Comments by P. Cinzano on the paper:
ENERGY CONSERVATION AND LIMITATION OF LIGHT POLLUTION
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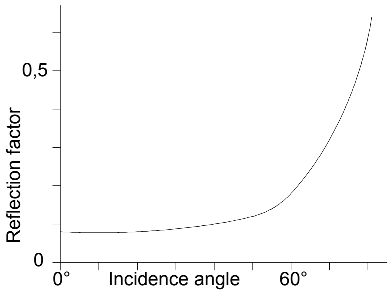
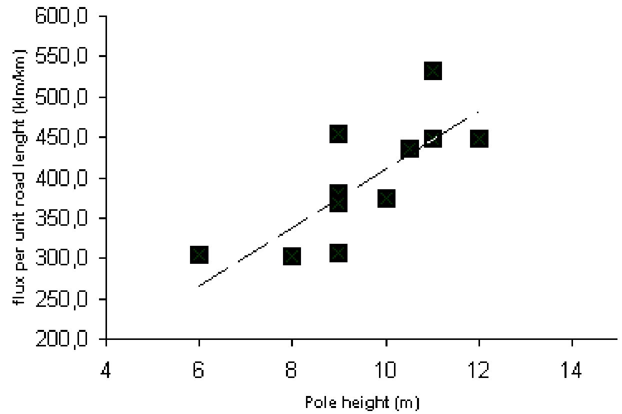
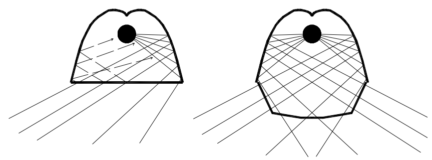
Section & par.	Text	Comments
ABSTRACT	The requests to limit light pollution for improving astronomical observations is often supported with expectations of large energy savings. Actually, the discussions within CIE and in the scientific community show the difficulties in complying with both objectives. The paper relates upward emission in public lighting with energy saving and reduction of star visibility and **shows that there is no advantage in reducing under a certain limit the spill light from the luminaires.** Keywords: road lighting, energy saving, light pollution	**The conclusions of the authors does not appears properly demonstrated and adequately supported**. Here I will present arguments leading to different conclusions. Here you will find two kind of comments: (1) Comments that invalidate the assumptions on which the paper and its conclusions are based; (2) comments that invalidate some results independently by the correctness of the assumptions and lead to different conclusions, (3) other comments judged interesting for the reader. The text of the paper is at left and commented sentences are in bold. Comments are at right and main comments are in bold too.
1. INTRODUCTION	Certainly public lighting impairs the visibility of stars, generating an artificial sky luminance, which reduces their contrast. **The increase of sky glow over the natural background is frequently associated, especially within some astronomical communities, only with the spill light emitted upward by the luminaires,**	Authors do not justify the word “frequently”. **The increase of sky glow over the natural background is commonly associated “*mainly*”, rather than “*only*”, with the spill light emitted upward by the luminaries. And this is correct, even if the authors ignore the reasons in this paper. This will lead them to some wrong conclusions in cap. 3 when evaluating the impact on the night sky of the considered kind of luminaries.** Here a short explanation of the reasons. Luminaries (in particular those with ULOR_inst<5% and prismatic glasses and curved glasses) emits their light at low elevations over the horizon. This light propagates more far from the sources and it is more addictive and, therefore, more effective in producing the zenith artificial night sky brightness on the territory. At 20 km from the sources (light pollution propagates even to 200 km) ~95% of the zenith artificial night

