Monarchs, Milkweed, and The Milky Way

Vayujeet Gokhale

Professor of Physics and Astronomy,
Truman State University

CAMPUS SHINE

Milkweed and the Milky Way

Acknowledgements

International Dark Sky Week

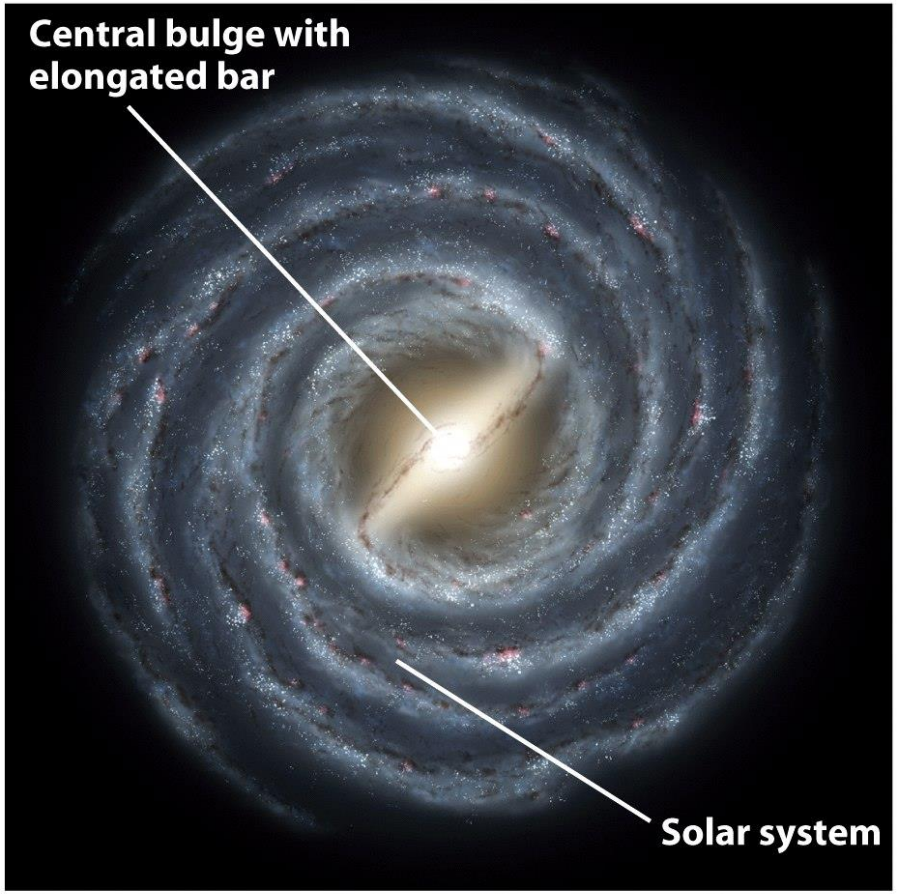
April 21 - 28, 2025


Saturday April 26th
in Arrow Rock, MO from 10-4
Nature and Garden Merch
Info Booths
Food
Fun
Wild Edibles Walk
Owls and Raptors!
Native Plants
Bird Walks
- ARROW ROCK -
BIRDS·BEES & BLOOMS
FESTIVAL

Spring time in America

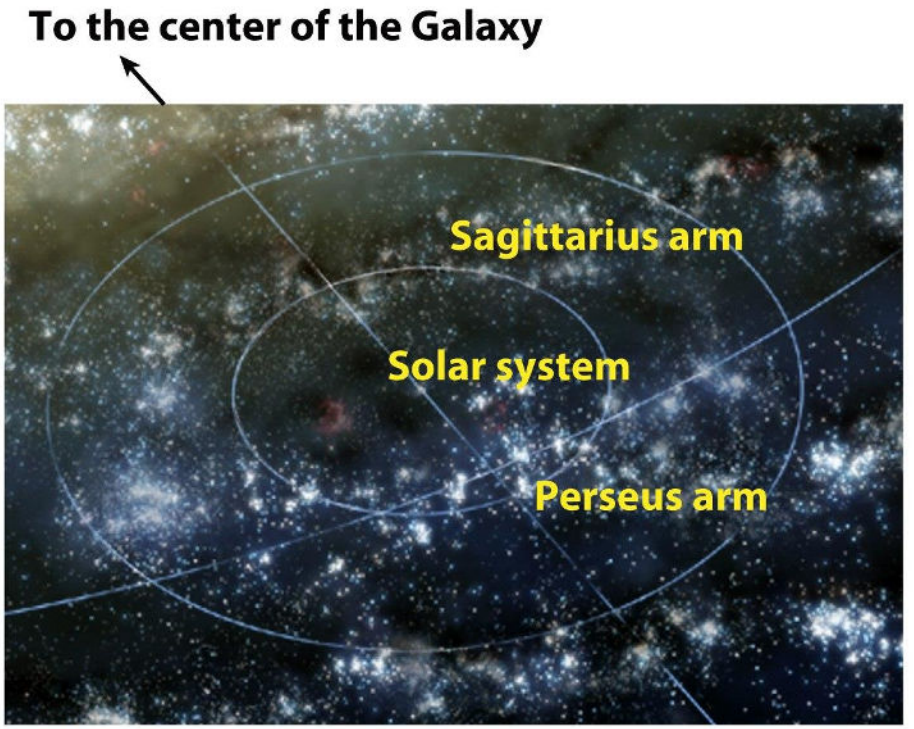
In the beginning…

Milkweed and the Milky Way



The structure of the Milky Way's disk

Figure 23-16a
Universe, Eighth Edition



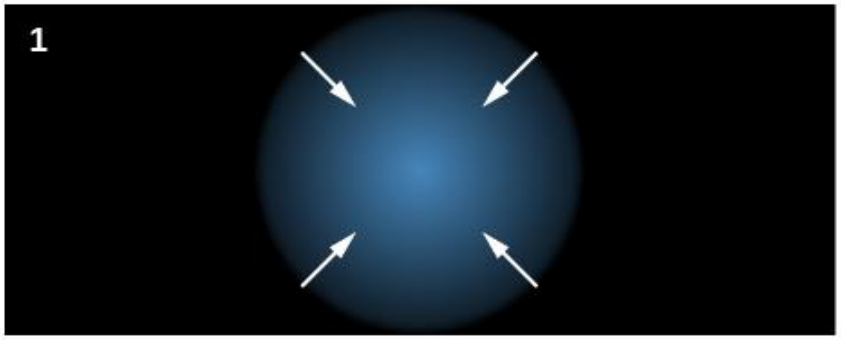
Closeup of the Sun's galactic neighborhood

Figure 23-16b
Universe, Eighth Edition

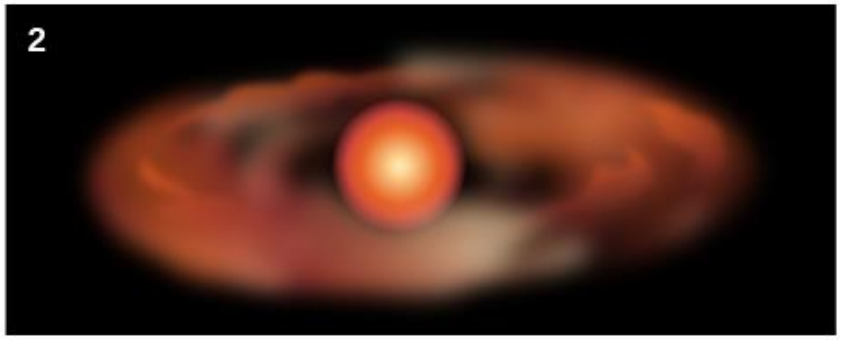
Our Galaxy: Artist's Impression

Milkweed and the Milky Way

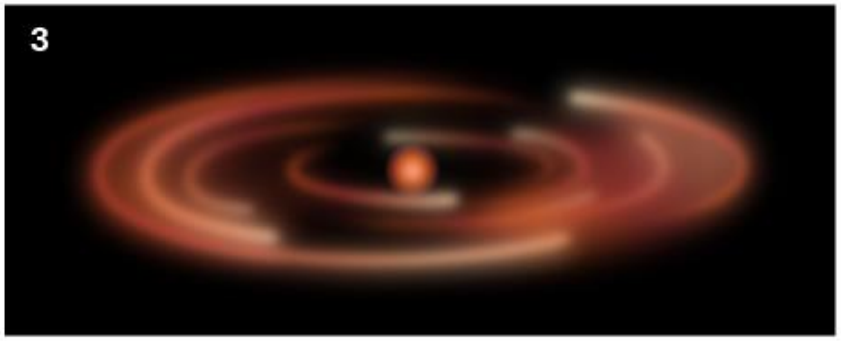
Milkweed and the Milky Way



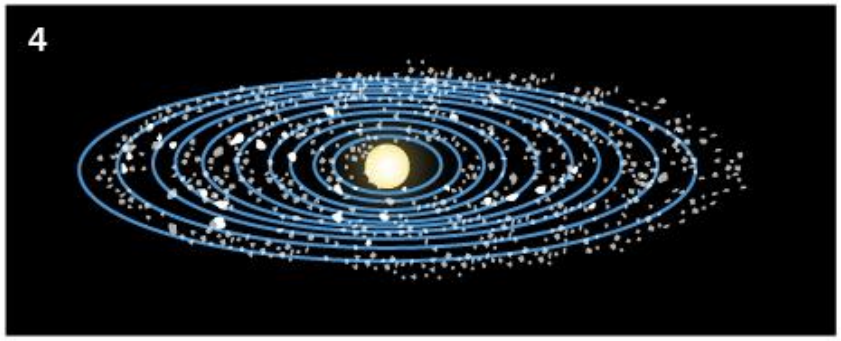
The solar nebula contracts.



As the nebula shrinks, its motion causes it to flatten.



