Predicting UV Sky (for future missions)

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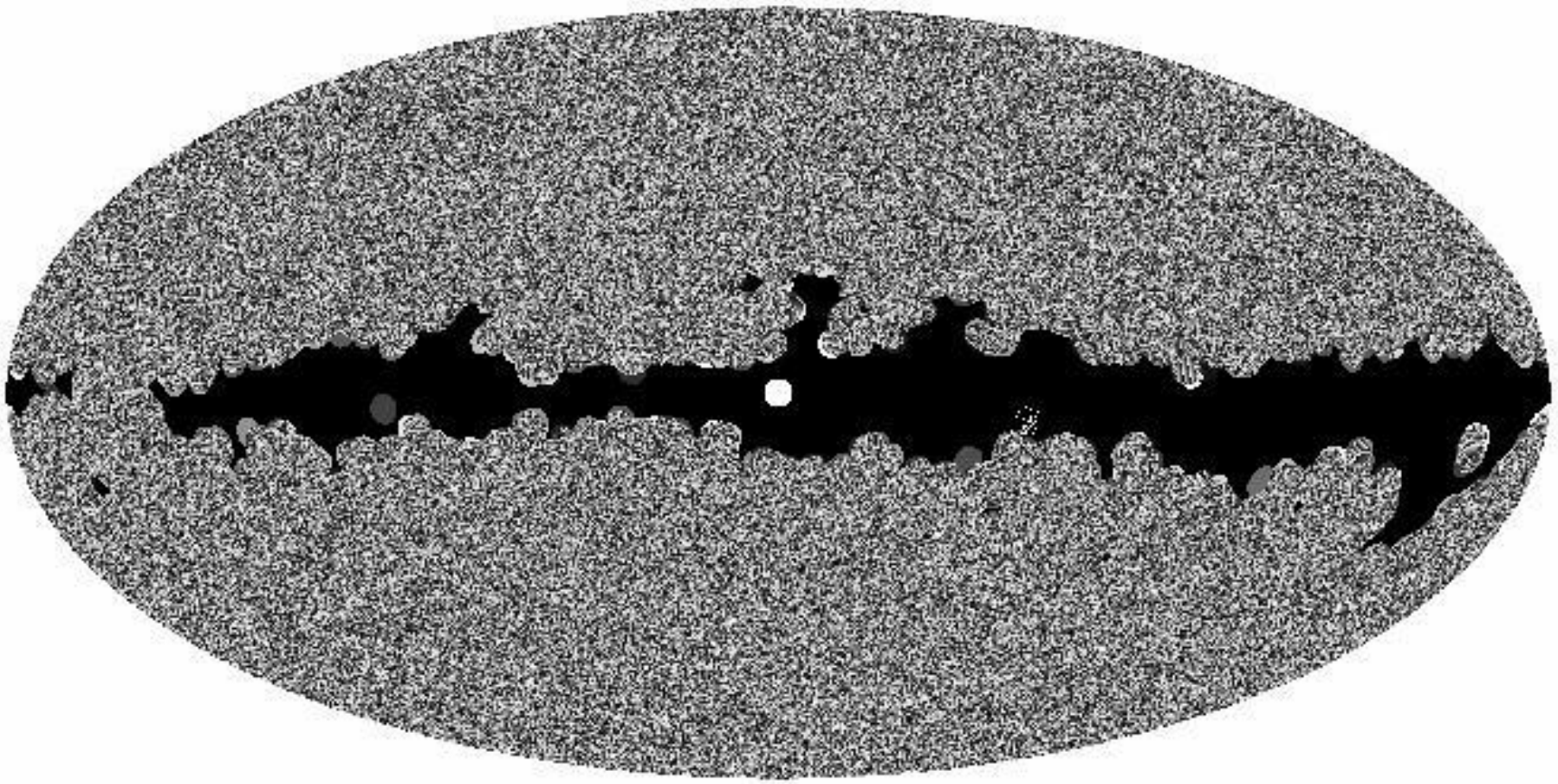


Keyword of modern astronomy — multiwavelength Universe

Missions in orbit:

