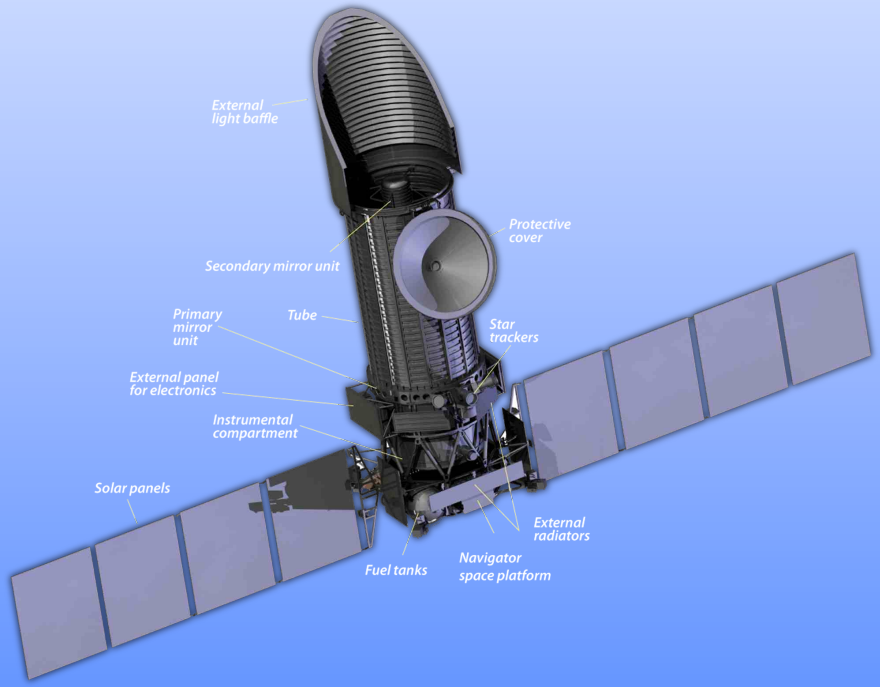
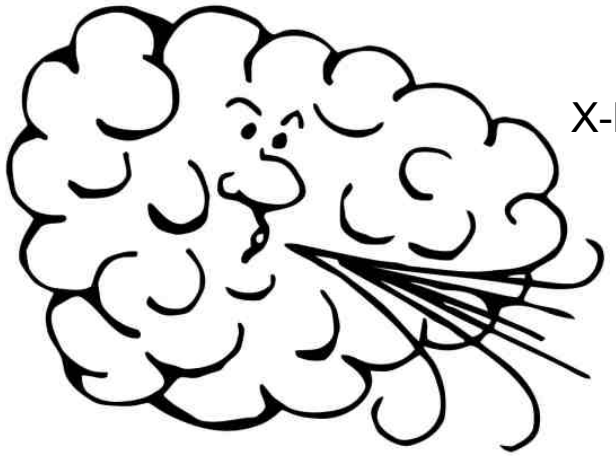
UV Astronomy with WSO/UV.

N.Kappelmann & UV Team

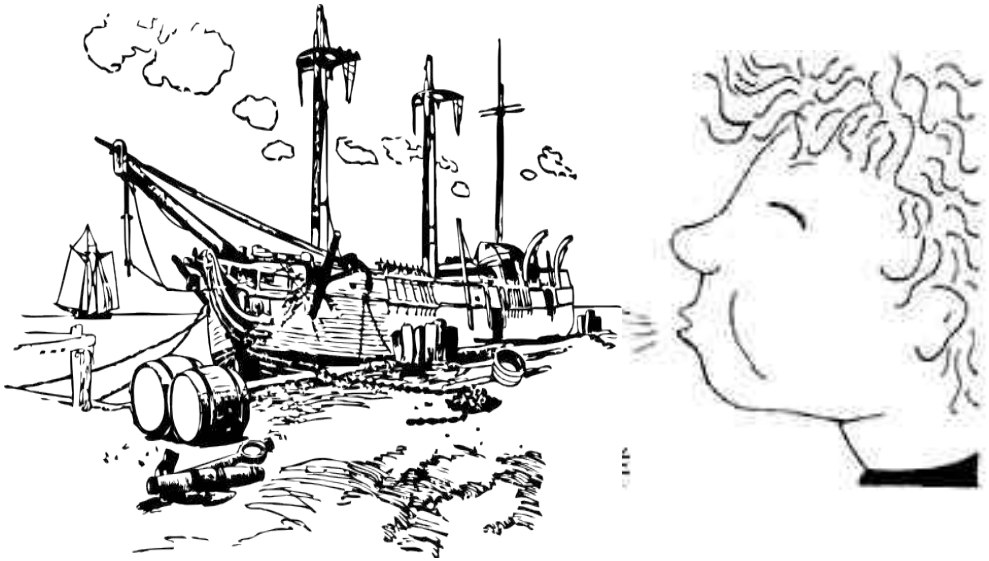


Experimental High Energy Astrophysics - Challenges for the new Decade 2010, Tübingen



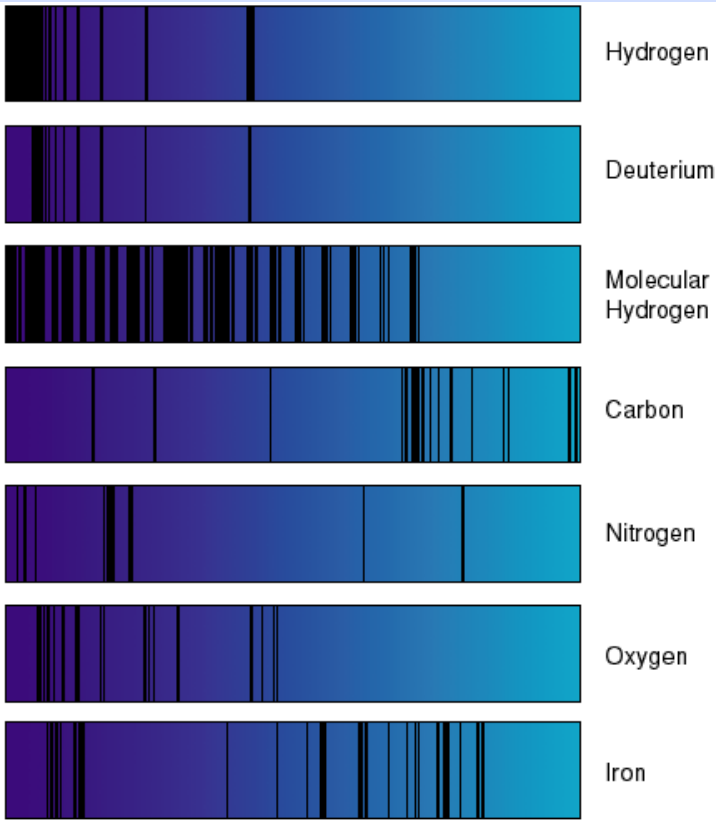
X-Ray Astronomy

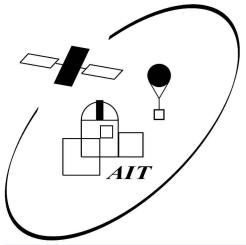
UV Astronomy



Why is the UV range important?

- Most resonance transitions from atoms, ionsare at UV wavelengths. Richness of experimental data for the study of ***plasma with temperatures in between 3,000K and 300,000K***.
  - unmatched by any other domain
- ***Electronic transitions of the most abundant molecules***, observed in this range
  - E.g. H_2, OH, or CO: also the most sensitive to the presence of large molecules such as the PAHs (Polycyclic aromatic hydrocarbon).





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Scientific Objectives: Overview

Hence: UV spectra provide most sensitive tools to

- trace distribution of (baryonic) matter in the Universe
- diagnose chemical composition, physical properties, kinematics of all types of astronomical objects:

Planets, Stars, Stellar populations in external galaxies, interstellar and intergalactic media, Galaxies and Active Galactic Nuclei

Therefore: UV astronomy contributes to the main scientific themes.

Extragalactic Astronomy

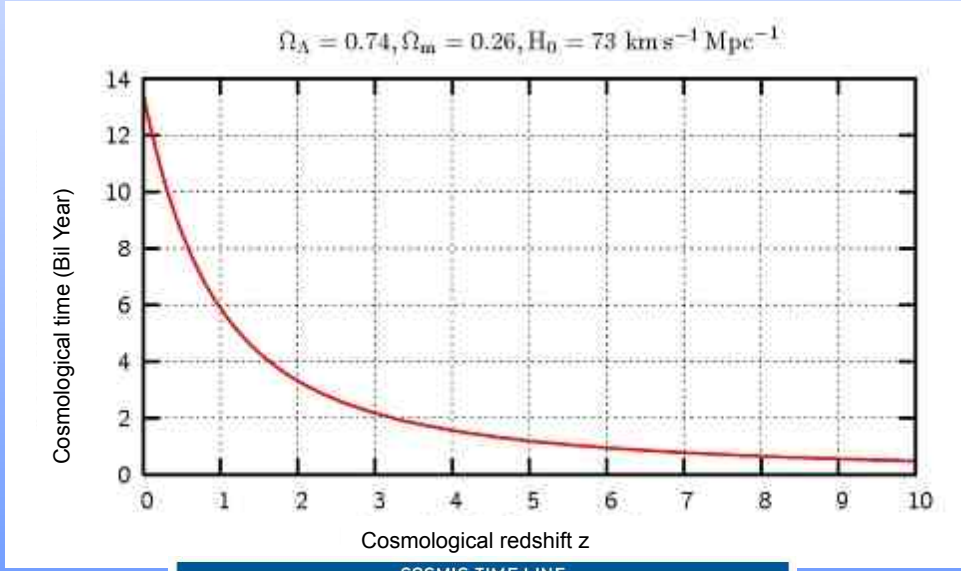
Evolution and development of galaxies within the z<2 Universe

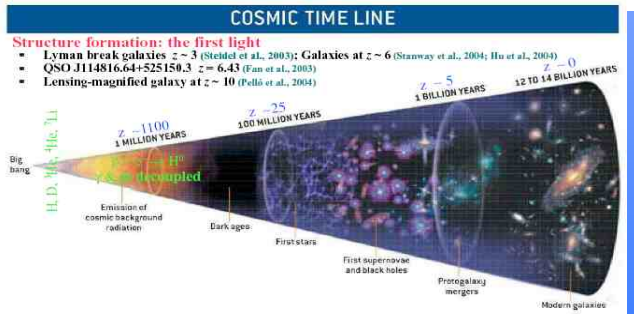
The bulk of the volume of the universe and 80% of the cosmic time are within z<2.
The main forming activities for the today‘s galaxy populations can be seen below z = 2
UV Spectroscopy is necessary for:

Reconstruction of the chronological development of

- Activities of star formation
- Chemical element abundance
- Morphologies
- Dynamics
- of the interstellar medium

... For all types of galaxies during the last 10 Billion years
(z=2: Highest rate of star formation, highest quasarpopulation etc.)

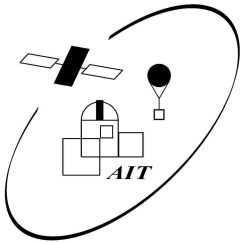




Extragalactic Astronomy

Development of the Intergalactic Medium (IGM)

Condensation of the IGM into the galaxies and exchange of the IGM with galaxies combine pre-galactic and galactic era.
Most interesting observing method: studies of absorption lines of distant quasars with UV-Spectroscopy.



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Stars are the engines of the chemical evolution of the Universe: Nucleosynthesis of elements heavier than hydrogen and helium

- Elements up to iron group (Fe, Co, Ni) are produced:

In **low-mass** stars (1-8 $M_\odot$) 3α-burning yields ^{12}C, ^{16}O and by further α-captures on ^{14}N: ^{22}Ne, ^{24}Mg,^{25}Mg

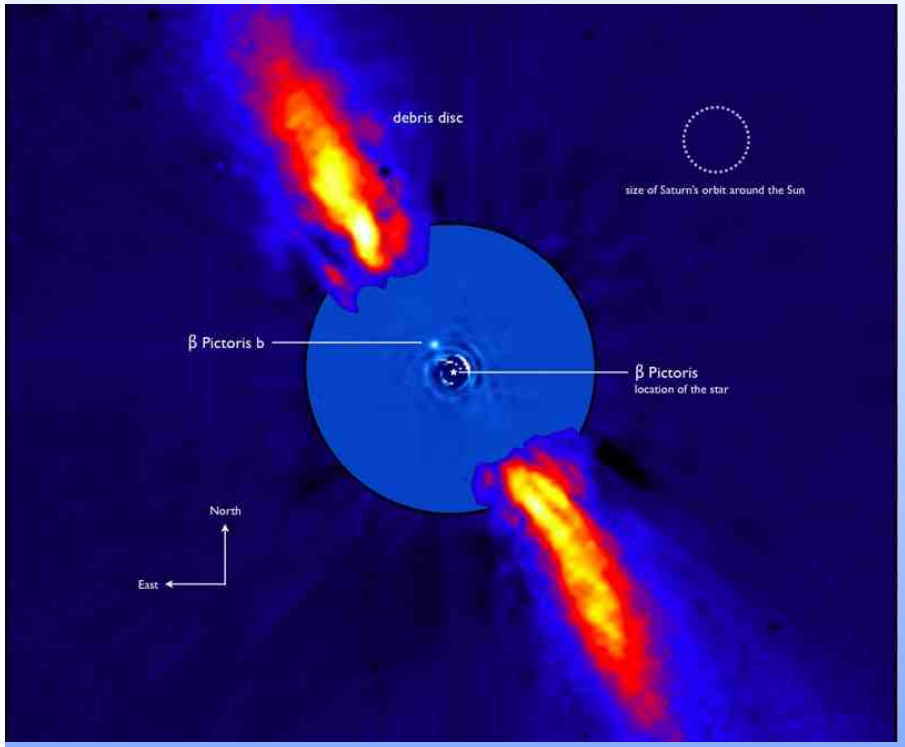
In **high-mass** stars through higher burning cycles up to Fe,Co,Ni (e-process "equilibrium burning"),

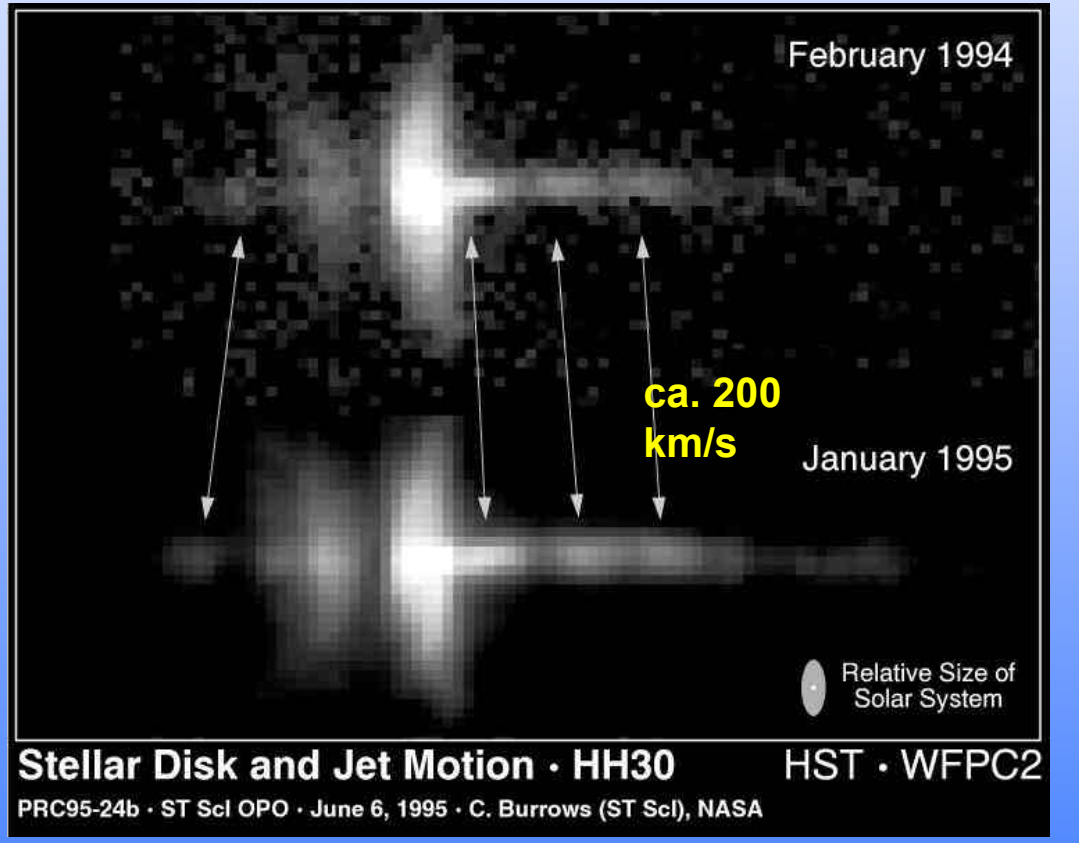
then explosive nucleosynthesis during supernova explosions: re-ignition of O- and Si-burning → additional synthesis of O,Si,S,Ca,Fe

- Nucleosynthesis of elements beyond the iron group:

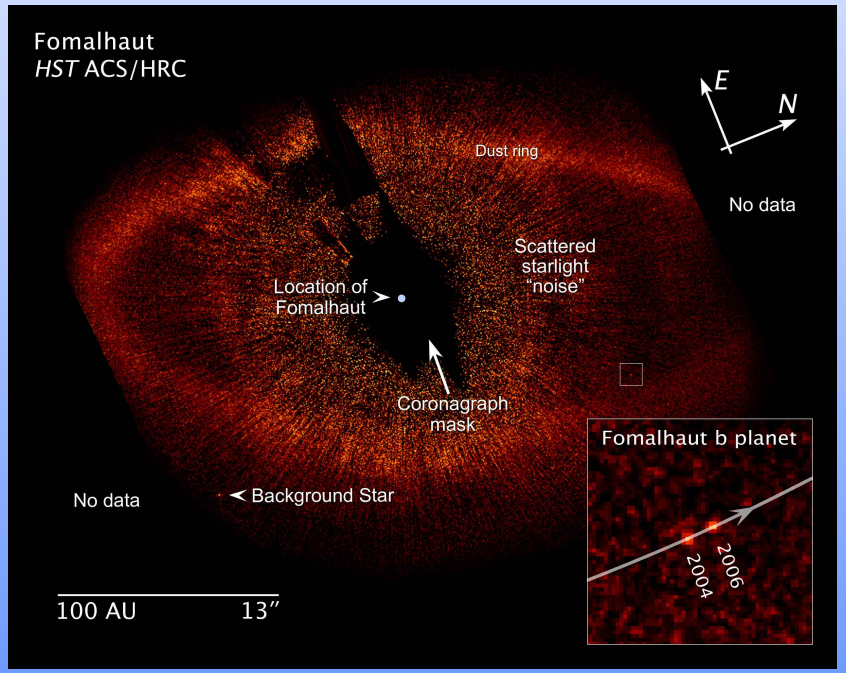
Because of high Coulomb repulsion of nuclei, only possible by neutron captures on ^{56}Fe seed nuclei. Essentially two possibilities: r- and s-process

Young stars are surrounded by very hot plasma emitting at UV that interacts with the disk





Understand the source of high energy radiation at the early stages of the Solar evolution and its role in young planetary disks chemistry



Young stars will be observed in the full UV range to determine the temperature, density and velocity of the whole System

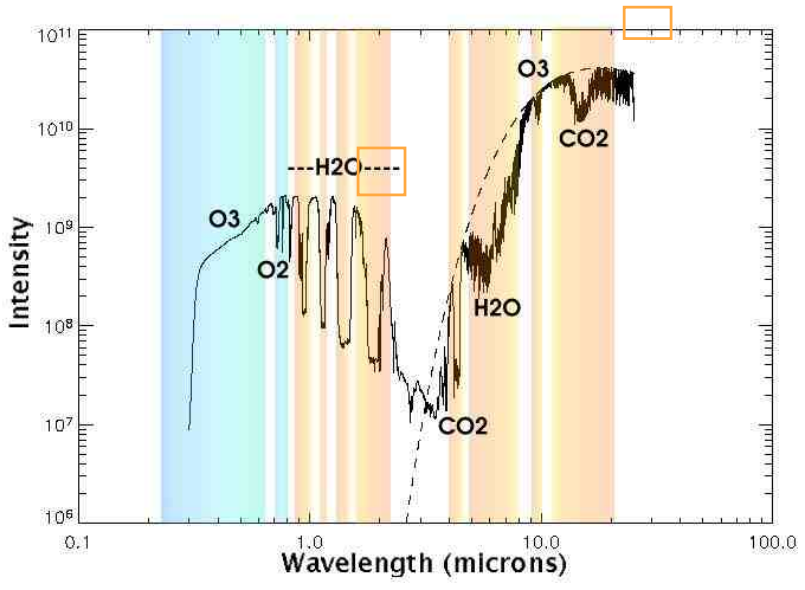
Cornerstones of planetary formation requiring UV:

- UV radiation (above 150nm) is an important photochemical agent: accelerates formation of large organic molecules
- Evolution of embryonic planetary atmospheres
- The planets-disk decoupling time

Atmospheres of Exoplanets

Composition of atmosphere:

- Atmospheres:
  O_3 (life induced?)
- Relative abundances
  H, H_2, O, C, CO, OH, etc.

