

From LEDs to Satellites:

Ground-based and Space-based Challenges to Dark Skies

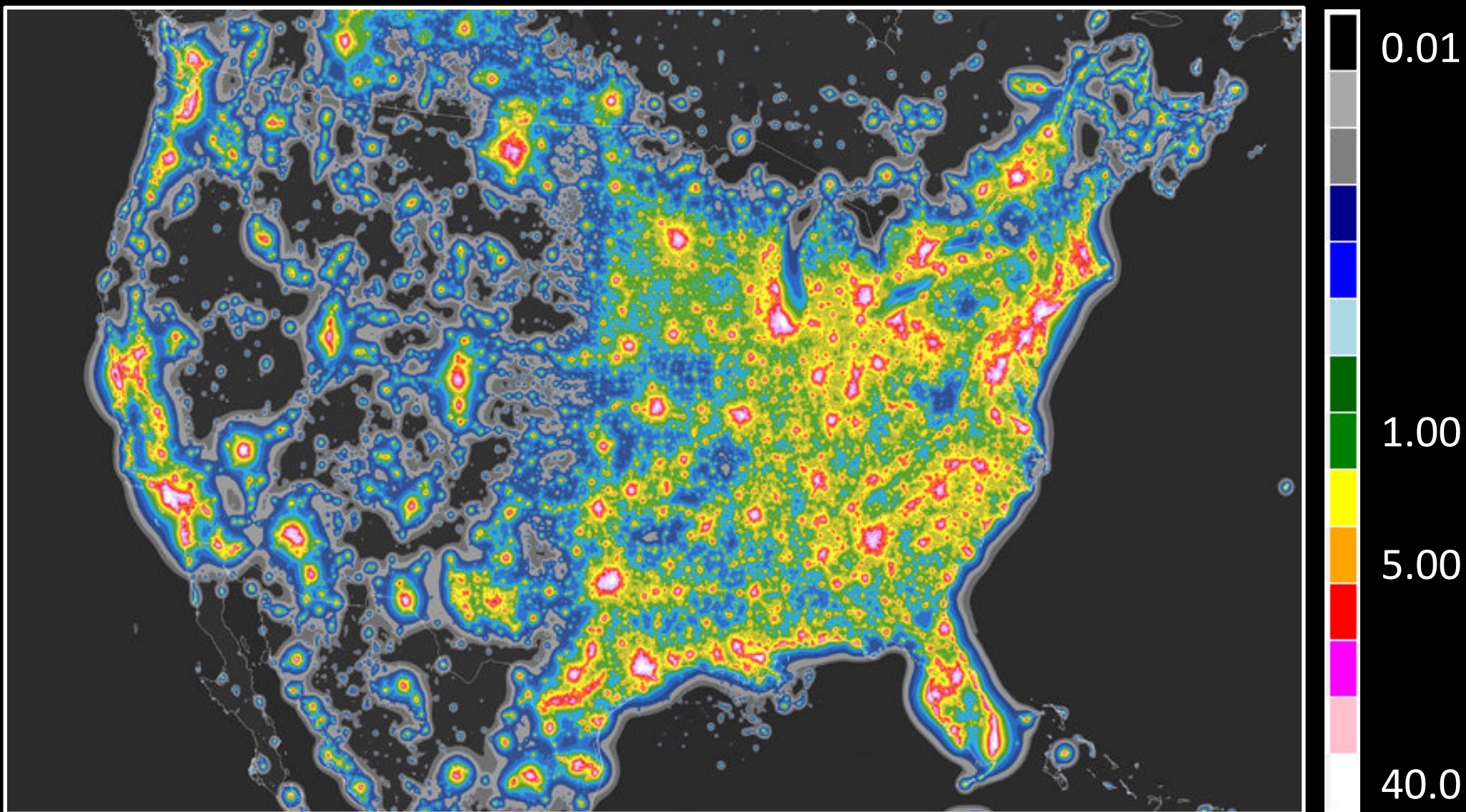
Jeffrey C. Hall
Lowell Observatory
Flagstaff, AZ

