A Gaia map of the natural sky brightness

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Abstract: The natural brightness of the night sky in different photometric bands is a relevant parameter for light pollution research, since it allows establishing a baseline against which to evaluate the light pollution levels experienced in urban, periurban, rural and pristine dark sites. We present a model to map the natural brightness of the sky. In this model, the radiance out of the Earth due to the stars is obtained from the Gaia-DR2 catalogue.

Introduction

The radiance of the natural night sky $L(z, h)$ in the direction z for an observer at height h is the sum of several contributions:

$$L(z, h) = L_{ISL}(z,h)+L_{DGL}(z,h)+L_{EBL}(z,h)+ L_{zl}(z,h)+L_{ag}(z,h)$$

- $L_{ISL}(z,h)$: integrated starlight (ISL)
- $L_{DGL}(z,h)$: diffuse galactic light (DGL)
- $L_{EBL}(z,h)$: *extraglactic background* galactic light (DGL)
- $L_{zl}(z,h)$: zodiacal light
- $L_{ag}(z,h)$: airglow $L_{ag}(z,h)$

This radiance is affected by attenuation (absorption and scattering), before it reaches the observer. The radiance for a filter with spectral response $S(\lambda)$ is:

$$L_{obs}(z,h)=\int_0^\infty L(\lambda,z)S(\lambda)T(\lambda,z,h)d\lambda$$

$T(\lambda,z,h)$: atmospheric transmission

The natural sky brightness is not uniform over the sky dome. Besides the dependence on the line of sight of the airglow radiance, absorption and scattering, the presence of the Milky Way or other bright sky patches has a direct impact in the value of the sky brightness in a given direction. The value of the brightness is therefore a function of the location, time, observing direction and atmospheric conditions.

Methodology

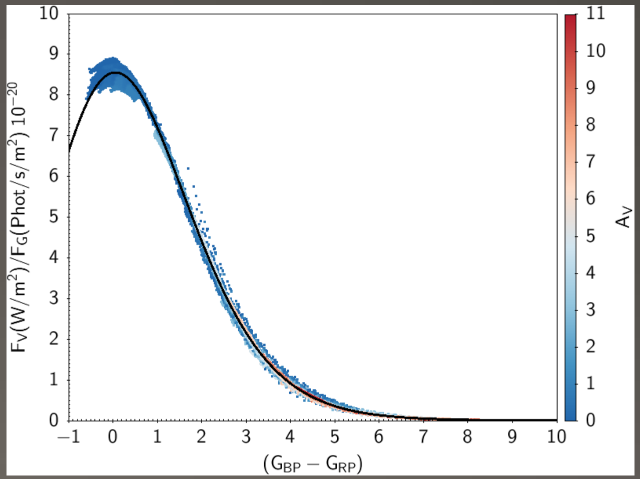
We have modeled all the contributions to build a tool to compute the natural sky brightness at any given location and time.

The main novelty of our model is to use Gaia-DR2 catalogue to compute the integrated star light (ISL). For bright stars, not present in Gaia-DR2, we use data from Hipparcos catalogue.

Multiband model: From Gaia (G, Bp and Rp) and Hipparcos (B, V) photometric data, it is possible to get the fluxes in other photometric bands. The transformation is a function of one color c^i:

$$F_B = F_A \, e^{\sum_i a_i c^i}$$

- Computation of synthetic photometry in all the bands from Basel-3.1 models of stellar atmospheres.
- Inclusion of the effect of interstellar reddening by using a wide range of possible absorption rates (from 0 to 11 magnitudes at 550 nm) of the Gaia and Hipparcos stars.
- Minimum least square fit is applied to get the a_i coefficients

