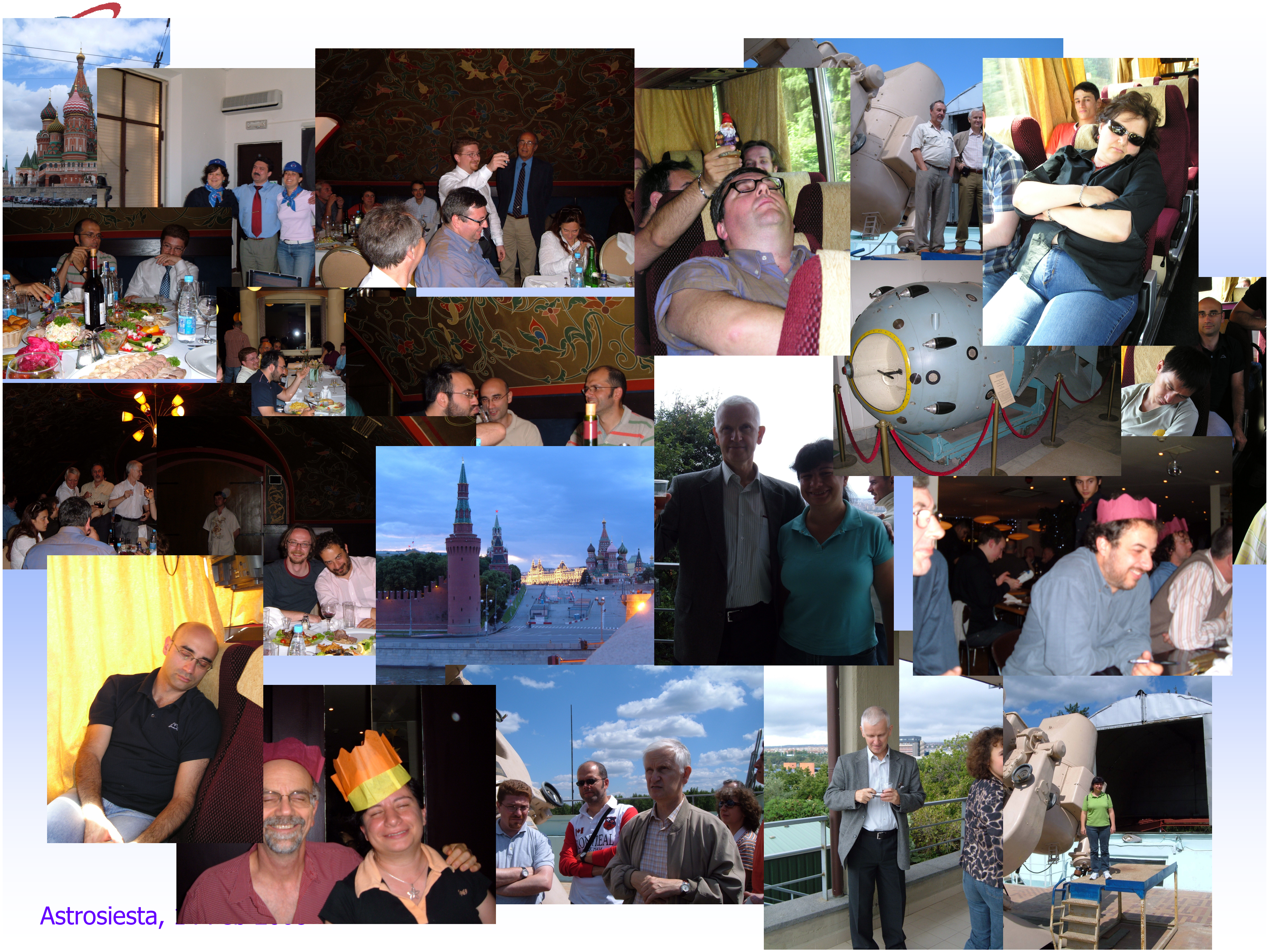
# FCU Team




Rome
Dec 6, 2006







Astrosiesta,

# WSO-UV in INAF LTP

- "Currently, NASA and ESA do not have plans for any future UV mission, which, as a consequence, cannot be expected before the 2020-2025 timeframe. This will produce a big gap between HST and the next ESA/NASA UV mission. It is important that INAF acts in the international context to explore all possibilities to ensure that the UV window remains open in the future. In this regard it is important to carefully evaluate the feasibility also of smaller projects, like WSO."

# More information on the web …

WSO/UV Project home page:

**http://wso.inasan.ru/**

Italian WSO web site:

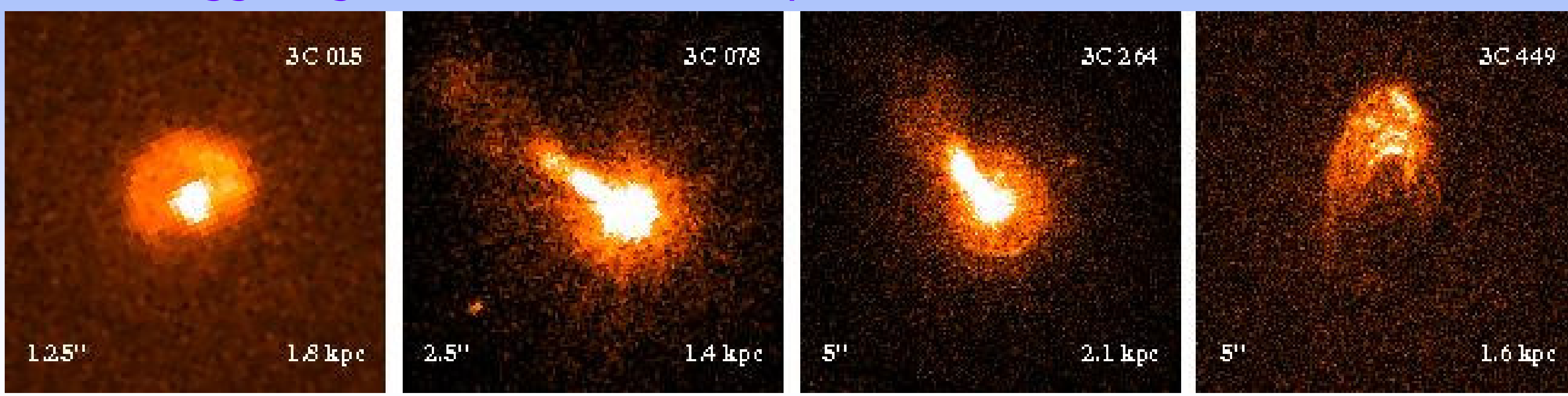
**http://www.oact.inaf.it/wso/index.htm/**


arXiv:0712.0970v1

# Some examples of the WSO science

# How do black holes accretion, jets, and outflows operate?

- AGNs are a fundamental class of astrophysical objects in view of the close connection between nuclear activity and the process of galaxy formation and evolution
- Most of the emission in the UV
- We want to understand the basic accretion and outflow processes and their influence on star formation activity. Why only a fraction of galactic nuclei are active? Which is the triggering mechanism of activity, and what sets its level?

