UV Astronomy and UVIT

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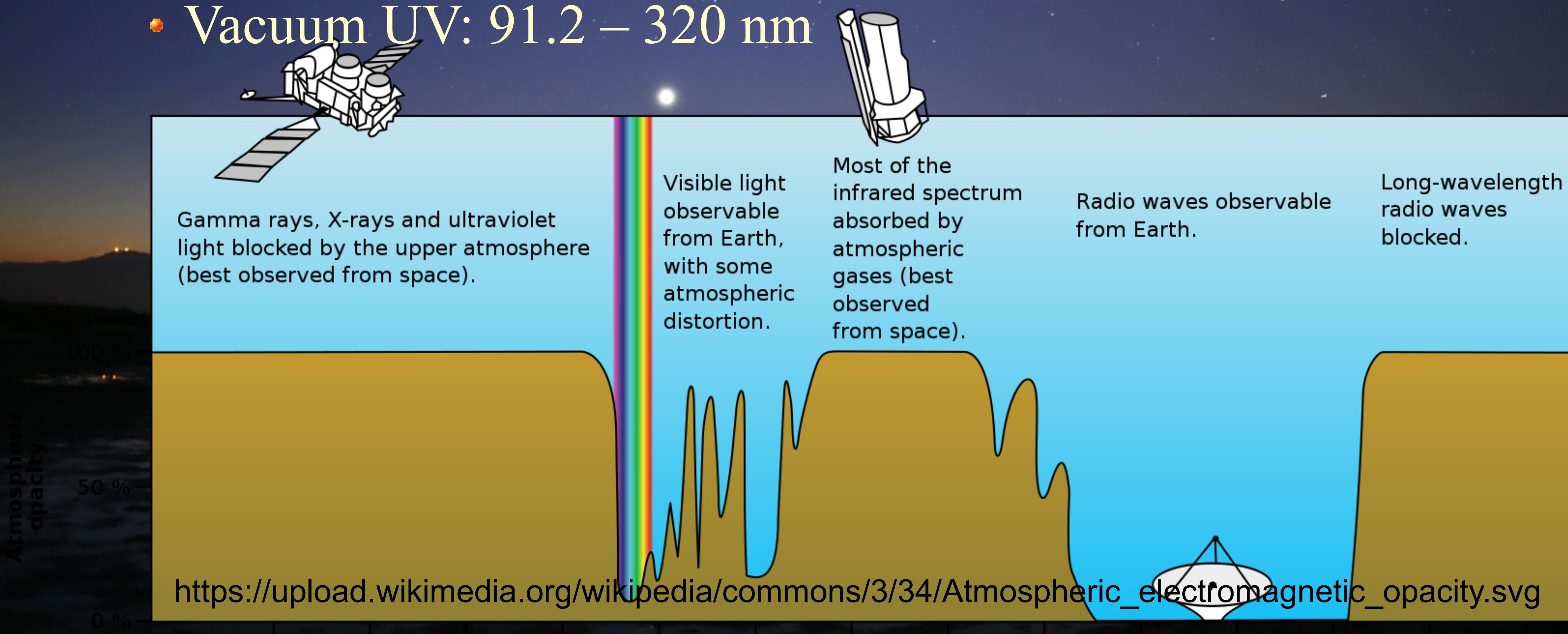
UV Definitions

- Wavelength regions defined by technology
  - EUV: 7 – 91 nm.
  - FUV: 91 – 120 nm (FUSE)
  - NUV: 120 – 300 nm (GALEX)
  - Vacuum UV: 91.2 – 320 nm



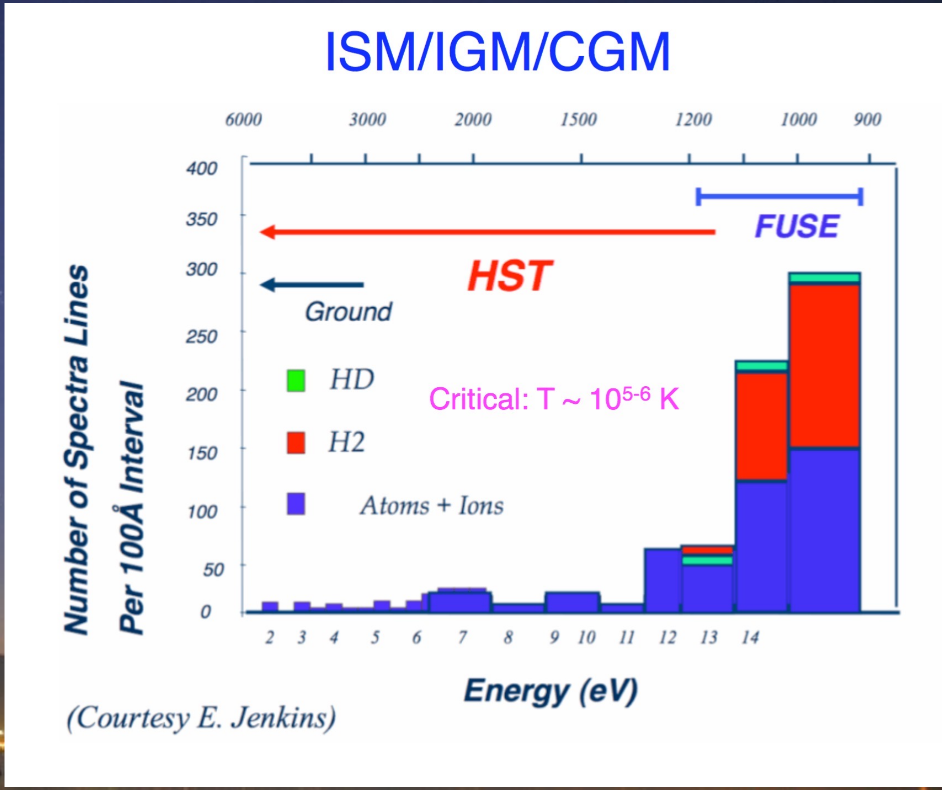
https://upload.wikimedia.org/wikipedia/commons/3/34/Atmospheric_electromagnetic_opacity.svg

History

- First UV observations made from V-2 rockets.
  - Operation Paperclip brought German rocket scientists to Huntsville, Alabama.
  - *The solar ultraviolet spectrum from a V-2 rocket.*
    - Tousey et al. 1947, AJ, 52, 158.
- Sounding rockets (many from NRL) made the first observations in UV, X-ray and gamma ray astronomy.
- Major push into UV astronomy because it was close to optical astronomy.

Why UV

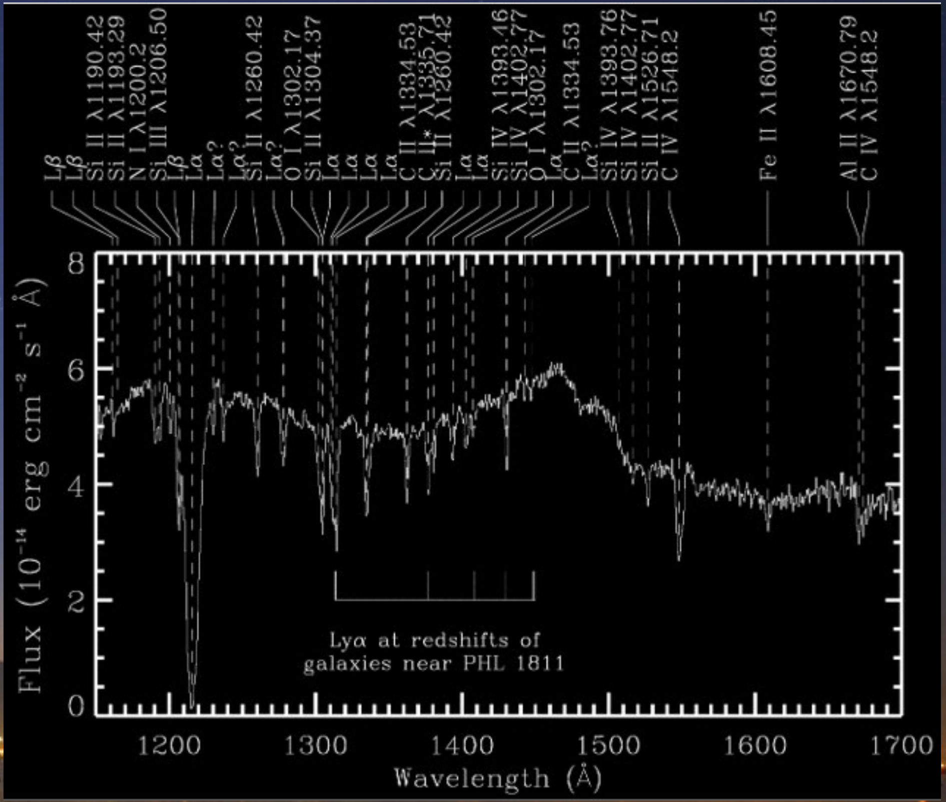
- Many electronic transitions of atoms/molecules.



