Generalitat de Catalunya
Departament de Territori i Sostenibilitat
Direcció General de Qualitat Ambiental
Servei per a la Prevenció de la Contaminació Acústica i Lumínica

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How clouds are amplifying (or not) the effects of ALAN

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LoNNe
ES1204
Loss of the Night Network

Measuring Night Sky Brightness

- There are different approaches to evaluate Night Sky Brightness to estimate Light Pollution:
  - From the space using satellites (e.g. Falchi et al 2016) or from International Space Station (e.g. Sánchez de Miguel 2015).
  - Measuring the night sky brightness from the ground with telescopes or specially designed devices.
- In our case we have done our work with ground-based measurements using SQM (Sky Quality Meter) devices.

Catalan Light Pollution Network (XCLCat)

- In cooperation with Catalan Service Against Light Pollution we have started a pilot plan of the Xarxa de Contaminació Lumínica de Catalunya (XCLCat).

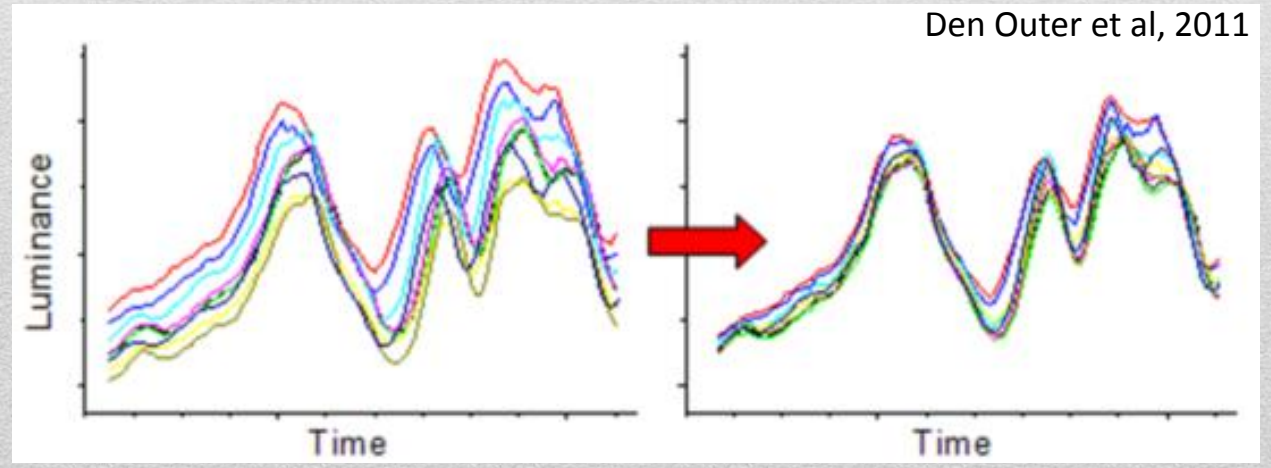
- To establish a measurement network we have defined composition, operation procedures and sites of each station.

- Each station is based on SQM-L devices, mainly LE (ethernet) but also LU (USB) can be used. All the devices have been intercalibrated to obtain comparable data.

- Data collection and storing is made using PySQM software (Nievas et al 2014). All the data sets are uploaded and stored in our server for the data processing and scientific analysis.

Intercalibration of Sky Quality Meters

- Intercalibration consists in a cross-calibration method based in pairing all the instruments. With this idea all the instruments will show the same value for the same situation.
- The initial accuracy of SQM is around 10% and with this method could be improved to 1% (eg. den Outer 2011, Bará 2013 o Ribas 2015).
- All the SQM devices of XCLCat have been intercalibrated in the station located in Centre d'Observació de l'Univers in Àger (Lleida, SPAIN).



