



The Globe at Night – Sky Brightness Monitoring Network

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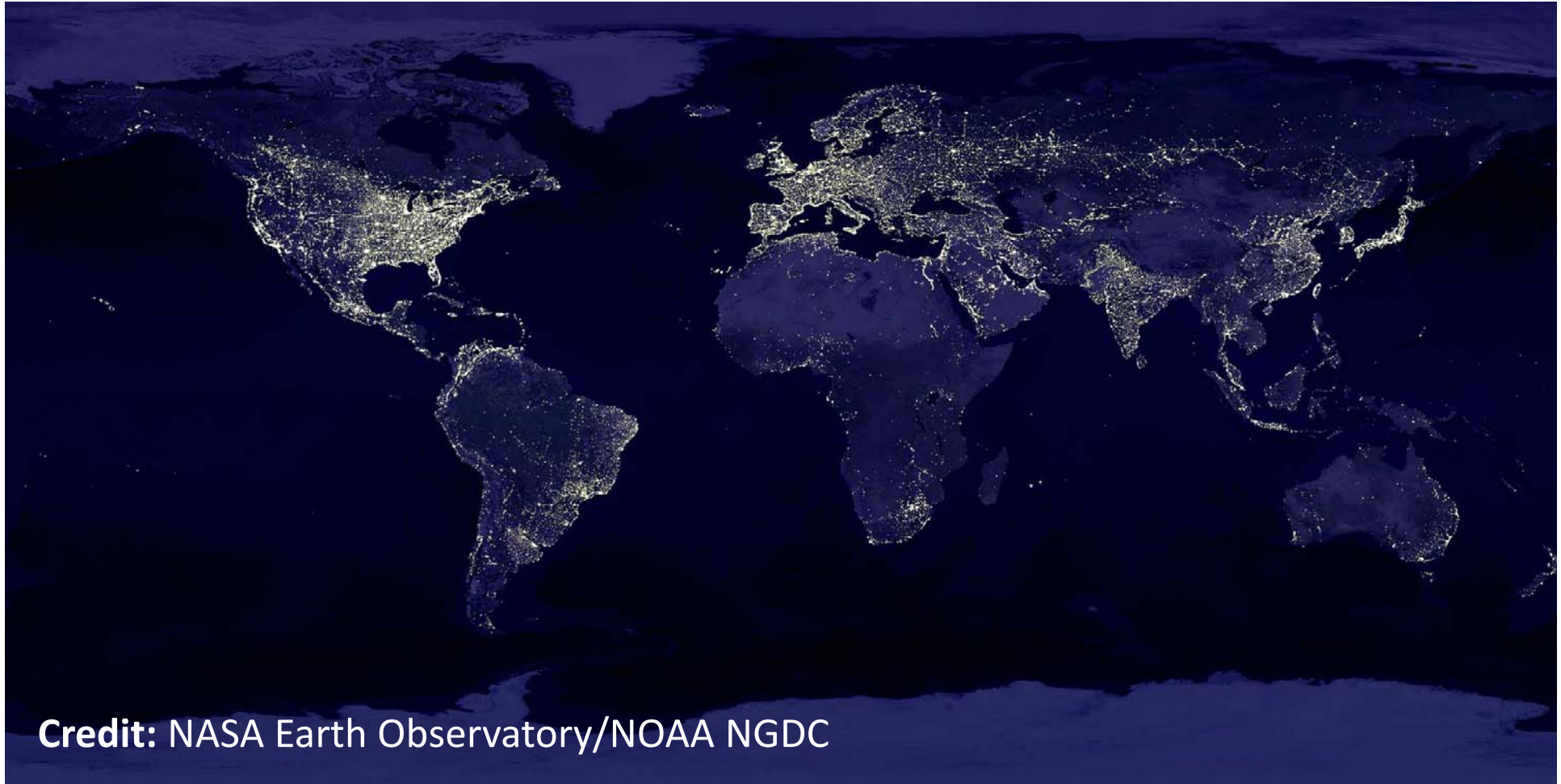
Dr Constance WALKER, National Optical Astronomy Observatory

Sze-leung CHEUNG, IAU Office for Astronomy Outreach

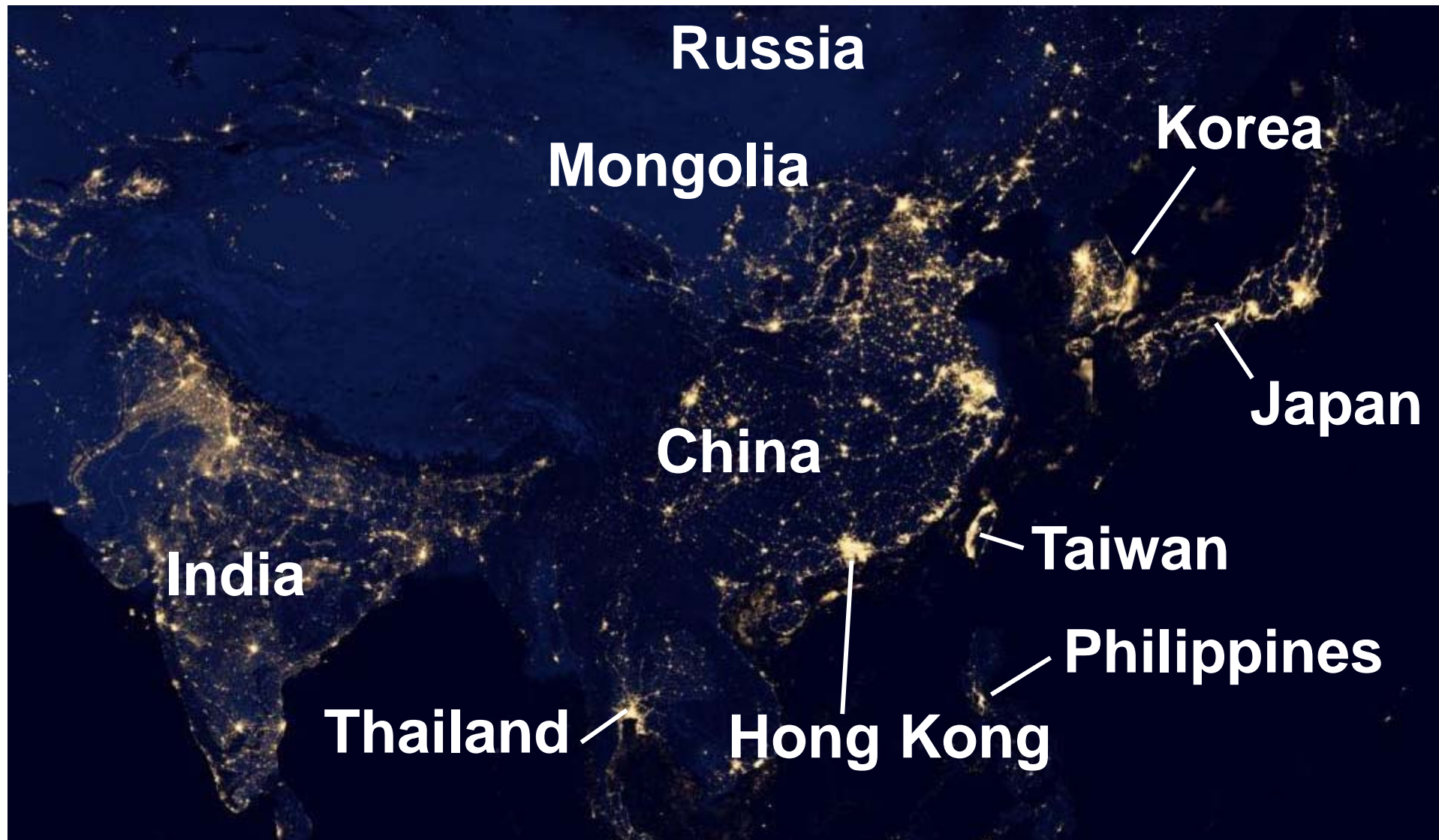
Dr Chun Shing Jason PUN, The University of Hong Kong