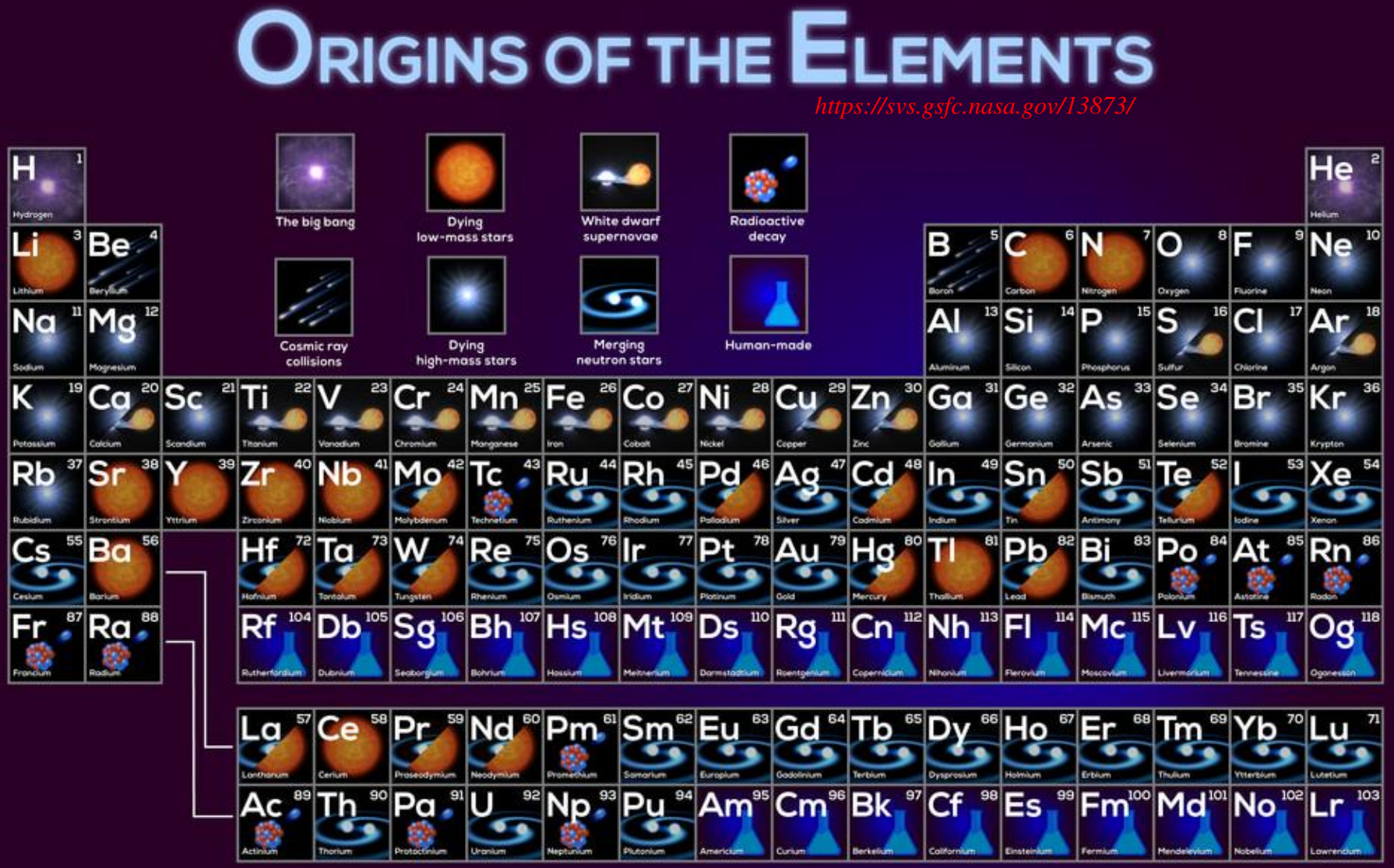
The nebula is a disk of matter with a concentration near the center.



Formation of the protosun. Solid particles condense as the nebula cools, giving rise to the planetesimals, which are the building blocks of the planets.

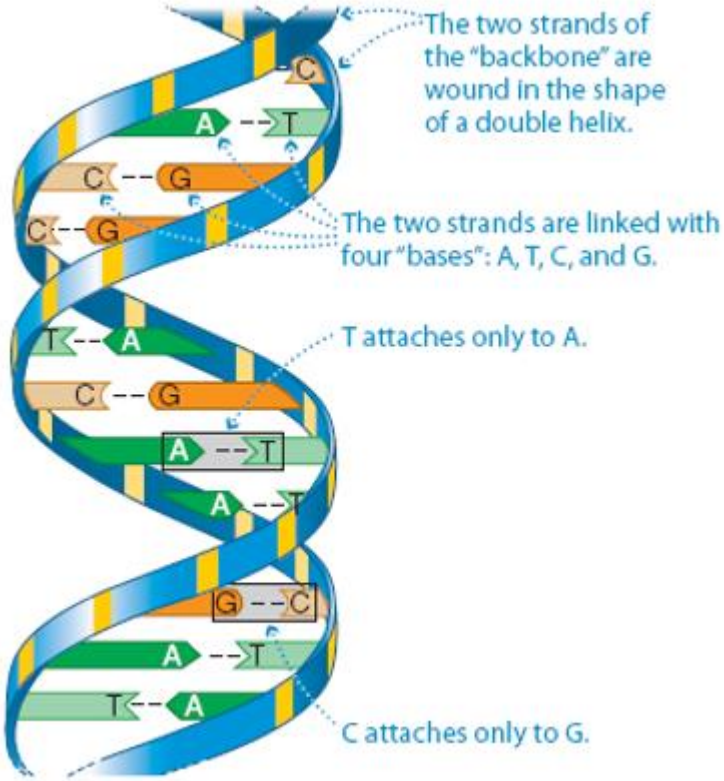
https://openstax.org/books/astronomy-2e/pages/14-3-formation-of-the-solar-system

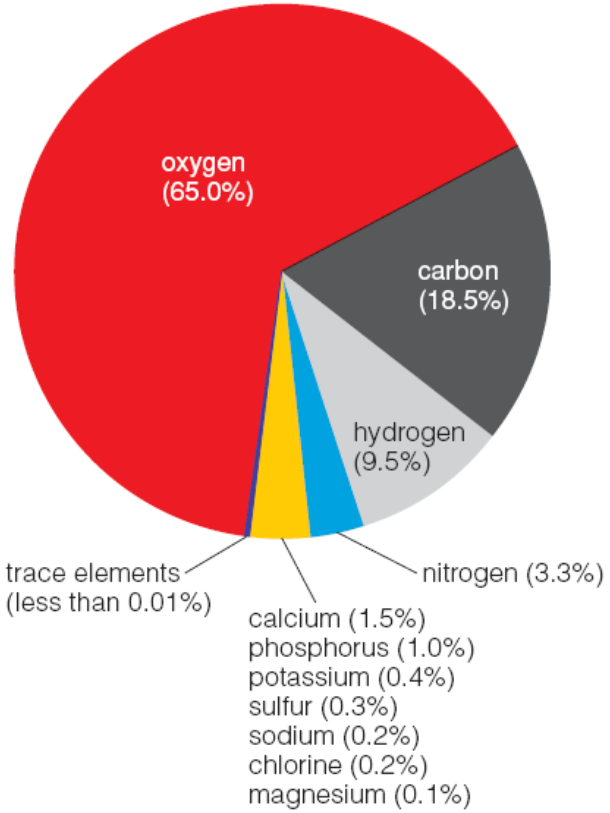
Milkweed and the Milky Way



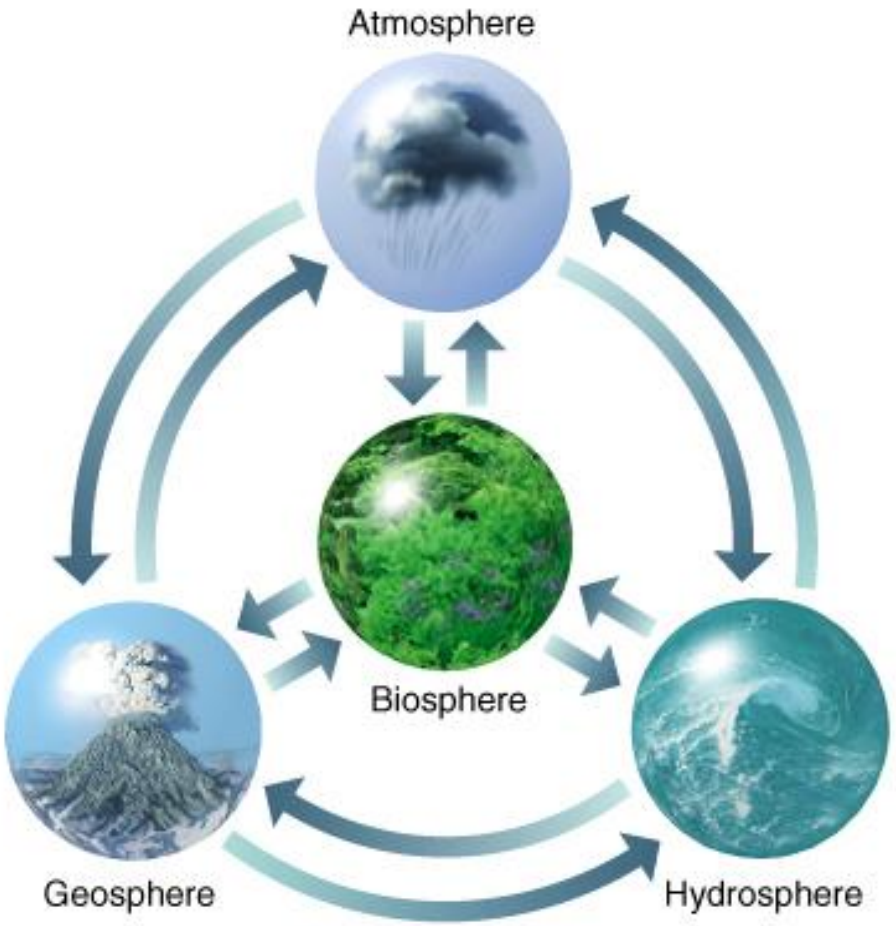
Milkweed and the Milky Way

Let there be Life…





Milkweed and the Milky Way

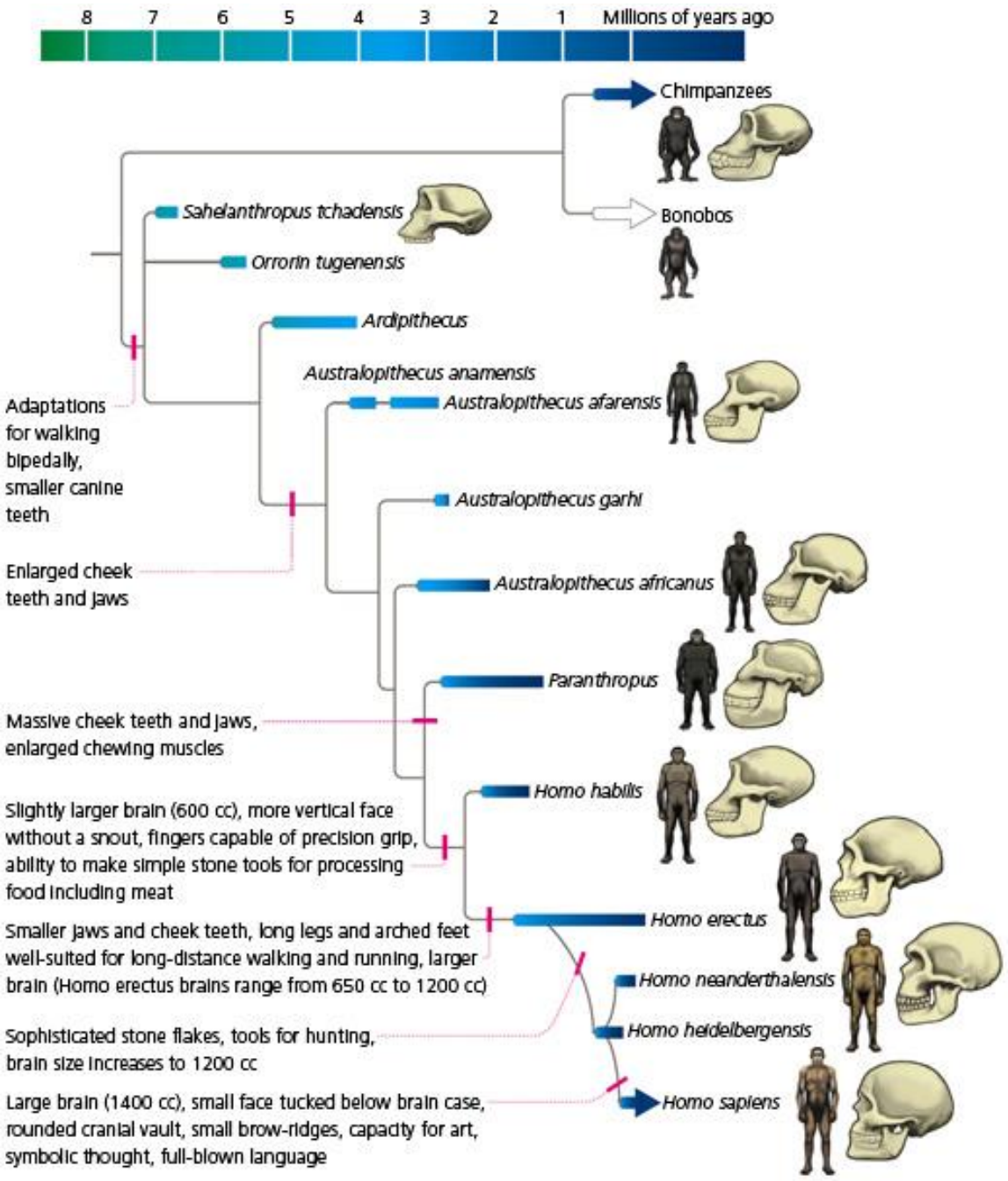


Earth and its neighbors Atmosphere

	Planet			
Gas	Venus	Earth (without life)	Mars	Earth (with life)
CO_2	96.5%	98%	95%	**0.03%**
N_2	3.5%	1.9%	2.7%	**79%**
O_2	Trace	0.0%	0.13%	**21%**
Ar	70 ppm	0.1%	1.6%	**1%**
CH_4	0.0%	0.0%	0.0%	**1.7 ppm**
T_s °C	459	240-340	-53	**15**
P (bars)	90	60	0.0064	**1.0**