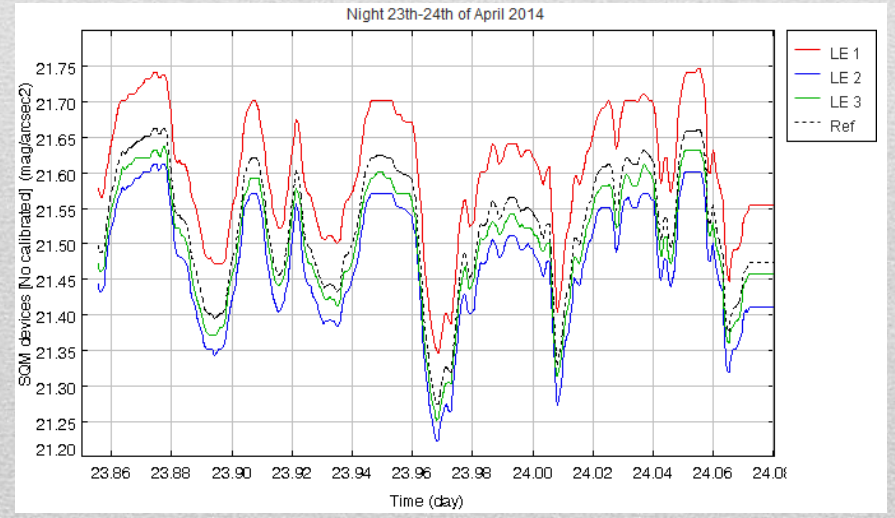
Intercalibration of Sky Quality Meters

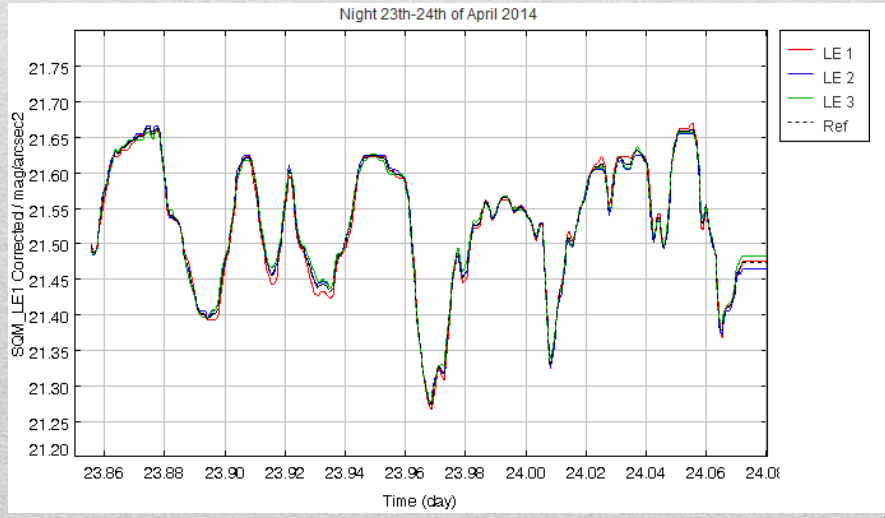
- Our strategy is based in the definition of a virtual reference device (*patró)*. This virtual device is defined from all the instruments in calibration. From this reference one by one all instruments are tuned.
- Different kind of fittings have been tested and we have seen an offset is good enough for our purposes.

$$mag_{patro}(t) = \frac{1}{n}\sum_{i=o}^{n} mag_i(t)$$

$$\text{Offset} = \frac{1}{d}\sum_{i=0}^{d} (mag_{patro}(i) - mag_{aparell}(i))$$

Núm. Dispositiu	Offset	σ_{offset}
SQM-LE-1	-0.079	0.013
SQM-LE-2	0.054	0.011
SQM-LE-3	0.025	0.009





Network of SQM stations in Catalunya

Àger (COU)

Sample	Num. Measurements	Magnitude (mag/arcsec^2)	σ_{mag} (mag/arcsec^2)
Total	361948	20.238	1.575
Without Moon	183564	21.380	0.430

Balaguer

Sample	Num. Measurements	Magnitude (mag/arcsec^2)	σ_{mag} (mag/arcsec^2)
Total	204441	18.131	1.370
Without Moon	102356	18.429	1.419