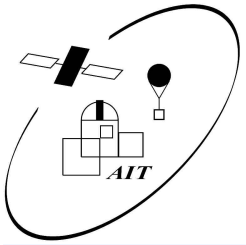


Hartley bands of O_3 are the main absorbers at 200-350 nm.

Artist's View of Extrasolar Planet HD 209458b

NASA, ESA, and G. Bacon (STScI) ▪ STScI-PRC10-21

Escaping atmospheres of evaporating ocean from water rich planets detected in Lyα.



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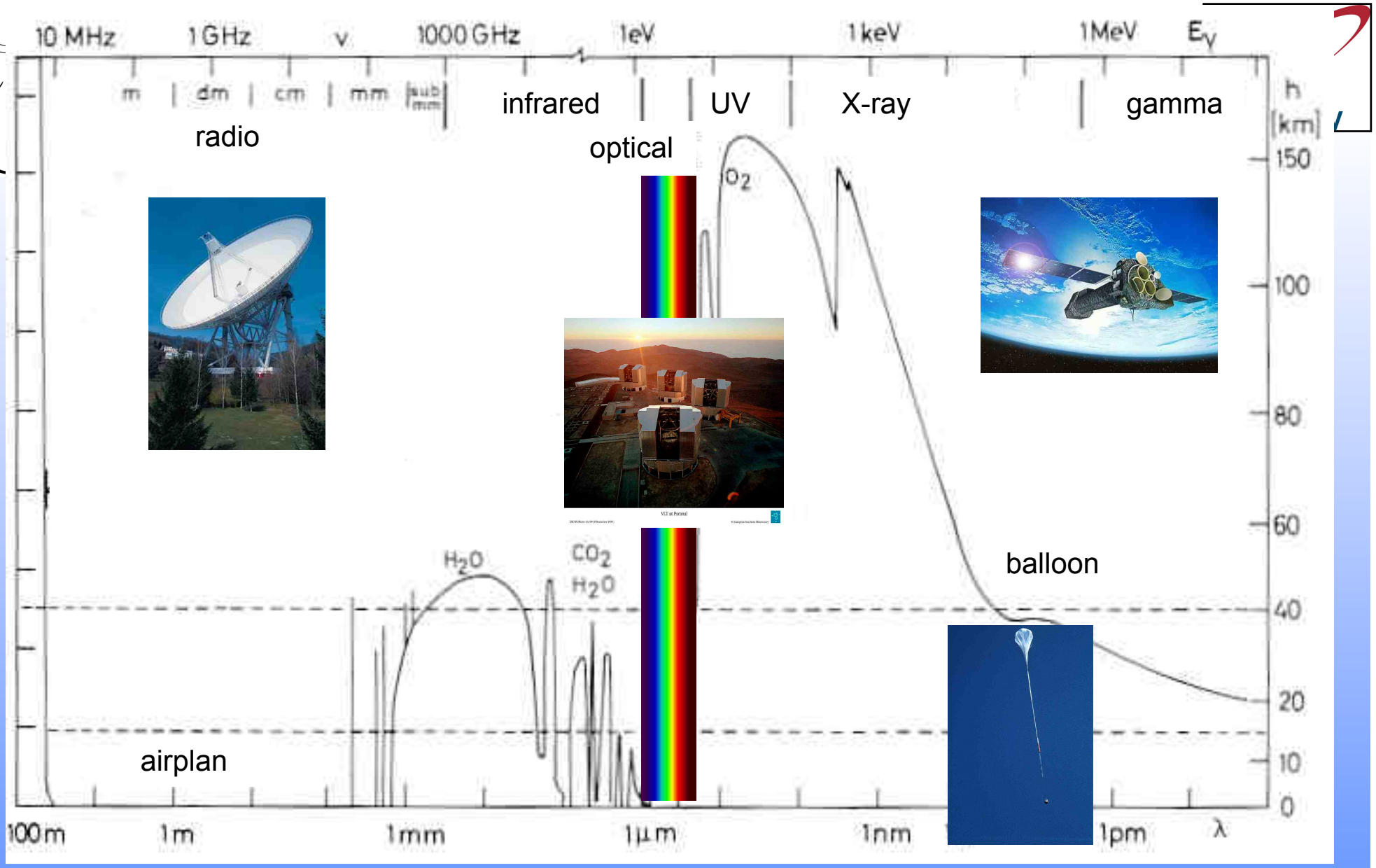
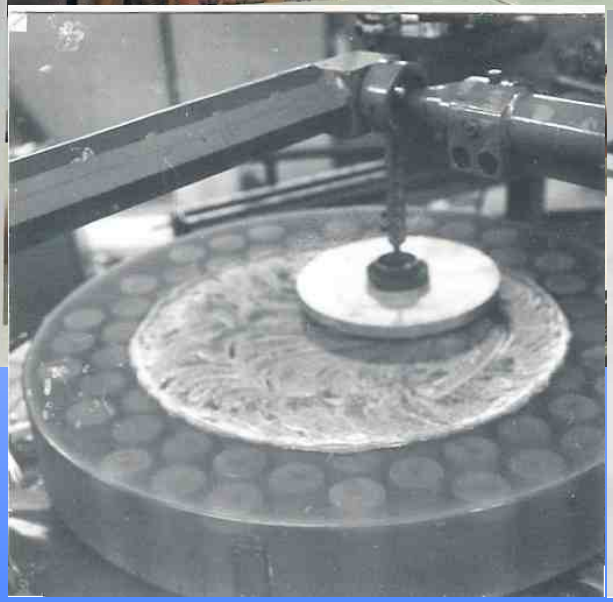
Summary

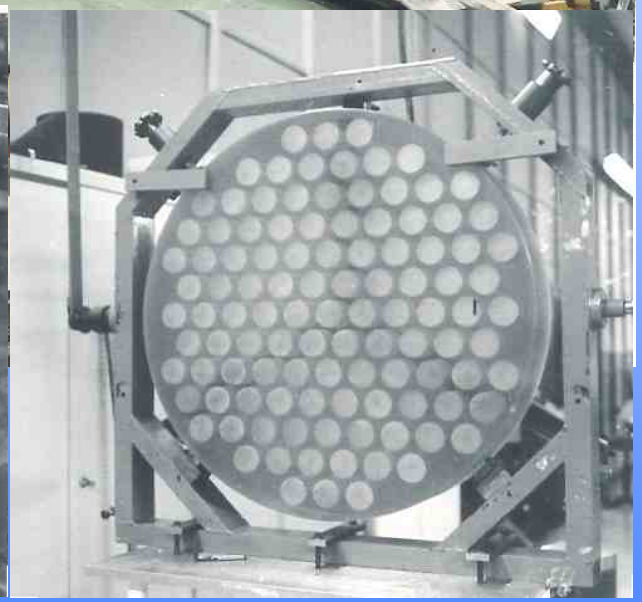
- How are heavy elements created and distributed through the modern universe?
- How are modern galaxies assembled, and how do they evolve?
- How do stars and planetary systems form, and how does this impact their likelihood of supporting life?
- Where are the baryons in the modern universe, and how are they distributed?



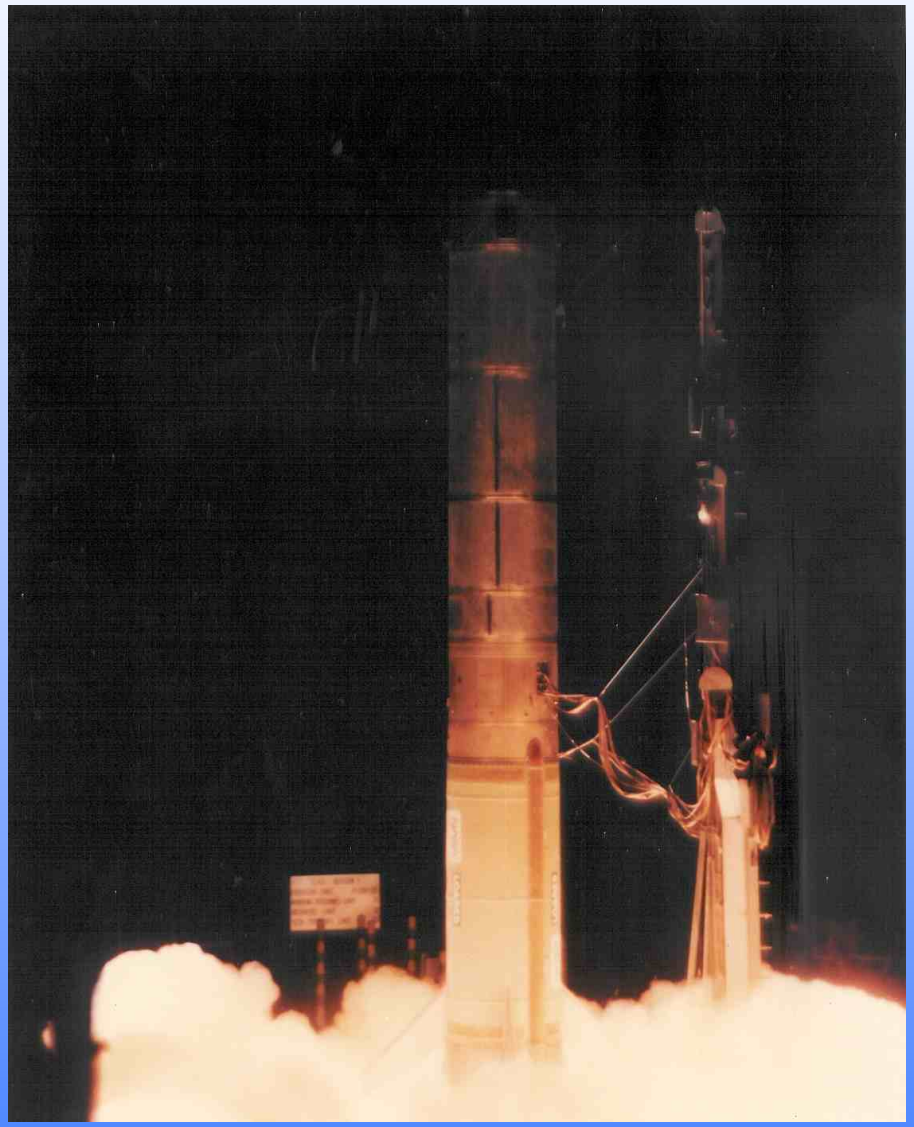
Half-absorption altitude, which is defined to be the altitude in the atmosphere (measured from the Earth's surface) where 1/2 of the radiation of a given wavelength incident on the upper atmosphere has been absorbed.