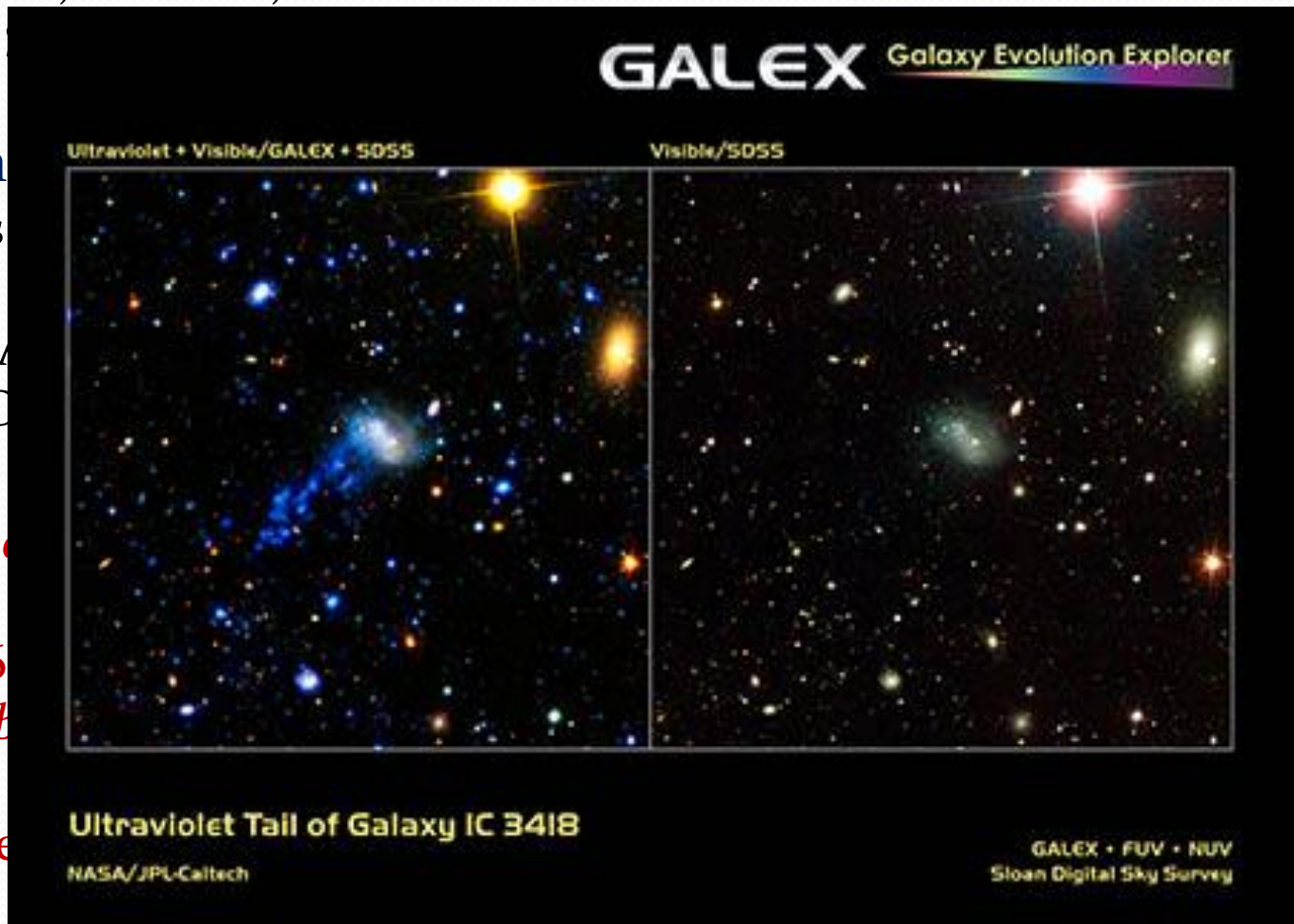
- 1 UV – GALEX (+ EUV CHIPS studying the Local Bubble, Hubble)
- 9 IR – Spitzer, IRAS, IRIS, Planck, Kepler, NICMOS(HST), Hershel, WISE
- 4 X-ray – Suzaku, XMM, Chandra, RXTE
- 3 γ-ray – INTEGRAL,

Future UV Mission

- No new UV missions by NASA or ESA
  - India: UVIT on A
    Russia-led WSO

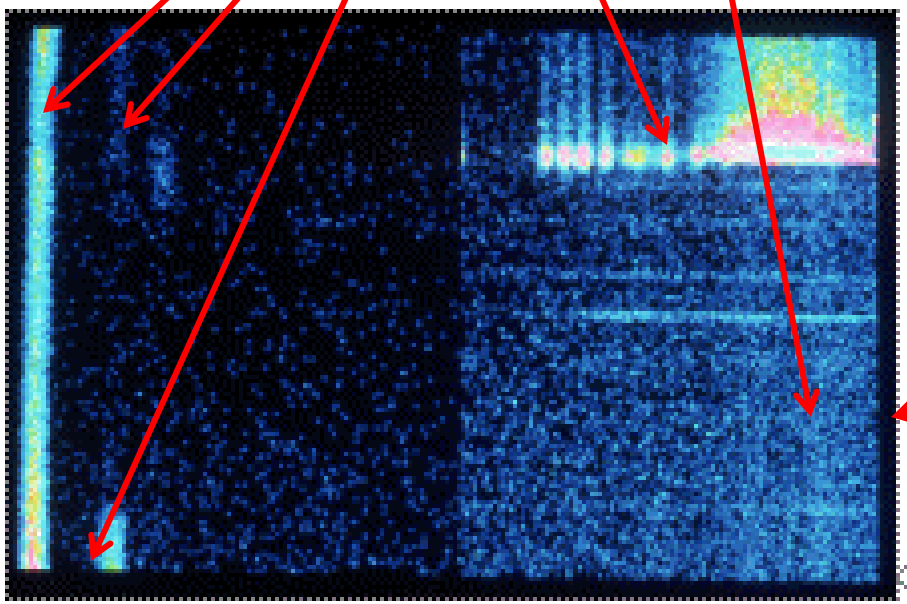
Importance of UV:

The Need for UV to Un
Cosmology
Wamsteker et al. 2006
UV Capabilities to Prob
Planets
Ana Gomez de Castro e



UV sky

- Discrete source (hot stars, AGN, etc.)
- UV background (diffuse radiation field):
  - Airglow (important in low-orbit missions)
  - Zodiacal light (scattered sunlight in Solar System)
  - Cosmic background (from beyond Solar System):



* Galactic component (scattering of sunlight off dust grains)

* Extragalactic component at the poles up to 25%? [Brosch '98])

\+ Dark instrument count — usually ~5 cts/cm²

UVX spectrometer on Columbia 1986 @ 330 km [Murthy '10]