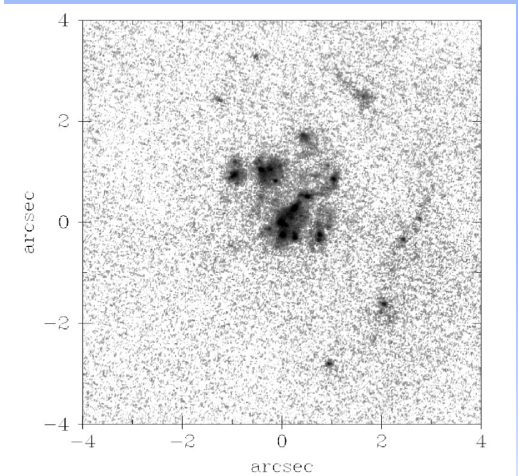


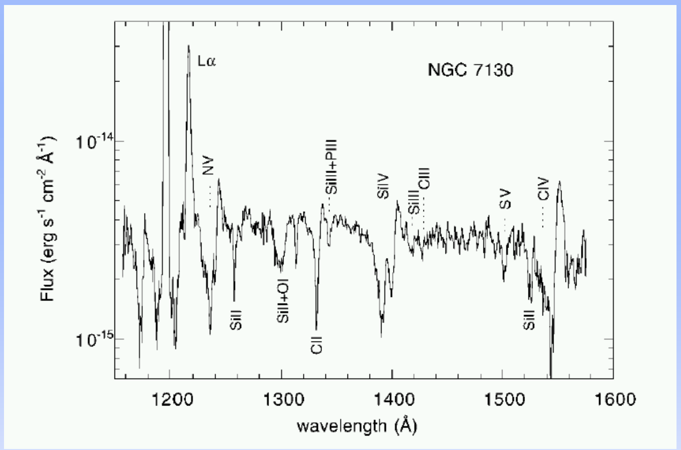
# The co-evolution of galaxies and central SMBH

The close connections between the Black Hole mass and the properties of the host galaxy require a co-evolution of galaxies and SMBH.

Galaxies growth ⟷ Star formation

SMBH growth ⟷ Active Galactic Nucleus



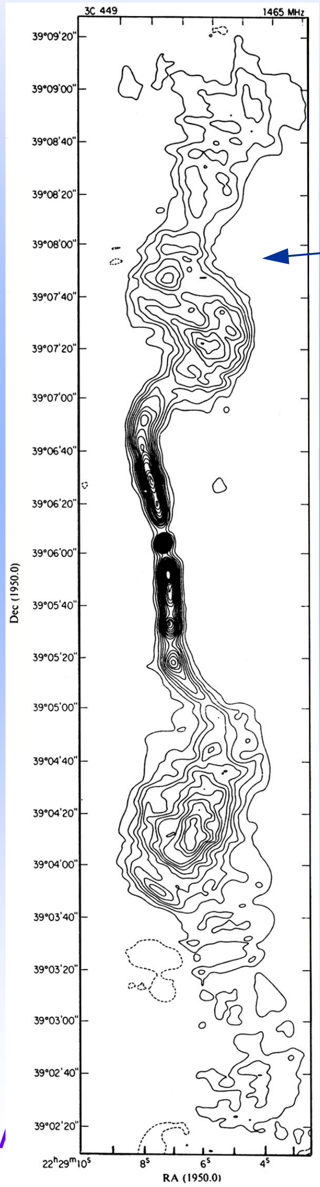




The Seyfert galaxy NGC 7130

UV image and spectrum.

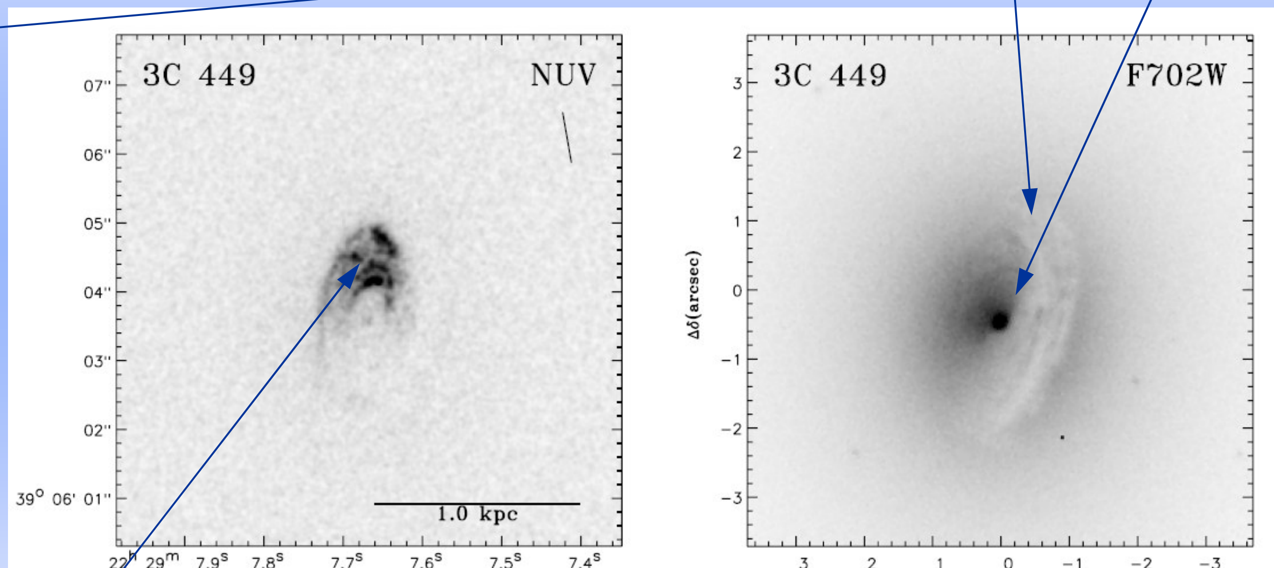
UV observations open a unique window since both AGN and Star Forming Regions emit most of the light in this band. A quantitative energy budget, separating the contribution of AGN and SFR, can be obtained only with high resolution multi-band UV imaging.
UV low resolution spectroscopy also provides important supporting diagnostics.