CALCON
September 22, 2020

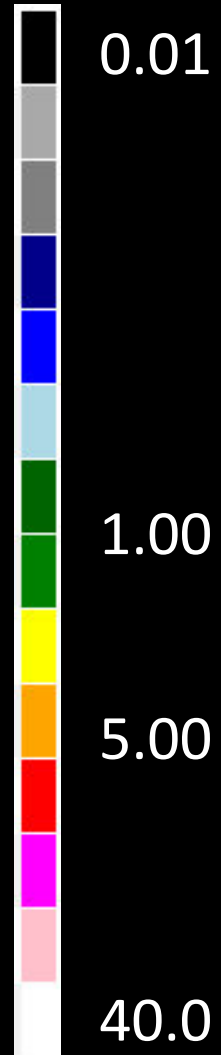
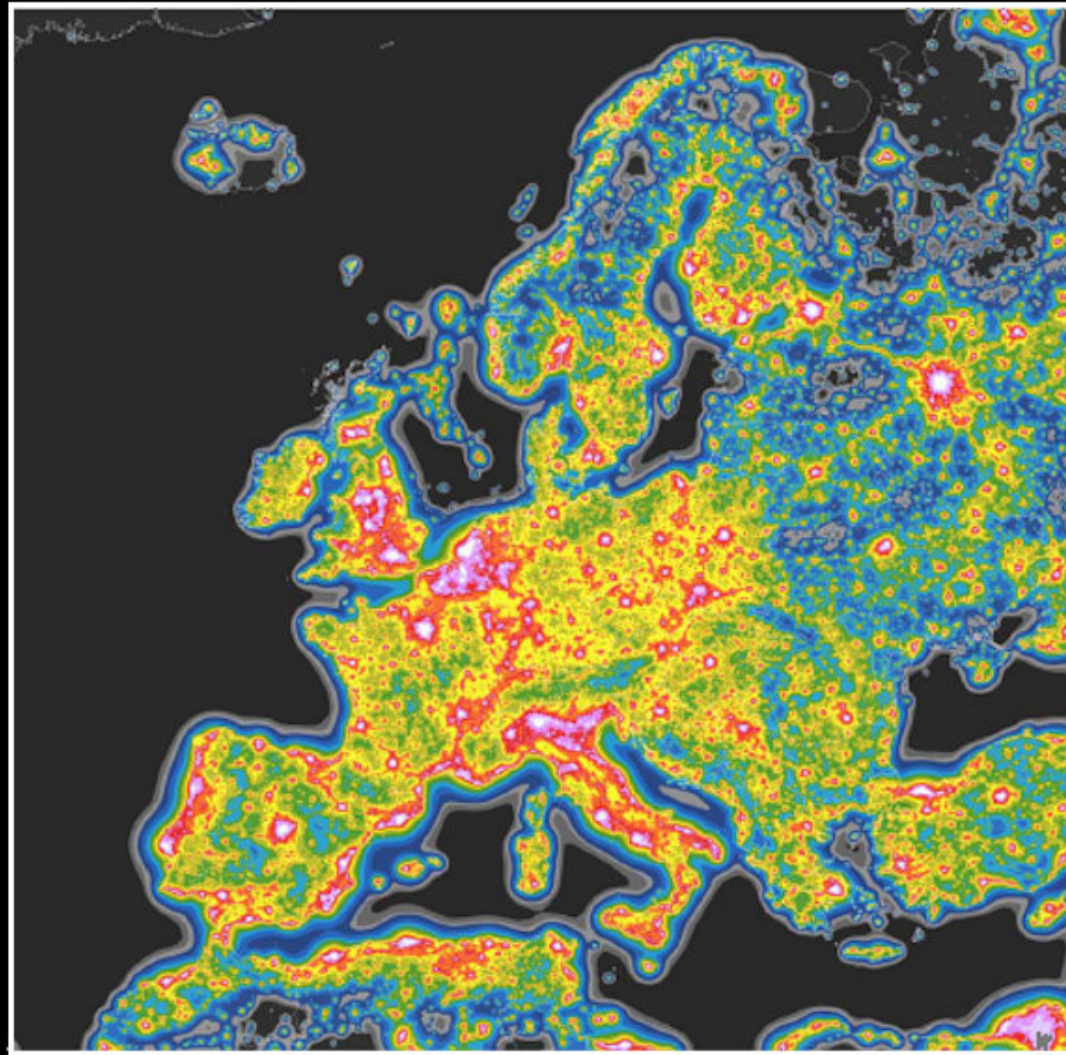
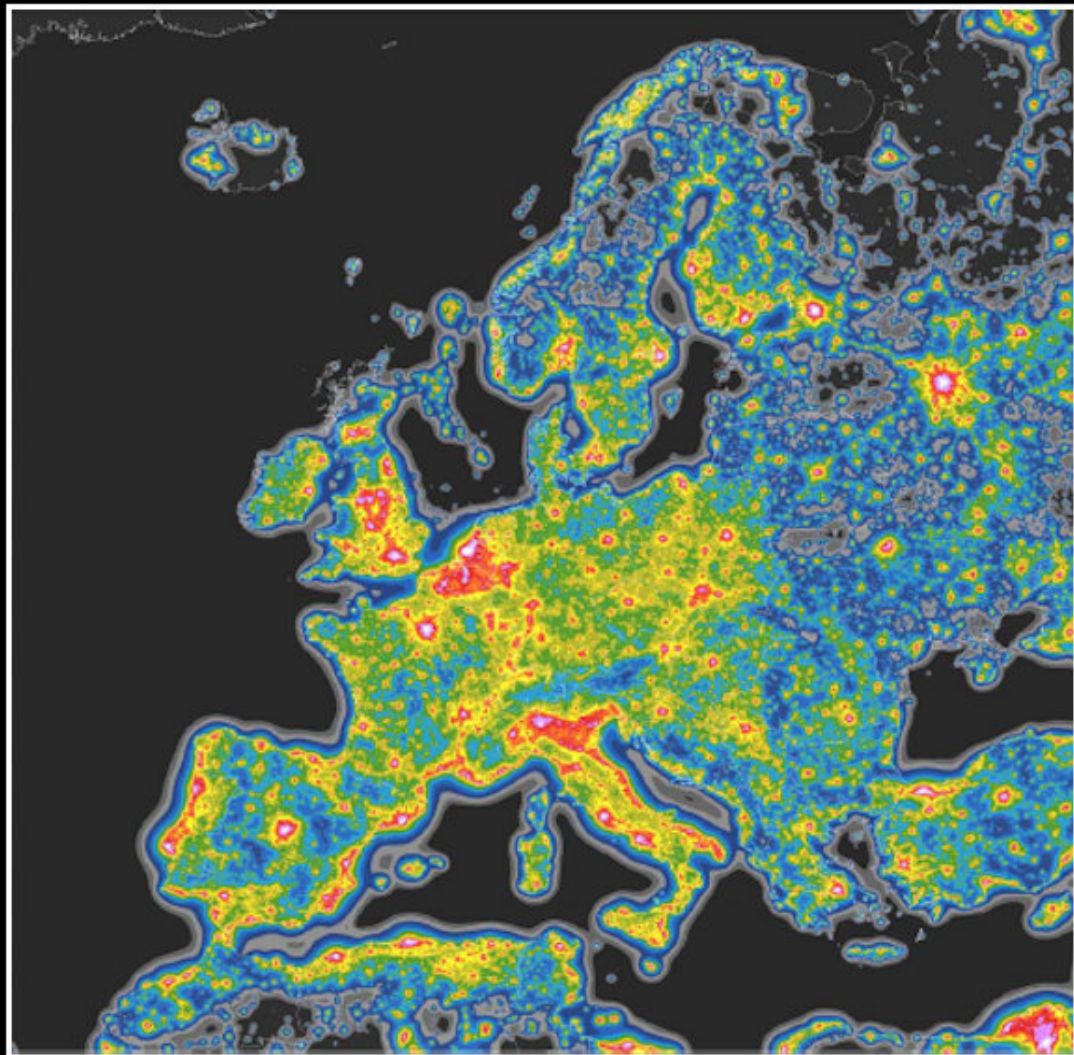
From the Ground

The LED Revolution






Falchi et al., 2016, *Sci Adv* 2 (6), e1600377



Falchi et al., 2016, *Sci Adv* 2 (6), e1600377






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Seaturtlelighting.net



Research today for a cancer-free tomorrow
CANCER PREVENTION STUDY-3

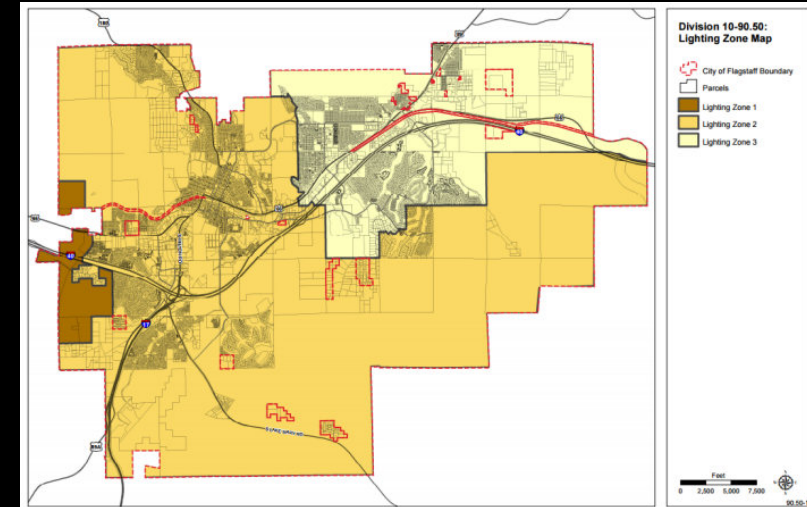
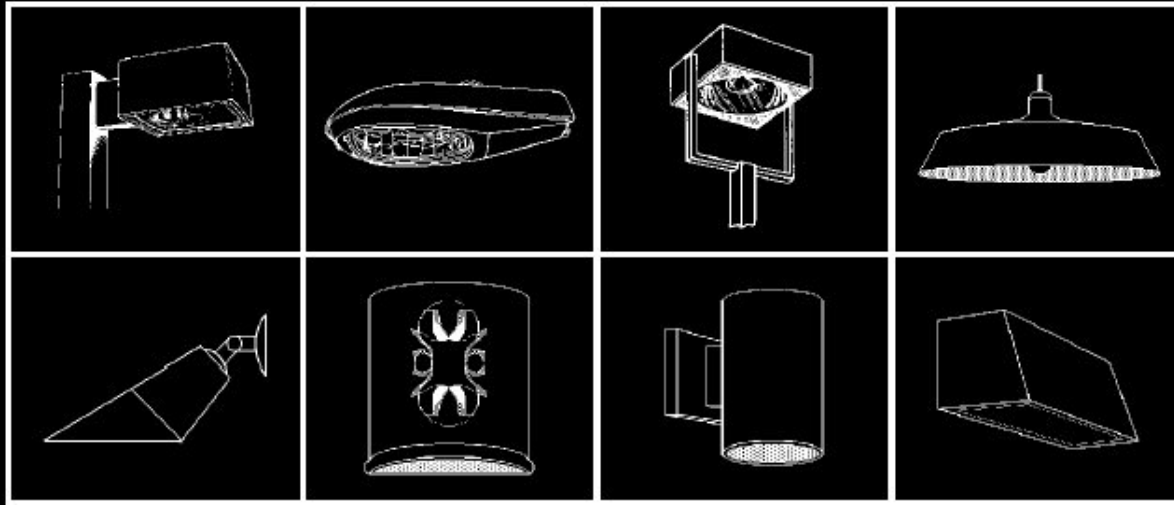