Supported by the HKU Knowledge Exchange fund

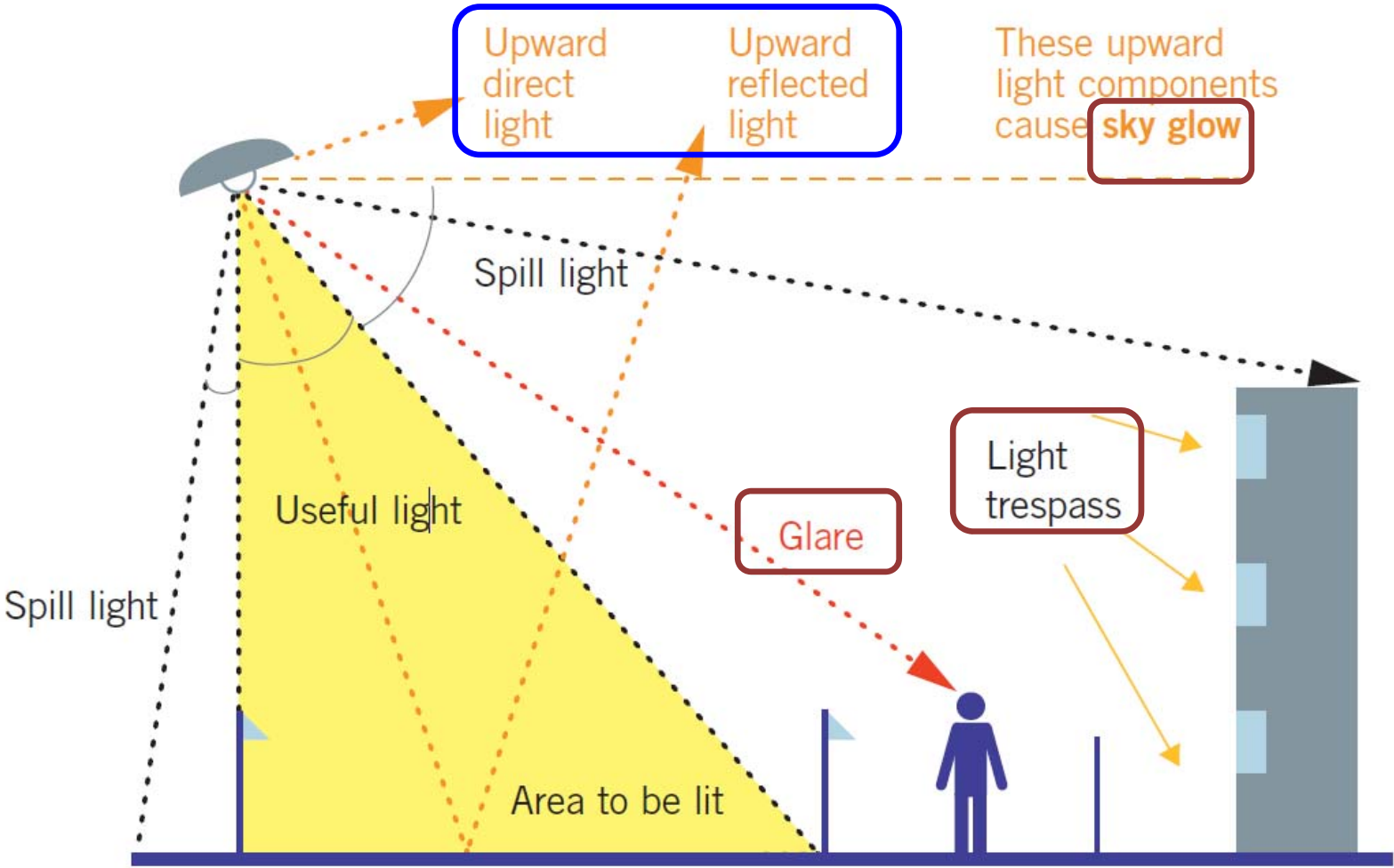
The Earth at Night



Credit: NASA Earth Observatory/NOAA NGDC



Light Pollution



Adverse effects of light pollution

- **Energy:** light not targeted at your eyes → wasted energy
- **Health:** light trespass, light nuisance
- **Environmental:** nocturnal species, unbalance ecological systems
- **Astronomical:** skyglow / “overglow” from urban lighting

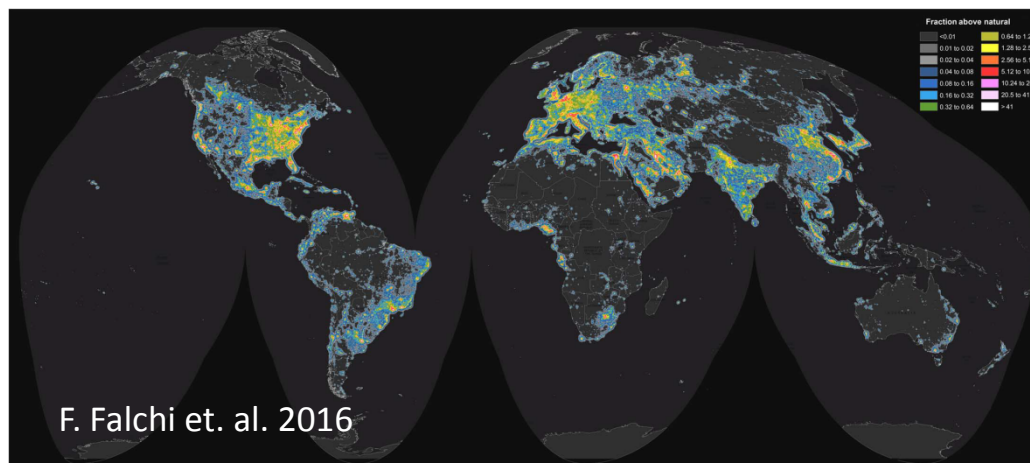
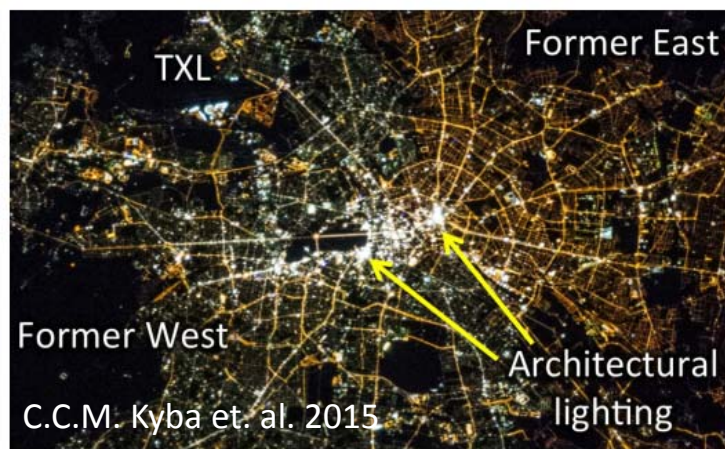
Light Pollution: environmental degradation due to artificial lighting

Challenge

**To measure the extent of light
pollution over large area**

1. Measuring Light Up ↑

- **Remote sensing** (DMSP, VIIRS, etc)
 - Upwelling light emitted directly from the light sources and light reflected off the Earth's surface.
 - Large spatial coverage (city → regional → global)
 - Challenging calibration issues but can be overcome
 - Low temporal sampling (specific mission for specialized flights or particular flyby moments)



2. Measuring skyglow $\uparrow\downarrow$

- **Limiting magnitude (e.g. *Globe at Night*)**
 - Citizen science project to report conditions of the night sky
 - Large geographical & temporal coverages with low cost
 - Uncertain data quality within the data set

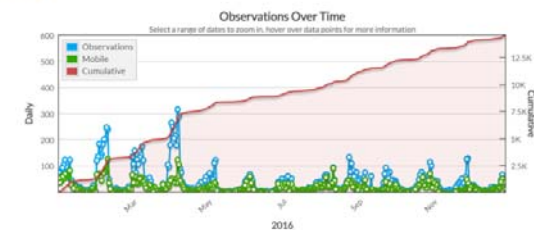


In 2016, Globe at Night received

14,611 Observations

from **97** Countries

& **52** US states



Data is submitted via mobile devices, as well as desktop & laptop computers

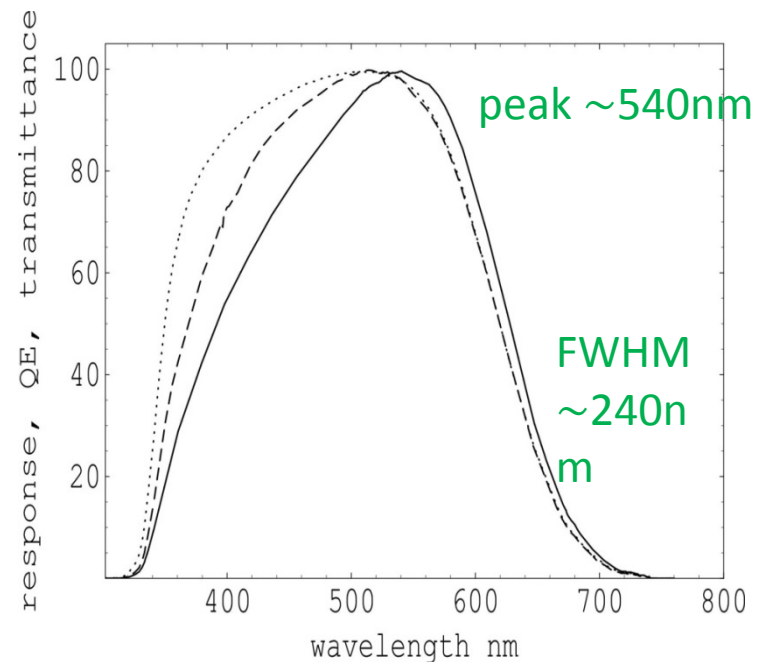


2. Measuring skyglow $\uparrow\downarrow$

- Measuring **Night Sky Brightness (NSB)**
 - Dedicated measuring devices: *Sky Quality Meter (SQM)*, can get accurate readings AND good temporal coverage
 - Temporal coverage provides a direct linkage with the pattern of light usage.



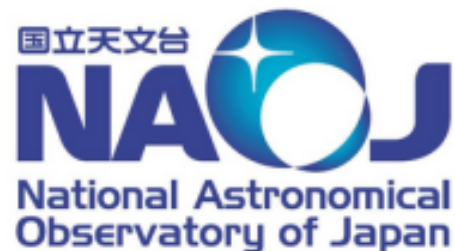
Image credit: Unihedron



P. Cinzano 2005

2. Measuring skyglow ↑↓

- Measuring **Night Sky Brightness (NSB)**
 - Dedicated measuring devices: *Sky Quality Meter (SQM)*, can get accurate readings AND good temporal coverage
 - Temporal coverage provides a direct linkage with the pattern of light usage.
 - Launched **Globe at Night – Sky Brightness Monitoring Network (GaN-MN)** in January 2015 (*Endorsed by the IAU Executive Committee Working Group for the **International Year of Light 2015** as a **major Cosmic Light program***)



The Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

- Project aims:
 - Promote a **Standardized** night sky measurement method for worldwide research on light pollution
 - Highlight the negative **environmental impacts** of abusive artificial lighting **for the general public and policy makers**
 - Sustain light pollution **public education** and **promote public engagement** by live worldwide night sky brightness data and night sky measuring programs

The Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

- Methodology and highlights:
 - Zenith night sky brightness (NSB) observation
 - Standardized observing method:
 - **SQM-LE**: Reasonable cost (~USD 300) and sturdy
 - Standard manufacturer housing
 - 30 seconds sampling interval
 - Standardized calibration scheme



Image credit: Taipei Astronomical Museum

The Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

- GaN-MN currently (June 2017) has:
 - **23** stations operating in **9** countries/regions in **3** continents
 - Over **30** million individual measurements had been collected

The Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

- Current stations (23 in total):



Data sharing:

1. Live NSB reporting (embedded in Google map)

<http://globeatnight-network.org/>



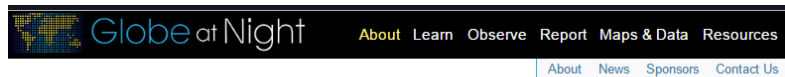
- Location currently at night: instantaneous real-time data
- Location currently during day-time: median value of NSB taken during previous night
- **Full sharing of real-time data among participants**

Data sharing:

2. Archival database (accessed through *Globe at Night* page)

<https://www.globeatnight.org/gan-mn.php>

(Home page > Maps & Data)



Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

The [GaN-MN](#) project, an extension of the original Globe at Night project, is a global night sky brightness monitoring network using a commercially available meter ([SQM-LE by Unihedron](#)) for long-term monitoring of the light pollution conditions in different places around the world.

