Inquinamento luminoso e astronomia

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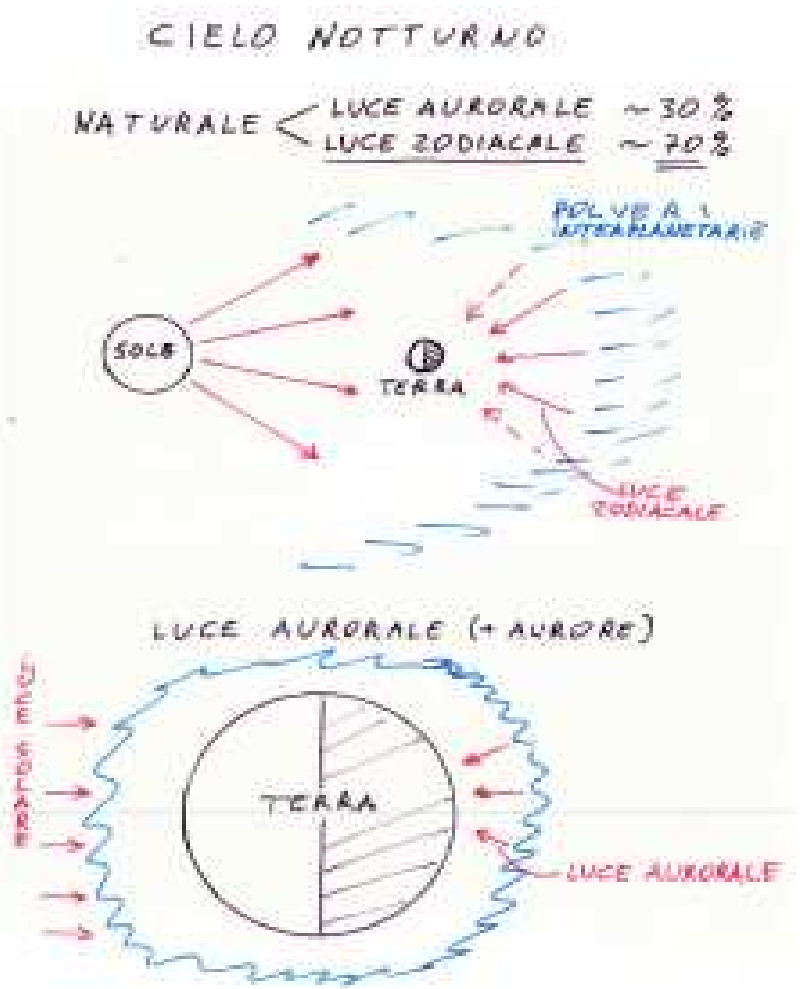
Non esiste solo il problema del mondo professionale:

“The arc of the Milky Way seen from a truly dark site is part of our planet's cultural and natural heritage”

Via Lattea dalla Namibia (F. Brewer) e aurora dalla Finlandia

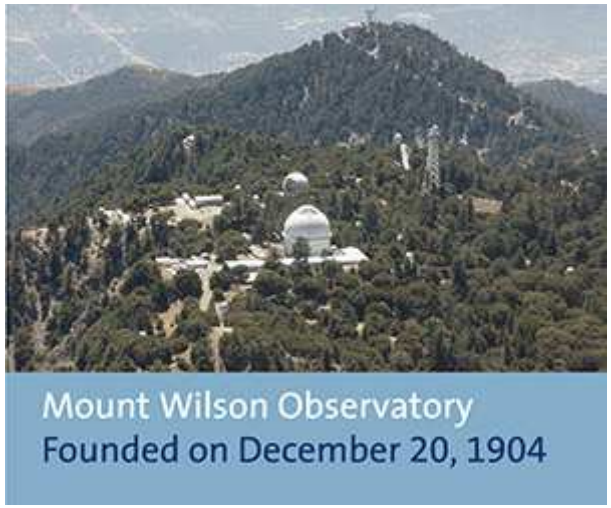
Cometa Schwassmann-Wachmann (2006), M 57, IC 1296

Il cielo notturno naturale: non è così buio…



La luce aurorale

L'osservatorio di Mt. Wilson e il telescopio da 100 pollici (2.5 m, 1917): Hubble scopre l'universo in espansione



Baade risolve Andromeda in stelle durante la guerra (1944)

Los Angeles, 1908-1988

Dati da Garstang

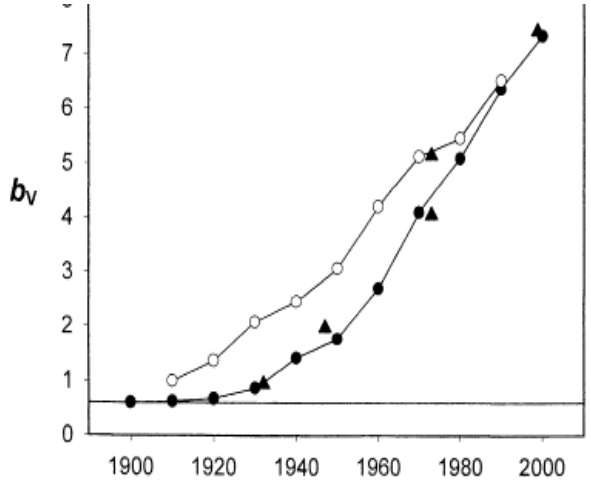
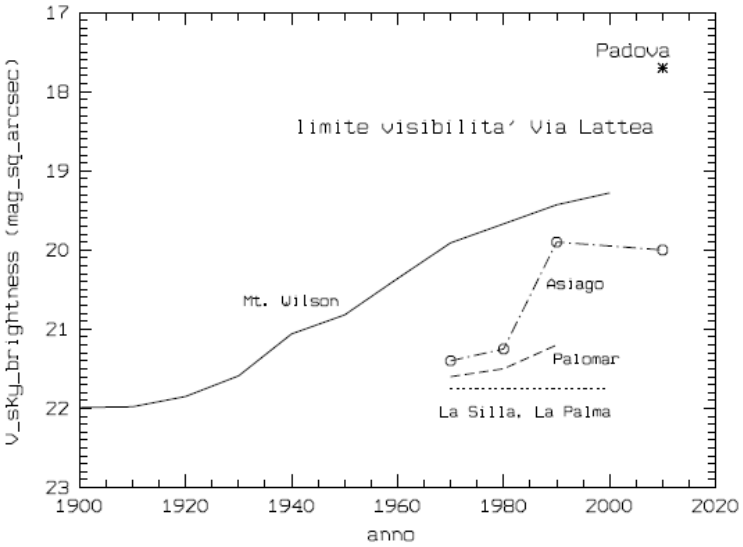
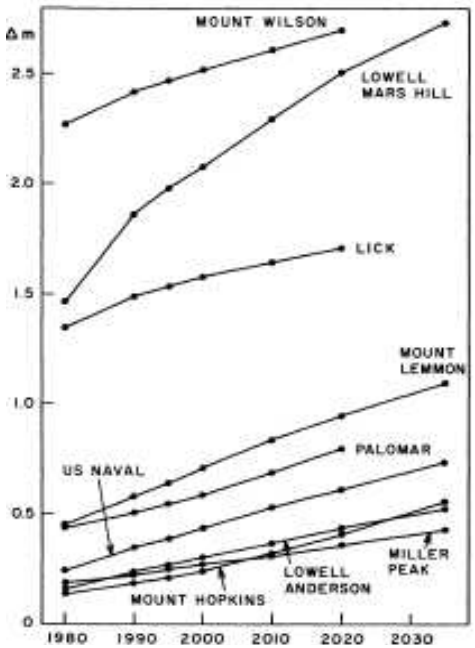


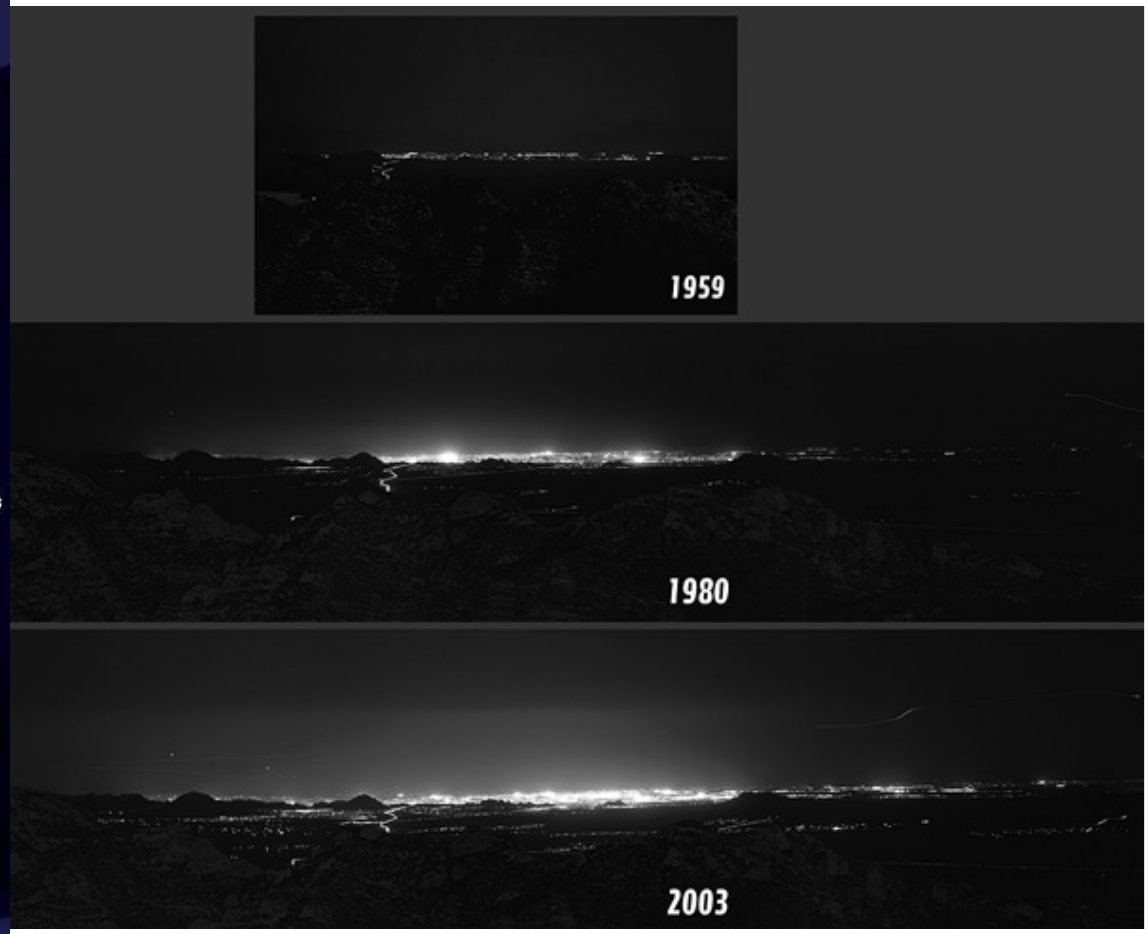
FIG. 2

The sky brightness b_V in the V band at the Mount Wilson Observatory in photons sec^{-1} cm^{-2} steradian^{-1}. Dots are the results of the present calculations, triangles are deduced from observations, and open circles are the results of earlier calculations[1] using only population data. The horizontal line represents the natural sky brightness at sunspot minimum. All points refer to the zenith and include the night-sky contribution at sunspot minimum.

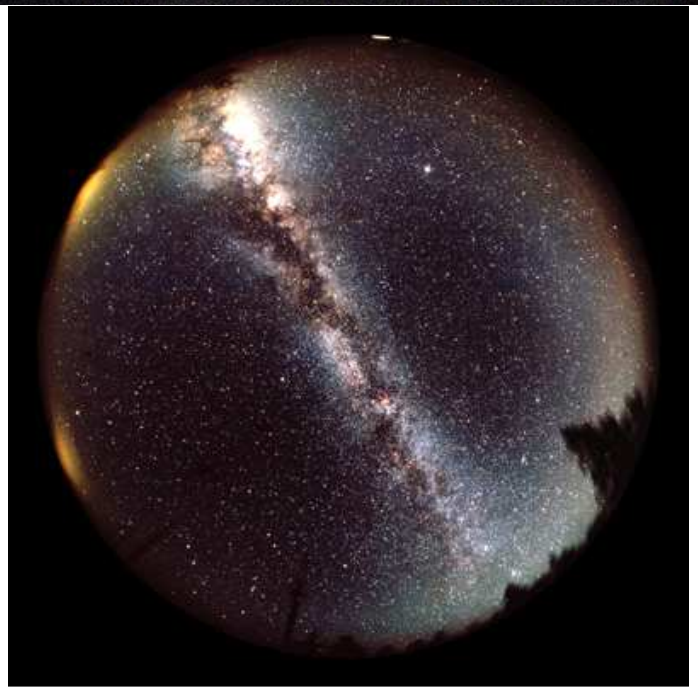


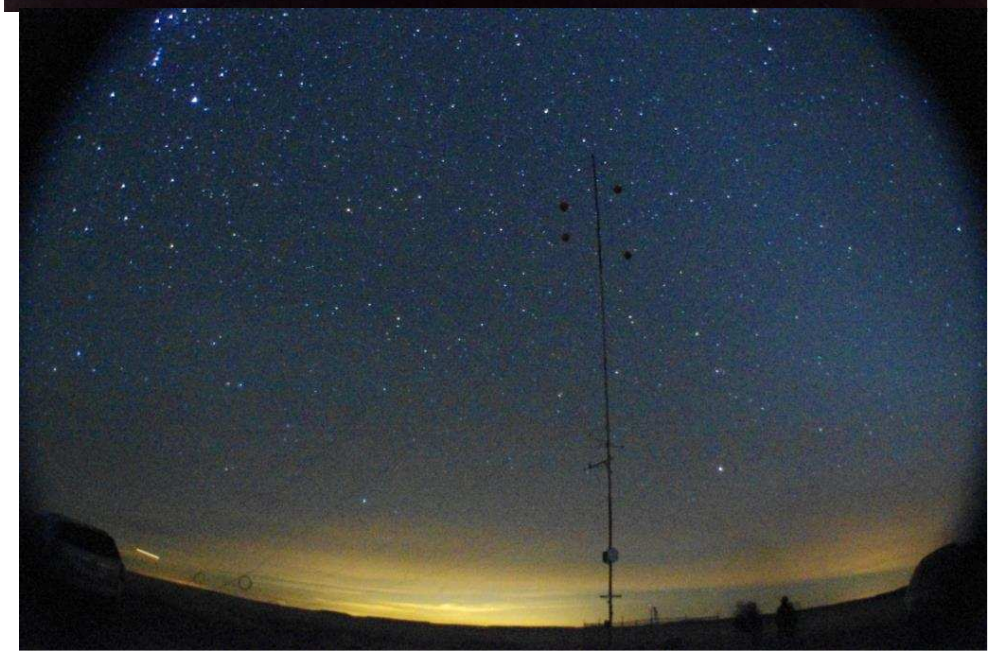


Kitt Peak Observatory, Tucson, Arizona, USA (1959-2003)