Dear JEFFREY HALL,

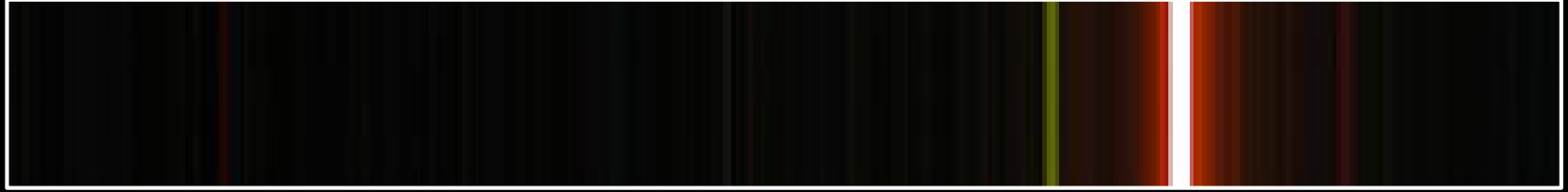
It's time to fill out your online 2018 Cancer Prevention Study-3 survey! With your help we can find answers that will save lives.

Dark Skies in One Slide

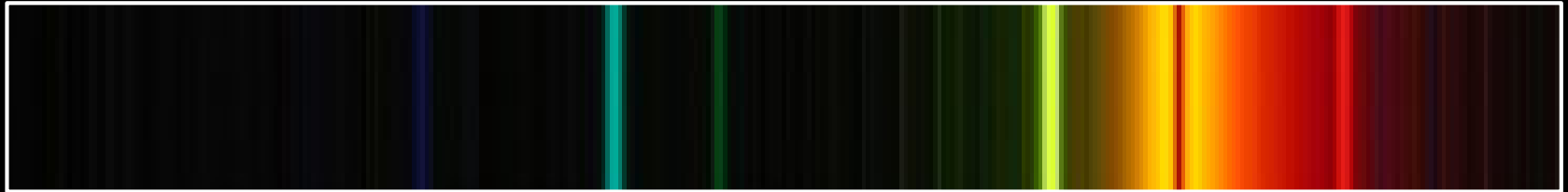
Shielding, Illumination management, Spectrum management



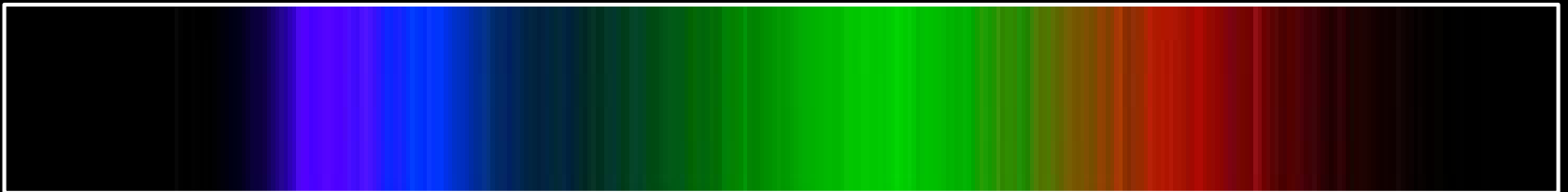
LPS



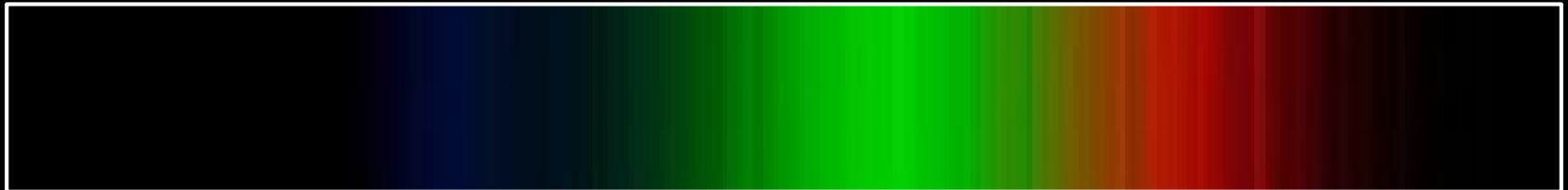
HPS



5000 K LED



3000 K LED



Flagstaff Dark Skies Coalition

Street Lighting for Enhancing Dark Skies

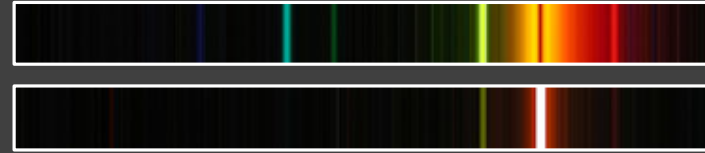
The Flagstaff SLEDs Project

FLAGSTAFF TODAY

HIGH-PRESSURE SODIUM
LOW-PRESSURE SODIUM

(30%)

(70%)