The project aims to:

1. deploy a standardized night sky measurement method for worldwide light pollution research;
2. highlight the negative environmental impacts of abusive artificial lighting for the general public and policy makers; and
3. sustain light pollution public education and promote public engagement by live worldwide night sky brightness data and night sky measuring programs.

About the GaN-MN Data

Globe at Night is hosting data taken by this network. It can be downloaded as a CSV file that can be opened in any spreadsheet application. The file has the following headers:

`id`: unique ID for each data entry
`created`: timestamp according to the server clock
`received_utc`: timestamp converted to UTC
`received_adjusted`: timestamp corrected to local time
`sqmle_serial_number`: serial number of SQM-LE
`nsb`, `sensor_frequency`, `sensor_period_count`, `sensor_period_second`, `temperature`: raw data reported by the unit, where `nsb`: reading in magnitudes per square arc second, see section 8.6 of [the manual](#)
`device_code`: code of monitoring station (location of SQM-LE). [complete list](#)

Download the GaN-MN Data

2017	2016	2015	2014
<ul style="list-style-type: none">• Jan_2017 (163.4 MB)• Feb_2017 (127.0 MB)	<ul style="list-style-type: none">• Jan_2016 (92.1 MB)• Feb_2016 (81.5 MB)• Mar_2016 (91.5 MB)• Apr_2016 (93.1 MB)• May_2016 (95.9 MB)• Jun_2016 (110.4 MB)• Jul_2016 (128.0 MB)• Aug_2016 (142.2 MB)• Sep_2016 (144.1 MB)• Oct_2016 (155.0 MB)• Nov_2016 (144.0 MB)• Dec_2016 (157.4 MB)	<ul style="list-style-type: none">• Jan_2015 (18.5 MB)• Feb_2015 (31.0 MB)• Mar_2015 (38.8 MB)• Apr_2015 (40.6 MB)• May_2015 (34.8 MB)• Jun_2015 (37.1 MB)• Jul_2015 (37.2 MB)• Aug_2015 (70.0 MB)• Sep_2015 (87.3 MB)• Oct_2015 (85.5 MB)• Nov_2015 (86.0 MB)• Dec_2015 (92.0 MB)	<ul style="list-style-type: none">• Nov_2014 (2.9 MB)• Dec_2014 (9.0 MB)

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- New archival data uploaded once per month
- **Welcome to download to conduct analyses!**
- Limited data quality check. Please contact us for details.¹⁶

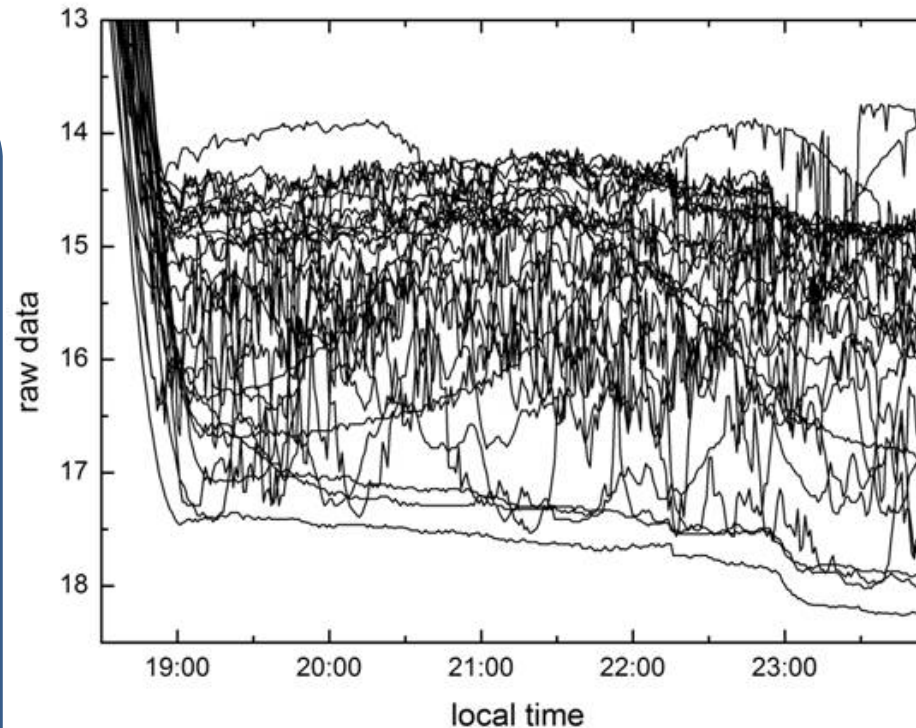
Raw data taken over one month at one place

WHAT CAUSED THESE VARIATIONS?

Astronomical



Galaxy, starlight,
moonlight,
sunlight, etc

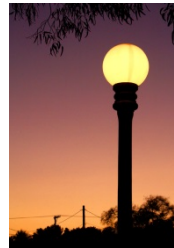


Meteorological / Atmospheric



Cloud, rain, air
pollution, etc

Anthropological



Public and private
lighting, different
colors, different
angles, LED, etc

Preliminary data analysis

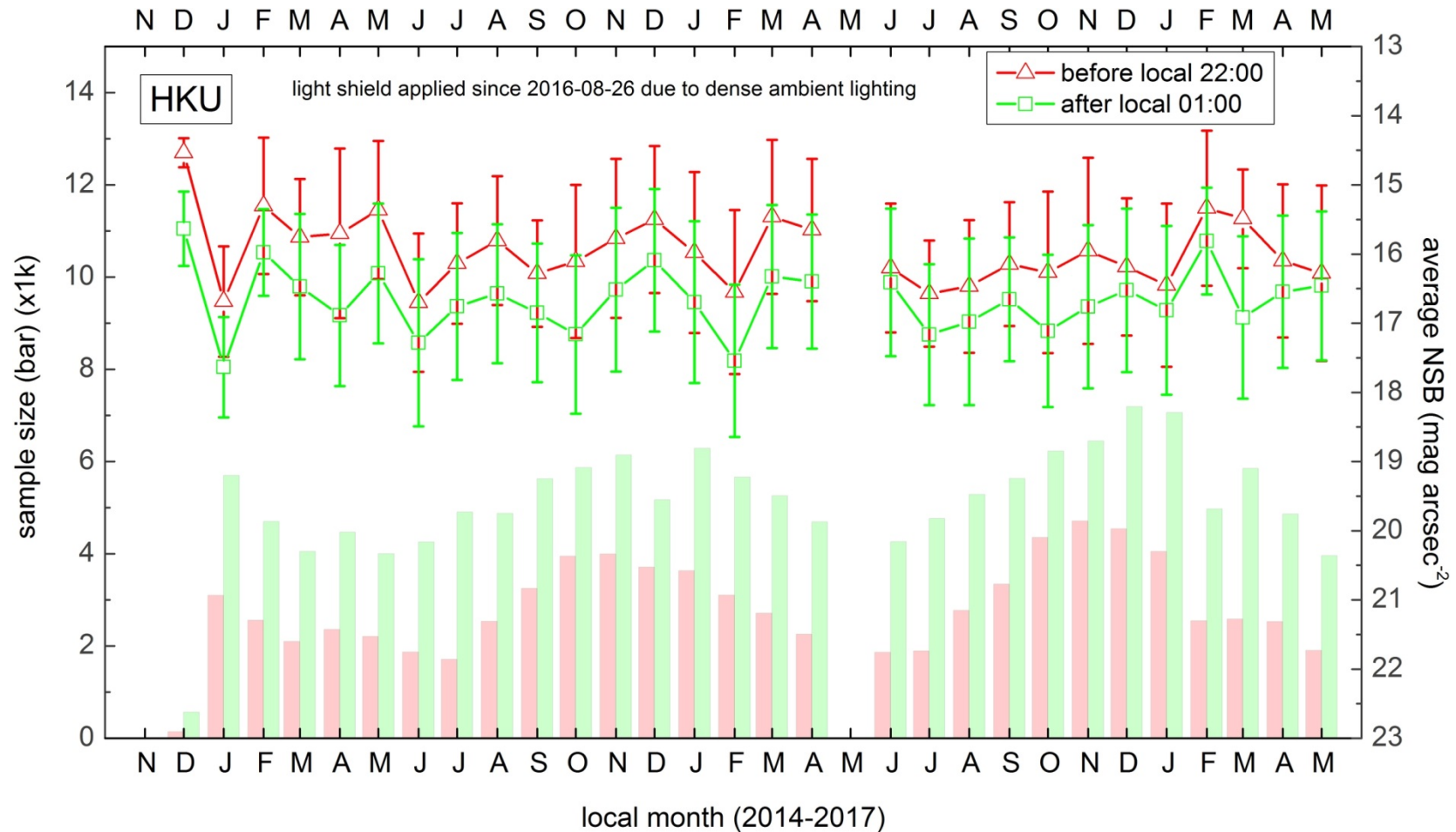
Data Selection

- For this particular analysis, focus on **how and how much artificial lighting affect** the observed NSB (urban skyglow)
- Data excluded due to:
 - Sun (twilight)
 - Moon
 - artificial activities (such as observatory functions, etc)
 - testing

