Current UV projects in Space

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Outline...

- Short note on actually flying missions
- The immediate future
- The (very) long term future
- How to fill the gap?

CAVEAT: I should restrict to actual UV (not redshifted...) but difficult...

and there are not only galaxies in the UV...

To quote Mike Shull...
(could be my summary...)

- Bright future for UV spectroscopy on Hubble COS

AGN, galaxies, OB stars, White dwarfs,

planets, nebulae, debris disks, ISM, IGM, ...

+ Community treasury project on IGM, AGN outflows, QSO absorption lines ?

- Imminent gap in UV/O missions (also X-rays) How to fill this gap, which drivers?

GALEX

- Baseline surveys

Completed (2007)

- Cycle 6 call ended june 19th...

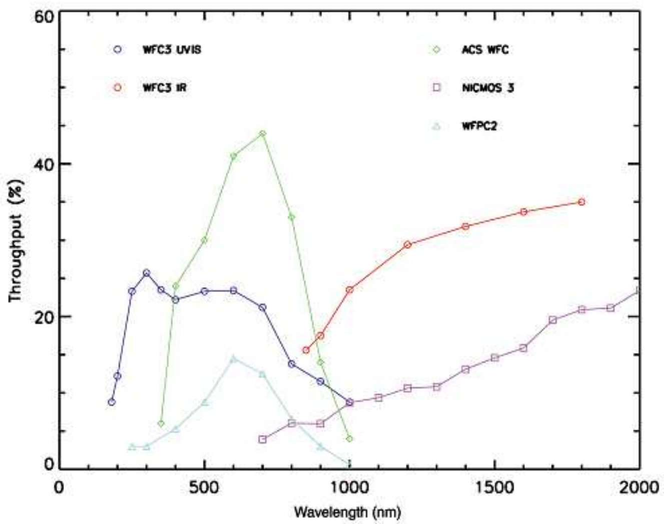
Survey	Exp. time (sec)	Sky (deg)2	mAB	Tiles GR2/3	Tiles GR4
All Sky	100	26000	20.5	15721	28000
Medium	1500	1000	23.5	1017	1615
Deep	30000	80	25.0	165	193
NGS	1500	300	28	296	433
MSS	150000	5	22	3	5

Galex Legacy Surveys

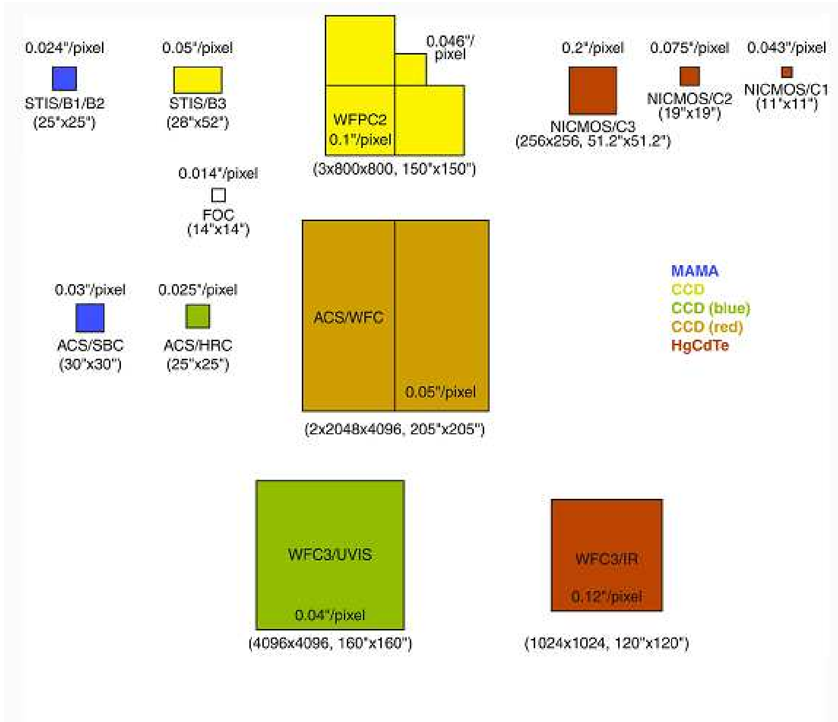
SURVEY		Exp. Time (sec)	Sky Cover. (Deg^{2})
Gal. Cap	SDSS footprint	1500	20000
Legacy Deep	PS-1, M31, SDSS	30000	100
MW Survey	SEGUE	1500	5000
Spectro. Legacy	SDSS	150000	20
Deep Galaxy	Nearby galaxies	15000	100
UltraDeep Imaging		300000	7

HST

- Imaging capabilities (not really a survey machine...)



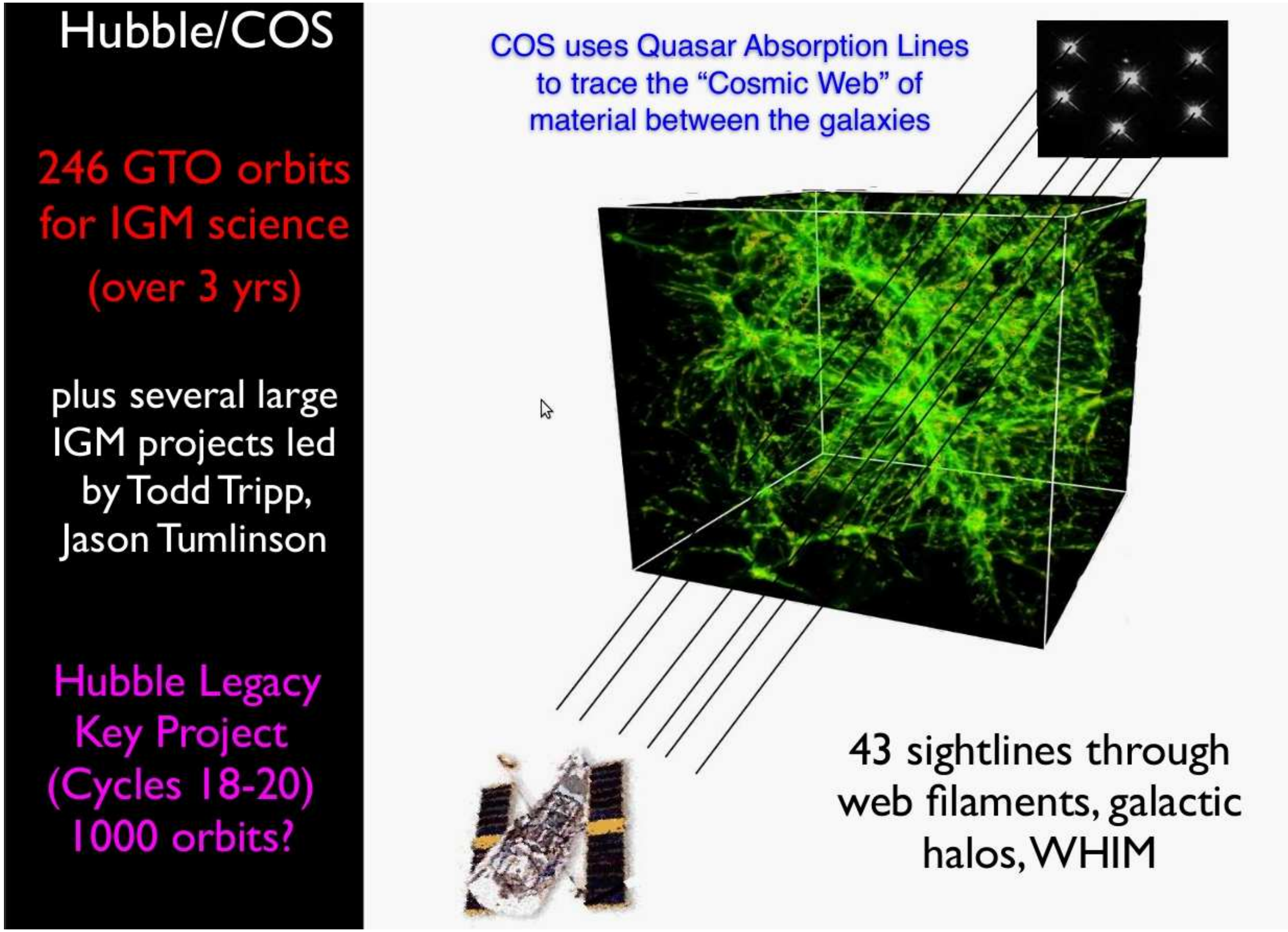
Throughput vs. wavelength of WFC3 UVIS, WFC3 IR, ACS, NICMOS 3, and WFPC2



Comparison of instruments' fields of view (FOVs)

How much time for UV??