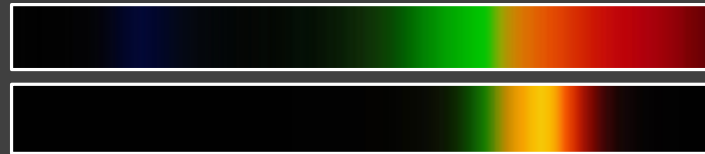
THE WORLD TODAY

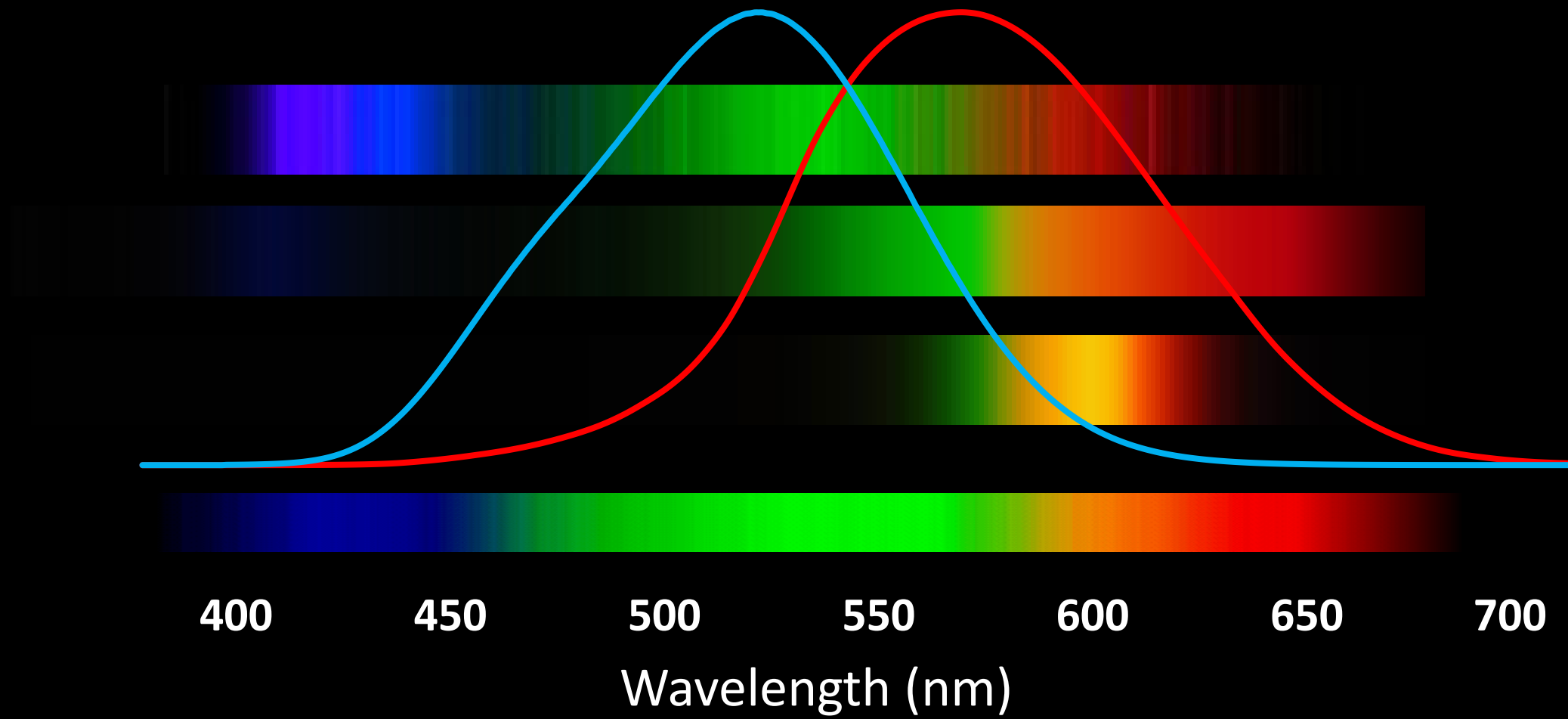
HIGH-TEMPERATURE WHITE LED



FLAGSTAFF TOMORROW

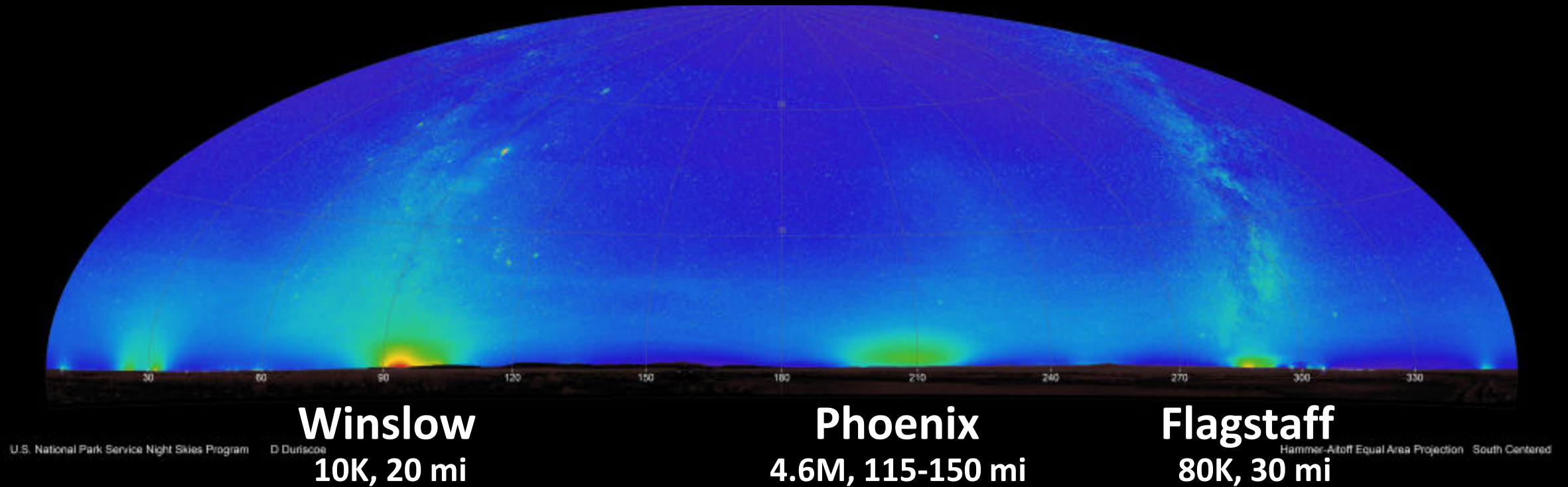
PHOSPHOR-CONVERTED AMBER LED (30%)
NARROW BAND AMBER LED (70%)





