



Chasing Awe

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<https://users.physics.unc.edu/~sheila/astroaweseeker.html>

New Science of Awe

- Awe = response to things that stretch the limits of our minds
- Physical reactions – chills, goosebumps, slowed heartrate
- Psychic reactions – wonder, humility, connectedness

Awe is at the heart of my work as an astronomer & our humanity

2024 was my Year of Awe – saw total solar eclipse & five+ auroras



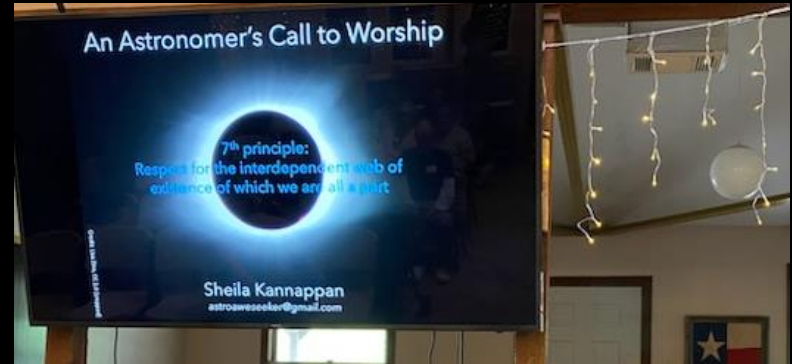
It began with the total solar eclipse...

6/21/2001 - Madagascar



Credit: NSO/AURA/NSF, CC 4.0

4/8/2024 - Texas



8/21/2017 - S. Carolina



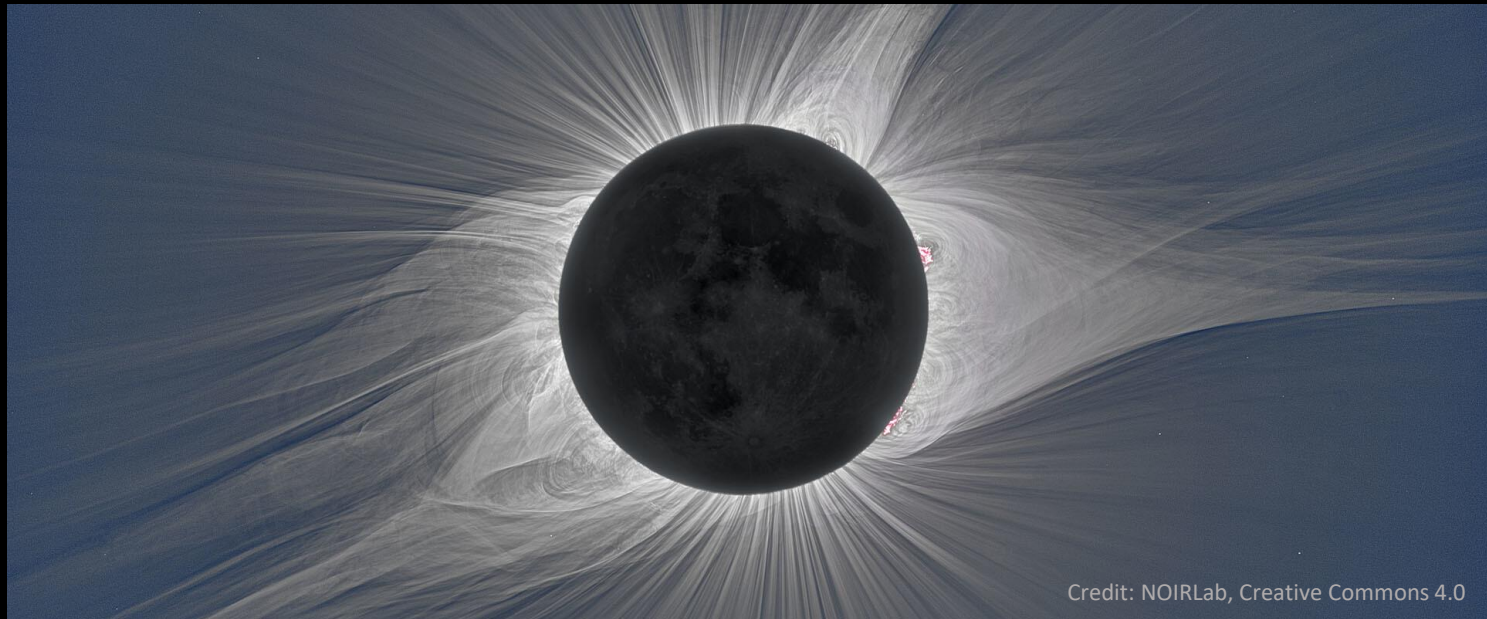
Image credit: storyboardthat.com)