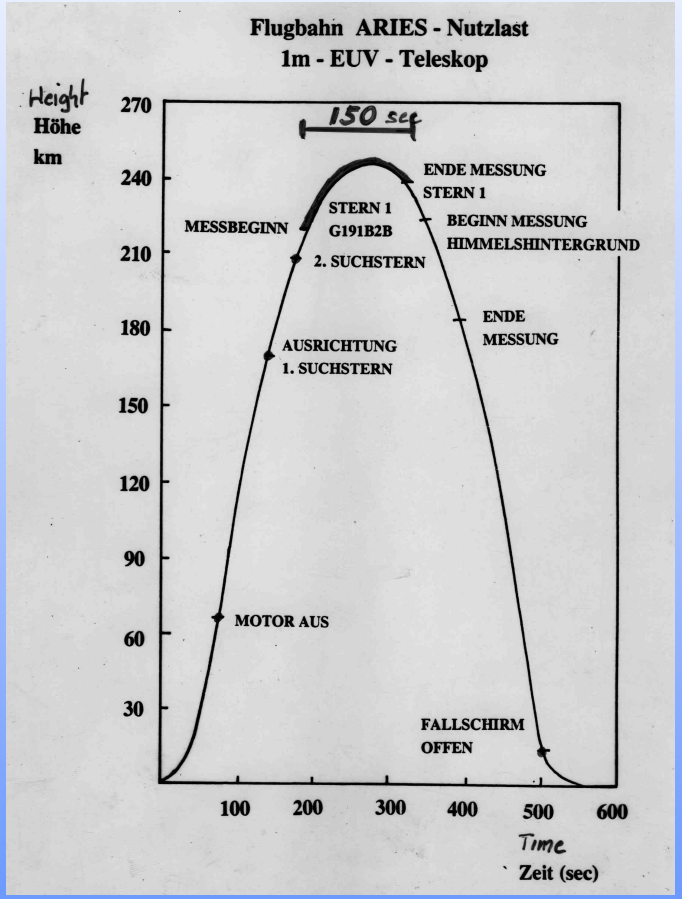
First Carbon Fibre Telescope

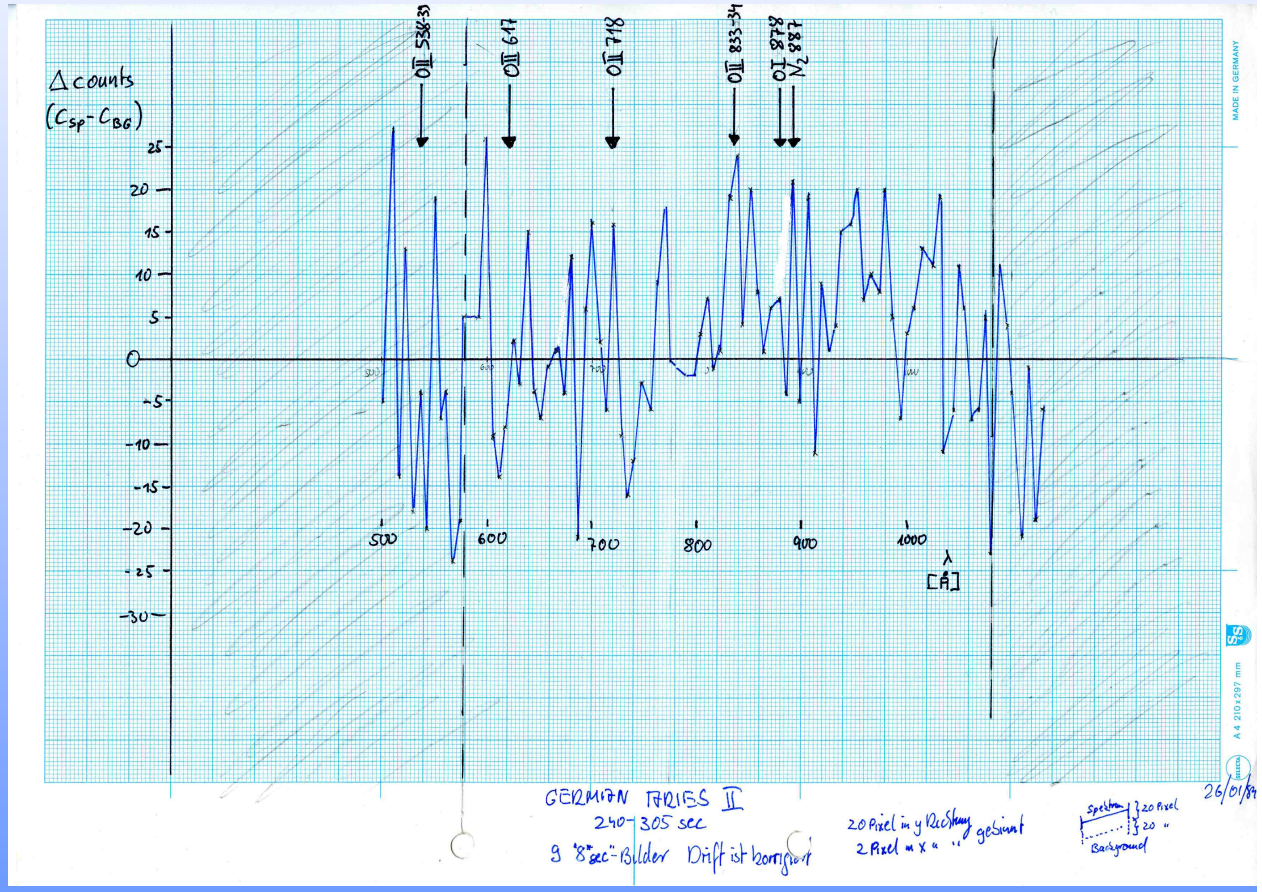


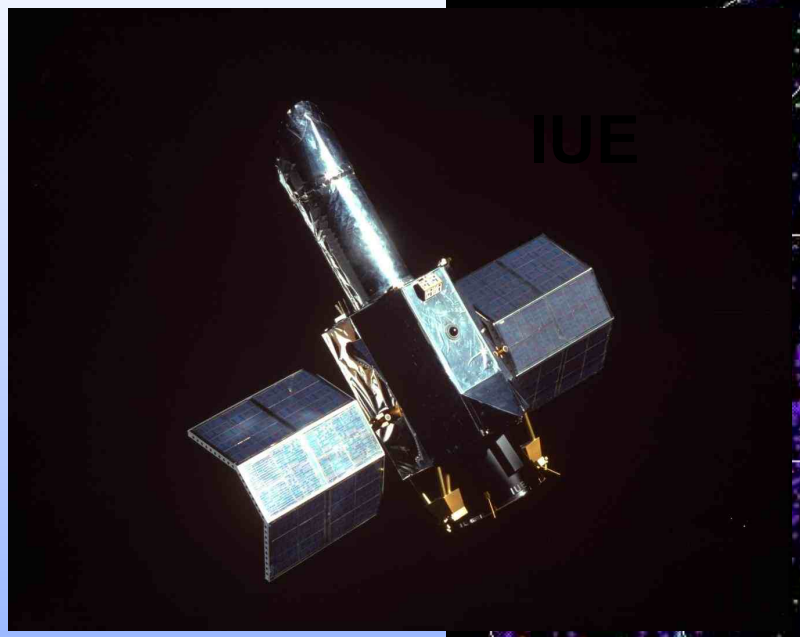


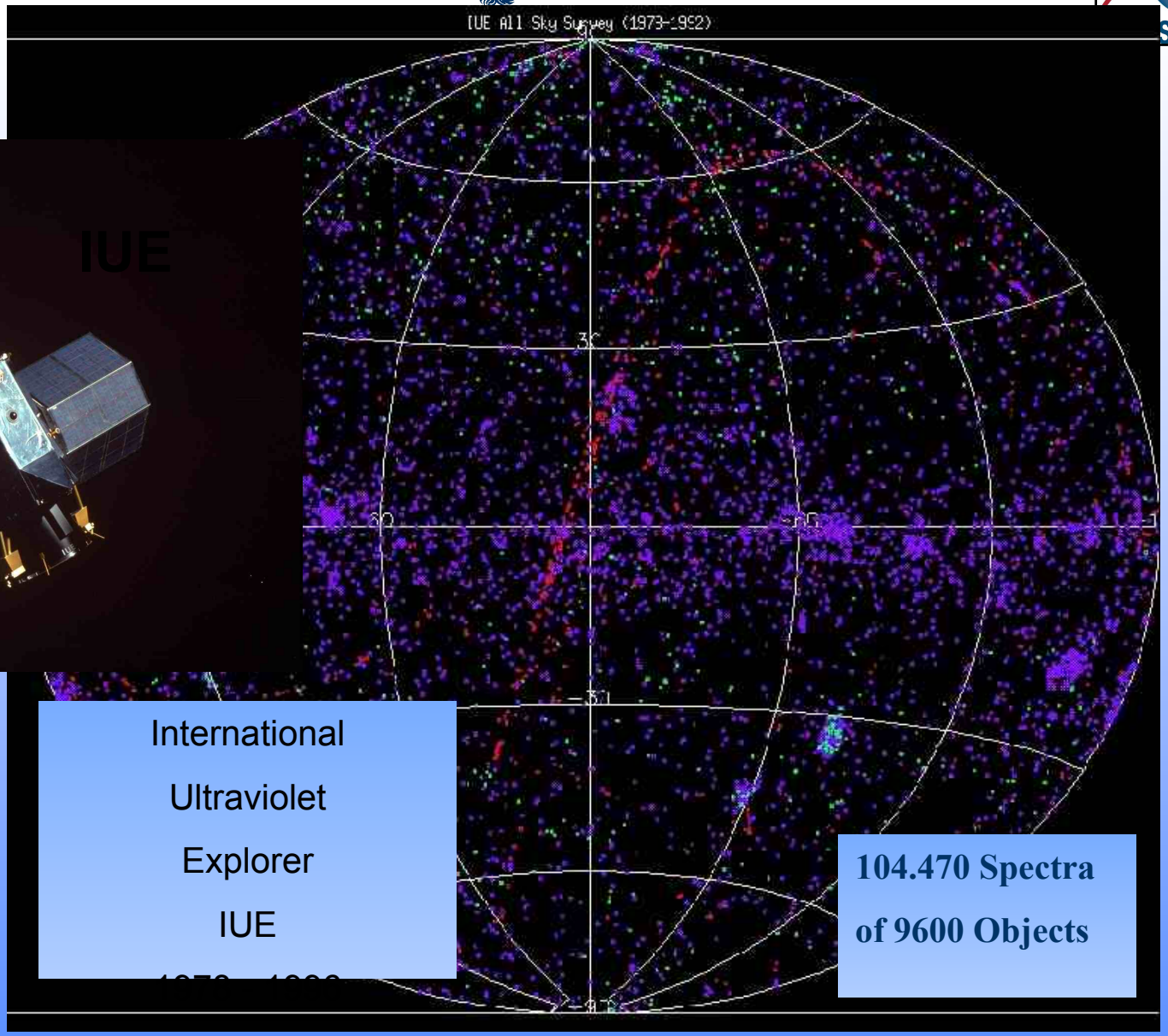
EUV -Telescope




Flugbahn ARIES - Nutzlast
1m - EUV - Teleskop
Height
Höhe
km
150 sec
ENDE MESSUNG
STERN 1
MESSBEGINN
STERN 1
G191B2B
BEGINN MESSUNG
HIMMELSHINTERGRUND
2. SUCHSTERN
ENDE
MESSUNG
AUSRICHTUNG
1. SUCHSTERN
MOTOR AUS
FALLSCHIRM
OFFEN
270
240
210
180
150
120
90
60
30
100
200
300
400
500
600
Time
Zeit (sec)


Δ counts
(C_SP - C_BG)
OII 538-53
OII 617
OII 718
OII 833-34
OI 8718
N2 8817
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
500
600
700
800
900
1000
λ
[Å]
GERMAN ARIES II
240-305 sec
9 "8 sec"-Bilder Drift ist korrigiert
20 Pixel in y Richtung gesamt
2 Pixel in x "
Spektrum 20 Pixel
Background 20 "
26/01/89





International

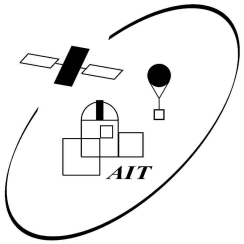
Ultraviolet

Explorer

IUE

104.470 Spectra

of 9600 Objects



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UV - Missions

DATES	MISSION	AGENCY	INSTRUMENT	RESOLUT.	RANGE (nm)
1993&96	ASTRO-SPAS	NASA/DARA	ORFEUS	~3000/ ~10000 Spectrometer	39-91/91-120
1993&96	ASTRO-SPAS	NASA/DARA	IMAPS	~200,000 Spectrometer	95-115
1990&95	ASTRO 1/2	NASA	WUPPE	~100	140-320
1990&95	ASTRO 1/2	NASA	UIT	Imager	120-300
1978-96	IUE	NASA/ESA	UV Spectrometer	~50 and ~5000	115-320
1992-2000	EUVE	NASA	EUV Spectrometer and Imager	~400	8-75
1989-03	HST	NASA/ESA	WFPC, GHRS	Imaging, 2000-80000	>115
1997- 2015	HST	NASA/ESA	STIS/COS	100-100000	115-310
1999-2007	FUSE	NASA	High Resolution Spectrometer	~22,000	90-120

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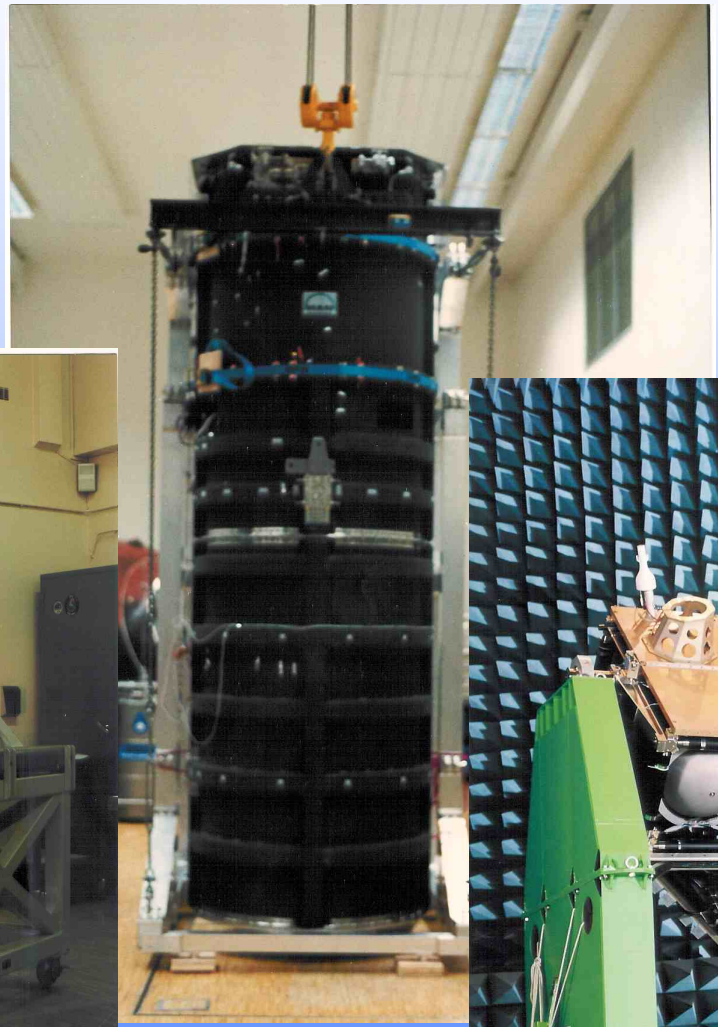
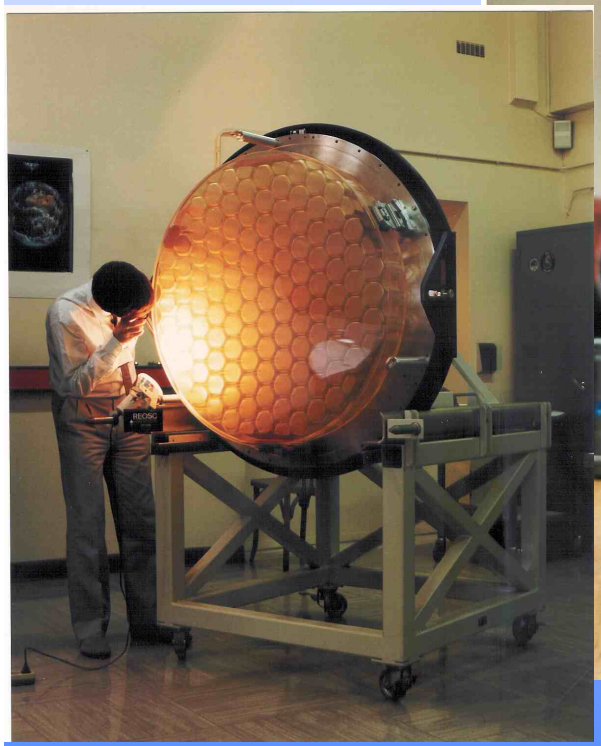
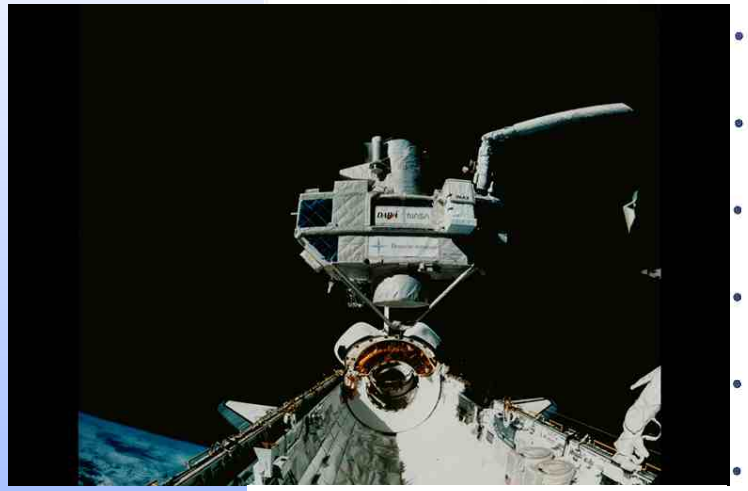
ORFEUS-SPAS





1984 - 1996

Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer



	Flight No. 1	FlightNo.2
• Time	12.09.-21.09.93	19.11.-7.12.96
• Duration	9.8 days	17.1 days*
• Free-Flying Time	5.9 days	14.0 days
• Switch-on Times	125.4 hours	263.0 hours
• Integration Times	56.1 hours	164.9 hours
• No. of Pointings	140	398 (PI 210, GO 188)

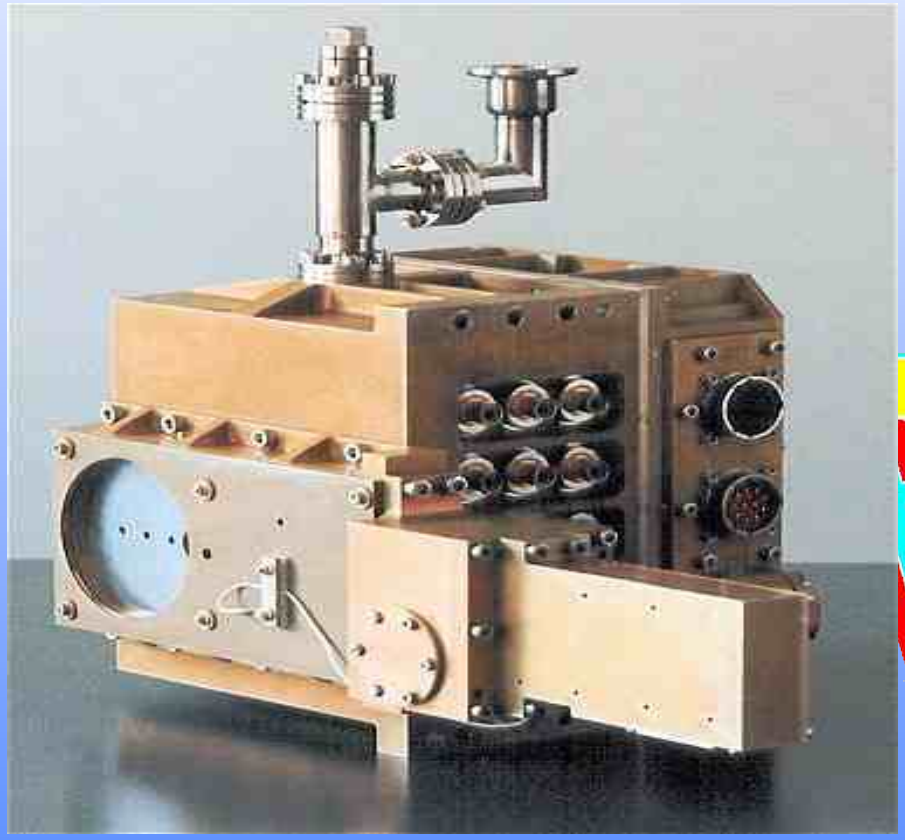
World Record

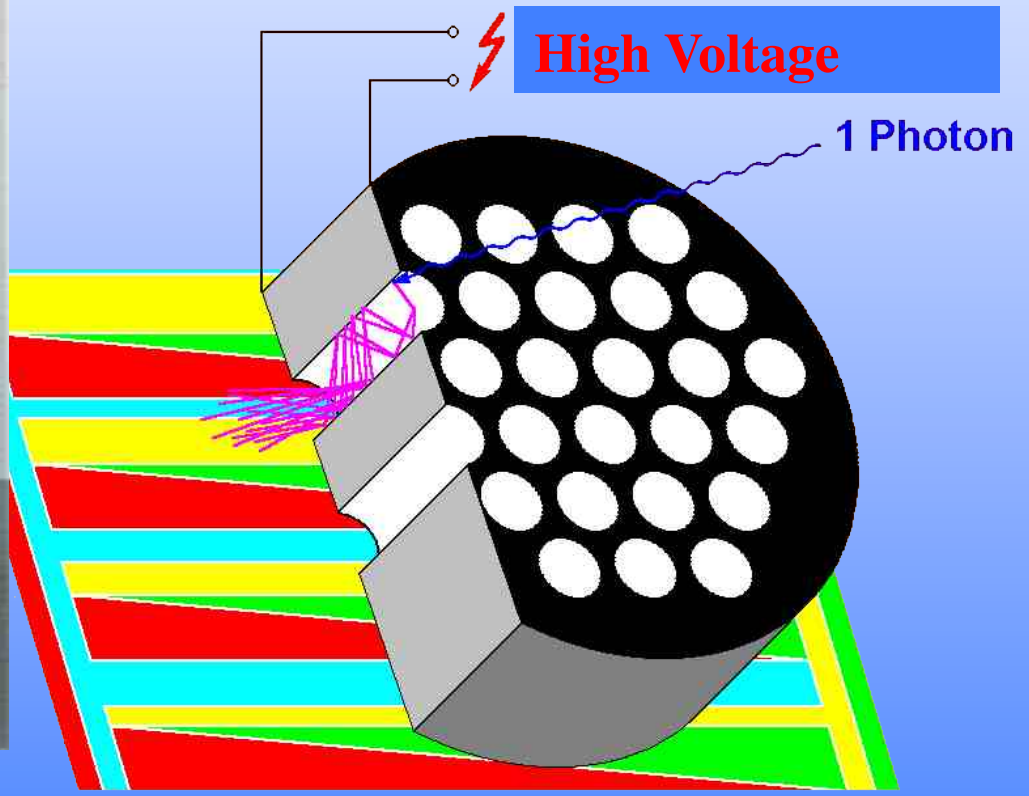
Mission – Time:

17 Tage, 15 Std, 53 Min, 18 Sek

Longest flight in the Shuttle history (19 days)

MCP-Detector with Wedge-and-Strip-Anode



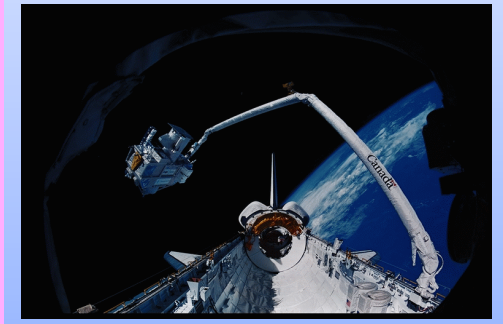


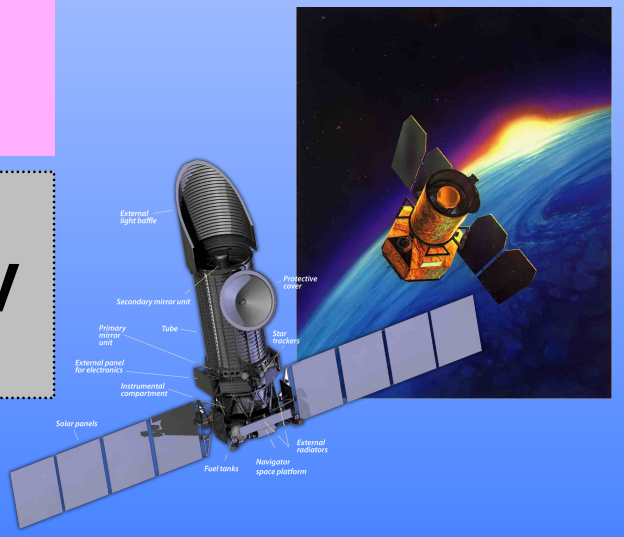
1970
1980
1990
2000
2010
2020

COPERNICUS
IUE
ASTRON

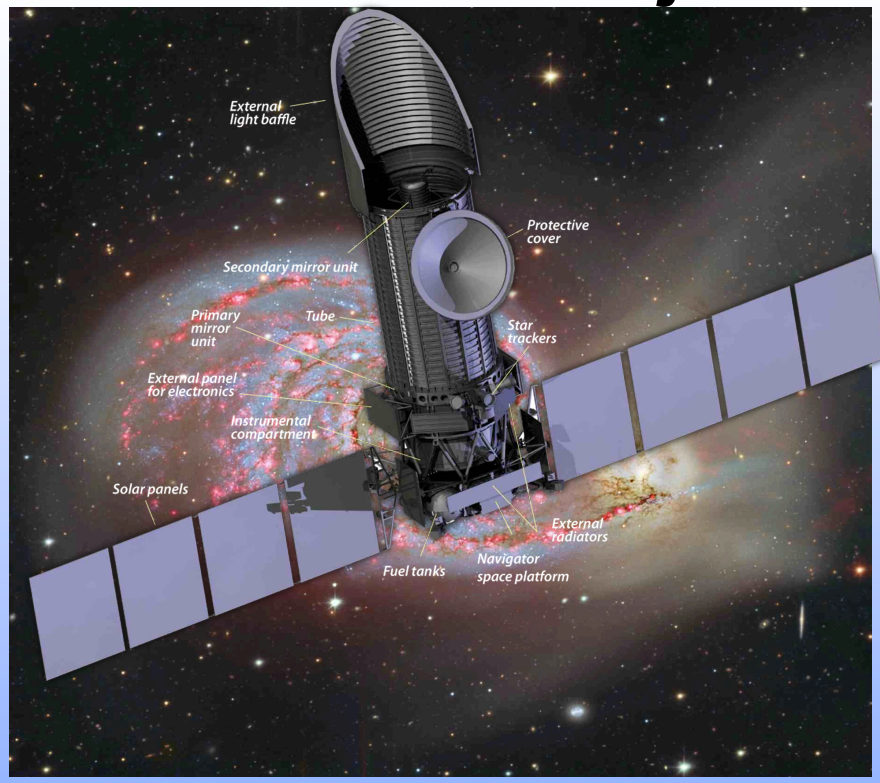
HST
ORFEUS
FUSE
GALEX

WSO/UV - Spectrum UV





WSO-UV Project



- **WSO-UV** is an international space observatory for observations in UV spectral range (~102-350 nm).
- It consists of a telescope with primary mirror of 170 cm and scientific instruments: Imaging field cameras and 3 spectrometers (R~1000 to 55,000).

