Global monitoring of light pollution and night sky brightness from satellite measurements

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Abstract: We summarize the situation of the project for the global monitoring of light pollution, night sky brightness and stellar visibility that we carry on based on DMSP satellite data.

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1. INTRODUCTION

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Our research work on "Global monitoring of light pollution and night sky brightness from satellite measurements" has a number of different applications on light pollution, remote sensing and aerosol physics:

1) Light Pollution
   a) Informations on processes and polluting sources
   b) Maps of the upward light emission and its growth (geographical distribution of sources, energy saving, evolution)
   c) Maps of the artificial night sky brightness (site testing and land monitoring (astronomy), index of environmental impact of artificial lighting (ecology and environmental sciences))

d) Maps of the loss of limiting magnitude and stellar visibility (impact of artificial lighting (human sciences and governments))
e) Other environmental impacts of light pollution (natural sciences)

2) Remote sensing
Validation and calibration of OLS-DMSP radiance data

3) Aerosol physics
a) Vertical extinction
b) geographical distribution of aerosols
c) Light scattering and stellar extinction
d) Constraint and testing of models of 3D aerosol distribution
e) validation of other data sources

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The main project is divided in many projects carried on at ISTIL or University of Padova and funded by different sources:
a) Second world atlas of the artificial night sky brightness and stellar visibility from satellite data (ISTIL)
b) Mapping night sky brightness on the entire sky of astronomical sites (or any other site of the world) from satellite data (Università di Padova)
c) Study of the upward emission from Earth cities
d) Growth of light pollution and its effects on the night sky
e) Earth-based measurement campaigns (three campaigns are carried on by ISTIL, University of Padova and IDA)

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Funding and collaborations:

a) Italian Space Agency (Contract: Global monitoring of light pollution and night sky brightness from satellite measurements)
b) University of Padua, Department of Astronomy (Young Researcher's Project: Light pollution and the protection of astronomical sites)
c) International Dark-Sky Association, Tucson (two grants)
d) Astronomical Observatories (NOAA/CTIO, VAT, Lowell, IAC/OTPC, etc.)
e) National and regional agencies for environmental protection

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Funding has been precious to support our studies. In particular, it allowed me to set-up the Laboratory of Photometry and Radiometry of Light Pollution (LPLAB). It provides the Light Pollution Science and Technology Institute (ISTIL) of instruments and calibration services to support the scientific and technological research on light pollution and related

environmental effects (luminancemeters, spectrophotometers, automatic night sky photometers, reflectance meters, calibration systems, etc.).

Started in late 2001, it is probably the first laboratory born specifically and exclusively to study light pollution. The laboratory equipments are characterized by low light intensity measurement and calibration capabilities and by the portability typically required by on-site measurements. Some of them have been set up for the specific needs of this field of study. Photometric and radiometric calibration services are provided by the laboratory to ensure that instruments are accurate and NIST traceable. More informations at www.lplab.it

2. DESCRIPTION

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The first step of the work is the reduction of OLS/DMSP radiance data and their analysis that we want improve in respect to the first world atlas. This allow a first set of result like maps of upward light flux, map of the growth of the upward light flux, statistical studies of the characteristics of the sources.

The second step is the modelling of the light pollution propagation accounting for Rayleigh and Mie scattering, Earth curvature, elevation and mountain screening. This provide a second set of results like maps of the artificial night sky brightness at sea level or with elevation, maps of stellar visibility and magnitude loss, maps of other kind of impact due to light pollution, statistical correlations with population distribution.

Third step is the comparison with Earth-based measurements, which allows a feedback to improve the modelling technique, assumptions, and atmospheric models. However they also provide information on the atmospheric aerosol content, both directly from the extinction measurements and from the fit of the measured brightness with the predicted one.

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What is the difference of this work with the first world atlas of night sky brightness that we already made?