Credit: James Kasting

Human Evolutionary Tree



The Natural Sky

"…shadows from the starlight,
softer than a lullaby…"

Blue Skies, Twilight, and Darkness at Night

Blue Skies, Twilight, and Darkness at Night

Milkweed and the Milky Way

Milkweed and the Milky Way

Flagstaff, Az
5 minute exposure, tracking ‘on’

“Darkness” at night

Milkweed and the Milky Way

and in the past hundred years…

Milkweed and the Milky Way

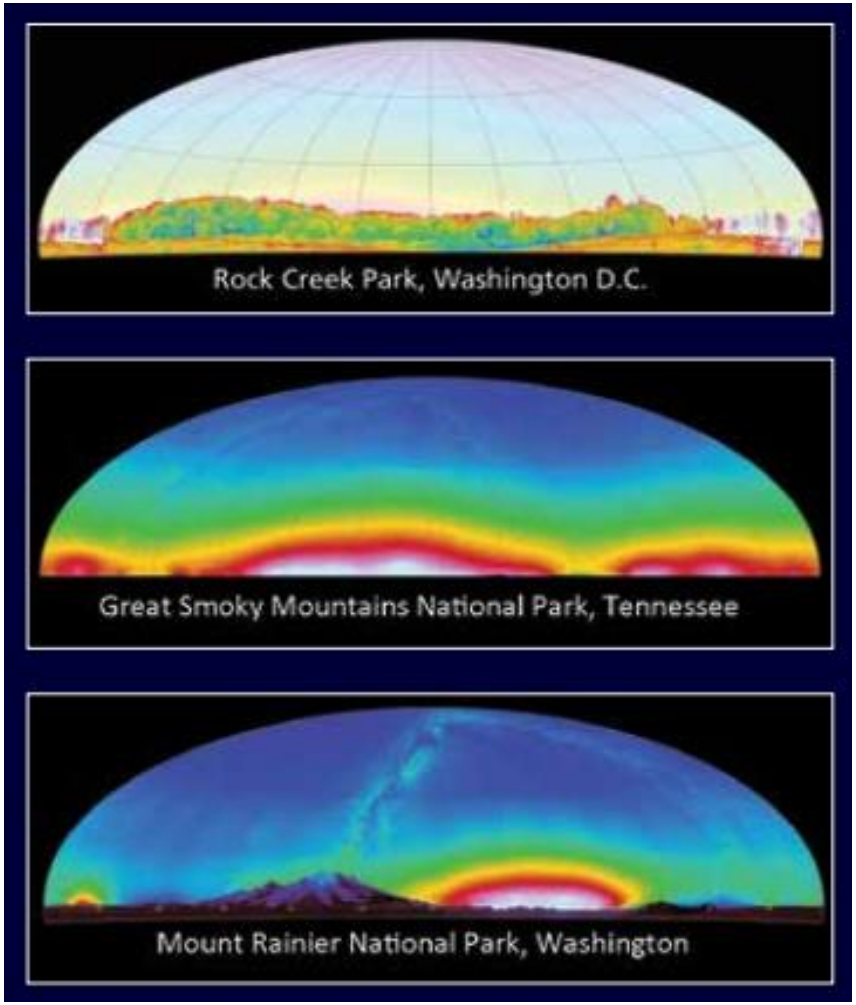
"There was once a town in the heart of America where all life seemed to live in harmony with its surroundings...

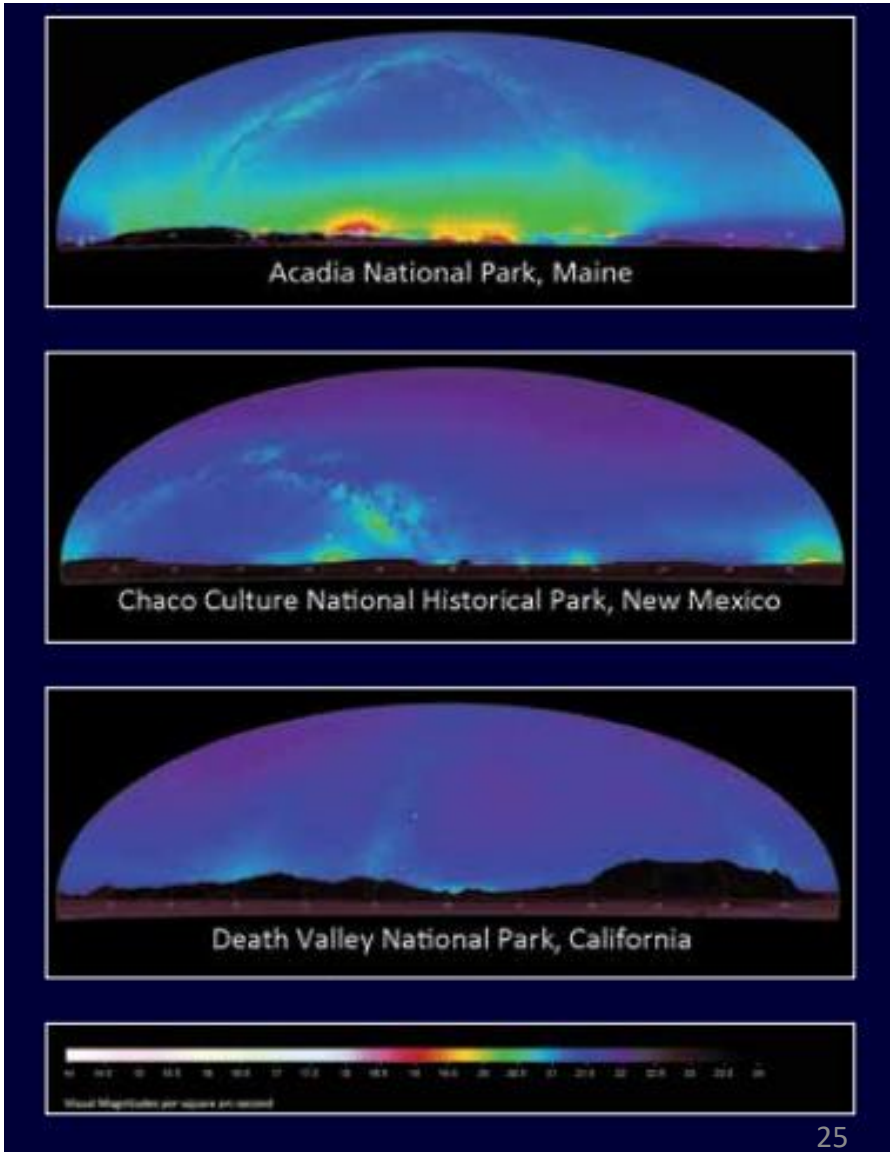
Then a strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death..."

Flagstaff, AZ

15 minute exposure, tracking ‘on’

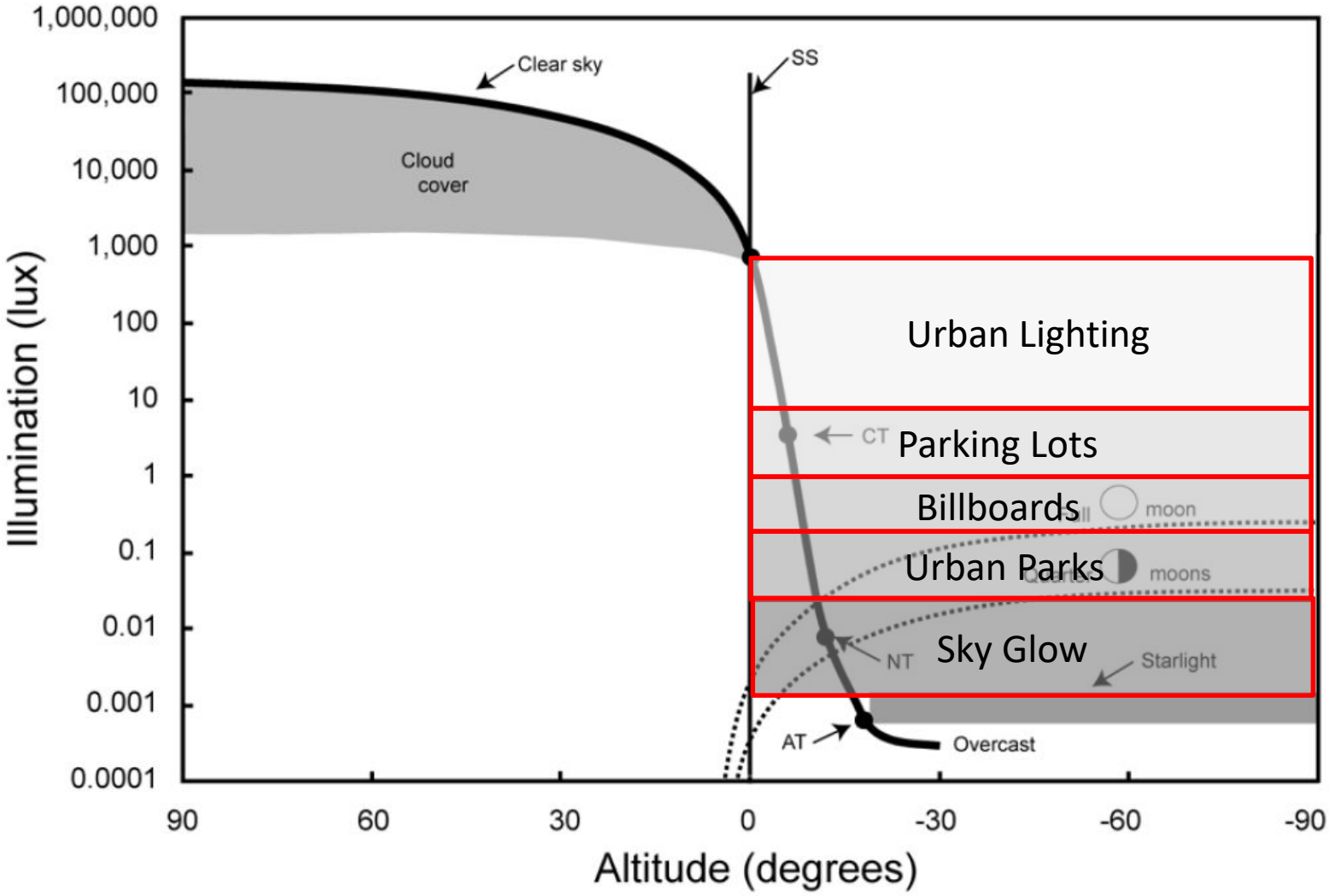
Sky Glow from 200 miles away





National Parks Service

Natural Illumination Night and Day



Credit: T. Longcore

Dark Sky International: State of the Science 2023, John Barentine

Similarities between Chemical and Light Pollution

Organism Impact	Chemical*	Light**	LP Examples
Human Exposure	yes	yes	urban/industrial settings
Wildlife Exposure	yes	yes	urban/industrial settings
Abnormal behavior	yes	yes	migrations, attraction/avoidance
Growth	yes	yes	plants, cancer cells
Reproduction	yes	yes	mammals, amphibians
Survival	yes	yes	sea turtles, birds
Death	yes	yes	sea turtles, birds

* Sufficient data generated by studies on numerous chemicals.