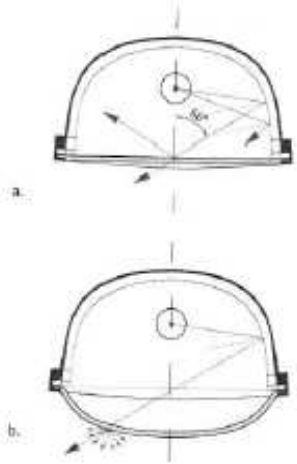


Non ci sono siti sulla Terra esenti da inquinamento luminoso e adatti alle osservazioni astornomiche (eccetto l'Antartide ...): Paranal, Mt. Graham, Meteor Crater

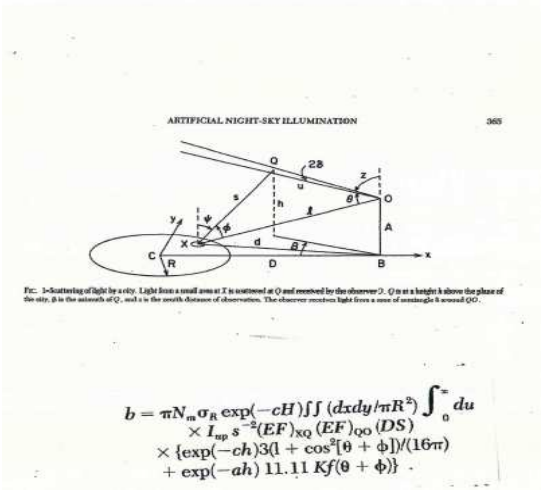


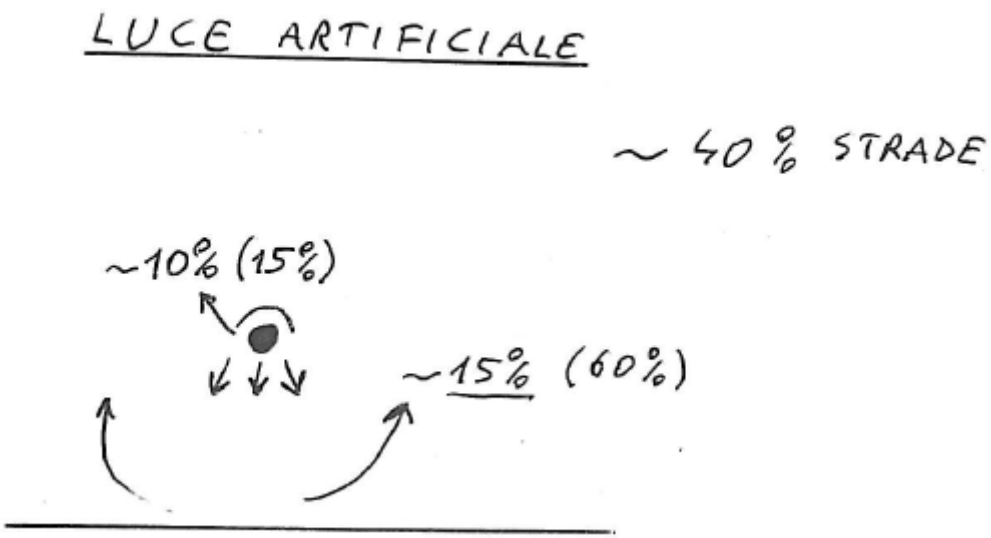


L’inquinamento luminoso: **40% stradale**. Dai modelli di Garstang le lampade emettono in media il 10% verso l'alto, il suolo il 15% (60% con neve).



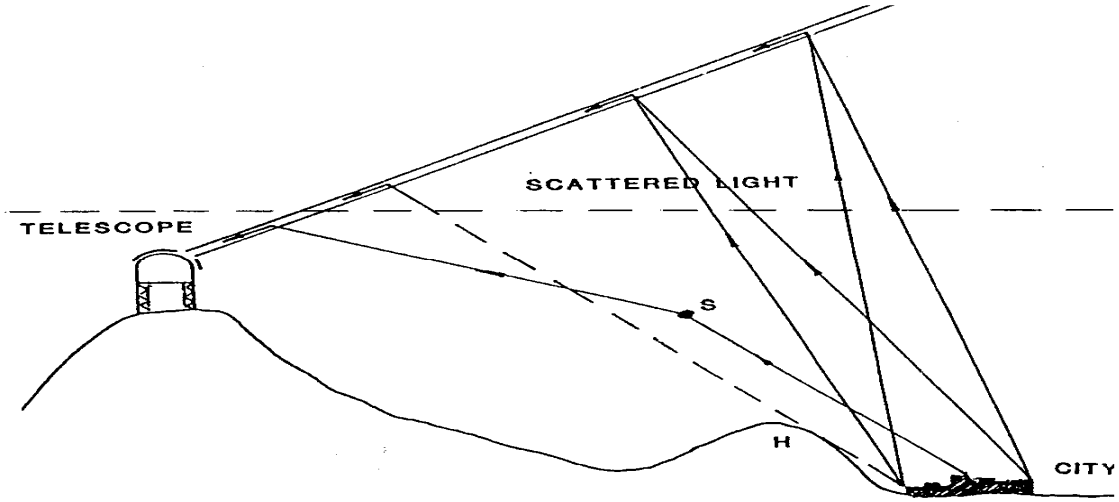
GARSTANG, 1986, PASP, 99, 364

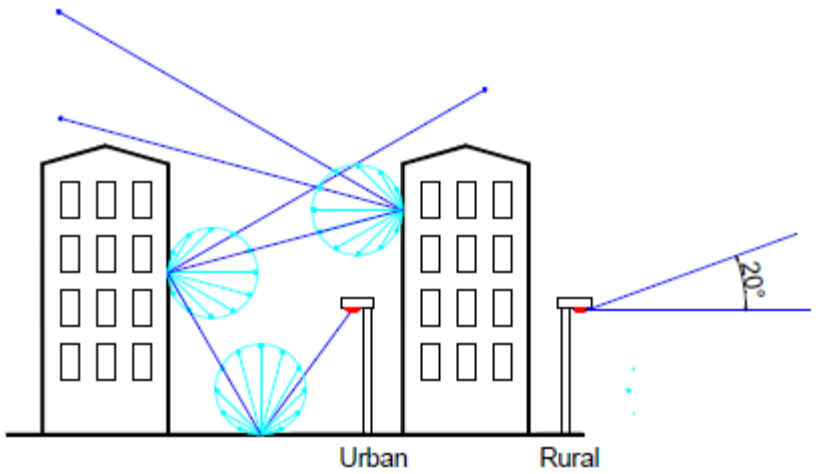


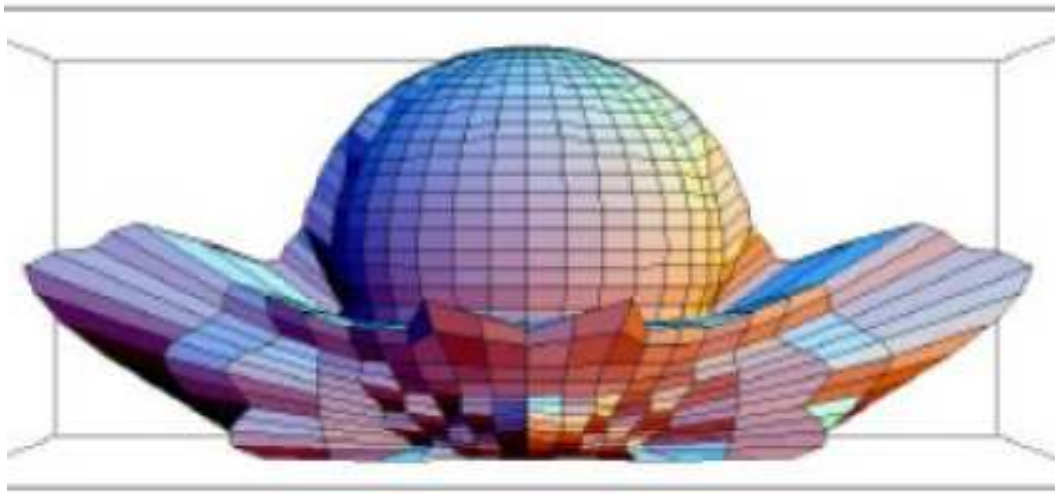


DI = 0.01 x pop. x dist.$^{-2.5}$

D. L. Crawford, 1992



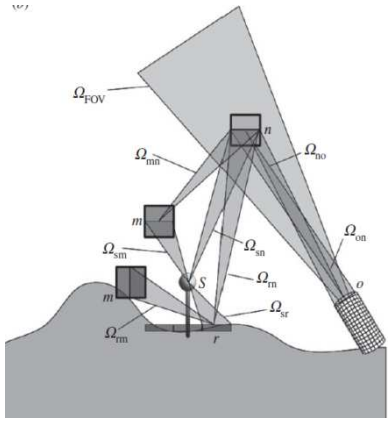




NB: **La distanza tra la sorgente (city) e l'osservatore e' mediamente molto superiore all'altezza dell'atmosfera (~10 km), quindi la propagazione della luce verso l'osservatore avviene a piccoli angoli o per scattering multiplo**

(1) Effetti di schermatura da edifici (palo 7m). 1% comunque in vantaggio

(2) Colore e propagazione dell'inquinamento luminoso (Aubé 2014)



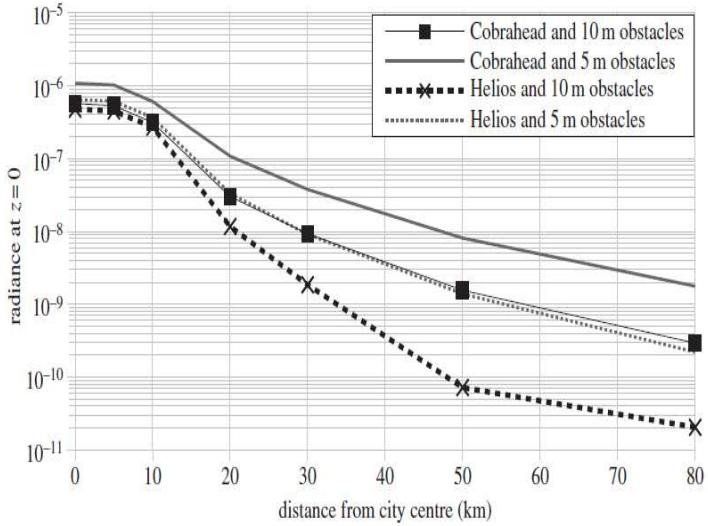


Figure 12. 569 nm zenith sky radiance as a function of distance from the city centre with two different light fixtures (Cobrahead ULOR = 7% and Helios ULOR = 1%) at AOD = 0.1.