We want not only to re-run a second atlas with new data but also to improve the method. The difficulty is the second one, otherwise a second atlas would be obtained rapidly. In particular, we want:

a) More accurate informations on upward light emission
b) To account for the shape of the upward emission when mapping night sky brightness and stellar visibility

c) Better account for differences in aerosol content
d) Faster code to account globally for elevation / screening
e) Accurate measurements of both brightness and aerosol content for checking the results more accurately

We postponed improvements of Garstang models. In facts:
a) Measurements are not sufficiently accurate to require and support more accurate modelling (and to evaluate if the improvement really improved the accuracy of predictions).
b) Accurate global maps of aerosol content are still unavailable. Any improvement on scattering is not useful if there is a large uncertainty on aerosol content.
c) Model improvements increase the computational time whereas we need a faster code for global mapping. Minor improvements on the accuracy of predictions sometime requires unpleasant assumptions on essential arguments in order to maintain a reasonable computational-time so "the game do not worth the candle".

3. EXAMPLES OF RESULTS

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An example from our already published work on the mapping of light pollution: the first world atlas of the night sky brightness (Cinzano et al. 2001).

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Sea level night sky brightness in Australia in clean nights. DMSP dataset was taken in 1996-97 but maps have been calibrated for 1998-99.

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Average radiance measured by OLS-DMSP in 1996-97 over South-East of Australia with Sidney. At lower left an enlargement of Sidney.

Note that this is not a map of upward flux but only the radiance seen by the satellite. We plan, using many orbits, to be able to evaluate the emission at various angles and to obtain the flux as a true integral. This is easier to say than to do, however, and we are still working on it.

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Sea level night sky brightness in South-East of Australia in clean nights. At lower left an enlargement of Sidney. DMSP dataset was taken in 1996-97 but maps have been calibrated for 1998-99.

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A map of the entire sky of an individual site. The figure shows preliminary results for Mount Graham in 1996-97 (right) compared with an image published in their web site (left). Milky way has been cut away. The image was not taken exactly at the site where the map was done, in fact at the horizon of the map are visible the two mountain heights (bottom and upper right).

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An example to show why we would like to account for upward light emission function of areas: the figure at bottom right shows that the upward emission of a road lighting installation is not Lambertian at all. The shape of the average function of an area is the sum of the functions of its lighting installations and likely it is not always the same inside a territory.

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The simple maps of this figure are obtained rescaling a map made for 1997 based on an average growth curve of light pollution. It is only a rough approximation, however it is in good agreement with the data published both by Walker and Berry. Our aim is to obtain much more accurate maps of this growth. Only an accurate study of the light emission allows to make a map of upward light flux from which to obtain an accurate map of the growth of night sky brightness.

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An increase of aerosol content decreases the night sky brightness across a territory due to the increased extinction, except near the sources where the extinction is small. This means that the aerosol content over the area must be known when night sky brightness measurement are made in order that they could be compared with maps. The measure of the stellar extinction is a way to easy obtain information on aerosol content and should be associated to any measurement of night sky brightness.

4. PROBLEMS AND CONCLUSIONS

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We suffer a number of problems. The two main ones are:

1. Funding

   a) ASI support expires next week. Money already “expired” months ago so that I was forced to provide 8000 euro by myself. Due to the new way in Italian politics on research funding, ASI will not renew contracts.

b) My Young Researcher Project at the University of Padova expires next January and I cannot apply a second time.
c) No other funding sources have been recognized. After January, the expenses for the research work likely will have to be supported by Dr. Cinzano, as before…

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2. So far we suffered any kind of delay:

a) Delay in delivery of DMSP data by NGDC. They were expected in 1999.
b) Delay due to problems in DMSP data calibration, set-up of instruments (including filters evaluation), LPLAB calibration systems, etc.
c) Delay in monitoring campaigns due to Fabio's CCD default, contract managements, etc.
d) Many time-expensive contributes required by the strong activity against light pollution in Italy
e) Other time-expensive activities like book publishing, public outreach, education, etc.

So that, in conclusion, we cannot at the moment present a schedule of the work. However I am working full-time on light pollution and I hope to obtain results as soon as possible.

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For interested peoples, the Proceedings of the Venice Conference published by ISTIL are available on-line at www.lightpollution.it/istil/venice/
Other publications are available at http://dipastro.pd.astro.it/cinzano

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