		sky brightness is due to light emitted between gamma=90° and gamma=135° and the main part is emitted at lower angles (see e.g. Cinzano and Diaz Castro 2000). Surfaces are almost Lambertian so that their intensity goes to zero for gamma approaching 90° and is maximum toward the zenith, so that their light is less propagating. Given the different light distributions of luminaries and surfaces, the light most effective in polluting the night sky comes ***mainly*** from luminaries (see later for a numerical evaluation). The reflected light become important for installations in which the spill light has been minimized (or where a lot of light is wasted outside the area to be lit).
	the spill light emitted upward by the luminaires, the so called "light pollution". From that the request to use only luminaires with zero upward emission, claiming further that in this way costs for installation and energy could be optimized.	I do not find "frequently" light pollution defined as "**spill light emitted upward by the luminaries"**. All the definition that I know refers to **either** the light emitted directly by the luminaries **and** the light reflected by surfaces. See as an example the Law of Lumbardy which says (rough translation)" *(To the aims of the present law) it is considered as light pollution of the atmosphere every artificial light irradiation that is dispersed outside the areas to which it is functionally dedicated and, in particular way, if oriented above the line of the horizon*". The light can be dispersed above the line of the horizon by the luminaire or by the surface.
	The increase of sky luminance is due also to the light reflected by the illuminated surfaces, **which makes useless, and even harmful, to reduce spill light under a certain limit**.**Given a value for road luminance, the "zero upward emission" option does not optimize the installed luminous flux, with an increase in installation costs, energy consumption and also sky luminance, i.e. the contrary of the claimed objectives.**	Curiously the authors draw theirs conclusions already in the Introduction where usually the purpose of the research is presented. **In any case their conclusions are based on a number of assumptions that does not appears to be true (as it will be shown). Our revision support different conclusions that are drawn in section 4**.

	Actually, CIE 126 [1] prescribes limits to spill light, without however associating them with the reduction of sky luminance and with installation and energy costs. The paper describes the factors which influence this problem and reports about measurements, surveys and researches recently carried out, which demonstrate that some spill light directly emitted upwards by the luminaires can optimize all objectives.	
2. ENERGY SAVING 2.1Road lighting	The objective of artificial lighting, particularly of public lighting, is to permit by night people to carry out their activities in safe conditions and to enjoy the environment. A side effect of exterior lighting is the increase of sky luminance, because of the luminous flux emitted by the luminaires and reflected by the illuminated surfaces: **while reflection is the objective of lighting**, it is worth verifying the effects of the direct upward emission.	**Not "*Reflection*" but "*Reflection from those surfaces that need to be lit and toward the observer*"** is the true objective of lighting. **This difference is important in defining the approach to the problem**. *Reflection from those surfaces that need to be lit* constitute a source of light pollution which cannot be eliminated but only controlled avoiding over-lighting. But, on the contrary, *reflection by those surfaces which there is no need to lit* constitutes an unnecessary source of light pollution and **must be minimized avoiding as possible to waste light outside the requested surfaces**.
	Some surveys in Italy show that road lighting involves 65-70% of the luminous flux generated in a town for public lighting, the remaining part being associated with large areas, industrial and commercial, and with entertainment and monument lighting. This is why attention is here paid to road lighting and particularly to lamps and luminaires which can assure the best conditions for optimizing energy consumption.	
2.2 Zero upward emission	**Only luminaires equipped with flat windows and installed horizontally can be classified as "zero upward emission",**	**This basic assumption of the authors is not true. This is the first point leading the authors to wrong conclusions. Here below two example of curved and prismatic glasses which are fully shielded over the horizon (ULOR_inst=0)**. The fixture in fig. A are limit cases but effective, more compact and nice fixtures can be made using low-curvature glasses, both transparent or prismatic.

		 Figure A: Fully shielded fixtures with prismatic glasses (semi-cut-off light distribution) **This already invalidate the conclusions of the chapter 2 about the necessity of a 3% of upward flux to optimize lighting**. However comments below do not support even the claimed superiority of the light distribution of prismatic glasses vs. flat glasses.
	even if it is difficult, if not impossible, to certify such feature: actually, the light diffused by the walls of the laboratory is measured by the photometric detector of a goniophotometer and **it is very difficult to subtract this light**. However, since all the other types of window, particularly the bowl ones, diffuse some light upward, apparently the flat windows should always be beneficial.	We are happy to see that many examples of laboratories that certify this feature without problems, attenuated Paolo Soardo's claims on the impossibility to certify it and changed them to "it is difficult". Javier Diaz Castro (OTPC) explained at the Athens TC 4-21 meeting how the light diffused by the walls of the laboratory is subtracted in their laboratories.
2.3 Reflections in luminaires	It is well known that the optimization of energy consumption requires to install luminaires with high luminous intensities at almost grazing incidence, up to an angle γ equal to 70-75° from the vertical, where the road surfaces show some regular reflection. Unfortunately, at such incidence the two interfaces of a flat window, figure 1, reflect up to 45% of the light back into the luminaires, figure 2, because of the different refraction indexes of the air and of the window, just like a panorama is reflected on the surface of a mountain lake. **This effect, which can not be avoided, reduces the efficiency of the luminaires** and overheats the lamps, with a consequent reduction of their life and an increase in maintenance costs.	When dealing with energy saving, the interest is not for the efficiency of the luminaires but for their downward flux factor DFF or, much better, for the used flux factor (utilance) of the installation or, still better, for the installed flux per unit road length. Even if the efficiency of prismatic fixtures can in some cases be greater than the efficiency of flat glass fixtures, when subtracting the light wasted upward, the fraction of flux sent downward (downward flux factor) is not much greater. When considering only the used flux factor (i.e. the fraction of flux emitted by the luminaire actually going on the road also called