# A spectacular example: the radio-galaxy 3C449




The center of the galaxy is surrounded by a disk of gas and dust.

The disk feeds the central black hole, producing an active nucleus that ejects a pair of relativistic jets.




UV imaging reveals that the gas in the disk is also forming stars.

A direct manifestation of co-evolution of the galaxy/black hole system.

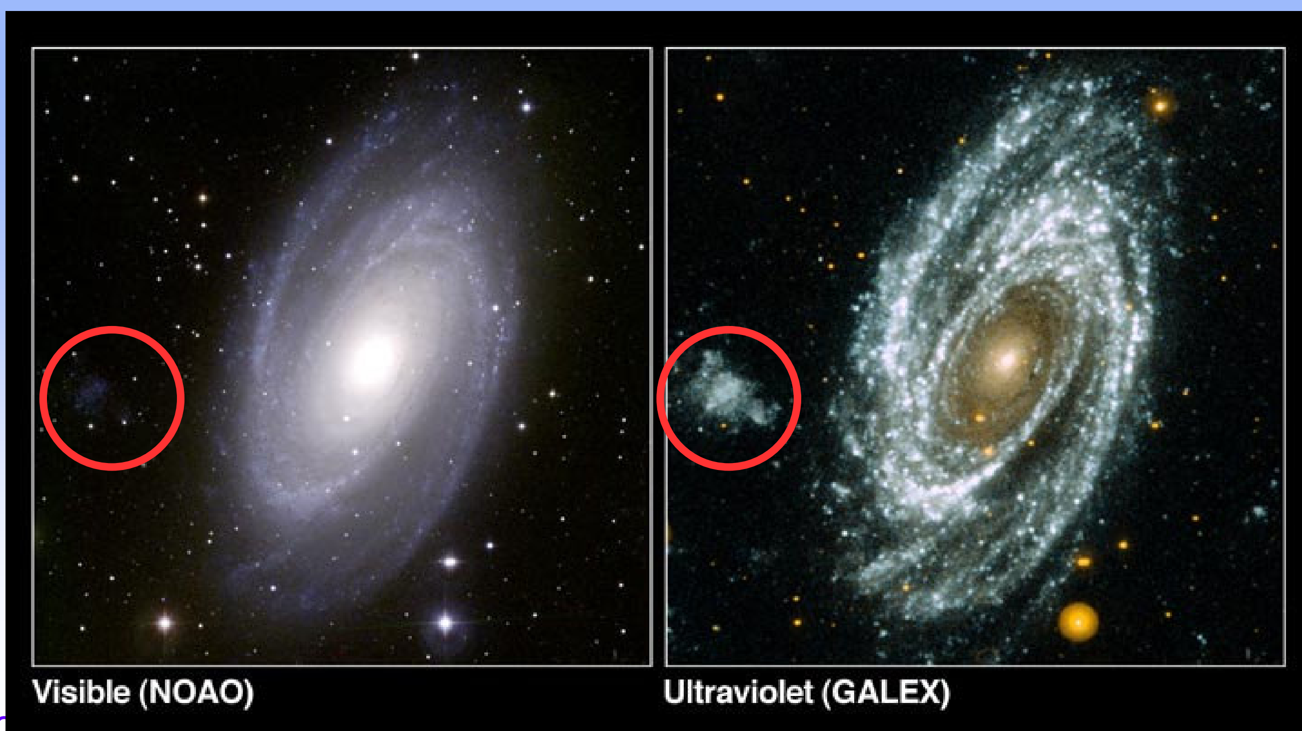
High angular resolution is an important requirement

# UV imaging of our own Local Group Analogs

i) Verify whether there is ongoing star formation;

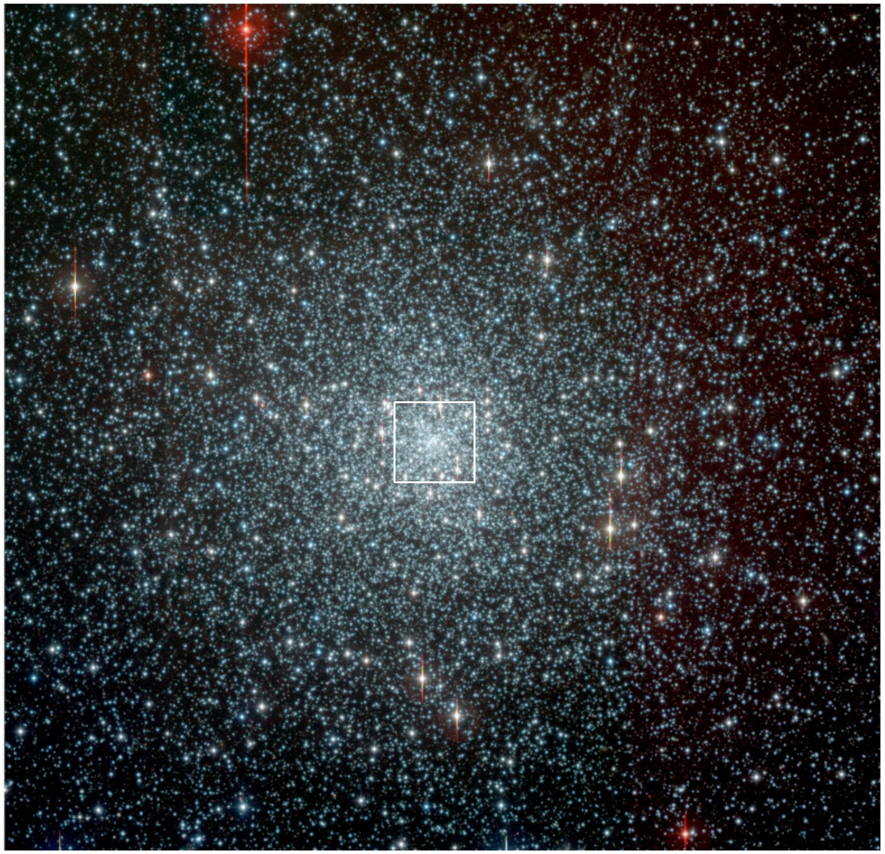
ii) Derive the number ratio of low-mass, star-forming systems to high-mass galaxies, addressing the so-called ''missing satellite'' problem;