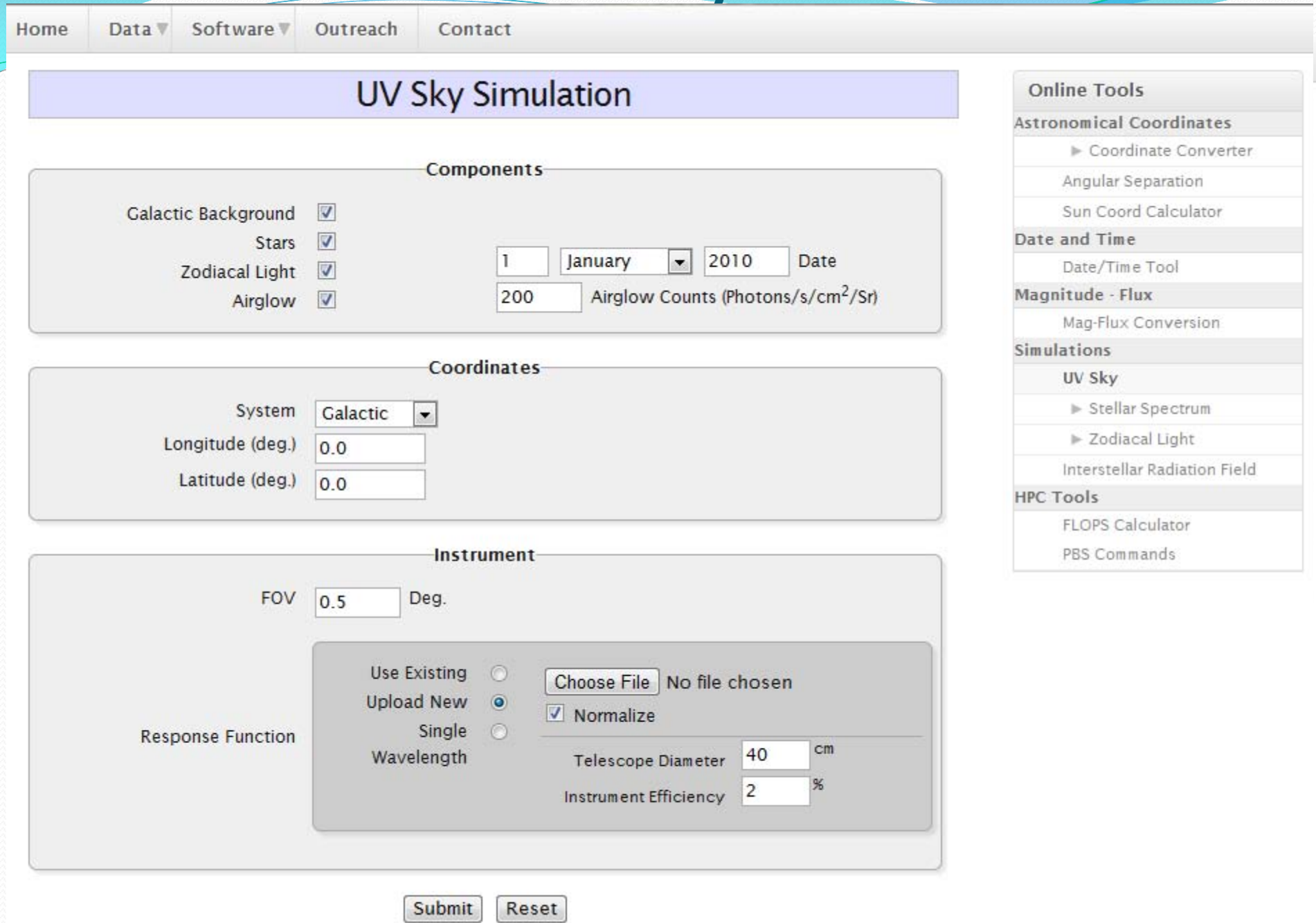
Web-based Sky Simulator

A simulation of the sky is important :
- For the purpose of mission planning
- To provide test data for development and validation of software pipeline

- Instrument-specific inputs:
  - FOV
  - Wavelength at which data/image to be generated
  - Filter curves (currently old UVIT; user-uploadable)
  - Dark count (not yet)

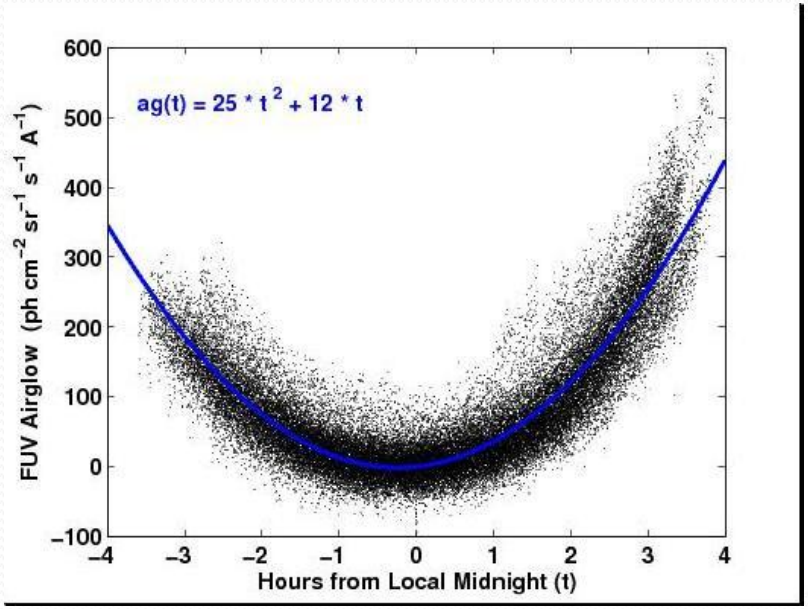
- Background contributors:
  - Airglow (currently set @ 200 ph/cm^2/sec/sr/Å; changeable)
  - Zodiacal light (depends on time, date and direction of observation)
  - Stellar contribution (now Hipparcos catalogue; will be uploadable)
  - Galactic background (GALEX database)