UBarU
Retreat
Center

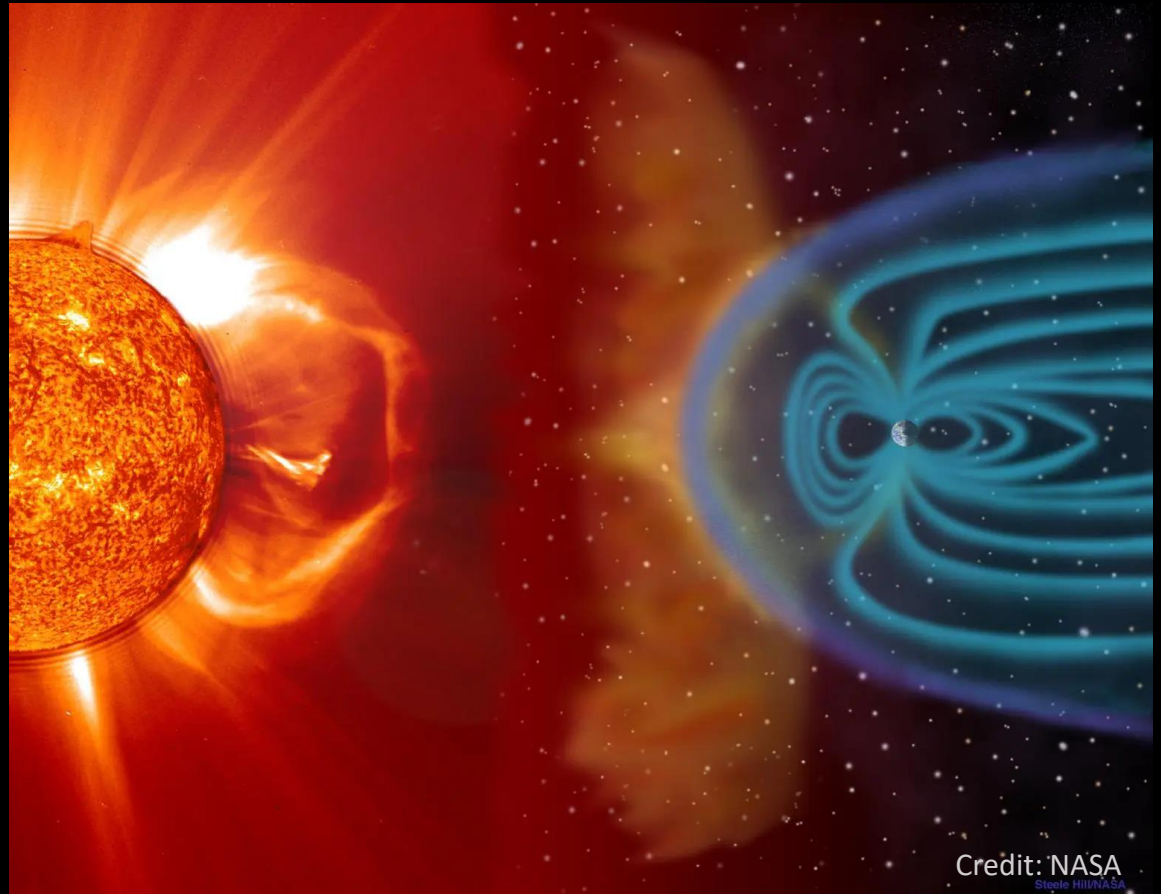


corona

from Latin: 'wreath, crown'



the Sun is a
dangerous
god of life



Earth must shield itself from the
solar wind



Credit: NASA

our planet answers with an echo of the solar crown

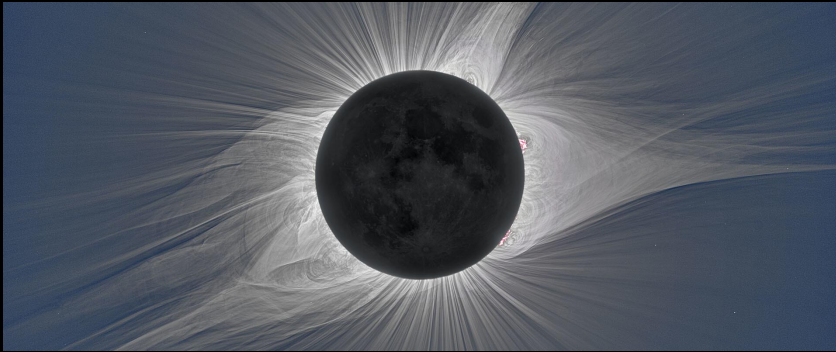
A photograph of the Earth's aurora, also known as the Northern Lights, captured from the International Space Station. The aurora appears as a vibrant, glowing green and blue arc across the horizon of the Earth, set against the dark background of space. The image is partially obscured by a red banner at the bottom.