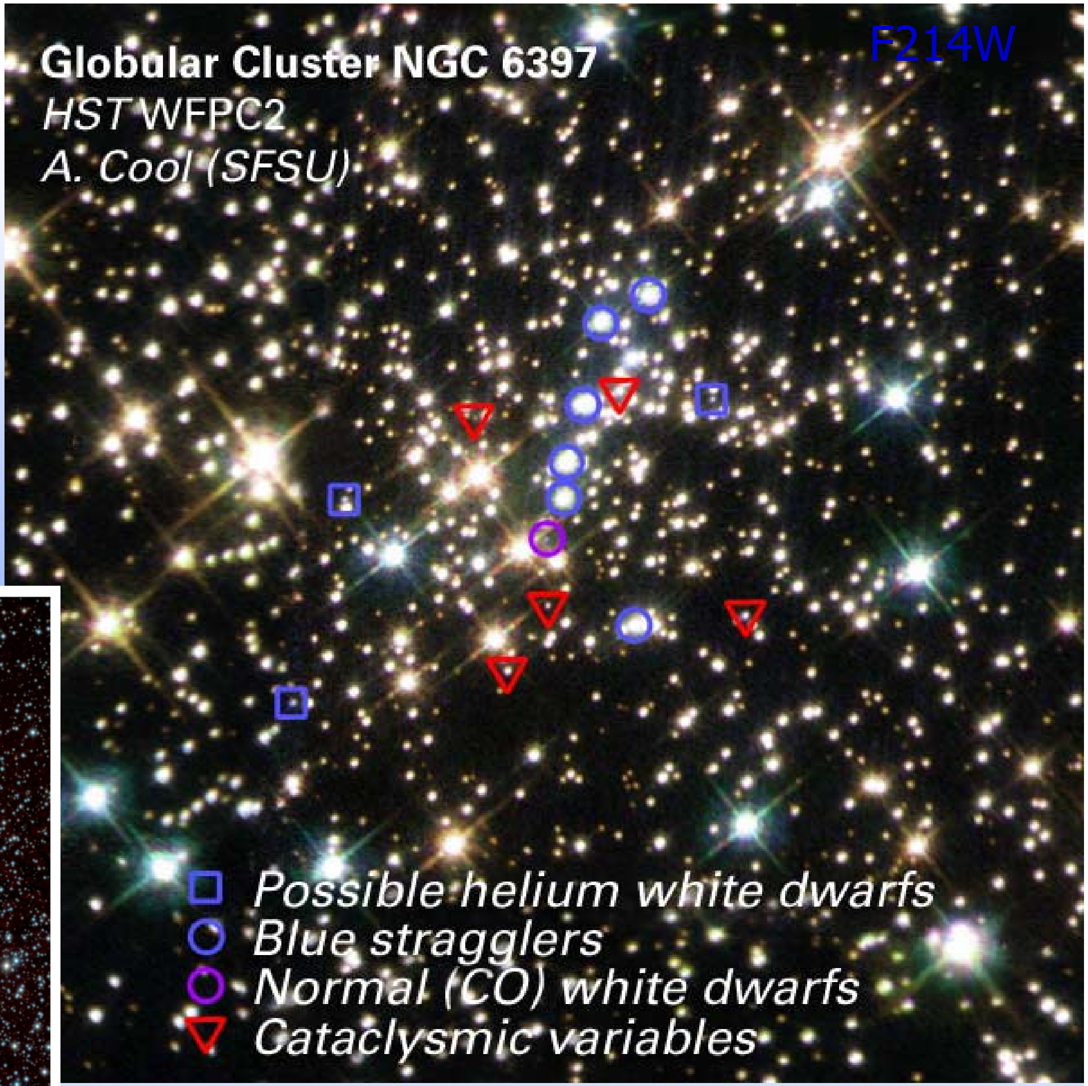
iii) Compare their properties with those of the Local Group dwarf satellites to better understand their formation and evolution.




Comparison of optical (left) and GALEX NUV+FUV (right) images of the nearby spiral M81. Notice how the satellite dwarf irregular Holmberg IX shows up at UV wavelengths.

In general, UV observations enable a number of studies on the stellar populations in dense star clusters





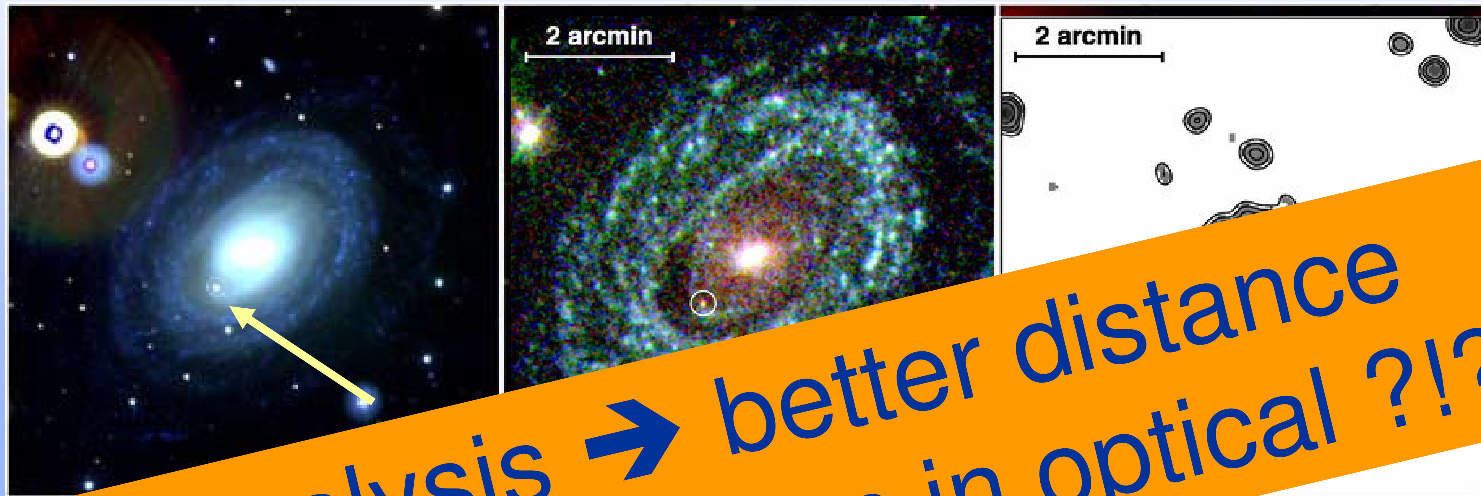

Globular clusters images in UV are not dominated by the red giant light, and therefore significantly less crowded.