Barcelona

Sample	Num. Measurements	Magnitude (mag/arcsec^2)	σ_{mag} (mag/arcsec^2)
Total	229801	16.674	1.176
Without Moon	113146	16.747	1.235

Lleida

Sample	Num. Measurements	Magnitude (mag/arcsec^2)	σ_{mag} (mag/arcsec^2)
Total	234304	16.670	0.868
Without Moon	115680	16.711	0.923

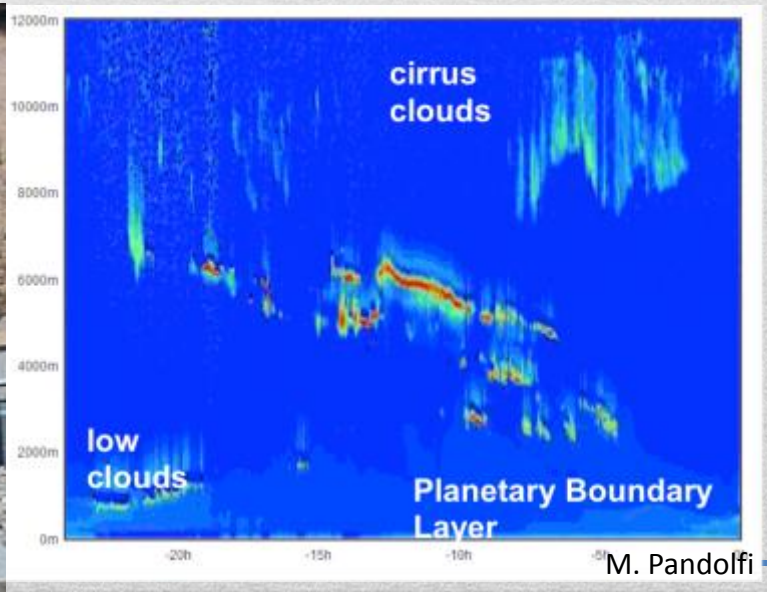
OAdM

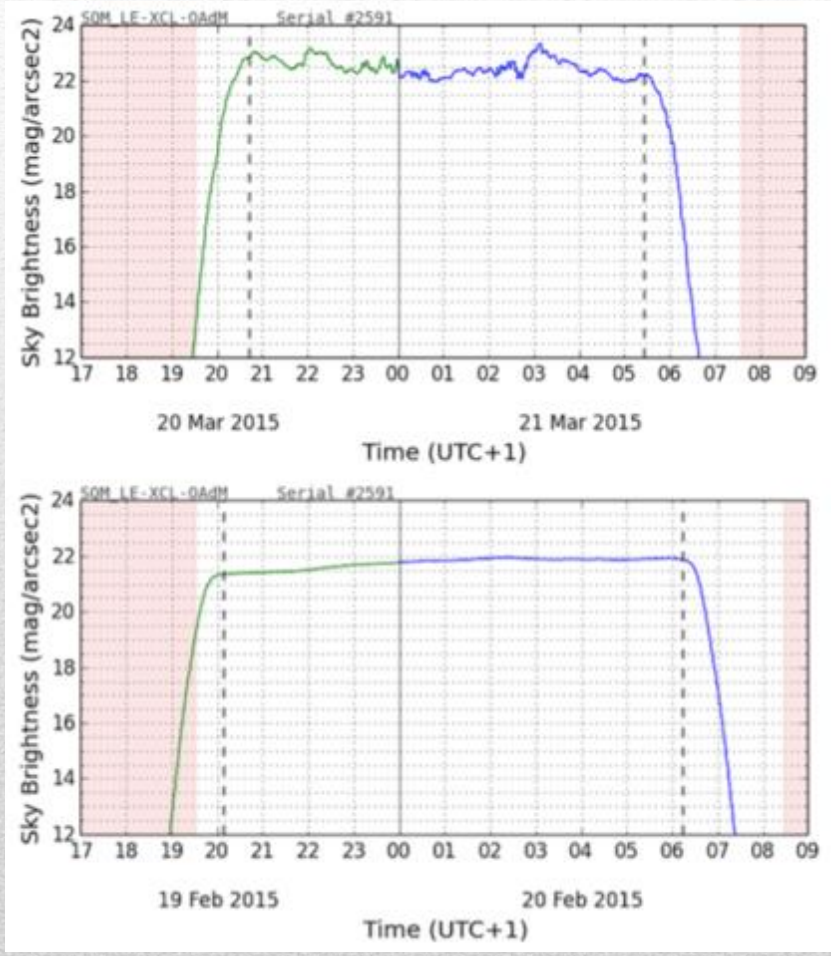
Sample	Num. Measurements	Magnitude (mag/arcsec^2)	σ_{mag} (mag/arcsec^2)
Total	246865	20.253	1.721
Without Moon	123652	21.480	0.587