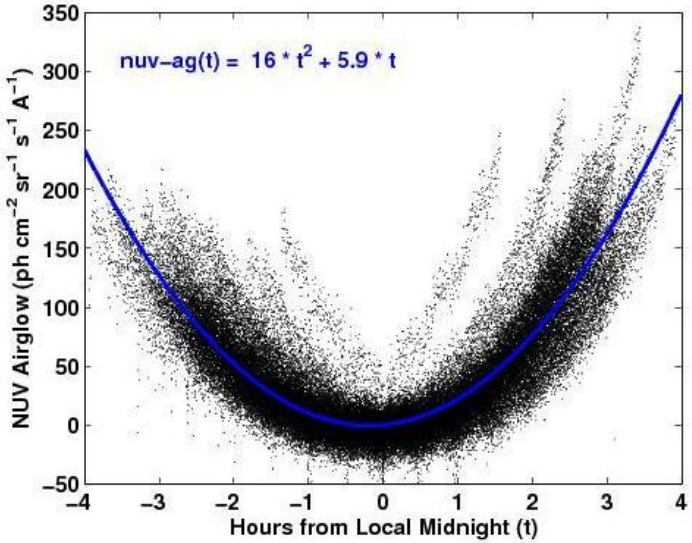
Web-based Sky Simulator



Web-based Sky Simulator

- Airglow
  - Important contributor to UV b/g for low-orbit missions, like GALEX and Astrosat
  - Strongly depends on the altitude, observation time, zenith angle and solar cycle
  - Strong function of the local time
  - Distribution usually determined empirically
  - Average level @~200 photons/cm²/sec/sr/Å [Sujatha et al. '09]





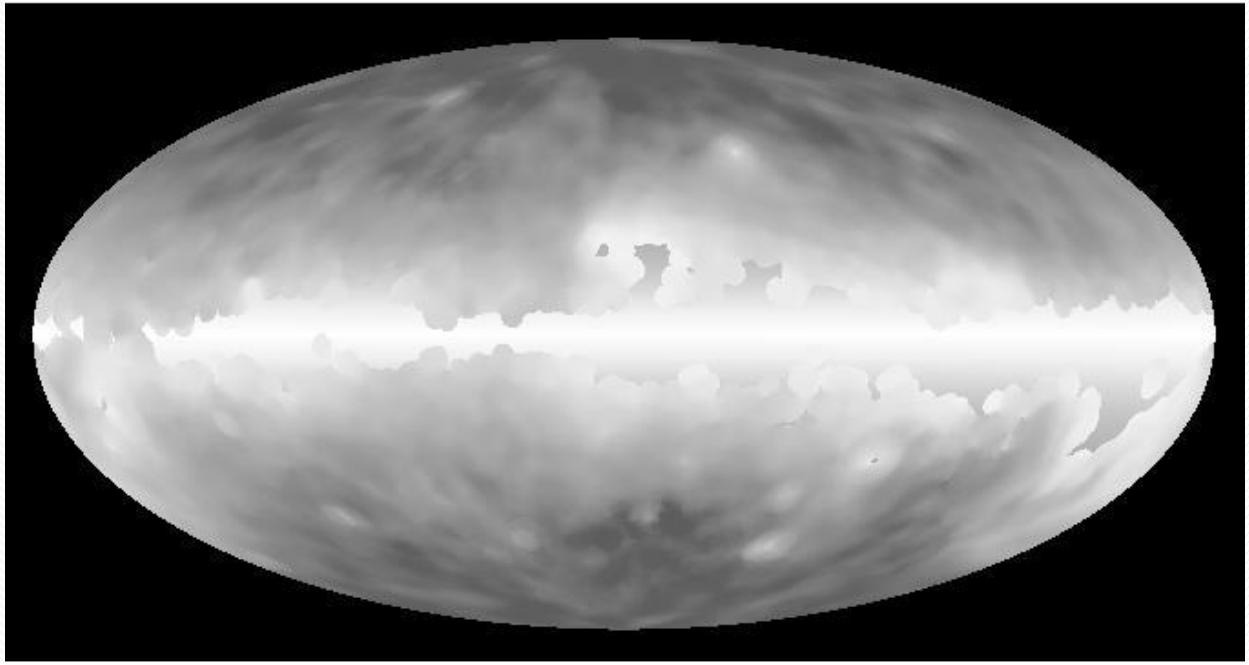
Web-based Sky Simulator

- Stellar contribution
  - Major contributor to diffuse sky b/g is scattering of starlight on IS dust
  - Used Hipparcos catalogue as data source (mags, distance, spectral type):

    250,000 stars
  - Kurucz models to get spectra [Kurucz '92]
  - Kurucz model scaled to V mags
  - Convolved with instrument response function to get counts

Web-based Sky Simulator

- Galactic background
  - Dominated by starlight scattered by IS dust
  - Varies on spatial scales from arcmins to degrees
  - Difficult to model [Murthy et al. '10]
  - Use GALEX database in FUV and NUV (pt source catalogue providing star flux with a background at its position); download median of backgrounds
  - Interpolate between FUV and NUV using B star spectrum
  - Subtract airglow and zodiacal light
  - Tabulate derived backgrounds



