

# Monarchs, Milkweed, and The Milky Way

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# 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

Wild  
Edibles  
Walk

Native  
Plants

Fun  
Owls and  
Raptors!

Bird  
Walks







# Spring time in America



# In the beginning...





# Milkweed and the Milky Way



Central bulge with  
elongated bar

Solar system

To the center of the Galaxy

Sagittarius arm

Solar system

Perseus arm

Closeup of the Sun's galactic neighborhood

Figure 23-16b  
*Universe, Eighth Edition*  
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The structure of the Milky Way's disk

Figure 23-16a  
*Universe, Eighth Edition*  
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## Our Galaxy: Artist's Impression

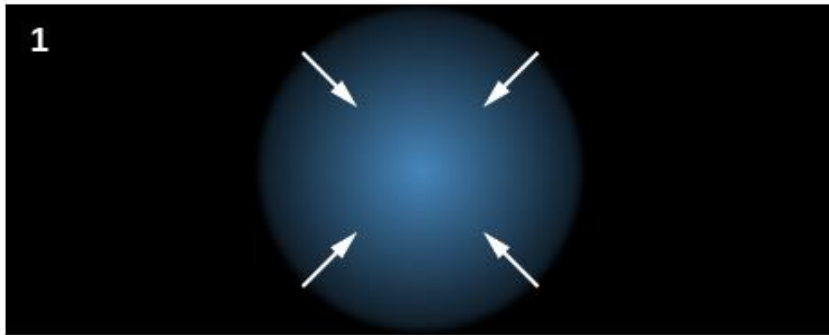
# Milkweed and the Milky Way



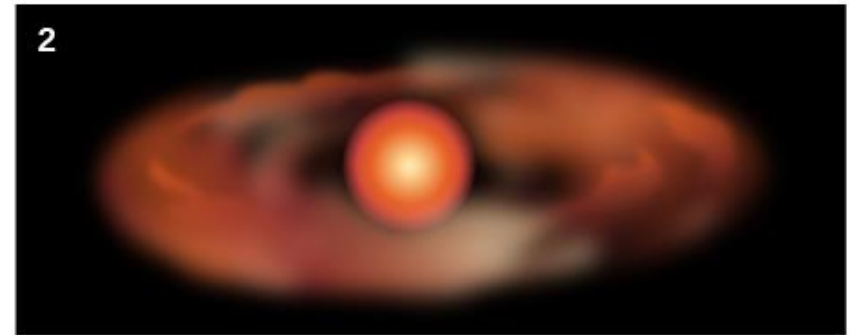
Image credit: Rob Gendler



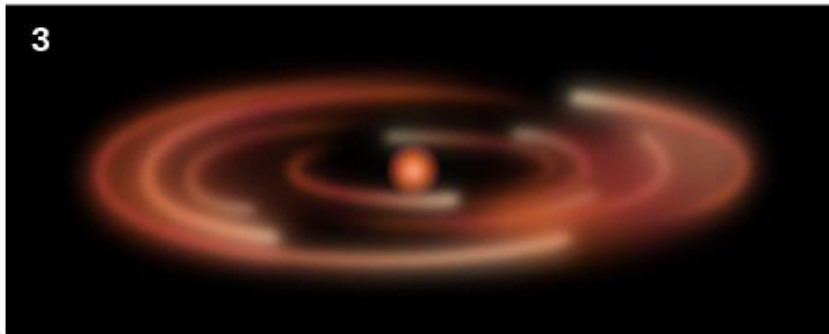
# Milkweed and the Milky Way



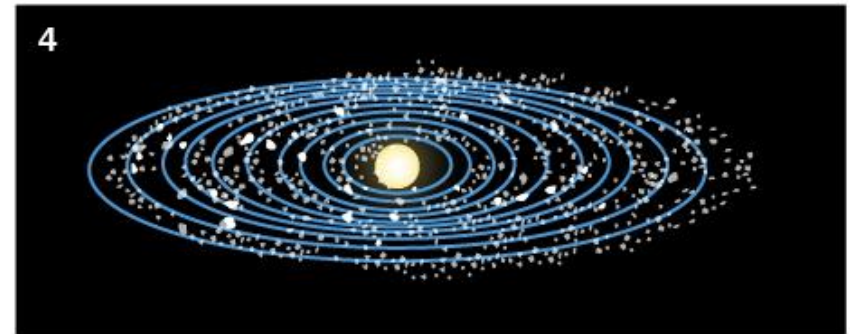
The solar nebula contracts.



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

## ORIGINS OF THE ELEMENTS

<https://svs.gsfc.nasa.gov/13873/>

<div>H<sup>1</sup></div> <div>Hydrogen</div>	<div><div><div>The big bang</div></div><div><div>Dying low-mass stars</div></div><div><div>White dwarf supernovae</div></div><div><div>Radioactive decay</div></div></div>																<div>He<sup>2</sup></div> <div>Helium</div>																	
<div>Li<sup>3</sup></div> <div>Lithium</div>	<div>Be<sup>4</sup></div> <div>Beryllium</div>	<div><div><div>Cosmic ray collisions</div></div><div><div>Dying high-mass stars</div></div><div><div>Merging neutron stars</div></div><div><div>Human-made</div></div></div>																<div>B<sup>5</sup></div> <div>Boron</div>	<div>C<sup>6</sup></div> <div>Carbon</div>	<div>N<sup>7</sup></div> <div>Nitrogen</div>	<div>O<sup>8</sup></div> <div>Oxygen</div>	<div>F<sup>9</sup></div> <div>Fluorine</div>	<div>Ne<sup>10</sup></div> <div>Neon</div>											
<div>Na<sup>11</sup></div> <div>Sodium</div>	<div>Mg<sup>12</sup></div> <div>Magnesium</div>																	<div>Al<sup>13</sup></div> <div>Aluminum</div>	<div>Si<sup>14</sup></div> <div>Silicon</div>	<div>P<sup>15</sup></div> <div>Phosphorus</div>	<div>S<sup>16</sup></div> <div>Sulfur</div>	<div>Cl<sup>17</sup></div> <div>Chlorine</div>	<div>Ar<sup>18</sup></div> <div>Argon</div>											
<div>K<sup>19</sup></div> <div>Potassium</div>	<div>Ca<sup>20</sup></div> <div>Calcium</div>	<div>Sc<sup>21</sup></div> <div>Scandium</div>	<div>Ti<sup>22</sup></div> <div>Titanium</div>	<div>V<sup>23</sup></div> <div>Vanadium</div>	<div>Cr<sup>24</sup></div> <div>Chromium</div>	<div>Mn<sup>25</sup></div> <div>Manganese</div>	<div>Fe<sup>26</sup></div> <div>Iron</div>	<div>Co<sup>27</sup></div> <div>Cobalt</div>	<div>Ni<sup>28</sup></div> <div>Nickel</div>	<div>Cu<sup>29</sup></div> <div>Copper</div>	<div>Zn<sup>30</sup></div> <div>Zinc</div>	<div>Ga<sup>31</sup></div> <div>Gallium</div>	<div>Ge<sup>32</sup></div> <div>Germanium</div>	<div>As<sup>33</sup></div> <div>Arsenic</div>	<div>Se<sup>34</sup></div> <div>Selenium</div>	<div>Br<sup>35</sup></div> <div>Bromine</div>	<div>Kr<sup>36</sup></div> <div>Krypton</div>																	
<div>Rb<sup>37</sup></div> <div>Rubidium</div>	<div>Sr<sup>38</sup></div> <div>Strontium</div>	<div>Y<sup>39</sup></div> <div>Yttrium</div>	<div>Zr<sup>40</sup></div> <div>Zirconium</div>	<div>Nb<sup>41</sup></div> <div>Niobium</div>	<div>Mo<sup>42</sup></div> <div>Molybdenum</div>	<div>Tc<sup>43</sup></div> <div>Technetium</div>	<div>Ru<sup>44</sup></div> <div>Ruthenium</div>	<div>Rh<sup>45</sup></div> <div>Rhodium</div>	<div>Pd<sup>46</sup></div> <div>Palladium</div>	<div>Ag<sup>47</sup></div> <div>Silver</div>	<div>Cd<sup>48</sup></div> <div>Cadmium</div>	<div>In<sup>49</sup></div> <div>Indium</div>	<div>Sn<sup>50</sup></div> <div>Tin</div>	<div>Sb<sup>51</sup></div> <div>Antimony</div>	<div>Te<sup>52</sup></div> <div>Tellurium</div>	<div>I<sup>53</sup></div> <div>Iodine</div>	<div>Xe<sup>54</sup></div> <div>Xenon</div>																	
<div>Cs<sup>55</sup></div> <div>Cesium</div>	<div>Ba<sup>56</sup></div> <div>Barium</div>			<div>Hf<sup>72</sup></div> <div>Hafnium</div>	<div>Ta<sup>73</sup></div> <div>Tantalum</div>	<div>W<sup>74</sup></div> <div>Tungsten</div>	<div>Re<sup>75</sup></div> <div>Rhenium</div>	<div>Os<sup>76</sup></div> <div>Osmium</div>	<div>Ir<sup>77</sup></div> <div>Iridium</div>	<div>Pt<sup>78</sup></div> <div>Platinum</div>	<div>Au<sup>79</sup></div> <div>Gold</div>	<div>Hg<sup>80</sup></div> <div>Mercury</div>	<div>Tl<sup>81</sup></div> <div>Thallium</div>	<div>Pb<sup>82</sup></div> <div>Lead</div>	<div>Bi<sup>83</sup></div> <div>Bismuth</div>	<div>Po<sup>84</sup></div> <div>Polonium</div>	<div>At<sup>85</sup></div> <div>Astatine</div>	<div>Rn<sup>86</sup></div> <div>Radon</div>																
<div>Fr<sup>87</sup></div> <div>Francium</div>	<div>Ra<sup>88</sup></div> <div>Radium</div>			<div>Rf<sup>104</sup></div> <div>Rutherfordium</div>	<div>Db<sup>105</sup></div> <div>Dubnium</div>	<div>Sg<sup>106</sup></div> <div>Seaborgium</div>	<div>Bh<sup>107</sup></div> <div>Bohrium</div>	<div>Hs<sup>108</sup></div> <div>Hassium</div>	<div>Mt<sup>109</sup></div> <div>Meitnerium</div>	<div>Ds<sup>110</sup></div> <div>Darmstadtium</div>	<div>Rg<sup>111</sup></div> <div>Roentgenium</div>	<div>Cn<sup>112</sup></div> <div>Copernicium</div>	<div>Nh<sup>113</sup></div> <div>Nihonium</div>	<div>Fl<sup>114</sup></div> <div>Flerovium</div>	<div>Mc<sup>115</sup></div> <div>Moscovium</div>	<div>Lv<sup>116</sup></div> <div>Livermorium</div>	<div>Ts<sup>117</sup></div> <div>Tennessine</div>	<div>Og<sup>118</sup></div> <div>Oganesson</div>																
		<div>La<sup>57</sup></div> <div>Lanthanum</div>	<div>Ce<sup>58</sup></div> <div>Cerium</div>	<div>Pr<sup>59</sup></div> <div>Praseodymium</div>	<div>Nd<sup>60</sup></div> <div>Neodymium</div>	<div>Pm<sup>61</sup></div> <div>Promethium</div>	<div>Sm<sup>62</sup></div> <div>Samarium</div>	<div>Eu<sup>63</sup></div> <div>Europium</div>	<div>Gd<sup>64</sup></div> <div>Gadolinium</div>	<div>Tb<sup>65</sup></div> <div>Terbium</div>	<div>Dy<sup>66</sup></div> <div>Dysprosium</div>	<div>Ho<sup>67</sup></div> <div>Holmium</div>	<div>Er<sup>68</sup></div> <div>Erbium</div>	<div>Tm<sup>69</sup></div> <div>Thulium</div>	<div>Yb<sup>70</sup></div> <div>Ytterbium</div>	<div>Lu<sup>71</sup></div> <div>Lutetium</div>																		
		<div>Ac<sup>89</sup></div> <div>Actinium</div>	<div>Th<sup>90</sup></div> <div>Thorium</div>	<div>Pa<sup>91</sup></div> <div>Protactinium</div>	<div>U<sup>92</sup></div> <div>Uranium</div>	<div>Np<sup>93</sup></div> <div>Neptunium</div>	<div>Pu<sup>94</sup></div> <div>Plutonium</div>	<div>Am<sup>95</sup></div> <div>Americium</div>	<div>Cm<sup>96</sup></div> <div>Curium</div>	<div>Bk<sup>97</sup></div> <div>Berkelium</div>	<div>Cf<sup>98</sup></div> <div>Californium</div>	<div>Es<sup>99</sup></div> <div>Einsteinium</div>	<div>Fm<sup>100</sup></div> <div>Fermium</div>	<div>Md<sup>101</sup></div> <div>Mendelevium</div>	<div>No<sup>102</sup></div> <div>Nobelium</div>	<div>Lr<sup>103</sup></div> <div>Lawrencium</div>																		