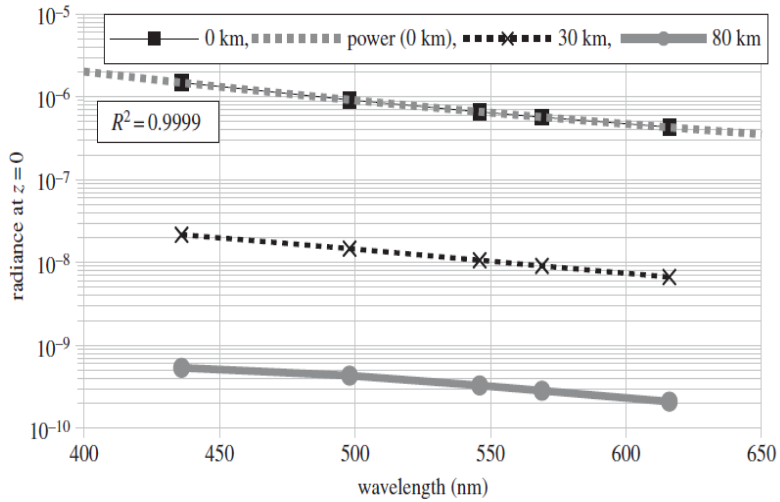


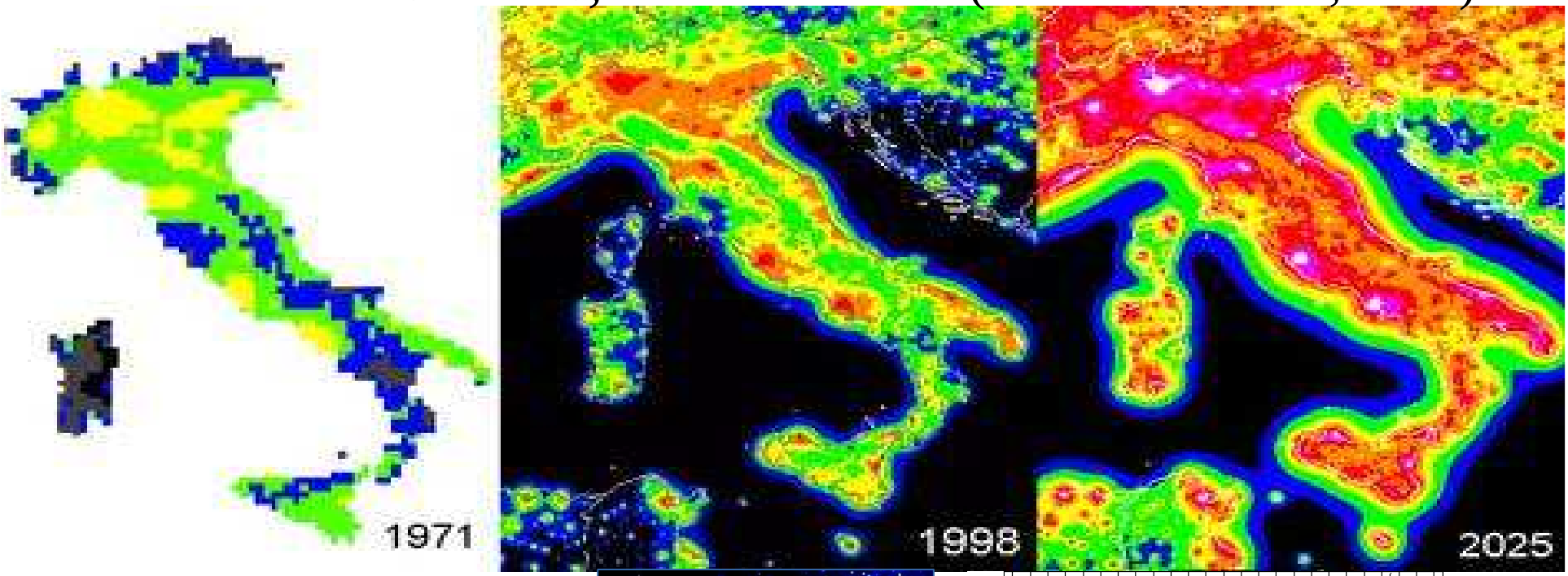
Figure 19. Zenith radiance as a function of wavelength for three distances from the city centre. The grey dotted line superimposed on the black squares is a power law fit of the data with a high correlation ($R^2 = 0.9999$).

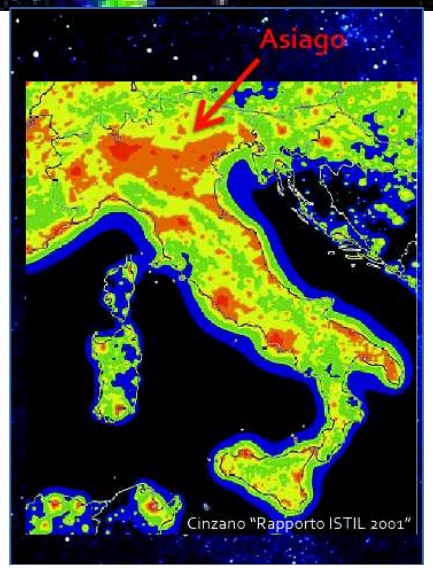
Sedi di attivita' astronomica **professionale** in Italia (Istituto Nazionale di Astronomia, INAF e dipartimenti universitari)**.** In giallo le sedi dei telescopi, in rosso gli istituti di ricerca

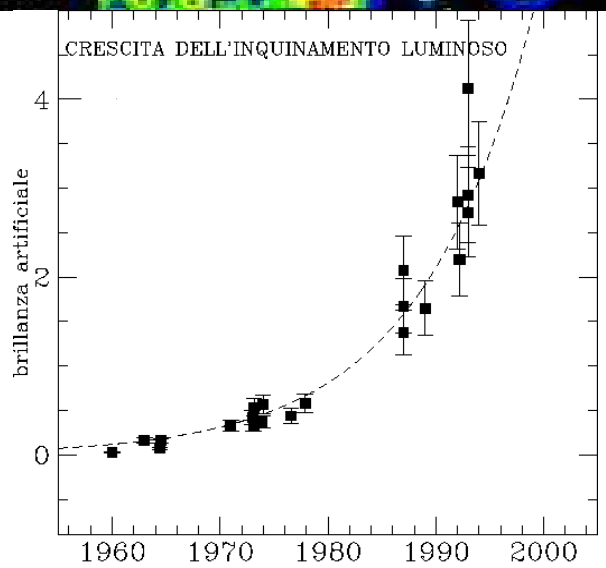
La maggior parte hanno limitato drasticamente le attività. I piu' attivi oggi sono: **Asiago**, Loiano, Teramo-Campo Imperatore, Toppo di Castelgrande, Serra La Nave

In totale lavorano in astronomia circa 1000 addetti strutturati

Situazione in Italia: verde +30%-100%, giallo 100%-300%, arancio 300%-900%, rosso >900% (P. Cinzano et al., 2000)







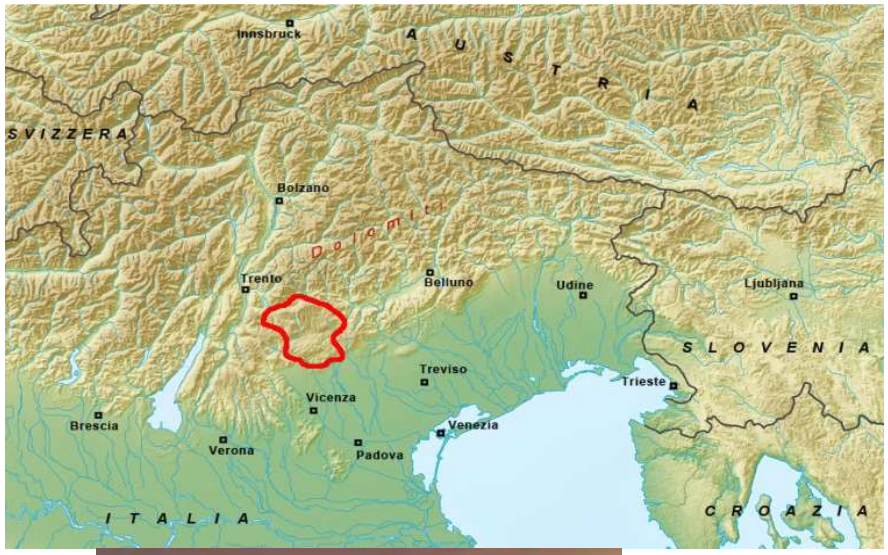
L’astronomia in Veneto (PADOVA)

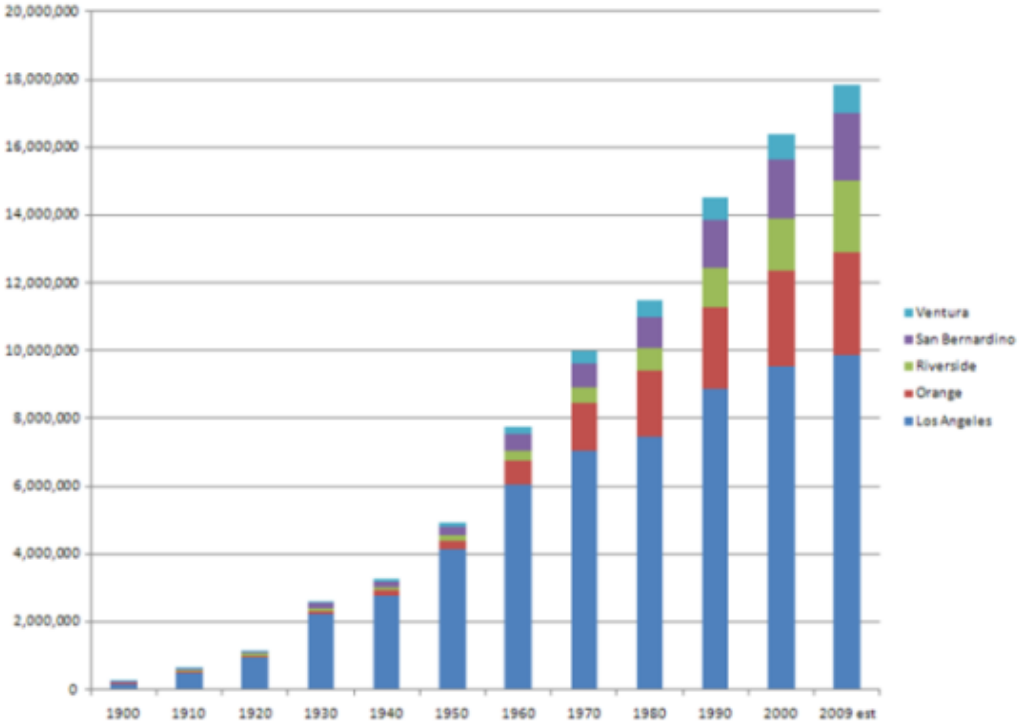
Totale 57 addetti (università + INAF)

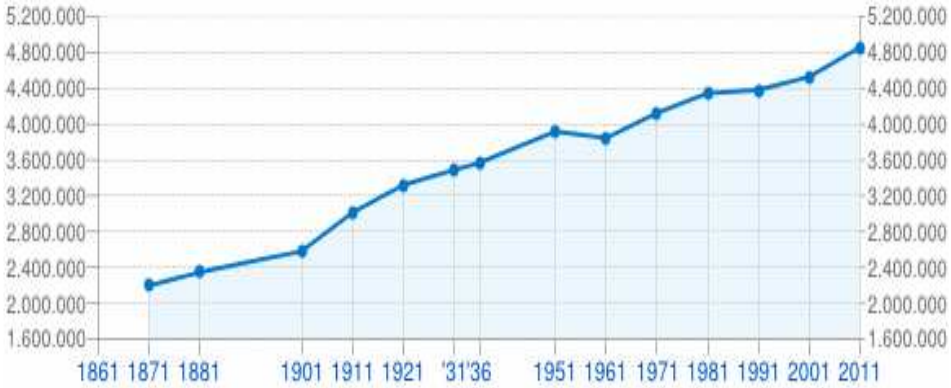
•**Il sito di Asiago (dal 1942): 200** notti/anno utilizzabili, **soprattutto invernali. Tra i migliori in Italia e in Europa** (mt. Graham 230 notti/anno, La Silla, Cile 260 notti/anno)

•4 telescopi in due siti: Pennar (vicino al paese) e Cima Ekar col telescopio da 182 cm, il più grande in Italia.

•La luminosità del cielo è aumenta di un fattore 4 dagli anni 70, perdita di circa il 40% in distanza e un fattore 3 nel volume esplorabile.