Workshop on the occasion of Eckhard Kendziorra's 65th birthday

WSO-UV Mission Model

Telescope: T-170M, *Russia.*
1.7 m diameter, primary λ range 110 - 340 nm,
Spectrographs:
UVES, VUVES, R ≈ 5-6 x 10^4; *Russia (and Germany?)*
LSS, R ≈ 1000
Imaging: FCU, *Spain*

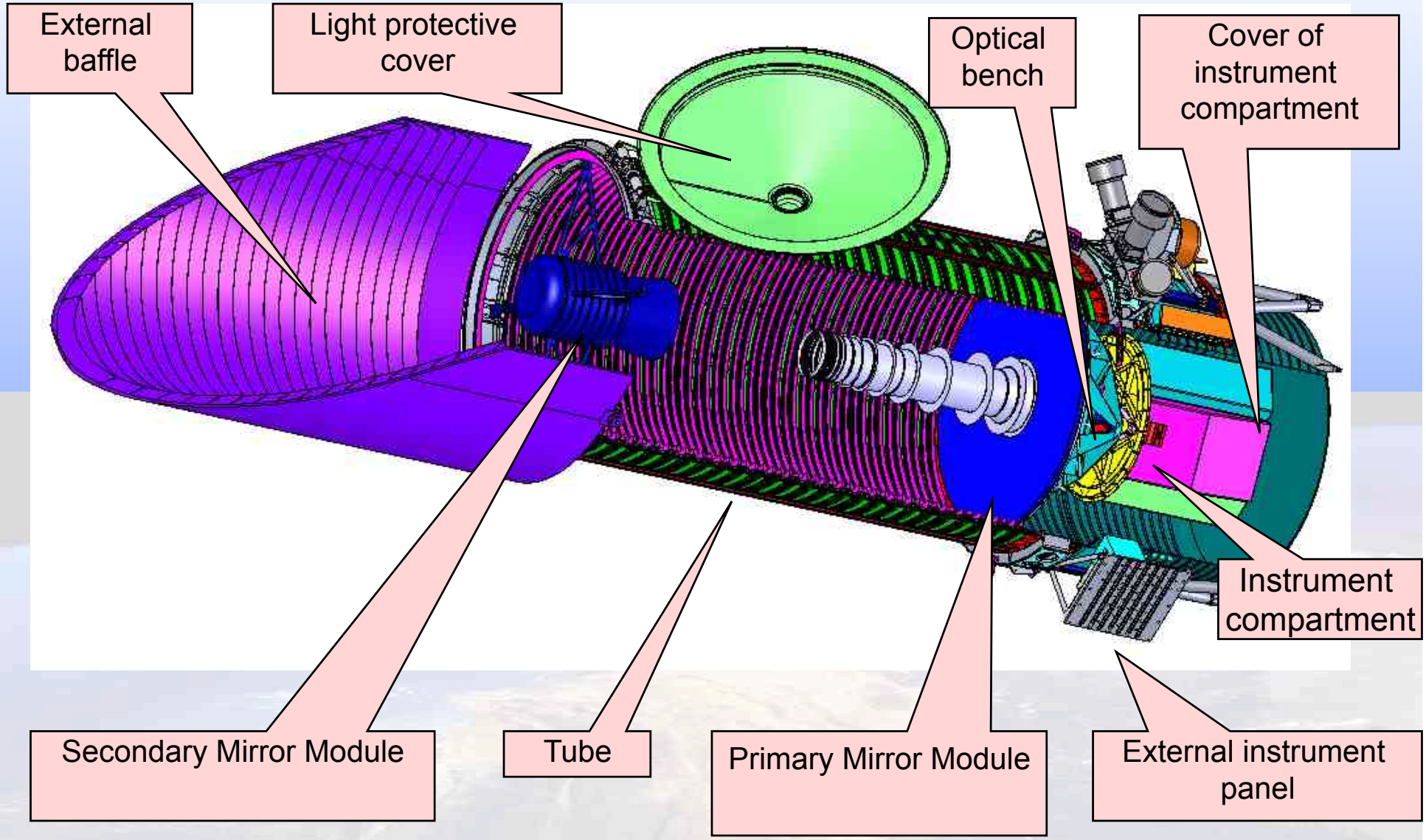
Platform: Navigator, *Russia*

Orbit: geosynchronous one with i=51.4°

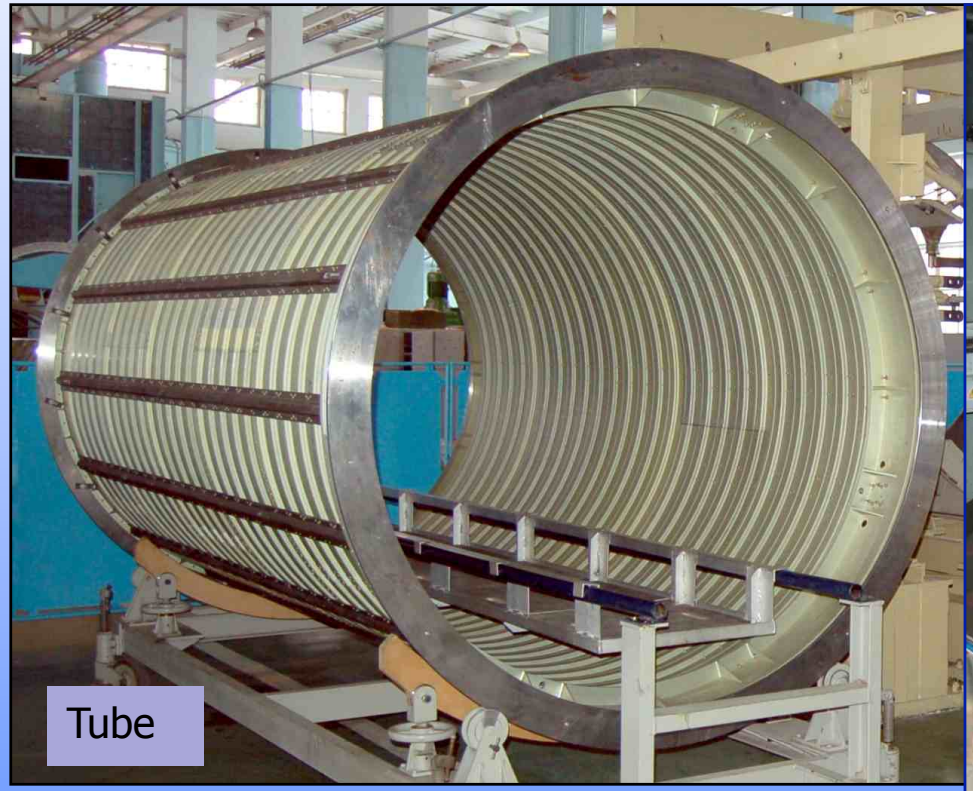
Launcher, launch: "ZENIT 2SB", end of 2014, Russia

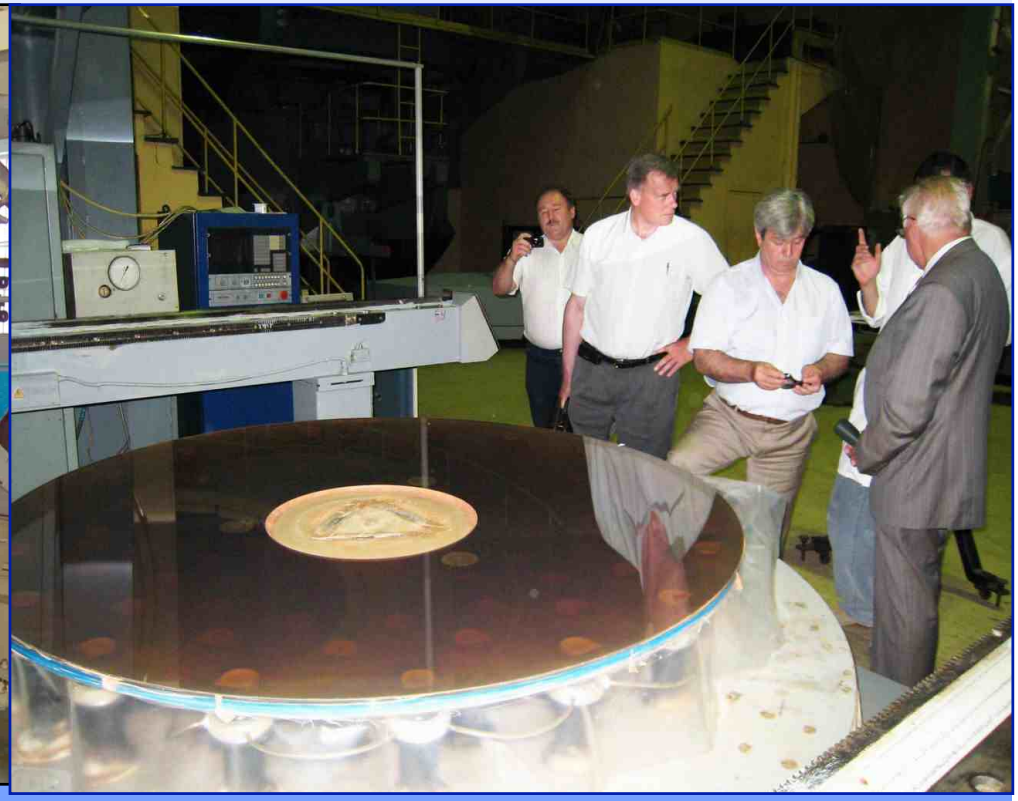
Ground Segment: *Russia and Spain*

Structure of the T-170M Telescope



The Telescope



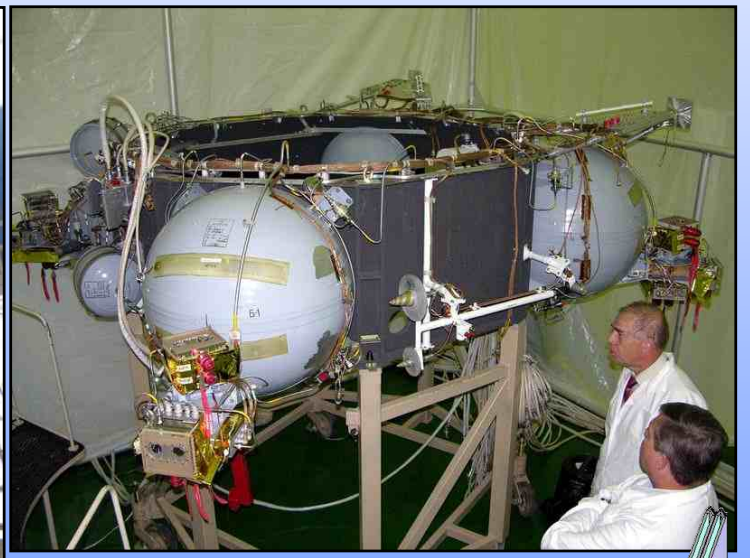


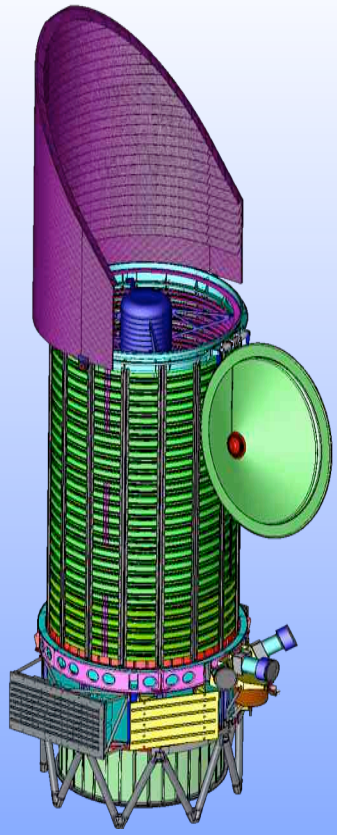
TheT-170M telescope structure (model for vibration and static tests)

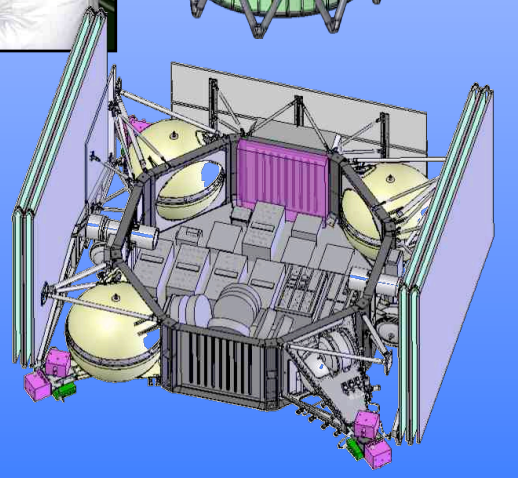
Test optics is manufactured at Lytkarino optical plant.

The Navigator Platform

- The WSO-UV bus is the Navigator service module used for other Russian projects: e.g. *Electro* and *Radio-Astron* and *Spectrum X-Gamma (eROSITA)*.







Flight models of Navigator bus for Electro and Radio-Astron have been assembled and tested.

Design Criteria WUVS

Wavelength Coverage : 103 – 310 nm

Spectral Resolution : > 50.000

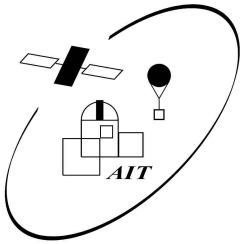
Simultaneous Coverage : as far as possible

Improvement of Eff. and FE of MCP-Detectors (ORFEUS Heritage)

Possibility to observe Bright Stars

„Slit – Monitor“

Reduction of Mechanisms



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History of the High Resolution Double Echelle Spectrograph:

1990 – 1997 (Spectrum UV):

1992 - 1993 **Feasibility Study of HIRDES**

1994 – 1997 **Technical Developments for HIRDES**

1998 –2007 (WSO/UV):

2000 - 2001 **HIRDES Phase – A – Study (JO)**
2005 - 2006 **HIRDES Phase – B1 – Study (KT)**
2007 **HIRDES Interfaces Study (KT)**
2011 **WUVS Phase – B2 – Study (LA-KT)**

WUVS:HIRDES+LSS

High Resolution Double Echelle Spectrograph (HIRDES)