Clouds and Night Sky Brightness

Evidences:

- Clouds and fog can generate oscillations in the measure of SQM's.
- It is well known that clouds or fog increase NSB in urban areas (e.g. Kyba 2011)
- We have ceilometer devices close to some SQM stations. Barcelona and Montsec (Àger-COU).



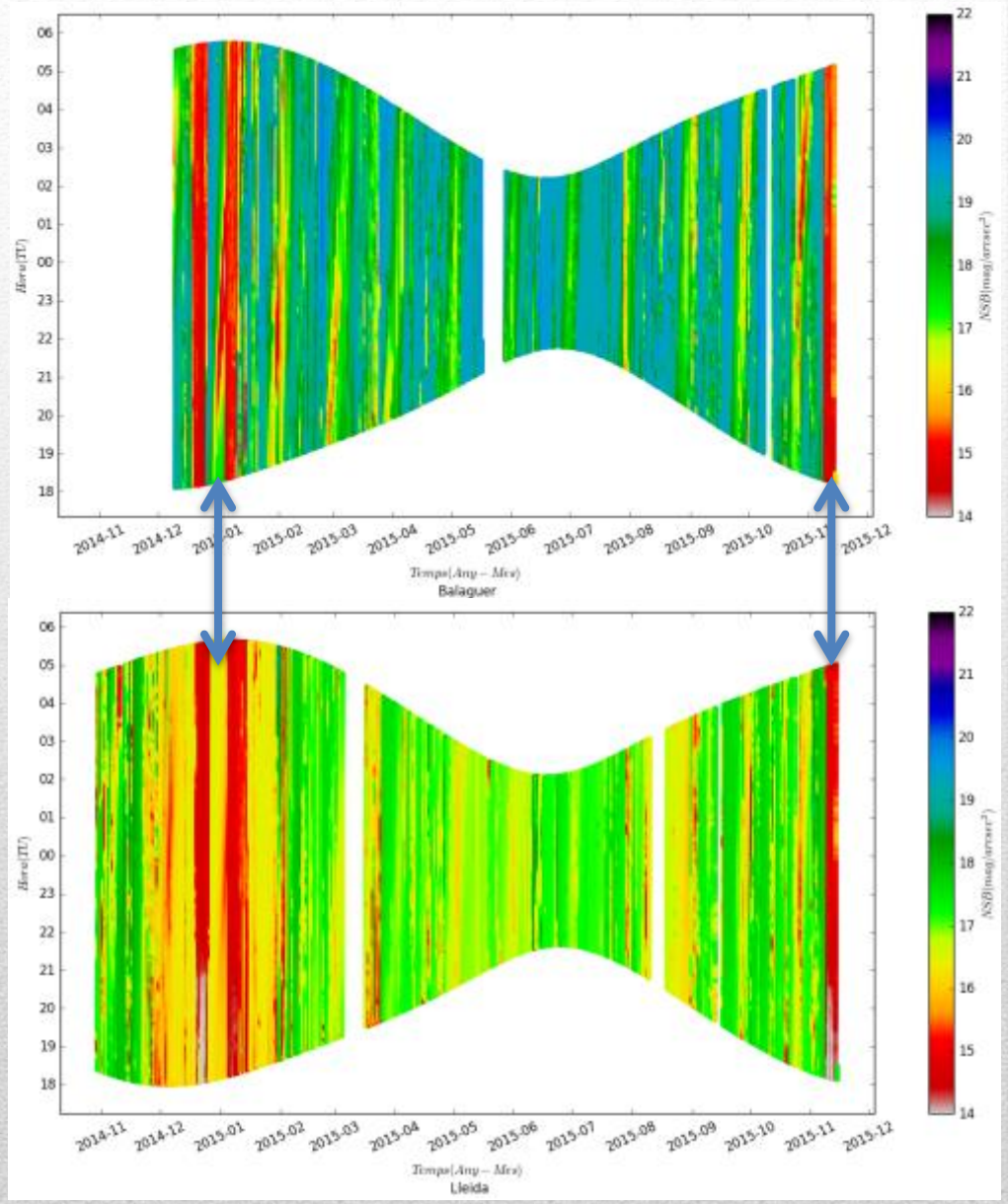