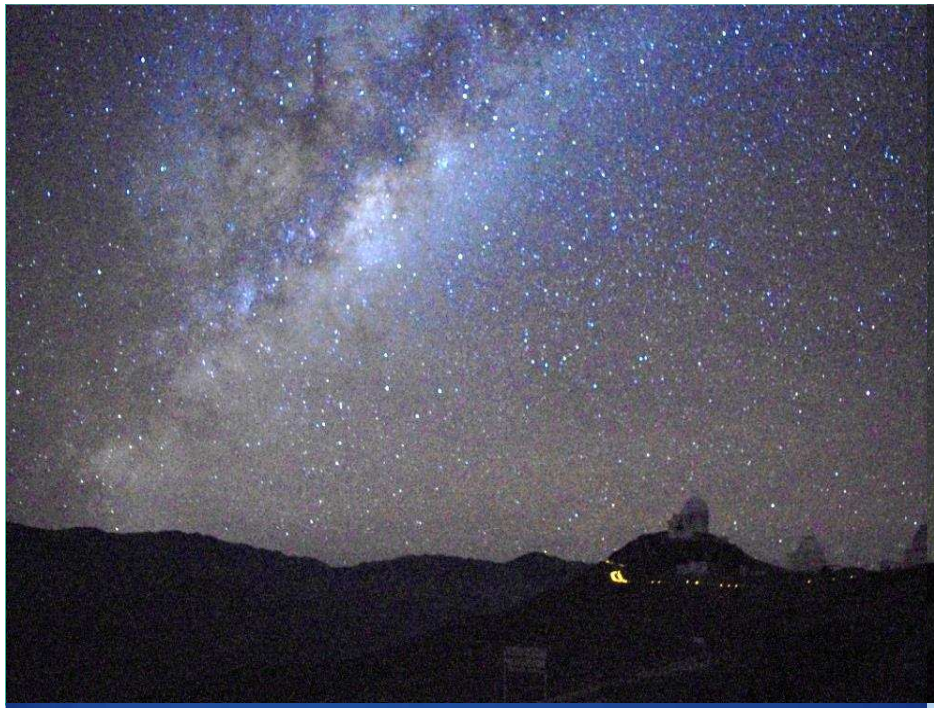
Popolazione residente ai censimenti

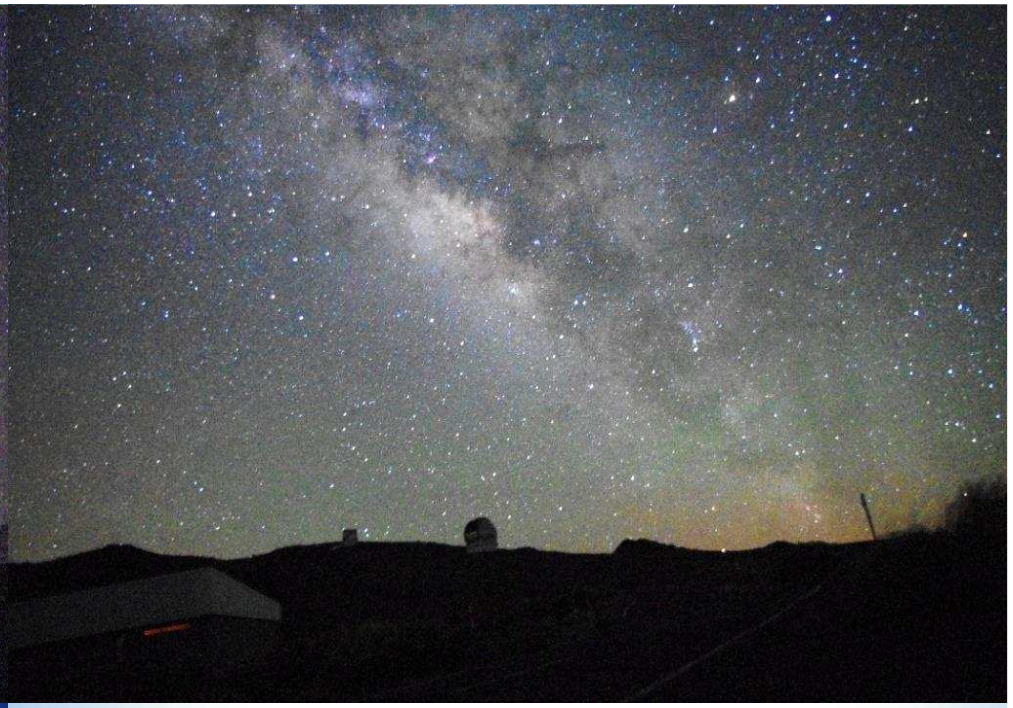
VENETO - Dati ISTAT - Elaborazione TUTTITALIA.IT

Popolazione residente ai censimenti

COMUNE DI ASIAGO (VI) - Dati ISTAT - Elaborazione TUTTITALIA.IT

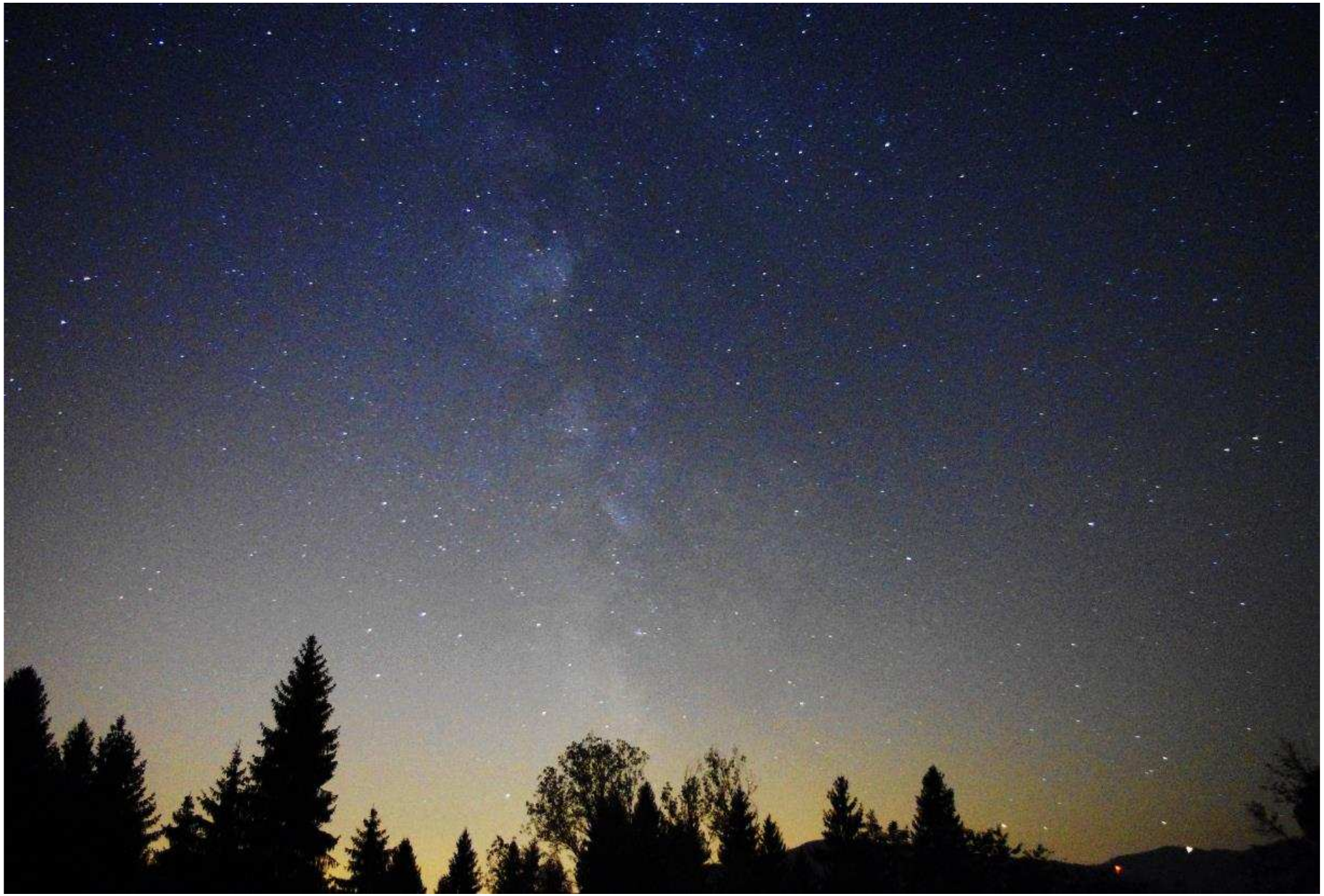
Gli astronomi italiani emigrano: European Southern Observatory, Paranal, Cile