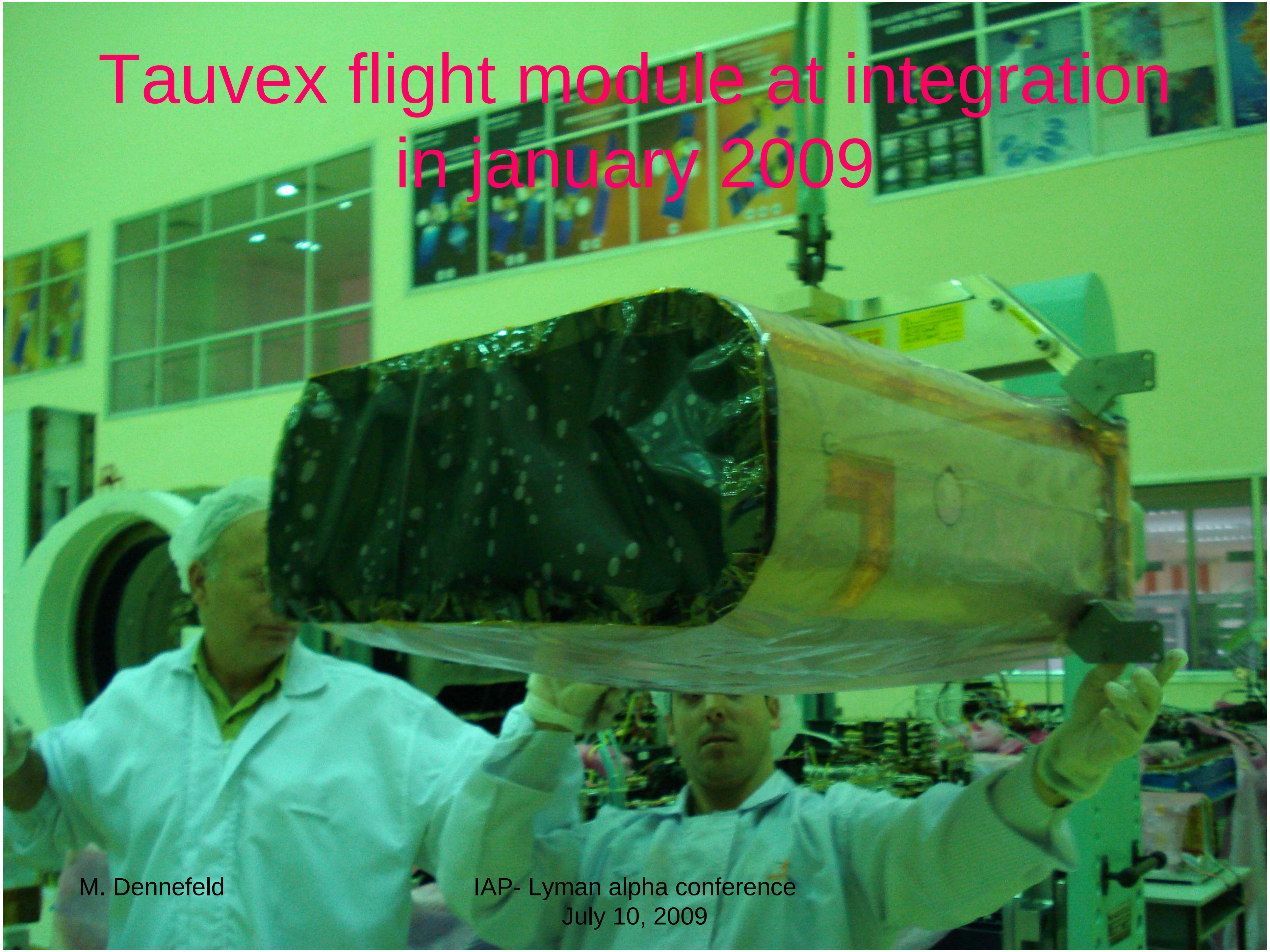
COS GTO program...



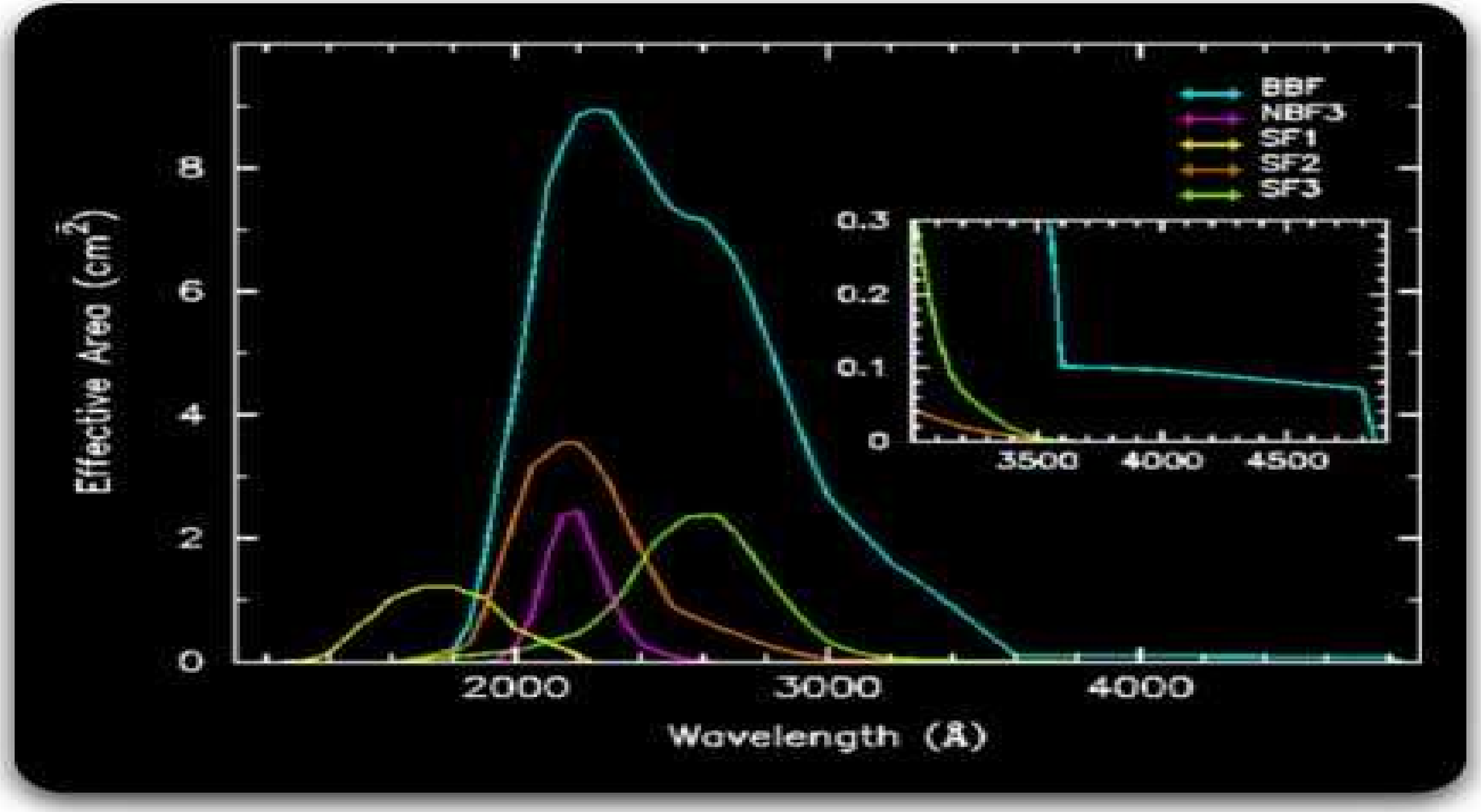
TAUVEX

- Tel Aviv University UV Explorer
- Will fly on Indian GSAT-4 (geostationary) mission in october 2009
- 3 x 20cm UV imaging telescopes, 1200-3200 Å, FOV 0.9 degrees diameter
- 3 Wedge and Strip photon counting detectors, each with 4 filters (1 blind)
- Core science program finalised now, progressively open after first year

Tauvex flight module at integration in january 2009



Tauvex Bands and Filters



ASTROSAT

- ISRO multi-λ astronomy mission
- 5 payloads:

  -Two 40cm UV imaging telescopes (UVIT)

  -Three X prop. Counters (LAXPC; 3-80 keV)

  -A Soft X Telescope (SXT; 0.3-8 keV)

  -A coded mask imager (CZTI; 10-150 keV)

  -A Scanning Sky Monitor (SSM; prop. counter)

Sky survey in hard X-rays and UV bands

Launch date: late 2010

ASTROSAT-UVIT

- To provide flux calibrated images at ~1.5 '' resolution, FOV ~0.5 degrees
- Two channels: FUV (1200-1800 A)

  NUV (1800-3000 A)

+ simultaneous visible (3500-5500)

Broad and narrow band filters + 1 grism/channel

FUV: 3 Cont., CIV, HeII

NUV: 4 broad, and 2 narrow (CIII, MgII)/ VIS: 4 narrow

Correlated temporal variations in V, UV and X of AGN's + core program

Proposal driven, general purpose observatory

Open to public from 3d year (35% +) onwards

Other flying missions...