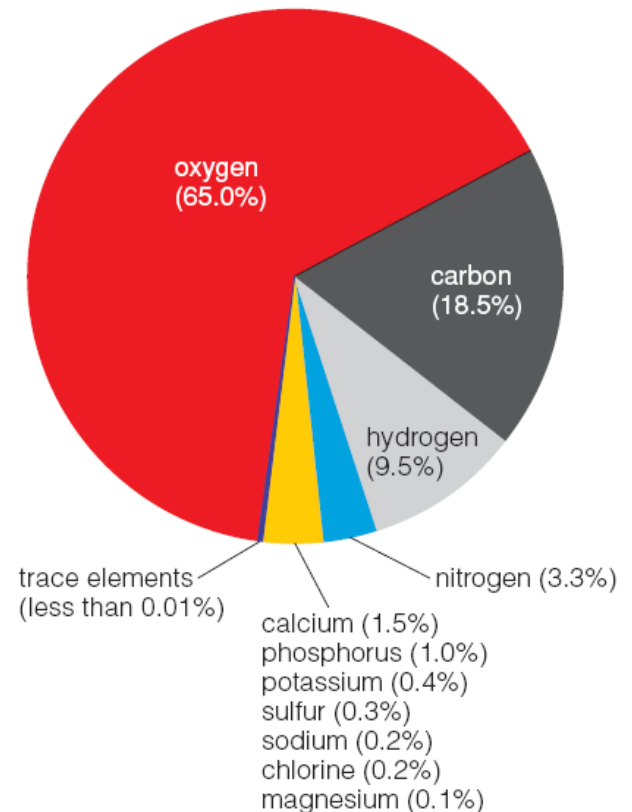
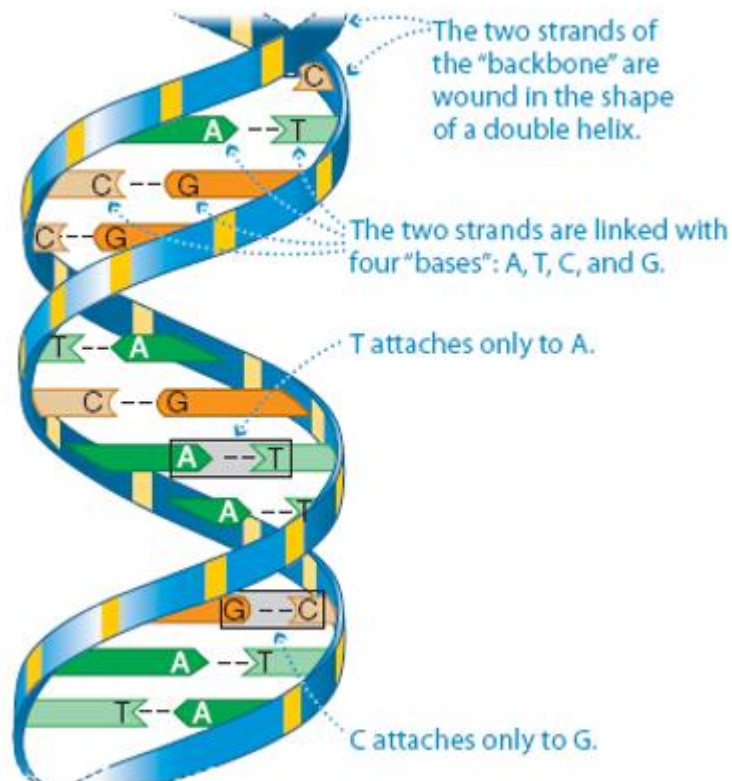
This periodic table depicts the primary source on Earth for each element. In cases where two sources contribute fairly equally, both appear.

# Milkweed and the Milky Way

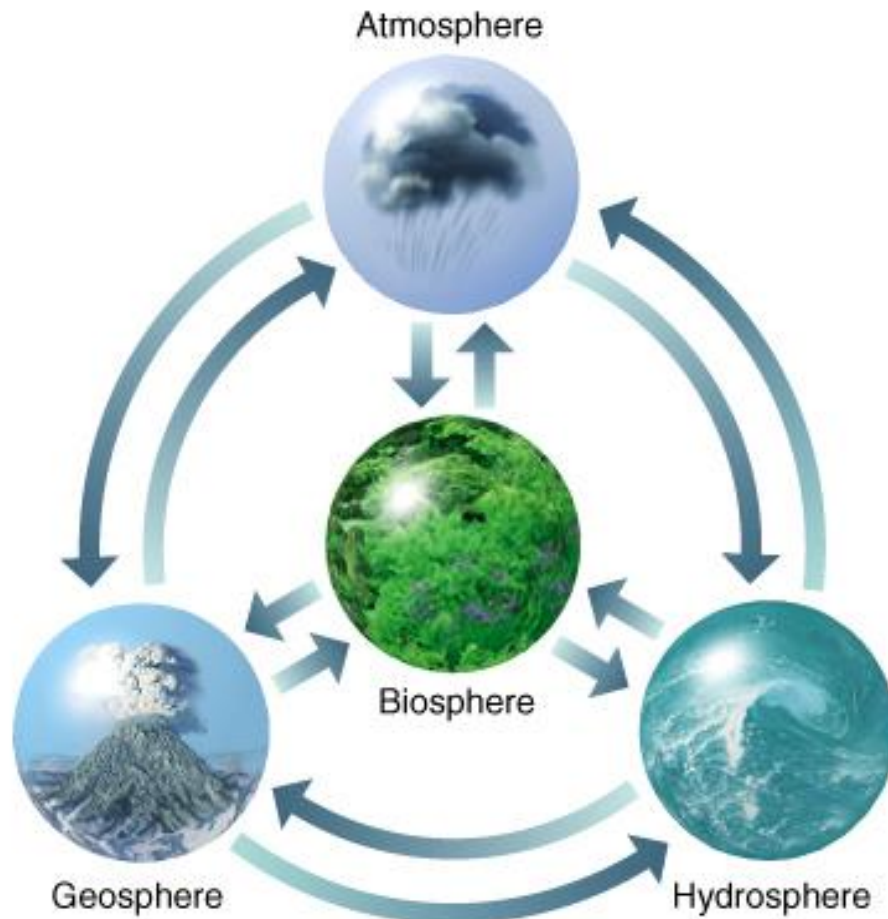




# Let there be Life...



# Milkweed and the Milky Way



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© Brooks/Cole, Cengage Learning