M.Uslenghi, IASF-MI

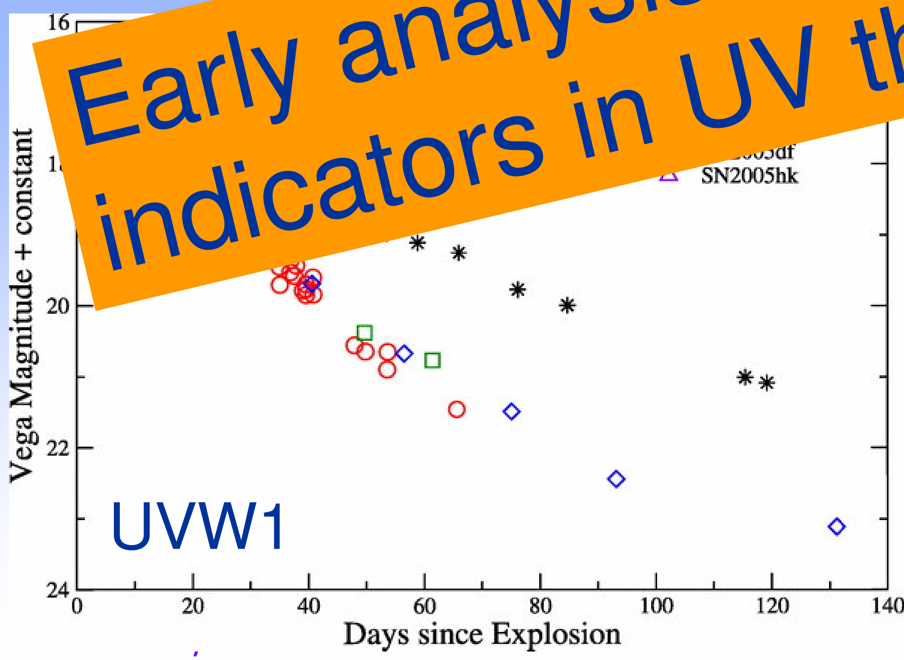
# Supernovae in UV

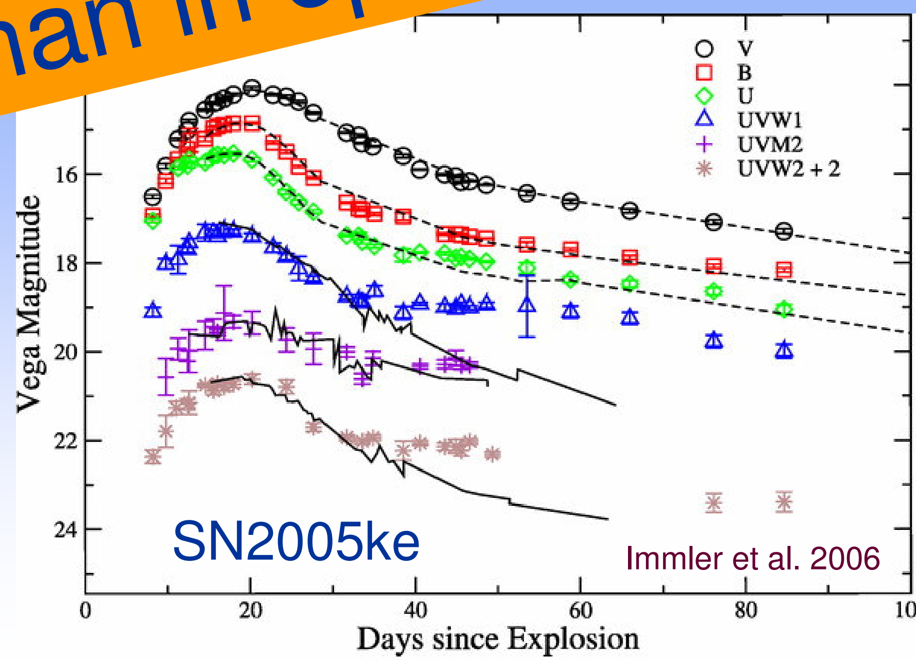
- Key cosmological probes
- UV observations fundamental to understand
  a) SED in UV/optical in the local Universe to interpret high-z SNe
  b) progenitors of SNe
  c) physics of the explosions
  d) interaction with the interstellar medium
  e) galaxy extinction law(s)

# New effort on SNe with Swift



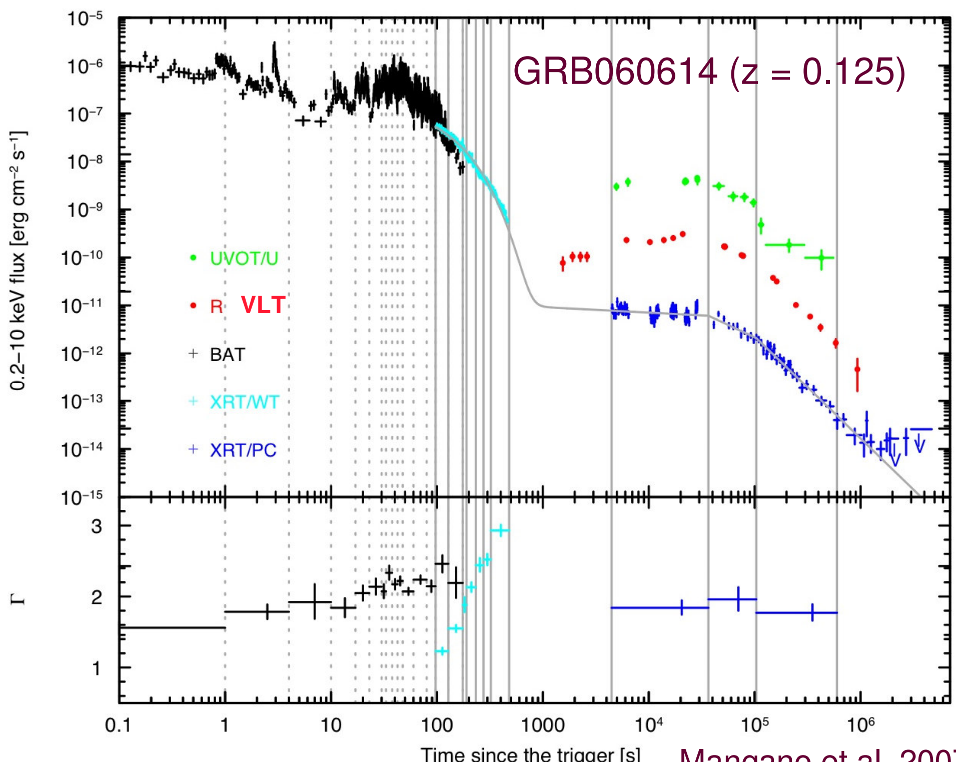

Early analysis ➔ better distance indicators in UV than in optical ?!?!