Chris Luginbuhl

Northern Arizona Skies from Meteor Crater



Dan Duriscoe

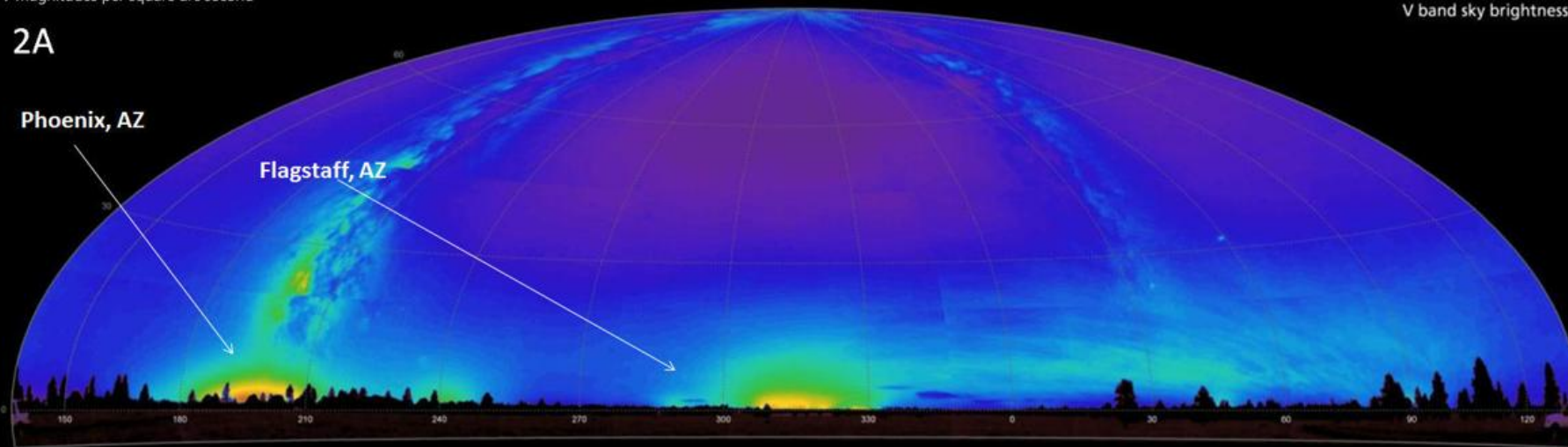


V magnitudes per square arc second

Ashurst Lake July 8 2016

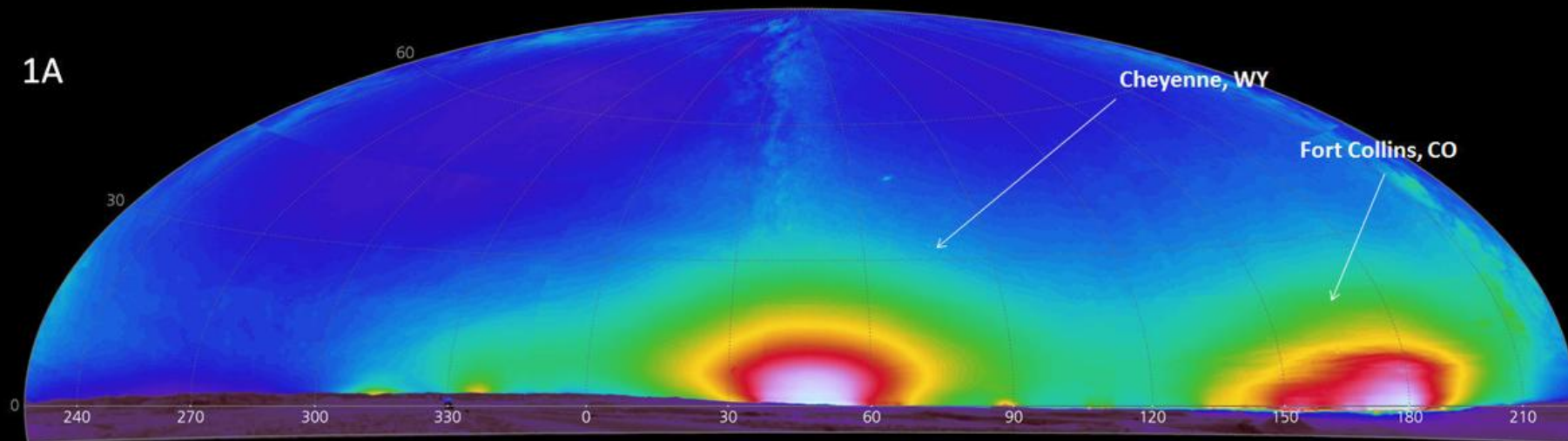
V band sky brightness

2A



Soapstone Prairie Natural Area, Colorado August 2, 2016 23.9 hours LMT

1A



Dan Duriscoe

Things we commonly hear

Dark skies = no lights

Astronomers like amber because they can filter it out

Astronomers don't start observing until midnight

Everybody hates yellow lights

More light = more safety / less crime



Talking points for advocacy

Dark sky measures are not dark ground measures

NBA LED may be overkill for communities far from observatories

PCA LED is here and viable

Frame interactions as solutions, not problems

Be open to a mix of perception-based and data-based outcomes

From Low Earth Orbit

The industrialization of space

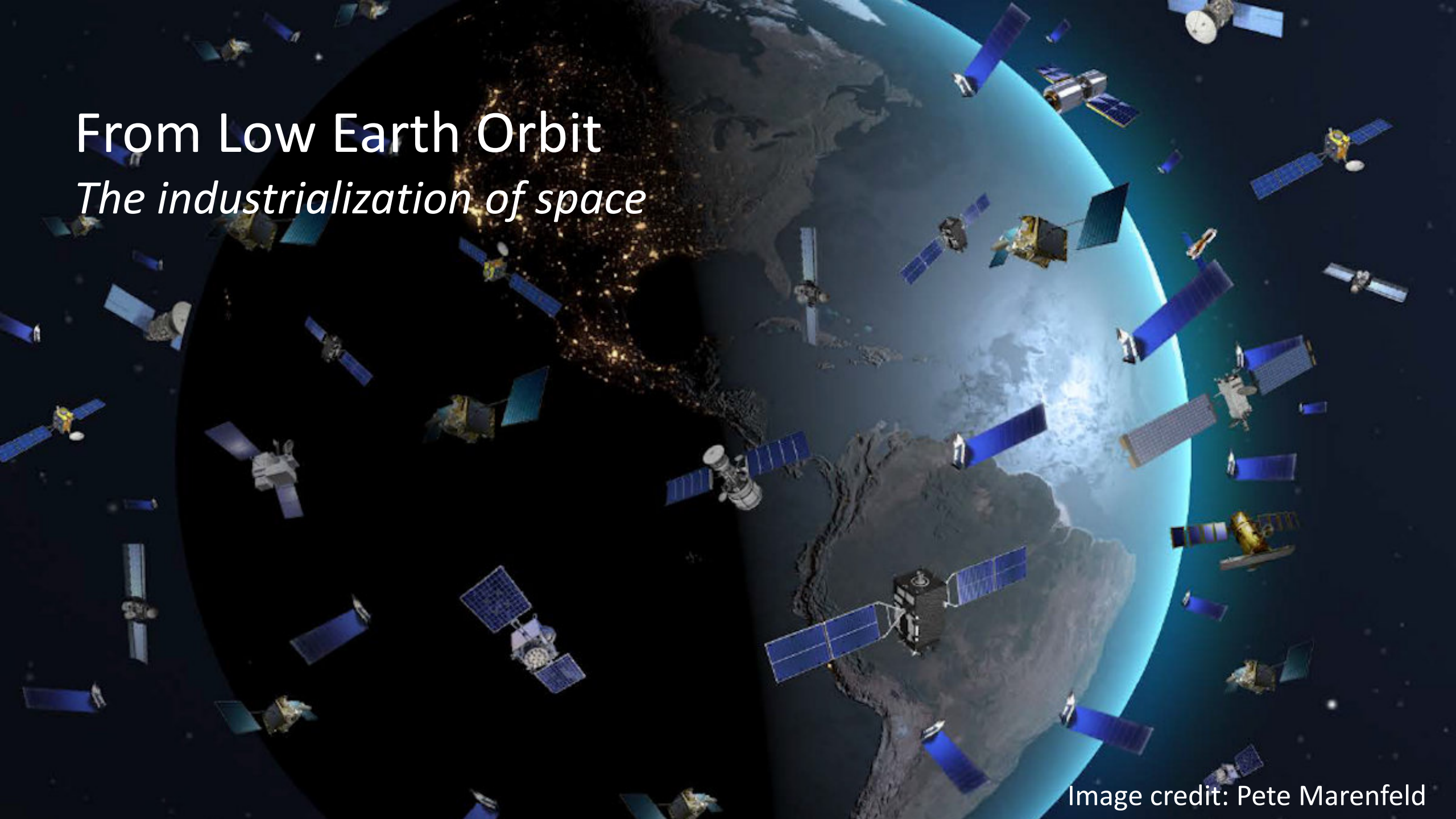
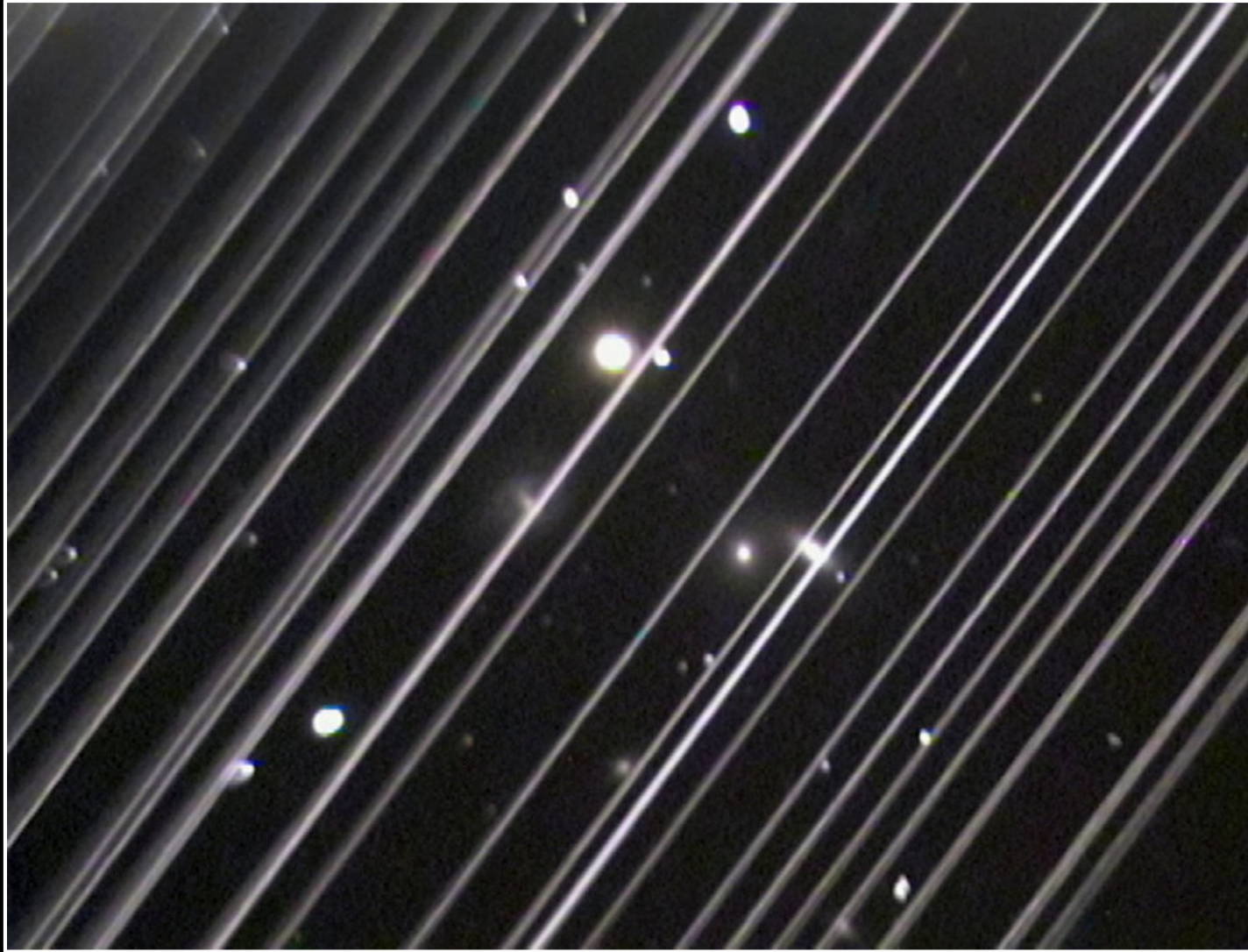