# Earth and its neighbors

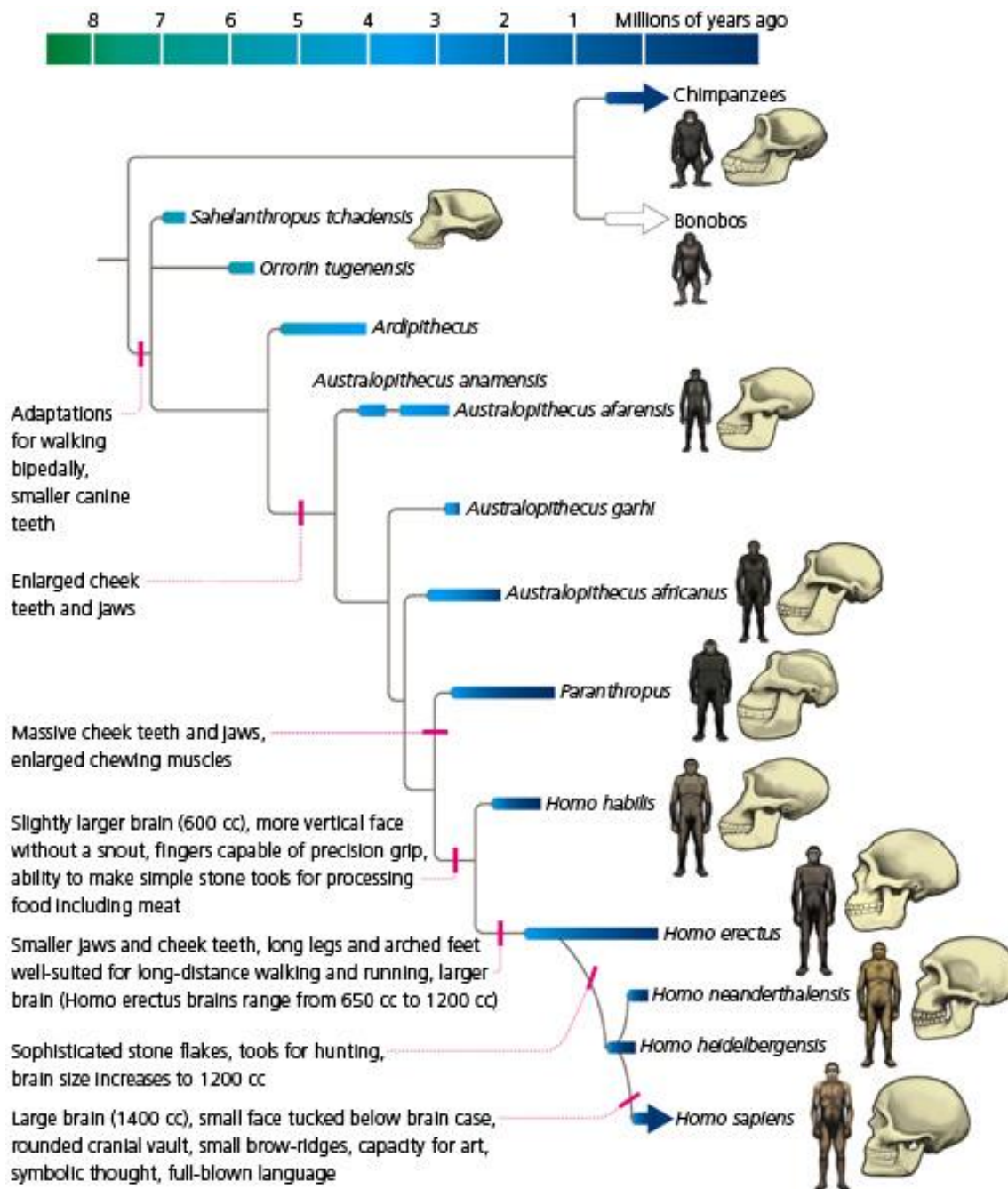
## Atmosphere

	Planet			
Gas	Venus	Earth (without life)	Mars	Earth (with life)
CO <sub>2</sub>	96.5%	98%	95%	<b>0.03%</b>
N <sub>2</sub>	3.5%	1.9%	2.7%	<b>79%</b>
O <sub>2</sub>	Trace	0.0%	0.13%	<b>21%</b>
Ar	70 ppm	0.1%	1.6%	<b>1%</b>
CH <sub>4</sub>	0.0%	0.0%	0.0%	<b>1.7 ppm</b>
T <sub>s</sub> °C	459	240-340	-53	<b>15</b>
P (bars)	90	60	0.0064	<b>1.0</b>

*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

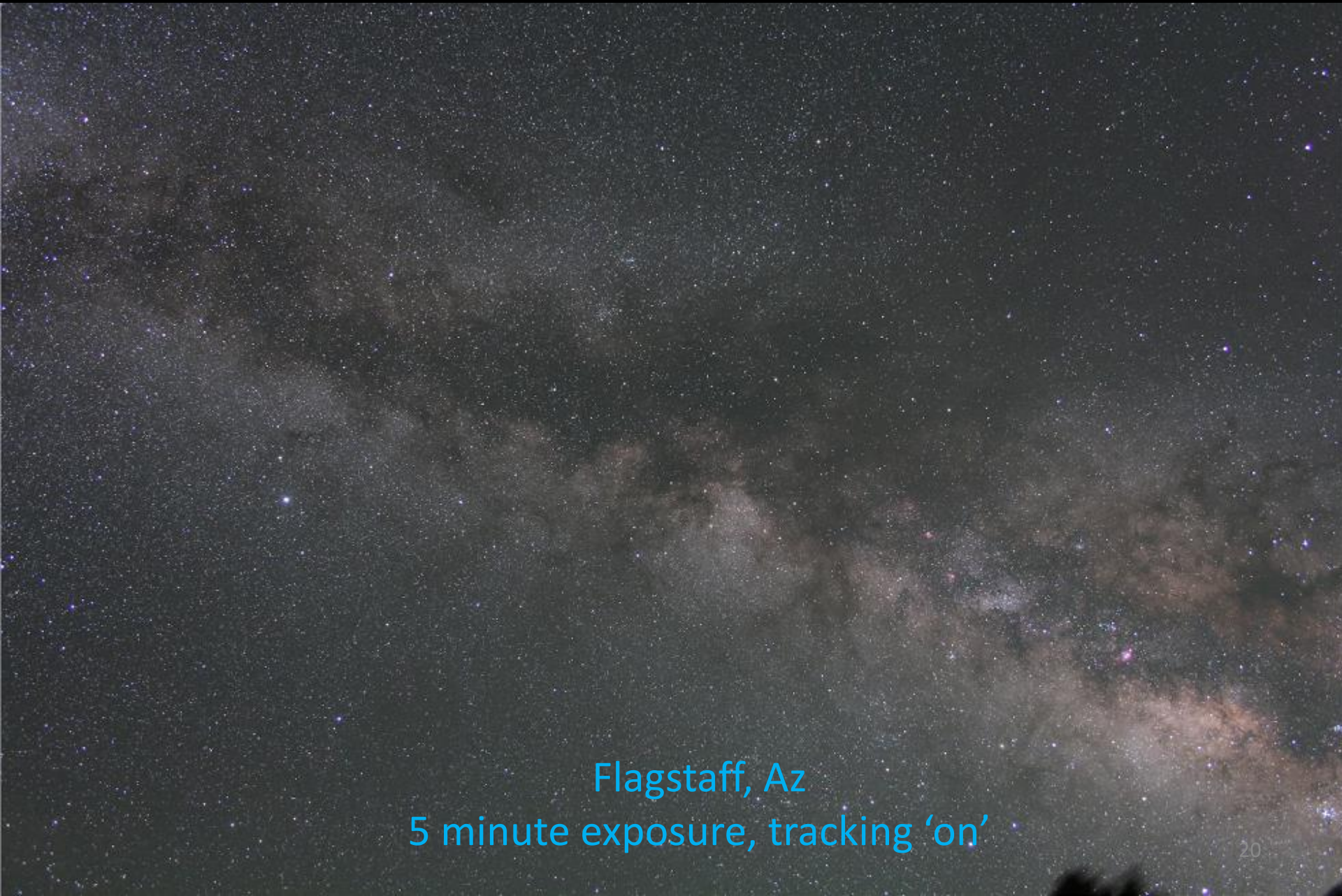


# Milkweed and the Milky Way





# 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...

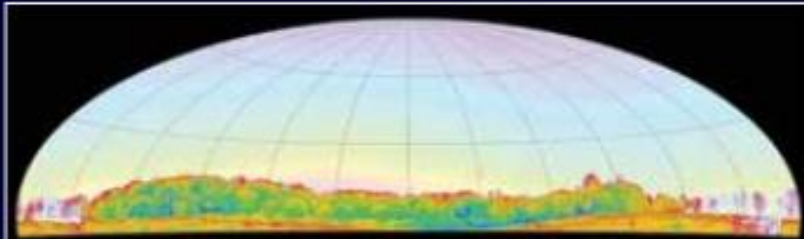
Then a strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death...”



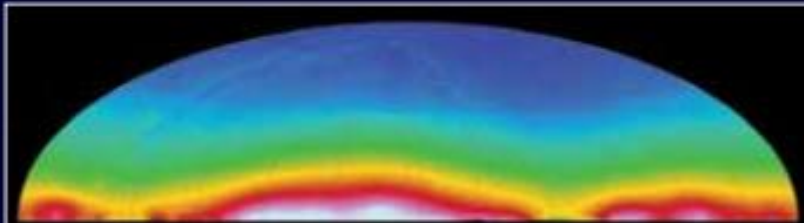


Kraigstief, Mo  
15 minute exposure, tracking on'

# Sky Glow from 200 miles away



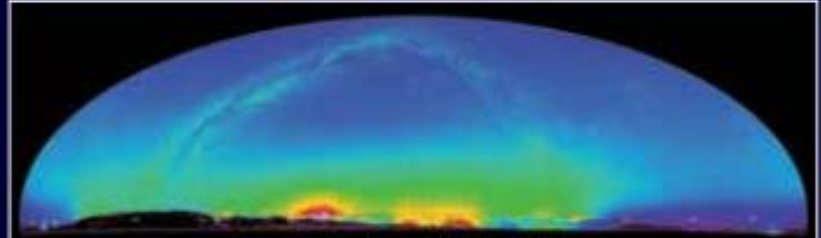
Rock Creek Park, Washington D.C.



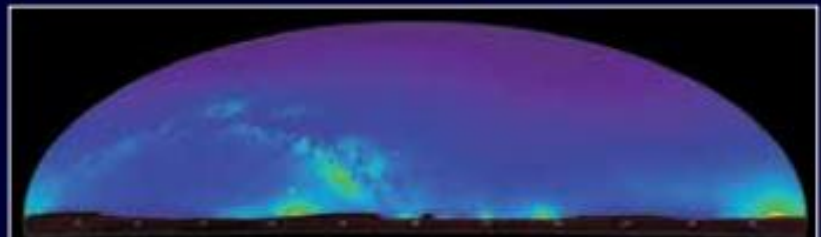
Great Smoky Mountains National Park, Tennessee