Data Selection

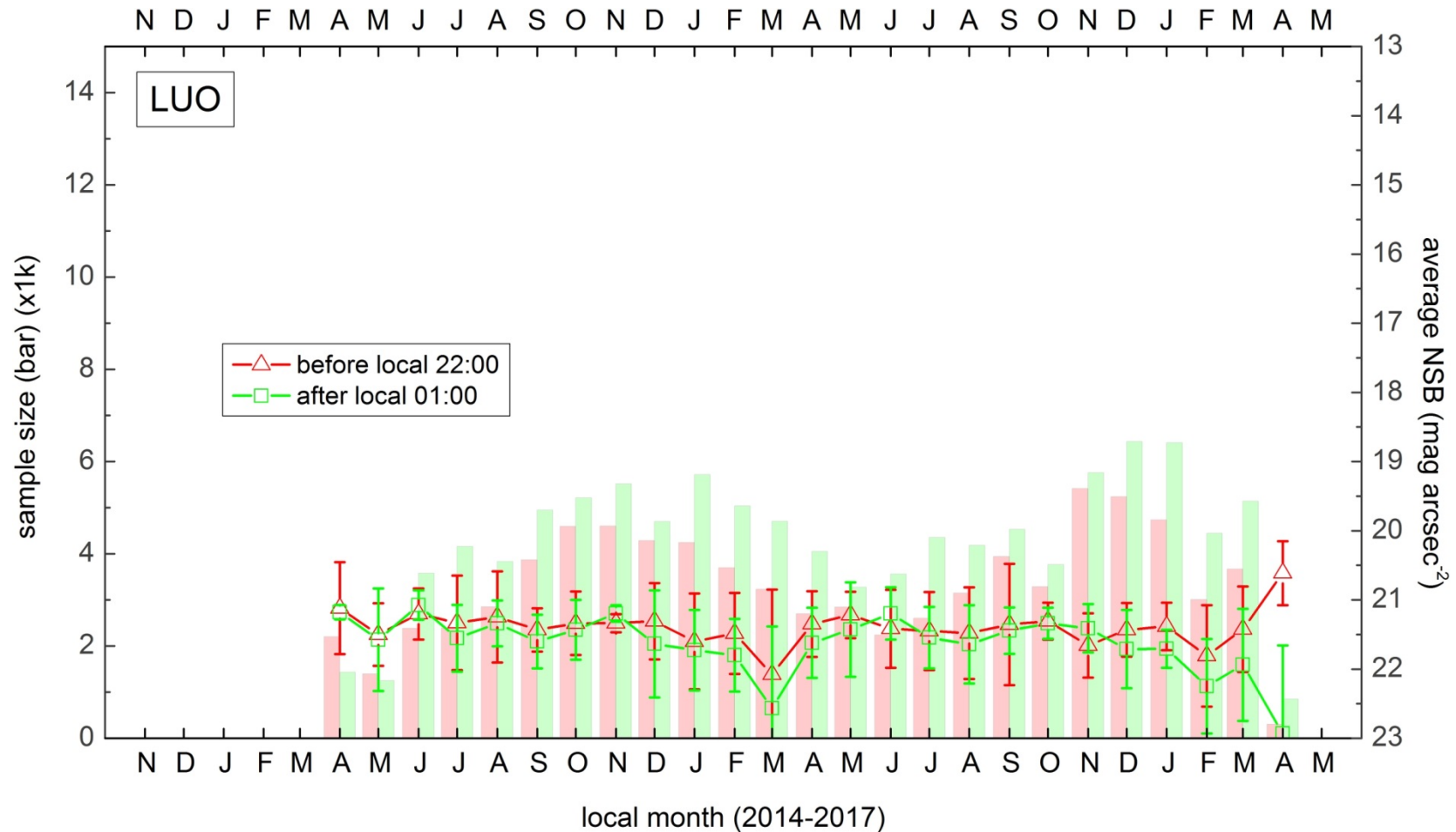
- For this particular analysis, focus on **how and how much artificial lighting affect** the observed NSB (urban skyglow)
- Data NOT excluded:
 - star/planetary light, Milky Way galaxy
 - rain
 - cloud

Monthly NSB average (red: before 10pm; green: after 1am) of a GaN-MN urban station (Hong Kong)



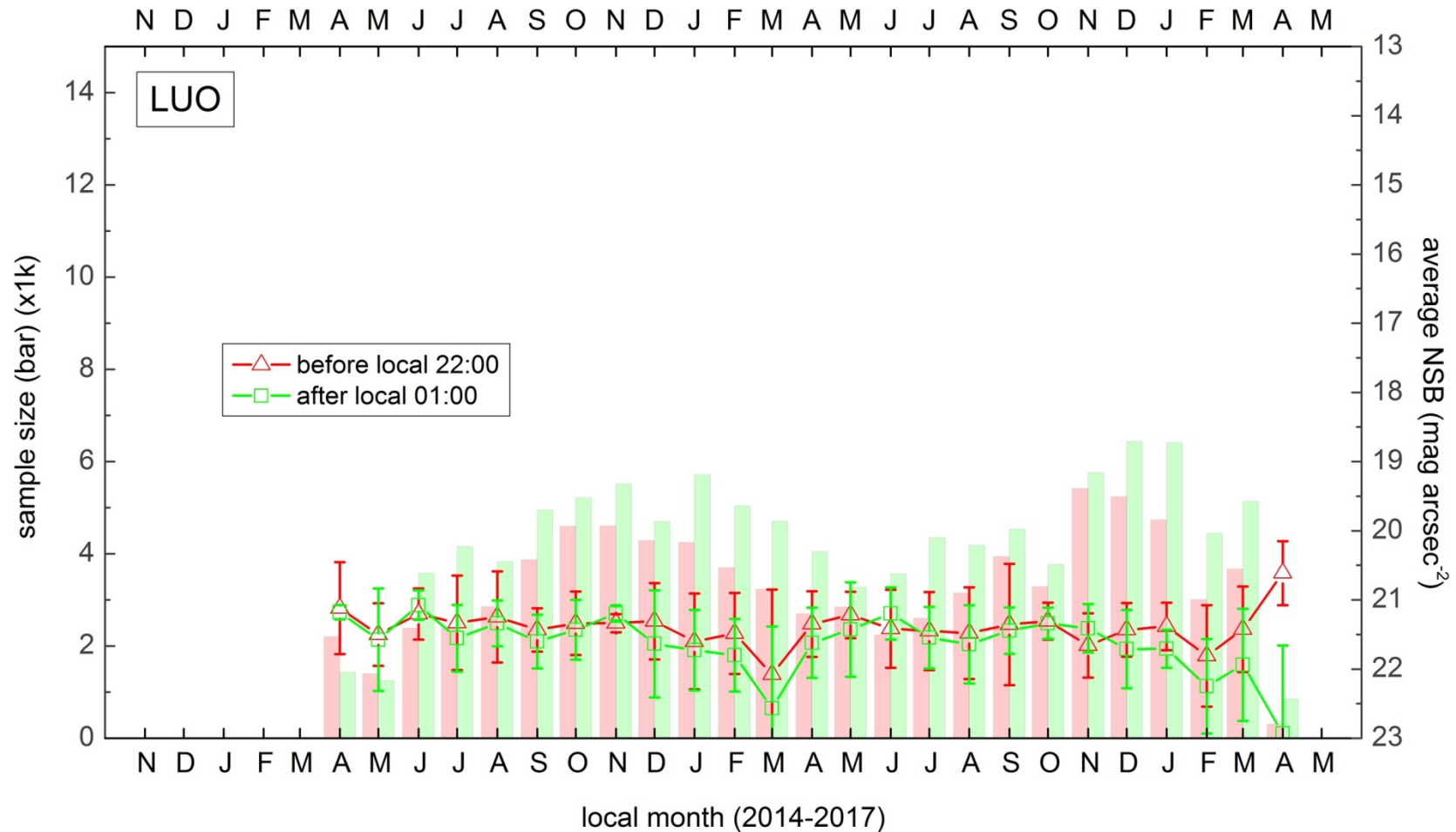
- ✓ Early evening brighter than late evening (lighting usage)
- ✓ Seasonal fluctuations (variations of cloud amount)

Monthly NSB average (red: before 10pm; green: after 1am) of a GaN-MN rural station (central mountain Taiwan)



- ✓ Much darker NSB (land utilization and population density)
- ✓ Similar early and late NSB (minimal lighting usage)

Monthly sample size (bars) and average NSB (lines) of a GaN-MN rural station (central mountain Taiwan)



