Comments of P. Cinzano on the “cavities” of P. Soardo v.2.0

Paolo Soardo wrote:<<In general, as far as interference with sky observation is concerned, public lighting luminaires in a town far from an observatory can not be seen as single isolated luminous sources at the observatory. Actually, luminaires are imbedded in cavities, composed by buildings and streets: such cavities emit light upwards mainly because the luminous flux is reflected by buildings and streets.

Thus, all public lighting installations in a town can be dealt with as a unique lighting source with a luminous flux equal to the sum of the luminous fluxes both emitted upwards by all luminaires and reflected by all lighted surfaces. The luminous intensity distribution of a source composed by luminous cavities is lambertian, i.e. diffusing, independently of the types of luminaires, of their luminous intensity distribution and of the photometric characteristics of lighted surfaces, both buildings and streets. This lambertian property is confirmed by the visual observation of a town by night through the windows of an aircraft: no appreciable change of brightness can be perceived while flying over the town, a typical characteristic of a diffusing luminous source. Thus, the luminous intensity distribution of the light emitted upwards by an urban area follows the cosine law (fig. 1), is independent of the luminous intensity distribution of each luminaire and can be characterised through a single parameter, the “average ratio of upwards emission”>>

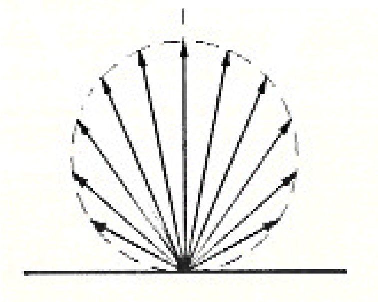

Fig. 1
A lambertian intensity distribution (cosine law).

This do not agree with experience for some reasons:

1) An effective screening of light emitted by fixtures can be obtained mainly perpendicularly the road, if the houses facing it are sufficiently high without front-gardens or parking (a screening at 20 degrees of a fixture 10 meters over the road requires e.g. a screen 20 meters high at 25 meters of distance –a building with 6 floors -, 46 meters high at 100 meters of distance and so on).
In case of a square the screening angle is small in many directions and along the road axis the screening is small too. A large street or an avenue are poorly screened. Lighting towers can be sufficiently high to be completely unscreened in cities where palaces are not very high or cross-roads are quite large and open. Between an house and another in many cases there are spaces where the light can spill consistently.
So an efficient screening can be obtained – if any – only for the very inner centre of cities having narrow streets with reasonably high palaces. Probably it could work reasonably well for Manhattan or Venice’s “Calli”. In the rest of the city, where the horizon is more open, the screening is very small or negligible at all, like the photos of urbanized areas show well (see e.g. the cover photo of the poster of the “Light pollution” Symposium of Athens, 7-9 May 1999 or the fig. 3 below). The same happen for suburban areas which in diffusely populated territories are a primary source of pollution (let’s think to the Padana

Plane in Italy which is an almost continuum sea of light). The reduction near zero of the upward emission by fixtures at low elevation angles requires the use of full-cut-off lighting installations. No way to avoid it.

2) A lambertian global emission by cities is not supported by available data. We can obtain information on the typical or average upward emission function of cities in many ways:

a) Measuring it with satellites. Results shows that the average emission of a large number of European cities increase going from zenith to the horizon, exactly the contrary than a Lambert law (Cinzano et al. 2000, MNRAS, 318, 641-657). See e.g. fig 2. This was confirmed from other measurements taken for cities in the United States.

b) The sky brightness at different distances from a city in a clear night is given by a set of well known laws based on measurements, the Walker Law, the Treanor law, the Berry law, the Garstang law, which differs only in small details. Given that the physics of the propagation of the light in the atmosphere is well known, the shape of these propagation laws is strictly related to the upward emission function (intensity) of the city. A long list of results from Garstang shows that the upward emission function of cities increase when going from zenith to horizon, the contrary of what happen for lambertian emission.