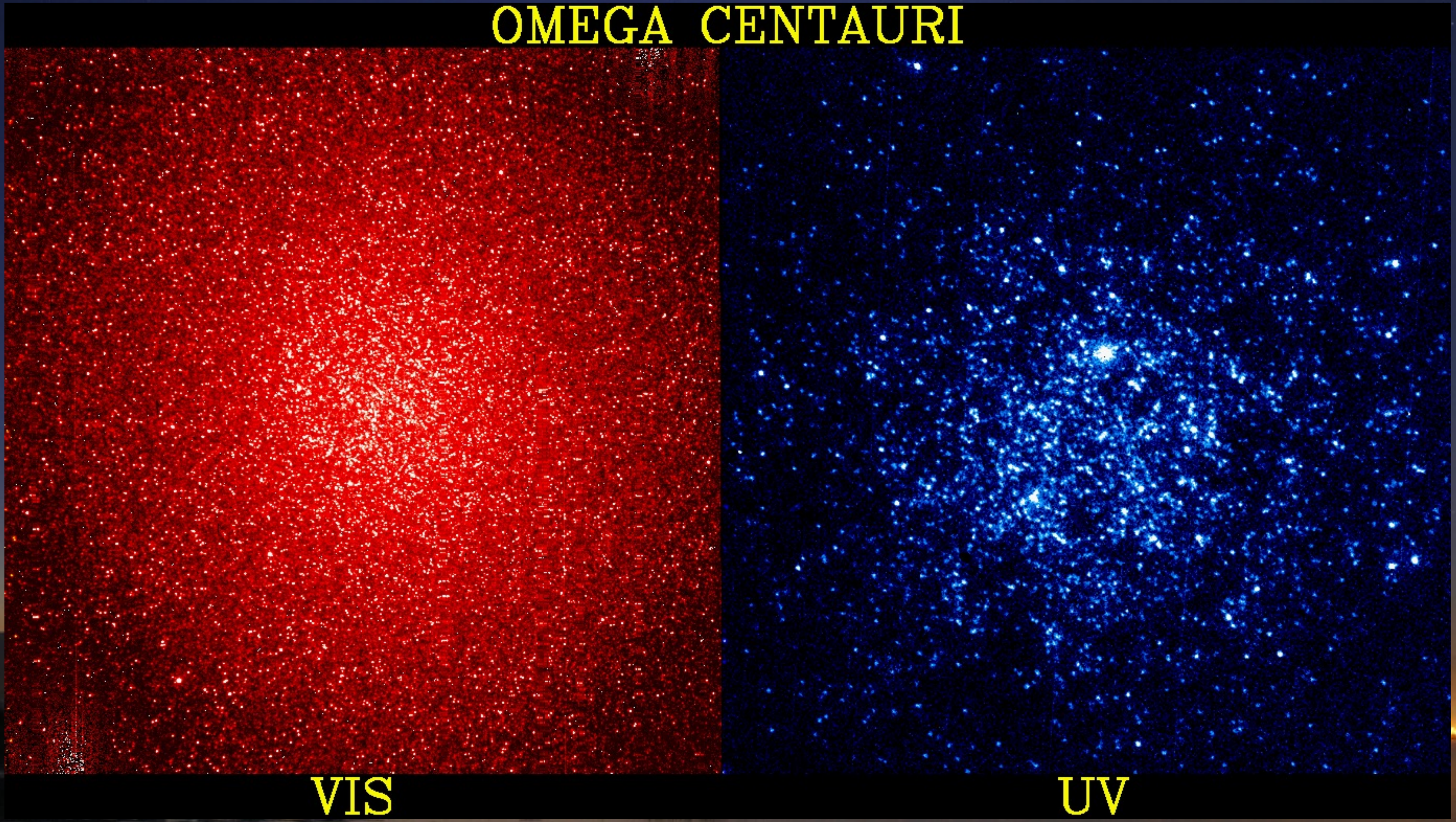
https://rwoconne.github.io/rwoclass/astr511/im/line-count-vs-wavelength-Jenkins-label.jpg

Why UV

- Many electronic transitions of atoms/molecules.
- Physics is in the UV.
    - Temperature, density, pressure, velocity.