	life and an increase in maintenance costs.  **Figure 1** Reflection factor of a flat window (both interfaces) versus incidence angle	utilance) the difference is still smaller and, not rarely, in favour of flat-glass fixtures. Incidentally, note that rays are emitted at many different angles by the lamp and the reflector, and they strike the glass in many different positions (see fig.2). Therefore whatever the shape of the glass, some rays would have a wrong incidence. Given that it is not possible to have incidence angles equal to zero for all rays, the requirement is only to reduce incidence angles larger than 60° to ~60°. So this argument is in favour of fully shielded low-curvature transparent glass fixtures rather than in favour of common curved glasses or prismatic glasses as the authors seems to believe.
	In order to avoid these inconveniences, **the manufacturers reduce the lighting angles of flat window luminaires. The lit surface on the road is in this way smaller than with bowl luminaires, or, in other words, a road lighting installation needs more flat window luminaires than bowl ones, with a consequent increase of costs for installation and energy**	**Costs for energy** For fixtures with quality optic, the installed flux per unit road length (i.e. the energy consumption) depends more on the capability of the optic to send most of the light inside the road surface minimizing the light wasted outside of the road (depending on the light distribution transversal to the road axis), rather than on the differences on the throw between flat-glass fixtures, curved glass fixtures and prismatic glass fixtures (depending on the light distribution along the road axis). This capability appears depending on the design of the individual fixture rather than on the kind of glass. Moreover **sometime pole spacing and installed flux per unit length act in opposite sense. In order to send a larger fraction of light on the road could be better to use lower pole height and this diminishes the pole spacing**. However the costs for the larger number of luminaires can be amortized by the smaller energy consumption. **The figure B below shows as an example** the trend between installed flux per unit road length and the pole height in a sample of 12 typical road lighting projects with prismatic glass fixtures obtained from an example-book.

		 Figure B: Installed flux per unit road length and pole height in 12 typical road installations See also Cinzano (2002) for some examples.
	and also of the luminous flux which is reflected by the road surface.  **Figure 2** Light transmission and reflection (dashed) in flat and bowl window luminaries	**Luminous flux reflected by the road** For constant luminance, the luminous flux reflected by the road depends on the average luminance coefficient of the installation which does not depends only on the throw but also on the light distribution transversal to the road axis and on the pole height. It appears depending more on the installation design than on the light distribution or on kind of glass of the fixture. A comparison of 5 installations with prismatic glass luminaries, convex transparent glass luminaries and flat glass luminaries showed that, depending on the design, an installation with flat glass luminaries could reflect even less light than the other installations (Cinzano 2002).
2.4 Spill light and energy consumption	The literature reports about **measurements and evaluations which relate the power consumption of a lighting installation with the percentage of the luminous flux directly emitted upward by the luminaires** (the so called spill	**This is the second point addressing the authors to wrong conclusions.** The cited literature mainly reports measurements and evaluations of power consumption limited to some kind of flat glass luminaries and unshielded curved or prismatic glass