- Fireball (Faint Intergalactic Redshifted Emission Balloon)

  Balloon borne, high-resolution UV Integral Field Spectrograph to map emission from the IGM, in Ly-α, CIV 1550, OVI 1033 Å

  Collaboration Caltech, Columbia, Marseille See Chris Martin's talk for details

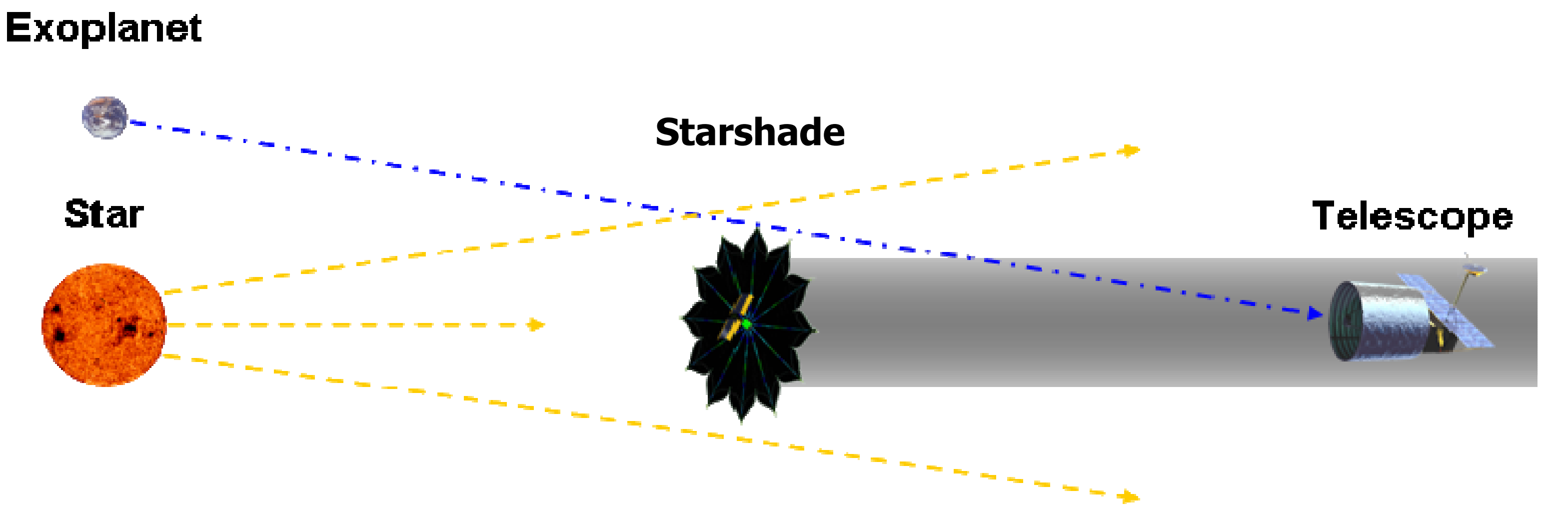
- UV channel on XMM-Newton (on-going surveys)
- SPEAR on STSat-1 mission

  Large-area all-sky spectral mapping (900-1750 λ) of hot and warm plasmas. Collaboration Korea + Berkeley

Various Exoplanet Mission concepts

- ACCESS (J. Trauger, JPL) R~20 spectro
  1.5m off-axis Gregorian + Lyot coronograph
- EPIC (M. Clampin, GSFC) R~20-50 spectro
  1.65m, high-contrast imager, Nulling Interfer.
- DaVinci (G. Vasisht, JPL)
  4 x 1.1m, Visible Nulling Coron. Interfero.
- PECO (O. Guyon, NAOJ) 1.4m off-axis
  Corono. observer with apodisation
  pre-PECO = EXCEDE (Smex mission) ?

NWO Occulter Diagram



- They studied:

- 50m diameter Starshade at (typically) 80,000km
- 4m Telescope Diffraction Limited at 0.5μ (25milliarcsec)

New Worlds Observer (W. Cash)

- Exoplan. Astronomy needs the very same technology as Extragalactic
- Starshades provide the path to a unified approach
- While starshade retargets, telescope is free for general astrophysics (can see within 50 deg of the sun)
- R > 100 spectroscopy

Combine UVO mission with Planet-Finder?
(need to solve the on-axis/off-axis question)

SFO (Rolf Jansen et al.)

A 1.65m UV/O tel. at L2, with 2 instruments: a 190-1100nm dichroic camera with 17’x 17’FOV, 0’’.06 pix, and a far-UV R~40000 spectrograph

Table 1 — Overview of science-driven technical requirements for *SFO*

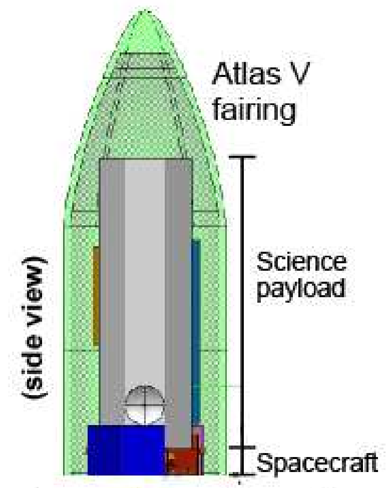
Imaging requirements:	FOV cannot be substantially smaller than $17' \times 17'$	(total area vs. depth requirement)
Focal plane geometry:	stable to $\lesssim 0''.001$ (0.017 pixel)	stable for $\gtrsim$ 4 hrs
Point spread function:	diffraction limited at $\gtrsim$ 200 nm and round to $\lesssim$10%	stable to $\lesssim$10% for $\gtrsim$ 4 hrs
Pointing jitter:	$\lesssim 0''.006$ (0.1 pixel)	stable for $\gtrsim$ 4 hrs
Photometricity:	amplifier gain, A/D conversion, QE, stable to $\sim 10^{-5}$	stable for $\gtrsim$ 4 hrs
Wavelength agility:	peak response 99%; $\gtrsim$40% over 205–1050 nm range	access to full 190–1100nm range

Filter requirements:	wheels must hold at least 10 blue and 12 red filters					(goal: 2×12 filters)		
Broadband:	F262W *UV2*	F278X* *UVW*	F330W *u*	F432W *B*			F612W *r*	F775W *i*	F885W *z*
Mediumband:	F218M *UV1*				F547M *y*	F980M Ly $\alpha_{z\sim7.1}$	F990M *Y*/Ly $\alpha_{z\sim7.2}$	F1020M Ly $\alpha_{z\sim7.4}$	F1050M Ly $\alpha_{z\sim7.6}$
Narrowband†*:*	F280N Mg II	F373N [O II]	F470N He II	F487N Hβ	F502N [O III]	F632N [O I]	F659N Hα+[N II]	F674N [S II]	F956N [S III]

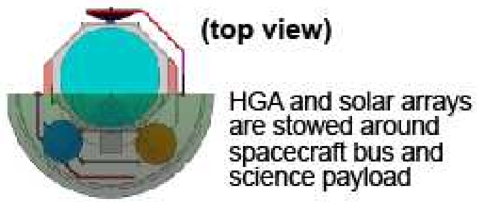
Far-UV spectroscopy:	must be able to access O VI at 103.2 nm and discriminate sources on scales of $\sim 0''.05$	
Resolving power:	$R \sim$ 40,000 over 100–175 nm range	(2 gratings)
	lower-resolution covering full bandpass	(1 grating)
Wavelength agility:	optimized for 100–115 nm response	access to full 100–175 nm range

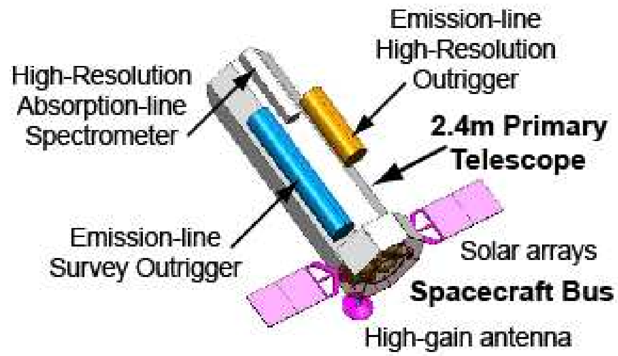
*Ultra-wide UV filter with $\lambda_c \sim$278 nm and FWHM$\sim$125 nm; †narrow-band filters must capture emission redshifted to $\sim$2500 km s^{-1}.