Image credit: Pete Marenfeld



Victoria Girgis / Lowell Observatory

Principal threats from satellite megaconstellations

We are entering the era of industrialization of space. Proliferation of satellites creates a perfect storm for astronomy along three principal lines:

- Brightness ($V = +3$ to $+4$ in parking orbit, $+7$ to $+9$ on station)
- Quantity (SpaceX + Amazon + OneWeb 70+K, total possibly $> 100K$)
- Lack of regulation (no requirement to mitigate, crowded space)

SATCON1

29 June – 2 July 2020

Report released 25 August 2020

Technical assessment

Four working groups (WG)

SATCON2

~Q1 2021

Policy & regulation



SATCON1 – Impacted science cases

Rare transients

Deep, wide, extragalactic imaging

Near-Earth objects (NEOs)

Deep multi-object spectroscopic surveys

Deep wide-field near-infrared (NIR) imaging

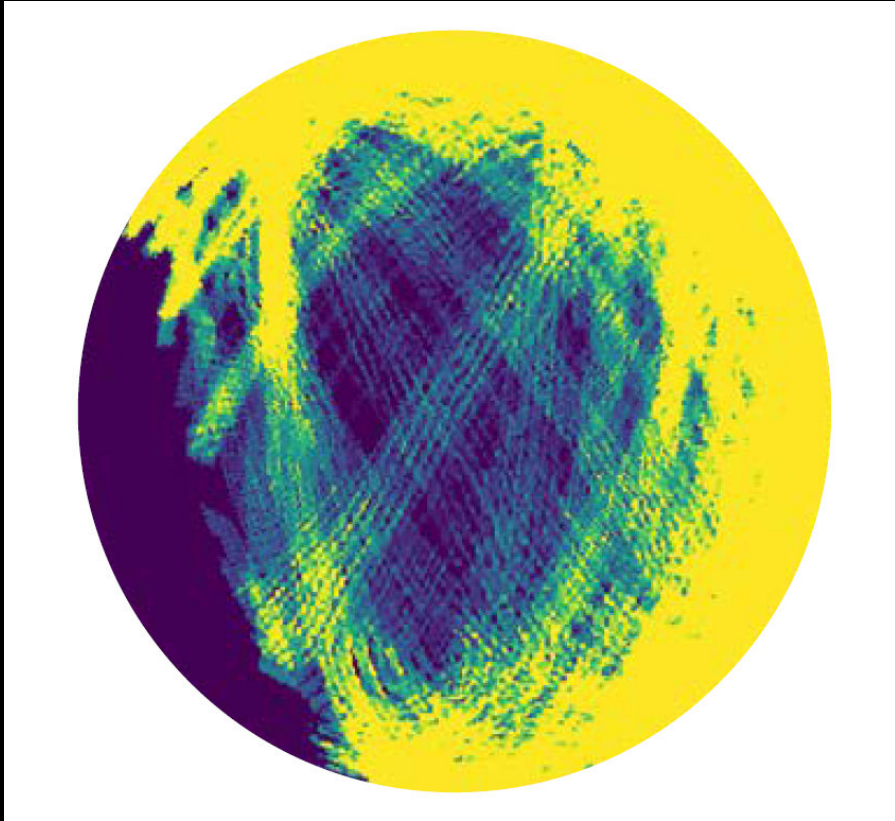
Imaging of large extended low surface brightness targets