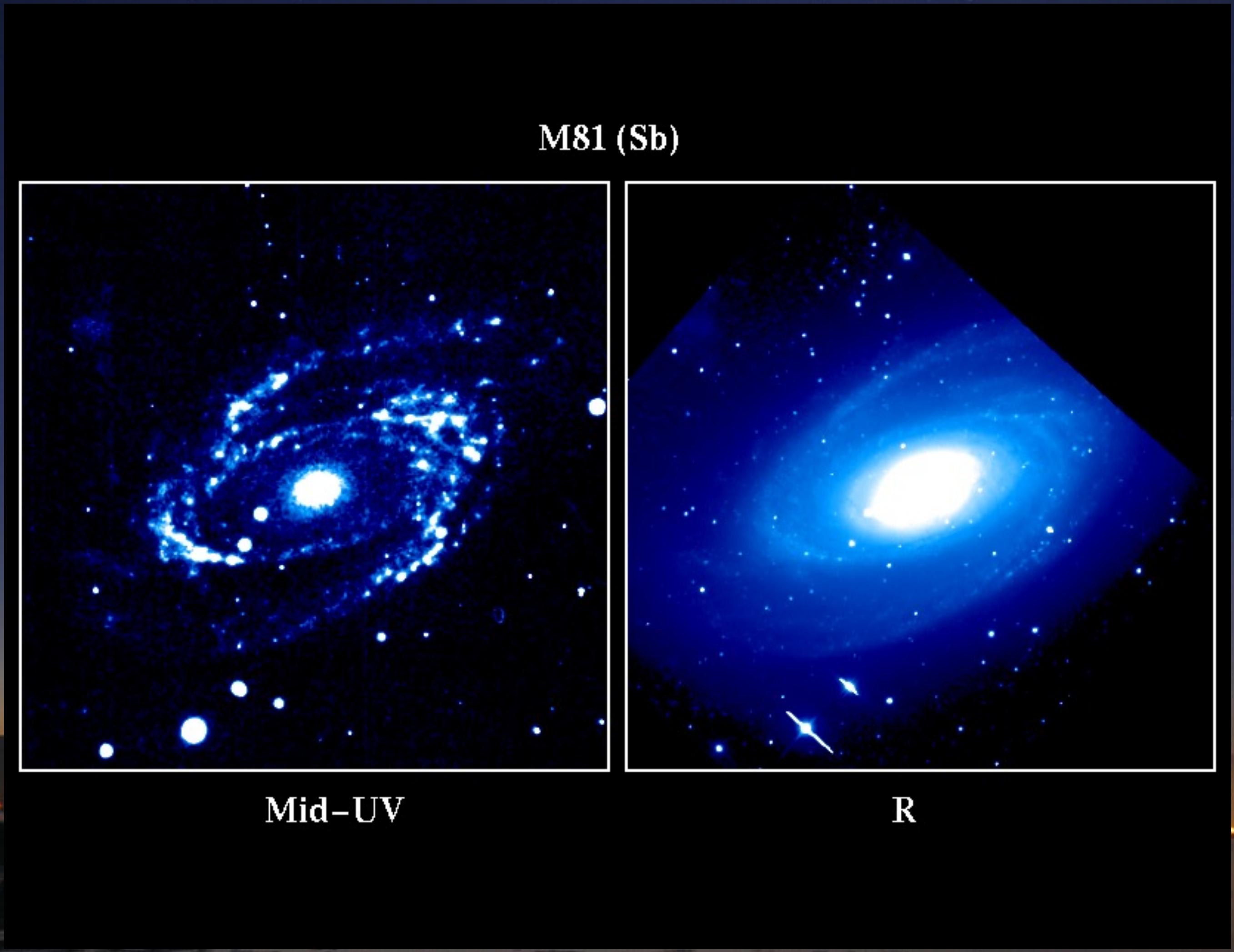


Why UV



https://apod.nasa.gov/apod/image/omgcen_uit_big.gif

Why UV



https://rwoconne.github.io/rwoclass/astr511/im/M81uvr.gif

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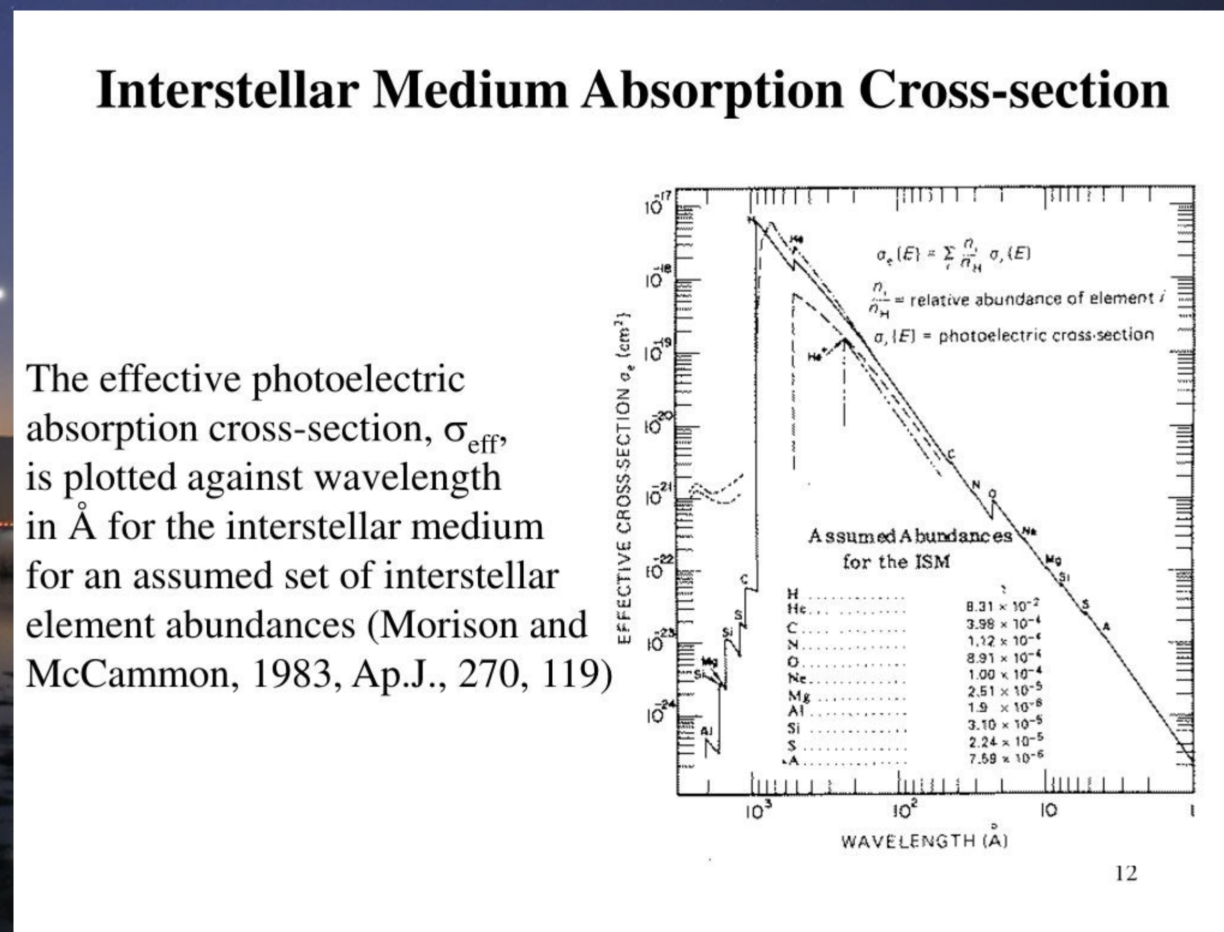
EUV

- EUV: 70 Å to 912 Å
  - Lower limit is decided by grazing angle optics.
  - Upper limit is HI ionization

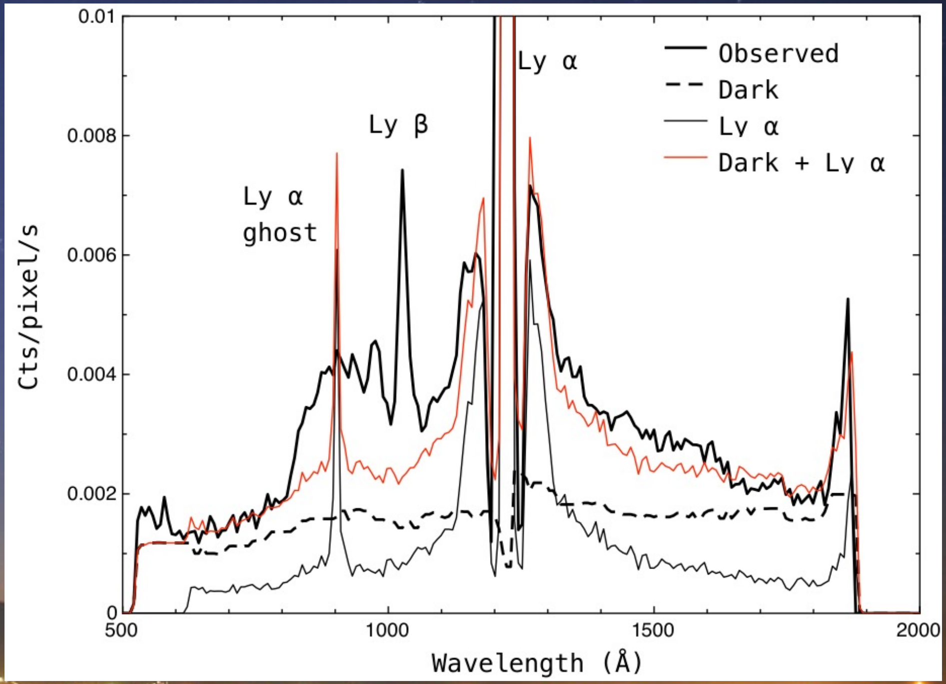
https://image.slideserve.com/404263/interstellar-medium-absorption-cross-section-l.jpg

https://www.slideserve.com/meg/radiation-processes



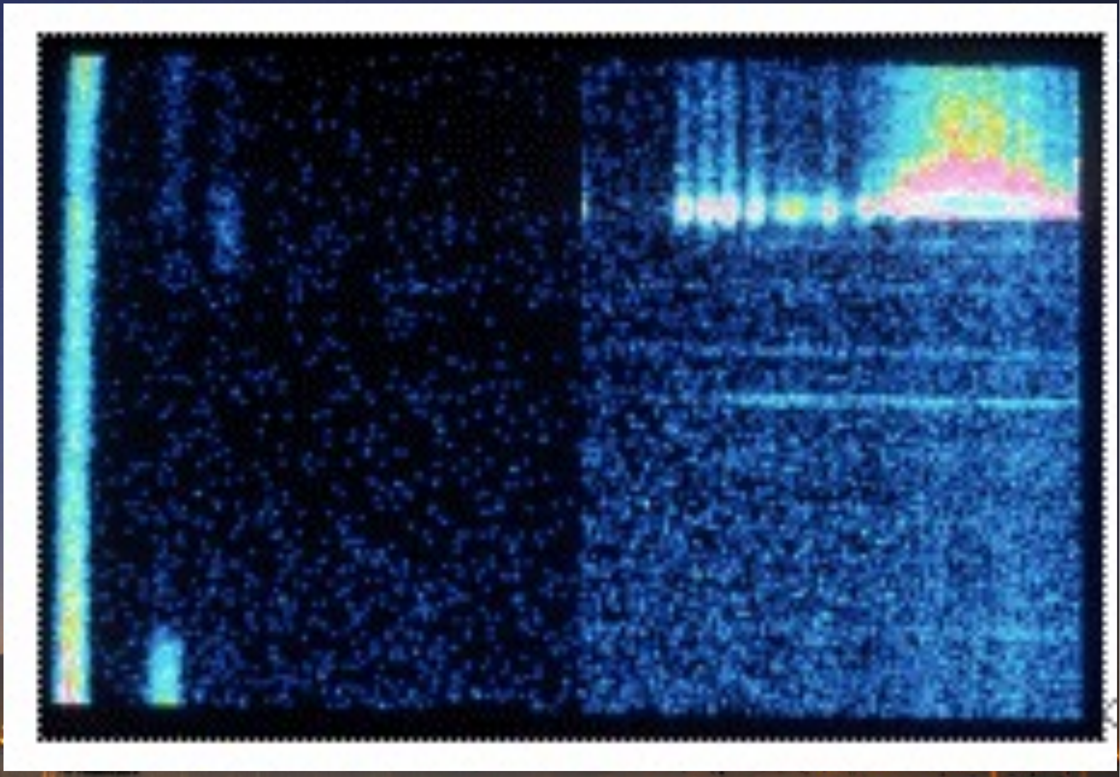
FUV

- FUV: 91 – 120 nm
  - 912 Å: HI ionization.
  - 1216 Å: HI Lyman alpha.
- Windowless detectors.