	light), which is identified through the ULORinst of CIE publication 126 (the Upward Light Output Ratio in the conditions of installation), equal to the ratio between the luminous flux emitted upward and the luminous flux totally emitted by the luminaire). The power consumption is further related to the luminous flux both emitted by the luminaires and reflected by the road surface, i.e. the total upward emission.	luminaries, so that **the sample in uncomplete toward the smaller power consumptions and the smaller upward fluxes**. See the examples in our comments below.
	Some of these data are reported graphically in figure 3: all of them refer to high pressure tubular sodium lamps and **were recalculated supposing an average reflection factor of 0,12 for road and off-road surfaces.** Most authors refer to the different types of windows which equip road lighting luminaires: flat window, curved glass, deep bowl, prismatic bowls. There are some differences in the reported values of the ULORinst for the different types of windows, but they do not lead to any contradiction, at least as far as the objectives of this paper are involved: thus, the values of ULORinst for a flat window are reported between 0 and 0,5% and for a prismatic bowl between 2,5% and 3,8%.	The reflection factor of 0.12 for road surfaces seems large for C2 standard surfaces that are recognized as the most used in countries like Italy. Gillet et al. (2002) measured a reflectance of about 0.07 for asphalt. If the reflectance factor is larger the upward light fluxes in figure 4 are overestimated.
	In figure 3 the increase of energy consumption is referred to the data on prismatic bowl luminaires with the value of the ULORinst reported by each author. The available data are not sufficient for evaluating a statistically significant fitting curve: however, the dashed line in figure 3 represents the trend of this relation. More data on this subject are expected. But figure 3 gives already a clear picture of the problem: **the reduction under about 3% of the ratio between the luminous flux emitted upward and the luminous flux globally emitted by the luminaire increases energy consumption, up to about 40% for flat window luminaries (ULORinst = 0).** This result is further confirmed by the brochures of the luminaire manufacturers.	**We added five points from Cinzano (2002) to the authors' fig. 3.** These data points refer to a prismatic glass installation, a convex transparent glass installation and three installations with the same flat-glass fixtures with different pole height. They have been computed for the same luminance, the same uniformities and the same road size. **The new figure 3 looks different.**

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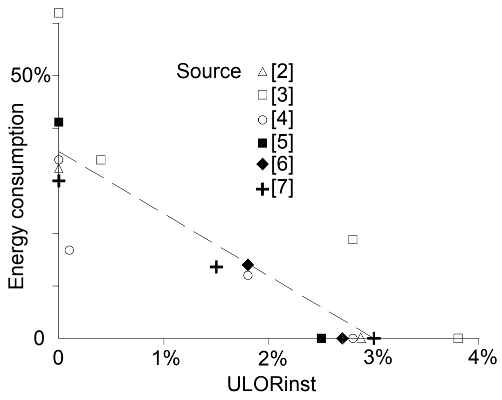

Figure 3 Increase in energy consumption versus ULORinst in road lighting.

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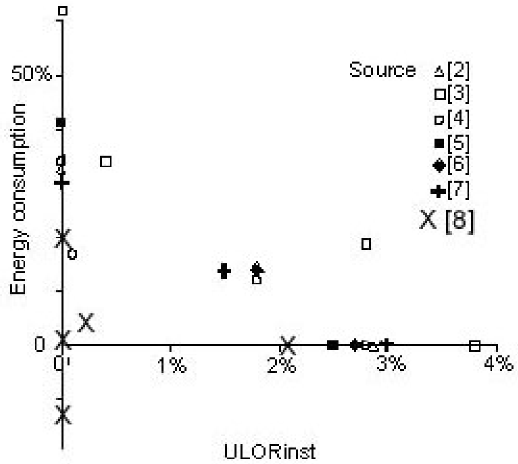

New fig.3. The figure shows that **there is a large scattering in energy consumption, particularly for ULOR_inst=0, confirming that it depends on the installation design and individual fixture optical design rather than on the ULOR_inst or the kind of glass.**

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Another interesting result which can be derived from the literature is the relation between ULORinst and the sum of the luminous fluxes emitted by the luminaires and reflected by the illuminated surfaces: in **figure 4** this sum has been reported in the same conditions described for figure 3, which makes the two figures compatible. Again, even if the dashed line of figure 4 is not a fitting curve and represent a trend, it shows however clearly that **the luminous flux globally addressed upward increases if the ULORinst decreases under 3%, up to about 20% for flat window luminaires with ULORinst = 0.**

From figures 3 and 4 it is evident that the flat window luminaires do not represent the best solution for road lighting for reducing either installation and energy cost and also sky luminance: with reference to prismatic bowl luminaries, costs actually increase by 30-40% and upward

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Looking at **figure 4** we noticed that:

(1) **the great scattering in data-points suggest that reflecting more or less light upward does not depend by the kind of glass or by the ULOR_inst but rather by the design of the installation**;

(2) **the strict resemblance between the disposition of data points in figure 3 and figure 4 suggest that there is a direct relationship between the energy consumption** (i.e. the installed flux per unit road length) **and the flux reflected by surfaces of each considered installation, i.e. that more consuming installations are the ones reflecting more light upward.**

Cinzano (2002) suggested that the fraction of light wasted outside the road surface could be the main design

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emission by 10-20%.