Mount Rainier National Park, Washington



Acadia National Park, Maine



Chaco Culture National Historical Park, New Mexico

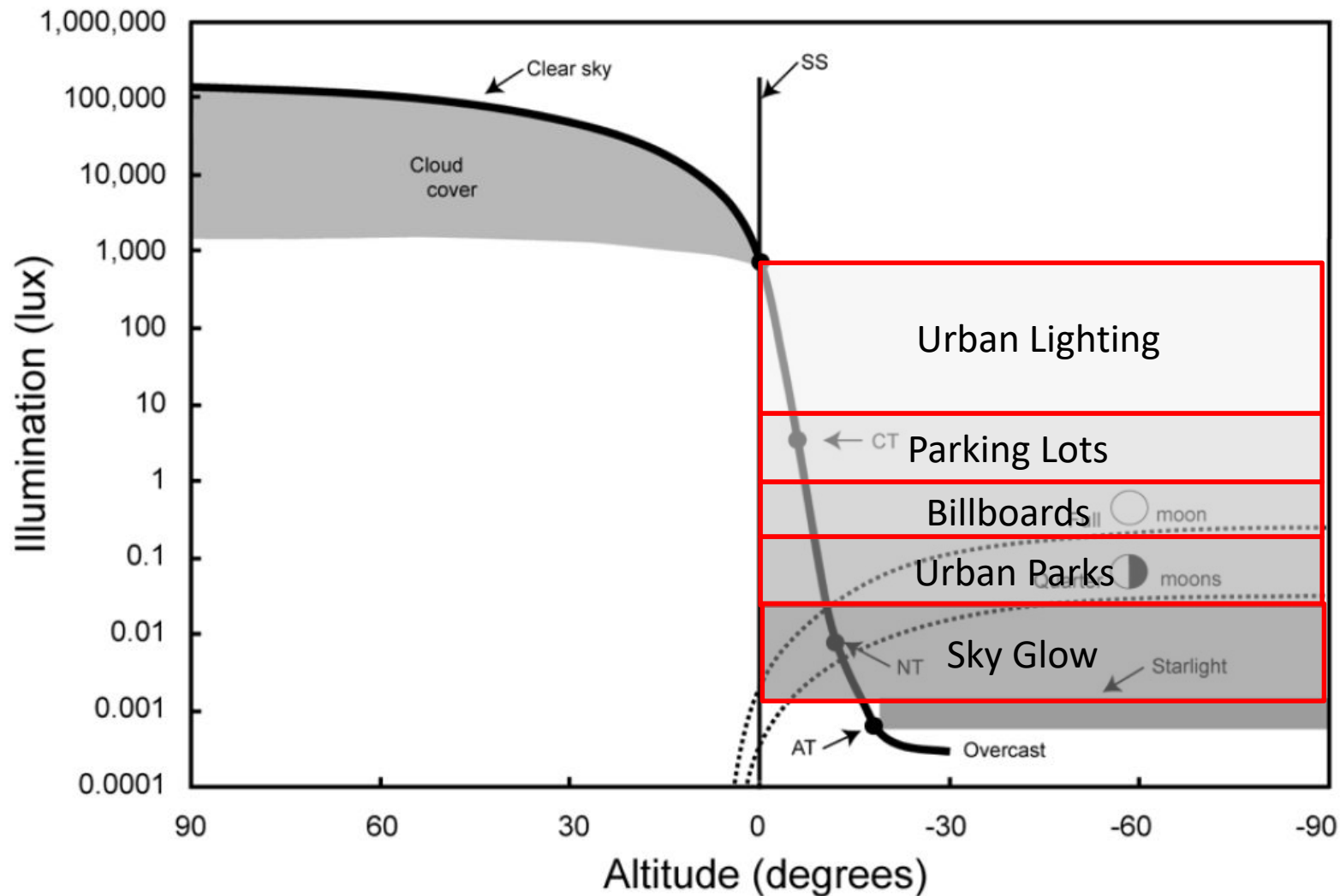


Death Valley National Park, California



*National Parks Service*

# Natural Illumination Night and Day



Credit: T. Longcore



# Similarities between Chemical and Light Pollution

<u>Organism Impact</u>	<u>Chemical</u> *	<u>Light</u> **	<u>LP Examples</u>
■ 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

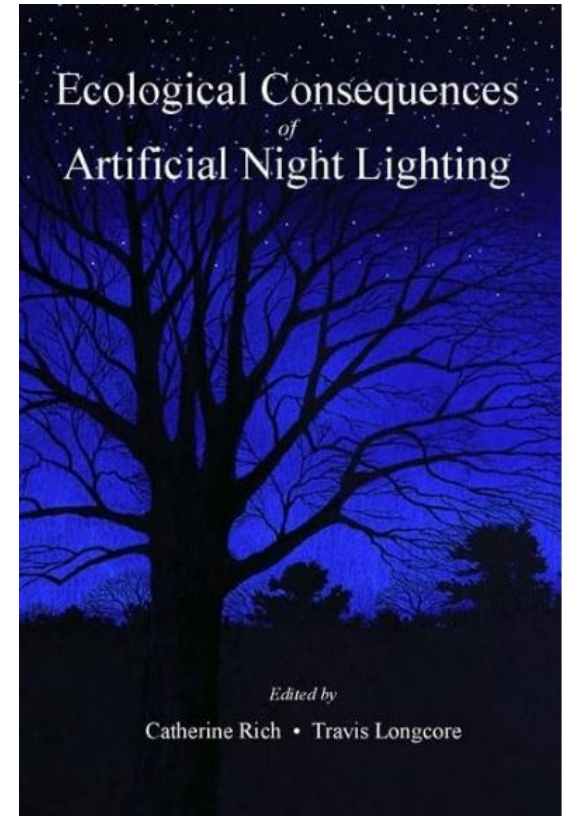
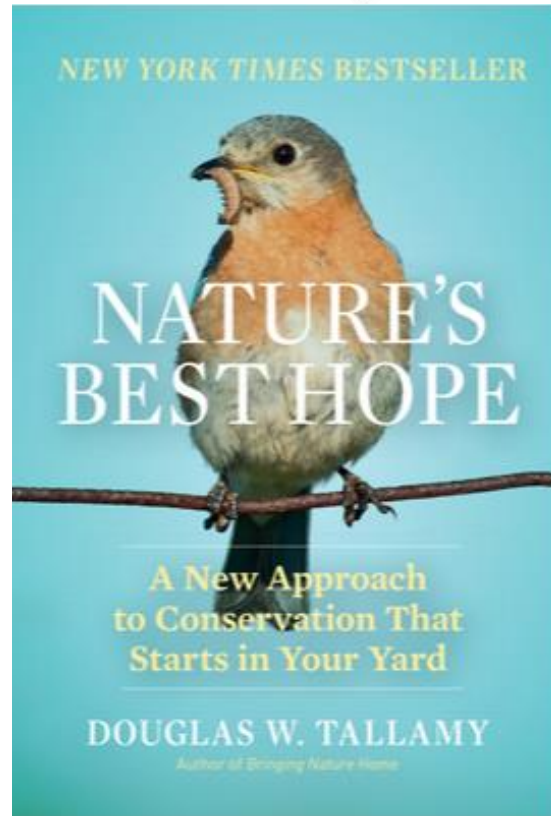
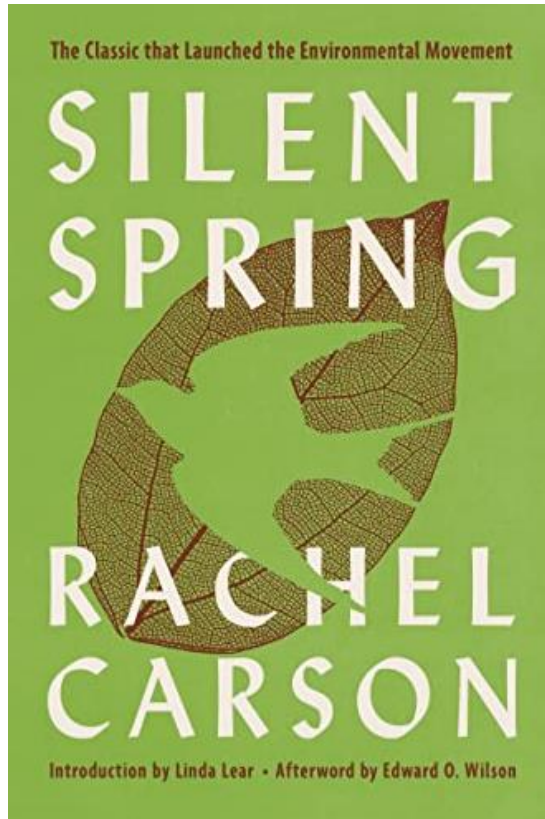
### Chemical Pollution (\$\$\$\$\$\$\$\$\$\$\$\$\$\$)

- 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 scarce 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 = **A**rtificial **L**ight **A**t **N**ight]

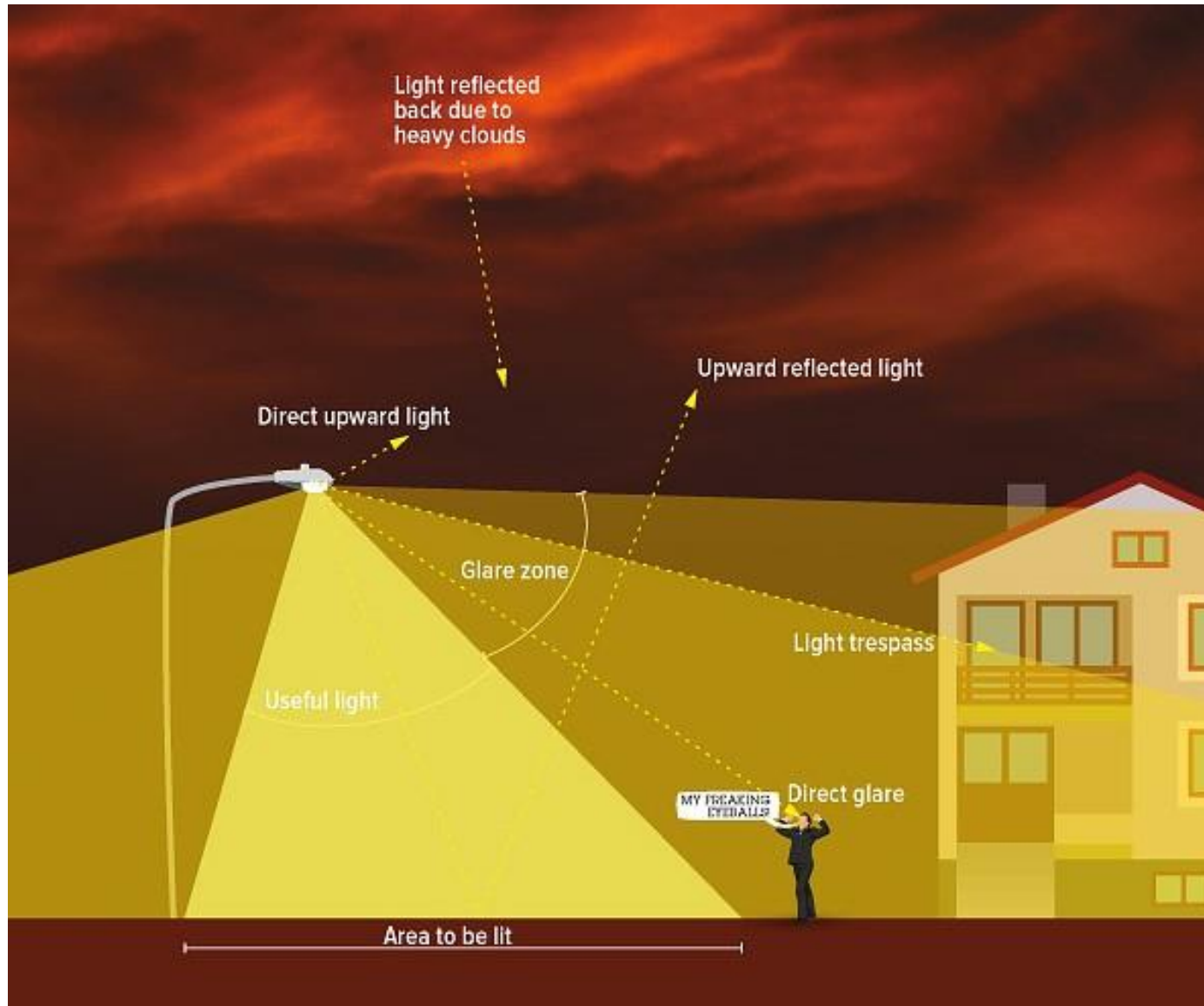
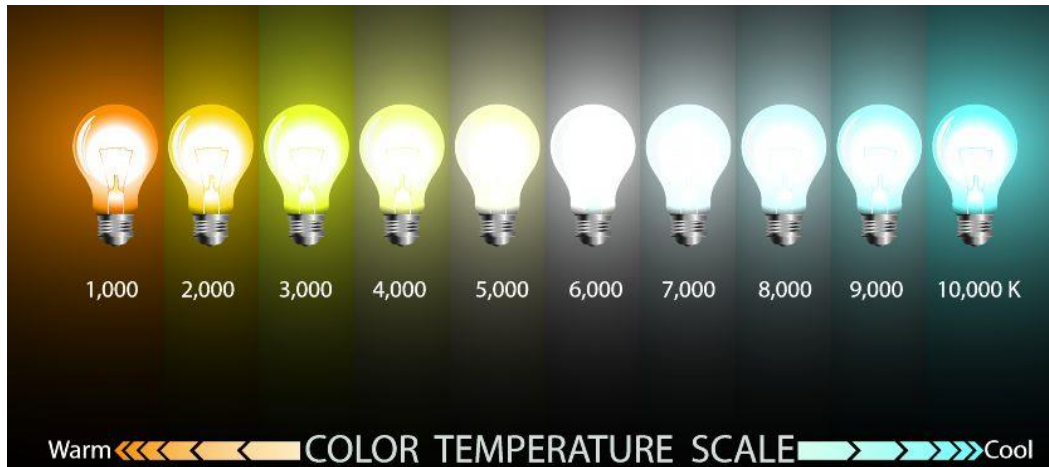