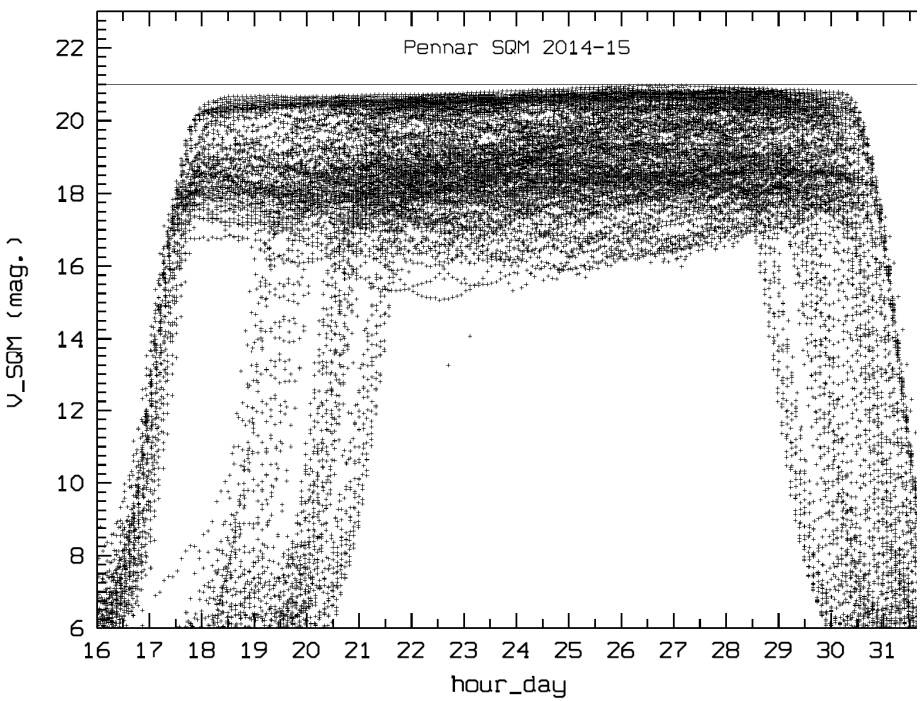


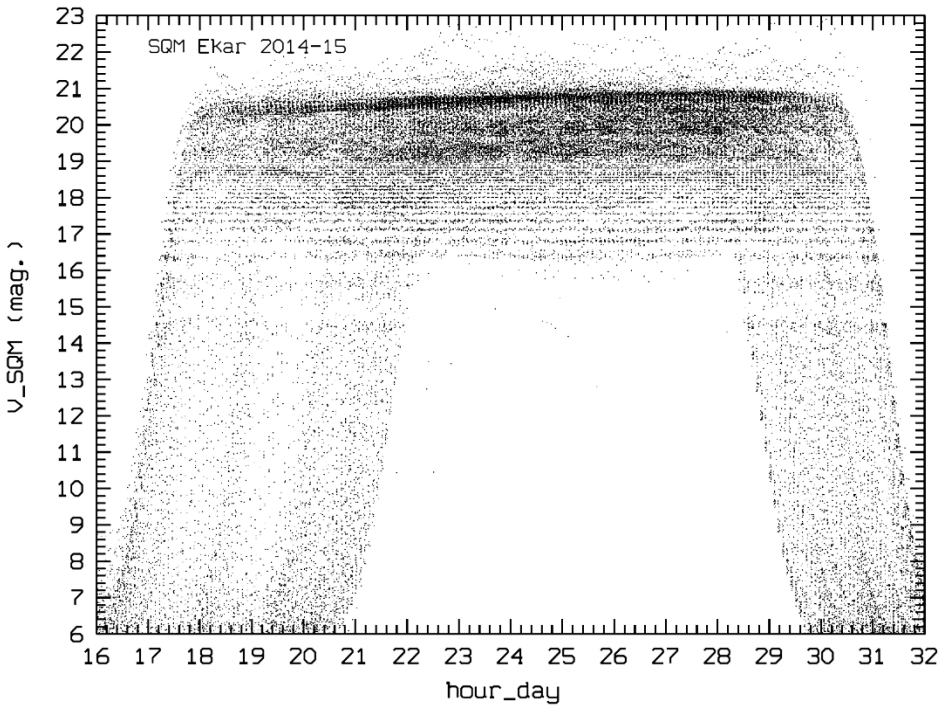
San Pedro Martir (3000 m), Messico

L’Altopiano di Asiago dal parco delle Dolomiti Bellunesi

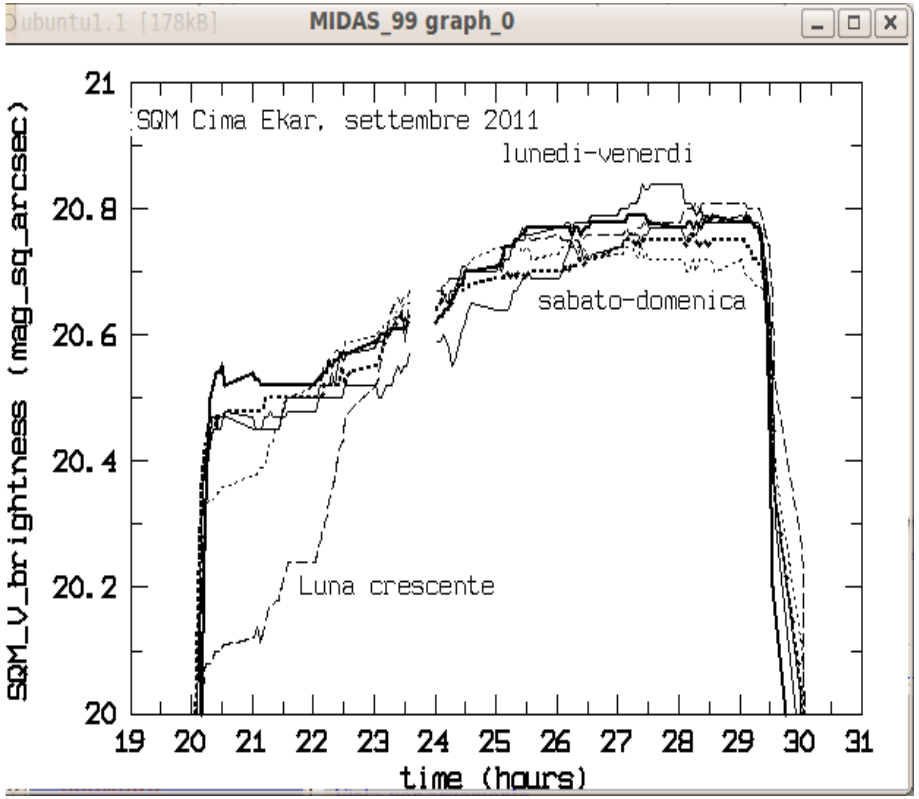


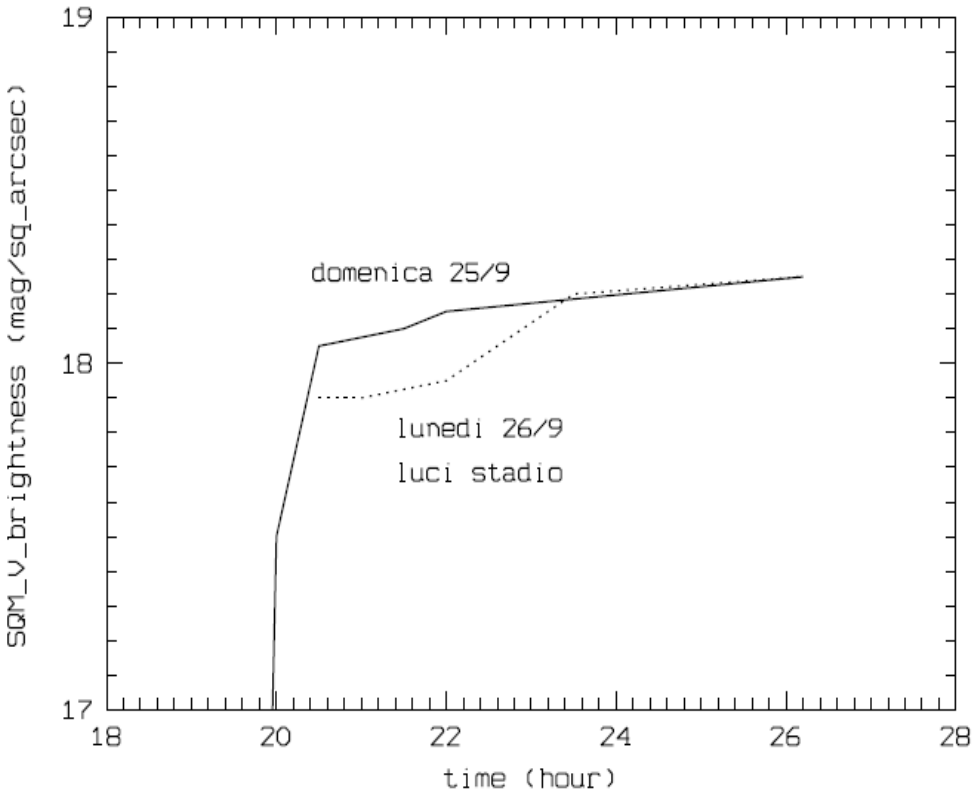
Misure del cielo ad Asiago (Pennar-Ekar)



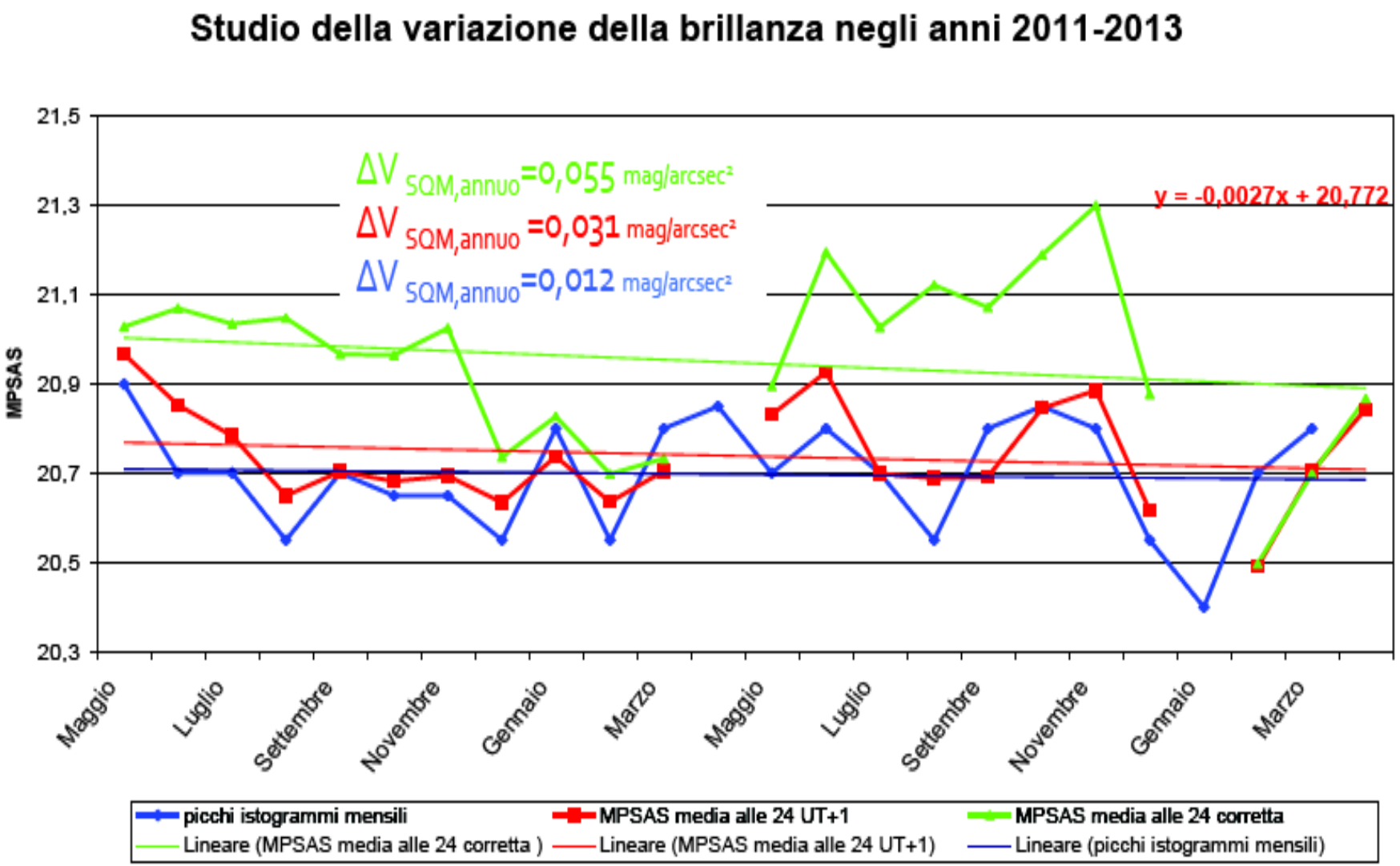


Misure a Cima Ekar e Padova, effetti locali

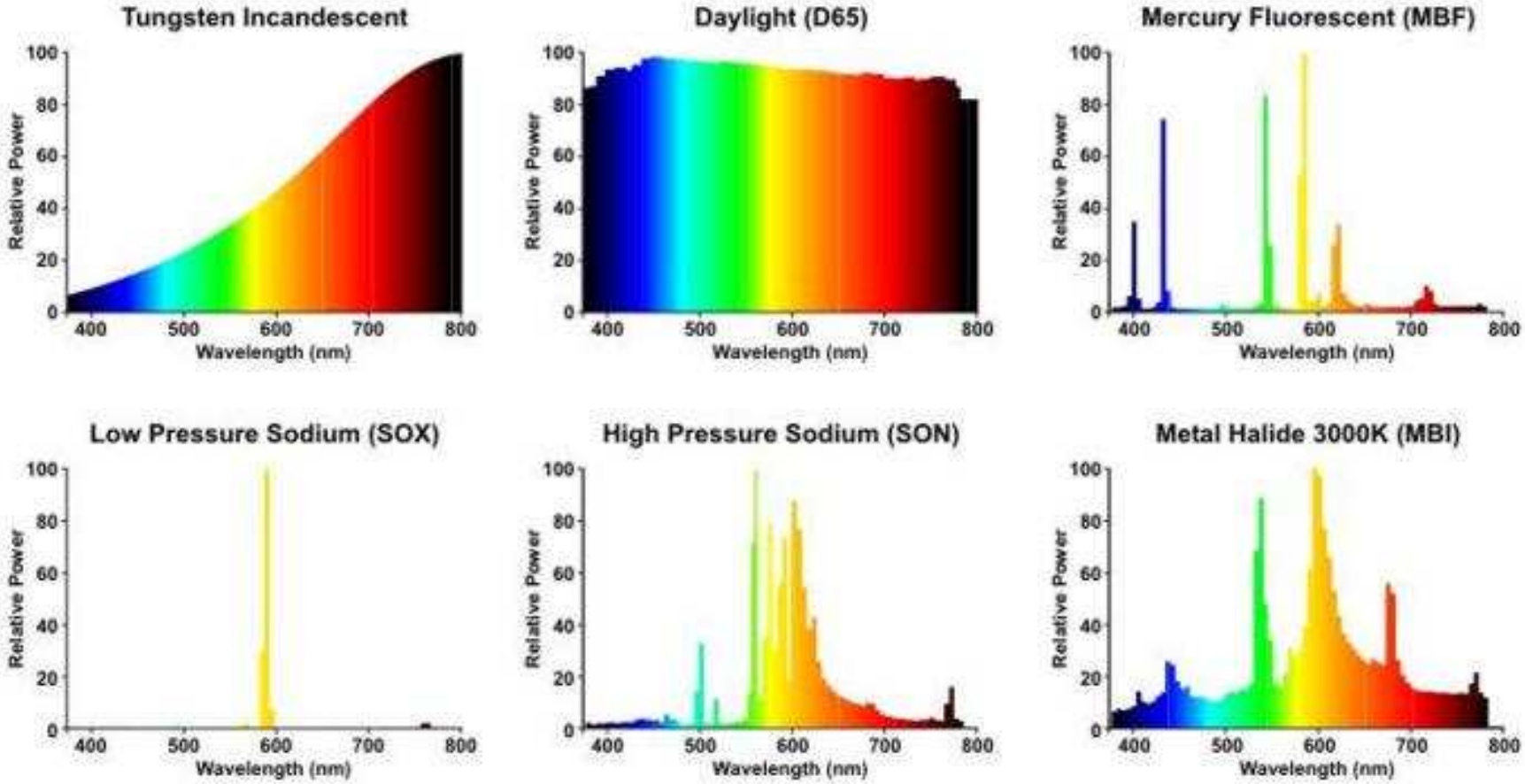




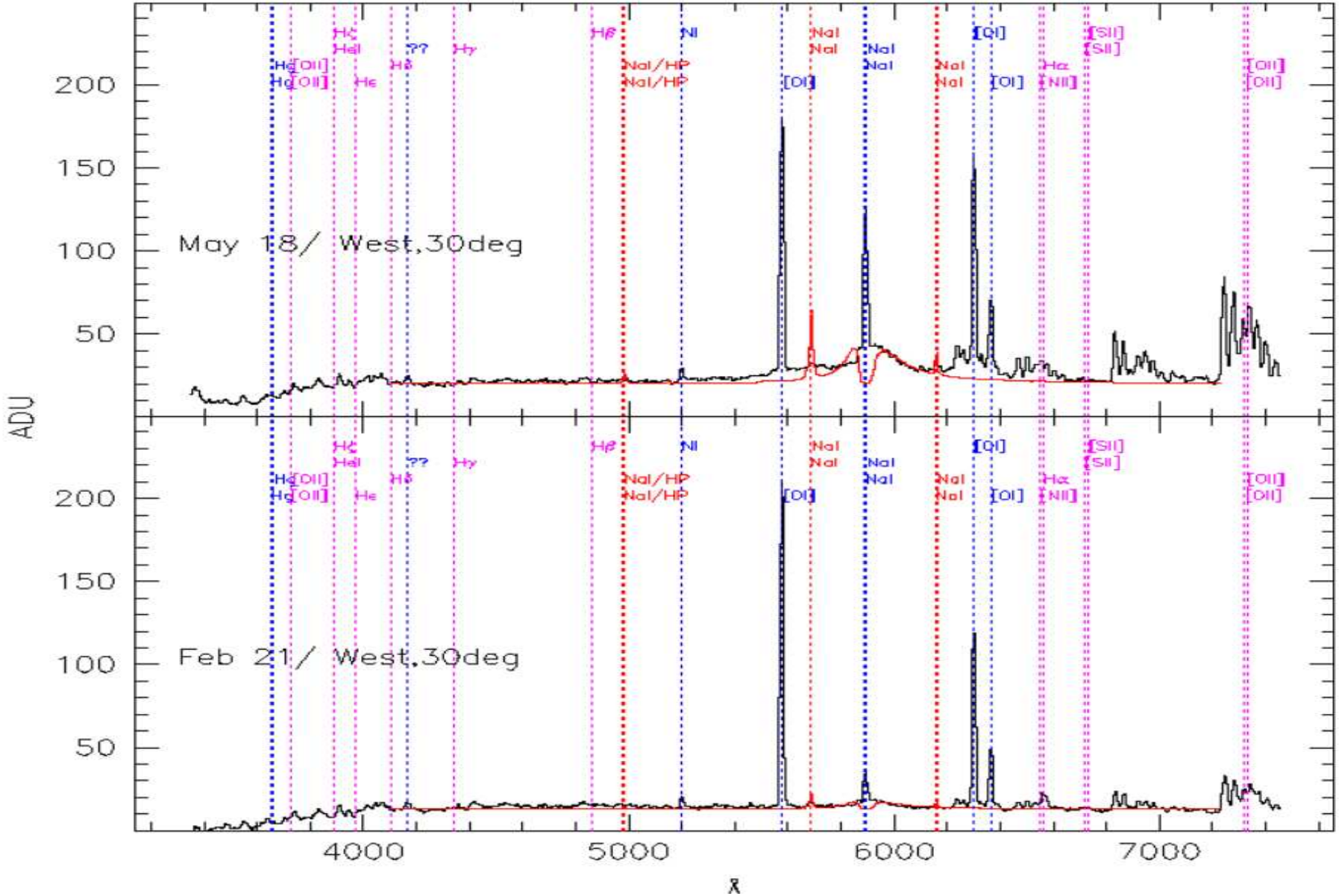
In questi ultimi due anni l'aumento di luminosità del cielo è stato molto contenuto (A. Vedovato, 2013)