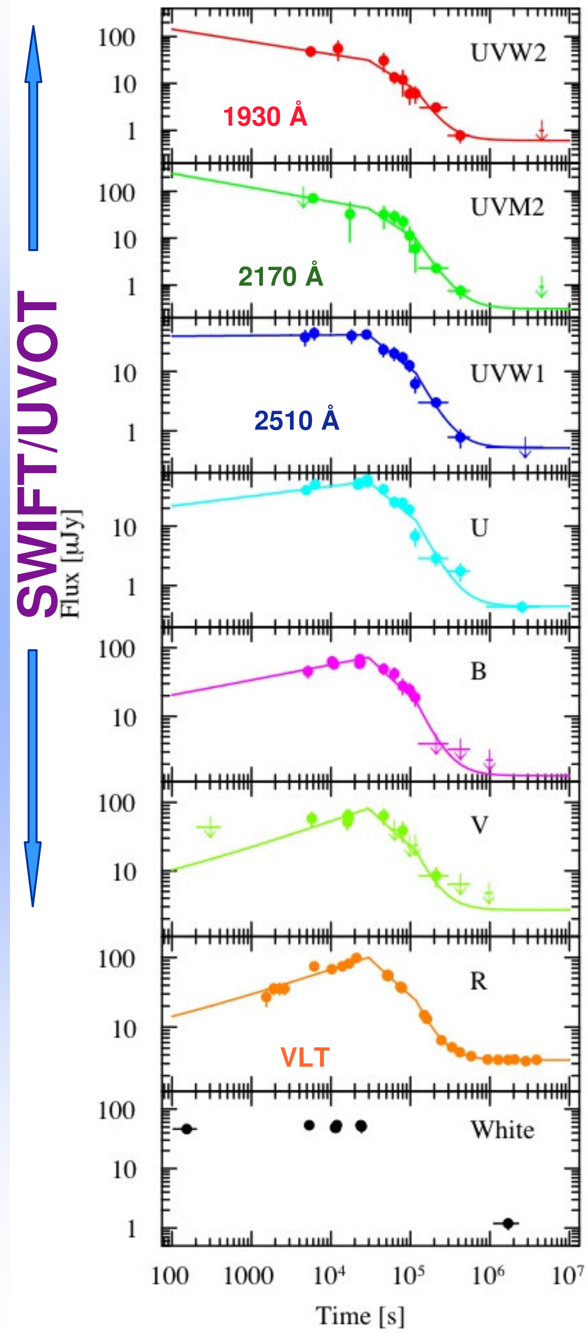



# Gamma Ray Bursts Physics

Early light curves and spectral flux distributions: crucial for understanding the mechanisms of the prompt event and afterglow, and the transition between the two.
In the first hours, X and otpical bands dominate the flux emission. **UV data are a still mostly missing link.**
Sometimes X and optical light curves show the same behavior. In other cases they do not. Different physical phenomena at work?
**UV data become critical.**




Mangano et al. 2007



# Summary of the FCU requirements

- The requirements toward the imager instrument on board WSO-UV in order to fulfill its **science objectives** are:
- the possibility to obtain **diffraction limited images** for $\lambda$>230 nm (goal $\lambda$ >200 nm).
- S/N=10 per pixel in one hour exposure time down to:
  - V=26.2 (21.5 – 11.1) for a O3 V (A0 V - G0 V) star in the band F150W
  - V=24.6 (21.9 – 19.5) for a O3 V (A0 V - G0 V) star in the band F250W
  - V=26.3 (26.3 – 26.3) for a O3 V (A0 V - G0 V) star in the band F555W
- Spectral resolution:
  - R=100 at $\lambda$=150 nm
  - R>100 at $\lambda \geq$250 nm
  - R=250 at $\lambda$=500 nm.
- Polarimetric filters
- High time resolution imaging
- The possibility to obtain wide field (~ 5x5 $arcmin^2$) images from Far-UV to visual wavelengths.
- Partial overlap between spectral range covered by FUV and NUV and NUV and UVO, for relative calibration purposes.

# NUV main science drivers

FOV of 60x60arcsec , wavelength coverage 150-280nm , optimally sampled PSF with 0.03 arcsec/px; **Spectro-polarimetric facilities.**

- **Imaging polarimetry and spectropolarimetry of AGN jets, GRBs, SNe, stellar jets, PNe and AGB shells**
- **GRB and SNe light curves in UV** (quick response facility of WSO-UV telescope to ToO objects)
- **UV light curve of transits of extrasolar planets as atmospheric diagnostic**

- UV light in nearby galaxies: additional local calibrator of SED, SBF..
- Exotica in star clusters and nearby galaxies
- Magnetic activity in the atmosphere of late type stars
- Exospheres and aurorae in Solar System planets, satellites, comets

# Imaging polarimetry and spectro-polarimetry

AGN: structure of the magnetic fields in jets; separation of genuine host galaxy light from scattered light emitted by the central QSO, test of the unified model

Asphericity of SNe explosions

Dusty shells, jets, stellar activity in star formation regions

Magnetic fields in young stars,, CVs, accreting WDs

Protoplanetary disks

RGB, AGB star mass loss and planetary nebulae

Envelope structure of giant stars

# Main science drivers of UVO

**UVO is a fundamental contribution to WSO-UV, because of its field (286x286 arcsec, 2 times larger than ACS, three times larger than WFC3/UVIS), wavelength coverage (200-1000 nm), and resolution (diffraction limit at 500nm,0.07arcsc/pix) of UVO? Note the field similar to FUV**

Optical couterpart of FUV (and JWST) surveys

High accuracy photometry in UV-optical

High accuracy astrometry

Extension of HST legacy (variabilty, proper motions, etc.)

# Does the Scientific Community request an UV/optical Space Telescope?

Cycle 16 HST: 821 proposals

581 GO, 17200 **requested orbits**

**(2000 available)**

**OVERSUBSCRIPTION:> 8 to 1!!!!**

33 LP + 4 Tre., **5272 requested orbits**

**(1000 available)**

**OVERSUBSCRIPTION: >5 to 1!!!!**

+ 2005 orbits for survey programs

+ 3505 targets for snapshot programs

(1/3 galactic panels, 2/3 extragalactic panels, 3.7% SS)