VUVES : 102.8 – 175.6 nm

λ/δλ : 60.000

UVES : 174.5 – 310.0 nm

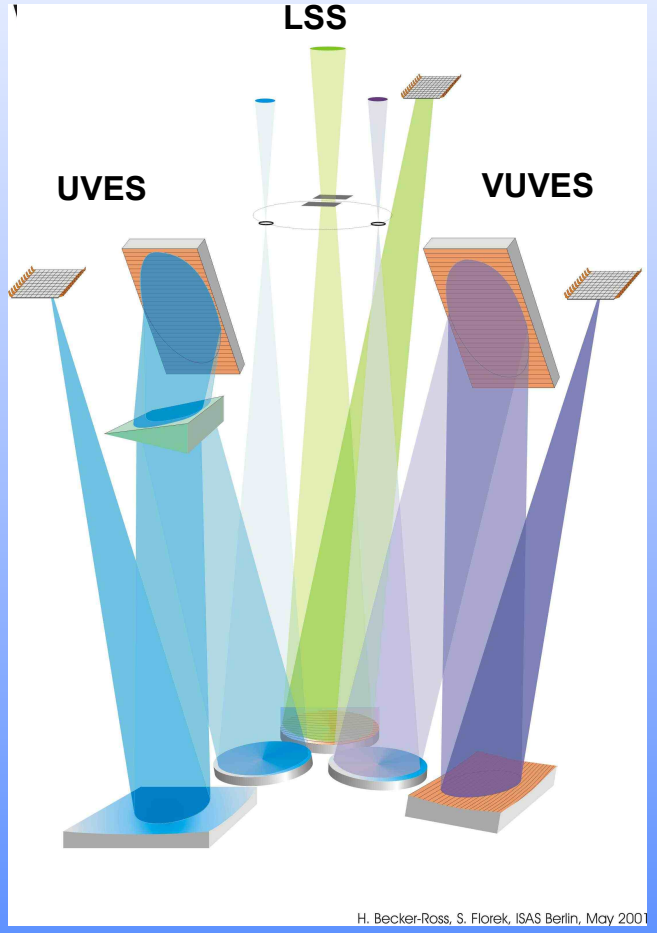
λ/δλ : 68.000

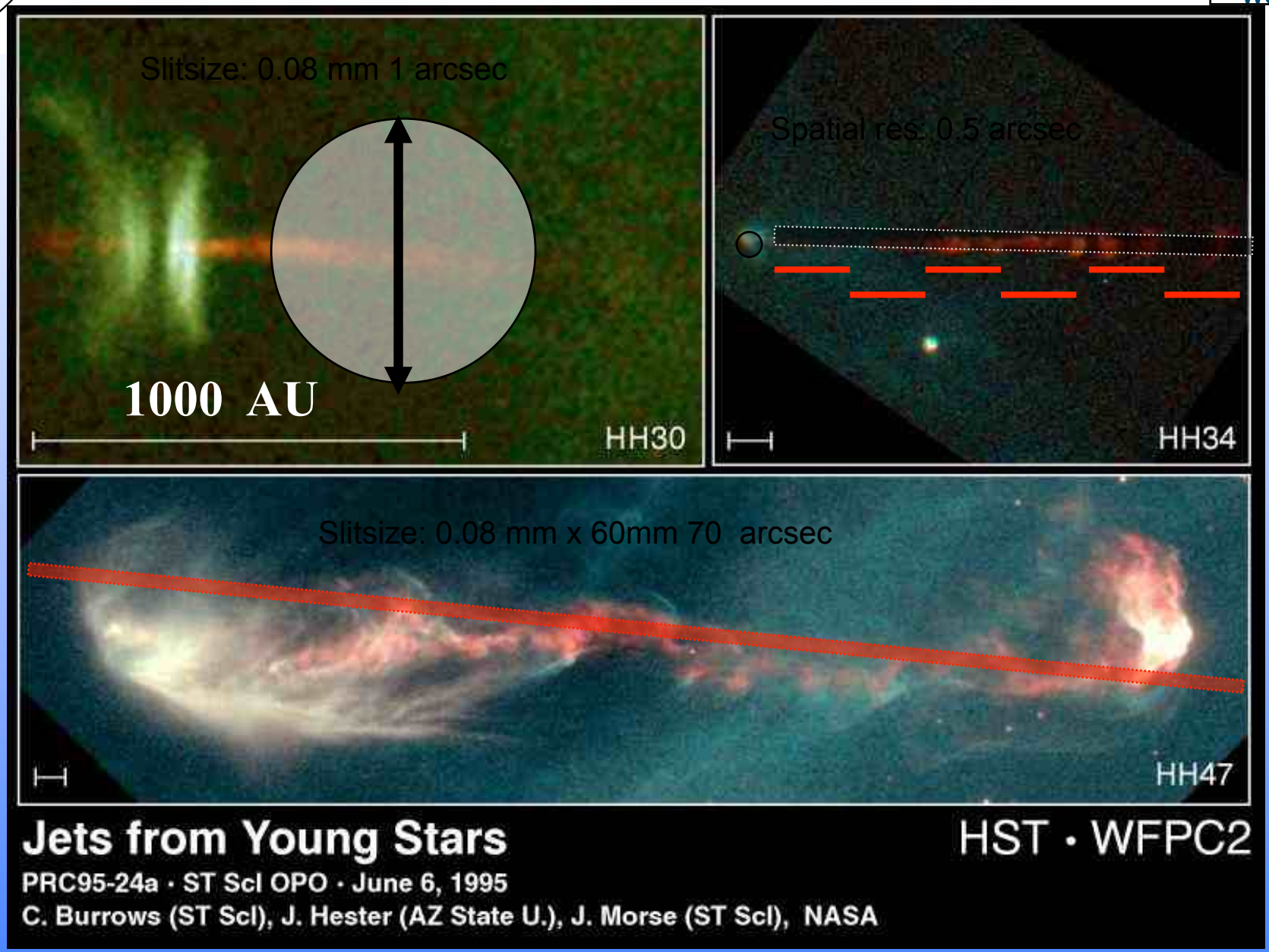
Long Slit Spectrograph

LSS : 103 nm – 310 nm

λ/δλ : 1000

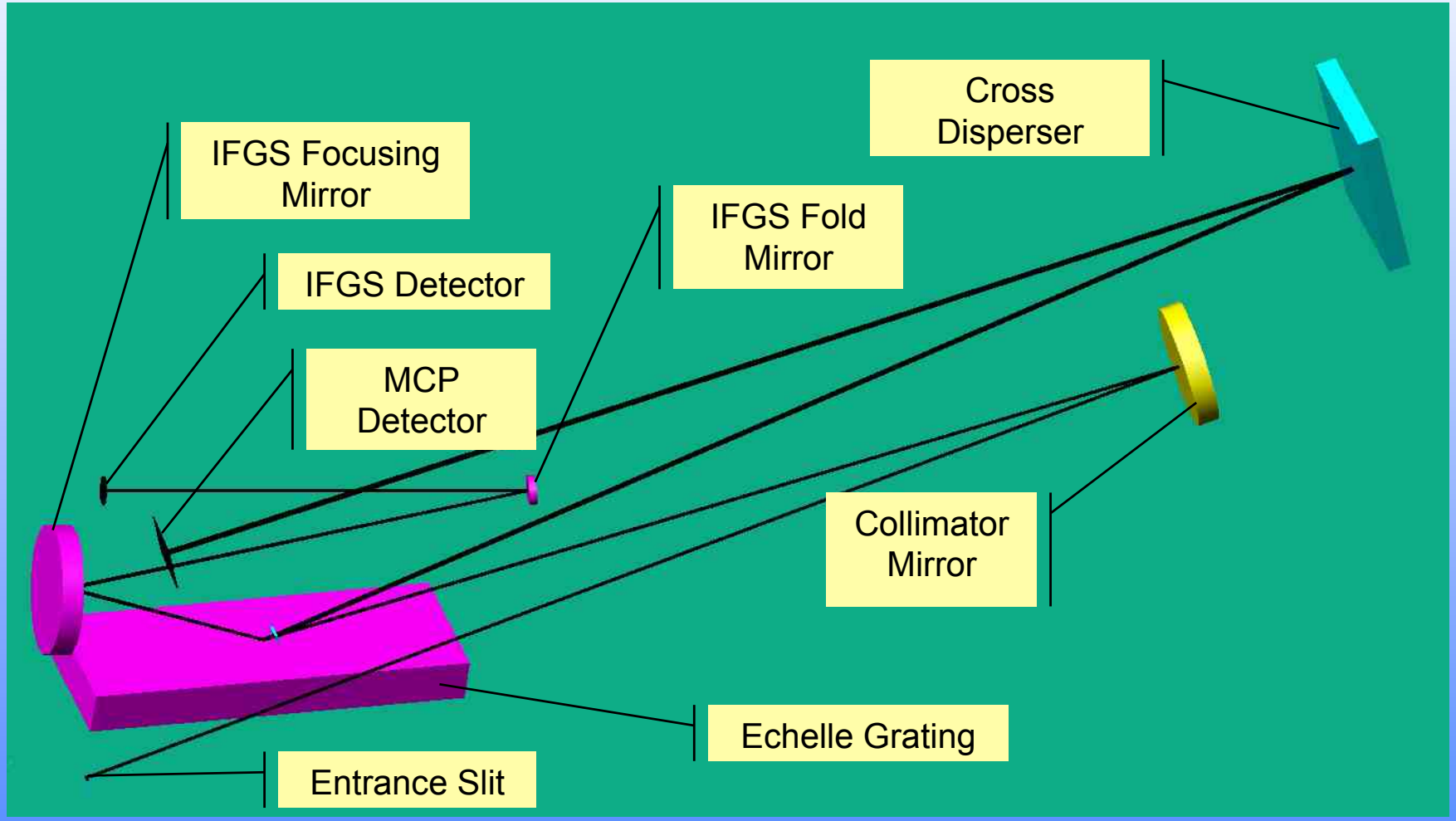
Spatial Resolution: 1 arcsec




Slitsize: 0.08 mm 1 arcsec
1000 AU
HH30
Spatial res: 0.5 arcsec
HH34
Slitsize: 0.08 mm x 60mm 70 arcsec
HH47
Jets from Young Stars
HST · WFPC2
PRC95-24a · ST ScI OPO · June 6, 1995
C. Burrows (ST ScI), J. Hester (AZ State U.), J. Morse (ST ScI), NASA