NUV

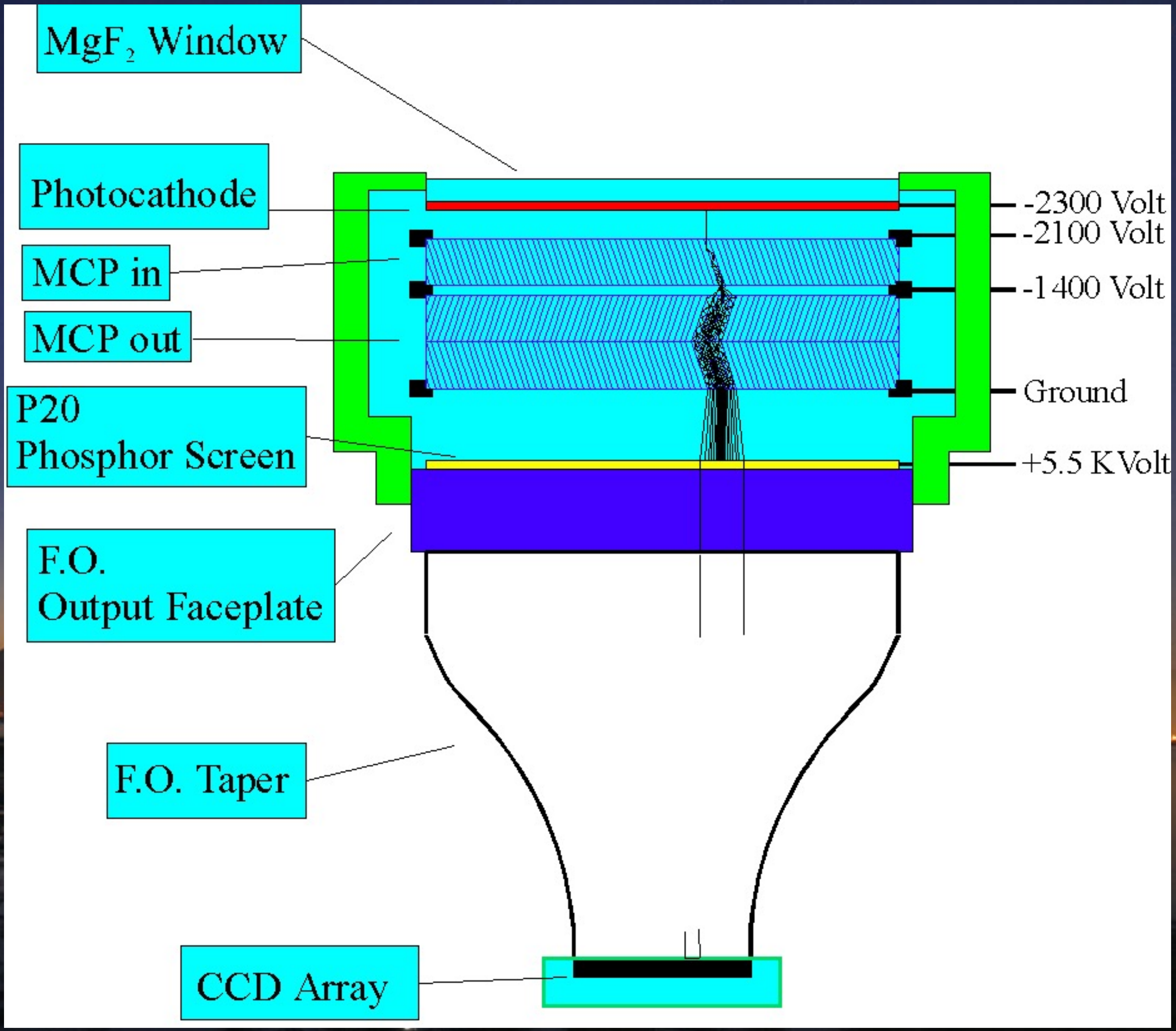
- NUV: 120 – 320 nm
  - 1216 Å: Ly α
  - 3200 Å: Solar flux.



Optics

- Normal incidence.
- Minimize number of elements.
- Long-pass crystalline filters.
  - MgF_2
  - CaF_2
- Mirror reflectivity
  - $Al+MgF_2$
    - 80% (> 1200 Å)
  - SiC
    - 40% (< 1200 Å)
- Filters ~ 80%
- Contamination control mandatory.

Detectors



MgF2 Window
Photocathode
MCP in
MCP out
P20
Phosphor Screen
F.O.
Output Faceplate
F.O. Taper
CCD Array
-2300 Volt
-2100 Volt
-1400 Volt
Ground
+5.5 KVolt

Microchannel Plate Detectors (current)

Our current workhorse is the cross delay line readout MCP detector

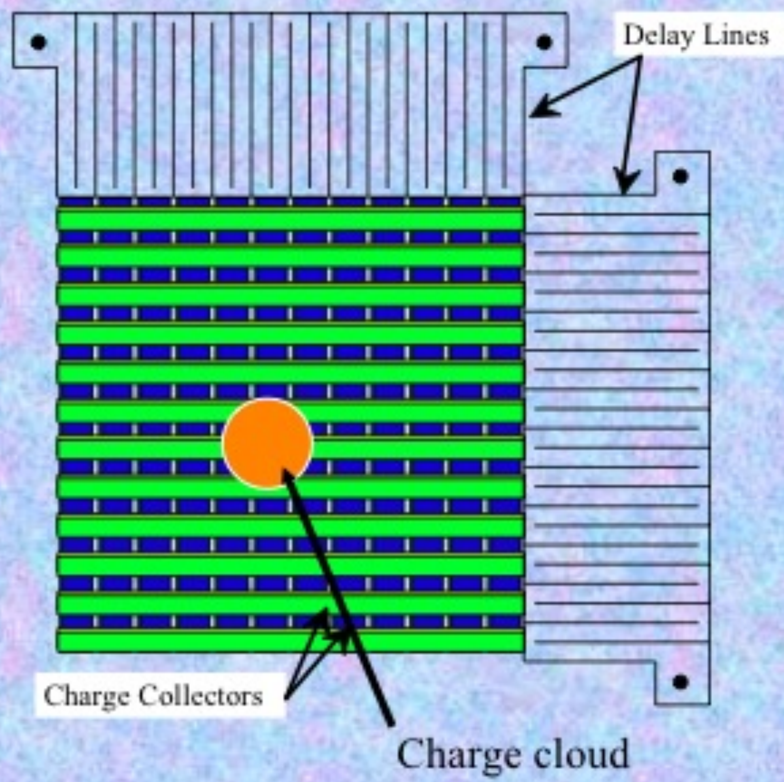
Typical characteristics

Use alkali halides for XUV QE (~50%),
Glass MCPs. Gain ~10^7
Photon, ion, electron, neutron sensing
Size formats to 100mm, Resolution ~30 m
Event rates to >1 MHz, (kHz/pixel rates)
Timing <100ps (~20ps limit)