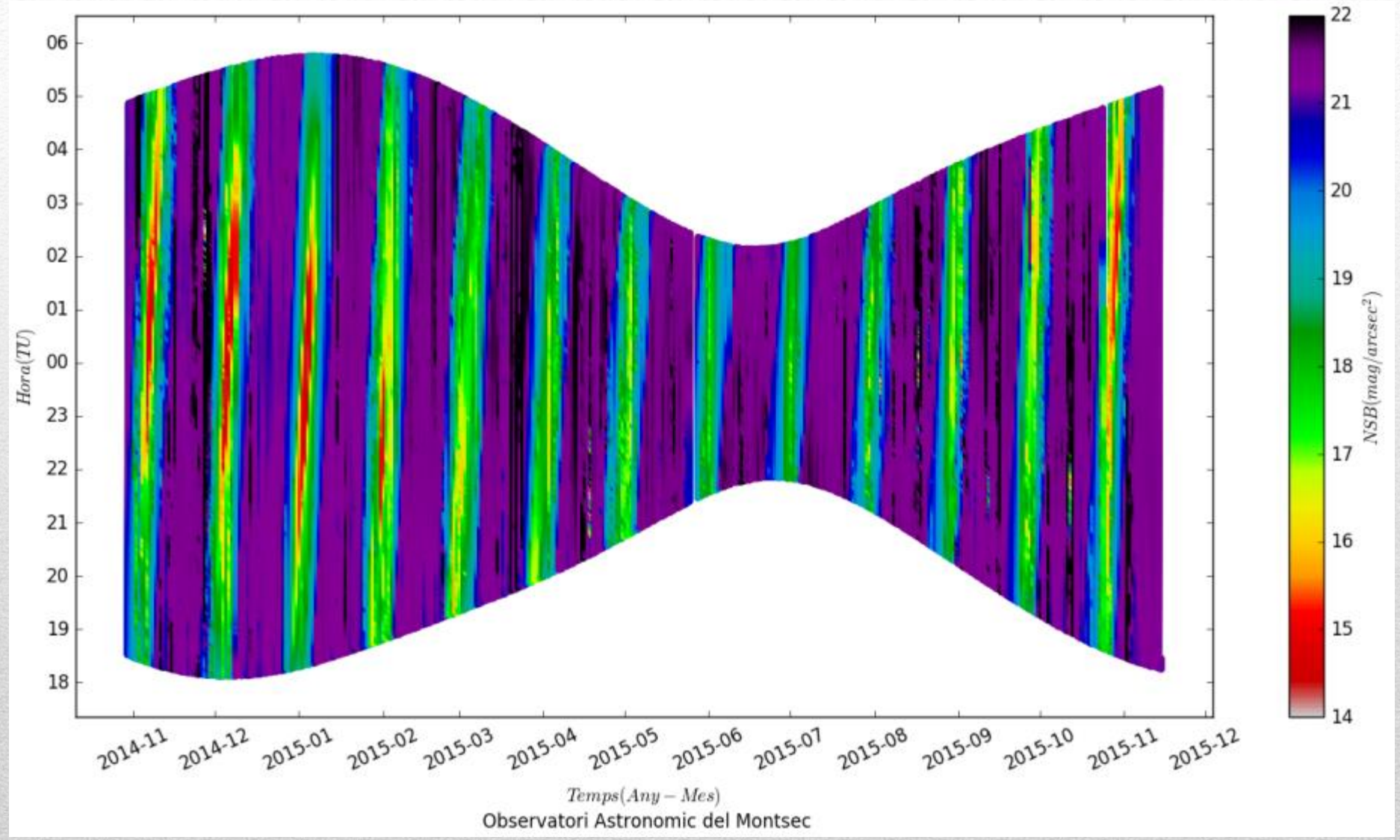
M. Pandolfi

Fog …

Balaguer & Lleida

- Without ceilometer data we can also detect some effects. This is the case of dense fog.
- Station in Balaguer, in a small size city, clearly show lunar cycle. In Lleida this cycle is not visible.
- Both station show three red vertical stripes. These brightest