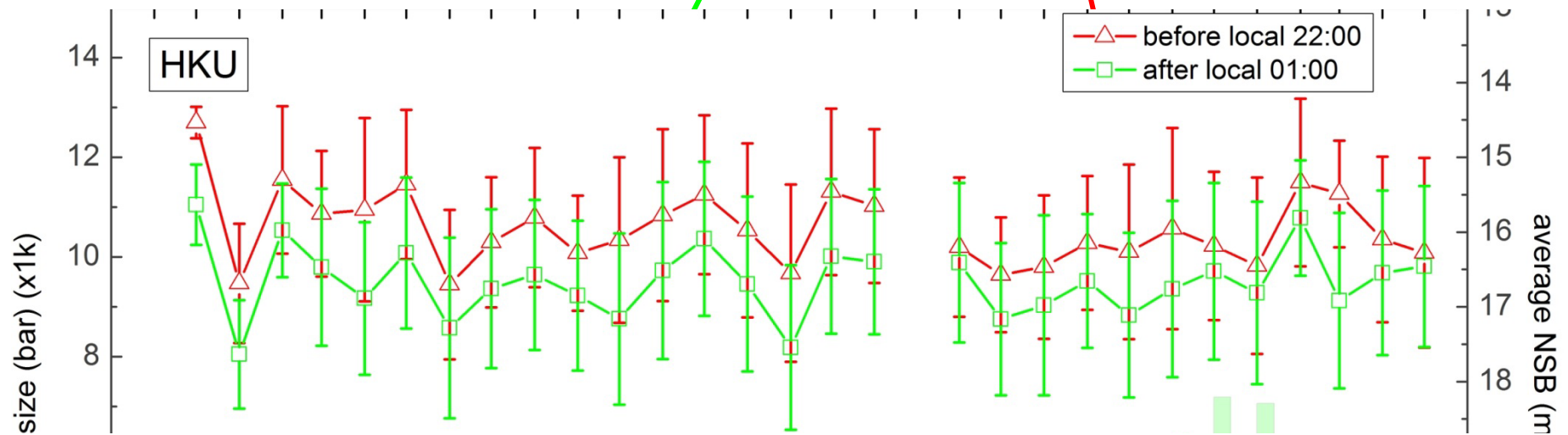
✓ Similar early and late NSB (minimal lighting usage)

Define parameter

$$\Delta\text{NSB}_{\text{late-early}} = \text{NSB}_{\text{late}} - \text{NSB}_{\text{early}}$$

Average NSB observed after
01:00 local time = NSB_{late}

Average NSB observed before
22:00 local time = $\text{NSB}_{\text{early}}$



Positive $\Delta\text{NSB}_{\text{late-early}}$ \Rightarrow **darker** after mid-night

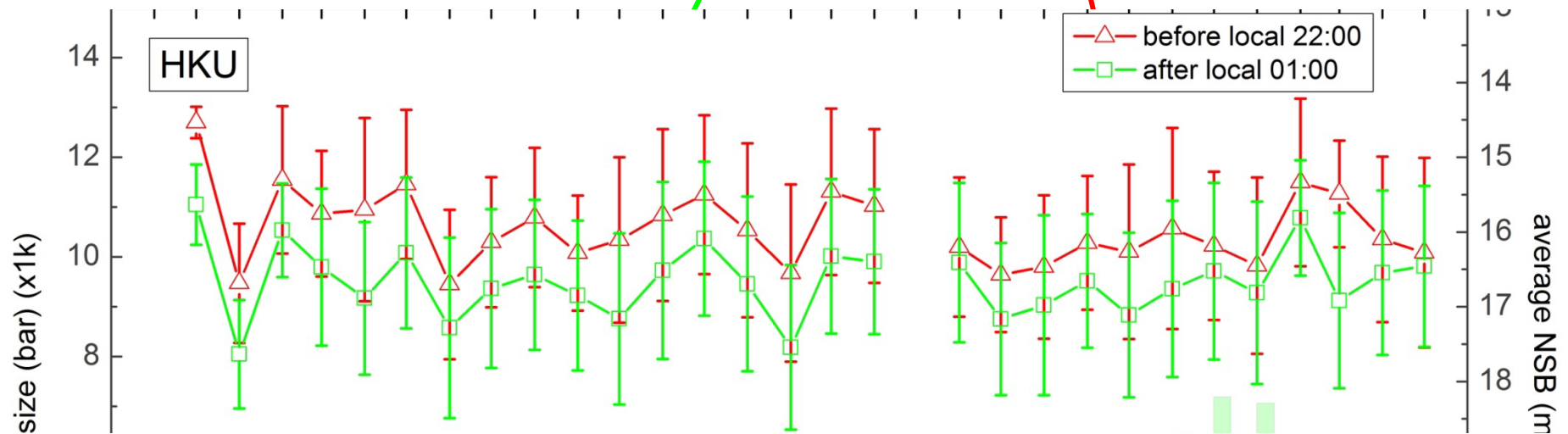
Negative $\Delta\text{NSB}_{\text{late-early}}$ \Rightarrow **brighter** after mid-night

Define parameter

$$\Delta\text{NSB}_{\text{late-early}} = \text{NSB}_{\text{late}} - \text{NSB}_{\text{early}}$$

Average NSB observed after
01:00 local time = NSB_{late}

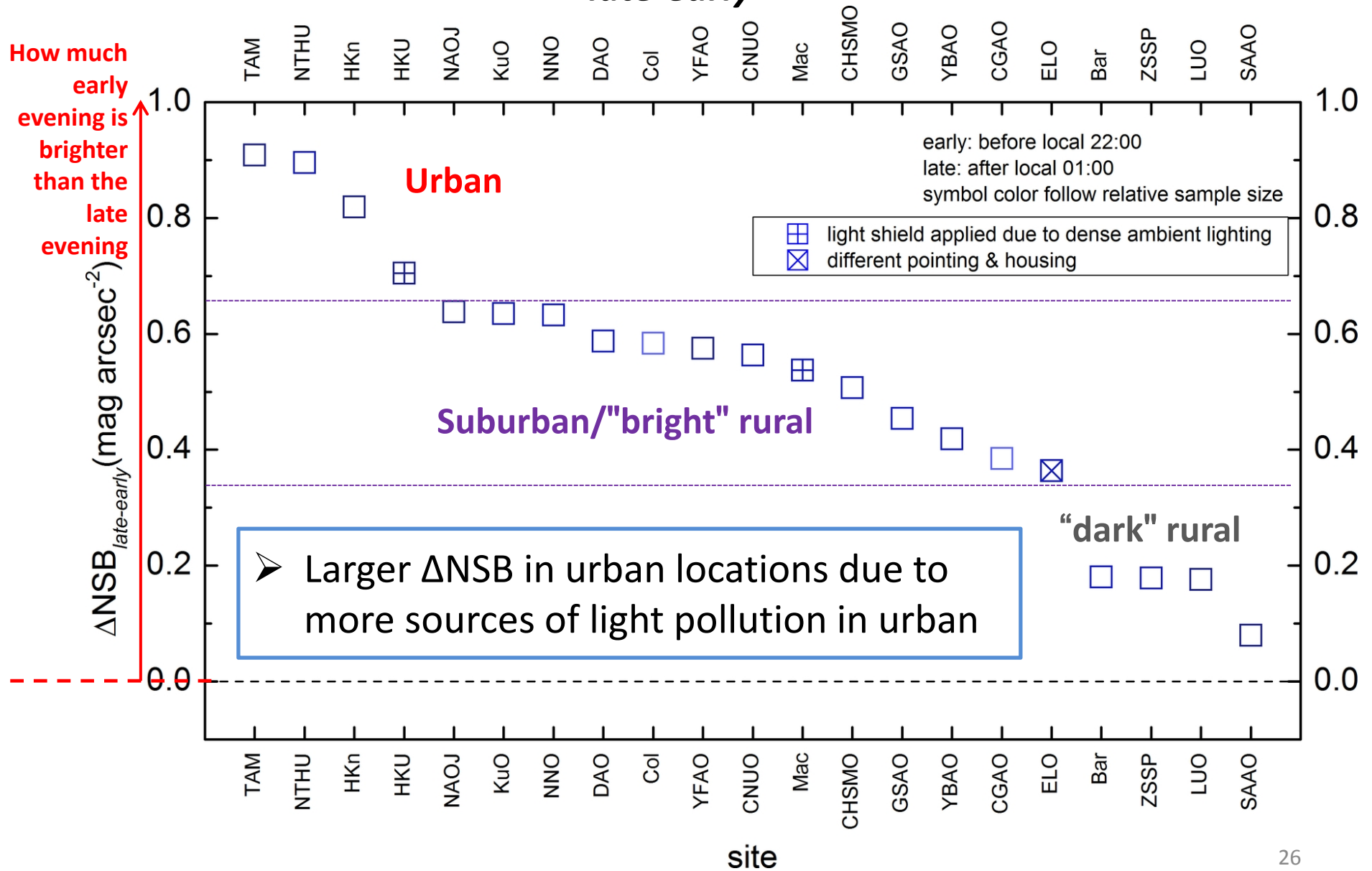
Average NSB observed before
22:00 local time = $\text{NSB}_{\text{early}}$