Baryonic Structure Probe concept (= USO, Ken Sembach)



Launch configuration



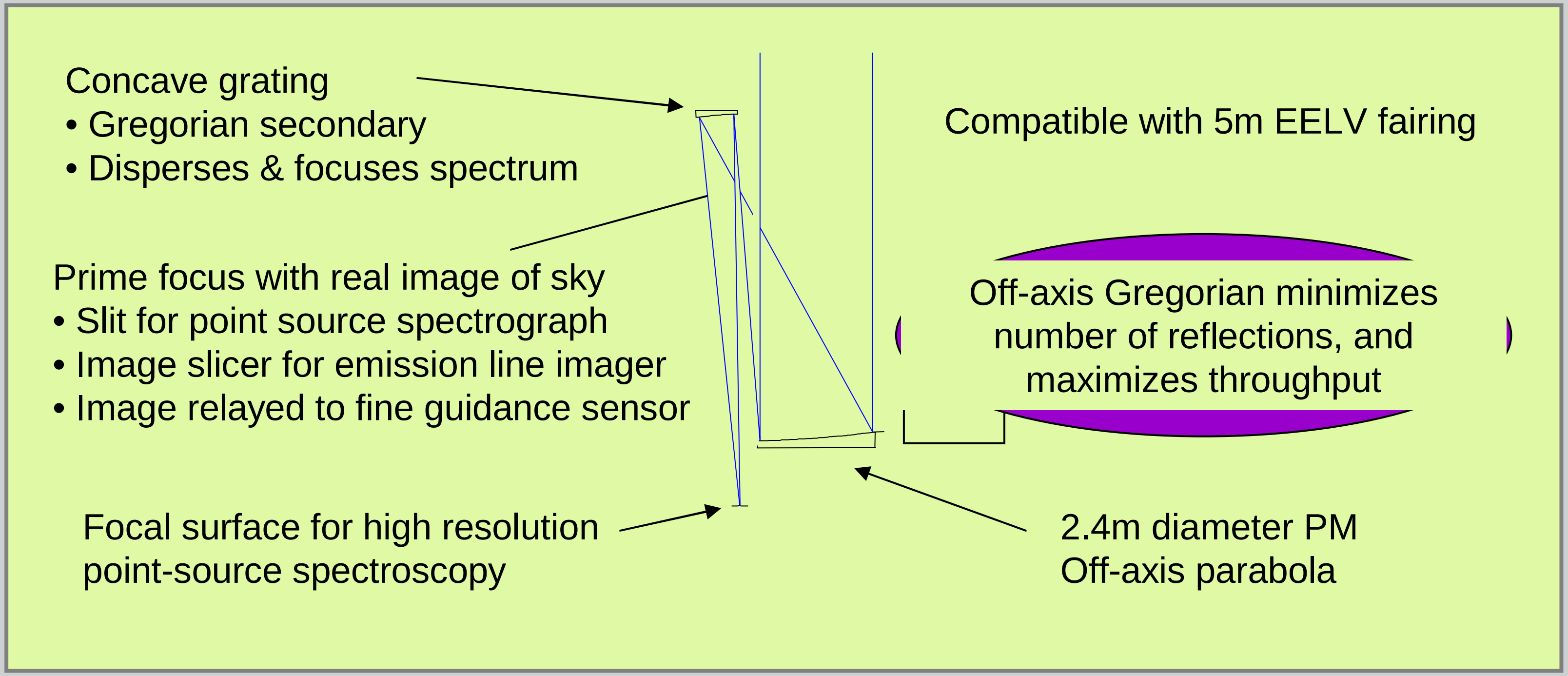


In-flight configuration

Benefits of an L2 Orbit
- No Lyα geocornal foreground
- Higher observing efficiency
- Stable thermal environment

Launch Vehicle	Atlas V 521 *or* Delta IV 4450 (both acceptable)
Fairing	5-meter diameter
Orbit	Direct insertion L2 Lissajous
Mass / Power	4600 kg / 1800 Watts (including 30% margin)
Size (approx)	9m x 4.5m
Attitude Control	3-axis stabilized, 50-100 milli-arcsec fine guidance
Sky Availability	40% (instantaneous), 100% (yearly)
Deployables	Solar arrays and high gain antenna
Consumables	Propulsion (hydrazine) [no cryogenics]
Station-keeping	Once/month, momentum dumps every 14 days
Communications	Ka-band downlink (daily), S-band uplink/ranging
Subsystems TRL	Spacecraft components at TRL≥7 (C&DH at TRL6)
Mission Lifetime	5 year (core science), 10 year design
Mission Cost (FY05$)	$670M (includes 30% contingency)

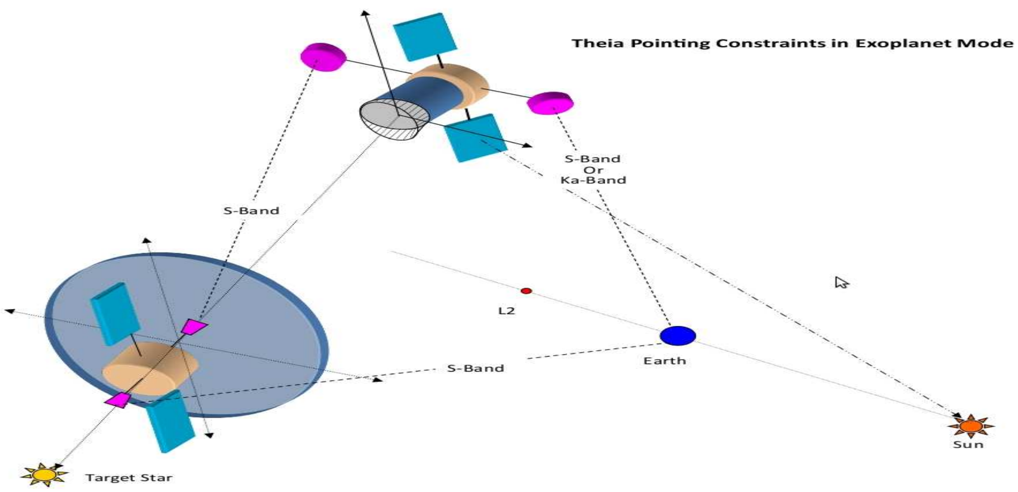
USO: Efficient Ultraviolet Spectroscopy

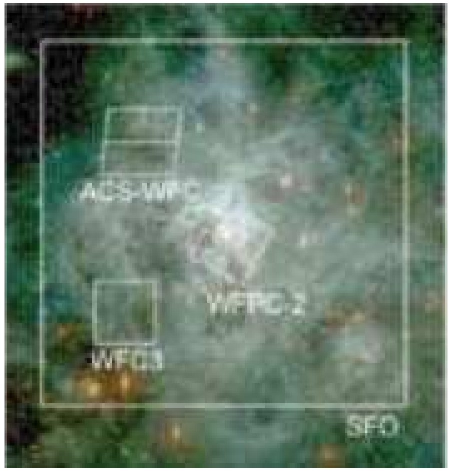


Instrument	$\lambda/\Delta\lambda$	$\Delta\theta$ (FWHM)	Field Size	S/N (10^5 s)	λ Range (Å)
Absorption-line	30,000	0.5”	0.5” x 1’	10	1000 - 3000
Emission-line (High Res)	3,000	10”	18’ x 18’	5	1030 - 2000
Emission-line (Survey)	1,000	2’	1° x 1°	5	1030 - 2000
S/N calculated for $F_\lambda = 10^{-16}$ erg cm^{-2} s^{-1} Å^{-1} or ϕ = 500 ph cm^{-2} s^{-1} sr^{-1}					

THEIA (D. Spergel et al.)

- XPC + UVS + SFC
- Occulter/telescope system
- 75% time general astrophysics





SFC Camera
FOV 17’x17’

THEIA instruments

- XPC 3 cameras (NUV: 250-400nm, B:400-700nm, R: 700-1100 nm) + IFU (R)
  narrow FOV for exoplanet imaging
- SFO 17’ x 17’ diffraction limited camera covering 200-1100 nm, for wide FOV surveys of gal. and extragal. star formation
- USO R > 30000 slit spectroscopy, at 102-200nm, possibly also 200-300nm (for studies of cosmic Web)

ATLAS-T (M. Postman, ST/ScI)

- Technology roadmap for the next decade
- **3 options** (hypothesis: Ares V built as planned by 2019, 65 tonnes to L2) :

- **An 8m monolithic** (prefered for exoplanets: PSF, diffuse light, etc...)

  in 2025

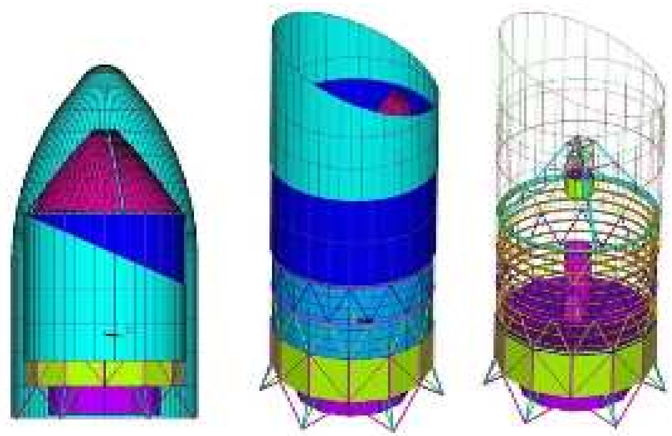


Figure. 5: (Left) 8-m *ATLAST* in Ares V fairing. (Center) After deployment of the sunshield. (Right) Cutaway view.

ATLAS-T (continued)

- A 16.8m, segmented, in ~2030 (largest extrapolation from JWST)

Figure 7: (Left) Stowed 16.8-meter OTA. (Center) 16.8-m *ATLAST* deployed but the sunshade and "kite tail" (to mitigate solar torque) are not shown. (Right) 16.8-m shown with sunshield, "kite tail," and arm-mounted OTA.