** Insufficient data; repeated observations of incidences and correlation to presence of artificial lighting.

Environmental Restoration Comparison
"Cleaning the Problem Up"

Hypothetical scenario – compare 10 acres of land in watershed environment contaminated by either hazardous chemicals or light pollution

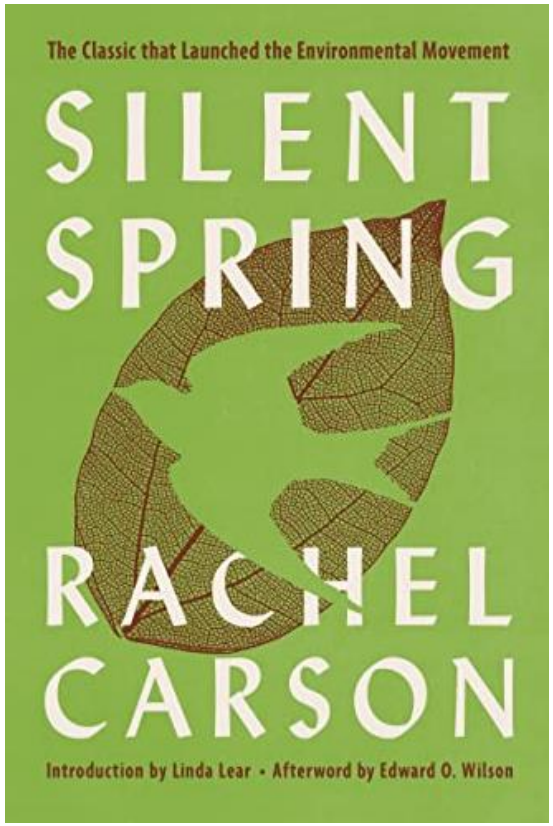
Chemical Pollution ($$$$$$$$$$$$$$)

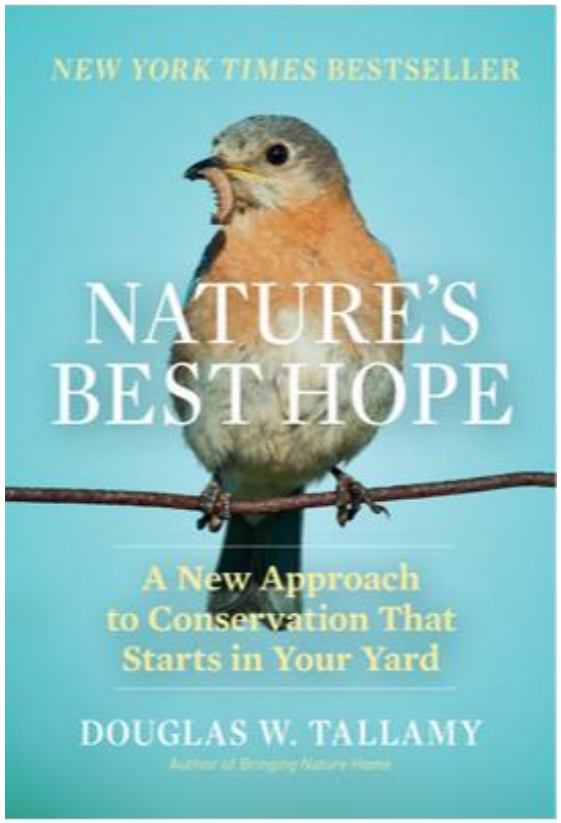
- Source – residual presence may persist after source is eliminated
- Environmental noncompliance fines
- Civil/criminal litigation costs
- Remediation/clean-up/disposal costs
- High Manpower/equipment costs
- Chemical Monitoring/recovery costs
- Long term recovery usually required
- Certain conditions may impede full recovery
- Public and wildlife health could potentially continue to be impacted after restoration.

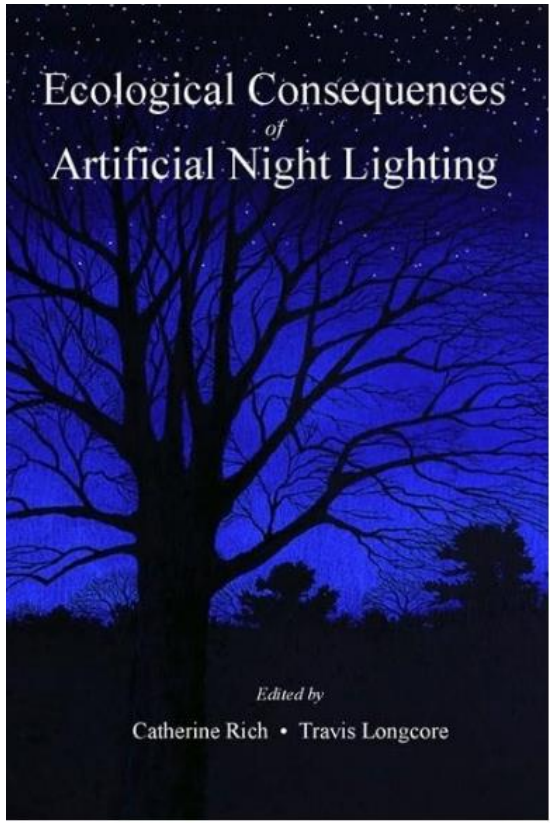
Light Pollution ($)

- Source – on/off; no residual presence after source is eliminated
- Planning and design costs
- Equipment retrofit costs
- Disposal/recycle of old equipment
- Less manpower/equipment demand
- Low/no monitoring requirement
- Short term recovery anticipated
- Minimum impediment to full recovery
- Public and wildlife health could potentially be significantly improved after restoration.

Milkweed and the Milky Way







Milkweed and the Milky Way

"We can no longer afford to consider air and water common property, free to be abused by anyone without regard to the consequences. Instead, we should begin now to treat them as scare resources, which we are no more free to contaminate than we are free to throw garbage into our neighbors yard."

Responsible Lighting

1) Need for Lighting
2) Directionality
3) Lumen Levels
4) "Correlated Color Temperature" or light color

Lighting Considerations
[ALAN = Artificial Light At Night]

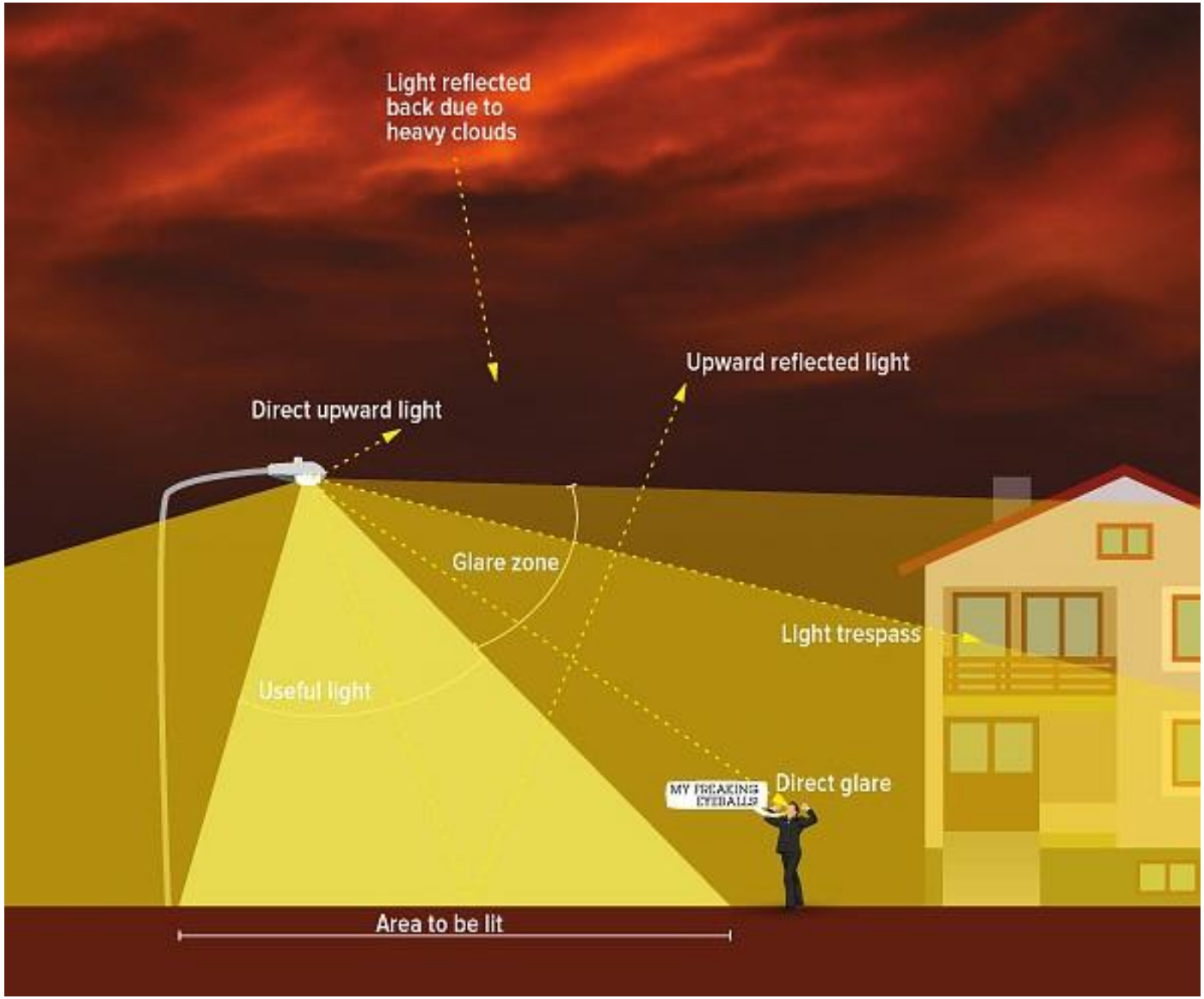
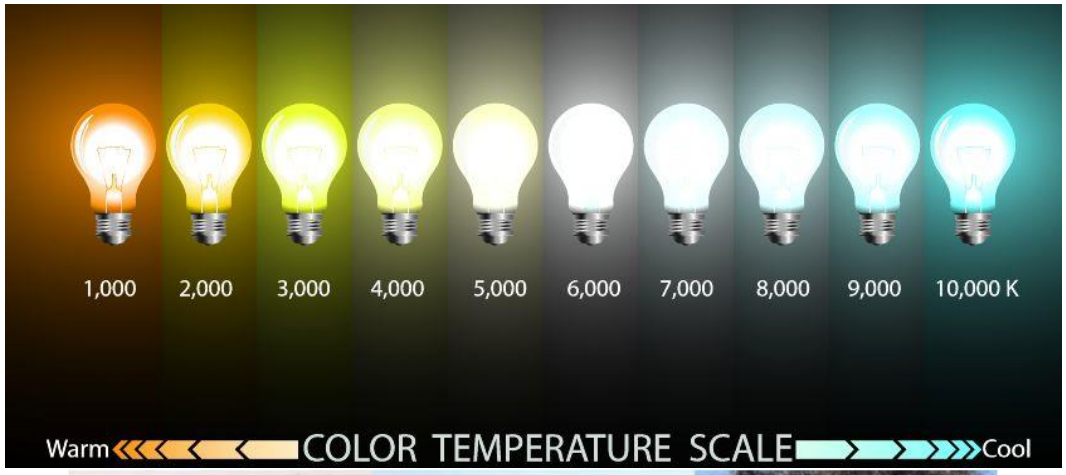
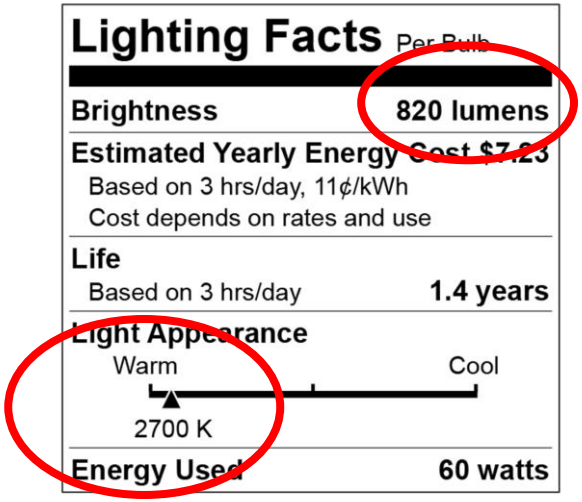