Photo Credit: IDA



Light Intensity and **Color** are both important



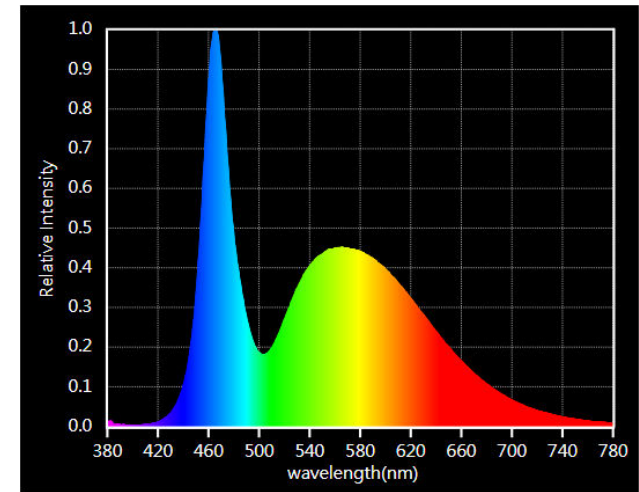
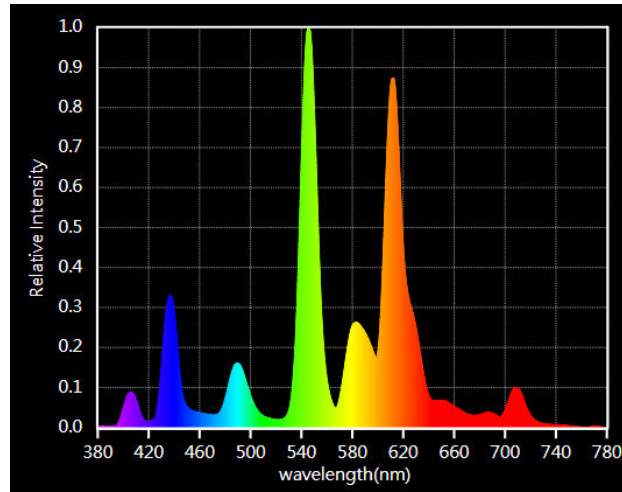
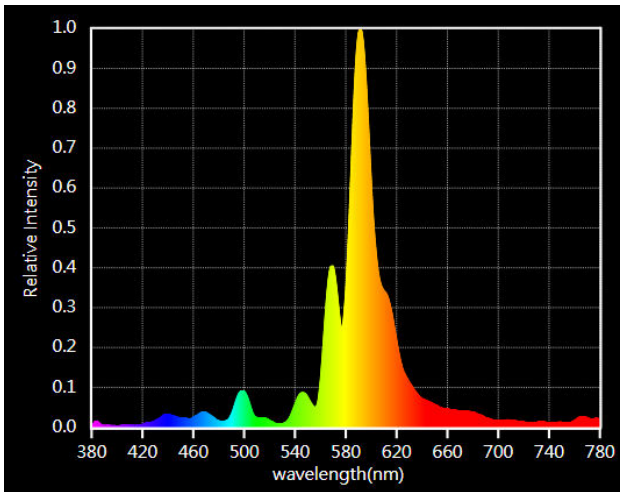
Lighting Facts	
Brightness	820 lumens
Estimated Yearly Energy Cost	\$7.23
Based on 3 hrs/day, 11¢/kWh	
Cost depends on rates and use	
Life	1.4 years
Based on 3 hrs/day	
Light Appearance	<div> <div>Warm</div> <div>Cool</div> <div>2700 K</div> </div>
Energy Used	60 watts



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

Orange/Red good, yellow bad, blue light ugly

**Color** is important but check **spectrum!**



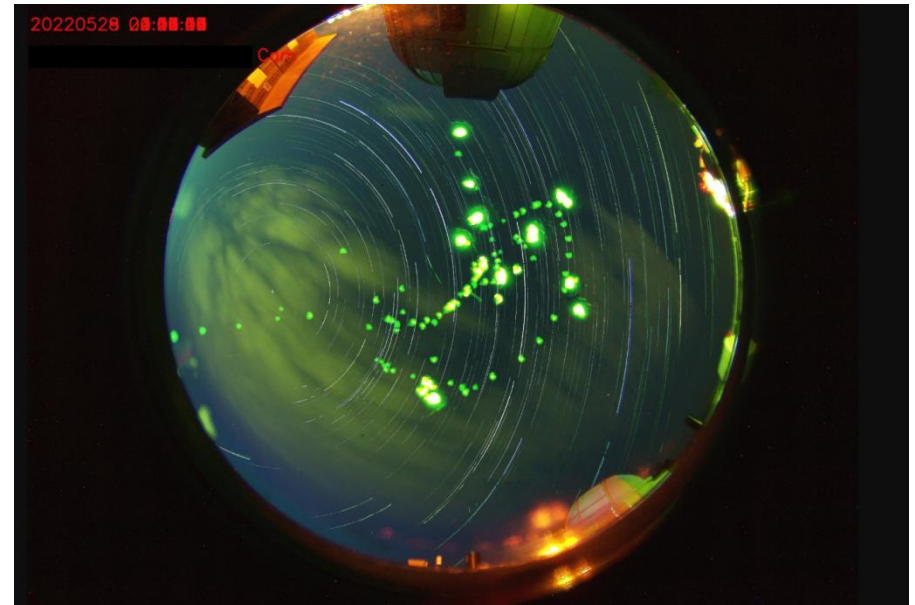
# Value of Natural Darkness: A Summary





# Why Responsible Lighting

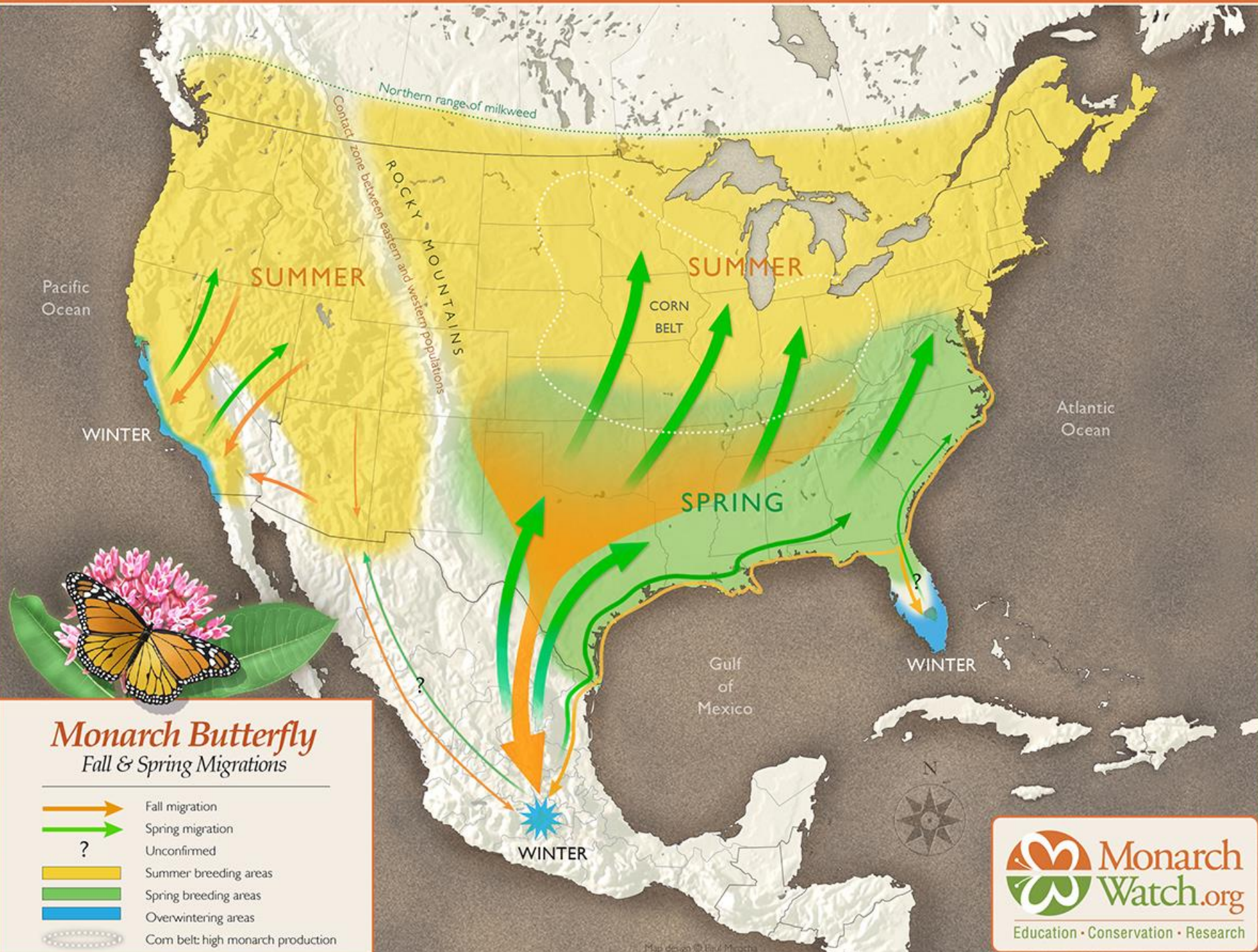
- Human Health and Safety
  - Circadian rhythm
  - Reduce direct glare
- Animal Health
  - Bird Migration, Sea Turtles
  - Bees, Fireflies, and other insects
  - Ecological impact
- The Environment
  - Reduced greenhouse emissions
  - Preserve precious natural resources
- Astronomy
  - Stargazing, astronomy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



