ISS IMAGES FOR OBSERVATORY PROTECTION

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1. Motivation
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1. MOTIVATION: LIGHT POLLUTION AND ASTRONOMY

• The Light pollution increases the brightness of the sky

• The sky brightness is an astronomical quality parameter

• The effects of light pollution on the sky brightness increase can be measured by photometric astronomical techniques.

Variación espacial, temporal y espectral de la contaminación lumínica y sus fuentes: Metodología y resultados. A. Sánchez de Miguel 2015

Model ILLUMINA Aubé 2005
1. MOTIVATION: LIGHT POLLUTION AND ASTRONOMY

- The evolution of light pollution used to be measured in astronomical observatories.

- Astronomical observatories move away as possible from sources of light pollution.

IAU Commission 50 works to safeguard professional astronomical sites and their members are involved with scientific projects such as the monitoring and modelling of light pollution.
**SOURCES OF SCATTERING AND ABSORPTION**

- **Air Molecules** -> Rayleigh diffusion
- **Aerosols** -> Mie diffusion

**Formación del ozono (O3 absorption)**

- Oxígeno (O₂) + Compuestos orgánicos volátiles (COV) + Óxidos de nitrógeno (NOx) -> Ozono (O₃)

*Figura 14: Formación del ozono (Rayleigh) generado por la inyección de ozono.*
 SOURCES OF THE SKY BRIGHTNESS

Airglow

Moon

Milky way

Light pollution

Zodiacal light
SOURCES OF THE SKY BRIGHTNESS

- Airglow (sun activity)
- Moon
- Milky way
- Zodiacal light
- Light pollution

The natural changes can hide the light pollution growth
Direct light detection is 14 times more sensitive than Sky brightness variations.
1. MOTIVATION: LIGHT POLLUTION AND ASTRONOMY

- The sky brightness is affected by light pollution sources located at great distances. The effect of these sources can be predicted by models of atmospheric diffusion.

- The models need some inputs:
  (a) Physical relationships. For example, the variation of sky brightness with distance to the sources.
  (b) Radiance emitted into the atmosphere from pollution sources.

This study contributes to the study of light pollution from ground and space. Studying emission sources and their effect on the brightness of the sky.

Tools and techniques have been developed for this purpose, they have been applied to several typical cases.
2. RESEARCH GOALS

• Develop methods to calibrate night time observations from satellites, for the measurement of absolute radiances of light pollution sources

• Study of the spatial, temporal and spectral variation of the light pollution sources and its relationship with the sky brightness variations

• Get a broad data set needed to validate the models of propagation of light pollution
3. METHODS AND RESULTS
3. WORKFLOW OF THE STUDY

Teledetection of the L.P. and its sources

Measurements of the Sky Brightness

Temporal Spatial Spectral Variation

Relationships

Temporal Spatial Spectral
3.1. Study of the light pollution sources
3.1.1. LIGHT POLLUTION STUDIES FROM SATELLITES

Meteorological and Earth observation satellites that take pictures at night on one panchromatic band, that is not designed for the study of light pollution. Although, it is possible to detect the presence of artificial light sources, they were not designed primarily for measuring radiances.

Main contribution of this study:

1) Calibration of the DMSP/OLS data (1992-2010)
2) Evolution of energy consumption in street lighting with satellite data
3) Absolute photometric calibration of nighttime images of the Earth from the International Space Station (ISS/D3S)
4) The cataloguing and georeferencing of the ISS image archive
3.1.1. IMAGES FROM SPACE

Night images of Madrid from the space
### 3.1.1. IMAGES FROM SPACE

<table>
<thead>
<tr>
<th>Satellite/Camera /Band</th>
<th>DMSP/OLS</th>
<th>SNPP/VIIRS/DNB</th>
<th>ISS/D3S/RGB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main application</td>
<td>Meteorological</td>
<td>Earth observation</td>
<td>Outreach</td>
</tr>
<tr>
<td>Calibration</td>
<td>A posteriori</td>
<td>Lab and day side</td>
<td>This thesis</td>
</tr>
<tr>
<td>Bands</td>
<td>(1) 0.5 -0.9 μm</td>
<td>(1) 0.5 -0.9 μm</td>
<td>(3) 0.40-0.65 μm</td>
</tr>
<tr>
<td>Flybys</td>
<td>Sunset &amp; sunrise</td>
<td>Midnight</td>
<td>Any</td>
</tr>
<tr>
<td>Resolution</td>
<td>5 km</td>
<td>742 m</td>
<td>1.5-740 m</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>~0.5 nW/cm2/sr</td>
<td>~0.02 nW/cm2/sr</td>
<td>~0.08 nW/cm2/sr</td>
</tr>
<tr>
<td>Errors</td>
<td>No estimated</td>
<td>Estimated 15%</td>
<td>Estimated &gt; 15%</td>
</tr>
</tbody>
</table>
## MEASURE LIGHT POLLUTION FROM SATELLITE