GALEX NUV b/g
Galactic plane modelled by cosec b law
[Murthy et al. '11]

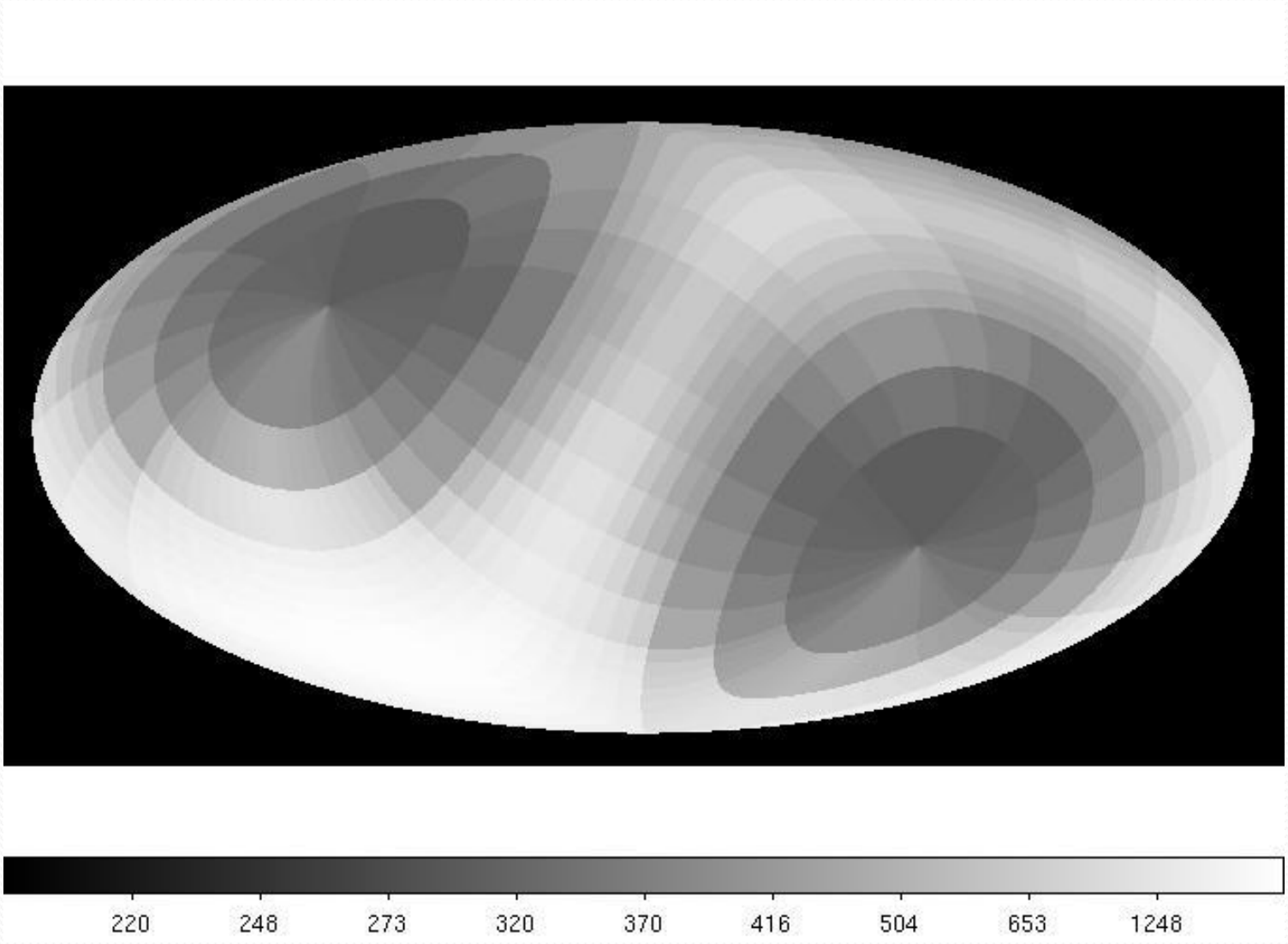
Web-based Sky Simulator

- Zodiacal light
  - Essentially a solar spectrum scaled to the UV; contributes only to NUV
  - Level depends on time and date of observation, look direction
- **Online Calculator**

  The online calculator is a front end to the C program. The only inputs required are the date and the observing direction. The output is the zodiacal light spectrum in units of photons/cm²/s/sr/Å plotted as a function of wavelength. This can be integrated with the filter response function to give a count rate in each of the filters. The spectrum itself can be downloaded by clicking on the image.
- **Implementation**
  - **Problem Statement :** In order to calculate the zodiacal light, we need:
    - Sun position (IDL algorithm for the Solar ephemerids converted to C code)
    - Zodiacal light spectrum (solar spectrum is from Colina et al. '96)
    - Zodiacal distribution (spatial dependence as a function of ecliptic coordinates from table by Leinert et al. '98)
  - **Input/Output**
    - The input of the program is: day-month-year : look_ra -look_dec
    - The output of the program is the zodiacal light level at the specified coordinates n FOV and date in units of photons/cm²/sec and a plot of spectrum.
    - Can also generate all-sky distribution