- A 9.2m, segmented, with Delta IV modified (EELV) by ~2028, if Ares V not available

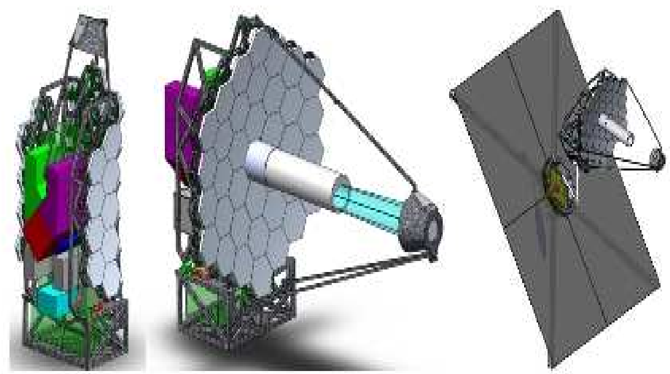


Figure 6: (Left) Stowed 9.2-meter OTA. Colored boxes are instrument envelopes. (Center) 9.2-m *ATLAST* Deployed. (Right) Sunshield and arm-mounted OTA. Spacecraft bus is on sun side of sunshield.

ATLAS-T properties

Table 3: Summary of ATLAST Point Designs

Aperture (meters)	Wavelength Coverage	Orbit	Primary Mirror	Secondary Mirror	Pointing (mas)	Launch Vehicle	Total Mass (kg)	Total Power (kW)
8.0	110 – 2500 nm	SE-L2 Halo Orbit	Monolithic	On-axis or Off-axis	1.6	Ares V	~59,000	11
9.2			Segmented	On-axis	1.4	EELV	~15,700	5.7
16.8			Segmented	On-axis	0.8	Ares V	~30,000	~10

(Total Mass and Total Power values include at least a 28% contingency)

Table 2: Tentative ATLAST Science and Facility Instruments and their FOV

Telescope	TMA Focal Plane Instruments				Cass Focal Plane Instruments		
	Vis/NIR Wide-field Imager	Vis/NIR Multi-Object Spectrograph	Vis/NIR IFU	FGS (FOV per FGS unit)	UV IFU & Spectrograph	Starlight Suppression	Exoplanet Imager & Spectrograph
8-m, 9.2-m	8x8 arcmin	4x4 arcmin	2x2 arcmin	3x3 arcmin	30 arcsec	Internal Coronagraph or Starshade Sensor	~10 arcsec
16.8-m	4x4 arcmin	3x3 arcmin	1x1 arcmin	~1x3 arcmin	15 arcsec		~10 arcsec

The European view ...

Astronet Science Vision

- How do galaxies form and evolve?

  -A 4-8m UV space telescope will be essential for goal 4 (metal content of the Universe) and complementary for goals 2,5 & 6 (detect the first objects; measure the metallicity of the IGM and missing baryon problem; measure the build-up of gaz, dust, stars)

- Origin & Evolution of stars and planets

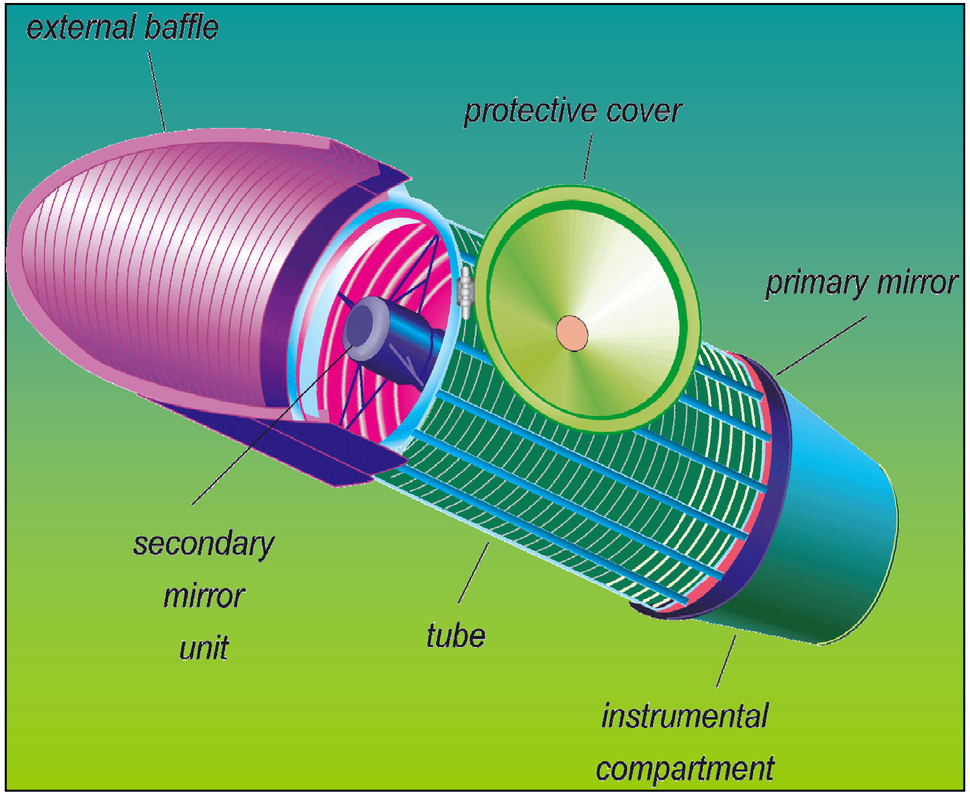
  -A next generation of UV and X missions will be essential for goals 1,2 & 3 (Initial conditions of star formation and their mass distribution; stellar stucture and evolution; life cycle of matter from the ISM to stars and back) and complementary for goals 4 & 5 (planet form. and chemical evolution; diversity of exoplanets)

Astronet Roadmap (panel B)

As a consequence of major new facilities absorbing the bulk of new funds: ...there will always be « gaps » between successfull missions and the next generation, and some observing capabilities may not exist at all for many years to come. This applies e.g. to UV astronomy after ESA, SERC and ESA have jointly built the IUE satellite (1978-1996).

Europe has since then not implemented another dedicated FUV/EUV follow-up mission and there are no significant plans to do so despite the emphasis that is put on such a mission in the Science Vision document.

WSO/UV: Telescope T-170



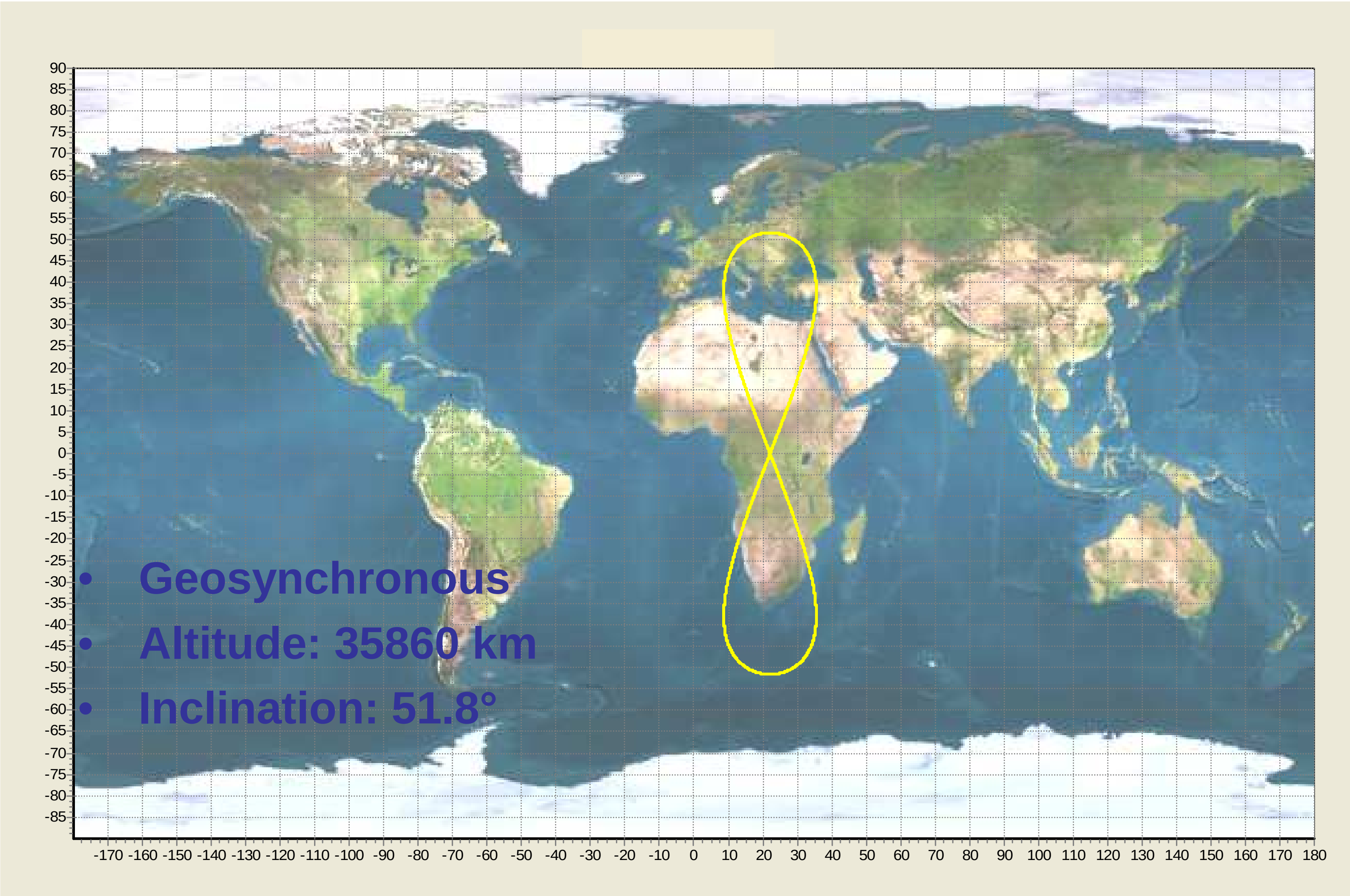
Optical elements are being manufactured by the Lytkarino Optical Glass Factory (Russia).