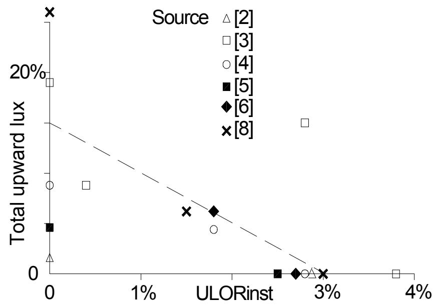

Figure 4 Increase in total upward luminous flux versus ULORinst in road lighting

parameter acting on both the total quantity of light reflected upward by the surfaces and the installed flux per unit road surface. Figures C and D here below support this hypothesis (Cinzano, priv. comm.).

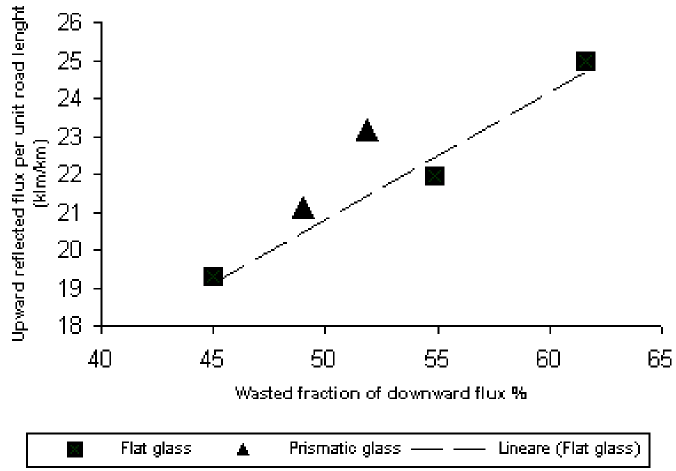

Fig. C

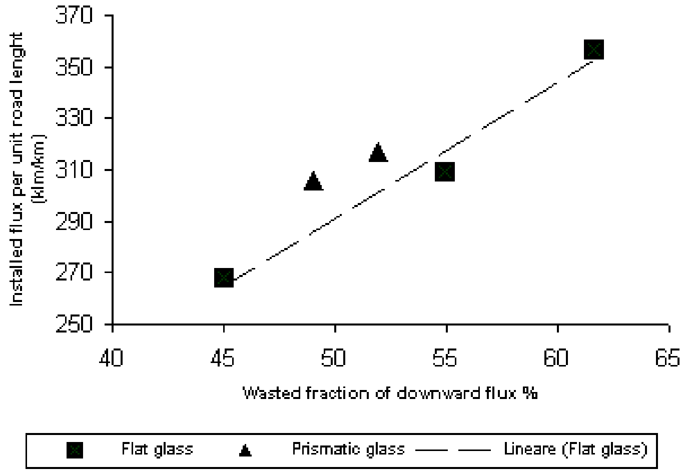

Fig. D

		The authors' figures 3 and 4 support the reasonable conclusion that when fully shielded fixtures are used, so that direct upward emission is nearly zero, both the more consuming installations and the more polluting ones are the ones wasting more light outside the road. Hence the conclusion is that the light wasted outside the road surface must be limited as much as possible with a careful design of the installations. **This papers suggest implicitly to the TC 4-21 and to legislators to add specific limits to the light flux wasted outside of the road surfaces.** Note that the five installations in Cinzano (2002) **does not shows any trend of increase of the upward light flux due to road reflection going from flat glass to prismatic glass**, nor in the upward light flux due to reflection by surfaces outside of the road. However both the greater and the smaller upward light flux due to reflection have been obtained for a flat-glass installations, again demonstrating that it depends on the design of the installation rather than on the kind of glass. In their considerations the authors mistake again the upward light flux with the sky luminance which is an effect of it depending not only on the quantity of upward light but also on the direction of its emission.
3. ROAD LIGHTING AND ASTRONOMY 3.1 Artificial sky luminance	External lighting, particularly road lighting, generates an artificial sky luminance through the scattering in the atmosphere of the light either directly emitted upwards by the luminaires and reflected by the illuminated surfaces. A recent survey based on satellite measurements mapped the upward light over the inhabited areas [9], but it was of course impossible to distinguish emissions from reflections.	
	Attention of lighting designers is called every day on the reduction of the luminous flux emitted upward **stating that presently a lot of light would be wasted because of spill light**. According to figures 3 and 4 **such statement is not correct**, but for a complete response one must evaluate the	The statement *is* correct: actually a lot of light is *wasted because of spill light*. Let's think simply to globes, lanterns, inclined prismatic bowls, projectors… Even when only fixtures with smaller ULOR_inst are considered, again, the statement that *a lot of light would be*