values are related to three huge fog periods. NSB increases up to 14-15 mag, the brightest measurements of our network.

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Temps(Any − Mes)
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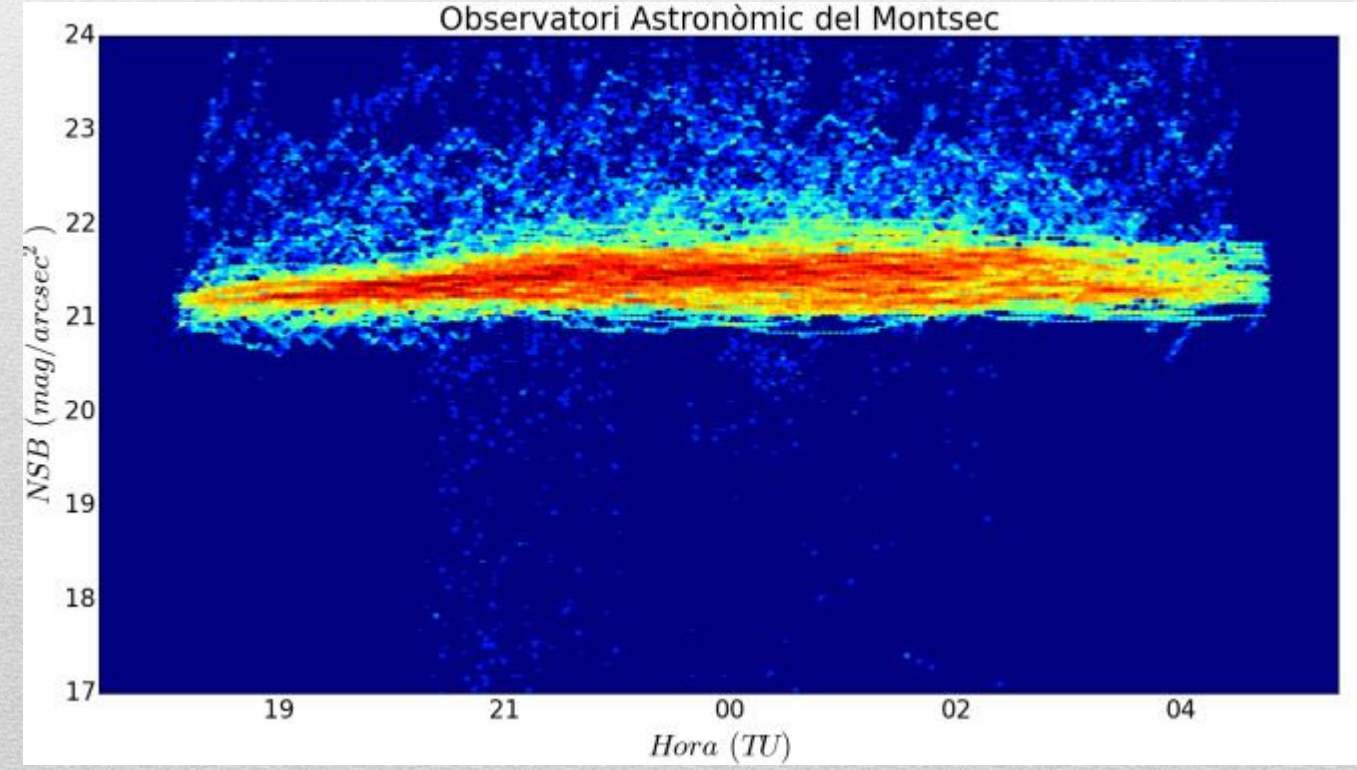
NSB(mag/arcsec²)
Observatori Astronomic del Montsec