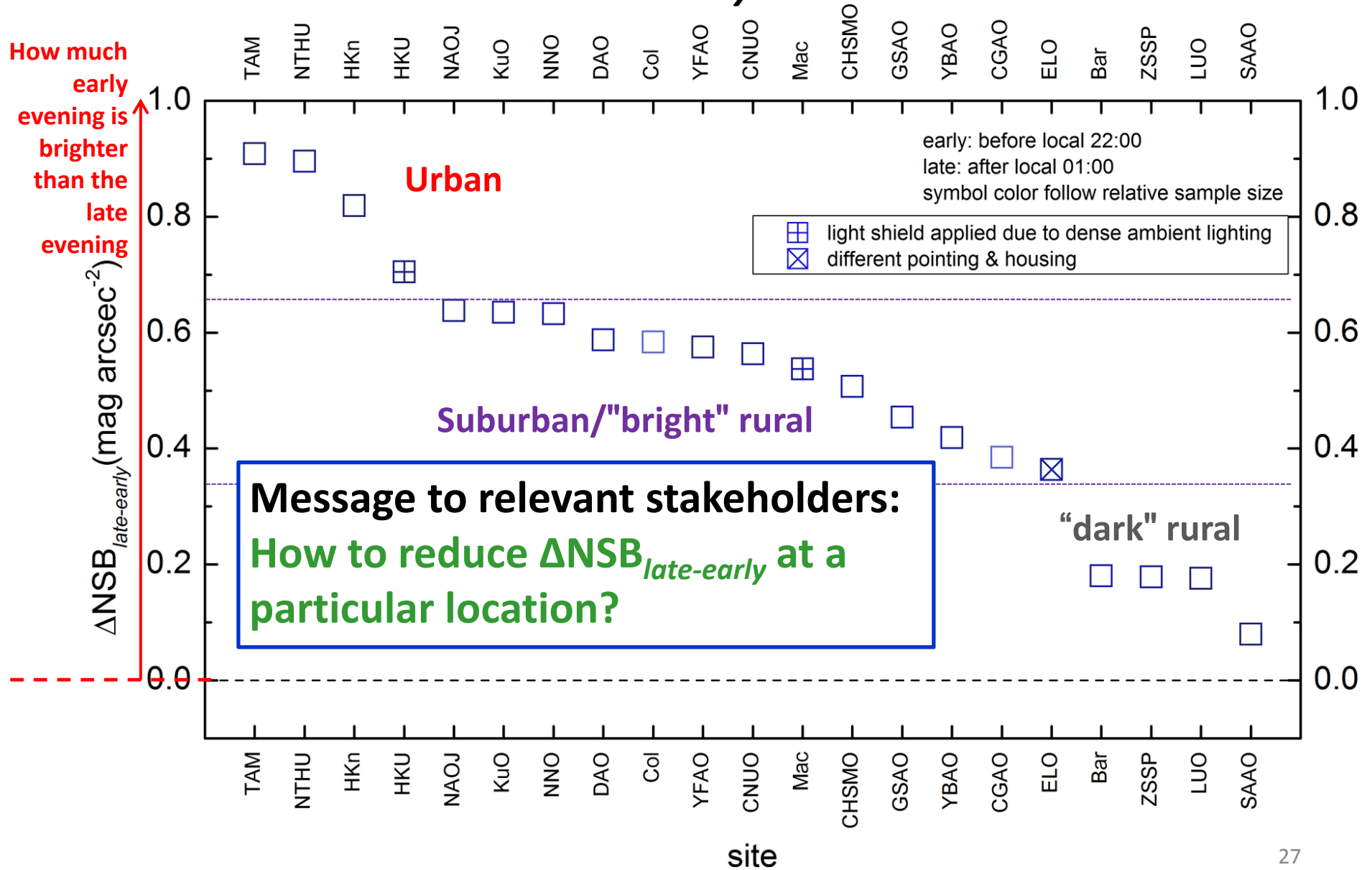
The parameter $\Delta\text{NSB}_{\text{late-early}}$ measures
how much light is turned off each evening.

Challenge: How to minimize $\Delta\text{NSB}_{\text{late-early}}$?

Average $\Delta\text{NSB}_{\text{late-early}}$ for each station

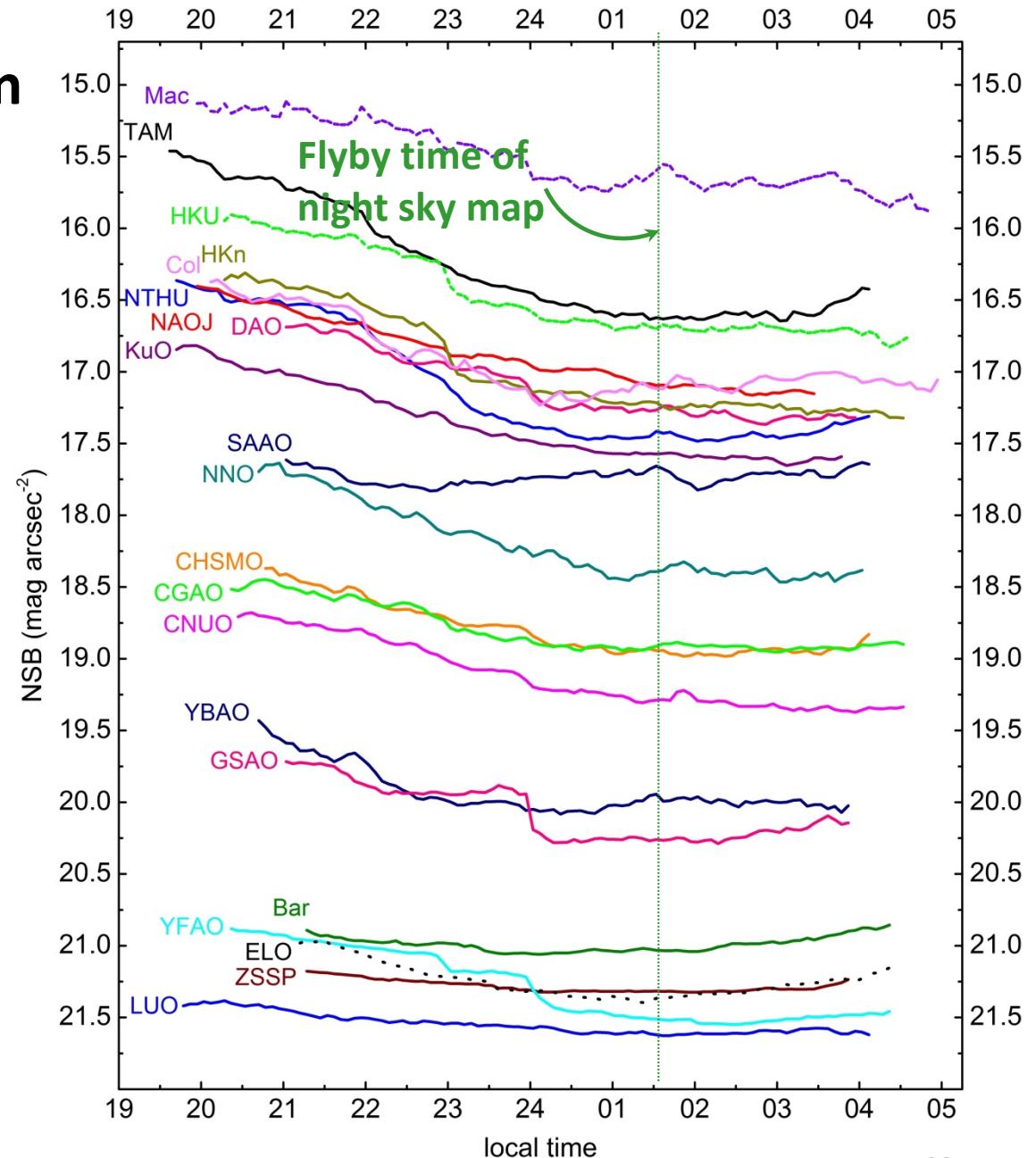


Average $\Delta\text{NSB}_{\text{late-early}}$ for each station



Average nightly variation of NSB for each station

- Huge range of NSB among stations
- Different latitudes of stations lead to different sampling time (astro dark durations)
- **Each curve is unique:**
Depicts the outdoor lighting usage at that particular location



Communicating with the public on light pollution

Hong Kong – Asia's World City



Hong Kong, a city of seven million people welcomes its heritage of diverse cultures. Its character is a mix of East and West, from its Chinese roots with traditions from its time as a British colony.



Religious worshipping – traditional Chinese style

A big challenge in a city deeply proud of her identity as the ***bright*** "Pearl of the Orient"

Strolling through this exciting city is difficult to picture that it was once a group of fishing villages. Although relatively small in size, the choice of things to see and do is vast. Visitors will be intrigued by the mix of old and new.

Visit museums, see colonial buildings alongside modern architecture; explore historical landmarks, Buddhist and Taoist temples hidden amid the contemporary skyscrapers; catch a show; shop and dine or have fun at a theme park. There are many ways to get around Hong Kong; it is internationally famous for its safe, affordable and reliable public transport system.

Communicating with the public on light pollution (some personal thoughts)

- Focus on **educating the general public on the concept of light pollution** through
 - Citizen-science research
 - School-based activities (workshop, student competitions, ...)
 - Public activities (reaching out to the biggest audience)
 - Field-trips (linking light pollution and its environmental impacts)
 - Public lectures and sharing sessions with stakeholders
 - *Teachers, students, amateur astronomers, ...*
 - *Architect, real estate developer, building surveyors, engineers, housing estate managers, lighting designers, medical professionals,*
 - Media engagements (mostly traditional mass media)

A Survey of light pollution in Hong Kong (2007 – 09)

- **Citizen science project**
- Report NSB readings from SQM through the web
- Invited high school students and volunteers (amateurs, camp-site managers) to participate
- Over 2000 measurements from 199 locations with 171 participants



Community Light Pollution Reach-out (2012-13): School program

- Organized **workshops for 4 secondary schools**
- Rundown of the workshop:
 - Lecture;
 - Measurement workshop;
 - Portable-dome observation
 - Exhibition
 - Student research



Community Light Pollution Reach-out (2012-13): Science Roadshow

- Science Roadshow at the Harbor front **during Earth Hour 2013**
- Allow participants to experience the dark sky when many city lights are out
- Contents of the Roadshow:
 1. Real-time nights sky measurements;
 2. Demonstrations;
 3. Video presentations (<https://youtu.be/mc7ipCEXGsc>);
 4. Panel exhibitions



Promotion Light Pollution Awareness: Research & Photography Competitions (2013-14)



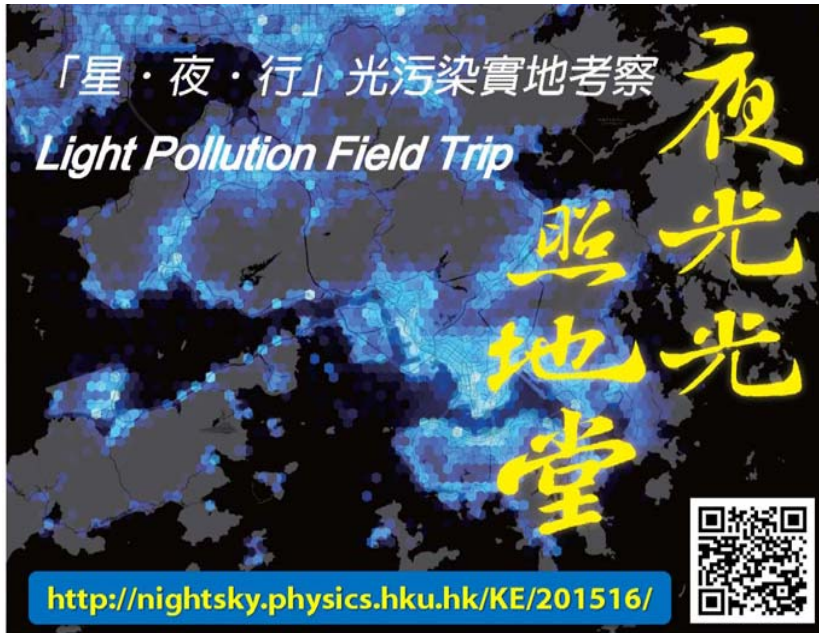


Light Pollution Photography Competition 2014 First-runner Up “Hong Kong Beneath the Castle Peak (Credit: Mr Leung Hoi Kit)