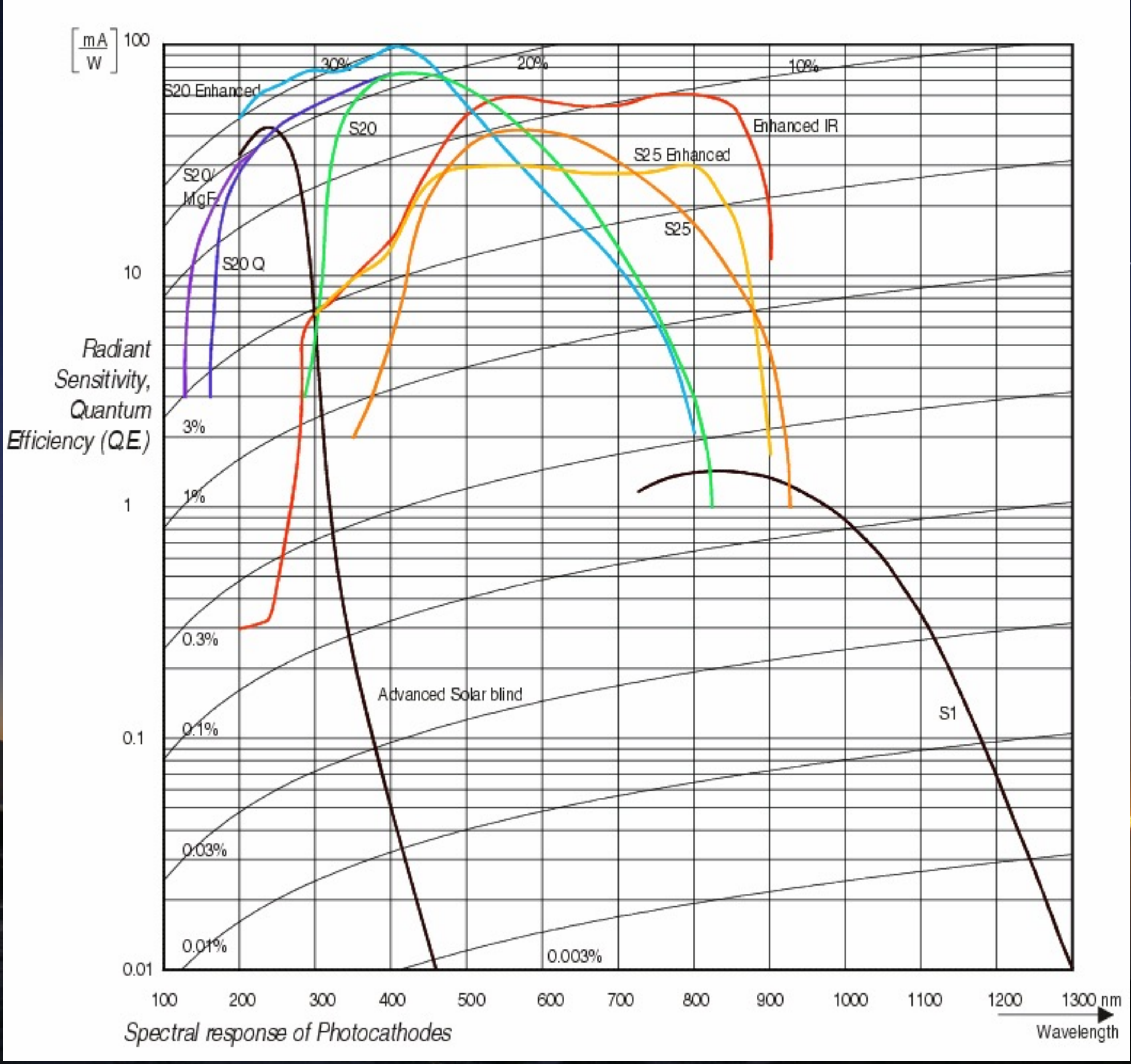
Issues,

High gain/lifetime/local-global rate limits
Single event sequential processing

Cross delay line anode is a multi-layer crossed conductor layout. Period is ~0.5mm on ceramic. MCP charge divides between upper and lower charge collectors, Event centroids are linearly proportional to signal arrival time difference at ends of delay lines. Fast event propagation (50 ns). Compact and robust (900°C).



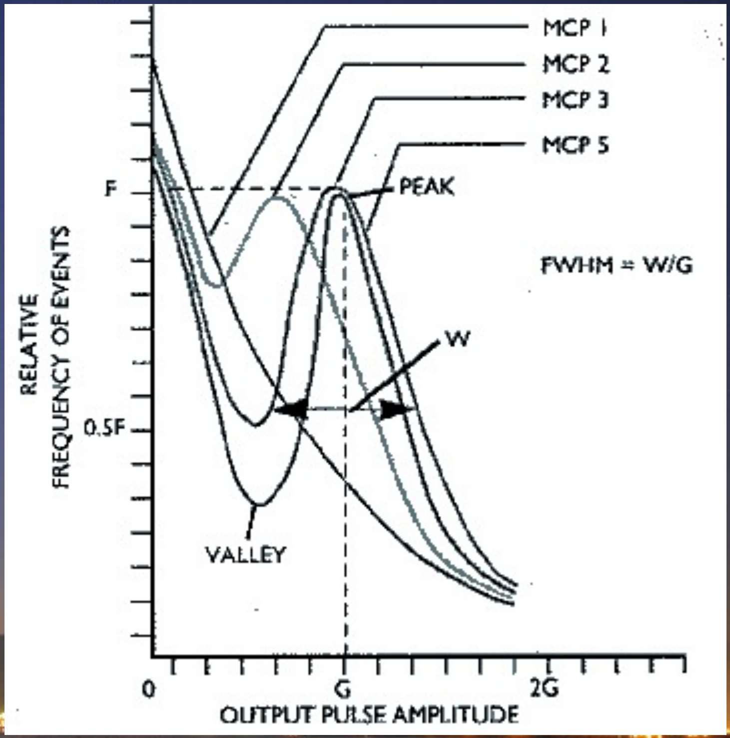
Cross delay line readout scheme



mA/W
100
10
1
0.1
0.01
Radiant Sensitivity, Quantum Efficiency (Q.E.)
30%
20%
10%
3%
1%
0.3%
0.1%
0.03%
0.01%
0.003%
S20 Enhanced
S20
S20/MgF
S20 Q
Enhanced IR
S25 Enhanced
S25
Advanced Solar blind
S1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300 nm
Wavelength
Spectral response of Photocathodes

Counting Events

- Measure X, Y, PH, time.
- Exclude background events.
- Not possible to distinguish multiple events.



Quantum Throughput

- q.t.(λ) = 0.8 x 0.8 x 0.8 x 0.1 = 0.05 = 5%
- Counts = F x A x Δλ x q.t.

Filter	Slot	Slope	Slope error	R	Conversion factor[a]
FUV CaF2_1	F1	0.3619	0.0013	0.9845	3.8689e-15
FUV BaF2	F2	0.3330	0.0018	0.9978	4.2036e-15
FUV Sapphire	F3	0.2574	0.0008	0.9986	5.4399e-15
FUV Silica	F5	0.0980	0.0011	0.9848	1.4273e-14
NUV Silica	F1	1.0586	0.0027	0.9873	1.9459e-16
NUV B15	F2	0.0353	0.0001	0.9956	5.8360e-15
NUV B13	F3	0.1995	0.0005	0.9941	1.0327e-15
NUV B4	F5	0.2959	0.0014	0.9825	6.9611e-16
NUV N2	F6	0.0736	0.0002	0.9723	2.7988e-15

[a] erg cm^{-2} $Å^{-1}$ cnt^{-1}

Units

- We measure counts per pixel per second.
- Magnitudes are difficult because A0 stars have no flux in UV.
  - **FUV:** $m_{AB} = -2.5 \times \log_{10}(Flux_{FUV} / 1.40 \times 10^{-15}$ erg $sec^{-1}\ cm^{-2}\ Å^{-1}) + 18.82$
  - **NUV:** $m_{AB} = -2.5 \times \log_{10}(Flux_{NUV} / 2.06 \times 10^{-16}$ erg $sec^{-1}\ cm^{-2}\ Å^{-1}) + 20.08$
- Limiting magnitudes ~ 20 magnitude in 100 second observation.