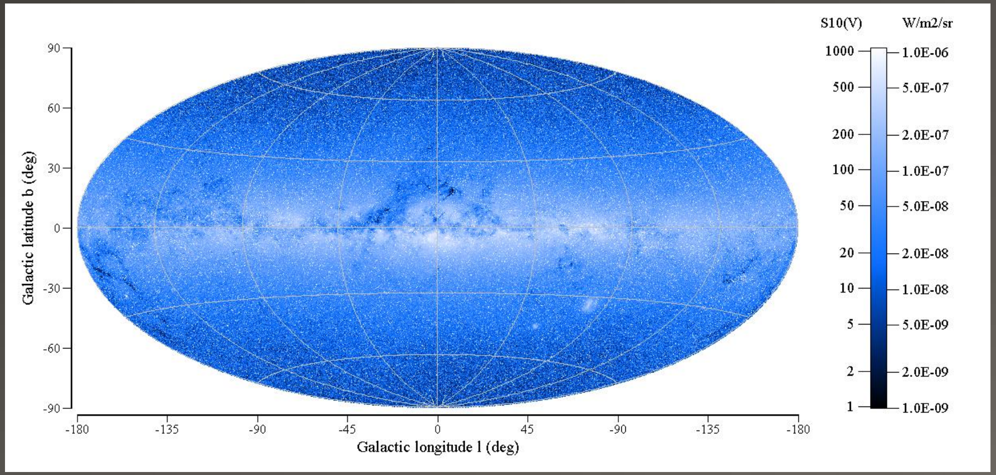


Transformation from *G flux to V* as function of (Bp-Rp) color.

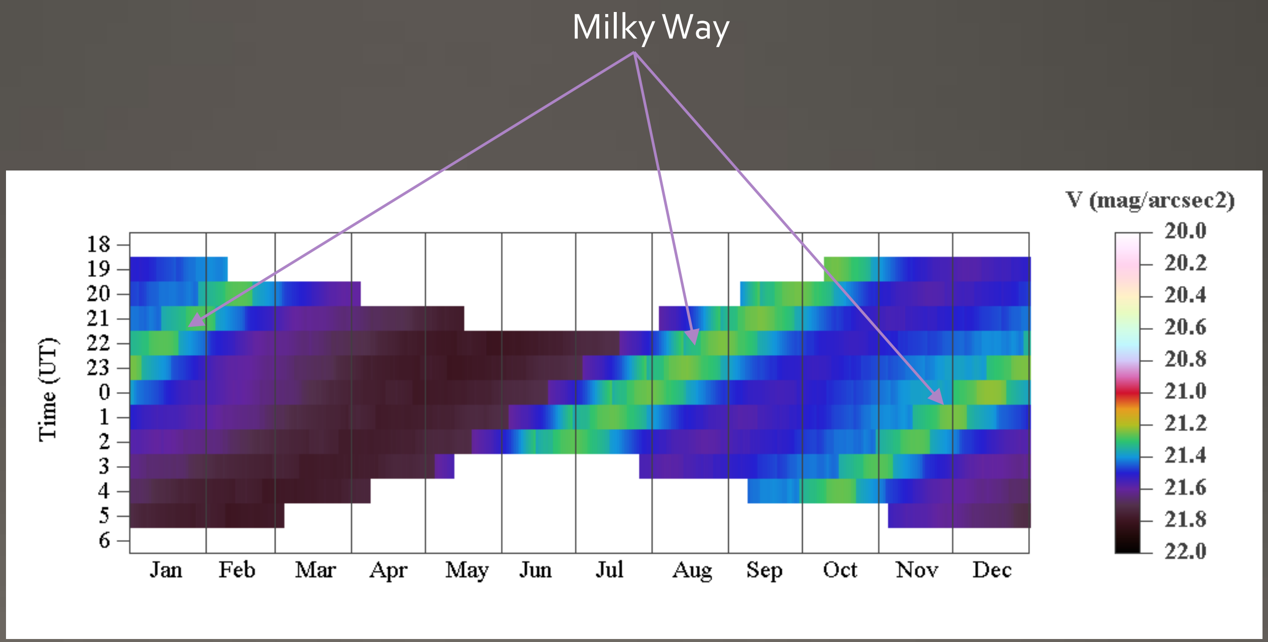
Results

As a first product, we have generated the map of the radiance outside the Earth's atmosphere, including the integrated star light, the diffuse galactic light and the extragalactic background light.

The model is also a powerful tool to analyze and characterize the natural sky brightness. For instance, it allows to study the variation of the sky brightness throughout the year in a given place due to the presence or absence of the Milky Way and zodiacal light. It can reach, at zenith, up to 0.5-0.6 mag and should be taken into account when trying to characterize the darkness of a given place.



Map of the radiance outside the Earth's atmosphere (V band)



Variation along the year of the zenith sky brightness for a location at 40N.