Exoplanet transits in wide-field surveys

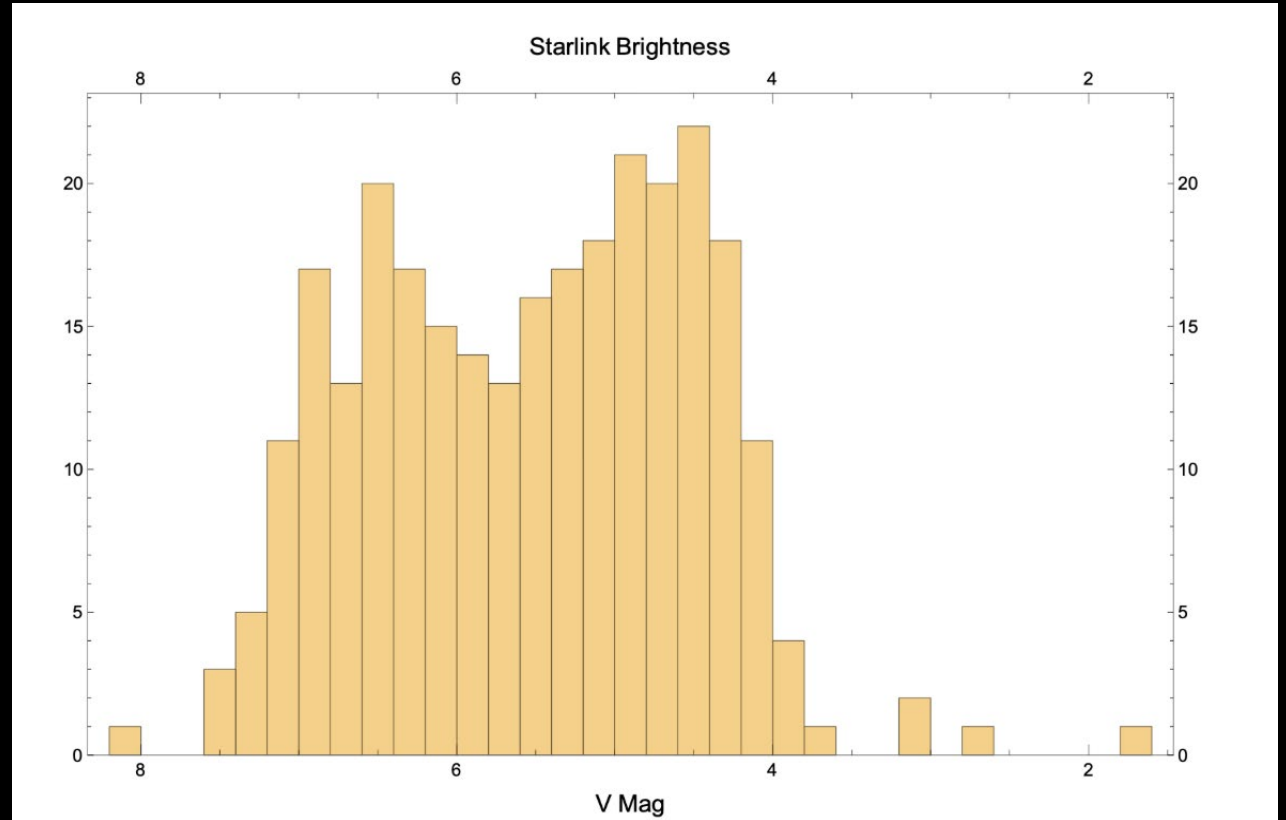
Discovery of new phenomena

Citizen science, amateur astronomers, and stargazers worldwide

SATCON1 – Observations WG (Lori Allen, chair)

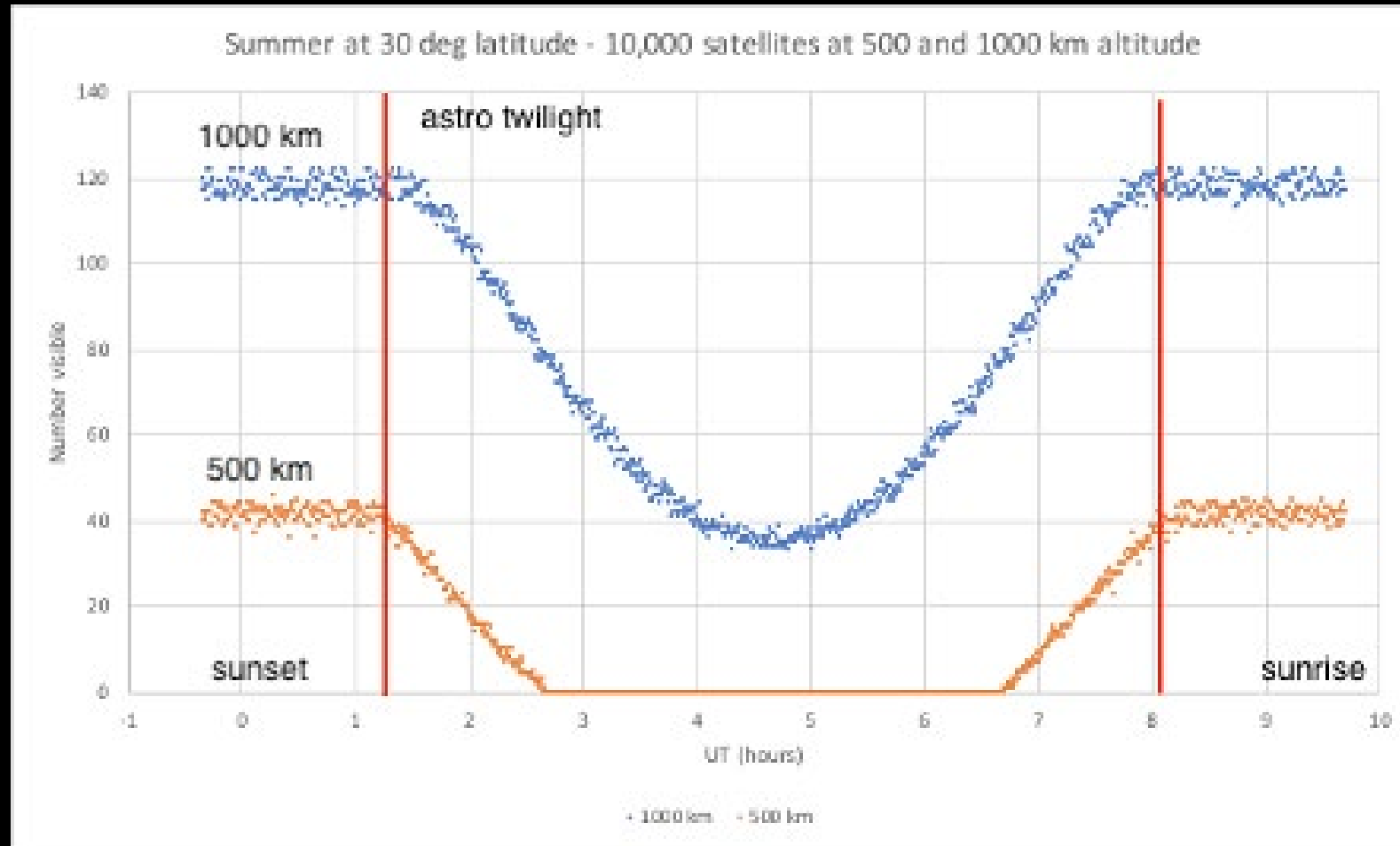


P. Yoachim / U Washington



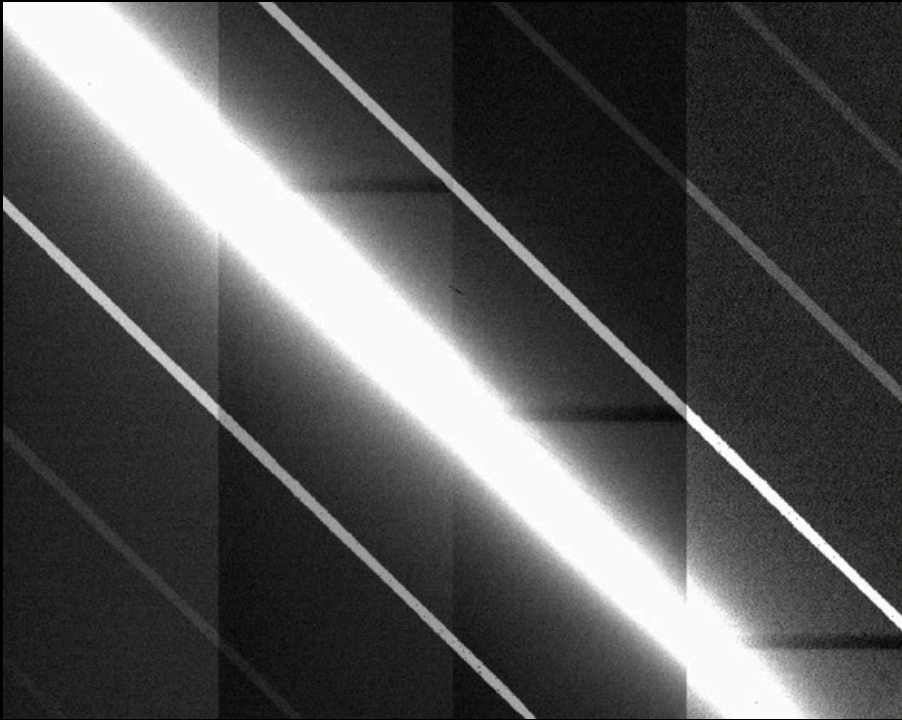
Harry Krantz / Pomenis obs.