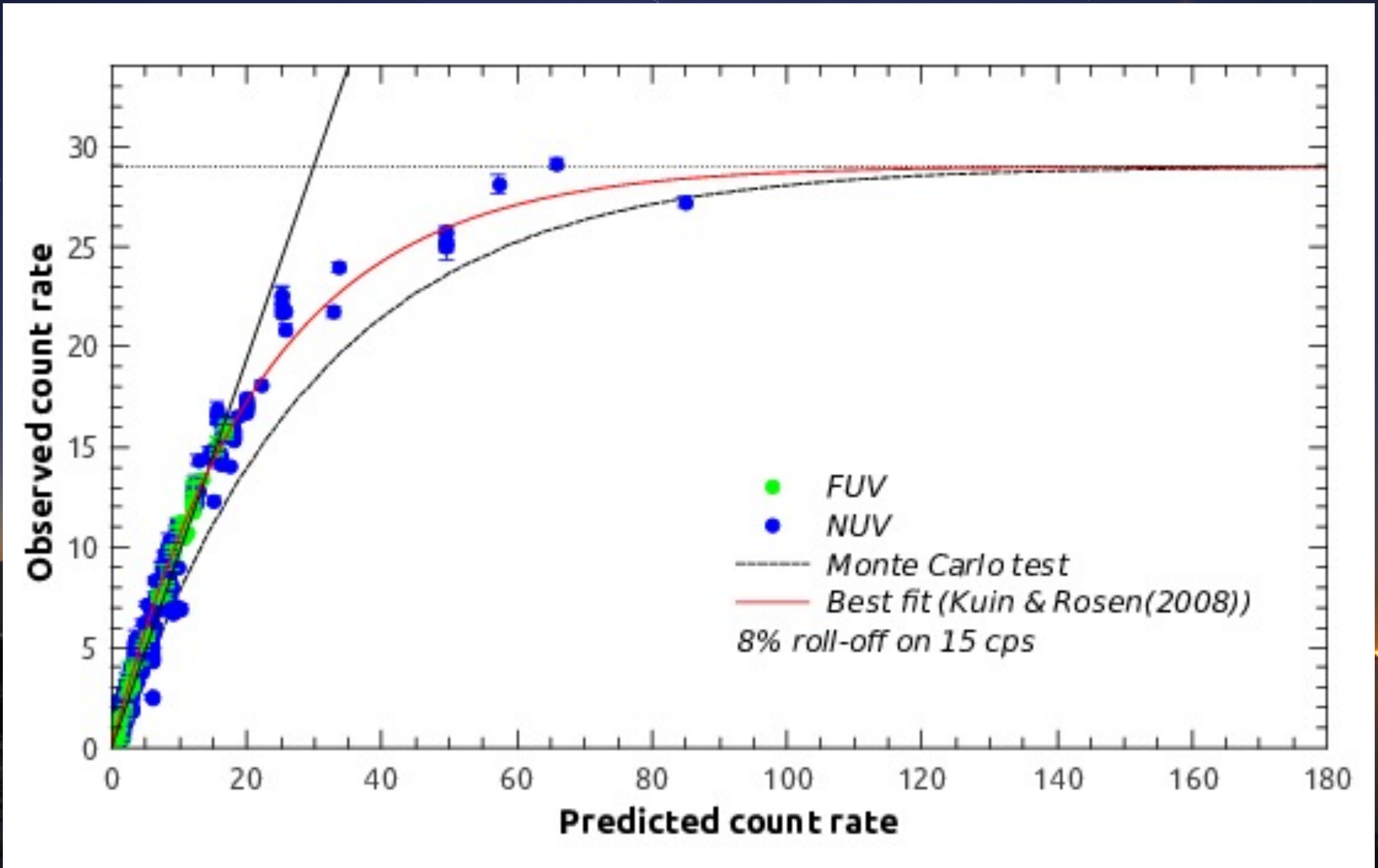
Counting details

- Zero noise detectors.
- Counts are Poissonian so S/N increases by square root of observation time.
  - 20th magnitude in 100 seconds (GALEX AIS) =>23rd magnitude (GALEX DIS) in 30,000 seconds.
  - 10 counts for 3 sigma detection.
- Similar scaling with mirror area.

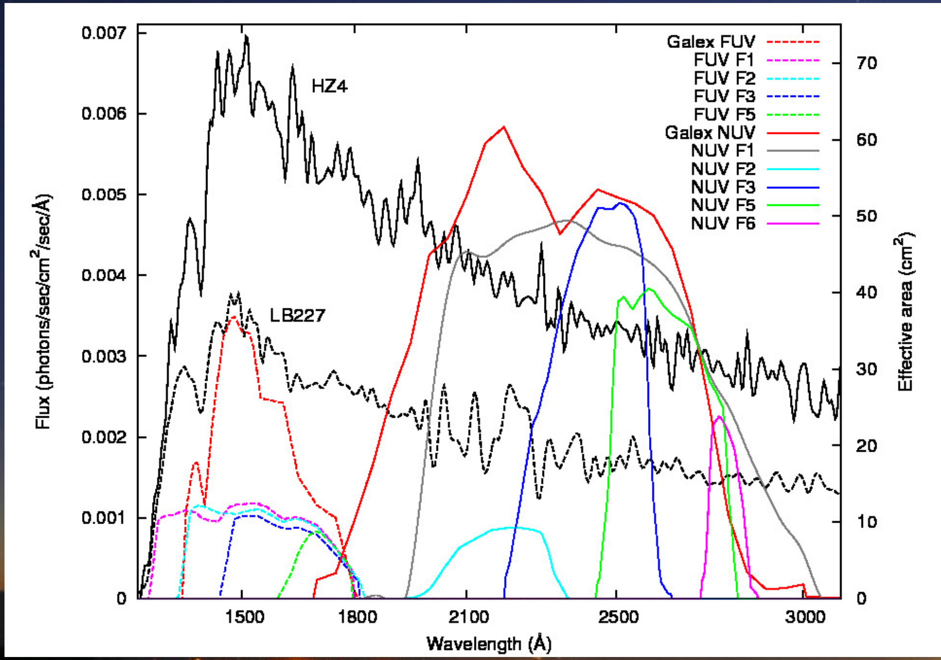
Detector Issues

- Lifetime of MCP ~ 1 Coulomb of charge.
  - Avoid bright regions, particularly in the beginning of a mission. For large FOV missions, diffuse background may be important.
  - There are only a countable number of hot stars which can be avoided.
- Avoid Galactic Plane, Magellanic Clouds.