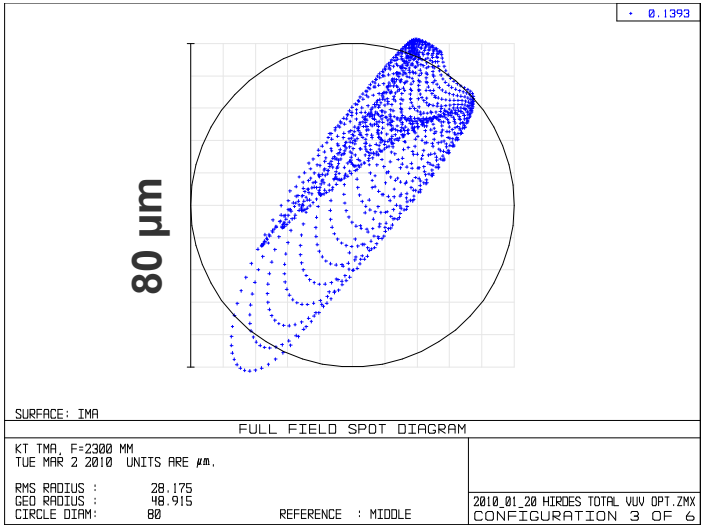
In Field Guidance Sensor

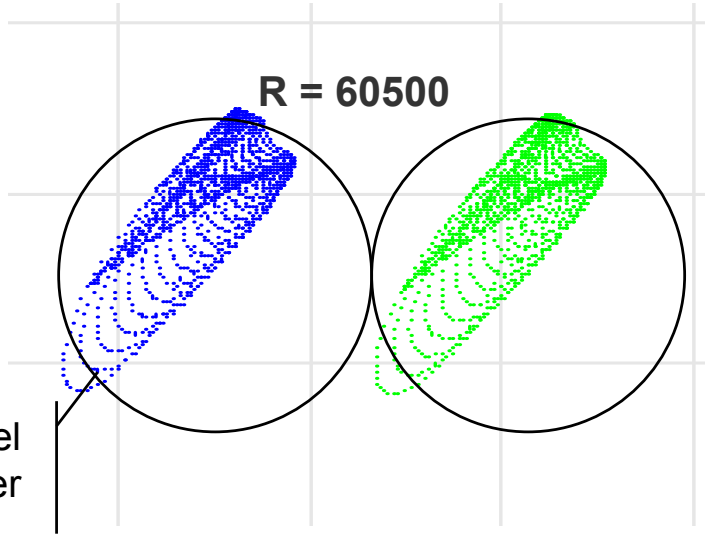
VUV Spectrograph



Performance VUV

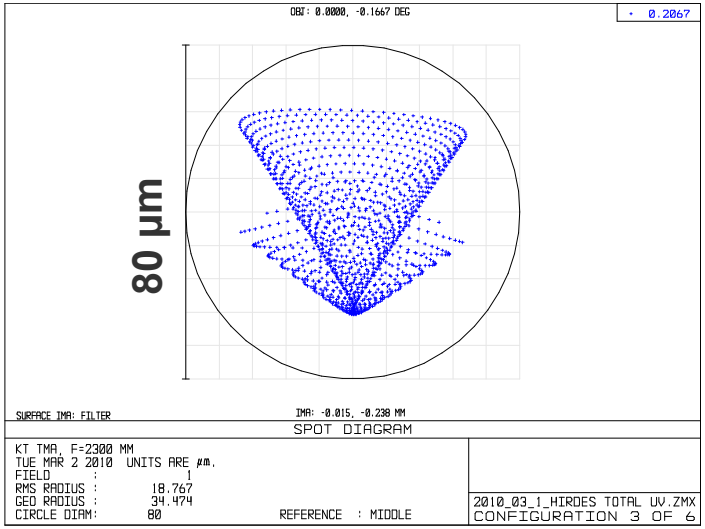
Spot Dimension

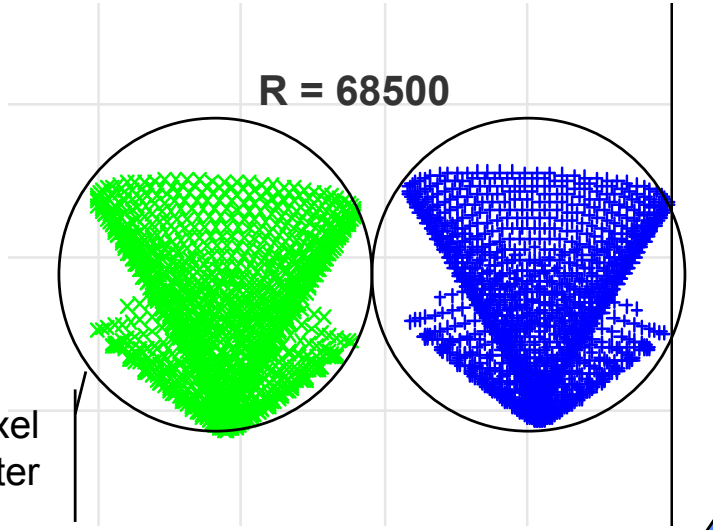




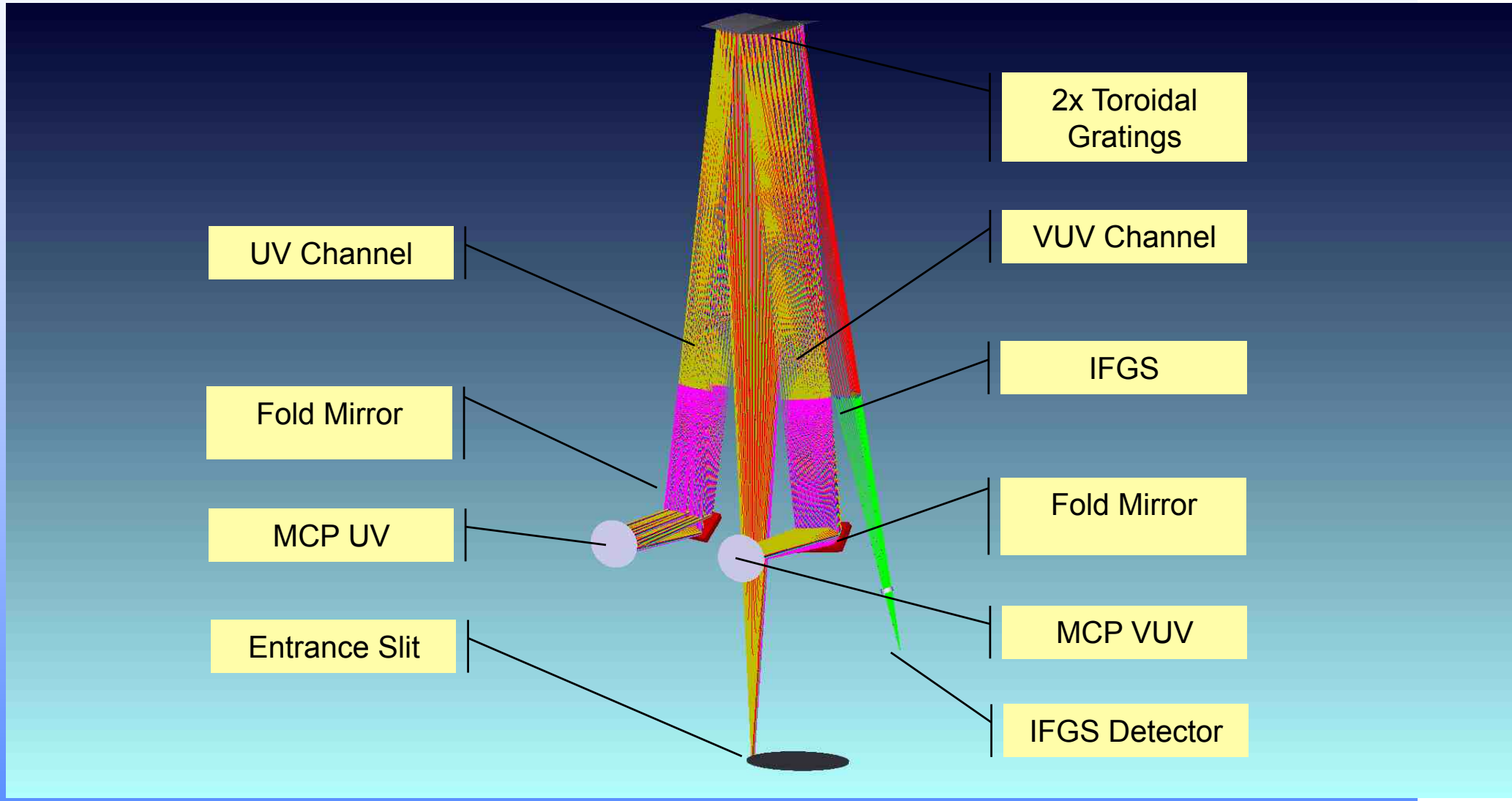
Performance UV

Spot Dimension



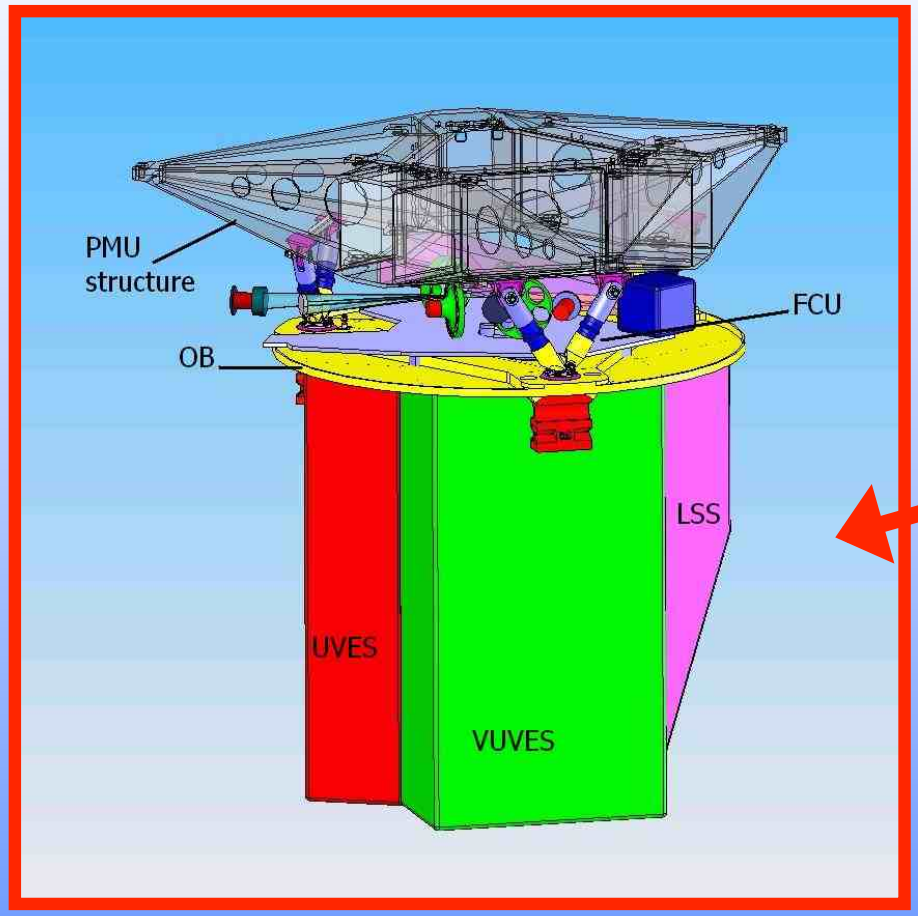


LSS Optical Design



Optical Bench

Thermostable CeSiC Structure

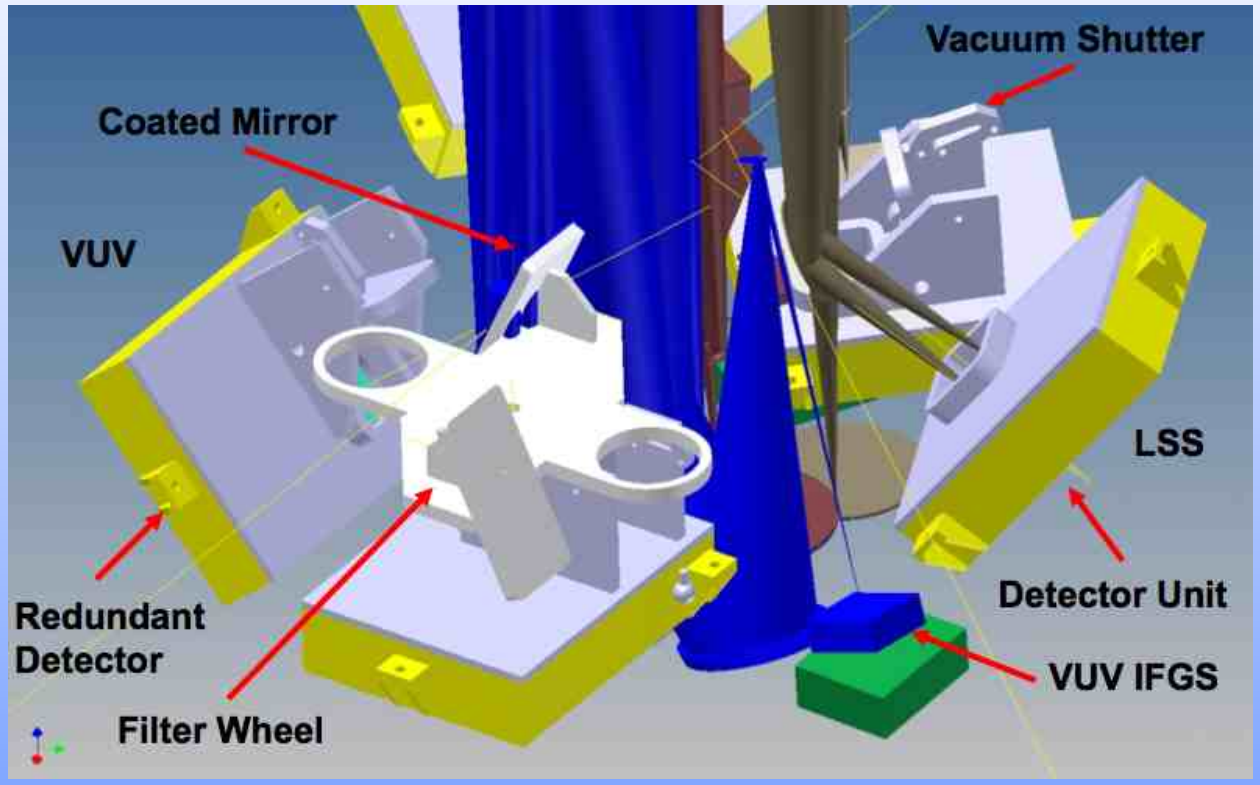


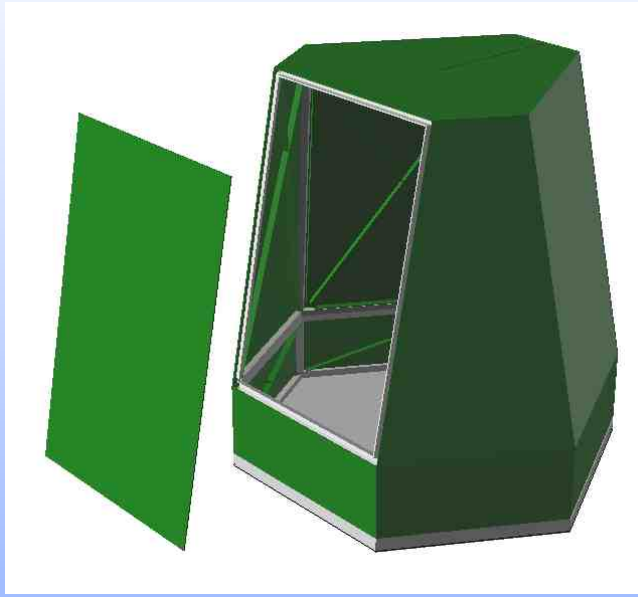
CeSiC Struktur

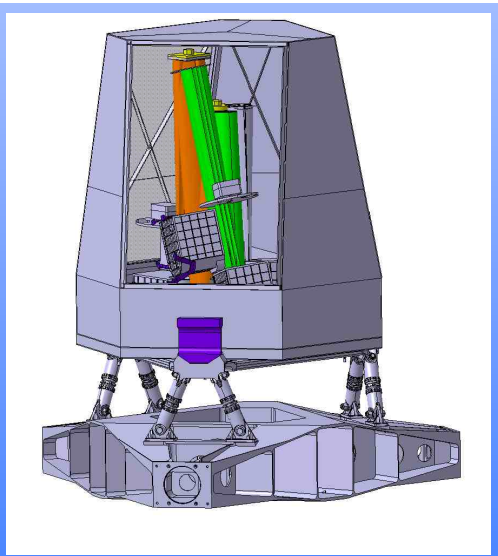
Required spectral resolution without active control of optical elements

End of Phase B: Complete CeSiC Breadboard of WUVS

Spectrographs





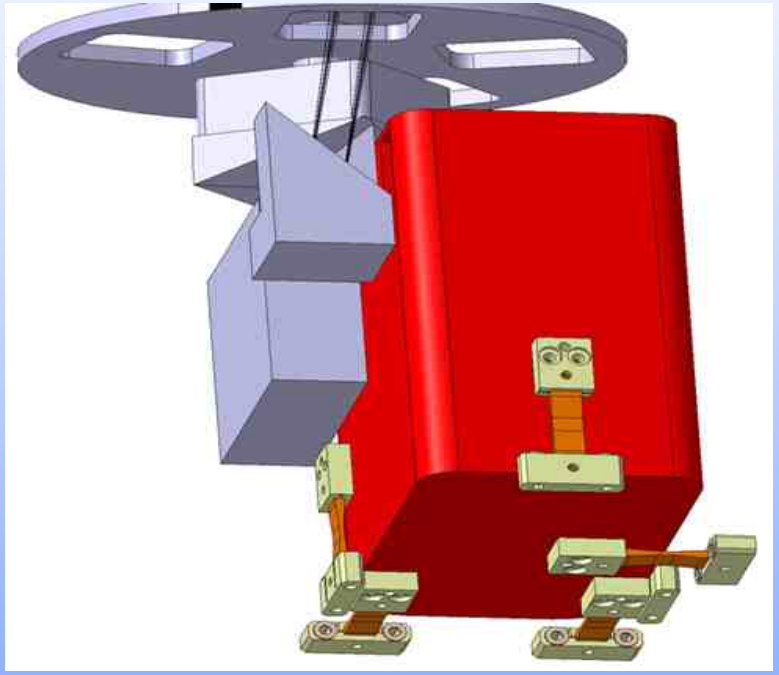


Single Unit Design

No need of fine / realignment

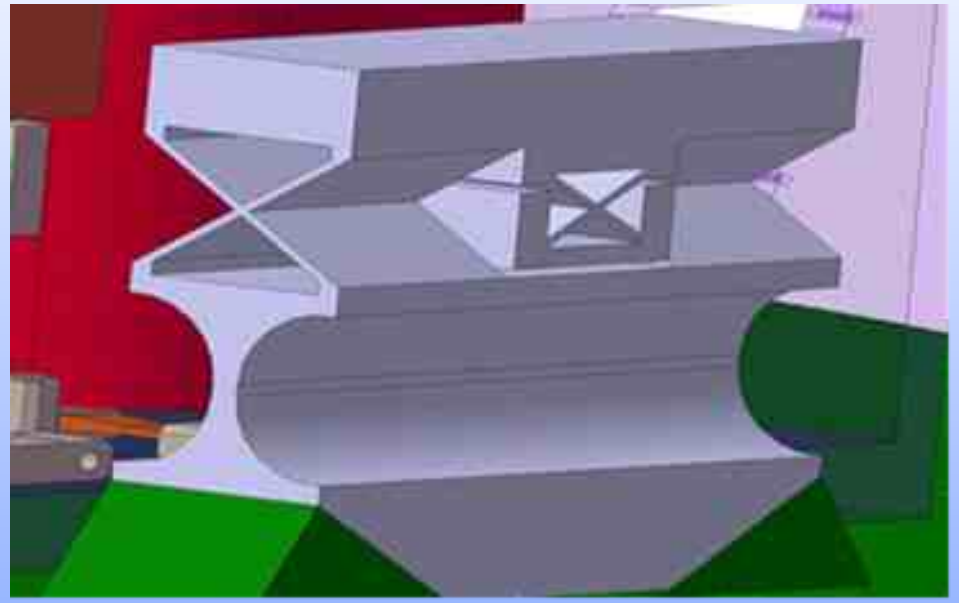
~ 30 kg less weight (WUVS budget)

Critical Components Design



Isostatic Suspension made from CFRP

(PACS heritage)



Invar Suspension with SS flexural Blades

(ORFEUS Heritage)

Mirrors and Gratings

- Quartz Glas with Invar flexural mounts
- Coatings: UV : Al + SiO_2 VUV: Al + MgF_2

QE of Cathodes

- GaN:
  - might be used for both detectors
  - special know-how required (partner needed)
  - sealed detector required
  - never flown in space
- CsI:
  - proven technique
  - handling under dry nitrogen
- CsTe:
  - special know-how required
  - production and handling under UHV conditions
  - sealed detector required

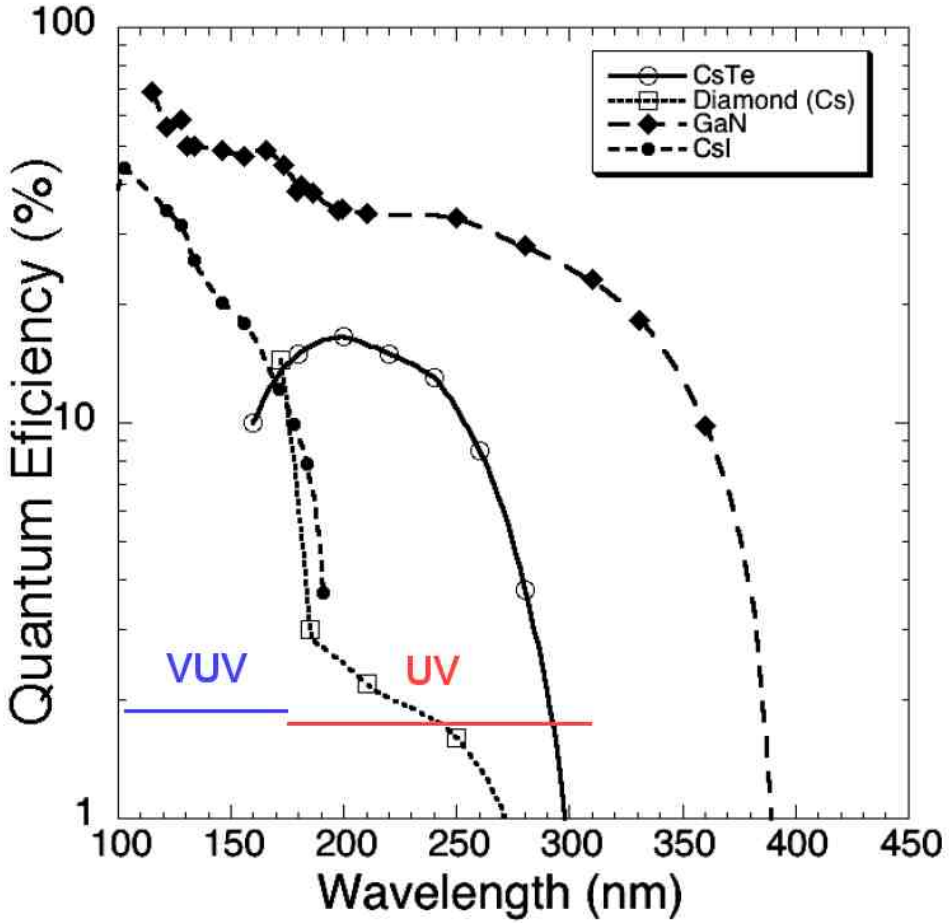
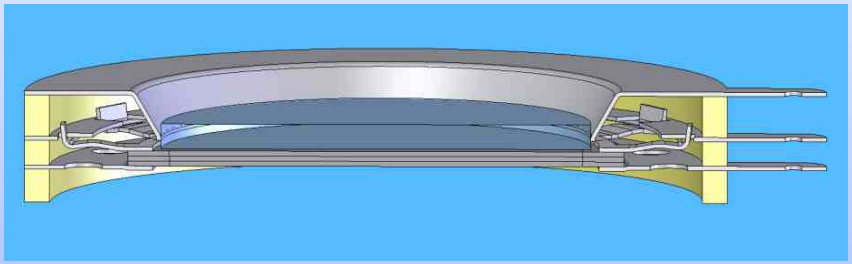


Figure 3. Comparison of different ultraviolet cathodes CsI on MCPs, opaque GaN and diamond[3], and CsTe.

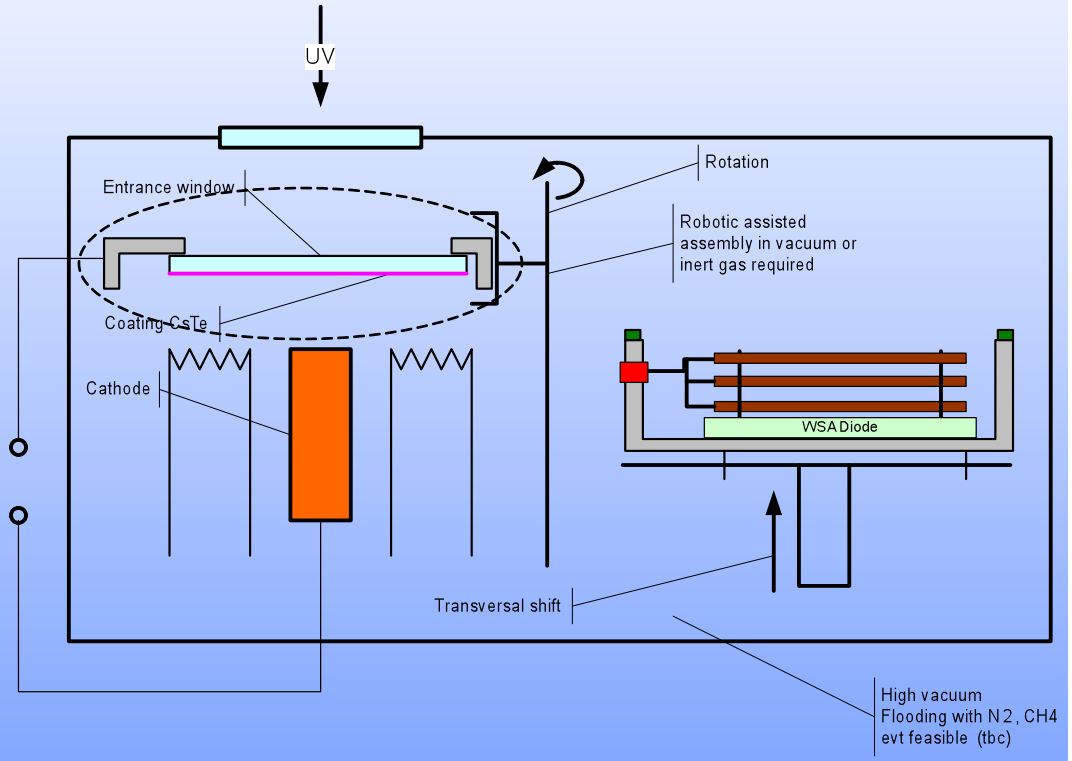
Siegmund et al., 2008 Proc. of SPIE Vol. 7021 70211B-2

Activities financed by DLR

Example: sealed detector tube



UV-MCP: Coating + Assembly Facility

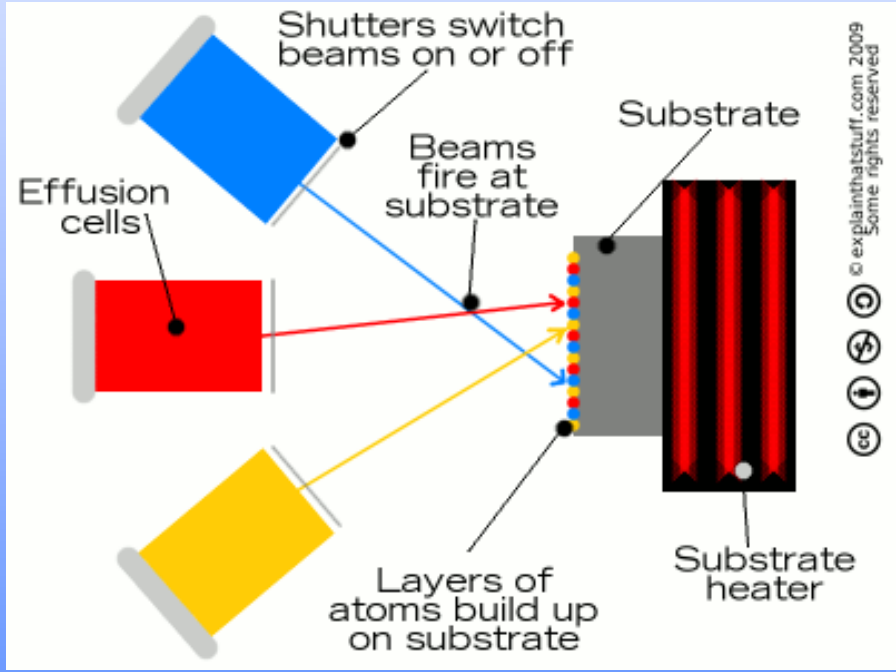


Coating + Assembly Facility
UV-MCP

- VUV Detector (CsI, IAAT):
  - Glove Box
- UV Detector (CsTe, IAAT):
  - UHV chamber, two parts separated by a shutter
    - Part 1: detector preparation (heating, burn in)
    - Part 2: cathode production
  - Transfer mechanism for cathode
  - Indium seal (melting point 160°C)

VUV/UV Detector (GaN Cathode)

- possible methods:
  - Metal Organic Chemical Vapor Phase Epitaxy (MOVPE, OMVPE)
  - Metal Organic Chemical Vapor Deposition (MOCVD, OMCVD)
  - Molecular Beam Epitaxy (MBE)
- expensive equipment, know how needed
  - collaboration required



- Research group "*Nanoscale Materials*" of the *DFG-Center for Functional Nanostructures* at the Karlsruhe Institute of Technology (D. Schaadt)
- The group is researching nanoscale materials and their applications. Fabrication is mostly performed by molecular beam epitaxial (MBE) growth, where also the growth of new materials and growth on new substrates is investigated. The group has full access to a double-chamber MBE system and a single-chamber MBE system

Possible Photocathodes

HIRDES + LSS

- VUVES (102-176 nm)
  - CsI (opaque) – *standard*
  - GaN (opaque) – *under development*

- UVES (174-310 nm)
  - CsTe (semitransparent) – *standard*
  - GaN (opaque or semitransparent) – *under development*

Default approach

Advanced approach, redundant detector type

Anode

Cross-Strip

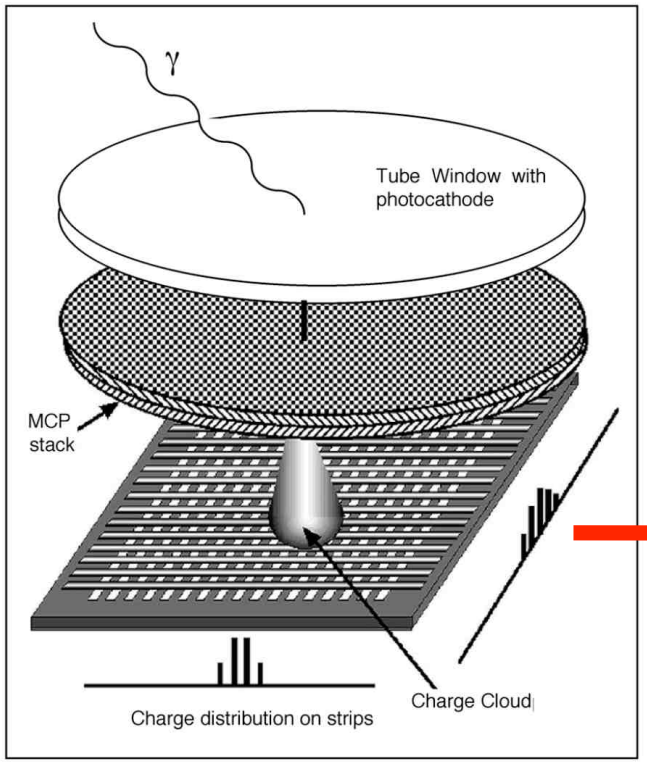


Fig. 1. Scheme of a cross strip anode microchannel plate sealed tube detector. Open face detectors without the window are used for short wavelength, and particle detection applications.