# FCU Limiting magnitudes in UV

Magnitudes giving SNR 10 on 3600 s

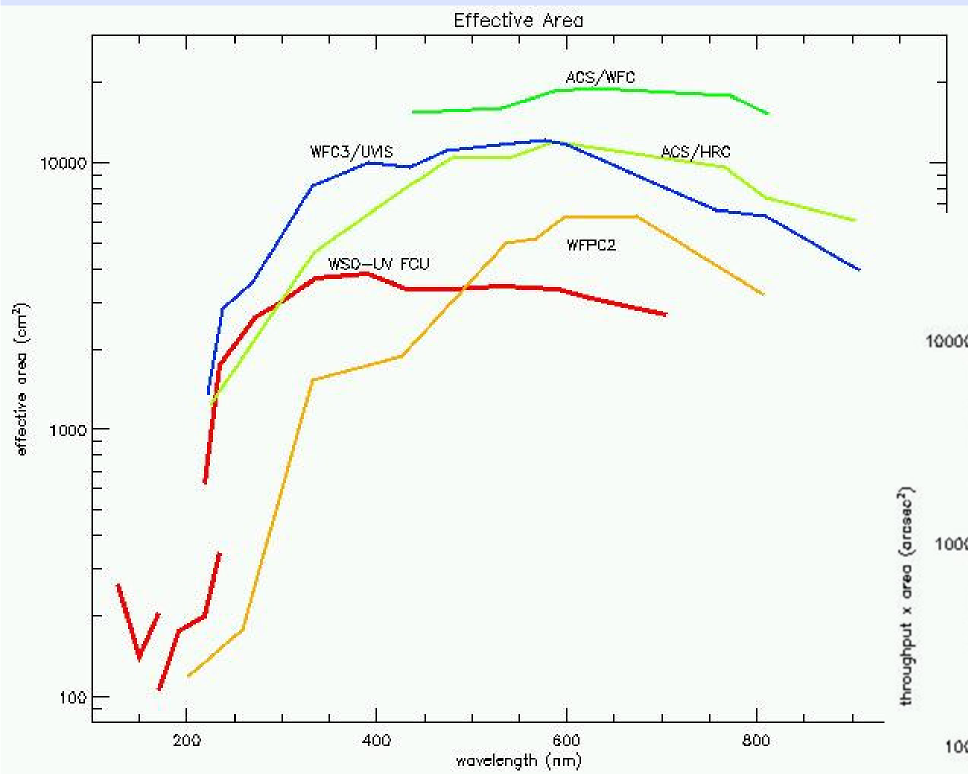
| | O3V | O5V | O6V | O8V | B0V | B3V | B5V | B8V | A0V | A5V | F0V | F5V | G0V | G5V | K0V | K5V | M5V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FUV F122M | 25.8 | 25.7 | 25.6 | 25.3 | 25.3 | 24.1 | 23.1 | 22.0 | 19.8 | 16.4 | 14.2 | 11.6 | 9.1 | 7.9 | 6.2 | 5.3 | 5.3 |
| FUV F130LP | 28.1 | 28.0 | 27.8 | 27.6 | 27.6 | 26.6 | 26.0 | 25.3 | 23.9 | 21.4 | 19.8 | 17.8 | 15.5 | 14.4 | 12.3 | 6.9 | 6.4 |
| FUV F157W | 26.4 | 26.3 | 26.2 | 26.0 | 26.0 | 24.8 | 24.1 | 23.3 | 21.7 | 18.8 | 16.6 | 13.8 | 11.2 | 10.0 | 7.8 | 5.5 | 5.5 |
| FUV F160BW | 26.4 | 26.4 | 26.2 | 26.0 | 26.0 | 24.8 | 24.1 | 23.1 | 21.5 | 18.9 | 16.8 | 14.1 | 11.5 | 10.3 | 8.2 | 5.6 | 5.5 |
| FUV F165LP | 26.3 | 26.2 | 26.1 | 26.0 | 26.0 | 24.9 | 24.2 | 23.5 | 22.4 | 21.3 | 19.7 | 17.1 | 14.6 | 13.5 | 11.3 | 6.2 | 6.0 |
| FUV F170W | 26.6 | 26.6 | 26.4 | 26.3 | 26.3 | 25.1 | 24.5 | 23.6 | 22.3 | 20.4 | 18.5 | 15.9 | 13.3 | 12.1 | 9.9 | 5.8 | 5.7 |
| FUV Clear | 28.9 | 28.8 | 28.7 | 28.5 | 28.5 | 27.3 | 26.5 | 25.6 | 24.0 | 21.8 | 19.9 | 17.4 | 14.8 | 13.7 | 11.5 | 6.3 | 6.1 |
| NUV F170W | 26.1 | 26.0 | 25.9 | 25.8 | 25.8 | 24.7 | 24.1 | 23.3 | 22.2 | 21.2 | 19.9 | 18.2 | 16.6 | 15.8 | 14.0 | 10.5 | 10.2 |
| NUV F218W | 25.7 | 25.7 | 25.6 | 25.5 | 25.5 | 24.5 | 24.0 | 23.3 | 22.3 | 21.8 | 21.0 | 19.9 | 18.8 | 18.0 | 16.0 | 11.6 | 11.2 |
| NUV F255W | 25.0 | 25.0 | 24.9 | 24.8 | 24.8 | 24.0 | 23.5 | 22.8 | 21.9 | 21.5 | 20.9 | 20.2 | 19.5 | 19.0 | 17.9 | 14.0 | 13.4 |
| NUV Clear | 28.7 | 28.7 | 28.6 | 28.4 | 28.4 | 27.4 | 26.8 | 26.1 | 25.1 | 24.5 | 23.8 | 23.0 | 22.2 | 21.7 | 20.6 | 16.8 | 16.1 |