Light Pollution Photography Competition 2014 Winner “Light Polluting Our Homes” (Credit: Mr Kwok Man Tai)

Promotion Light Pollution Awareness: Research & Video Competitions (2015-16)



「星·夜·行」光污染實地考察
Light Pollution Field Trip

夜光
照地
堂

<http://nightsky.physics.hku.hk/KE/201516/>

日期：2015年11月28日（星期六）
Date: 28 November 2015 (Saturday)

時間：下午4時至晚上9時半
Time: 4:00pm - 9:30pm

地點：香港大學明華綜合大樓T4講堂（集合地點）、大埔滘自然護理區、西貢天文公園
Venue: HKU Meng Wah Complex Lecture Hall T4 (gathering), Tai Po Kau Nature Reserve, Astropark

費用全免，名額有限，先到先得。
Free of charge, limited quota, first come, first served

截止報名日期：2015年11月13日
Deadline: 13 November 2015

活動內容：介紹光污染、簡介「光污染研究比賽2015-16」及「光污染短片製作比賽2015-16」、螢火蟲觀賞、觀星、到受光污染影響的地點考察
Contents: Introduction to light pollution, briefing of "Light Pollution Research Competition 2015-16" and "Light Pollution Video Competition 2015-16", firefly viewing, stargazing, visit to sites affected by light pollution

歡迎公眾參與 Welcome for public
報名及活動詳情請瀏覽上述網站 Please visit the above website for details

Light Pollution field trip:

- Start with introduction talks on light pollution
- To experience impacts of light pollution first-hand :

1. Start from urban city center
2. Country park firefly viewing
3. Stargazing in astro-park

Promotion Light Pollution Awareness: Research & Video Competitions (2015-16)



Winning entry
<https://youtu.be/oCGmrZ74Hg4/>

Public roadshows to promote light pollution education (2016-17)

Bringing the message of light reduction AND dark sky preservation to the public:

- Astronomy-related education activities
- Telescope observations
- Computer simulation of impact of light pollution
- Hands-on experience of light pollution measurement
- “Good” lighting demonstration



SciFest 2017



Public roadshows to promote light pollution education (2016-17)

Bringing the message of light reduction AND dark sky preservation to the public:

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Outreach in Shopping Mall



Public roadshows to promote light pollution education (2016-17)

Bringing the message of light reduction AND dark sky preservation to the public:

- Astronomy-related education activities
- Telescope observations
- Computer simulation of impact of light pollution
- Hands-on experience of light pollution measurement
- “Good” lighting demonstration

Outreach in city park



Communicating with the public on light pollution (some personal thoughts)

- ~~Stakeholders and professionals in the community~~
(We talk to everyone who's willing to listen!)
 - Public lectures for general public and professional bodies, e.g.
 - The Hong Kong Institution of Engineers
 - The Hong Kong Institute of Housing (Managers)
 - The Hong Kong Institute of Surveyors
 - *Top 5 real estate developer in Hong Kong*
 - Junior Chamber International Harbour Hong Kong Ltd
 - International Association of Lighting Designers
 - The Hong Kong Paediatric Association
- **Challenges:**
 - Learn the roles of various professionals in the community
 - Learn the “language” of the different communities

Communicating with the public on light pollution (some personal thoughts)

- **Media:**

- Light pollution a new issue when we started in 2003
- 140 newspaper/webpage reports, 30 TV/radio appearances including CNN, Wall Street Journal, Financial Times, CCTV, ...
- Usually sympathetic of our concerns and willing to listen
- Fast-thinking and efficient in learning new ideas and concepts



Communicating with the public on light pollution (some personal thoughts)

- **Challenges:**

- Explaining quantitative and logically complex arguments
- It was a struggle to explain “*The night sky in Tsim Sha Tsui is 1200 times brighter than the dark standard.*” to reporters
- Striking ***balance between objective scientific positions and passionate social advocacy***
- Schedule: local newspaper reporters usually complete their articles after 6pm (phone calls during dinner time)
- **Needs to be very careful with all information released.**
- It takes valuable **time and patience** to handle the different requests

Please join us!

1. Join us to conduct analyses of the data received:
 - Archival data constantly updated
2. Join us to be a participating station:
 - **All you need are: A working SQM-LE, power supply, and network**
 - Understand light pollution in your location and present it to real-time.
 - Data to present to policy makers
 - Light pollution is a **local problem**, need **local data**, and hopefully develop **local solutions**.

Thank you!

For more information on the GaN-MN or willing to join,

- 1) Visit: <http://globeatnight-network.org/>
- 2) Email me (C. S. Jason Pun) at:
globeatnight.network@gmail.com or
gan-mn@qq.com

Backup

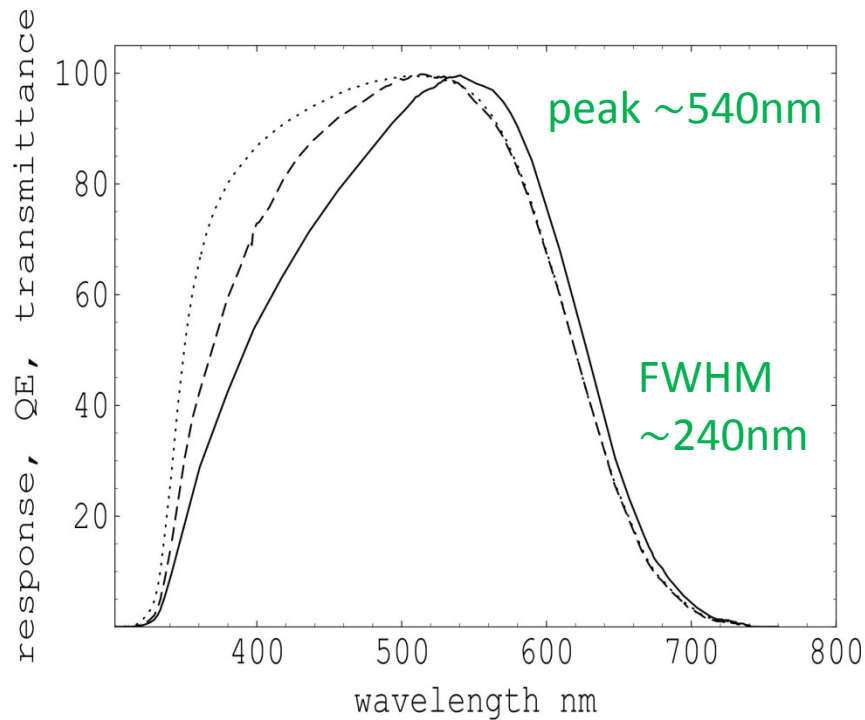
Sky Quality Meter – Lens Ethernet (SQM-LE)



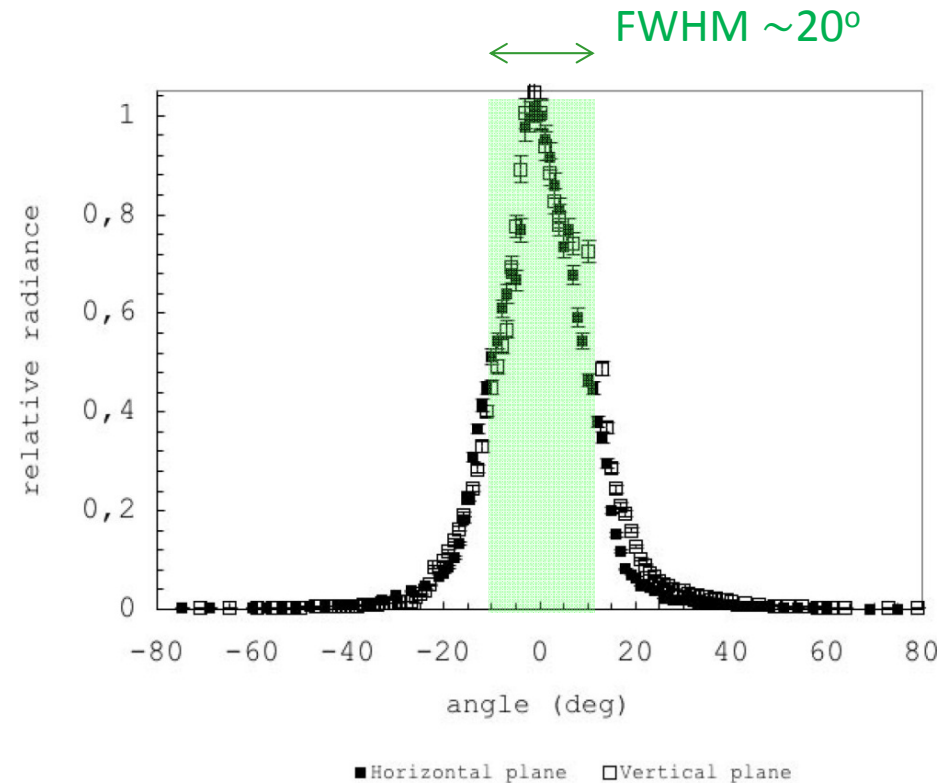
Figure source: Unihedron

- Manufacturer: Unihedron (Canada)
- Light sensor: TAOS TSL237 High-Sensitivity Light-to-Frequency Converter
- Near-IR blocking filter: Hoya CM-500
- Size 3.6 x 2.6 x 1.1 in.
- Operates from 5-6V DC adapter
- Night sky brightness given in unit mag arcsec⁻²
- Accuracy of ± 0.1 mag arcsec⁻²
- Calibrated by the manufacturer before shipment