Nonlinearity



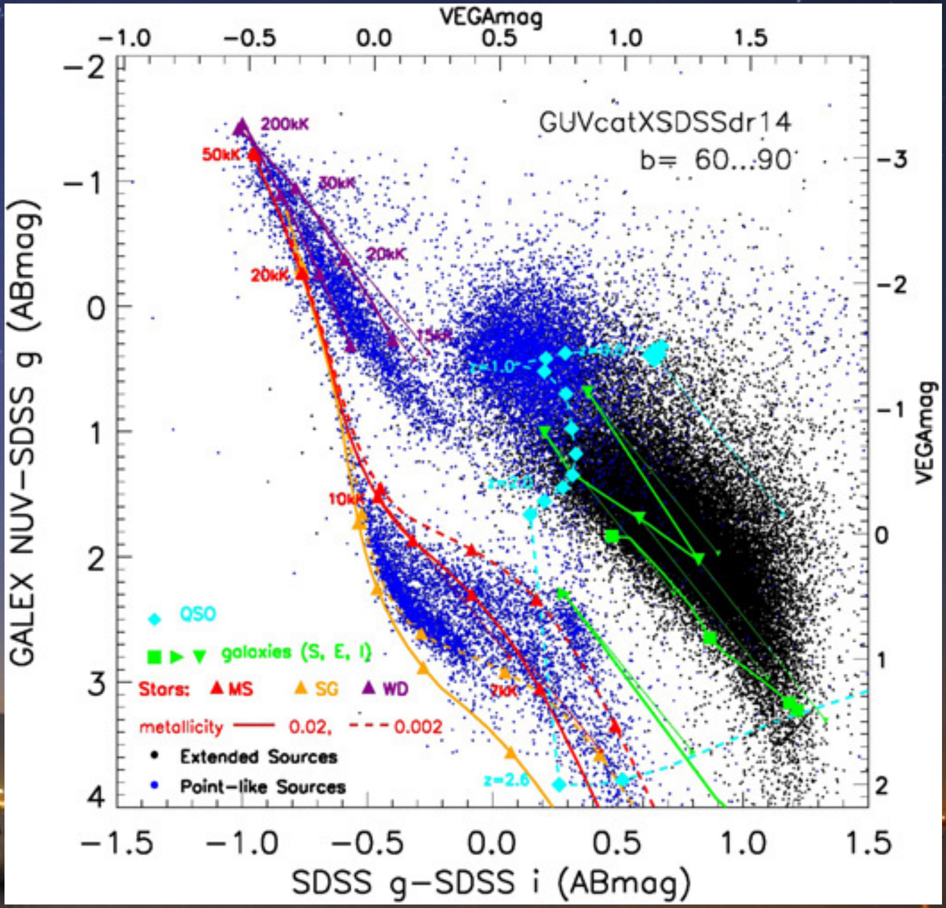
GALEX/UVIT



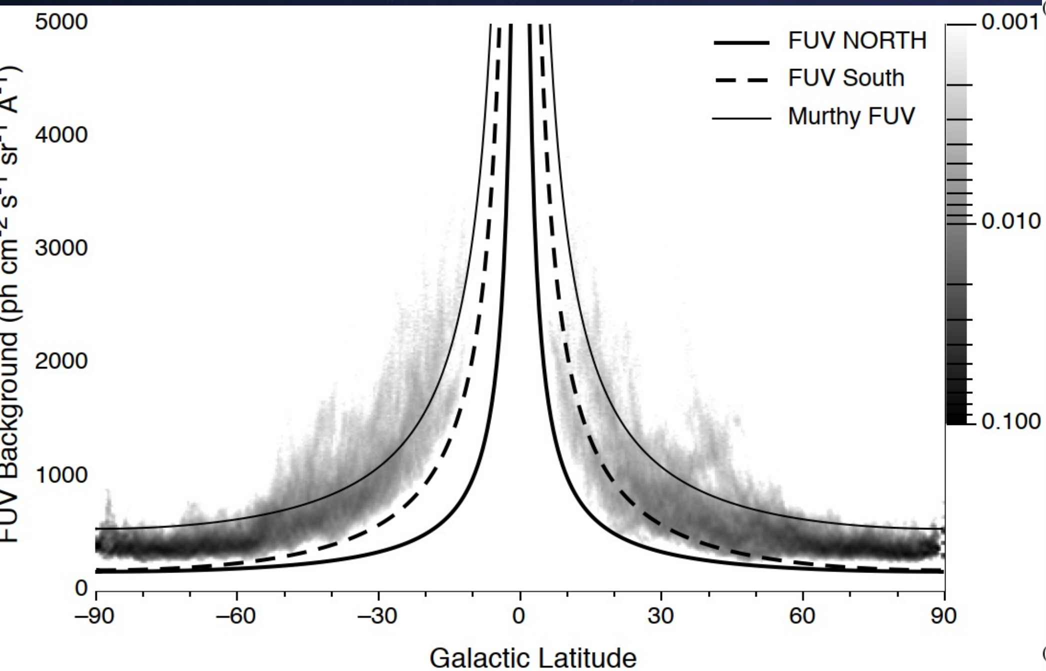
- UVIT multiple filters.
  - ~1.5 arcsec resolution
- GALEX: 2 filters
  - ~5 arcsec resolution

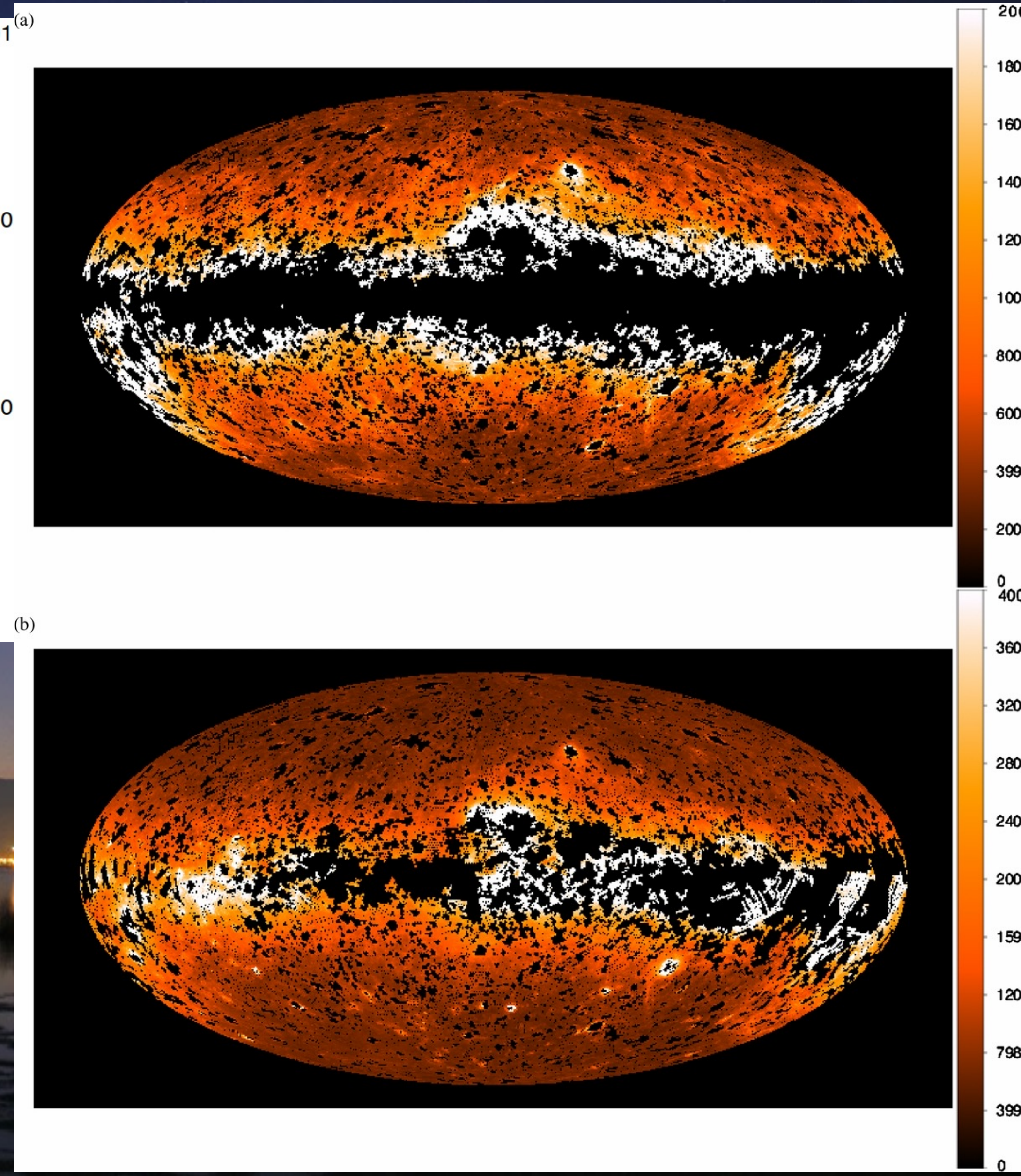
GALEX Data

- Available from MAST.
- Point source list.
  - https://ui.adsabs.harvard.edu/abs/2020ApJS..250...36B/abstract