Web-based Sky Simulator

All-Sky Zodiacal Light for April



Web-based Sky Simulator

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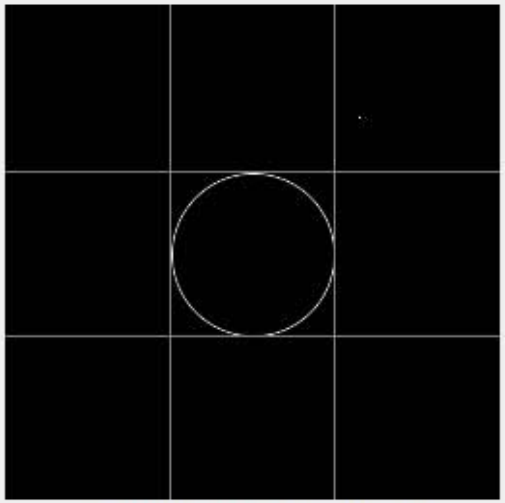
UV Sky Simulation

Input Values

Components	UV-Background, Stars, Zodiacal-light, Airglow
Date	23 november 2011
Airglow	200.0000
Galactic coordinates	(0.0000, 0.0000) deg
Filter	uvit_FUVB1
Field of View	0.5 deg.

Output

Galactic Background:	255.7 Ph/s/cm^2
Stars:	30.17 Ph/s/cm^2
Zodiacal Light:	6.36 Ph/s/cm^2
Air Glow:	0.02 Ph/s/cm^2
Total:	292.2 Ph/s/cm^2



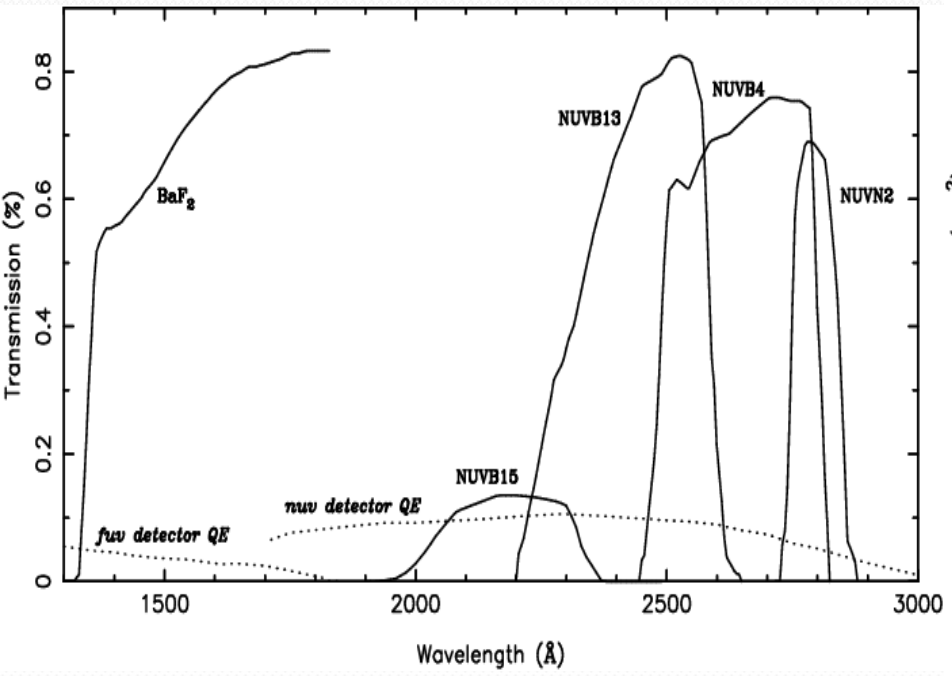
Download zipped FITS [1.1KB]

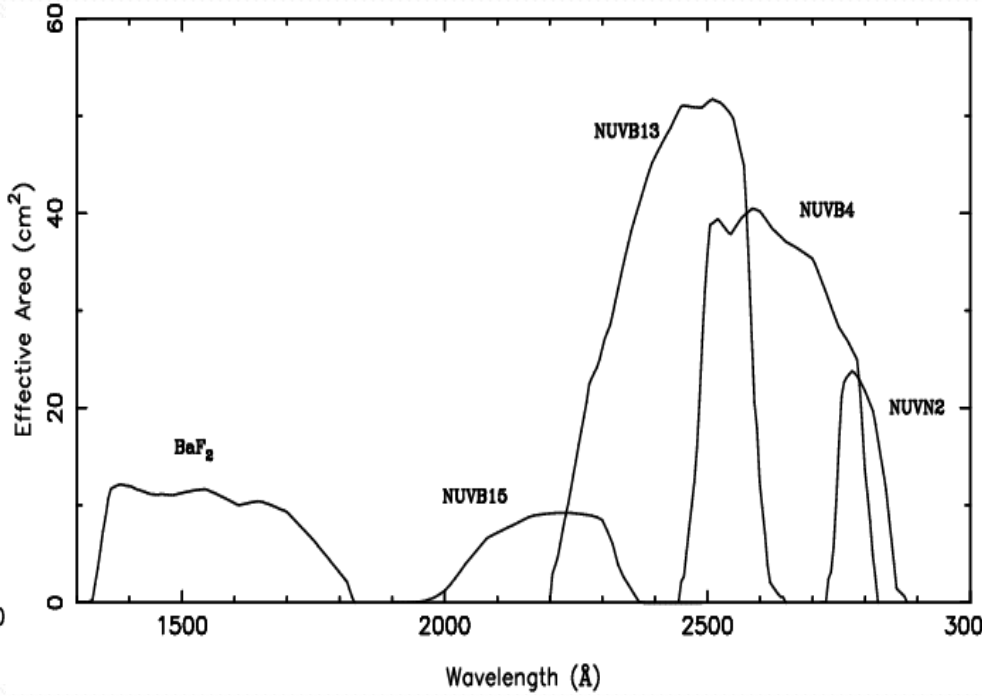
Online Tools

- **Astronomical Coordinates**
  - ▶ Coordinate Converter
  - Angular Separation
  - Sun Coord Calculator
- **Date and Time**
  - Date/Time Tool
- **Magnitude - Flux**
  - Mag-Flux Conversion
- **Simulations**
  - **UV Sky**
    - ▶ Stellar Spectrum
    - ▶ Zodiacal Light
  - Interstellar Radiation Field
- **HPC Tools**
  - FLOPS Calculator
  - PBS Commands