SATCON1 – Simulations WG (Pat Seitzer, chair)

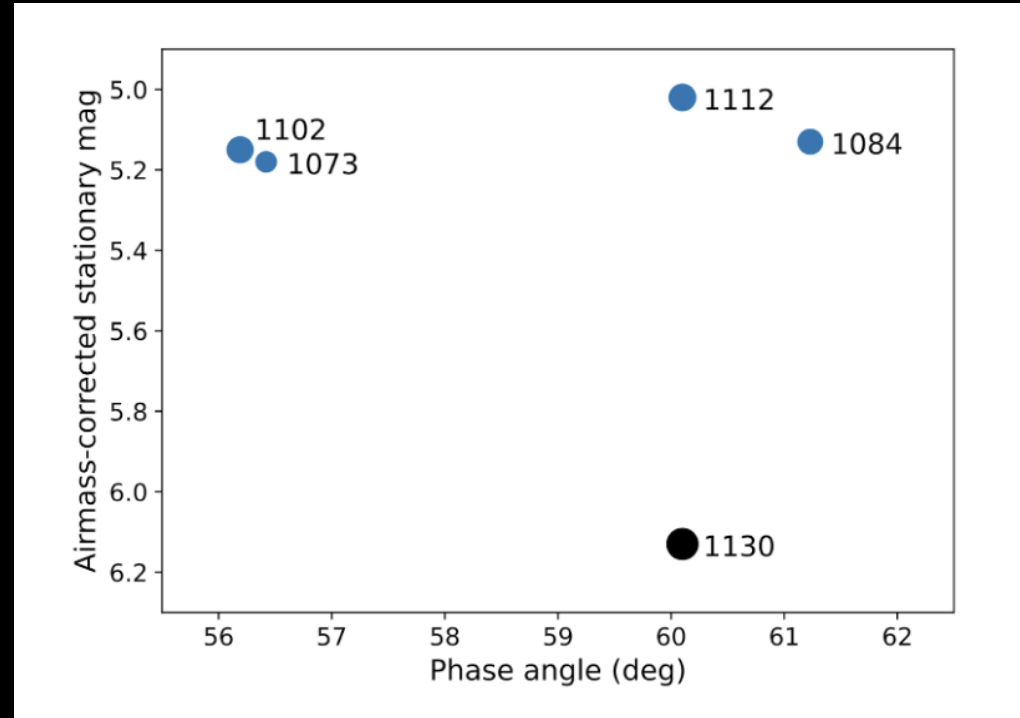


Pat Seitzer, U. Mich.

SATCON1 – Mitigations WG (Tony Tyson, chair)



T. Tyson, Rubin Obs.



Tyson et al. 2020, submitted

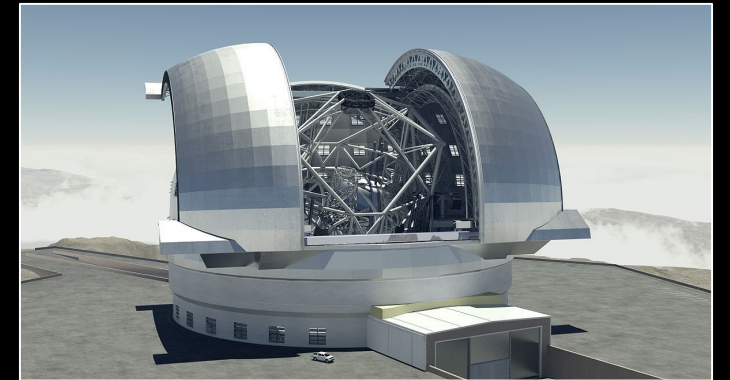
SATCON1 – Metrics WG (Richard Green, chair)

Findings

Wide field and twilight programs will be most severely impacted

Fly low

No combination of mitigations will eliminate the impacts to astronomy



SATCON1 – Metrics WG (Richard Green, chair)

Recommendations for Observatories

Create more robust software tools for trail masking and removal

Create more robust predictive tools for satellite transits

Better understand systematics of trail-masking on resultant images

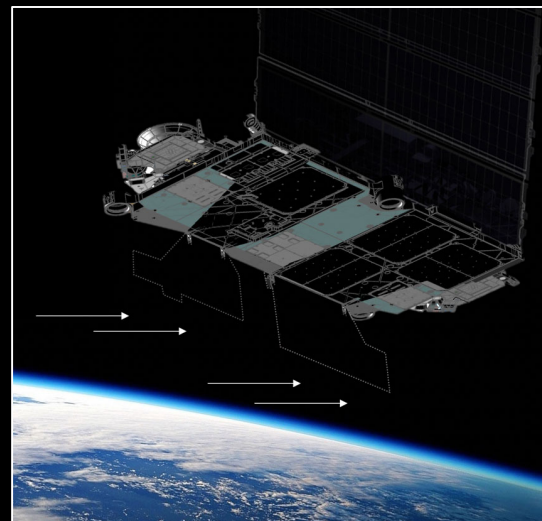
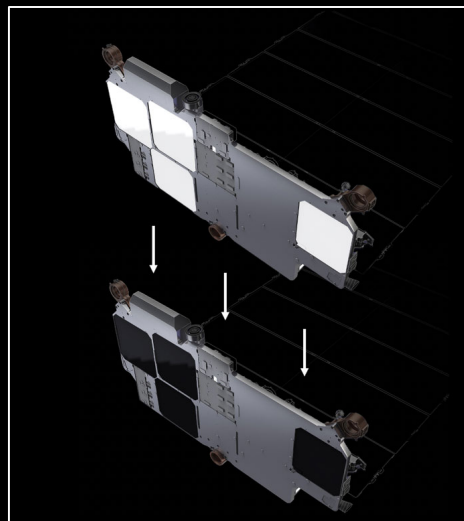
SATCON1 – Metrics WG (Richard Green, chair)

Recommendations for Operators

Incorporate thorough BRDF measurements in satellite design

Design for fainter than $7.0 \text{ V mag} + 2.5 \times \log(r_{\text{orbit}} / 550 \text{ km})$

Minimize specular reflection in the direction of observatories



SATCON1 – Metrics WG (Richard Green, chair)

Recommendations for Operators & Astronomy in Collaboration

- Clump satellites while in parking orbits

- Create a comprehensive satellite observing network (incl. citizen science)

- Greatly improve ($\sim 10X$) publicly available positional information

- Adopt a new standard format for ephemerides beyond present TLEs

A watershed era

From the ground

+ Constructive advocacy re white and amber LEDs is imperative

From space

+ Kudos to SpaceX

+ Amazon and OneWeb also getting engaged

+ Collaborative development of policy is imperative