Photo Credit: IDA

Light Intensity and **Color** are both important



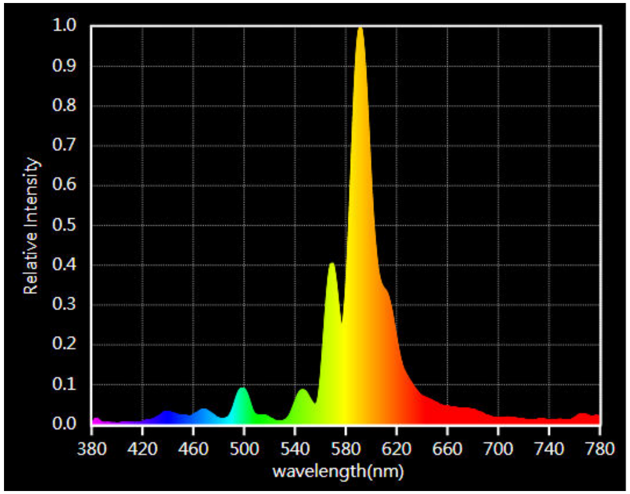


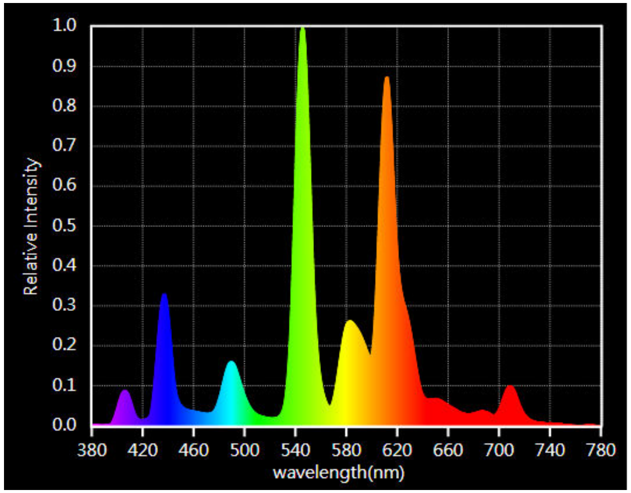
For outdoor lighting, aim for 3000 K and below, preferably about 2000 K.

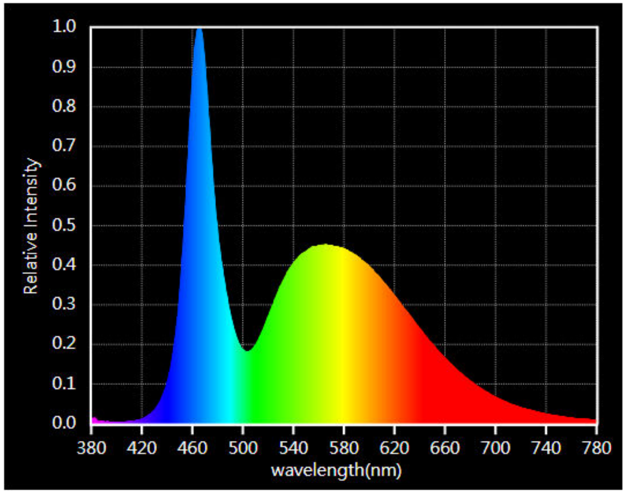
Orange/Red good, yellow bad, blue light ugly

Truman State University DarkSky Missouri

Color is important but check **spectrum**!