Application to UVIT

$$A_{eff} = A_{geom} \times QE(\lambda) \times T_F(\lambda) \times Optics Effi ciency(\lambda)$$





Ref: AstroSat Handbook

Application to UVIT

	BaF2	NUVB15	NUVB13	NUVB4	NUVN2
λ range	1300-1830	1900-2400	2200-2650	2445-2825	2730-2880
Δ effective	378.0	281.7	270.5	282.3	89.5
λ mean	1549.6	2435.5	2183.0	2428.0	2790.0
λ pivot	1544.6	2433.6	2181.0	2616.4	2789.7
λ effective	1232.3	2433.2	2171.0	2629.0	2792.0

$$\Delta_{eff} = \int A_{norm}(\lambda) d\lambda$$

Effective bandwidth

$$\lambda_{mean} = \frac{\int \lambda A_{norm}(\lambda) d\lambda}{\int A_{norm}(\lambda) d\lambda}$$

Mean (central) wavelength

$$\lambda^2_{pivot} = \frac{\int A_{eff}(\lambda) \lambda d\lambda}{\int A_{eff}(\lambda)\, d\lambda/\lambda}$$

Pivot wavelength

$$\lambda_{eff} = \frac{\int \lambda A_{eff}(\lambda) F(\lambda) d\lambda}{\int A_{eff}(\lambda) F(\lambda) d\lambda}$$

Effective wavelength (A1V star for BaF2; Vega for NUV filters)

Web-based Sky Simulator **for UVIT**

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UV Sky Simulation

Components

Galactic Background ☑
Stars ☑
Zodiacal Light ☑
Airglow ☑

1 January 2012 Date

200 Airglow Counts (Photons/s/cm^2/Sr)

Coordinates

System: Galactic
Longitude (deg.): 209.0
Latitude (deg.): -19.4

Orion Nebula

Instrument

FOV: 5.0 Deg.

Response Function:
- Use Existing ◉ — UVIT NUV B4
- Upload New ○
- Single Wavelength ○ — ☐ Normalize

Submit | Reset

Online Tools

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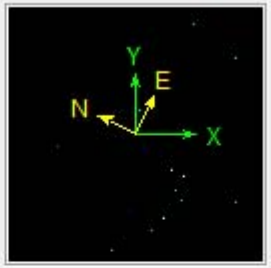
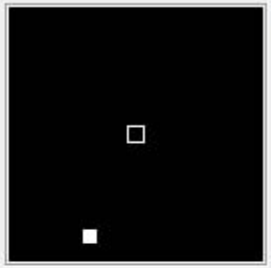
for UVIT

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

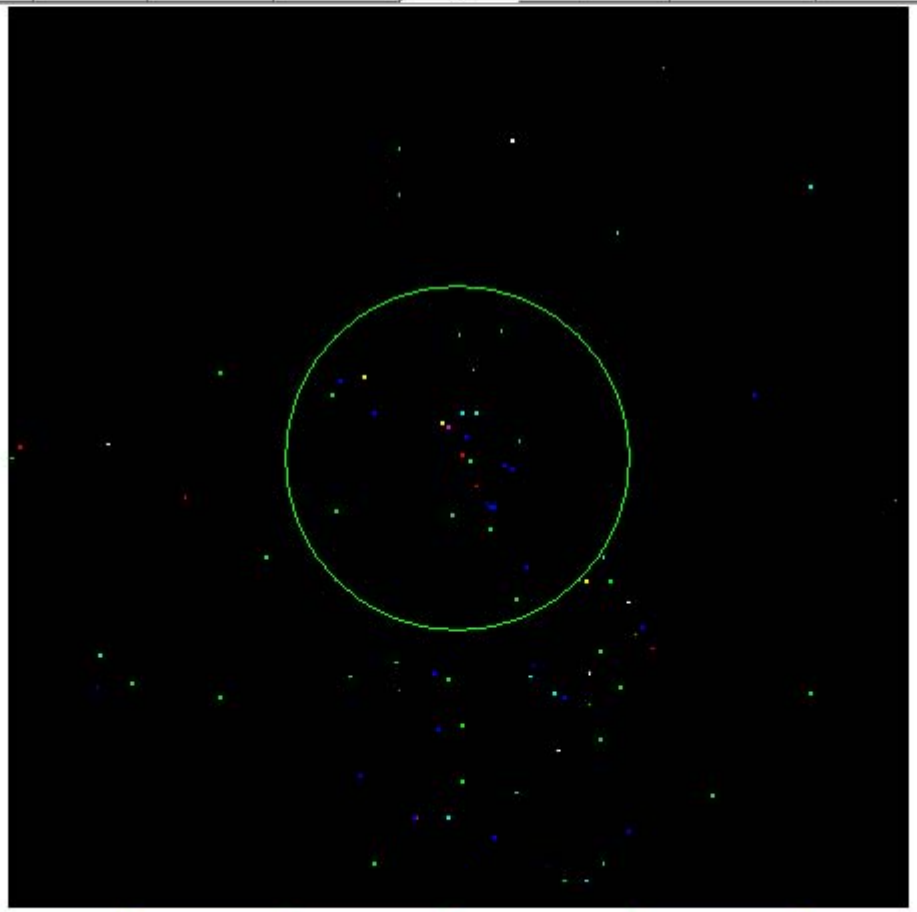
File	00662063.fits			
Object				
Value	142.222			
FK5	α	05:32:16.256	δ	-04:57:48.41
Physical	X	115.916	Y	121.173
Image	X	115.916	Y	121.173
Frame 1	Zoom	1.758	Angle	0.000