GALEX Diffuse Observations

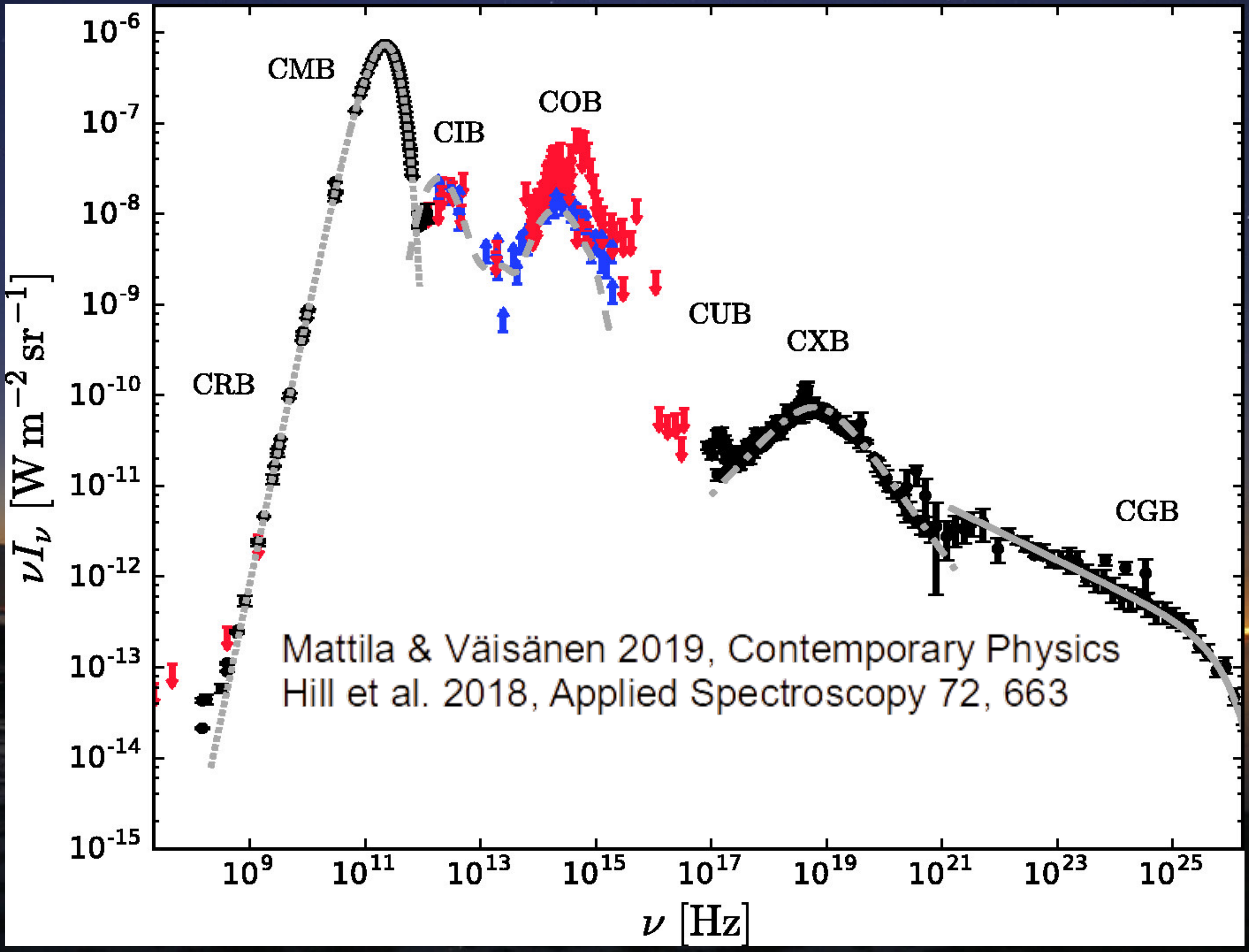




- Murthy 2014
- Cosecant falloff from plane to poles.
- Baseline of about 200 photon units.its: photons cm-2 s-1 sr-1 Å-1.

100 ph cm^{-2} s^{-1} sr^{-1} Å^{-1} = 2 nW m^{-2} sr^{-1}.

EBL


CMB
CIB
COB
CUB
CXB
CRB
CGB
νI_ν [W m^{-2} sr^{-1}]
ν [Hz]
Mattila & Väisänen 2019, Contemporary Physics
Hill et al. 2018, Applied Spectroscopy 72, 663

Future Directions

- No UV capability once HST/UVIT die.
- World Space Observatory
  - 1.7 m telescope.
  - ~2025 launch


WSOUV (Spain): Home

www.wso-uv.es/index.php?id=33

World Space Observatory - Ultraviolet

WSO - UV

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About Spektr-UF / WSO-UV

The World Space Observatory – Ultraviolet (Spektr-UF / WSO-UV) is part of ROSCOSMOS scientific program and has been developed in collaboration with Spain. Spektr-UF / WSO-UV is the third mission of the Spektr (spectrum) series of the Russian Federal Space Program after Spektr-R (in orbit since 2011) and Spectr-RG (with Russian ART- and e-Rosita payloads). All missions of the Spektr series use the NAVIGATOR platform.

The scientific payload consists of a 170cm primary space telescope, equipped with instrumentation for imaging and ultraviolet spectroscopy in the 115 to 315nm range, from Lyman-alpha to the atmospheric cut-off. The Spektr-UF / WSO-UV will be placed in geosynchronous orbit in 2025 by an Angara A5 launcher becoming the first 2-m class ultraviolet observatory flown into High Earth Orbit (HEO).

The mission is run by an international consortium led by Russia and also involving Spain. This is the web page of the Spanish team. Visit here the Russian site.

The Spektr-UF / WSO-UV premises at the Universidad Complutense of Madrid are provided by the Joint Center for Ultraviolet Astronomy (JCUVA).

The Spanish participation is funded by the Ministry of Industry, Energy and Tourism (industrial activities) and the Ministry of Economy and Competitiveness (scientific activities). The Universidad Complutense de Madrid (UCM)is the scientific responsible for Spain.

WSO-UV spacecraft

Future Directions

- No UV capability once HST/UVIT die.
- ULTRASAT
  - Large FOV.
  - Continuous UV alerts.

Future Directions

- No UV capability once HST/UVIT die.
- World Space Observatory
  - 1.7 m telescope.
  - ~2025 launch


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WSO-UV spacecraft

Future Directions

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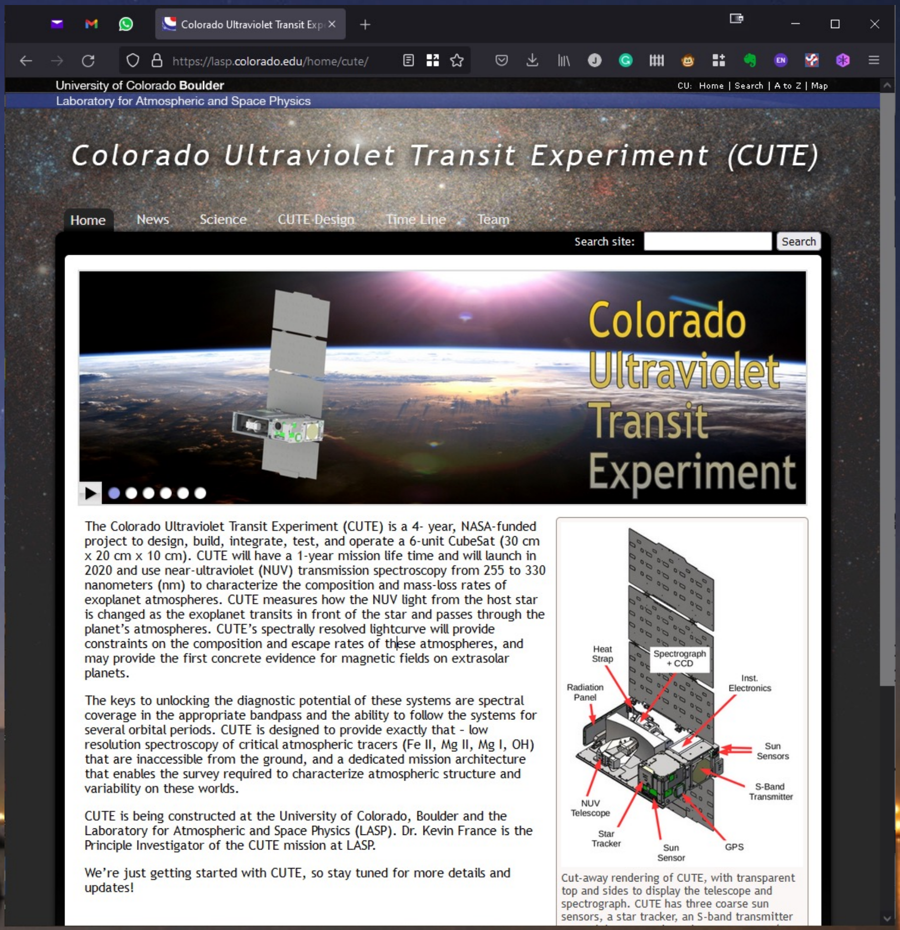
- CUTE
  - Atmospheres of exoplanets.
  - To launch ~2021



Future Directions

- SING
  - To fly on CSS in 2023
  - Low resolution spectroscopy of nebulae.
- NUTS
  - Planned for PS4 launch.
  - ~3 degree FOV to search for transients.
  - Total cost: ~USD 30,000 + 1 graduate student.

Small Satellites

- UV is where to go for niche science at low cost!