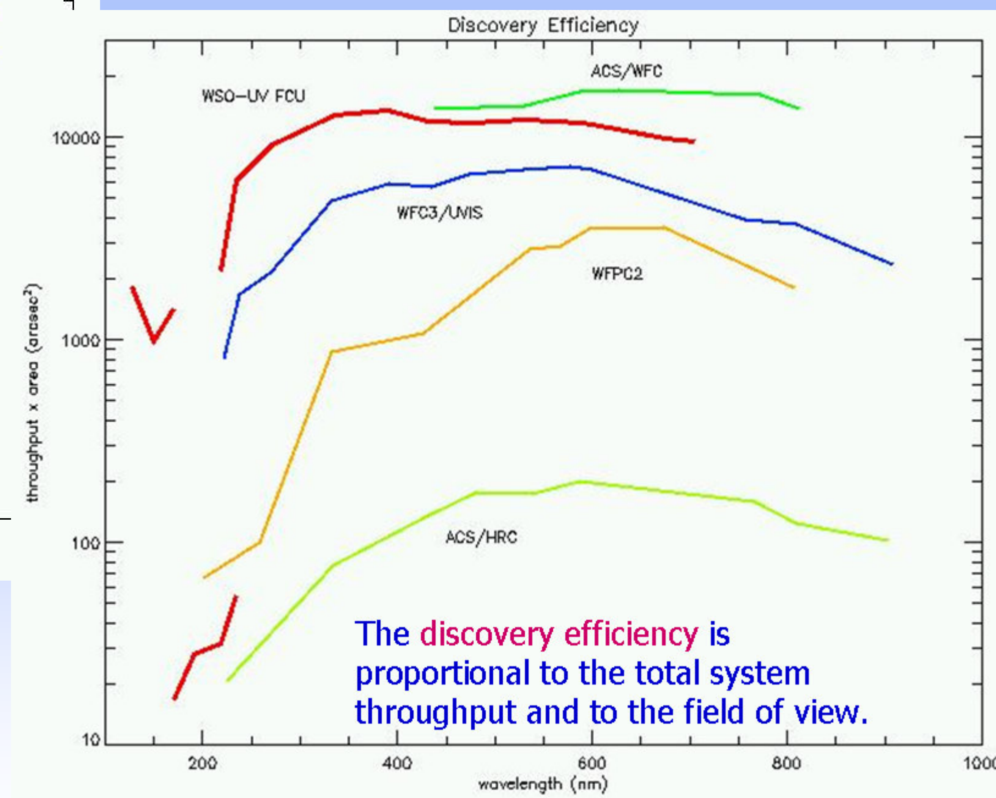
V Johnson mag



M.Uslenghi, IASF-MI

# WSO-FCU vs HST ACS & WFC3

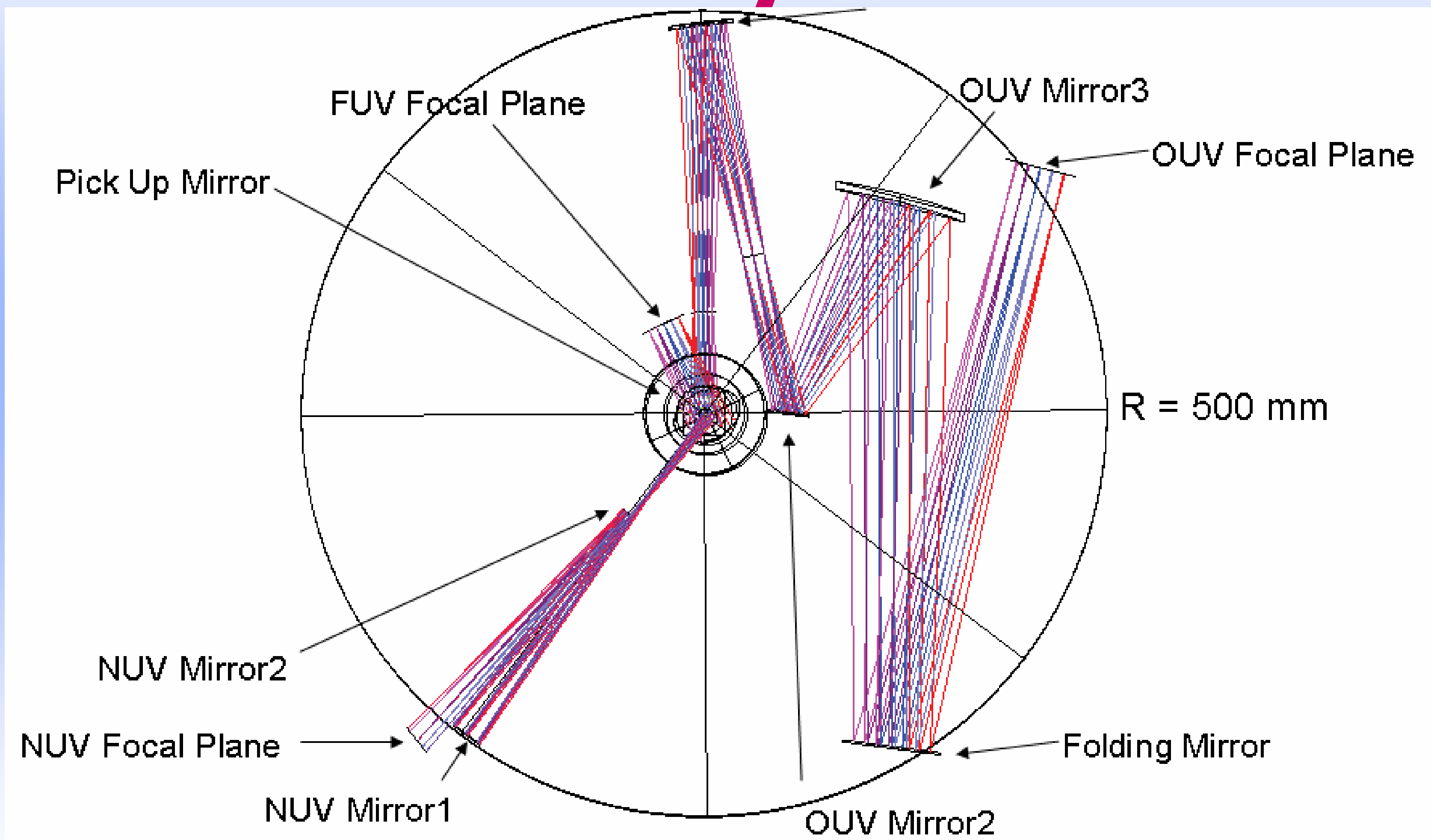


# WSO-UV collaboration

| Country | Main Contribution | Funding Agencies /Institutions/Industries |
|---|---|---|
| **Russia** | Telescope, FGS, Platform, Optical Bench, Launcher, Launch facilities, Ground Segment | FSA(Roscosmos)<br>INASAN<br>Lavochkin Ass. |
| **China** | LSS (Long Slit Spectrograph), Ground Station | CNSA<br>CAS(NAOC) & NIAOT |
| **Germany** | HIRDES (UVES & VUVES Spectrographs) | DLR<br>Tuebingen University<br>Kayser Threde |
| **Italy** | FCU (Field Camera Unit) & GS station | ASI<br>INAF & Univ, of Florence & Univ. of Padua<br>Galileo Av. & Thales-Alenia Space IT (MI) |
| **Spain** | Ground Station (MOC, SOC) | CDTI – Ministerio de Industria<br>UCM<br>G.M.V. S.A. & TCP Sistemas e Ingenieria |
| **Ukraine** | Coating of optical T170-M elements | National Space Agency of Ukraine<br>Crimean Astrophysical Observatory |
| **Kazakhstan** | Money | Bilateral agreement with Russia approved |
| **South Africa, Argentina** | Tracking stations | |
| **UK, France** | Participation in LSS | University of Leicester (UK)<br>LAM (FR) |

# FCU Layout


FUV Focal Plane
OUV Mirror3
OUV Focal Plane
Pick Up Mirror
R = 500 mm
NUV Mirror2
NUV Focal Plane
Folding Mirror
NUV Mirror1
OUV Mirror2