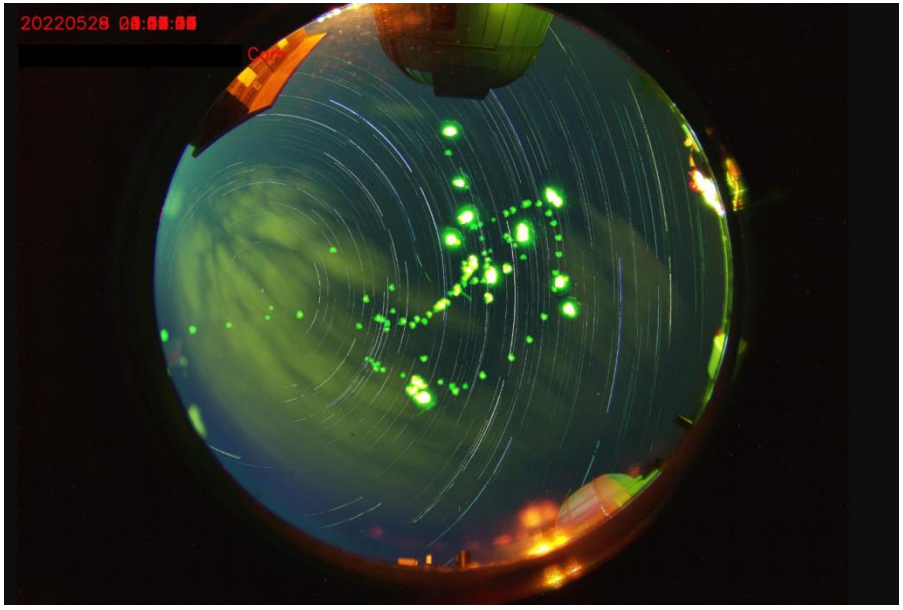




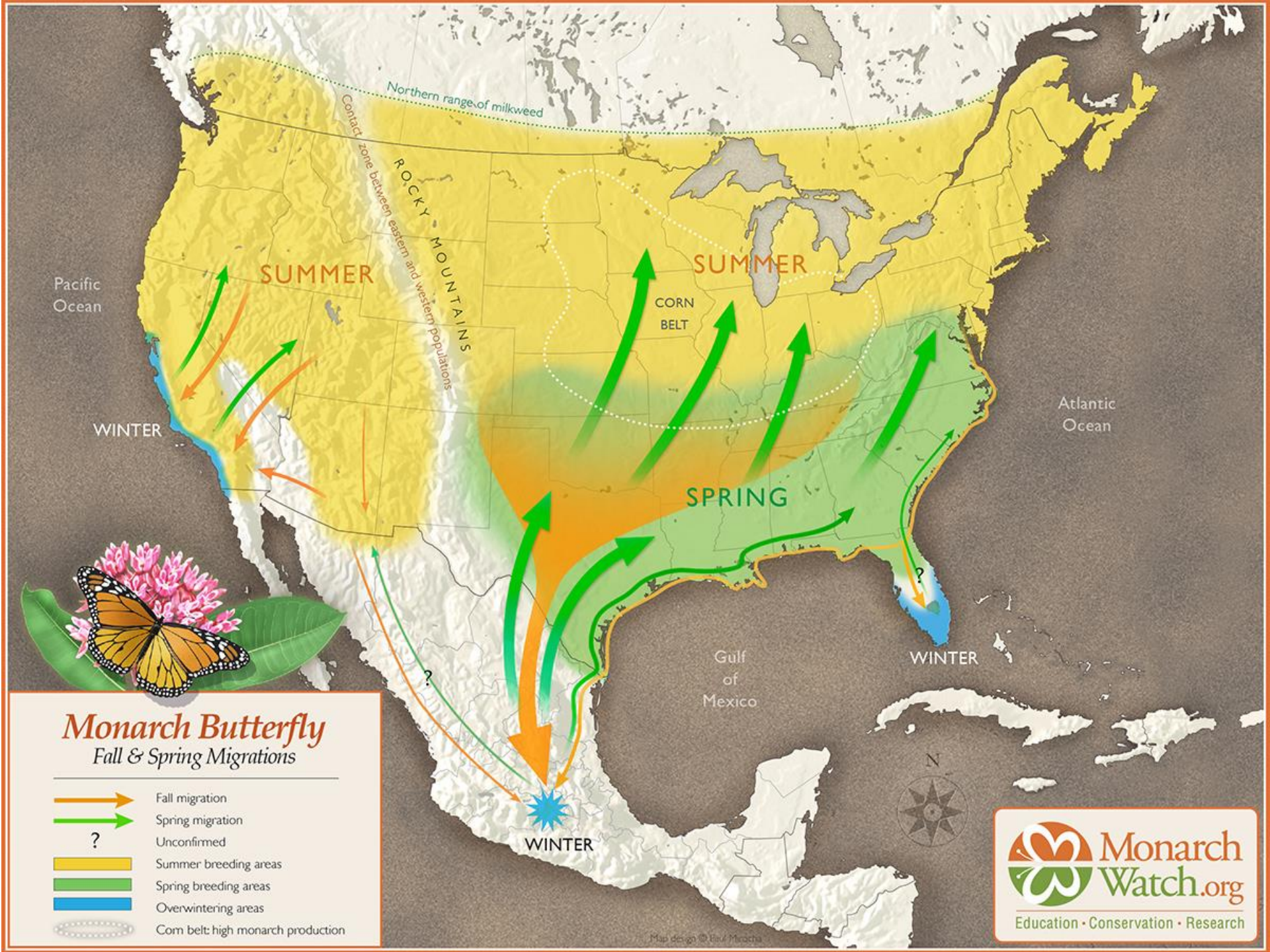
Value of Natural Darkness: A Summary

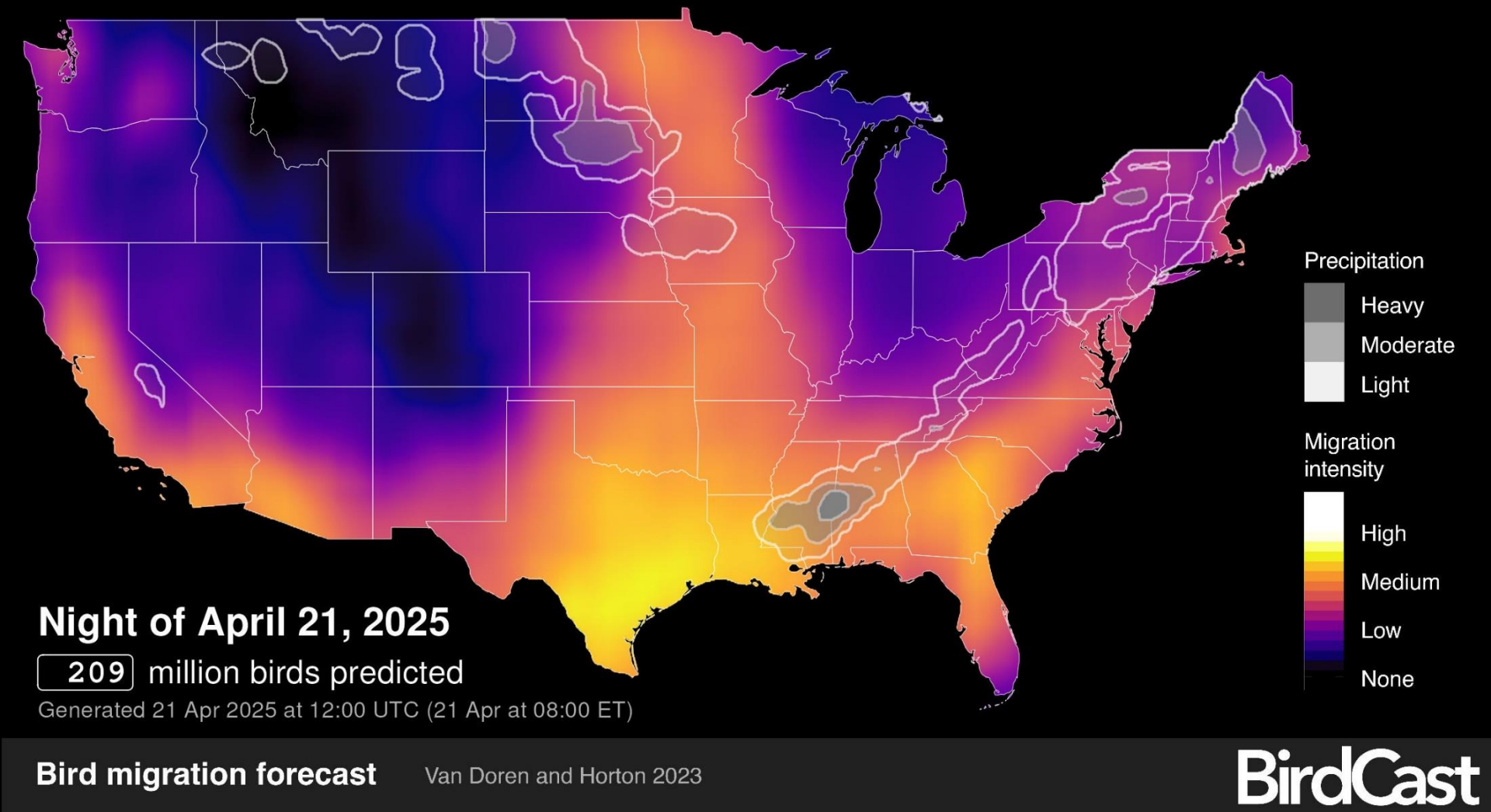
Why Responsible Lighting

- Human Health and Safety
  - Circadian rhythm
  - Reduce direct glare
- Animal Health
  - Bird Migration, Sea Turtles
  - Bees, Fireflies, and other insects
  - Ecological impact
- The Environment
  - Reduced greenhouse emissions
  - Preserve precious natural resources
- Astronomy
  - Stargazing, astronomy research
  - Aesthetics



Fireflies photobomb the all -sky-camera at the Truman State Observatory


Northern range of milkweed
Contact zone between eastern and western populations
ROCKY MOUNTAINS
SUMMER
SUMMER
CORN BELT
Pacific Ocean
Atlantic Ocean
WINTER
SPRING
?
Gulf of Mexico
WINTER
?
WINTER
N
Monarch Butterfly
Fall & Spring Migrations
Fall migration
Spring migration
? Unconfirmed
Summer breeding areas
Spring breeding areas
Overwintering areas
Corn belt: high monarch production
Monarch Watch.org
Education • Conservation • Research



Bird migration forecast Van Doren and Horton 2023

BirdCast

How to Preserve Darkness at Night

Milkweed and the Milky Way

"Humans are not genetically programmed to care about the future… I will not be asking for sacrifices that will build a better world later on.

I will suggest action that heal our damaged landscape right now, actions that create immediate, short-term gains. That such actions will also deliver long-term ecological benefits in just icing on the cake…"

Responsible Lighting

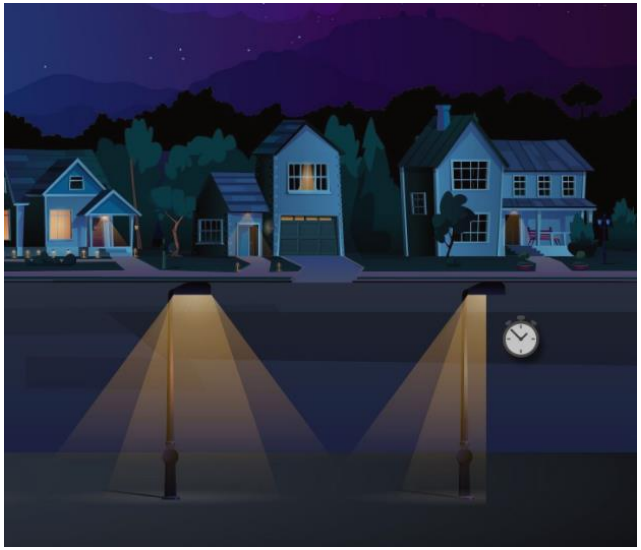
Responsible Lighting

Shielding

Intensity

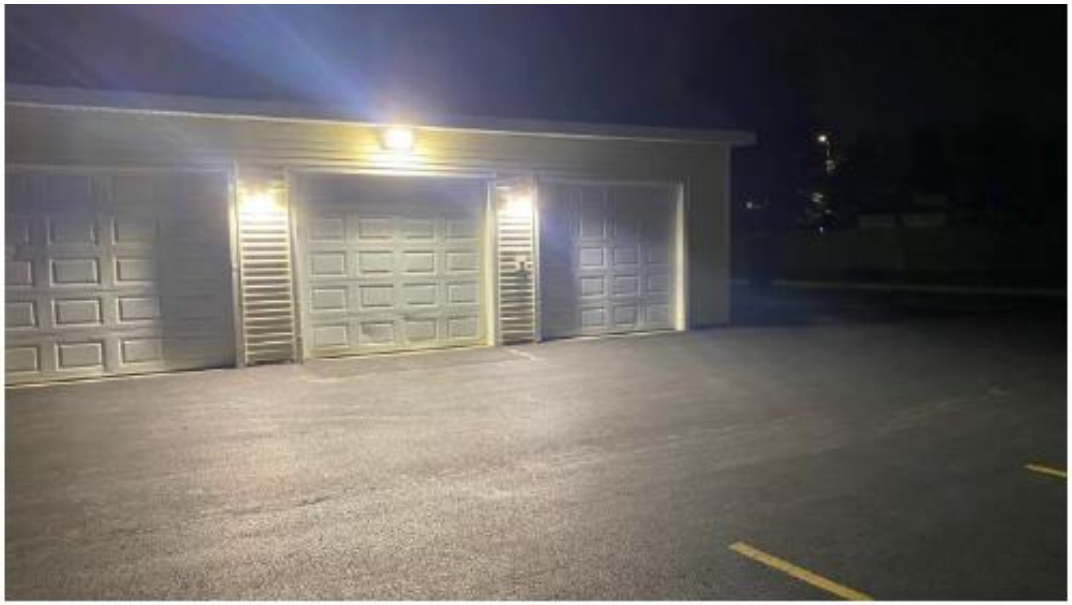
https://www.bigbenddarkskyreserve.org/lighting

Color



Purpose & Timing

Direct Glare and Safety



Direct Glare and Safety

Examples: Residential

Near Big Bend NP, Texas

Las Cruces, NM

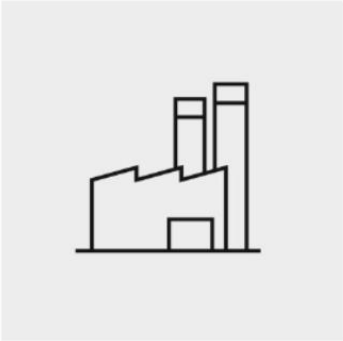
Responsible Lighting: Examples

Printco@Alpine, Tx

Walmart @Flagstaff, Az

Oil Tanks@
Balmorhea, Tx

How to find Responsible Lighting Products



Search by Company

Search by Use

Search by Retailer

Color Temperature

Residential

Credit: Lampas / Photo by Torben Eskerod

DARKSKY APPROVED

Reduces light pollution

How to find Responsible Lighting Products

1. Porch light
2. Post light
3. Street Light
4. "Starpath"

Lighting products

1. I have these in my kitchen, kids' bedrooms, and bathrooms as just ambient light. We have additional lights when we are cooking, for example:. Lumen level is low – so this is not meant to be a reading light or such. But it gives the room a nice warm-amber glow as i get the kids ready for bed, and i am telling them stories etc.
   https://www.amazon.com/Neporal-Equivalent-Blocking-Healthy-Nursery/dp/B08P5M8KHY

2. I have these in my labs at school, use them for demos, and in my study area at home:
   https://www.amazon.com/Cree-Lighting-Connected-Compatible-CMA19-60W-AL-9ACK-B3/dp/B09XYXVZH9
   You need to install an app on your phone, and need wireless network to connect for the first time. Programmable to change color and intensity, but i usually just do it based on what we are doing. I have it on amber light when i am on my computer, and if the kids are playing or we are reading etc., i set it on "white light".

3. These are yellow lights – similar to the "bug lights" that have been around. Slightly more blue content than option 1 above, but still pretty good. I don't use these simply because i already have the above two. I do have a bunch of these that i give away or use for demos in my lab: https://www.amazon.com/LOHAS-LED-Equivalent-Lighting-Decorative/dp/B0CPDS4VLV

Conclusion

The ability to see the Milky Way at night from one's front yard is just as much an indicator of a healthy, natural environment as is the presence of a pesticide free, natural habitat with natives that attracts, say, the iconic monarch butterflies.

Start with your own home and/or business

Talk to your neighbors, and advocate for responsible lighting

Talk to city officials, or the local school or University or car dealership to do the same

!! BECOME A DARKSKY ADVOCATE !!

!! BECOME A MEMBER OF DARK SKY Missouri!!