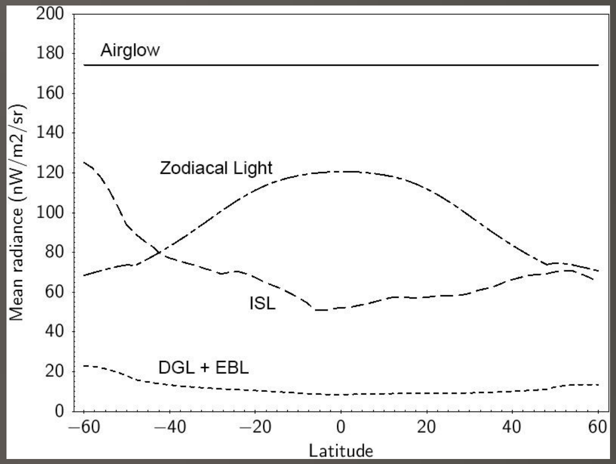
Results

The contributions to the natural sky brightness and how they vary with the observer latitude or date can be studied with the model. This variation is mainly due to the Milky Way and the height of the Ecliptic above the horizon.

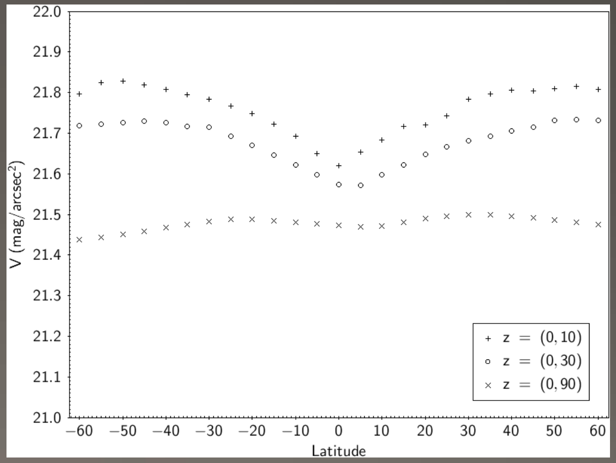
Component	Percentatge at zenith (%)
Airglow	53.4
Zodiacal Light	25.0
Integrated Star Light	18.9
Diffuse Galactic Light	2.5
Extragalactic Background Light	≈ 0.2

Mean contributions to the natural sky brightness (latitude=40N)

Variation of the contributions with the observer latitude (same airglow and atmospheric conditions).



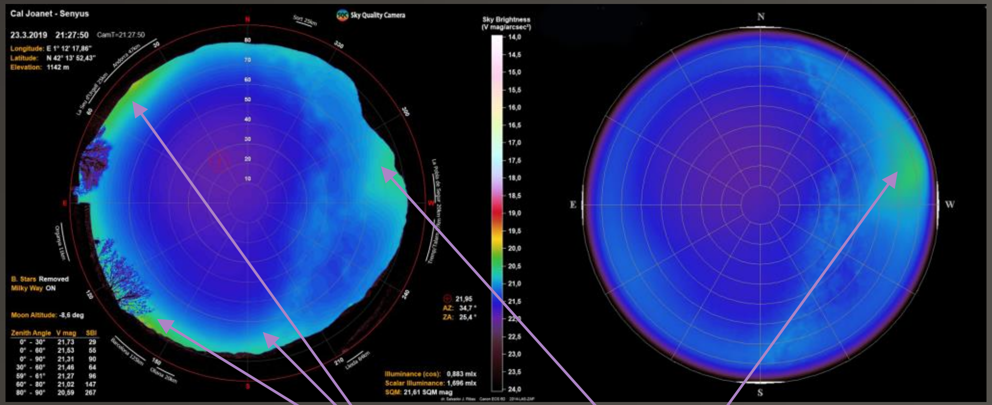
Darkest sky as function of the latitude. This value is significant in light pollution studies, as it establishes a limit to the actual measurements of the sky darkness. Fainter measured values could indicate a high atmospheric attenuation (for instance by anomalous amount of suspended dust particle) or rare episodes of low airglow intensity. The darkest value of the natural sky depends on the observer latitude and time of observation.



Darkest sky vs. latitude for 3 different areas of the sky: two around the zenith and all-sky.

Future work

- Use of the model to evaluate light pollution by comparing with actual images:



Light pollution

Zodiacal light

Actual image (left) vs. model (right)

- Explore the multiband capability, in particular including the Sky Quality Meter (SQM) passband in order to compare the model with SQM measurements.
- Web version in preparation.
- Paper in preparation.