Siegmund *et al.*, Nuclear Science Symposium Conference Record, 2007. NSS '07. IEEE, Vol. 3, pp. 2246-2251

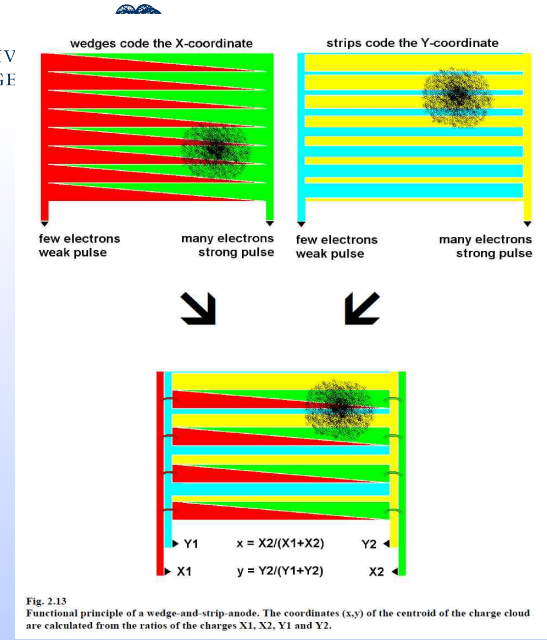


Fig. 2.13
Functional principle of a wedge-and-strip-anode. The coordinates (x,y) of the centroid of the charge cloud are calculated from the ratios of the charges X1, X2, Y1 and Y2.

Wedge-and-Strip

+ 4 charge amplifiers
- high signal required > 10^7 e^- (life time)

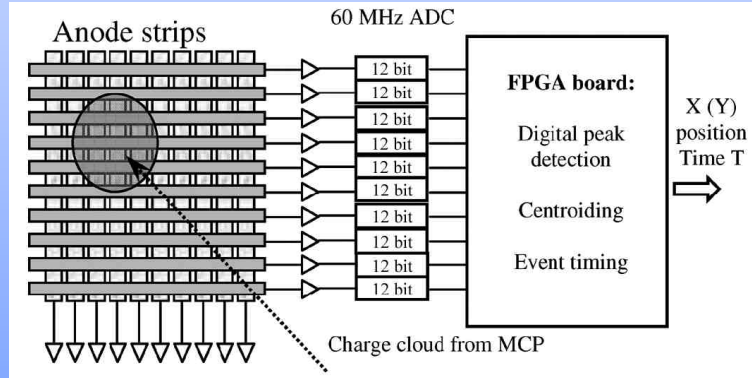


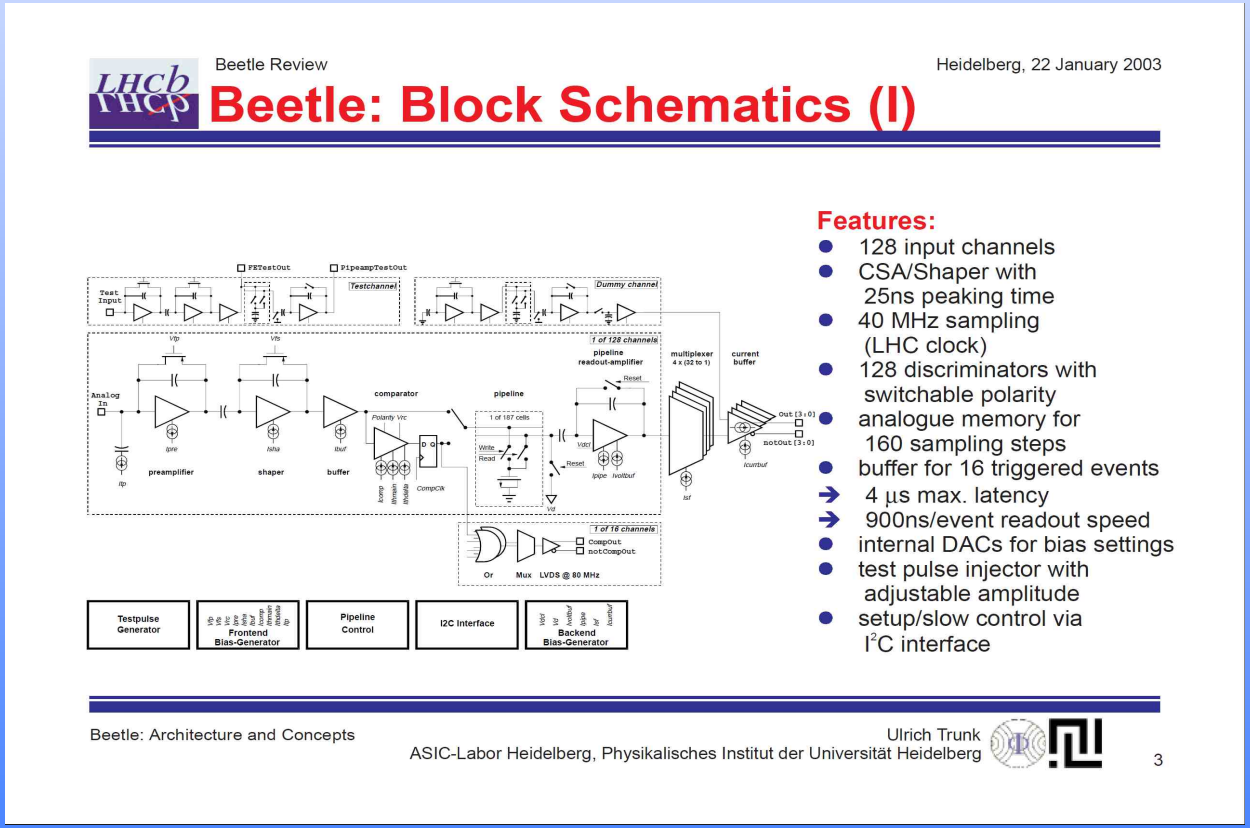
Fig. 2. Schematic diagram of the parallel cross strip data processing electronics. Each electrode of the two orthogonal set of fingers is connected to a charge sensitive preamplifier followed by a fast ADC. All digitized channels are fed into Vertex5 FPGA, where an event is detected, peak values are calculated for the electrodes which received charge from MCP cloud followed by the event centroid calculation. The same data is used for calculation of the event timing. Only one set of fingers has its electronics shown.

Termsin *et al.*, IEEE Transactions on Nuclear Science, Vol. 56, pp. 1148-1152, 2009

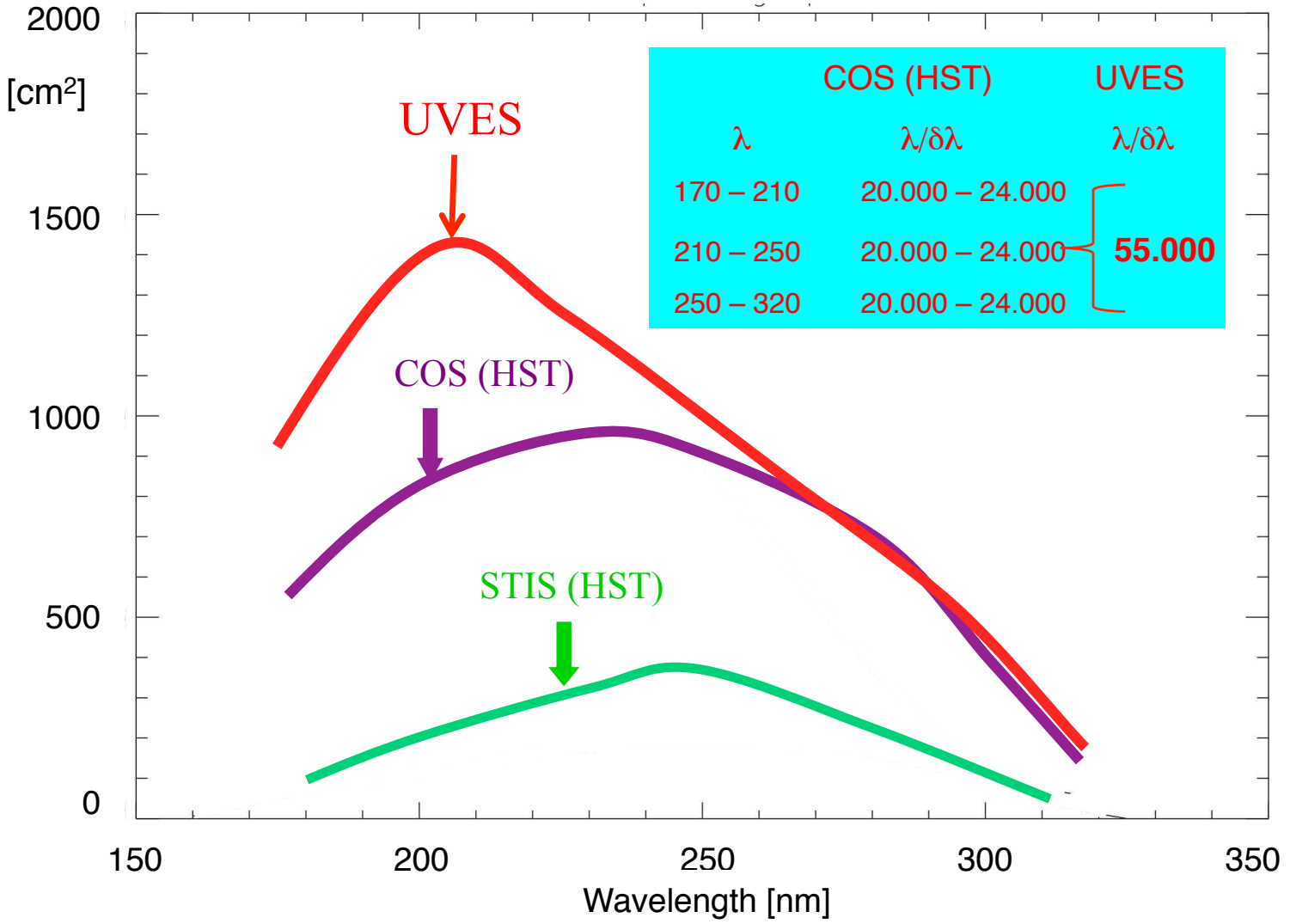
- number of charge amplifiers

BEETLE Chip

- Charge sensitive amplifier (CSA) with 128 input channels
- Developed for LHC accelerator experiments by ASIC Laboratory, University of Heidelberg
- Radiation hard (10 Mrad TID)



Effective Area of UVES



Design Criteria WUVS

Wavelength Coverage : 103 – 310 nm

Spectral Resolution : > 50.000

Simultaneous Coverage : as far as possible

Improvement of Eff. and FE of MCP-Detectors

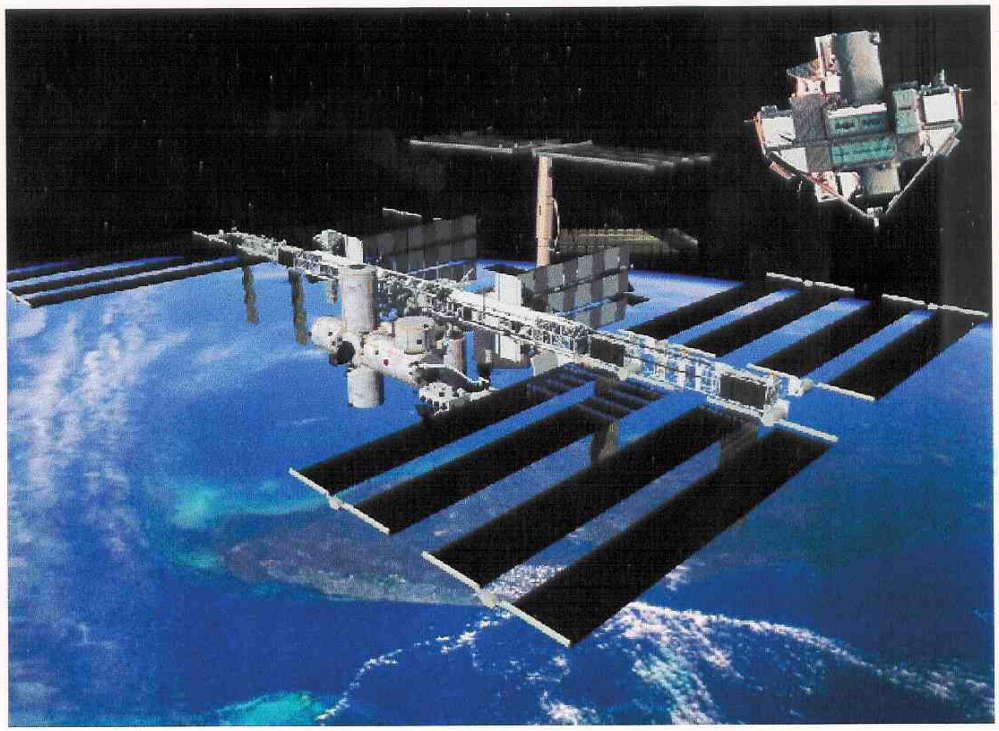
Possibility to Observe Bright Stars

„Slit – Monitor“

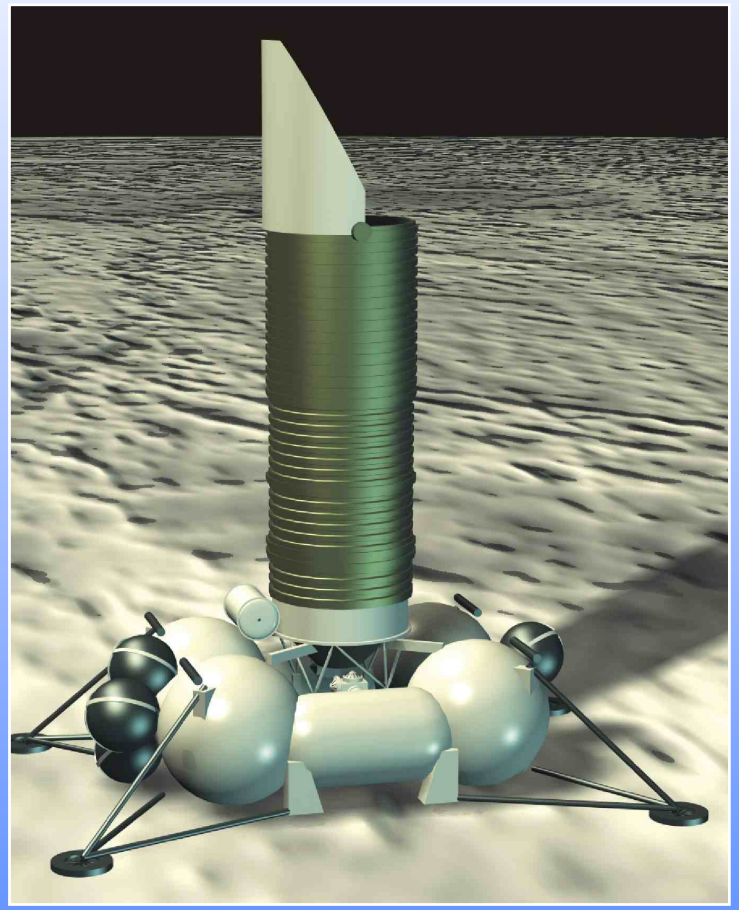
Reduction of Mechanisms

STATION - FLYER
ORFEUS - SPAS

Instruments : Modified HIRDES
Mission Life Time : > 1 year
Mission Control : IAAT



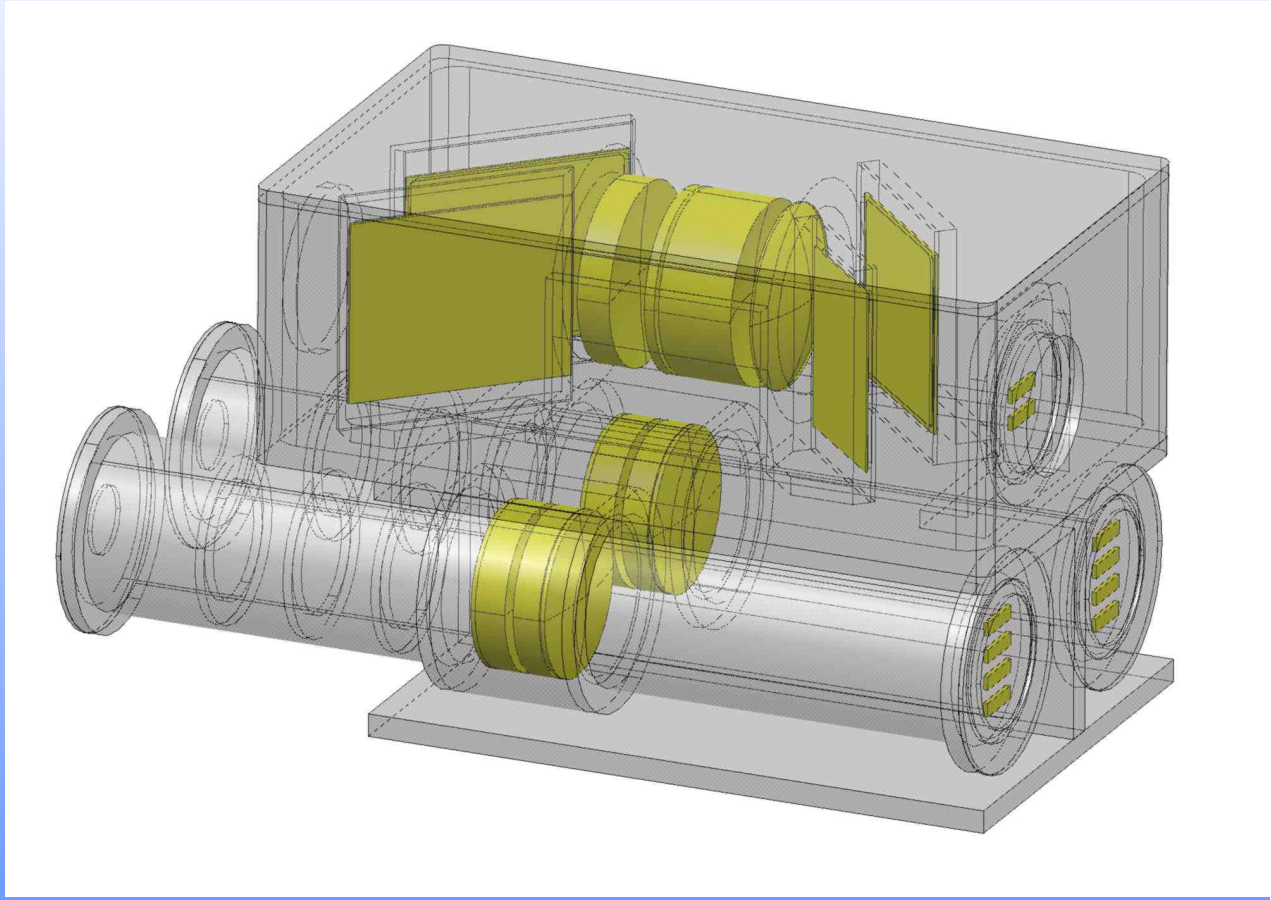
DIVA – UV Instrument:
Double Interferometer for Visual Astrometry



WSO/UV Telescope
2m class Telescope

UV Spectral Mapping Instrument (USMI)