The WSO-UV telescope (T-170M) is under the responsibility of Lavochkin Association (Russia).

Optical System	Ritchey-Chretien aplanat
Aperture:	170 cm
Tel. f-number	10.0
FOV	30' (150 mm in diameter)
λ range	100-310 nm (+visible)
Primary λ	200 nm
Optical quality	Diffraction limited in the center
Mass	1570 kg (1600 with adapter truss)
Size	5.67x2.30 m (transport) 8.43x2.3 m (operational)

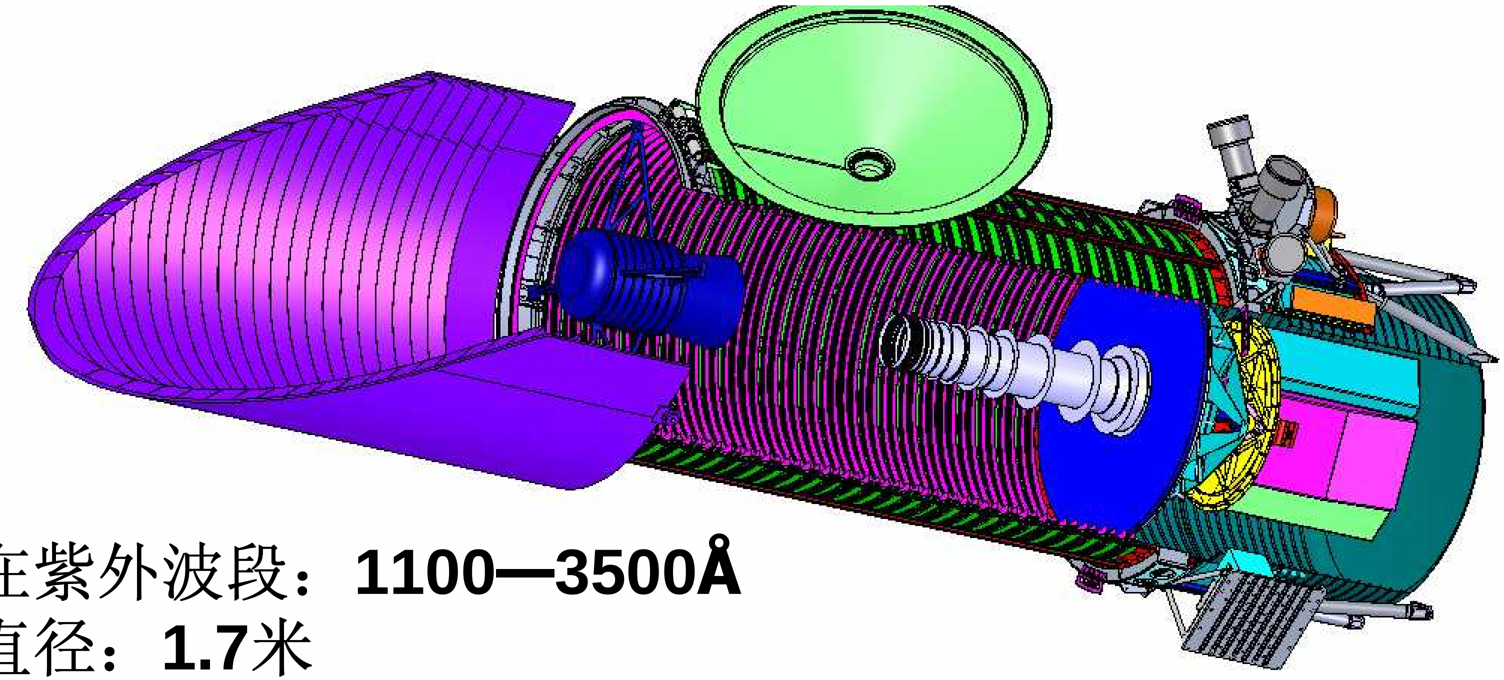
The main units of the structural model of the T-170 telescope have successfully passed vibrostatic and thermal vacuum tests.

WSO-UV Orbit

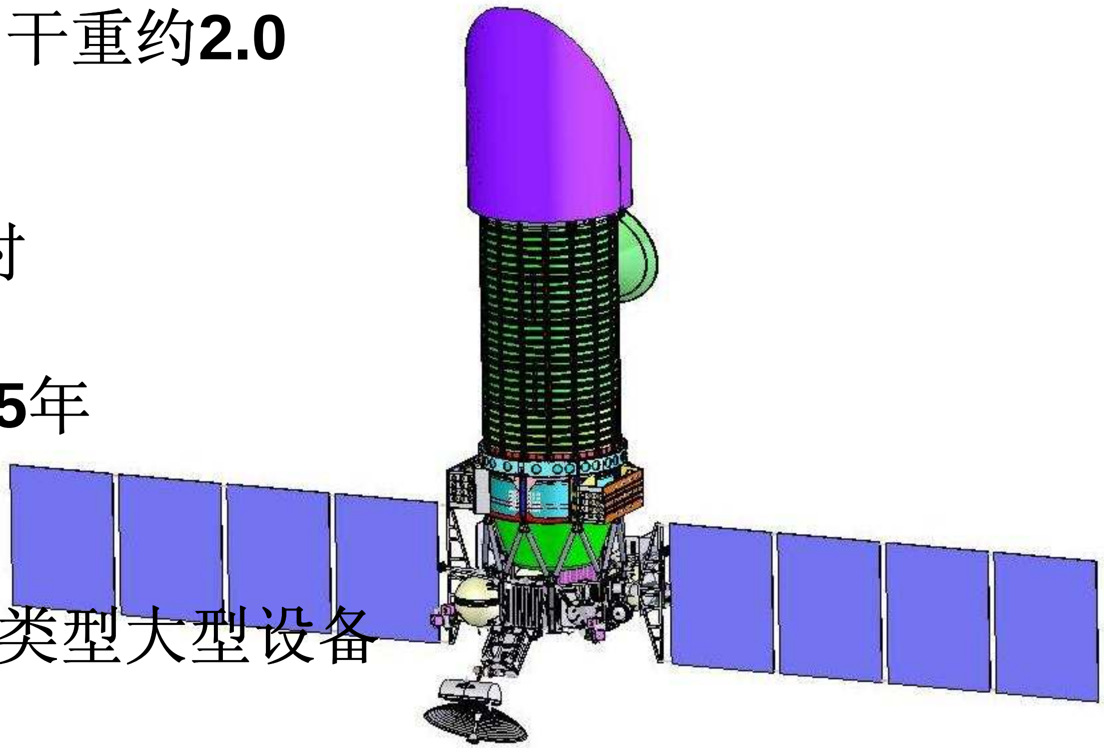


- **Geosynchronous**
- **Altitude: 35860 km**
- **Inclination: 51.8°**

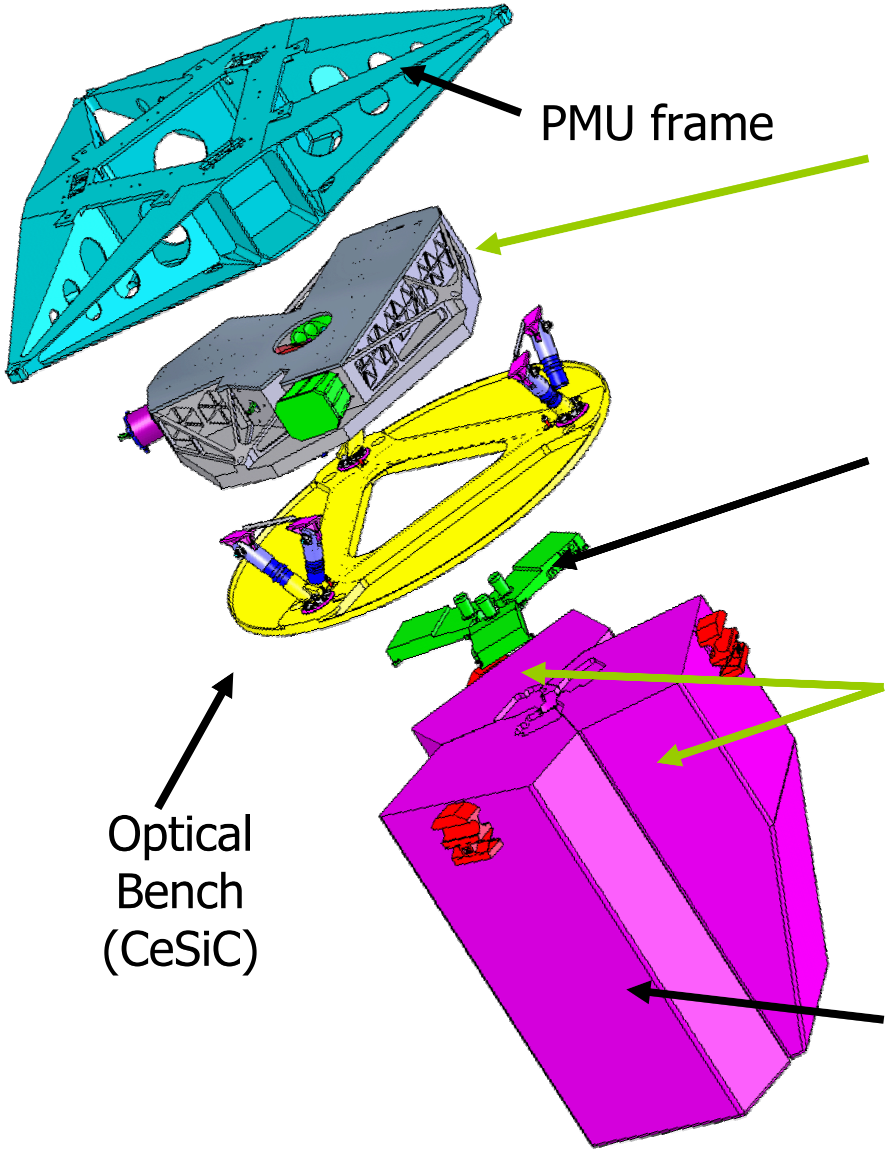
For the chosen orbit the effects of the radiation belts will be negligible and the observing efficiency high.