Time Evolution

Observatori Astronòmic del Montsec

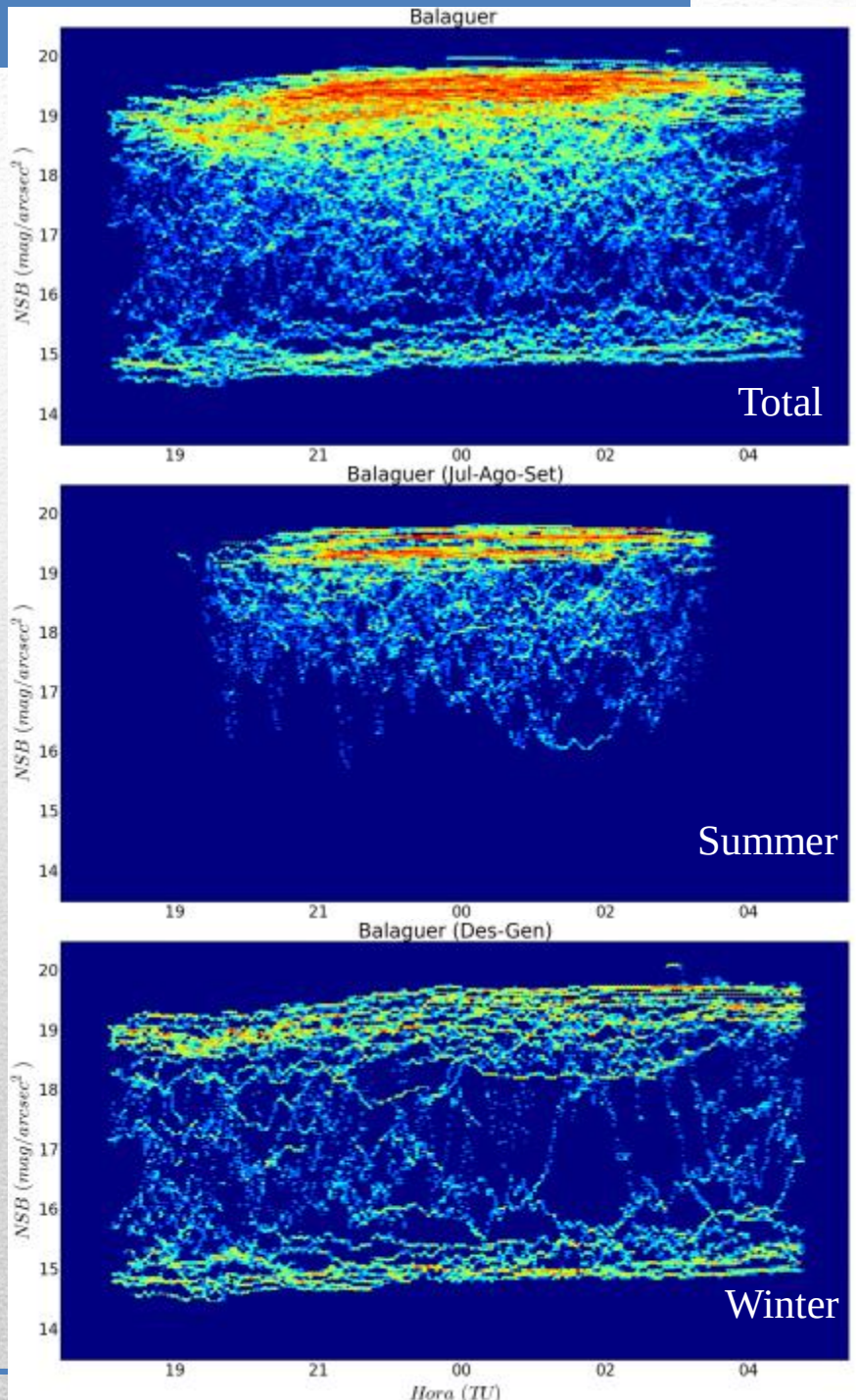
- The most common values are located in 21-22 mag.
- Scattered values moves towards darkest positions of the plot.
- What is the origin of this scattered values?