- Multispectral image data of the moon surface
- Scanning of the moon surface in the UV in 9 spectral band-passes covering the 200 nm – 400 nm wavelength range
- 10 meter/pixel

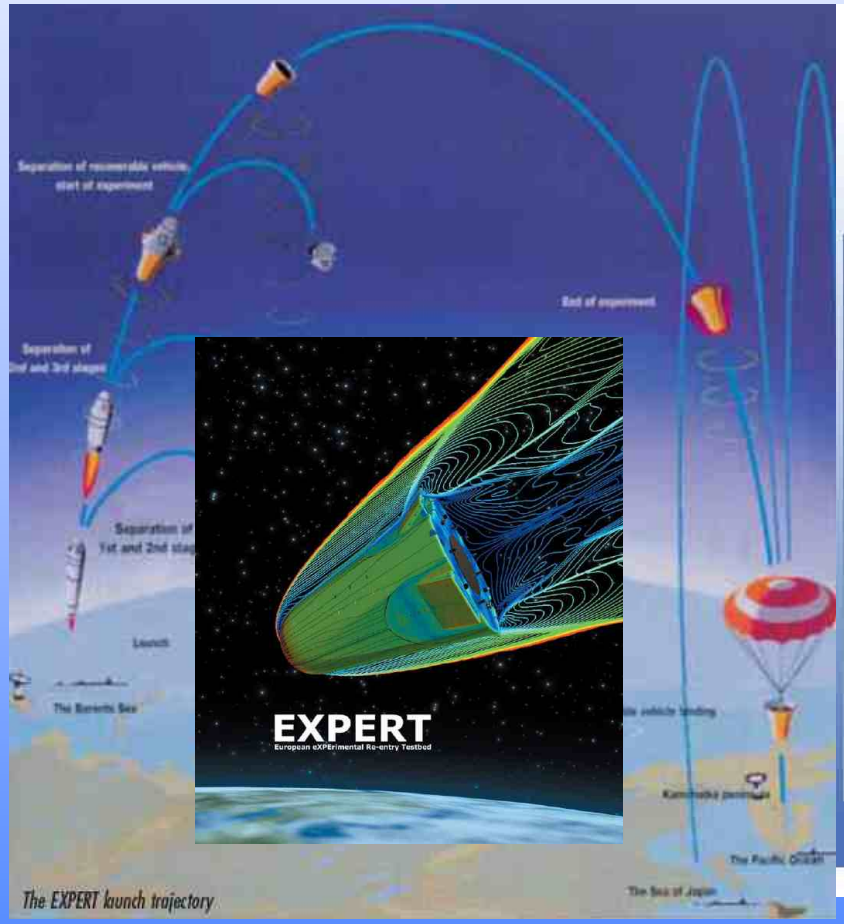


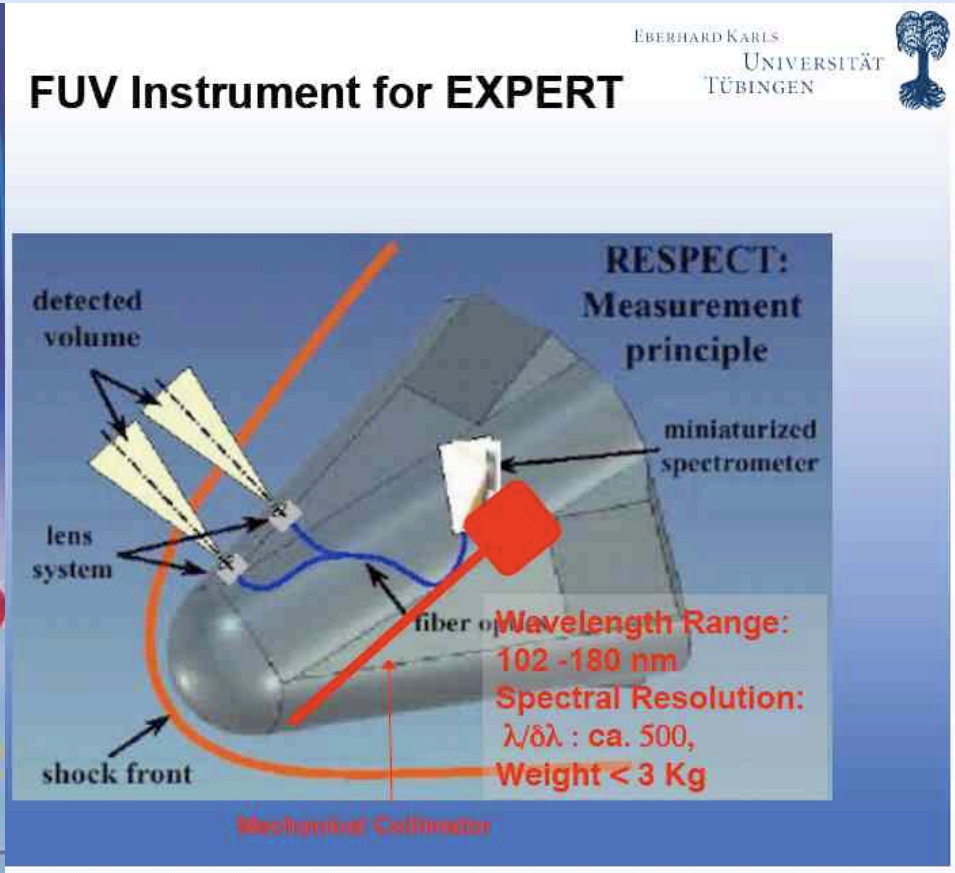
Main Characteristics:

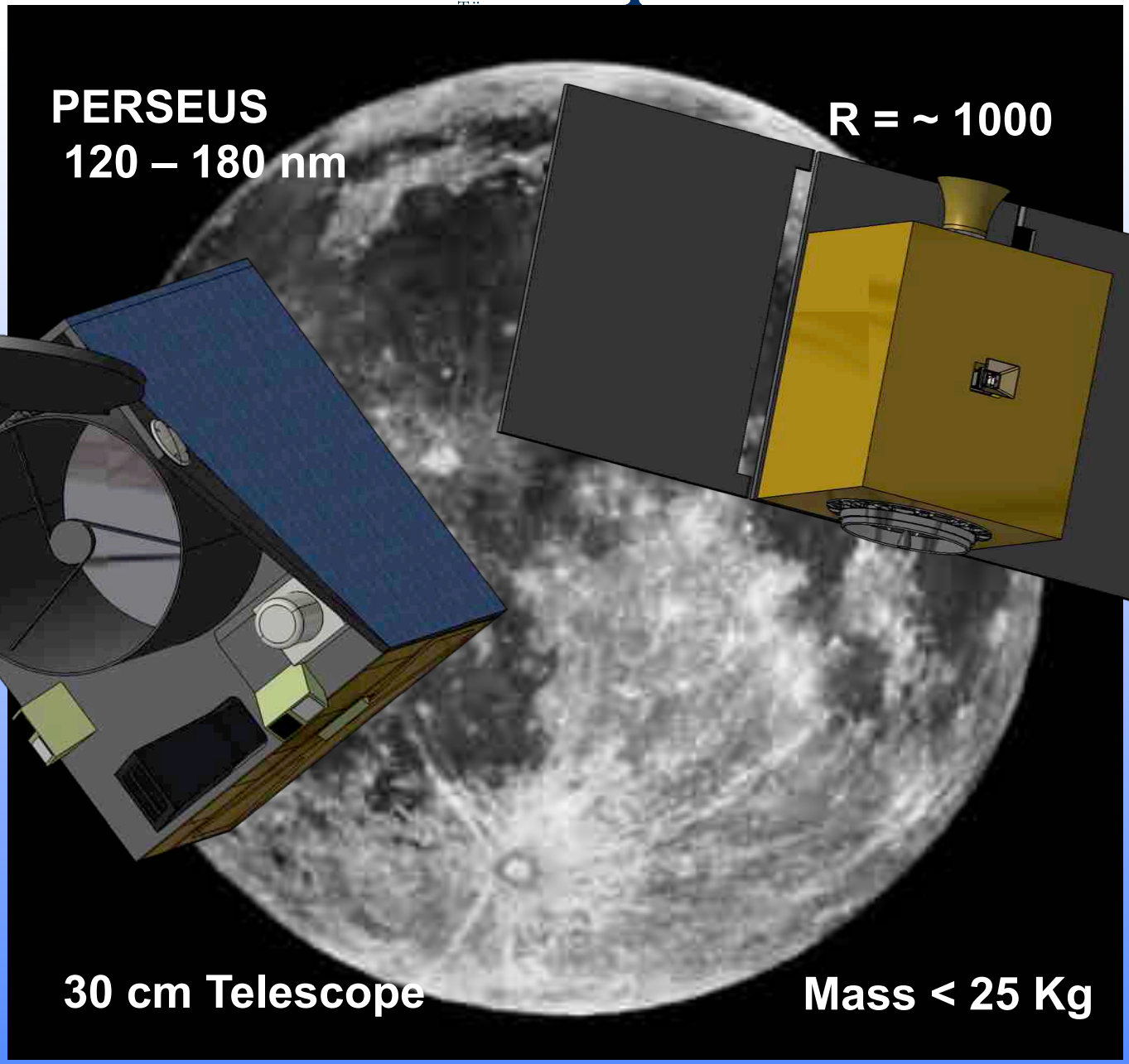
- 3 independent optical units
- Unit with reflective channel on top of the 2 others

Cosmic Vision L-class mission EJSM/Laplace

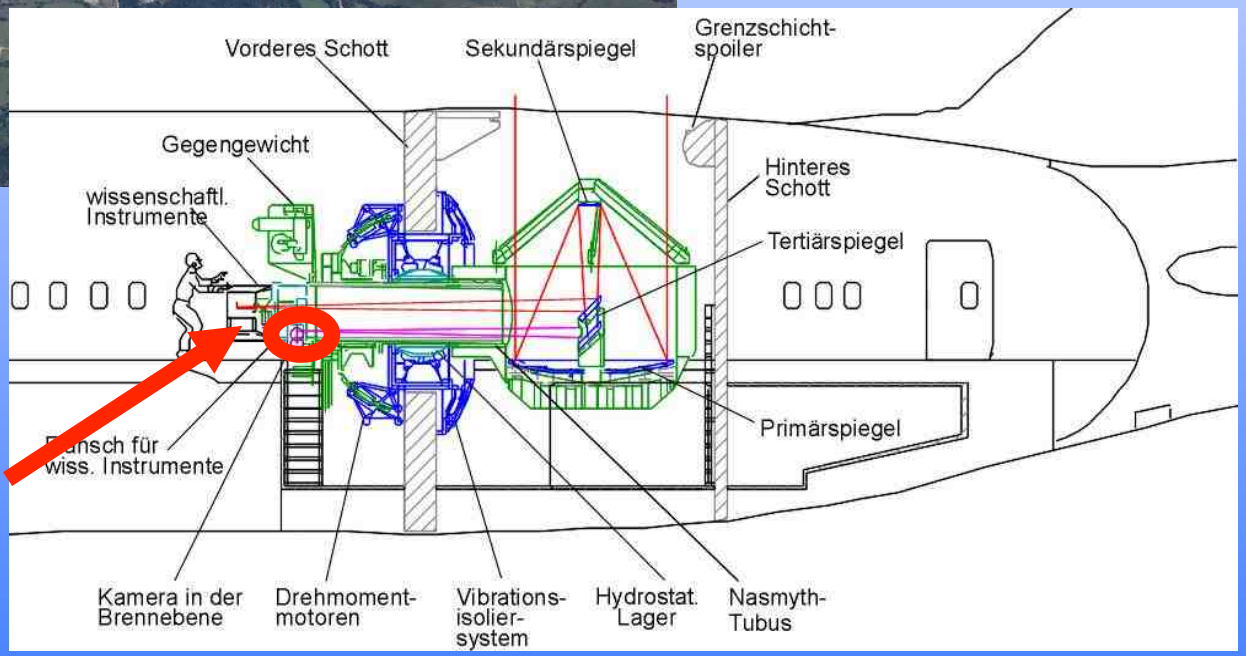
EXPERT
European Experimental Reentry Testbed





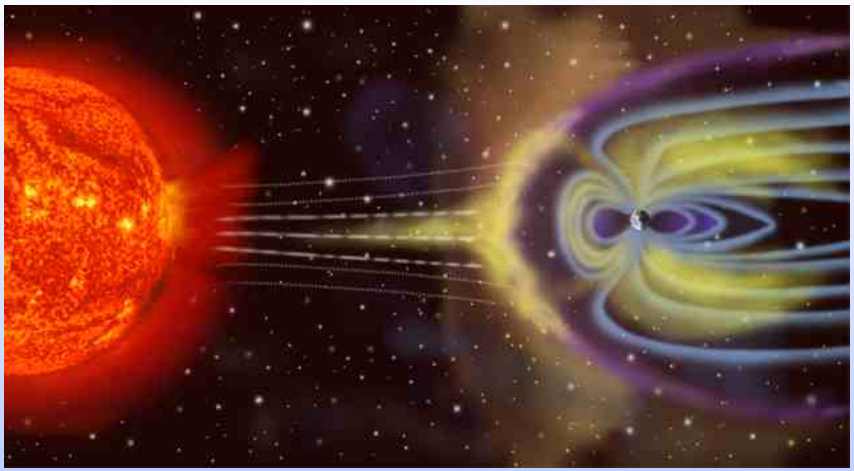

PERSEUS
120 – 180 nm
R = ~ 1000
30 cm Telescope
Mass < 25 Kg

SOFIA

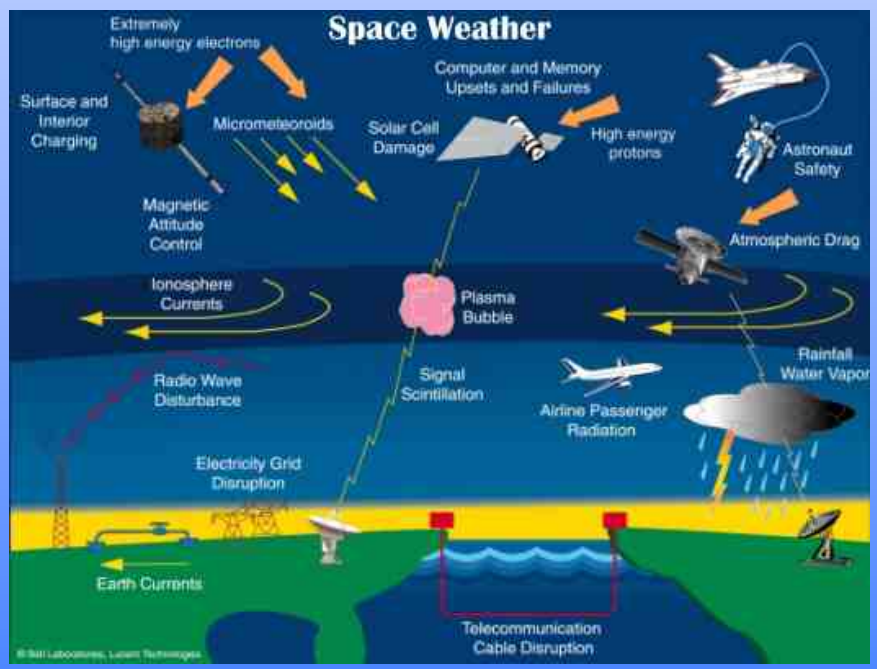


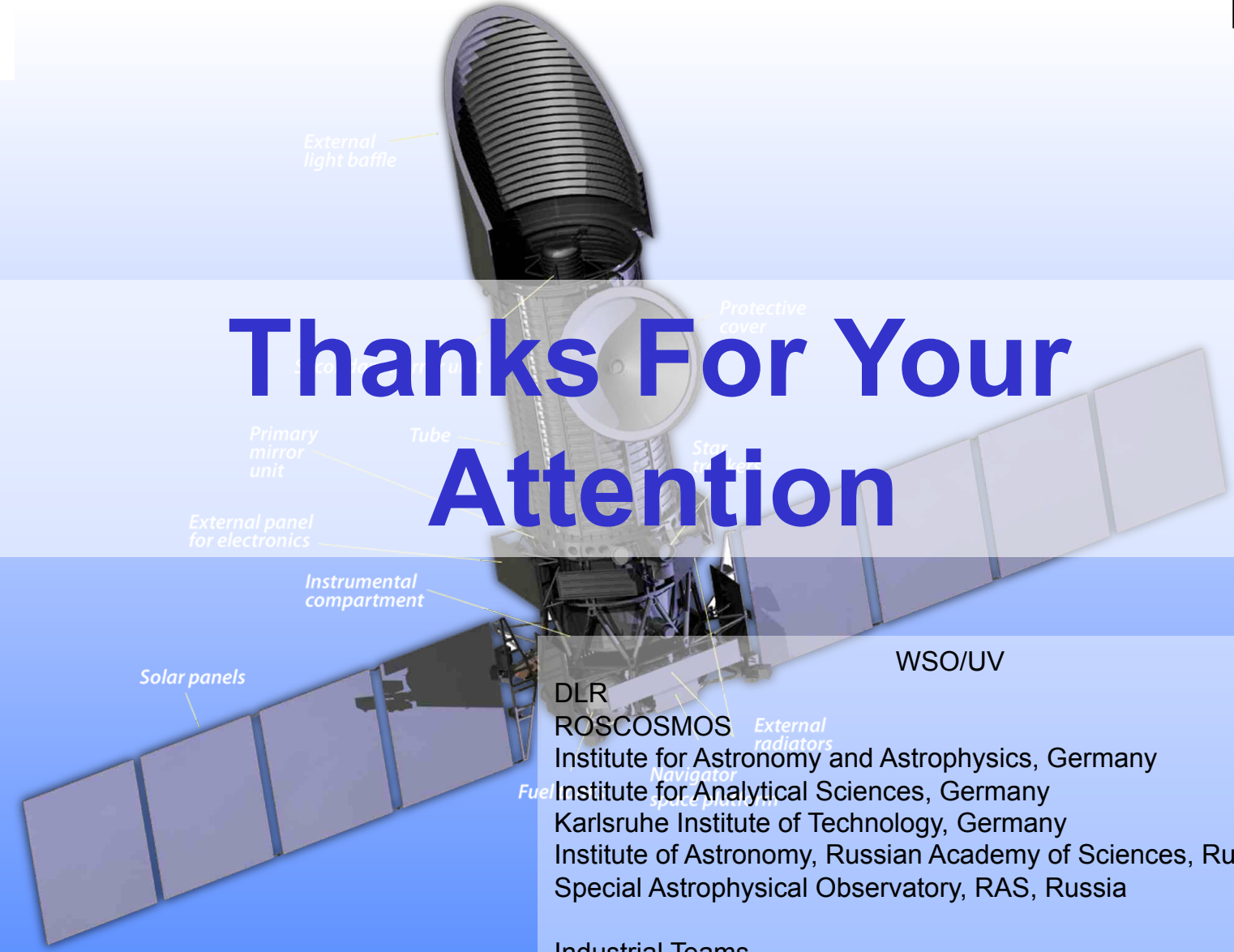
UV-Spectrograph

small progress



UV instruments may help x-ray missions to survive





Thanks For Your Attention

WSO/UV

DLR
ROSCOSMOS
Institute for Astronomy and Astrophysics, Germany
Institute for Analytical Sciences, Germany
Karlsruhe Institute of Technology, Germany
Institute of Astronomy, Russian Academy of Sciences, Russia
Special Astrophysical Observatory, RAS, Russia

Industrial Teams
Lavochkin Ass., Russia
Kayser-Threde GmbH, Germany