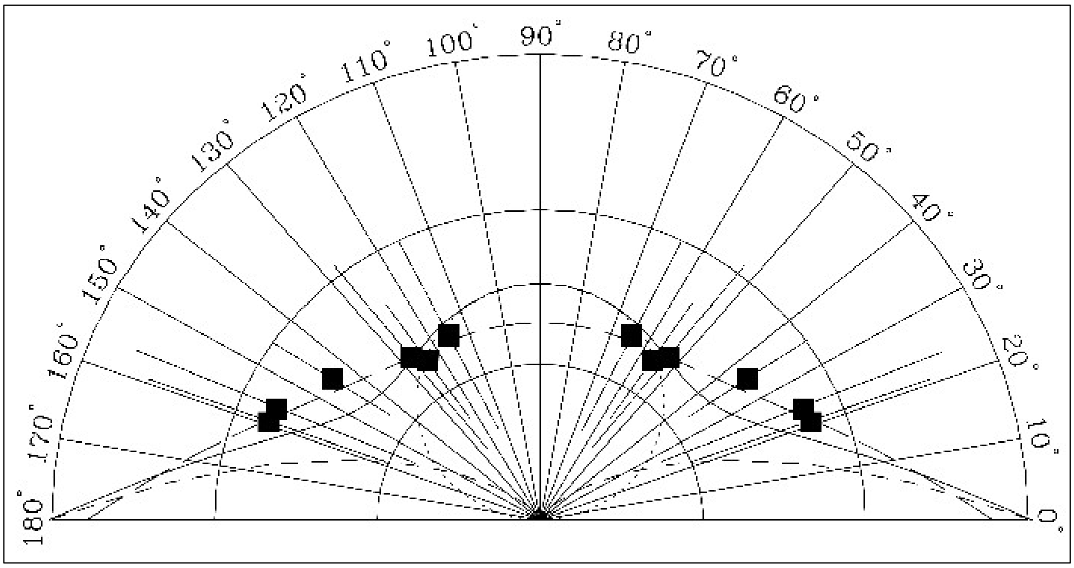

Fig. 2
Squares: Average upward emission function (intensity) measured by DMSP satellites.
Continuum line: The typical shape of the upward emission function (intensity) which allowed to Garstang the best fit to measurements of night sky brightness in many sites and to the Walker Law.

c) Direct observations are more difficult because they require to measure a large number of cities of many sizes in many directions and elevations in order to obtain a adequate statistic. However direct observations of large urbanized city areas (not only the inner city centres) shows that typically in the majority of cases where lighting is not full-cut-off, a sea of individual fixtures is visible. See e.g. fig.3.