<table>
<thead>
<tr>
<th>Spectro</th>
<th>ISS-D3S</th>
<th>VIIRS</th>
<th>DMSP</th>
<th>SQM</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>G</td>
<td>R</td>
<td>B/G</td>
</tr>
<tr>
<td>LPS</td>
<td>0.04</td>
<td>0.95</td>
<td>4.10</td>
<td>0.04</td>
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<tr>
<td>HPS-1</td>
<td>0.21</td>
<td>0.88</td>
<td>2.03</td>
<td>0.24</td>
</tr>
<tr>
<td>HPS-Cocheras</td>
<td>0.21</td>
<td>1.06</td>
<td>2.72</td>
<td>0.20</td>
</tr>
<tr>
<td>HPS-Maja</td>
<td>0.09</td>
<td>1.09</td>
<td>2.62</td>
<td>0.08</td>
</tr>
<tr>
<td>HPS-Calle</td>
<td>0.11</td>
<td>0.98</td>
<td>2.64</td>
<td>0.12</td>
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<tr>
<td>HPS-Cocheras2</td>
<td>0.23</td>
<td>0.84</td>
<td>2.16</td>
<td>0.27</td>
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<tr>
<td>MV vieja</td>
<td>0.34</td>
<td>0.88</td>
<td>1.09</td>
<td>0.38</td>
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<tr>
<td>MV</td>
<td>0.36</td>
<td><strong>1.58</strong></td>
<td>1.76</td>
<td>0.23</td>
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<tr>
<td>MV nueva</td>
<td>0.43</td>
<td>1.10</td>
<td>1.16</td>
<td>0.39</td>
</tr>
<tr>
<td>CFC</td>
<td>0.27</td>
<td><strong>1.33</strong></td>
<td>2.09</td>
<td>0.20</td>
</tr>
<tr>
<td>CMH</td>
<td>0.58</td>
<td><strong>1.48</strong></td>
<td>1.71</td>
<td>0.39</td>
</tr>
</tbody>
</table>

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3.1.1. IMAGES ISS/D3S

ISS026-E-026493

Nikon D3s
F/4 1/15s ISO 12800
Focal Length: 200 mm
2011:02:11 23:11:50
3.1.1. PHOTOMETRIC CALIBRATION OF IMAGES ISS/D3S

- DSLR camera operated by astronauts from the ISS
- Nikon D3S with CMOS sensor and Bayer matrix
- Three-band images (R, G, B)

RAW decoding $\rightarrow$ FITS

Sánchez de Miguel et al. (2012) SpS 17 XXVIII IAU –GA Beijing
3.1.1. PHOTOMETRIC CALIBRATION OF IMAGES ISS/D3S

Astrometry, detection and measurement of stars

TopCat + Aladin

IRAF (ccmap, cctsetwcs)

SExtractor

Flat field
3.1.1. PHOTOMETRIC CALIBRATION OF IMAGES ISS/D3S
3.1.1. PHOTOMETRIC CALIBRATION OF IMAGES ISS/D3S

- Extinction and tilt

- Linearity

- Noise

- Window transmission
The proper calibration except for the windows transmission problem
It does not affect the spectrum / color
3.1.1. CALIBRATION TEST
ISS/D3S       VIIRS/DNB

La Palma island

Madrid

The proper calibration except for the windows transmission problem
It does not affect the spectrum / color
3.1.1 EMITTING SOURCES ISS/D3S

Color - color diagram of the luminaries of Madrid
3.1.1 EMITTING SOURCES ISS/D3S

Color - color diagram of the luminaries of Madrid

Color distribution

- MV
- MH
- HPS

5km
3.1.1 VARIATION IN RADIANCE AND TYPE OF LIGHTING

Switching to LED lighting on Rivas 2014

Detectable spectral variation
Variation in radiance ~ 21%

Radiance (nW/cm²/sr)
How to use this to protect an observatory?

- Guess spectra through synthetic colors
- Better identification of the sources
- Temporal and angular resolution
3.1.1 EMITTING SOURCES  ISS/D3S

Island of La Palma
3.1.2 SKY SPECTRUM AND LAMPS
We can create synthetic light pollution spectras before to approve light installations.
One Earth at Night, under One Sky

On this website you can find a gallery of cities over the world at night. This gallery has been compiled to show how much we have changed the ecosystem of the night and also how humanity looks from Space.

- Check the gallery
- Help to classify images here!
- FAQ
- Our maps

Citizen science program

Categories
Positions
Maps

136778 tasks
16965 volunteers have contributed
136743 tasks done
35 pending tasks

99% completado
First step to build a color map of light pollution globally

- IDA Dark Sky defender award 2014
- Science x Kickstarter Hackathon selected project
3.3 SKY BRIGHTNESS AND RADIANCES FROM SATELLITES

DMSP/OLS

Diffuse light

VIIRS/DNB

ISS/D3S/G
3.3 COMPARISON OF MAPS SKY BRIGHTNESS
3.3 COMPARISON OF MAPS SKY BRIGHTNESS

Control of the sky glow growth

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4. WORK IN PROGRESS

- Implement measures to new models (Aubé and Falchi)

- ISS application for specific pictures of observatories (U.S. researchers are welcome)

- Improvement of the light pollution spectra based on image classification

- Get funds to keep alive this research
5. CONCLUSIONS

• The Earth observation satellites don’t provide data to make an spectral protection of the observatories

• None of the first class observatories is completely safe against light pollution.

• Only the ISS pictures can now give an spectral information/protection