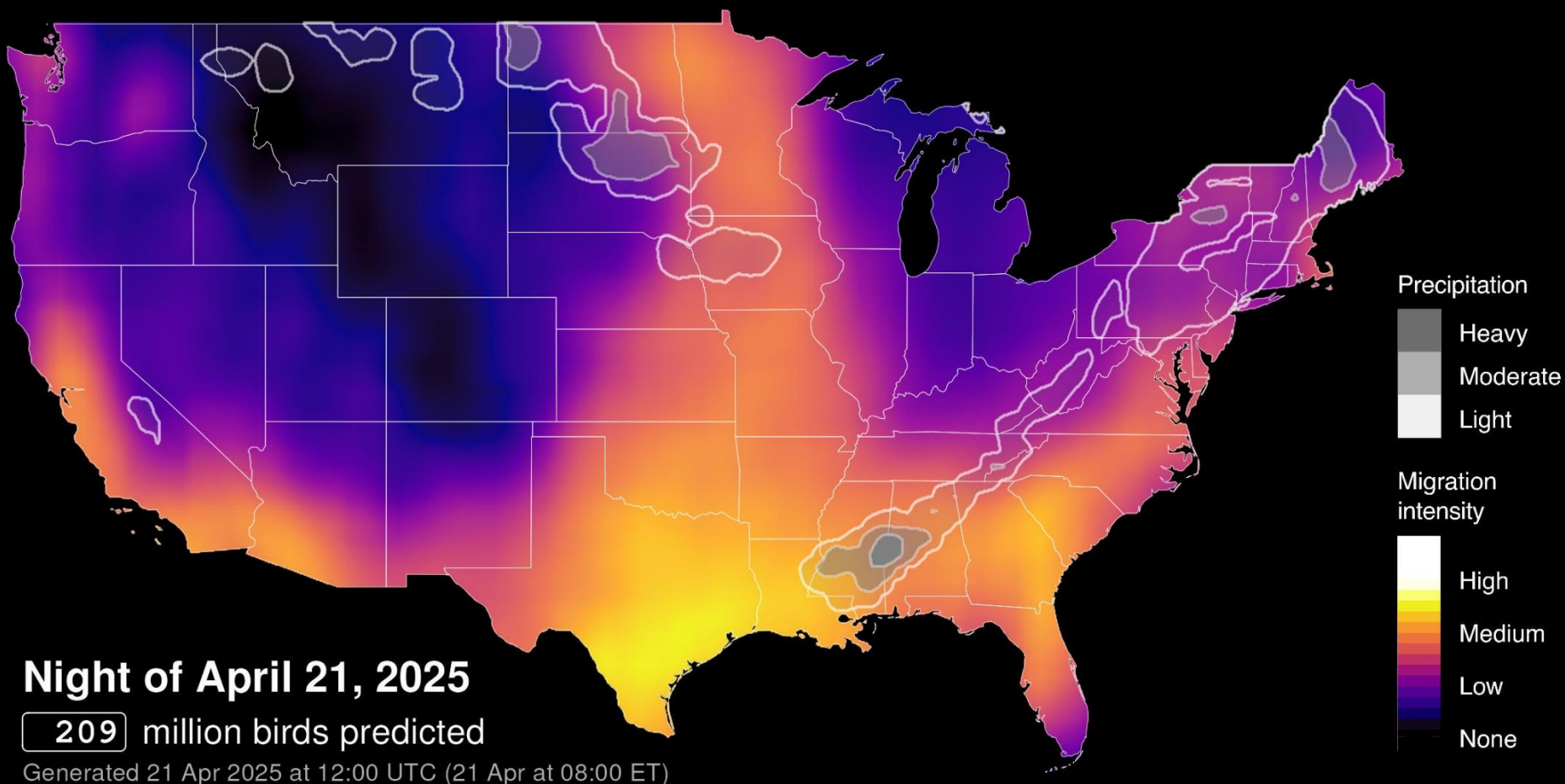
*Fireflies photobomb the  
all-sky-camera at the  
Truman State Observatory*











**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

## Five Lighting Principles for Responsible Outdoor Lighting



Responsible outdoor lighting is

### 1 Useful

#### Use light only if it is needed

All light should have a clear purpose. Consider how the use of light will impact the area, including wildlife and their habitats.



### 2 Targeted

#### Direct light so it falls only where it is needed

Use shielding and careful aiming to target the direction of the light beam so that it points downward and does not spill beyond where it is needed.



### 3 Low Level

#### Light should be no brighter than necessary

Use the lowest light level required. Be mindful of surface conditions, as some surfaces may reflect more light into the night sky than intended.



### 4 Controlled

#### Use light only when it is needed

Use controls such as timers or motion detectors to ensure that light is available when it is needed, dimmed when possible, and turned off when not needed.



### 5 Warm-colored

#### Use warmer color lights where possible

Limit the amount of shorter wavelength (blue-violet) light to the least amount needed.