!! BECOME DARK SKY ADVOCATES !!

Printco@Alpine, Tx

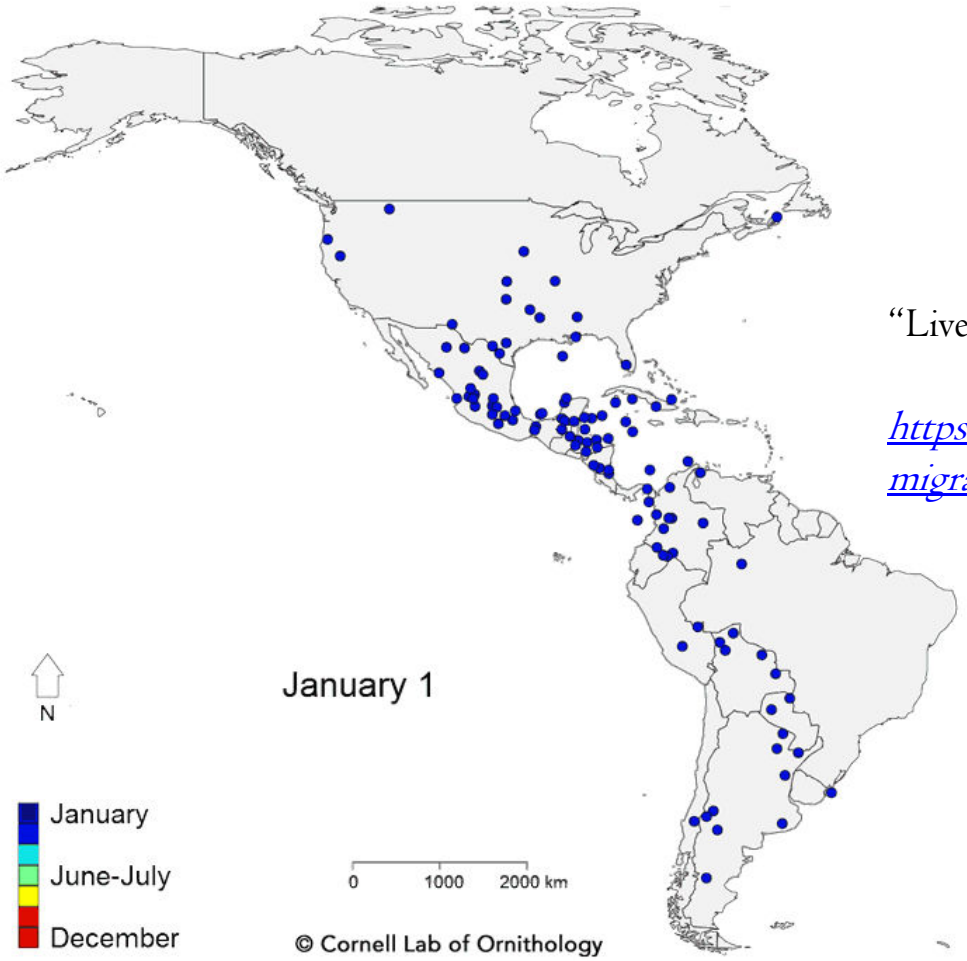
Walmart @Flagstaff, Az

FACEBOOK: DARKSKYMISSOURI

Extra Slides

ALAN And Bird Migration

- Twice each year, billions of birds fly between wintering and breeding grounds, facing innumerable threats along the way.

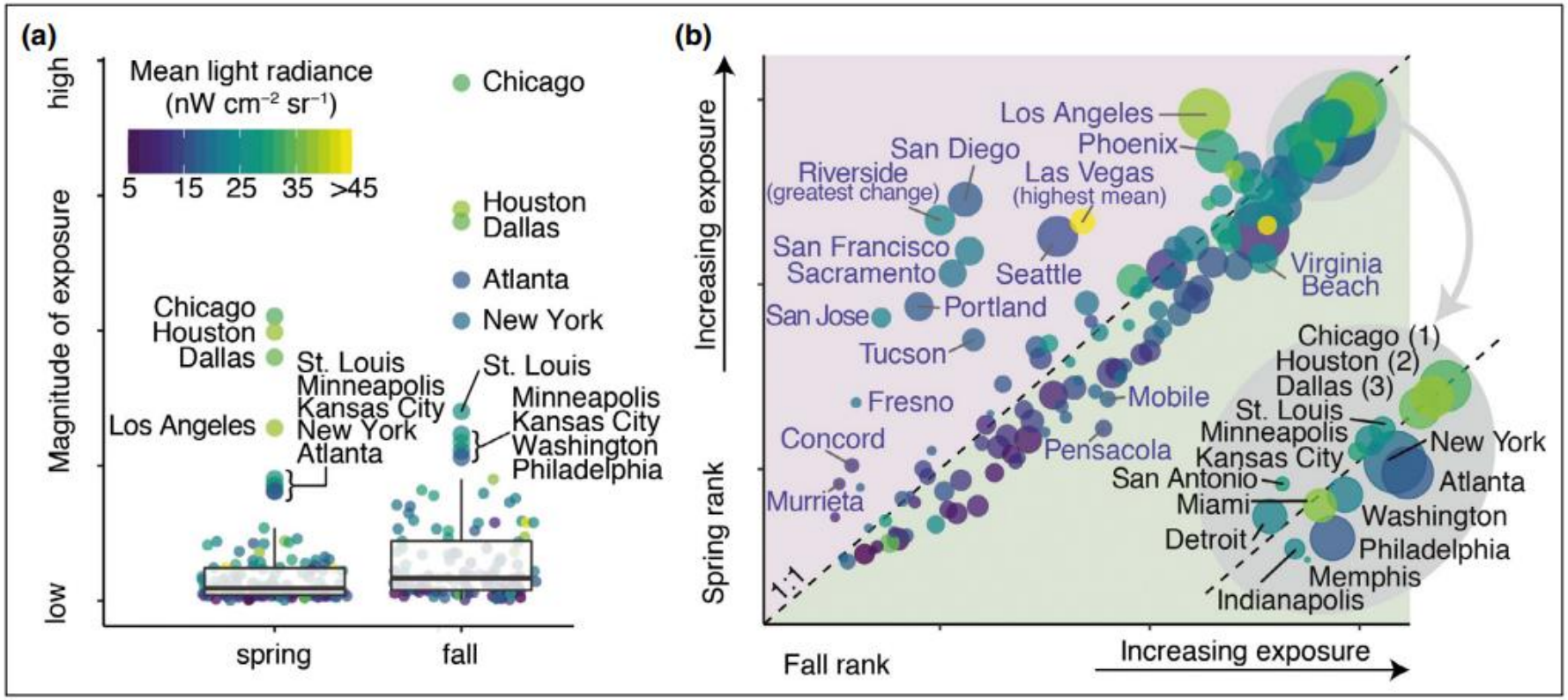


"Live" bird migration maps!

https://birdcast.info/migration-tools/live-migration-maps/

https://www.allaboutbirds.org/news/mesmerizing-migration-watch-118-bird-species-migrate-across-a-map-of-the-western-hemisphere/

ALAN And Bird Migration (Horton et al., 2019)



Seasonal (a) magnitude and (b) relative rankings of the 125 largest urban areas in the continental US. Point color shaded by the mean light radiance and sizes (in [b]) are scaled by the square root of urban area.

Inset in (b) depicts the top 15 (spring or fall) rankings

ALAN And Birds

Birds trapped in light domes near Big Bend National Park (left) and Kirksville, Missouri (right)

ALAN And Birds

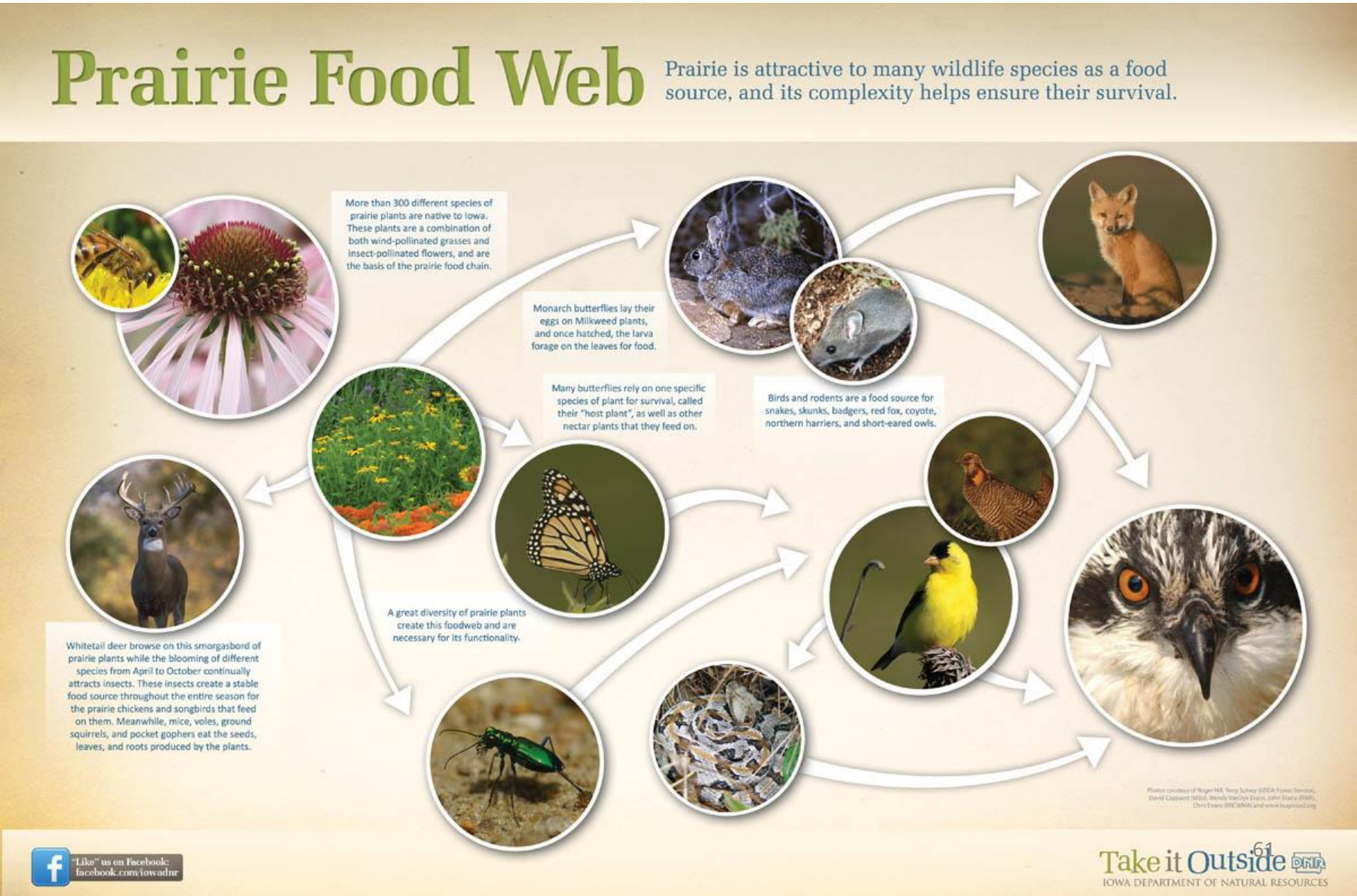
Birds belly's are lit up by upward pointing light (and also due to reflection off the snow). These birds should be "invisible" at night, but are not.