CROWN AURORA

Northern Lights

seen from the International Space Station

Credit: ESA/NASA, Thomas Pesquet



And then came the aurora of May 11



Source: WRAL



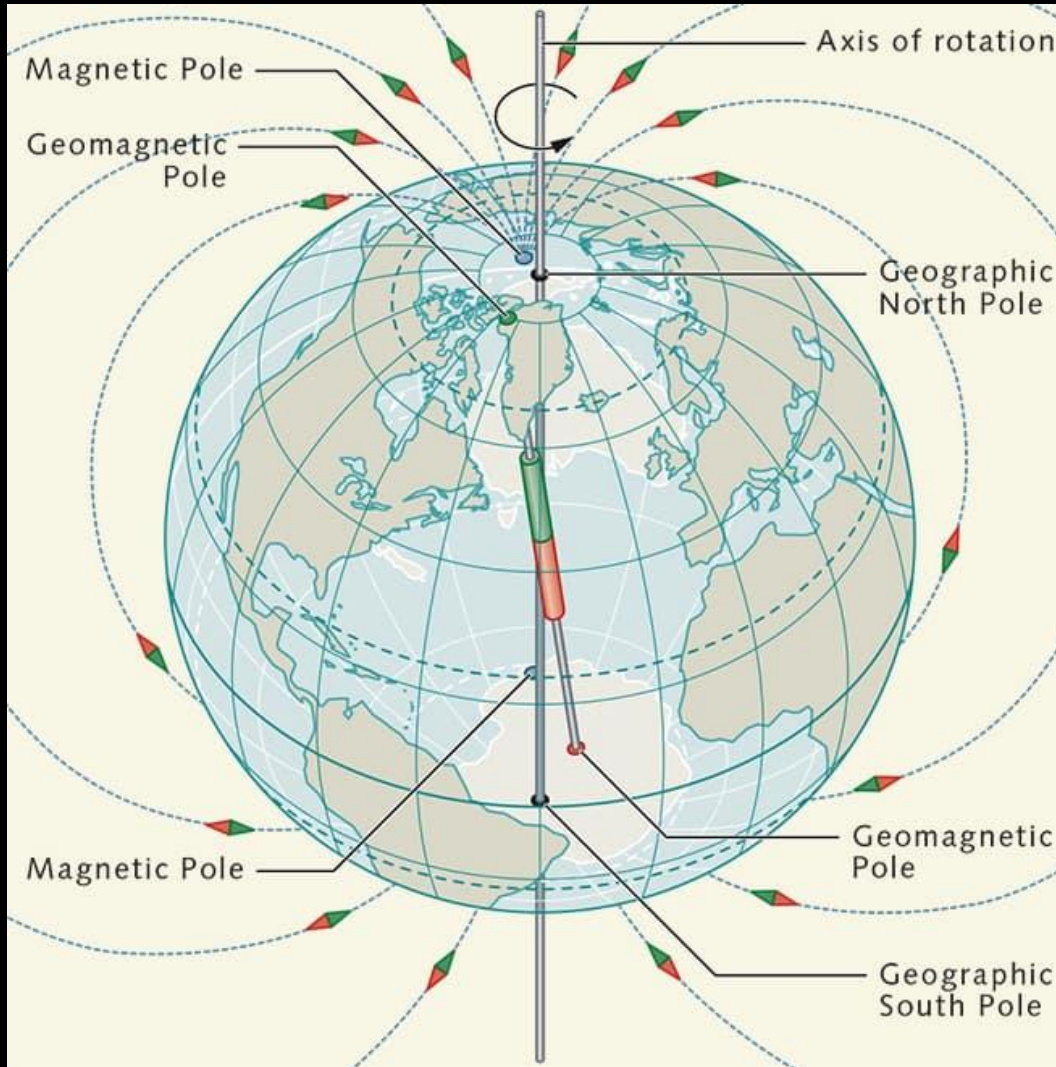
We missed it!



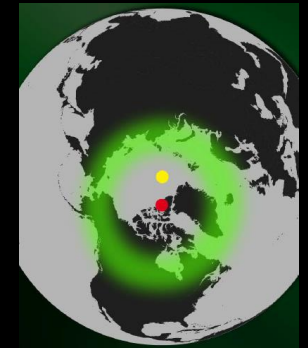
But I had just decided to retire...