# Responsible Lighting



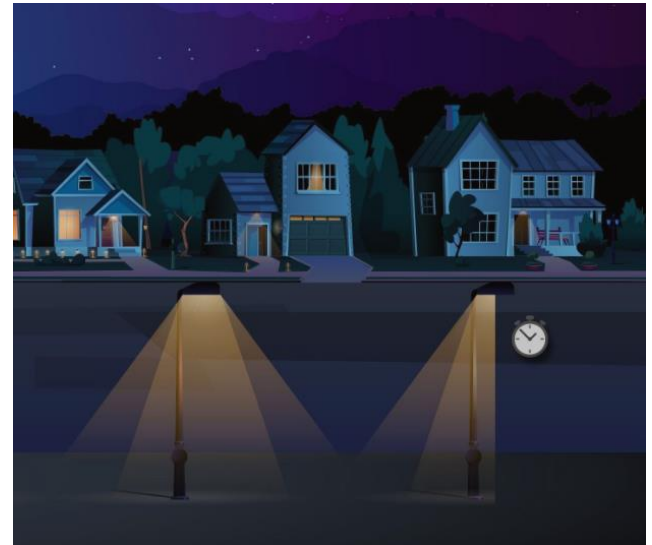
Shielding



Color



Intensity



Purpose & Timing

<https://www.bigbenddarkskyreserve.org/lighting>

# Direct Glare and Safety



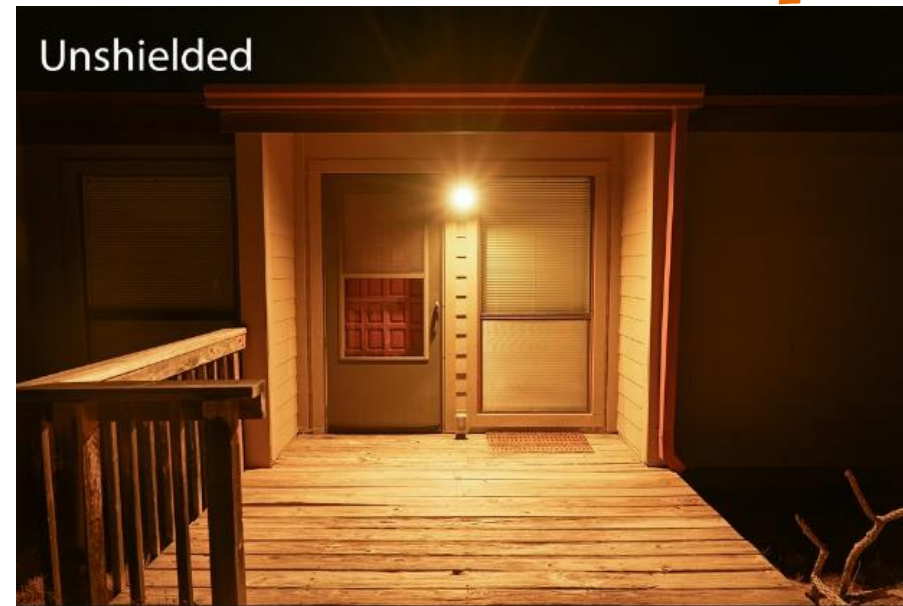
# Direct Glare and Safety



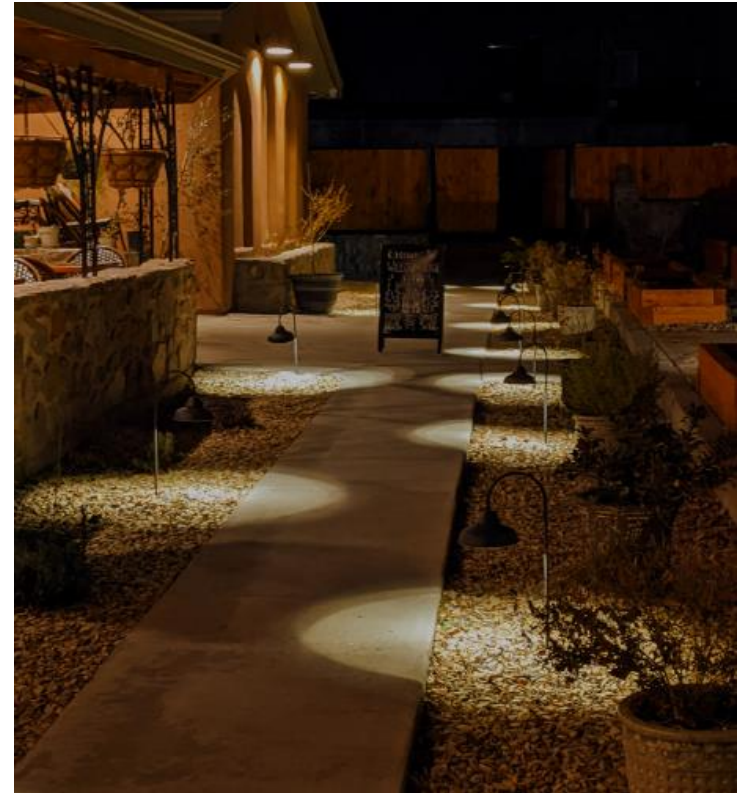


# Examples: Residential

Unshielded



Shielded



Las Cruces, NM

Near Big Bend NP, Texas

# 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

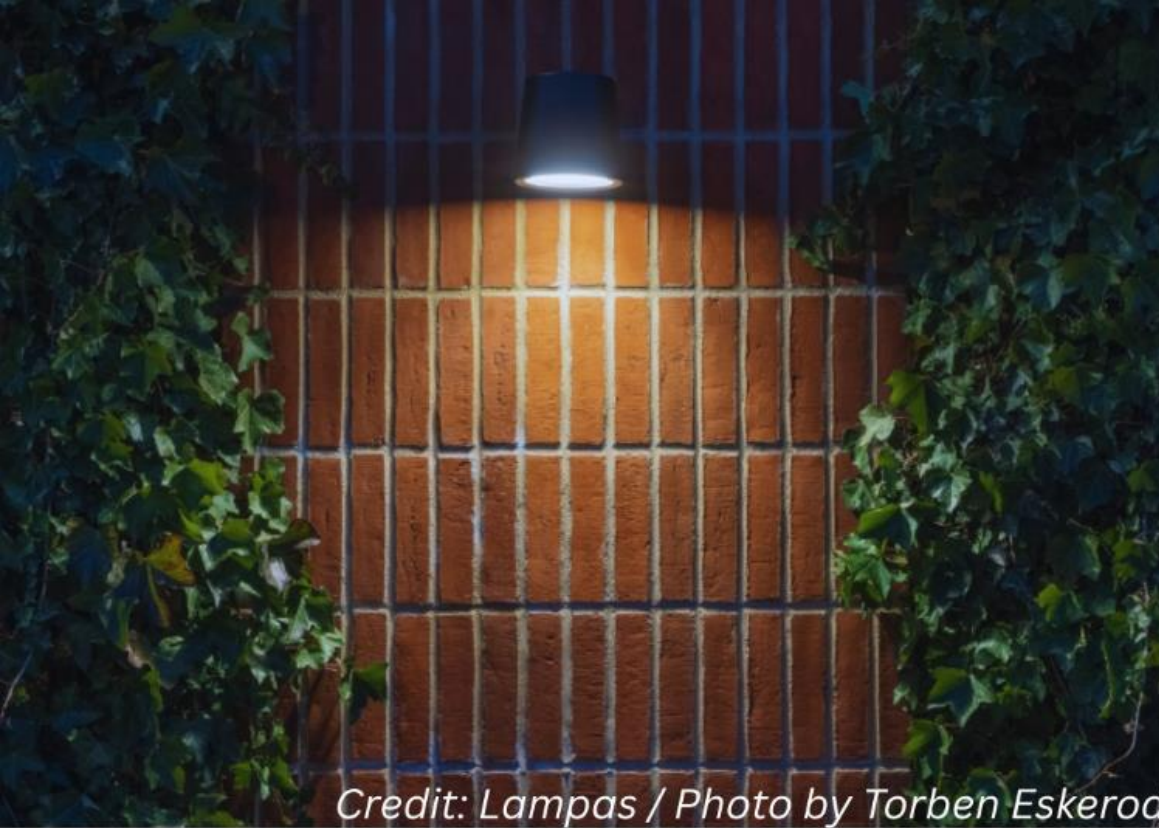


Residential



DarkSky Approved,  
the seal you can count on.





*Credit: Lampas / Photo by Torben Eskerod*



# 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.

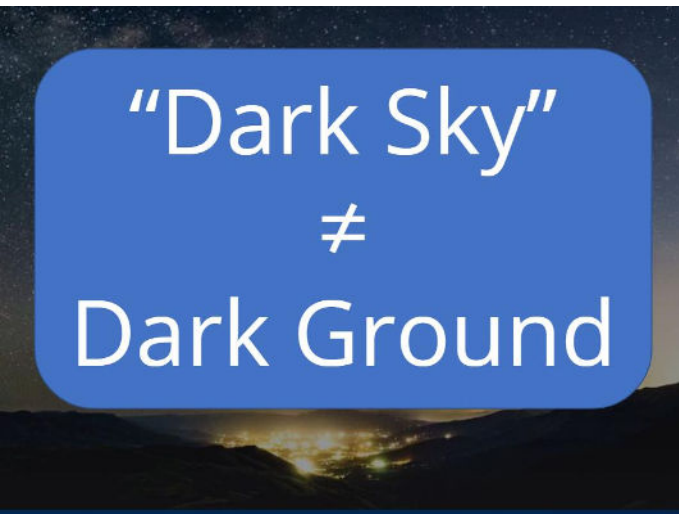
Start with your own home and/or business

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

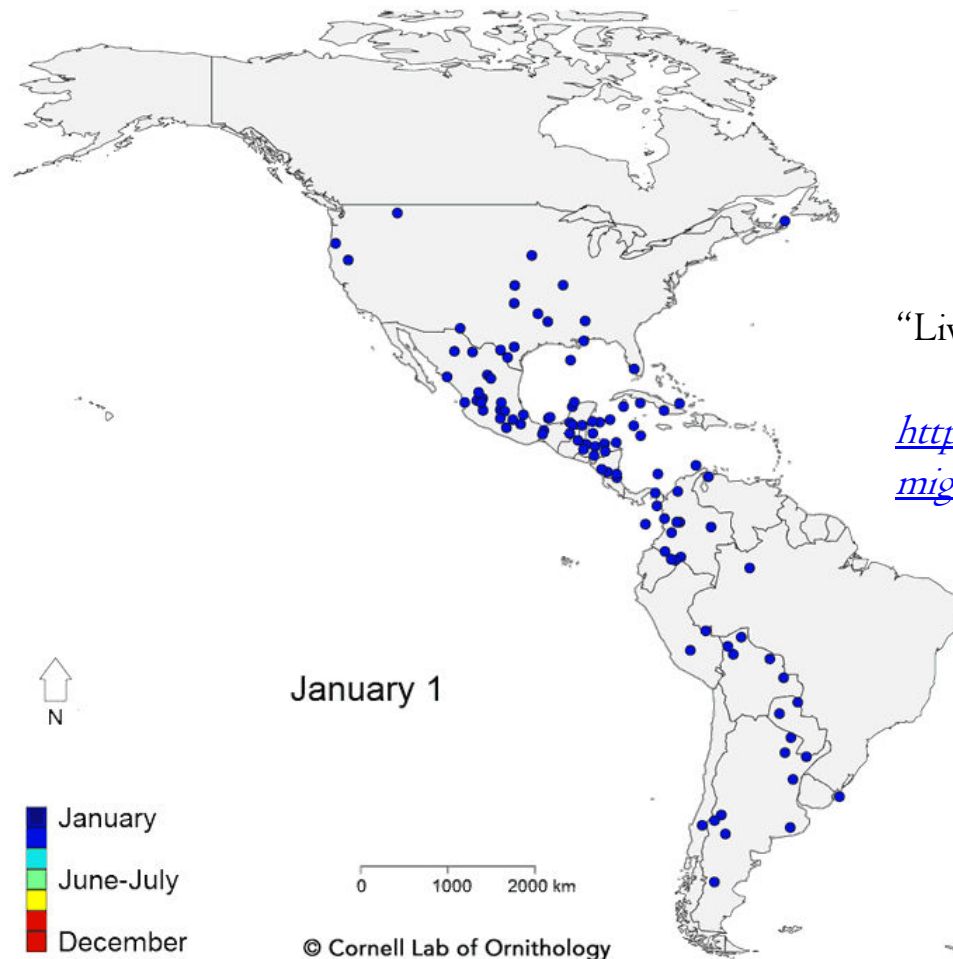


**FACEBOOK:** DARKSKYMISSOURI

# 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!

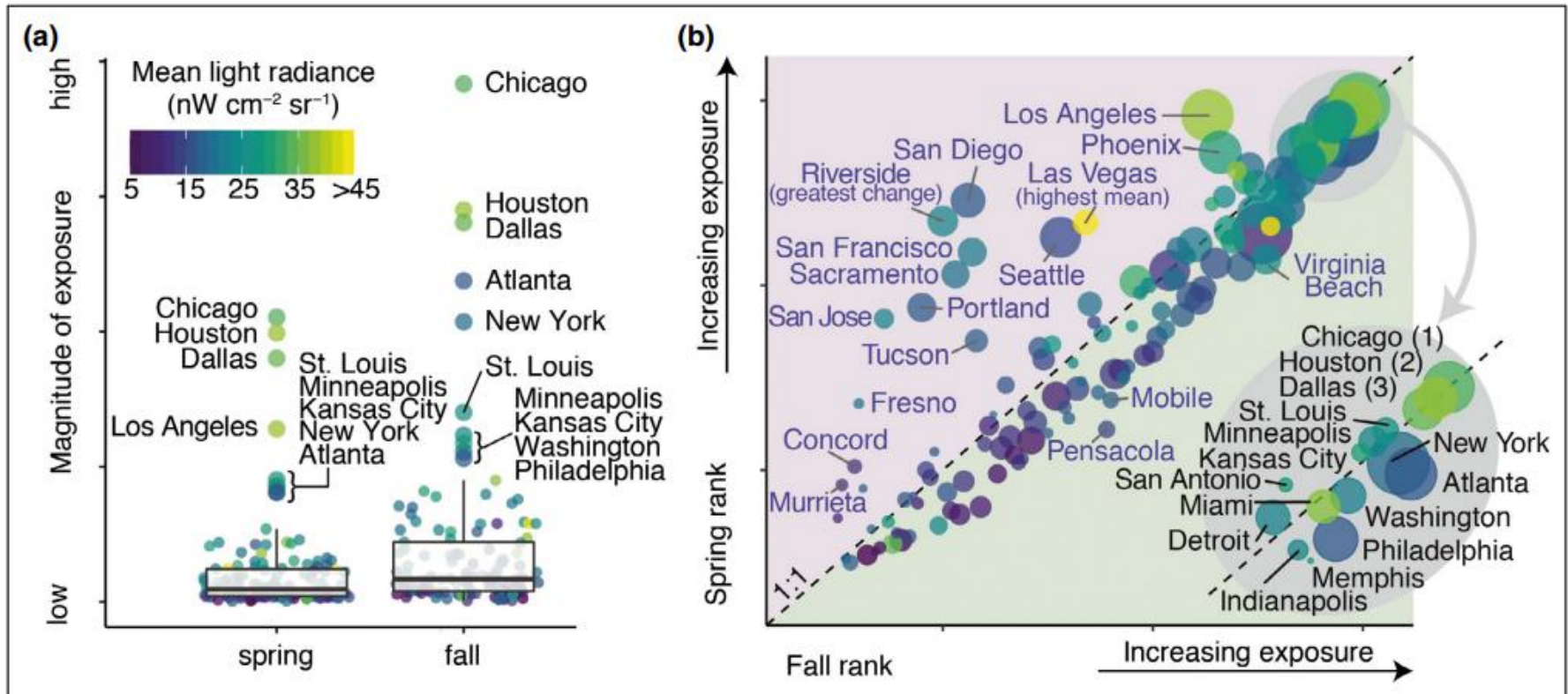
<https://birdcast.info/migration-tools/live-migration-maps/>