	correct, but for a complete response one must evaluate the effects of all parameters involved in this picture, separating the contribution to sky luminance of the spill light and of the unavoidable reflections form the illuminated surfaces.	*wasted* due to spill light is correct considering the great quantity of light spilled downward but outside the road surface (a simple check of some lighting designs can show that even 50% of downward flux is spilled outside the surface to be lit). This light must be minimized. A lot of light is wasted because of the lighting designs and lighting habits which do not take care of energy saving as much as requested. However the common statement it is **not** that *"a lot of light would be wasted because of spill light"* **but** that "*a lot of light pollution will be produced because of spill light*". The authors correctly say that the sky luminance must be evaluated separating the contributions by direct and reflected light but they do not take into account the proper mechanism through which they produces the sky luminance (summarized in our comment to the Introduction).
	A recent model described the public lighting installations of a town as a single diffusing source [10]. **This model assumes that most luminaires are imbedded into partially opened cavities, whose walls are roads and buildings. The number of such cavities being rather large, the few lighting installations which do not behave in this way (large pedestrian areas, monument lighting, etc.) have a small influence on the emission diagram of a town, that can thus be considered like a diffusing source.**	**This is the third point addressing the authors to wrong conclusions. The theory of cavities is not supported by experience and the emission diagram of urbanized areas does not follow in general a Lambertian law** (cosine law). See the attached document which resume the main critics. The use of this assumption when evaluating the alterations to the night sky brightness produced by the upward light emission lead to wrong results. **This already invalidate the conclusions of the chapter 3 about the produced sky luminance**. Accounting for low angle emissions and scattering processes results became very different as it will be shown. See also the additional comments below.
3.2 Luminaires and star visibility	Stars are classified according to their magnitude, a quantity which is basically the logarithm of the ratio of the illuminances generated on the eye by a star and by a reference star: fainter stars have higher magnitudes. The light emitted upward by the lighting installations is scattered by the atmosphere because of different effects, including atmospheric pollution, and increases sky luminance [1], reducing the contrast of the stars on the sky	

	background: it follows immediately that the visibility threshold magnitude of the stars is reduced, i.e. many stars are no longer visible.	
	Through the said model the reduction of threshold magnitude due to the luminous flux emitted upward by all luminaires in a town can be separated from the contribution of the flux reflected by lit surfaces. **For such town the luminous intensity distribution follows the cosine law and the total upward emission can be characterized through the "average ratio of upwards emission"** R_n, i.e. the ratio between the sum of the luminous fluxes Φ_{iU} emitted upward by the i^{th} luminaire extended to the n luminaires of a town and the sum of the total luminous fluxes Φ_{iT}: $$R_n = \sum_n \Phi_{iU} \Big/ \sum_n \Phi_{iT} \qquad (1)$$	As the attached document shows, the luminous intensity distribution of a town generally does not follows the cosine law at all. So this assumption lead the authors in this section to wrong conclusions about the artificial night sky brightness produced by the considered luminaires. **However, even assuming a screening effect by "cavities", the light distribution of the luminaries considered in this paper does not resemble the light distribution of a Lambertian horizontal surface at all. So, even in this case, the effect of the upward light cannot be correctly evaluated if the direction of emission is neglected** and if only an integrate quantity like the average ratio of upwards emission R_n. is taken into account. The model proposed by the authors could work only when lighting is made exclusively by fully shielded fixtures so that the direct upward flux by luminaries is zero…  Left: Light distribution of a Lambertian horizontal surface (cosine law); Right: Emission of a prismatic glass fixture

In these conditions, the decrease in threshold magnitude ΔM due to the sole spill light is limited between the two functions (2) and (3), which depend on R_n and on the average reflection factor ρ of the lit surfaces:

$$\Delta M = 2,5 \log (1 - R_n) \qquad (2)$$

$$\Delta M = - 2,5 \log [1 + R_n / (r \ (1 - R_n))] \qquad (3)$$

R_n is equivalent to ULORinst of CIE 126 averaged over the whole town. Its values are thus lower than the ones in the four CIE zones: the Italian norm UNI 10819, which complies with CIE 126, prescribes R_n equal to 1%, 5% and 10% in its zones 1, 2 and 3, equivalent to CIE zones E2, E3 and E4.