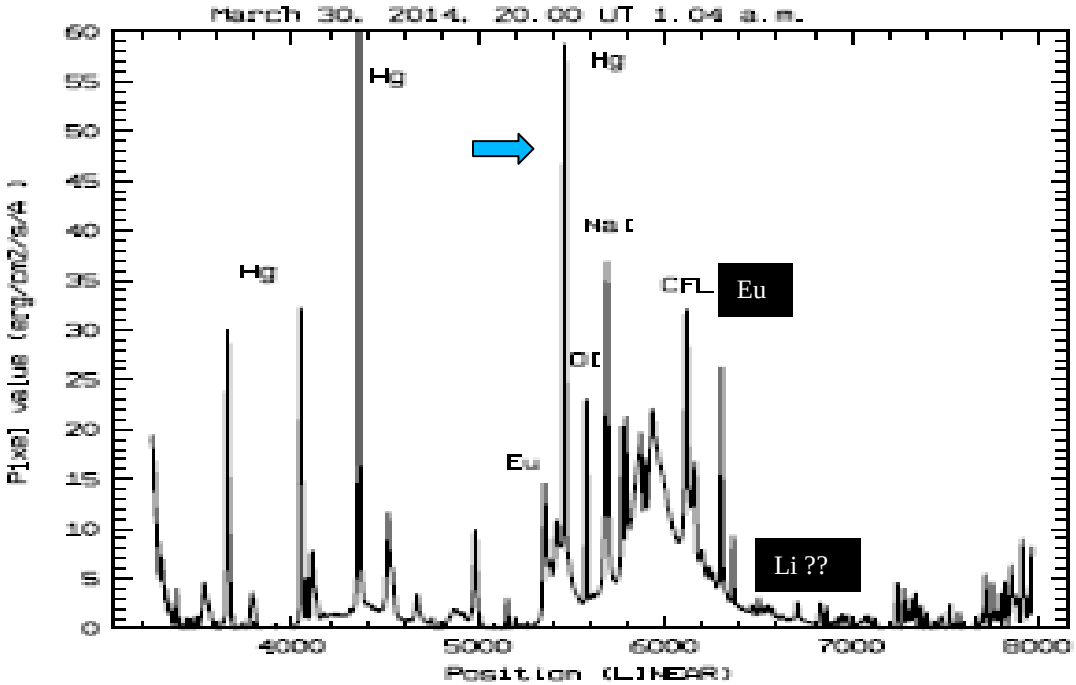
Lampade tipiche dell'illuminazione pubblica

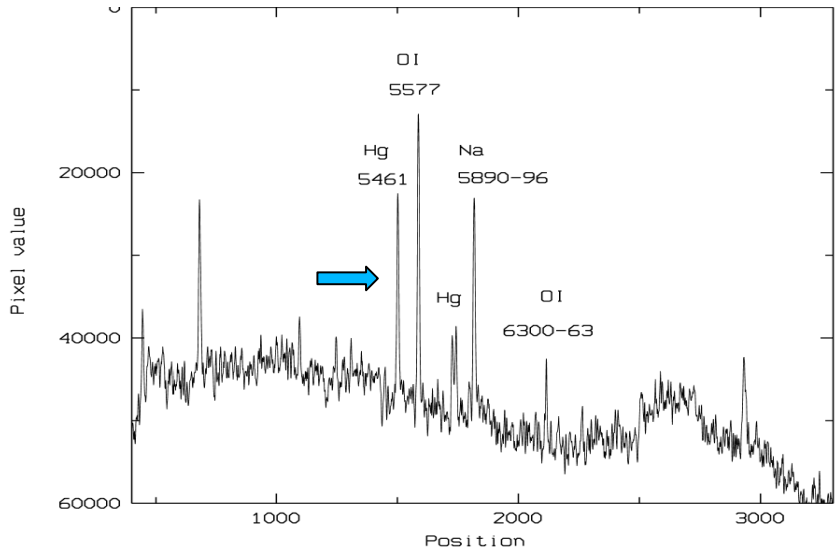


Spettri ottenuti a La Silla, Cile, 2015 col telescopio NTT (3.5 m) (I. Saviane)

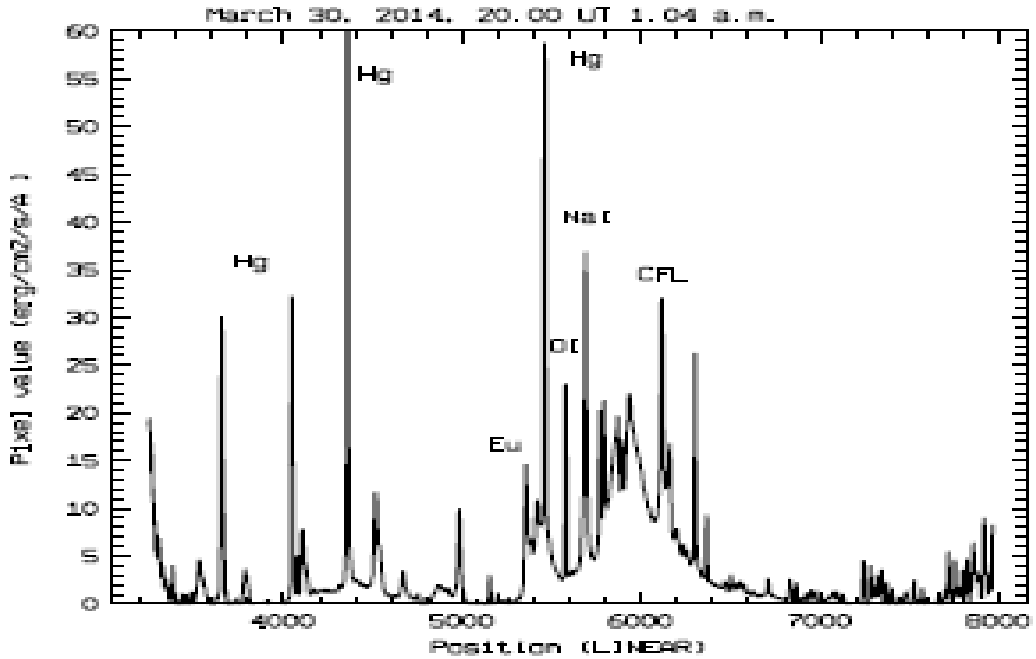


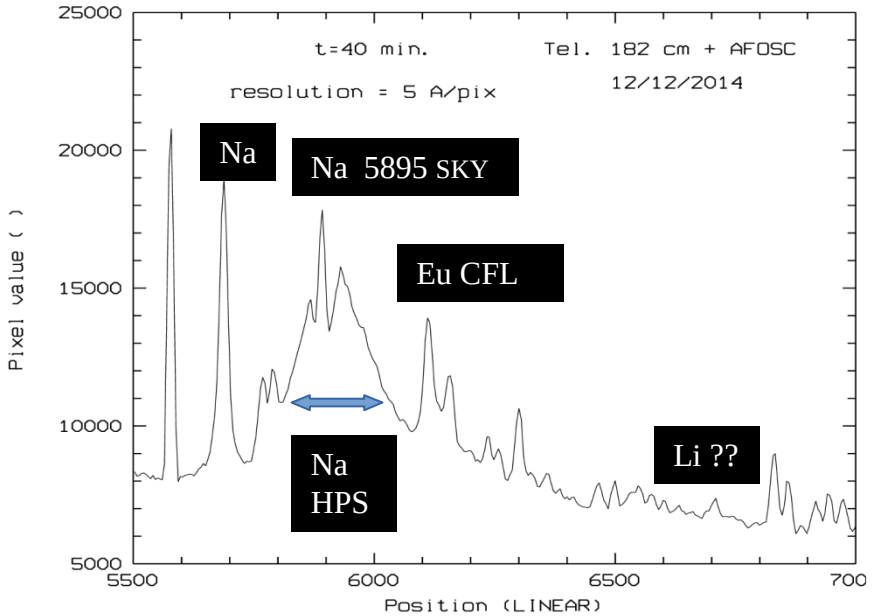
Polluting the sky: 2014 spectra (Berton 2014) + **old plates from 1979, low pollution sky (Hg lamps only, no Na)**

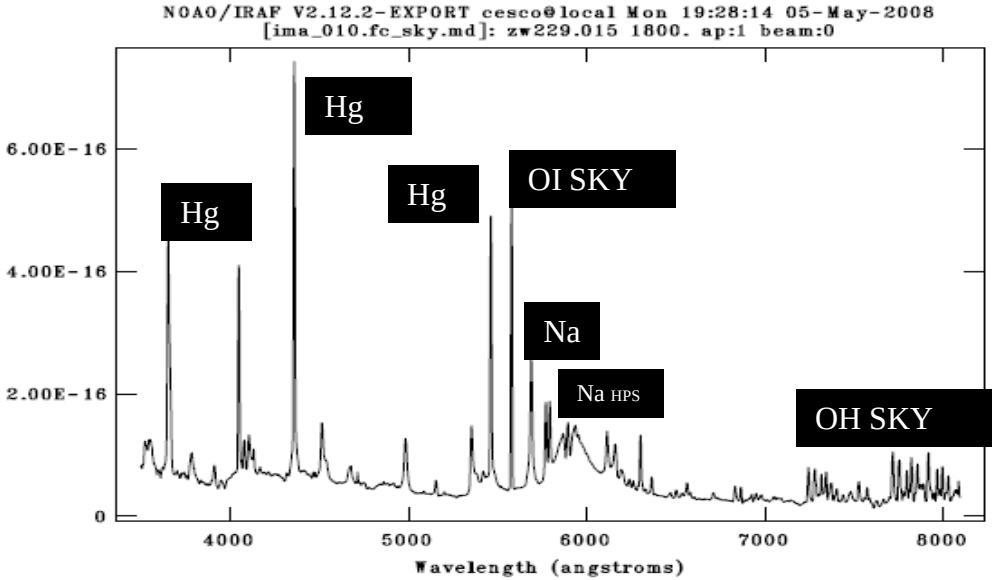


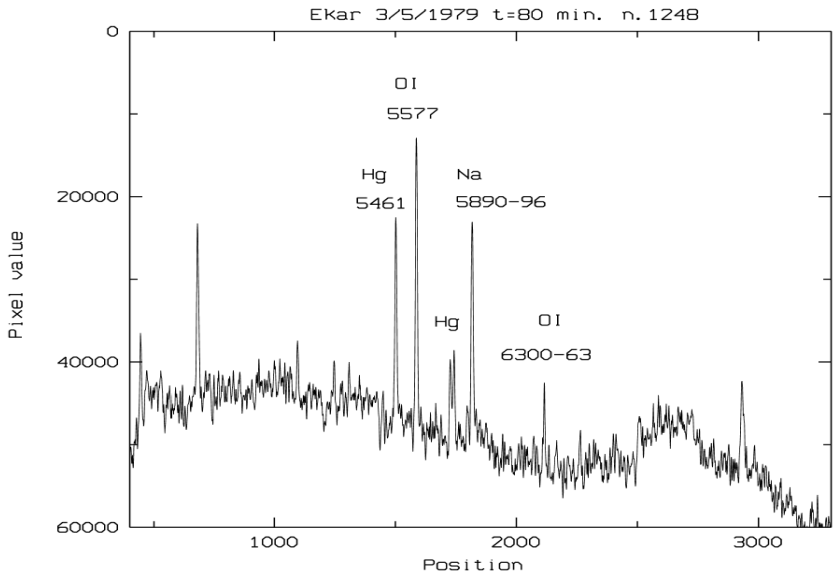


Evoluzione dell lampade dagli spettri ? Spettri 2014-2008 (Berton 2014, SN PD group 2008) + **1979 dalle prime lastre di Ekar**