<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



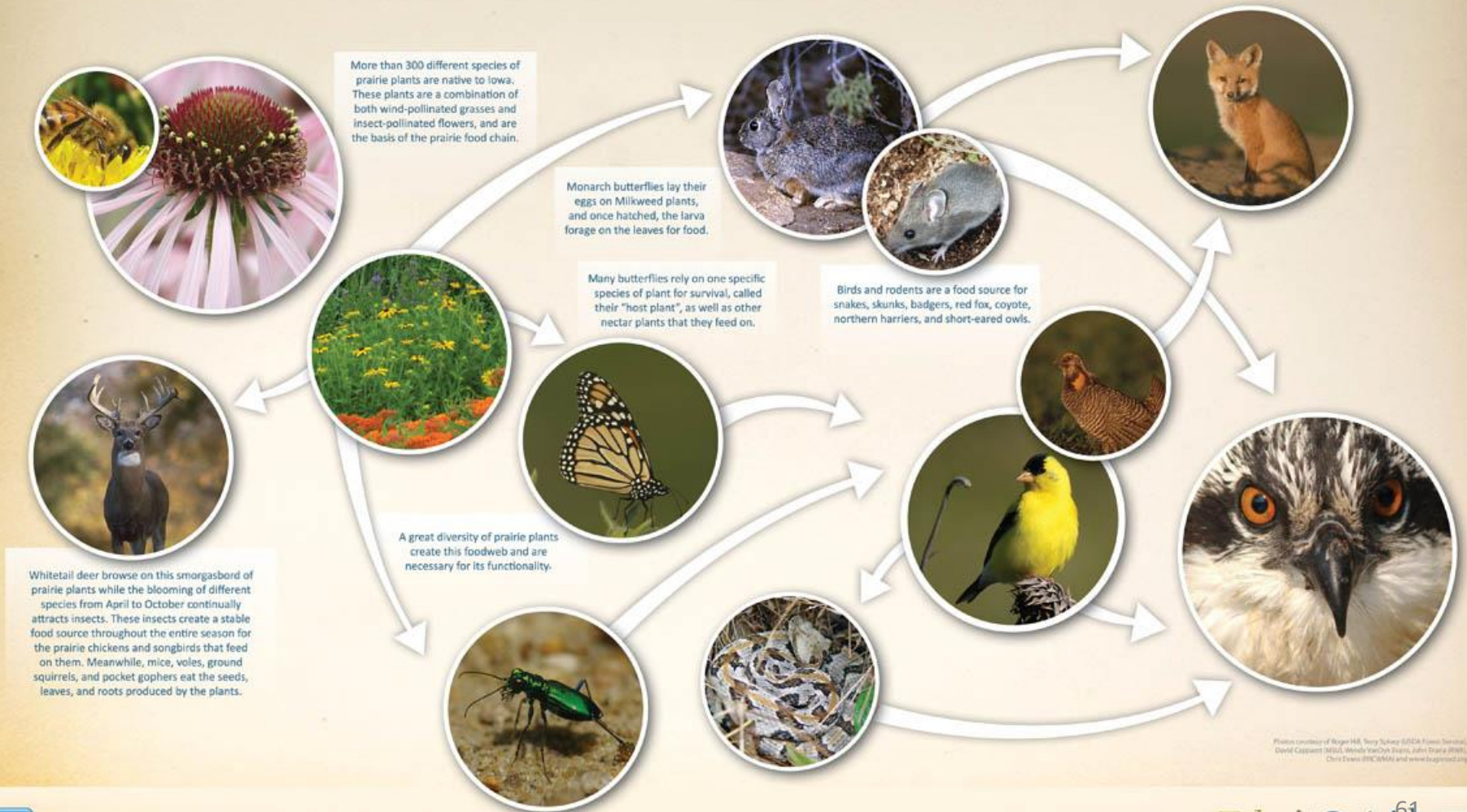
<https://birdcast.info/news/major-collision-event-in-chicago-4-5-october-2023>



# Prairie Food Web

## Prairie Food Web

Prairie is attractive to many wildlife species as a food source, and its complexity helps ensure their survival.



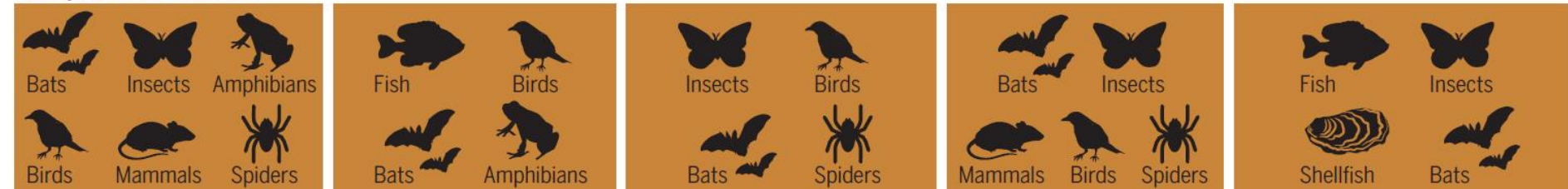
Photos courtesy of Roger Hill, Terry Schreyer (USDA Forest Service), David Casperson (MSU), Wendy VanOck (Iowa DNR), John Drake (IOWA), Chris Evans (IOWA DNR) and www.bugwood.org

# ALAN = Artificial Light At Night

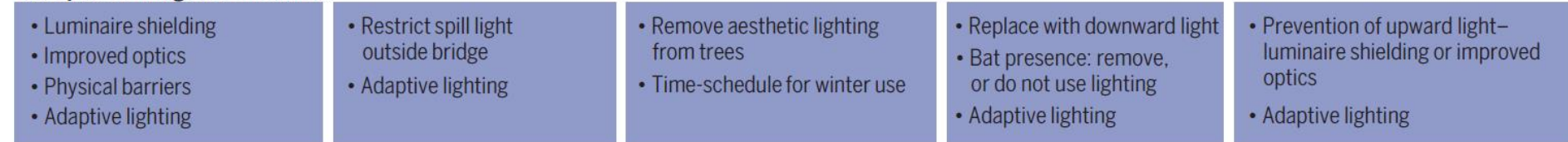
## Examples of anthropogenic light



## Examples of affected taxa



## Examples of mitigation measures



*“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



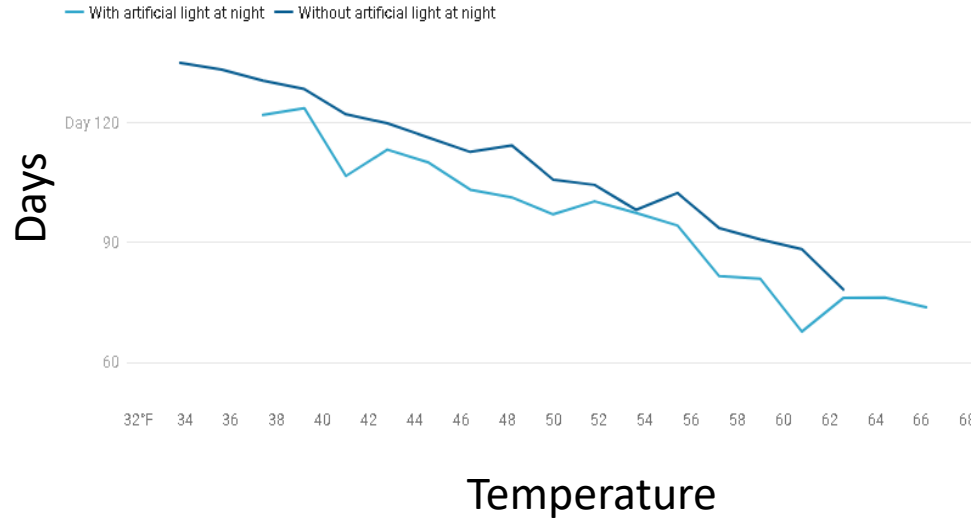
The study found three main effects of lighting on soybean plants:

- 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



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.

Meng et al., 2022

<https://academic.oup.com/pnasnexus/article/1/2/pgac046/6569705>

# 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.

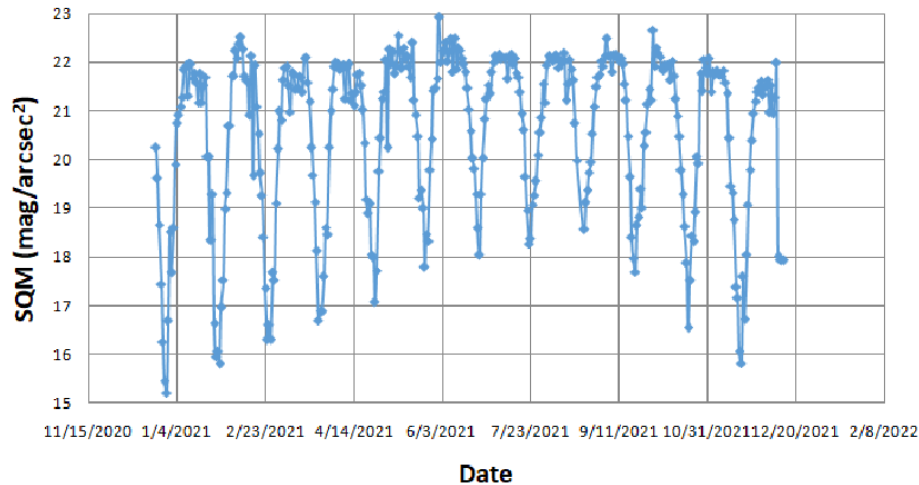


Picture Credit:

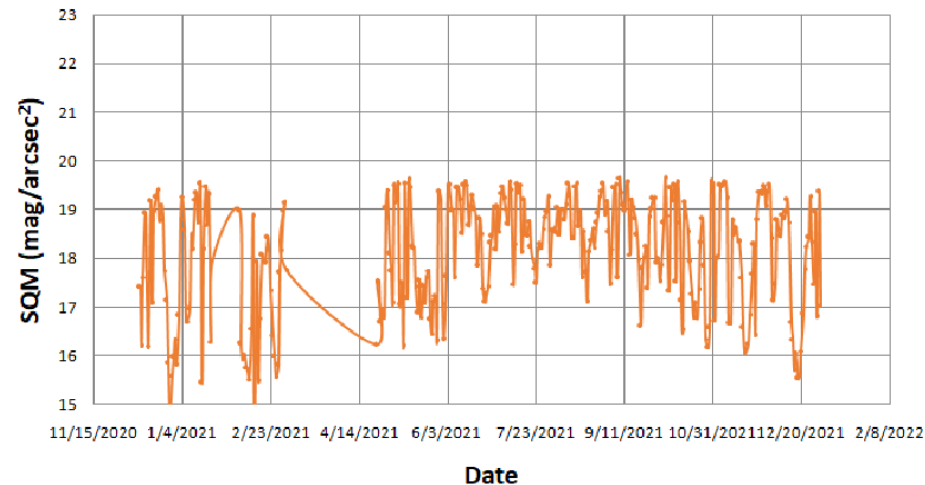
<http://www.missouriskies.org/>

# ALAN and Natural Cycles of Darkness

Grand Gulf 2021



Ozark 2021



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 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>