Equations (2) and (3) are shown in figure 5: ?M is reported versus R_n for ρ = 0,12, i.e. the same reflection factor of figures 3 and 4. The advantage of flat windows with R_n = 0, figure 5, against refractor bowls ($R_n \cong 3\%$) is only $0,03 \le \Delta M \le 0,25$ magnitudes. But this small advantage disappears taking account of the higher installed flux for flat window luminaires, according to figure 4.

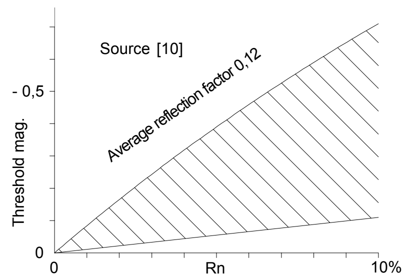

Figure 5 Threshold magnitude versus R_n

Figure 5

Eq. 3 express the logarithm of the ratio between the total upward flux and the upward reflected flux by surfaces:

$$\Delta M = -2,5 \log\left(\frac{1}{1 + R_n / (r \ (1 - R_n))}\right) = -2,5 \log\left(\frac{\Phi_{Upward,total}}{\Phi_{Upward,reflected}}\right)$$

so in the adopted model eq.3 indicates the reduction of the so-called "threshold magnitude" due to the addition of the direct flux by luminaries to the flux produced by surfaces. But it is unclear what exactly means eq. 2:

$$\Delta M = 2,5 \log (1 - R_n) = -2,5 \log\left(\frac{1}{1 - R_n}\right) = -2,5 \log\left(\frac{\Phi_{Total}}{\Phi_{Downward}}\right)$$

Eq. 2 appears the limit of eq.3 for a reflectance ?=1.
So its use in fig 5 is not understandable.

We would expect in fig. 5 that the upper and lower curves defining the limits of the threshold magnitude be given both by eq. 3 with respectively the minimum and the maximum average reflectivity found in cities and countries. As an example we would expect ρ_min=0.07 and ρ_max =0.12 or few more. In this case the figure became (roughly drawn):

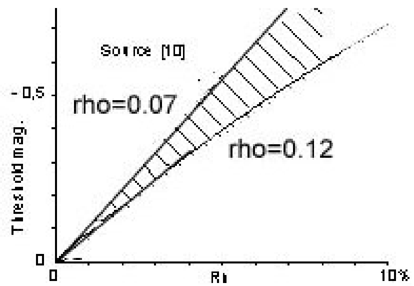

Figure 5 bis - Increase of threshold magnitude versus R_n for an imaginary town lighted with imaginary luminaires with

		an upward emission following the Lambert (cosine) law. The sentence commenting the figure now became: "The advantage of flat windows with $R_n = 0$, figure 5, against imaginary lambertian bowls with $R_n \cong 3\%$ is $0,25 \leq \Delta M \leq 0,3$ magnitudes, which means a 30% decrease of the artificial night sky brightness. Note that the number of visible stars doubles approximately every 0.6 magnitudes. **As an example, a detailed study taking into account the light distribution of luminaire and surfaces (Cinzano 2002) shows that a prismatic glass fixtures with ULOR_inst=2% produces an increase of 200% of the scattered flux due to emission at low elevations over the horizon (where light pollution propagation and addition is more effective) in respect to the flux produced by the road surface alone** (ρ=0.07)**.** The flux reflected by the surfaces outside of the road can be limited under the road value with an accurate design of the installation. Note that the authors evaluated the ratio between directly emitted upward flux and reflected upward flux (an effect of the approach taken by the authors in section 2.1) whereas it must be evaluated the ratio between necessary and not necessary light. This means that both the direct upward light by luminaries and the reflected light by surfaces outside of the road must be minimized in respect to the necessary light emitted by the road surface.
4. CONCLUSIONS	To reduce the luminous flux emitted upward under about 3% of the flux of a luminaire does not pay: **costs, for both installation and energy, increase and so does also the luminous flux reflected by lit surfaces.**	The conclusions of the authors in left panel are not proved by this paper, as the discussion above showed. The conclusions obtained from the above discussion are: **(1)** There is no necessity of a 3% of upward flux to optimize lighting and sky luminance; **(2)** "Zero upward emission" optics minimize zenith night sky brightness in a large territory around the sources if the installation design is properly made;