file edit view frame bin zoom scale color region wcs help

grey a b bb he i8 aips0 heat cool rainbow



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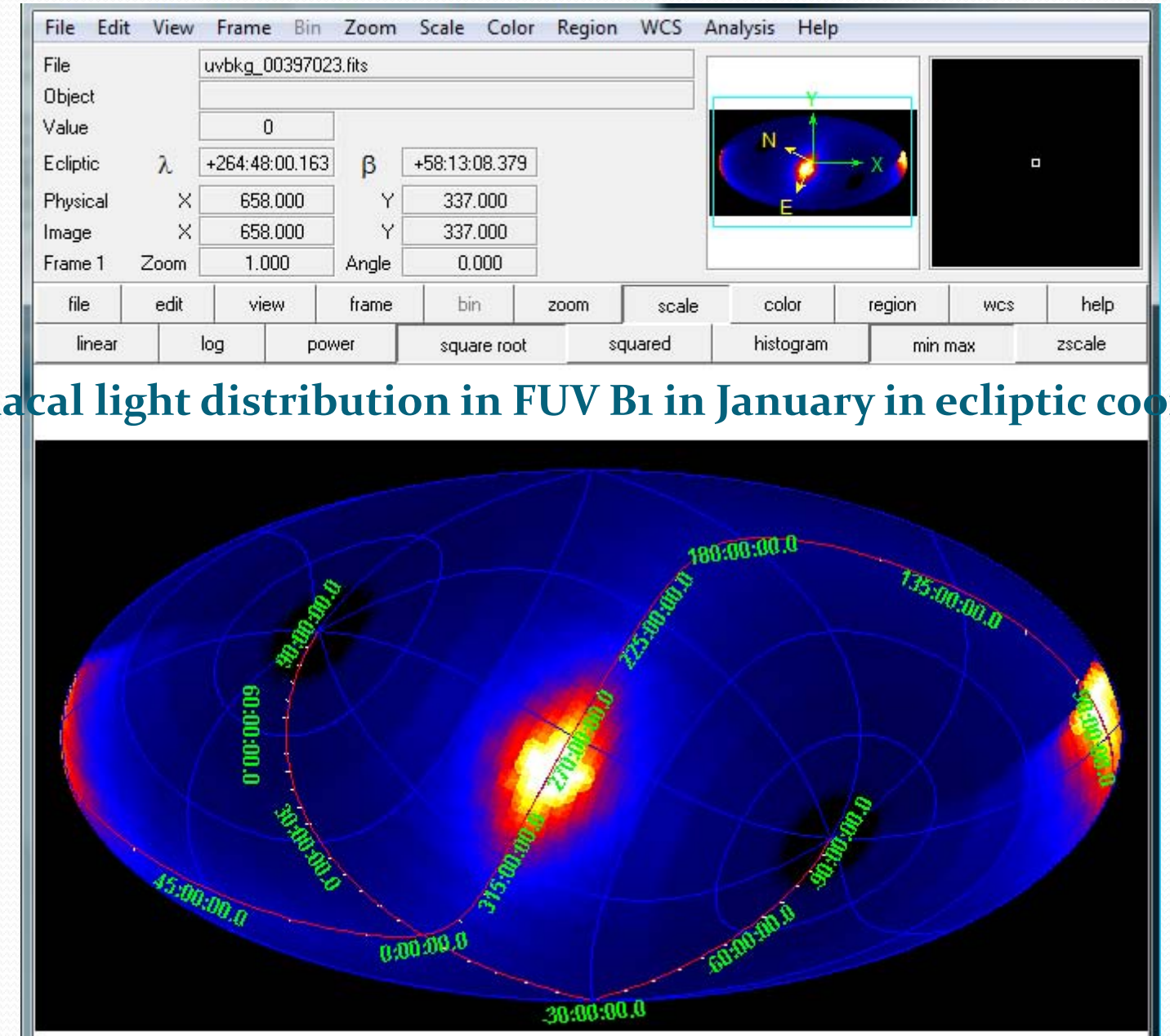
Orion Nebula

Web-based Sky Simulator for UVIT

Components of the simulation:



Zodiacal light distribution in FUV B1 in January in ecliptic coordinates

Web-based Sky Simulator

To do:

- Include user-uploadable catalogues
- Update new UVIT effective areas
- All-sky images in 5 UVIT filters for different seasons
- Flag for overbright areas for 5 UVIT filters (now assuming GALEX brightness limits), but eventually user-changeable
  - NUV: 50,000 cps ($F\lambda \sim 3.0 \times 10^{-11}$ erg/cm^2/sec/Å)
  - FUV: 15,000 cps ($F\lambda \sim 9.0 \times 10^{-12}$ erg/cm^2/sec/Å)
- Time-variability of the background for few UV astrometric standard fields