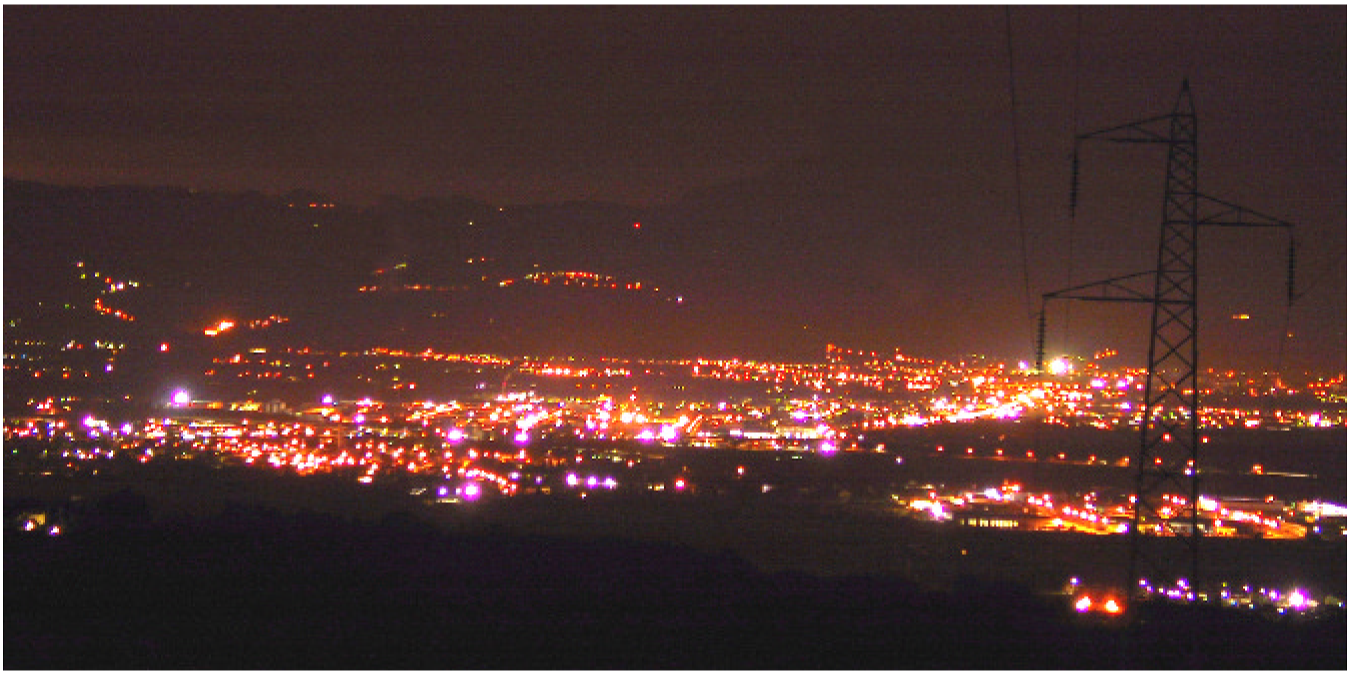

Fig.3
Nighttime panorama.
Note how the luminaries are more luminous than the road surface
(see e.g. the road at right)

3) Luminaires generally do not have a lambertian light distribution and, even applying a partial screening, the light distribution does not became lambertian. As an example we show in fig. 4 the (preliminary) upward emission functions obtained with the software Roadpollution for a road installation with ULOR_inst=2%. Figure 4 shows at left the function of the luminaries alone and at right the function including either the light emitted by the luminaries and reflected by the road and by the other surfaces.

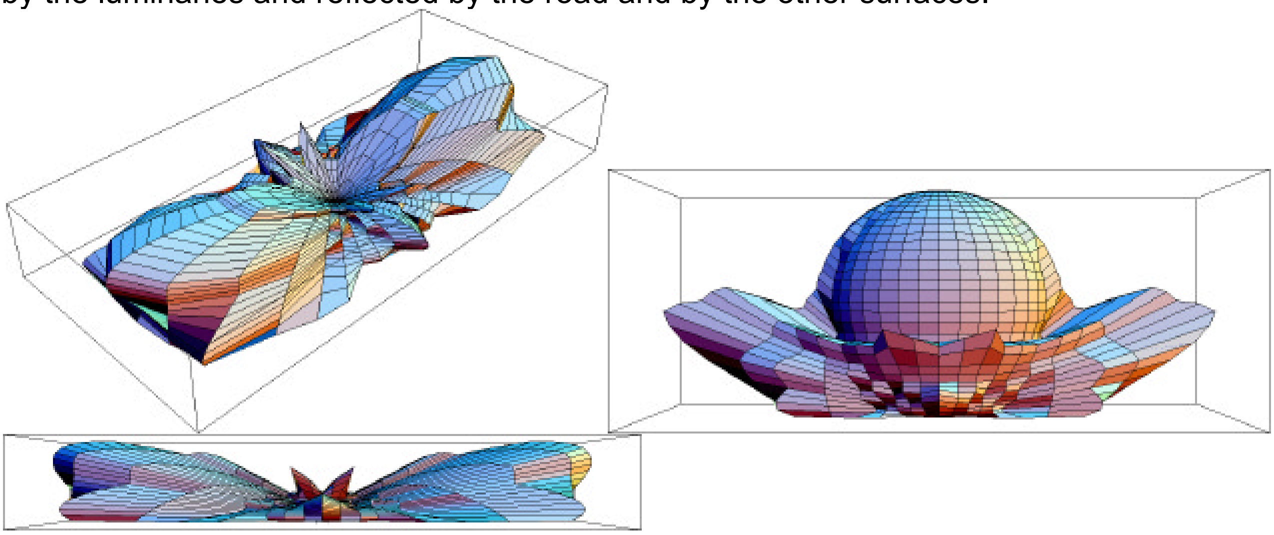

Fig. 4:
Upward emission functions of a road installation with ULOR_inst=2%