Methodology

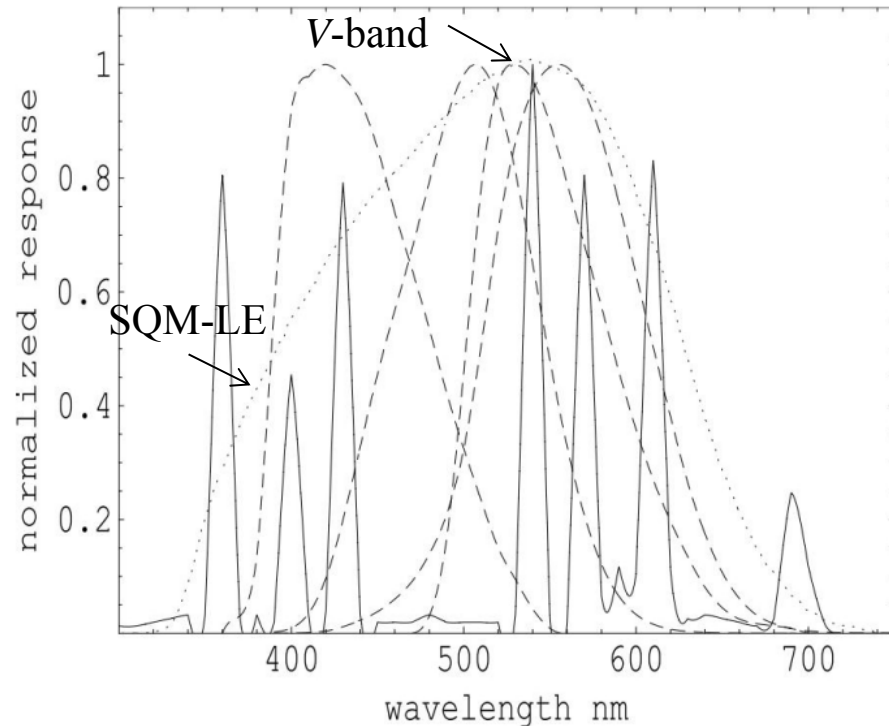


Spectral response function of SQM-LE (solid), quantum efficiency (dashed), and filter transmittance (dotted)
(Cinzano 2005)



Angular response function of SQM-LE
(Cinzano 2007)

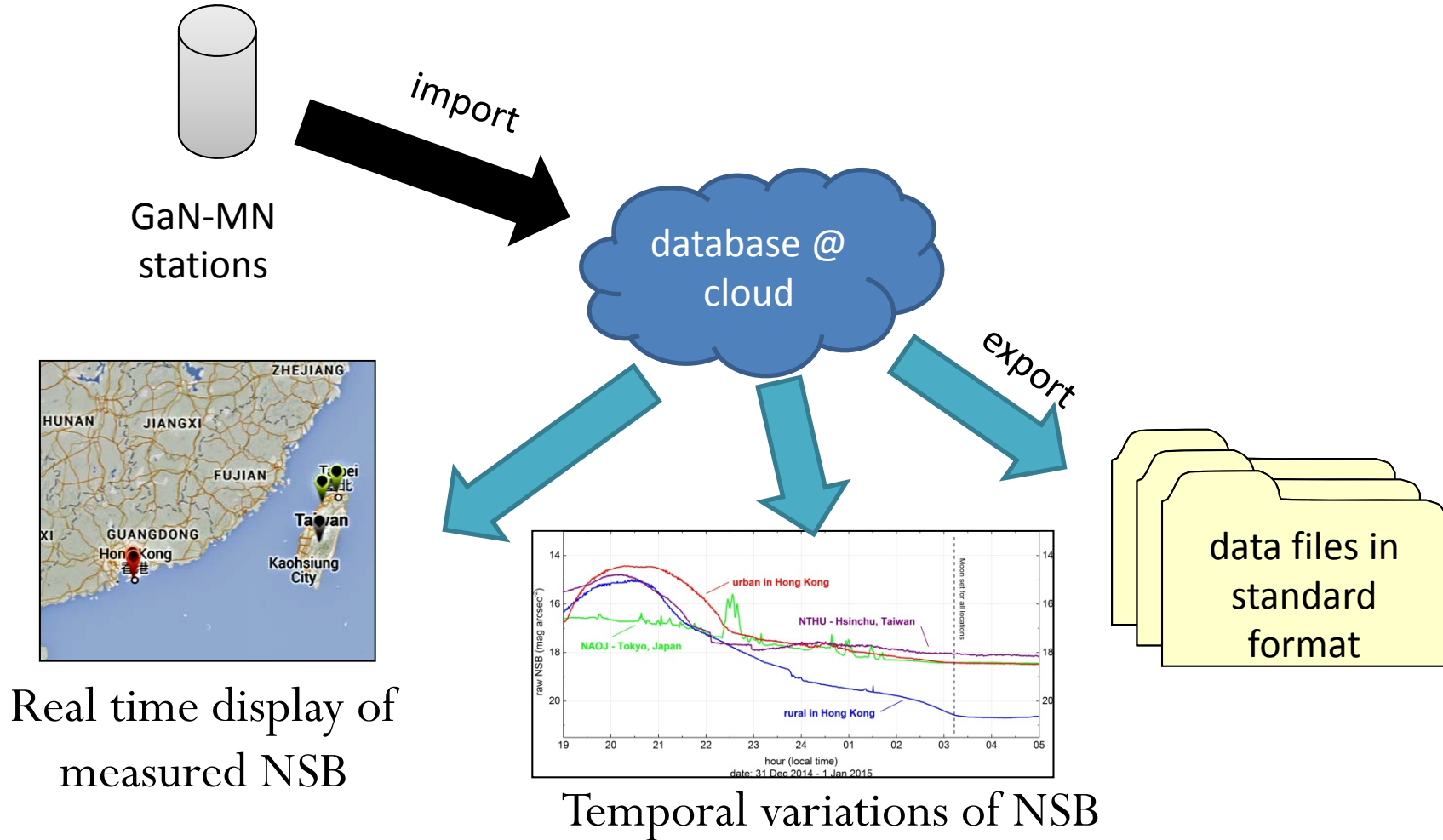
Measuring NSB by SQM-LE



Comparison of **SQM-LE normalized spectral response** (dotted curve) with the spectral curves of Johnson B-band, scotopic, **Johnson V-band**, and photopic (dashed curves from left to right) and the emission spectrum of a mercury vapor lamp (solid curve) (Cinzano 2005)

- Compare photometric Johnson V-band vs SQM-LE response:
 - FWHM:
 - SQM-LE: 240 nm
 - V-band: 84 nm (Bessell 2005)
 - Peak:
 - SQM-LE: 540 nm
 - V-band: 545 nm (Bessell 2005)
- The offsets between V-band and SQM-band:
 - Depends on sky spectrum and cloud condition
 - 0 - 0.25 mag arcsec⁻² (Cinzano 2005)
 - Up to 0.6 mag arcsec⁻² when cloudy (Puschnig et. al. 2014)

GaN-MN night sky brightness (NSB) database: data flow



The Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

- Current stations (more on next page):

Organization	Country /region	Operational date
Taipei Astronomical Museum (TAM)	Taipei, Taiwan	2014-11-19
National Astronomical Observatory of Japan (NAOJ)	Tokyo, Japan	2014-12-19
The University of Hong Kong (HKU)	Hong Kong	2014-12-26
National Tsing Hua University (NTHU)	Taiwan	2014-12-30
Yeongyang Firefly Astronomical Observatory (YFAO)	Yeongyang, Korea	2015-01-24
Chungbuk National University Observatory (CNUO)	Cheongju, Korea	2015-01-27
Lulin Observatory (LUO)	Taiwan	2015-03-27
Ho Koon Nature Education cum Astronomical Centre (HKn)	Hong Kong	2015-04-18

The Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

- Current stations (con't, more on next page):

Organization	Country /region	Operational date
South African Astronomical Observatory, Cape Town (SAAO)	South Africa	2015-07-28
Kuzuha Observatory (KuO)	Japan	2015-08-01
National University of Mongolia (NUM)	Ulan Bator, Mongolia	2015-08-05
Zselic Starry Sky Park (ZSSP)	Hungary	2015-08-24
Hungarian Astronomical Association (Bar)	Hungary	2015-09-11
Elsterland-Observatory (ELO)	Germany	2015-09-25
Nagasaki Nishiyama Observatory (NNO)	Japan	2016-03-19
Daejeon Astronomical Observatory (DAO)	Daejeon, Korea	2016-03-20

The Globe at Night - Sky Brightness Monitoring Network (GaN-MN)

- Current stations (con't):

Organization	Country /region	Operational date
Yeongwol Byeolmaro Astronomical Observatory (YBAO)	Bongrae, Korea	2016-06-15
Cheonan Hongdaeyong Science Museum Observatory (CHSMO)	Cheonan, Korea	2016-06-16
Chung-ju Goguryeo Astronomical Observatory (CGAO)	Chungcheongbuk-do, Korea	2016-06-17
Gokseong Soemjingang Astronomical Observatory (GSAO)	Jeollanam-do, Korea	2016-07-08
University of Saint Joseph (Mac)	Macau Peninsula	2016-08-21
University of Saint Joseph (Tai)	Taipa, Macau	2016-12-14
University of Saint Joseph (Col)	Coloane, Macau	2016-12-14