		(3) "Zero upward emission" optics allows to optimise the installed light flux per unit road length if the installation design is properly made and quality fixtures are used; Large differences in energy consumption for installations with ULOR_inst=0 suggest that an accurate lighting design is more important than differences on the kind of glass or ULOR_inst when quality fixtures are used; **(4)** The reflected light become particularly important for installations in which the direct upward light has been minimized; **(5)** Reflection by those surfaces which there is no need to lit constitutes an unnecessary source of light pollution and must be minimized, avoiding as possible to waste light outside the requested surfaces. **(6)** Light wasted outside the road surface could be the main design parameter acting on both the total quantity of light reflected upward by the surfaces and the installed flux per unit road surface; **(7)** Pole spacing and installed flux per unit length sometime act in opposite sense. In order to send a larger fraction of light on the road could be better to use lower pole height even if this diminishes the pole spacing. Less energy could require more luminaries. **(8)** TC4-21 should consider the possibility to add in the draft 5 some limits to the downward wasted light. **(9)** The effect of the upward light on the sky luminance cannot be correctly evaluated if the direction of light emission is neglected;
	The best solution for road lighting appears to be the prismatic bowl luminaire, which optimizes energy saving and light pollution, even if immediately close to an observatory direct emitted light could disturb more than reflections.	The discussion above showed that unshielded prismatic glasses do not optimise light pollution and do not seems to optimise energy saving more than other kind of fixtures. It is unclear why direct upward emission by luminaries would not have any effects on the night sky and on the contrary it "could disturb more than reflections immediately close to

		astronomical observatories".
	However, **star visibility can be assured only avoiding any lighting, but this policy can be followed only in national parks.**	The conclusion "Star visibility can be assured only avoiding any lighting" is unclear because that star visibility depends on the "**quantity"** of artificial night sky brightness. Maybe authors mean "*Full star visibility* can be assured only avoiding any lighting". In this case, it would be necessary avoiding lighting in very large areas due to propagation of light pollution. **This imply that the national parks proposed by the authors must have radii of hundreds of kilometres, quite difficult to set up in most European countries.** **Authors implicitly conclude that the only way to limit the night sky brightness is to put limits to the installed light flux, i.e. to limit the nigh-time lighting. This approach necessarily lead to limit lighting by law. It could also stimulate a strong opposition against new lighting by environmentalists and a raising of complains each time that a new installation is announced.** This seems in contrast with the approach of CIE TC4-21 **to make any effort to limit as much as possible light pollution with effective measures avoiding to create a general opposition against light.**
REFERENCES	[1] CIE 126-1997 *Guidelines for minimizing sky glow* [2] CIE TC 5.12-1995 *Guide on the limitation of the effects of obtrusive light* [3] REMANDE, C. Pollution and harmful effects, *CIE Div. 4 Symposium*, 2000 [4] DIJON, J. *pers. communication*, 1998 [5] GILLET, M. Precise Evaluation of Upward Flux from outdoor Lighting installations, *Light trespass Symp.*, 2001 [6] AEM, *pers. communication*, 1999 [7] KEITH, D. Roadway lighting design for optimization of UPD, STV and Uplight, *CIE Div. 4 Symposium*, 2000 [8] HAVARD, J.A. Visibility and lighting parameters in roadway lighting, *CIE Div. 4 Symposium*, 2000	Cinzano P., Diaz Castro F.J., The artificial sky luminance and the emission angles of the upward light flux, in *Measuring and modelling light pollution* (ed. P.Cinzano), Mem. Soc. Astron. Ital., 71, 251-256 (2000) Cinzano, P., Light pollution by luminaires in road lighting, 2002, in preparation

	[9] CINZANO, P. The artificial night sky brightness mapped from DMSP satellite, *Mon. Not. R. Society*, p. 641-657, 2000 [10] SOARDO, P. Compatibility between public lighting and astronomical observations, *to be published* P. Soardo, P. Iacomussi, G. Rossi - IEN, Strada delle Cacce 91, 10135 Torino (Italy) fax +39-011-346384 email paolosoardo@virgilio.it L. Fellin - University, Padova (Italy) fax +39-049-8277599 email fellin@die.unipd.it	