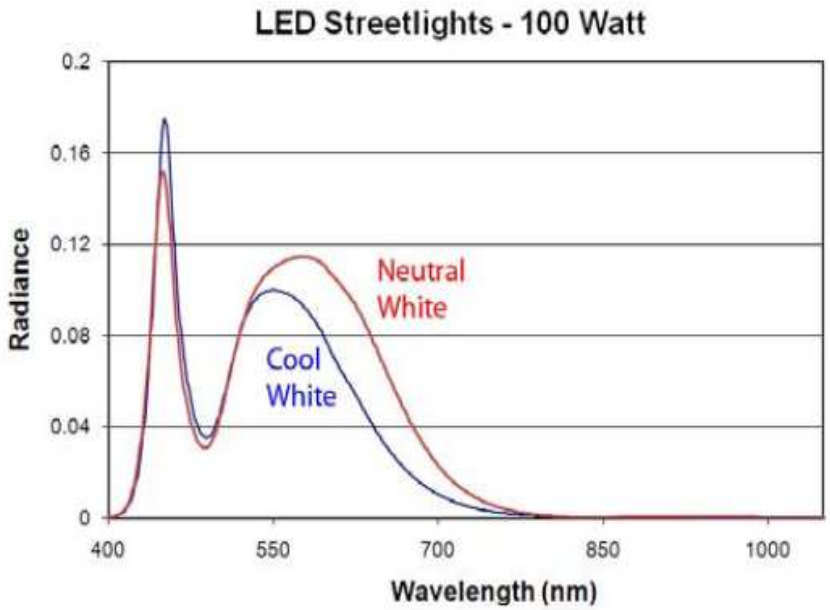


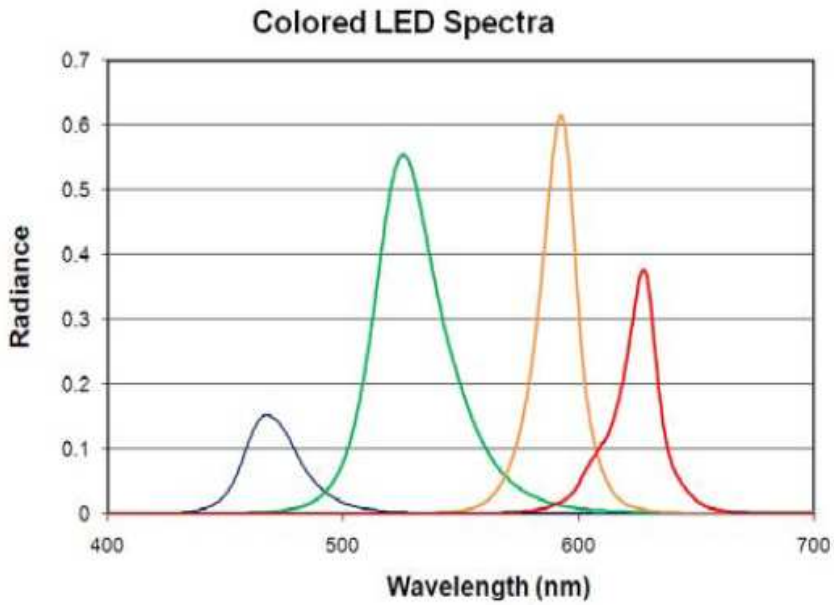


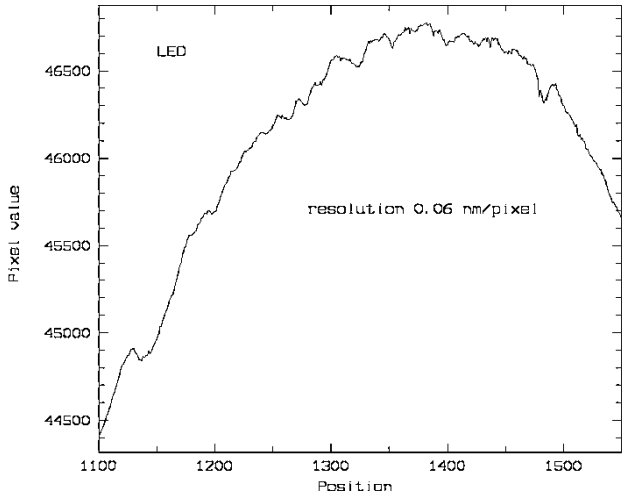




I LED: problema dell'emissione blu e del continuo. Quali conseguenze dall'»invasione» dei LED ?







suggerimenti…

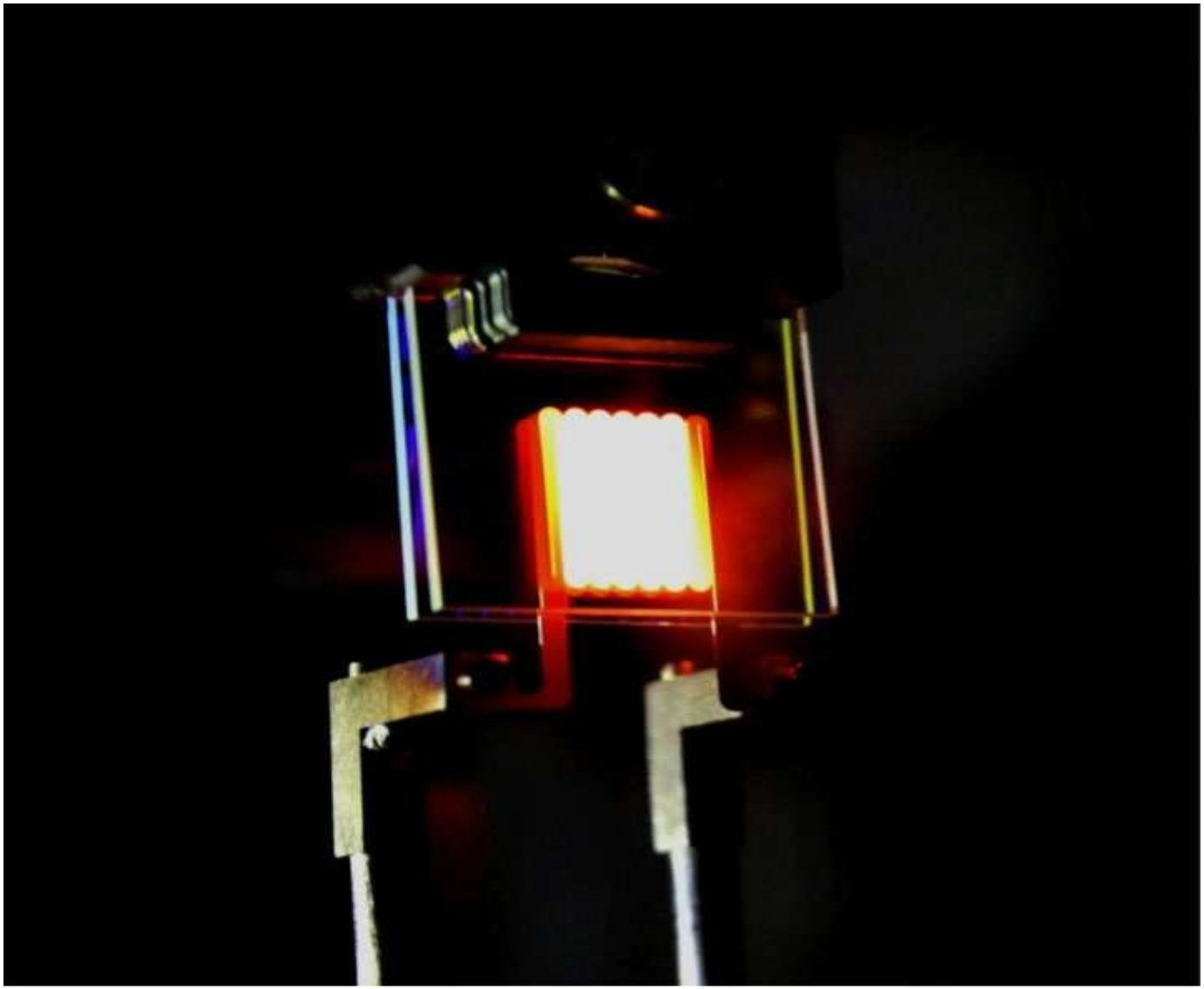
- La riduzione dei livelli di illuminazione (inclusa l'emissione diretta verso l'alto) e’ una misura certamente positiva per l’ astronomia.
- Misure molto restrittive ma senza controlli ne’ sanzioni servono poco. **Gli impianti devono essere controllabili senza eccessive difficoltà**
- **Restrizioni su impianti privati**, spesso privi di senso e fortemente inquinanti, soprattutto se in ambienti extraurbani, sono auspicabili.

lamps efficiency

- Old bulbe-filament lamps 15 lm/W
- Alogen lamps 20
- “compact” fluorescence lamps 60
- Iodin lamps 60-100
- LED (tunable !) <80-100 (250), T dependent !
- Sodium lamps 85-200
- Max theoretical 680

Duration of the best “lamps” 3000-50000 h

Il futuro: nuove lampade a filamento e nanotubi (Nature, 2016) rendimento attuale 40 lm/W, previsione 300 lm/W, senza emissione nel blu né necessità di elettronica. Possibilità di dimming e intermittenza.



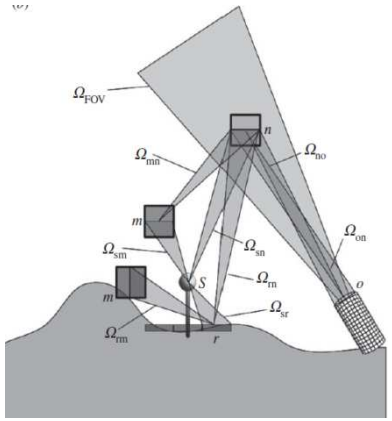
Alcune conclusioni…

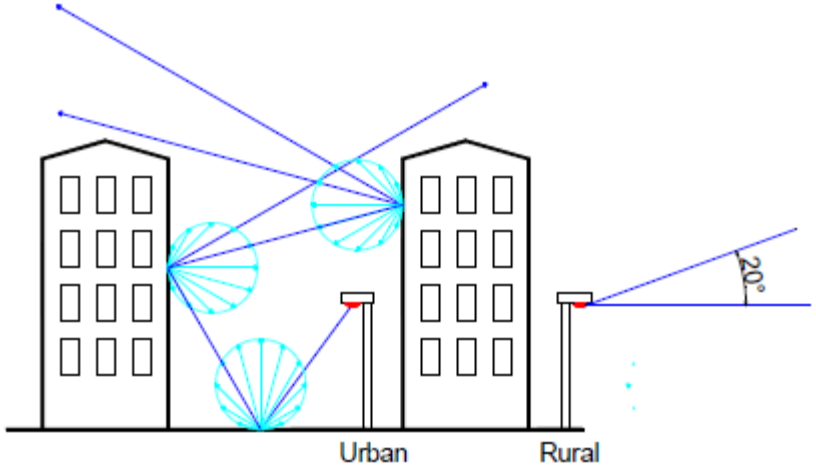
L’inquinamento luminoso ha effetti negativi in astronomia perche’ degrada o impedisce le osservazioni di corpi celesti **sia lontani che vicini** (dalle comete alle galassie).

- Ad Asiago l'aumento è stimabile attorno ad un fattore 4 con perdita di circa il 40% in termini di distanza limite a parità di luminosità della sorgente. E' un fattore 3 nel volume campionato.
- L’inquinamento luminoso ha subito un progressivo aumento un po’ ovunque e appare un fenomeno inevitabile, perche’ legato all’**estensione delle aree illuminate** (**non necessariamente all'aumento della popolazione**), ma puo’ essere contenuto con opportune scelte tecniche e pianificazioni specifiche.
- L'aumento considerevole è avvenuto tra gli anni 80 e 90. Sembra aver avuto una pausa nell'ultima decade ma la diffusione di nuovi impianti sembra preludere ad un nuovo aumento

(1) Effetti di schermatura da edifici (palo 7m). 1% comunque in vantaggio

(2) Colore e propagazione dell'inquinamento luminoso (Aubé 2014)





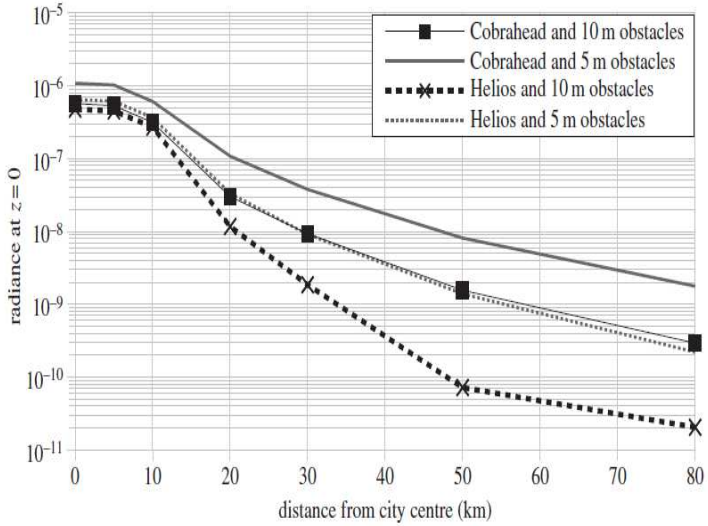


Figure 12. 569 nm zenith sky radiance as a function of distance from the city centre with two different light fixtures (Cobrahead ULOR = 7% and Helios ULOR = 1%) at AOD = 0.1.