- 工作在紫外波段：**1100—3500Å**
- 主镜直径：**1.7**米
- 直径**2.2**米、长度**8.5**米；干重约**2.0**吨；**750**瓦
- 指向精度：**0.05~0.1″**
- 不间断观测时间：**30**小时
- 发射时间：暂定**2010**年
- 寿命：**5**年，预期可延长**5**年
- 数据传输：**> 1 Mbps**
- 总投资**3-4**亿欧元
- 运行模式**:** 多功能天文台类型大型设备



WSO-UV Payload



ISSIS: 2-channel Imager:

FUV, NUV

+ slitless spectroscopy

FGS: Fine Guidance System (3 sensors 1kx1k)

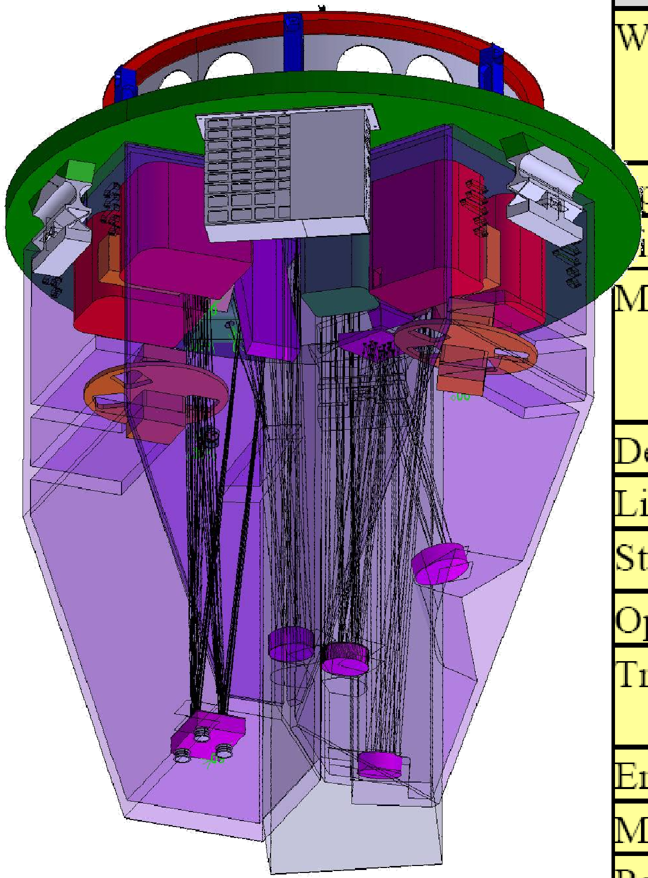
HIRDES: high-res echelle spectrographs:

UVES (178-320nm)

VUVES (102-180nm)

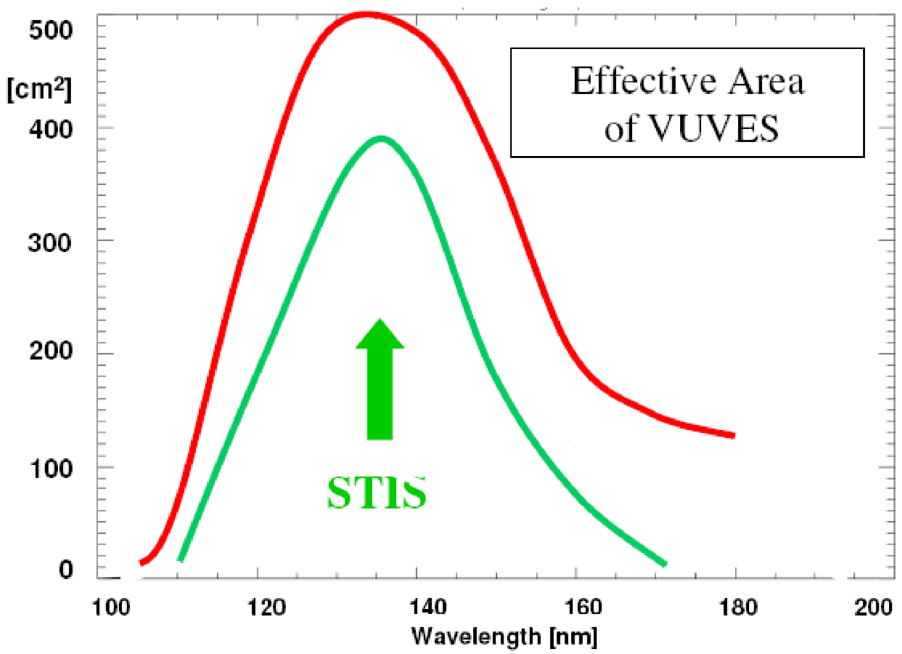
LSS: 102- 320 nm, low-res long slit spectrograph

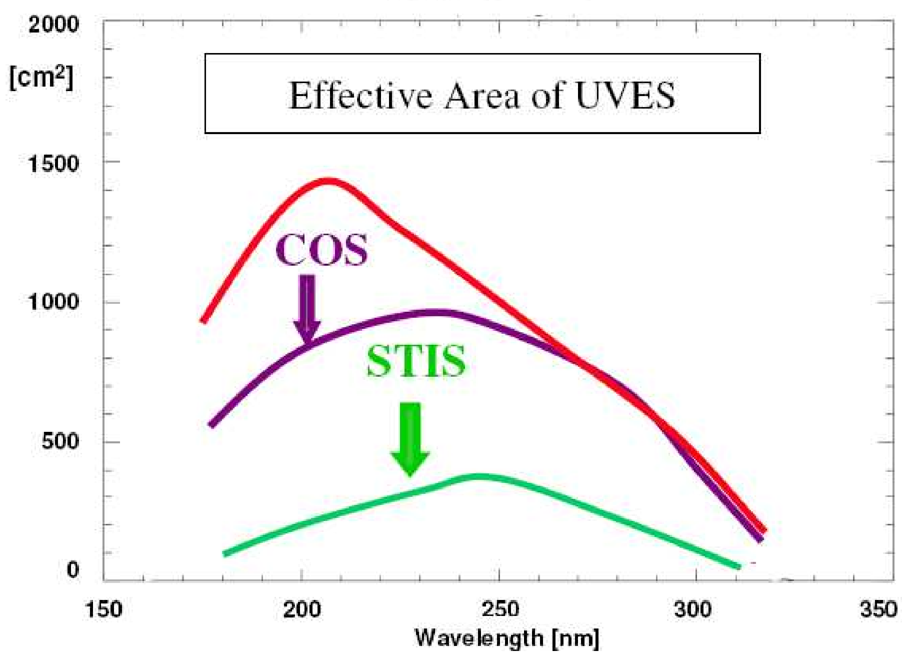
WSO-UV HIRDES



Parameter	Baseline Requirements
Wavelength coverage • UV Spectrograph • VUV Spectrograph	 174-310 nm 102-176 nm
pectral Resolution	> 48000
imultaneous coverage	As far as possible
Minimum sensitivity • SNR= 10 in 10 h • SNR= 100 in 10 h	 16 mag (VUVES); 18 (UVES) 11 mag (VUVES); 13 (UVES)
Detectors	MCPs
Limit loads in all axes w/o SF	15 g (tbc)
Stiffness (first fundamental eigenfrequency)	> 40 Hz (tbc)
Operational temperature	20 °C +/- 1°C (tbc)
Transmission	> 60 % (300 nm) -tbc > 30 % (100 nm) -tbc
Envelope	1080 x 920 x 670 mm^3
Mass	155 kg - tbd
Power	150 W – tbd
Data Rate (raw data/downlink)	Tbd / 1.6 Mbit/sec

HIRDES effective area





Wavelength Range	Resolwing Power	**COS** Eff. Area
115-150	20.000 – 24.000	2.200 (>4 times VUVES)
140-178	20.000 – 24.000	1.200 (>3 times VUVES)

LSS Spectrograph

Parameter	Requirements
Wavelength coverage • FUV channel • NUV channel	 102~190 nm 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 or ?