Time Evolution

Balaguer, Lleida & Barcelona

- In the small city of Balaguer the highest density is located in values between 18-20 magnitudes.
- Scattered values moves towards brightest side of the plot.
- In winter we can see the extremely bright values related to dense fog days.
- In Lleida we can see again the fog effect and we have detected an additional stripe related to Christmas lighting.
- In Barcelona we can see values moving towards brightest side. In this case there are not fog episodes, so no fog stripes are appearing.



Clouds and Night Sky Brightness

Adding ceilometer data:

- Using only astronomical night and without Moon data.
- We have used ceilometer data in Barcelona from August to November 2015.
- Clouds are increasing the NSB in all the cases. Low clouds show the highest increase in NSB, with values up to 2 mag brighter.

Barcelona

Sample	Num. Measurements	Magnitude (mag/arcsec^2)	σ_{mag} (mag/arcsec^2)
Total	27645	16.789	1.210
w/o Clouds	14375	17.707	0.398
With Clouds	13270	15.794	0.987
Low Clouds	8427	15.528	0.958
Medium Clouds	3642	16.075	0.844
High Clouds	1200	16.813	0.630

Clouds and Night Sky Brightness

- In Montsec – Protected area we are using ceilometer data obtained from November 2014 to April 2015.
- In dark places clouds are not always reflecting artificial light, because this is almost not present. The effect of clouds is blocking the natural light from the sky (stars, Milky Way, etc).
- This feature is specially clear with low clouds providing the darkest values ever measured with the SQM station (limit of the instrument). In the other side high clouds can still slightly increase the NSB.

	OAdM			Àger - COU		
Sample	**Num. Measur.**	**Magnitude (mag/arcsec^2)**	**σ_{mag} (mag/arcsec^2)**	**Num. Measur.**	**Magnitude (mag/arcsec^2)**	**σ_{mag} (mag/arcsec^2)**
Total	66492	21.472	0.595	72838	21.385	0.437
w/o Clouds	31752	21.439	0.561	34657	21.414	0.393
With Clouds	34740	21.502	0.623	38181	21.358	0.471
Low Clouds	7837	21.818	0.883	8581	21.515	0.701
Med. Clouds	15537	21.500	0.600	17023	21.352	0.441
High Clouds	11366	21.286	0.209	12577	21.258	0.221

Conclusions

- **For first time** Catalunya has a a permanent network to evaluate NSB. It has been started with 9 SQM stations. All the SQM devices have been **previously intercalibrated**.
- Time evolution during showed scattered values moving towards **dark side of the plot for natural protected areas** and to bright side for urban places.
- Annual study allowed us to identify the brightest values measured in urban areas. These are values are around 14 mag and are directly related with dense fog episodes in Lleida an Balaguer locations.
- Combining SQM data with ceilometer (clouds) data confirm the effect of increasing the NSB in urban areas. In the case of Barcelona **increases up to 2 magnitudes** of NSB.
- For first time we have shown quantitative values of clouds effects in dark places (Montsec). **Clouds** can darken the NSB, obtaining **the darkest values** of all the data sets.

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Thanks for your attention!

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