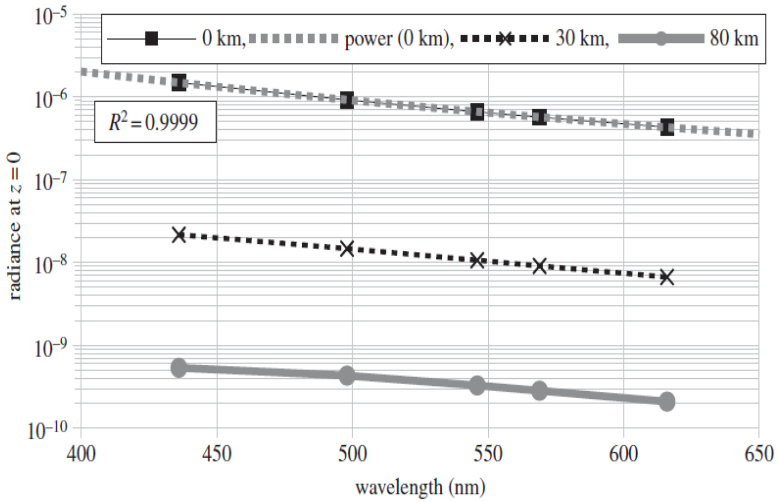


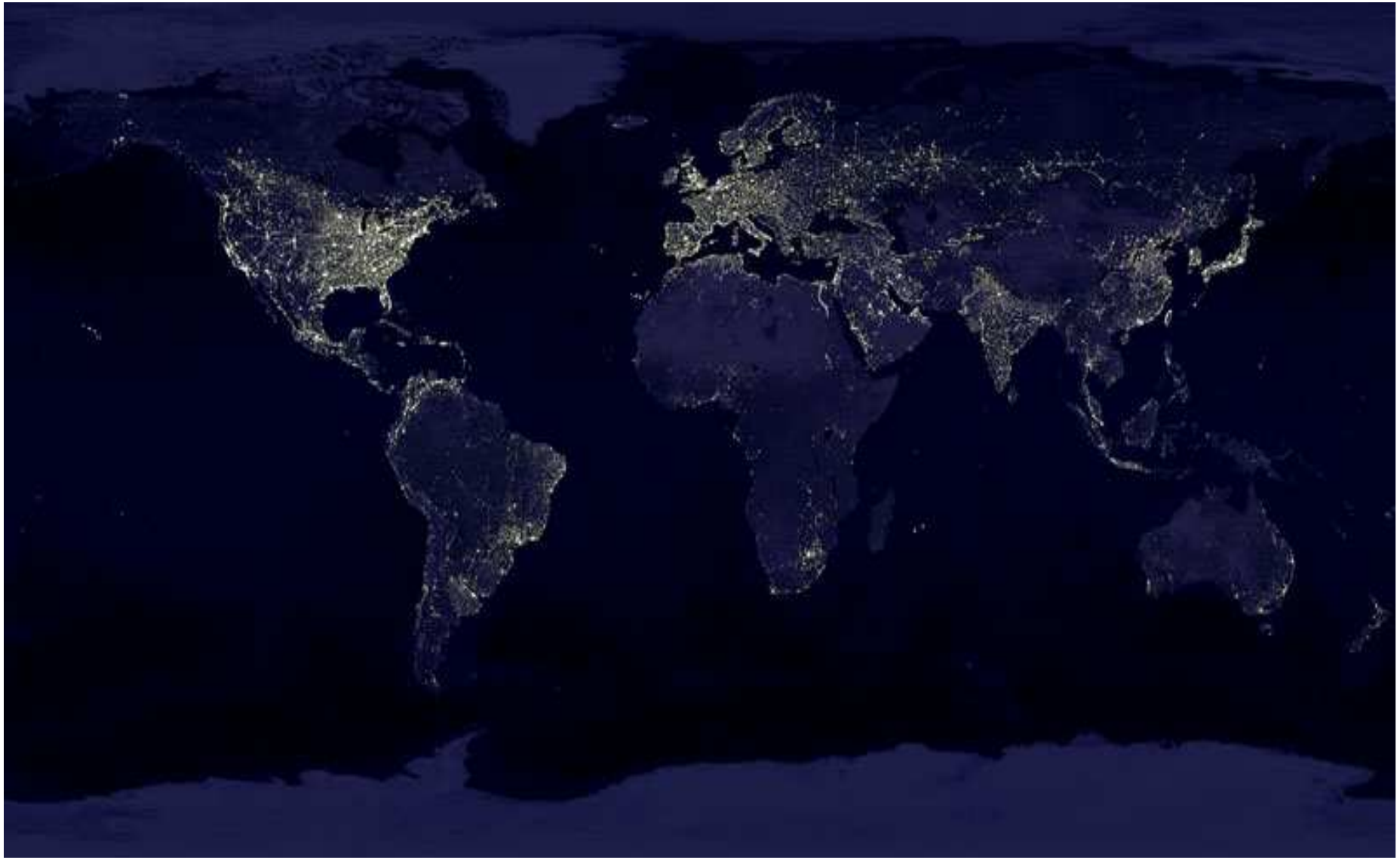
Figure 19. Zenith radiance as a function of wavelength for three distances from the city centre. The grey dotted line superimposed on the black squares is a power law fit of the data with a high correlation ($R^2 = 0.9999$).

Il cielo ad Asiago-cima Ekar

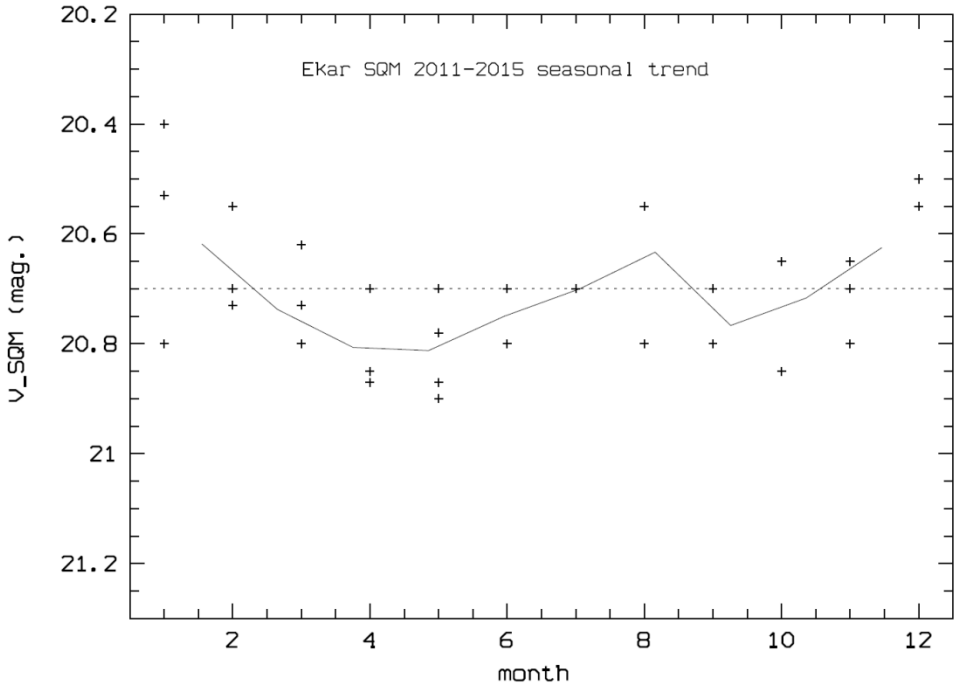
Misure continue SQM dal 7 maggio 2011

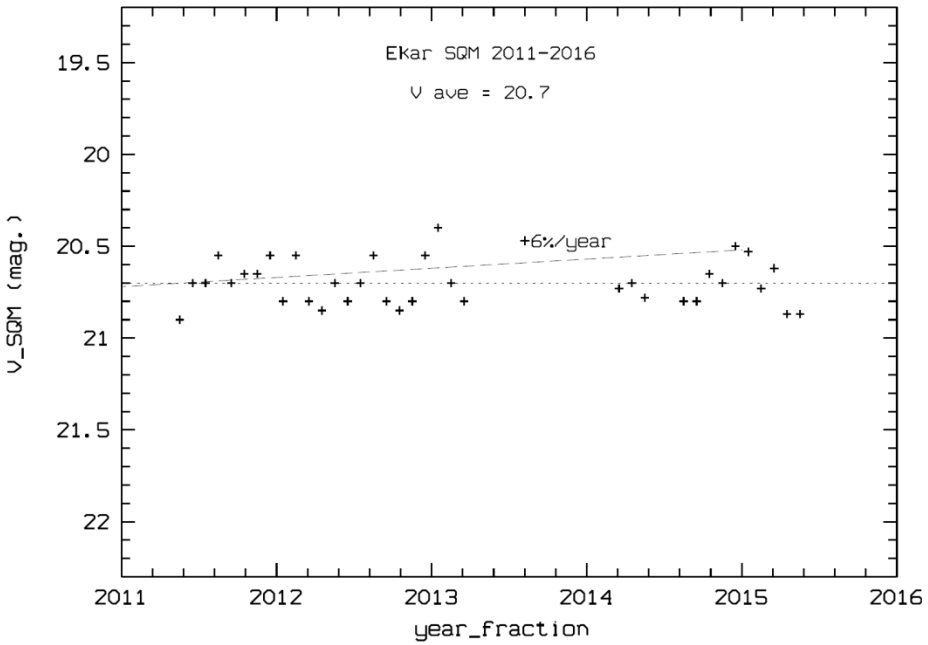
- Via Lattea ora visibile solo per poche decine di gradi, brillanza V=20 al telescopio, SQM 20.5-6.
- La luminosità del cielo diminuisce sensibilmente durante la notte.
- Ad Ekar contributo teorico stimato circa 70% dalla pianura, 30% altopiano.
- Al Pennar la situazione si ribalta con netta prevalenza di inquinamento locale dall'altopiano.

La Terra di notte (dall’alto…): effetti di varie attività, incluse estrazioni, pesca. Sono esenti le foreste equatoriali e distese desertiche di bassa altitudine e sabbiose spesso non adatte all’astronomia (es. Sahara)

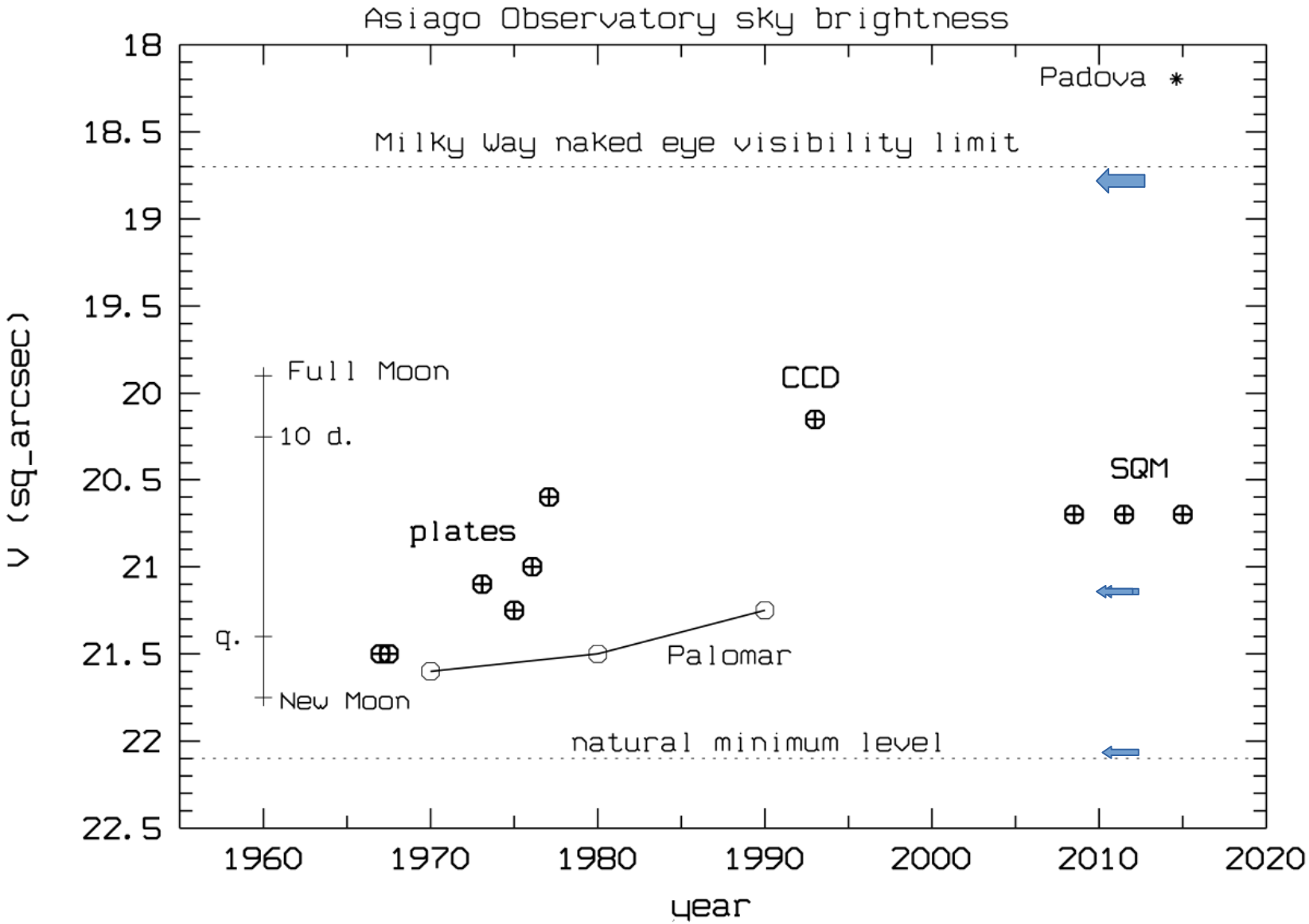


Sky brightness at Ekar 2011-2015:
-seasonal trend, darkest in the low season
-no brightness increase in the last 5 years in spite of luminance increase





A dramatic increase in luminosity at Asiago Observatory between 1975 and 1985



Osservatorio di Asiago: 4 telescopi (1.8m, 1.2 m, 2 telescopi Schmidt) in due siti. (1) Pennar, 1000m, vicino ad Asiago, e (2) cima Ekar 1300 m, più distante (7-8 km), ma vicino al bordo dell'altopiano. Abbiamo 200 notti utilizzabili/anno