ESA-CV : EUCLID

- Merging : DUNE +SPACE
- PI : Réfrégier, Cimatti (at IAP: Y. Mellier et al.)
- Tel. 1.2m
- WL + BAO primary probes (Cluster+ISW+ z-distortion secondary probes)
- WL + BAO over 20000 deg^2
- Vis. (R+I+Z) + NIR (Y, J, H)
- Photometry
  - Vis. (R+I+Z) very broad filter , AB <24.5 over 20000 deg^2
  - NIR Y,J,H : H_{AB}=24 over 20000 deg^2 ,
  - NIR Y,J, H : H_{AB}=26 over ~ 50 deg^2,
- Sliteless spectro-survey
  - Spectro H_{AB} = 22 over ~15000 deg^2 ; $1x10^8$ galaxies
  - Spectro H_{AB} = 24 over ~ 50 deg^2 ; $2x10^6$ galaxies.
- n(z) WL .
- + Ground based visible photometry

Fresnel Interferometer (L. Koechlin, Toulouse)

Concept study, for a submission to next Cosmic Vision's call

>2025: Presently studied in the optical, can be extended to UV

TWO COMPONENTS FLYING FORMATION TELESCOPE
Focusing by diffraction

Key technology: Ionic engines for a long living facility

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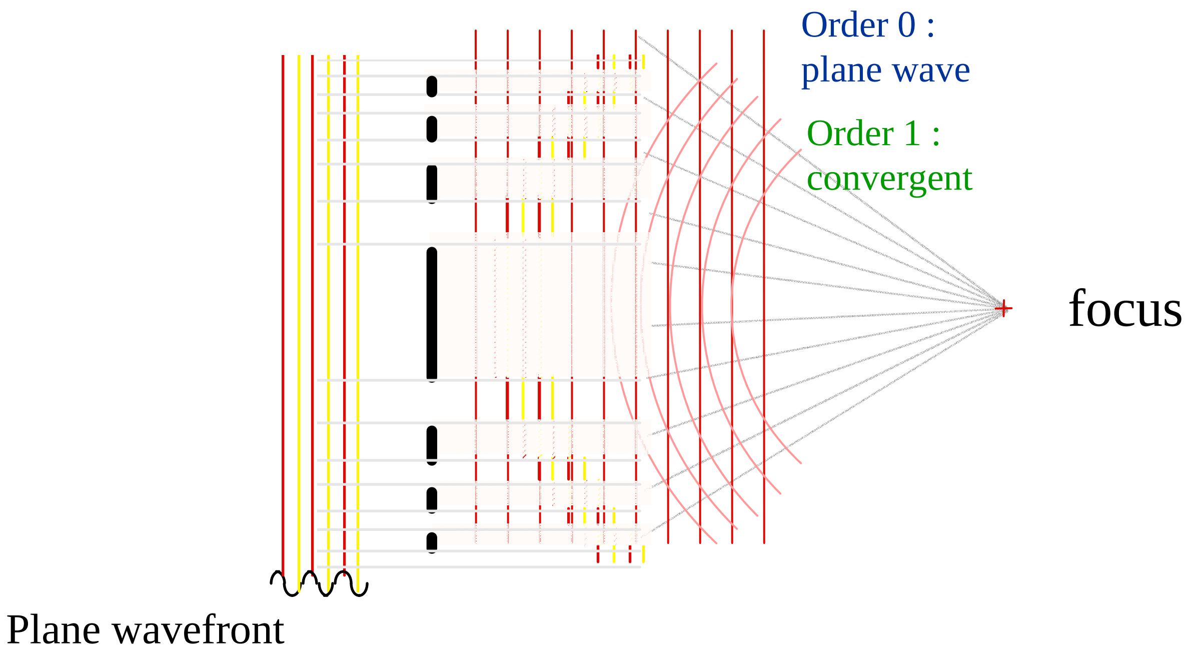


US UV question: what is the right strategy?

1. Compete for a 3-5 B$ flagship mission
2. Identify a Midex (350 M$) or Probe (650 M$)
3. Convince NASA to pursue another « Great Observatories » program (international ?)

+ Explorer/Probe

Flagship: $4B, 10years, 400 M$/yr
Probe: $750M, 5 years, 150 M$/yr
MidEx: $ 360M, 3 years, 120 M$/yr
SMEX: $ 180M, 2years, 90 M$/yr

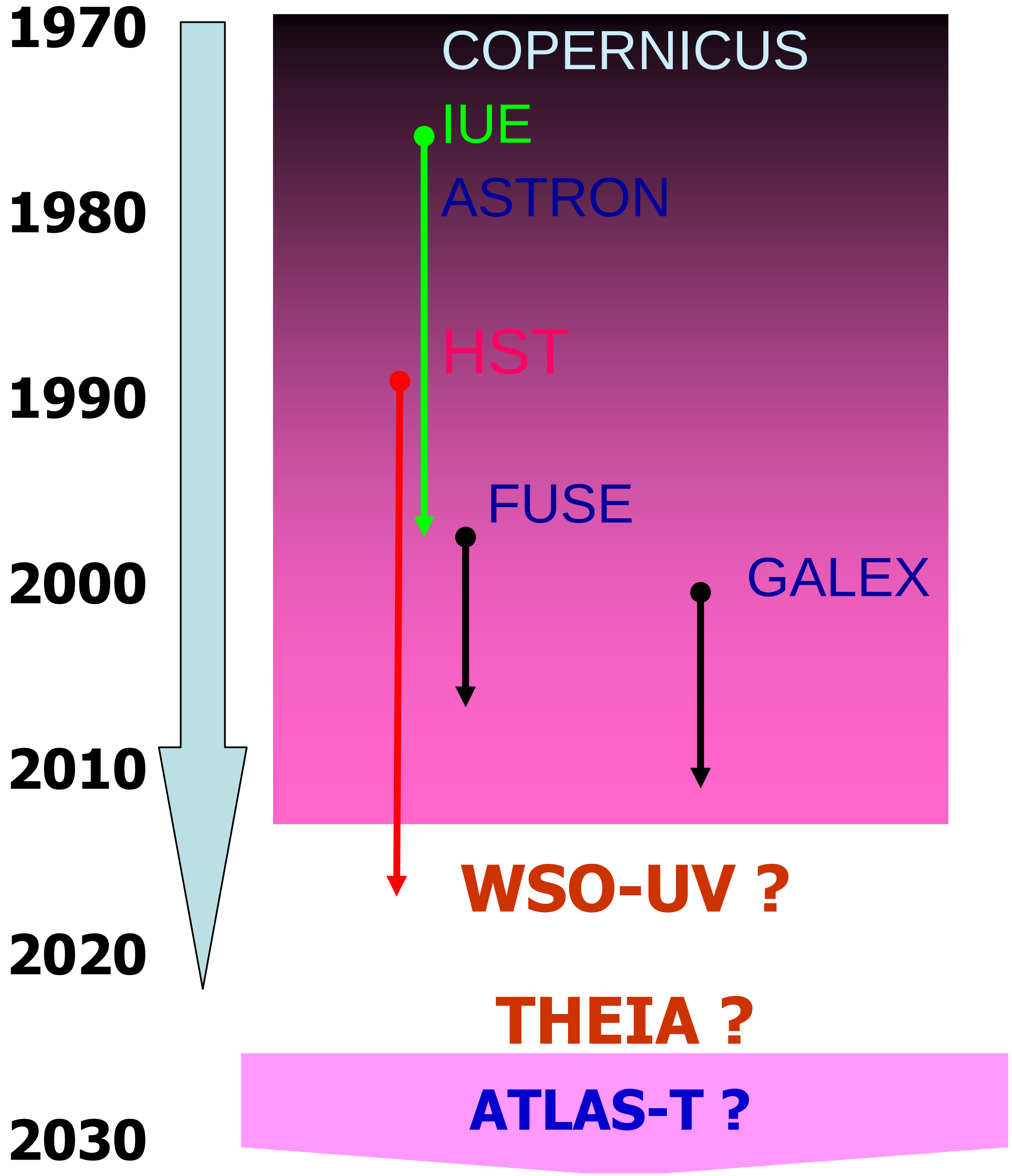
TOTAL is « only » 760 M$/yr .... (Mike Shull's proposal...)
Matt Mountain: be bold! Science inspires the Nation...

European UV question: any UV??

- No big mission in sight at ESA level...
- We should definitely plan a share in ATLAS-T for the long term
- To fill the gap, international collaborations (Theia, WSO/UV, etc...)
- Effort needed on detectors: no point in going to very large diameters if detectors remain at 7% efficiency, go first at 2-3m with 70%!
- Low dispersion (R~1000-5000) needed
- EU UV community dispersed, needs to be better structured, underway via the NUVA network (www.ucm.es/info/nuva) Do join!!

UV

year



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