Picture Credit: http://www.missouriskies.org/

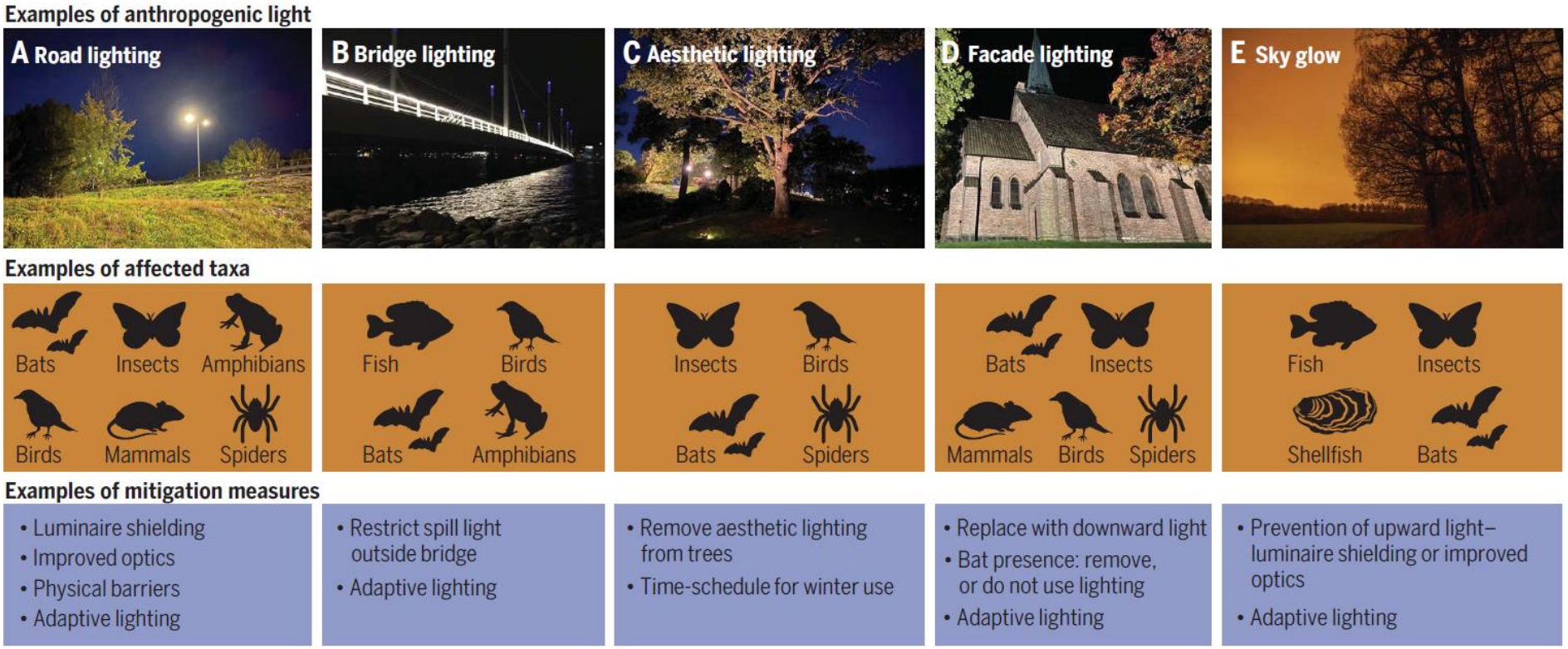
One Example, Chicago: October 2023

https://birdcast.info/news/major-collision-event-in-chicago-4-5-october-2023

Prairie Food Web



ALAN = Artificial Light At Night



"Effects of anthropogenic light on species and ecosystems"
-- Annika K. Jägerbrand and Kamiel Spoelstra,

Science: Light Pollution Special Issue 2023

Pollinators and ALAN

- Moths, including sphinx or hawk moths, are especially common and diverse nocturnal pollinators.
- Nocturnal pollinators use natural light from the stars and moon in the night sky to navigate.
- This light-seeking behavior draws them to artificial light where they become confused and trapped.

- Artificial light leaves pollinators exposed, making them easier to spot and reducing their ability to see these predators.
- Turn off unneeded lights whenever possible and shade windows during the twilight hours.

https://www.pollinator.org/

ALAN: Plants, Crops, Trees

ROADWAY LIGHTING'S IMPACT ON ALTERING SOYBEAN GROWTH: VOLUME 1

Illinois Center for Transportation
June 2017

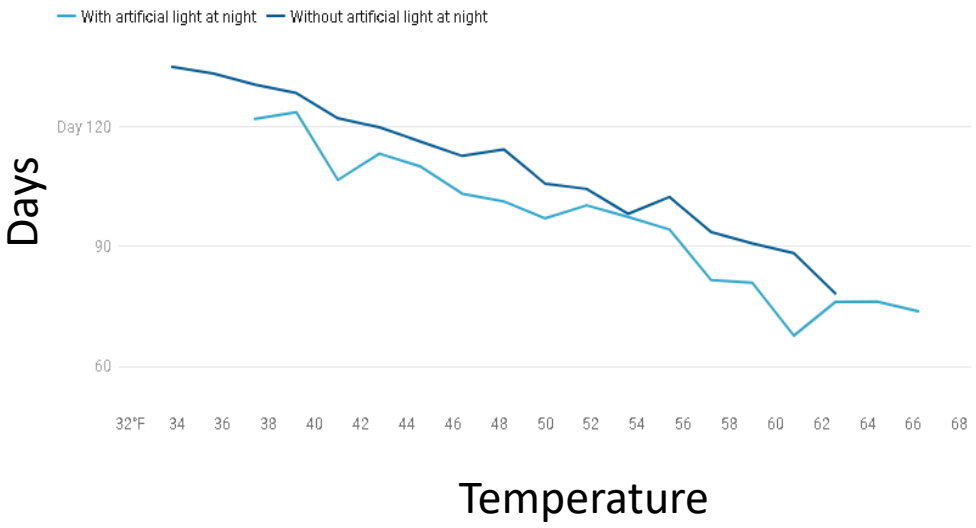
The study found three main effects of lighting on soybean plants:

a) development delays,
b) yield reduction, and
c) height increase.

This study was done with typical High-pressure Sodium lights!

LEDs are expected to make the problem worse.

ALAN: Plants, Crops, Trees



Meng et al., 2022
https://academic.oup.com/pnasnexus/article/1/2/pgac046/6569705

ALAN profoundly disturbs the natural cycles of light and darkness that plants rely on to leaf out.

The date of breaking leaf buds advances and coloring of leaves is delayed.

In a warmer and brighter night future, breaking leaf buds will continue to shift earlier, but the coloring of leaves will show a more complex response.

Birds and ALAN: Bird Migration

ALAN And Birds

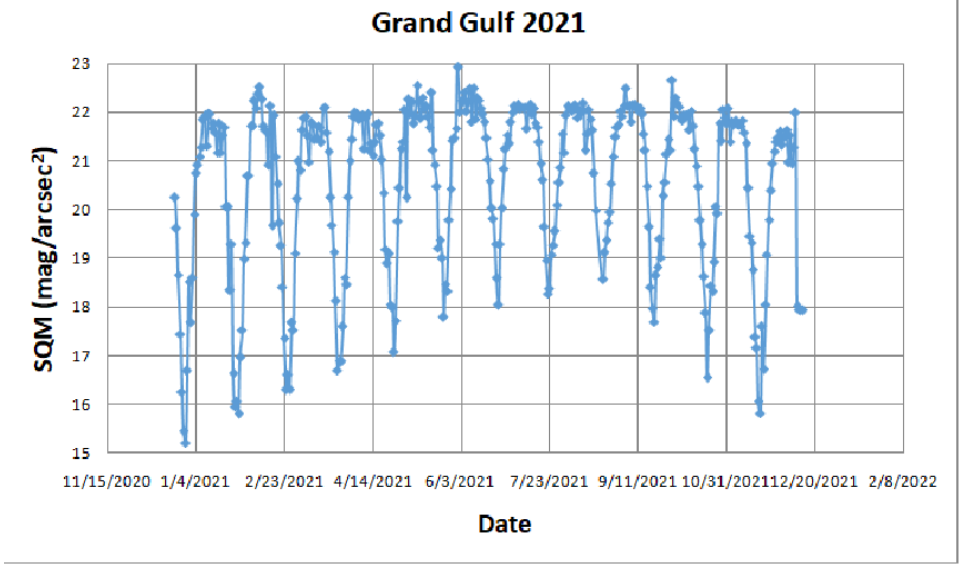
Birds trapped in light domes near Big Bend National Park (left) and Kirksville, Missouri (right)

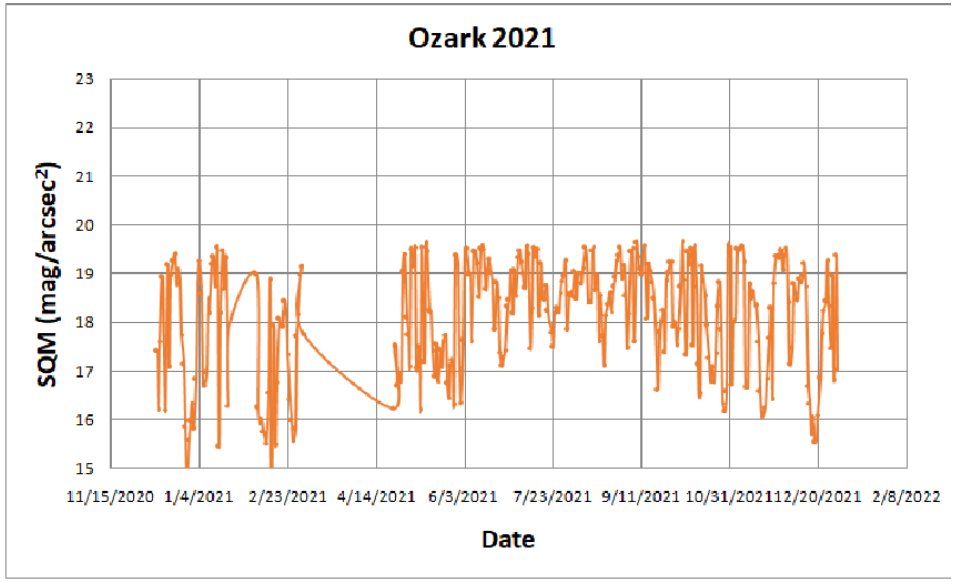
ALAN And Birds

Birds belly's are lit up by upward pointing light (and also due to reflection off the snow). These birds should be "invisible" at night, but are not.

Picture Credit: http://www.missouriskies.org/

ALAN and Natural Cycles of Darkness





Daily average SQM measurements for Grand Gulf State Park (minimal ALAN) and the City of Ozark (significant ALAN) for the year 2021. Note the clear periodic pattern in sky brightness corresponding to the Moon phase at the GGSP station. Not only is the sky brightness in the city of Ozark is significantly higher, but the rhythmic pattern corresponding to Moon-phase is severely compromised. ALAN reflects off the clouds and mimics Moonlight.

What consequence could this have of biota like migratory birds that rely on Moon phase for navigation!?

[Note: Some data in Feb and March are missing from the Ozark station due to SQM malfunction]

One Example, Chicago: October 2023

https://birdcast.info/news/major-collision-event-in-chicago-4-5-october-2023