To the North!

Credit: World Ocean Review



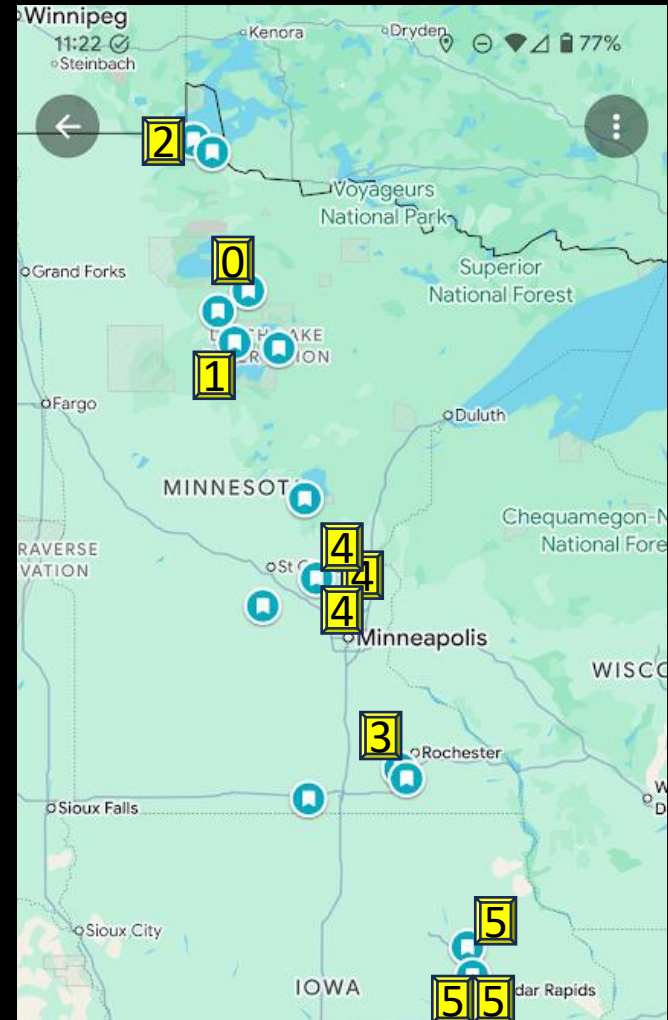
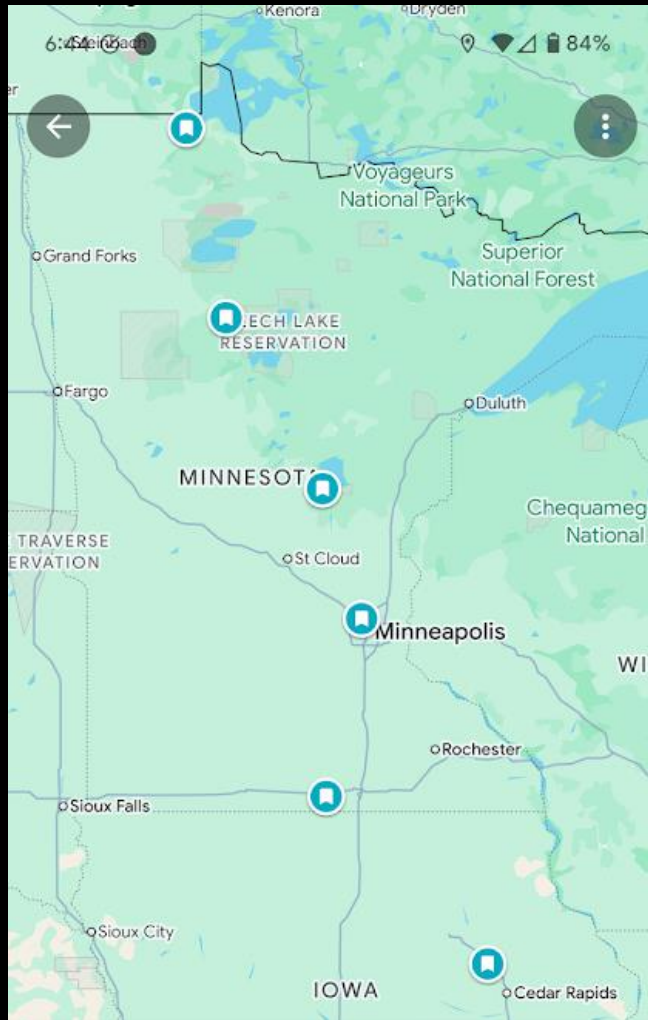
Notice how lucky you are to live in North America!



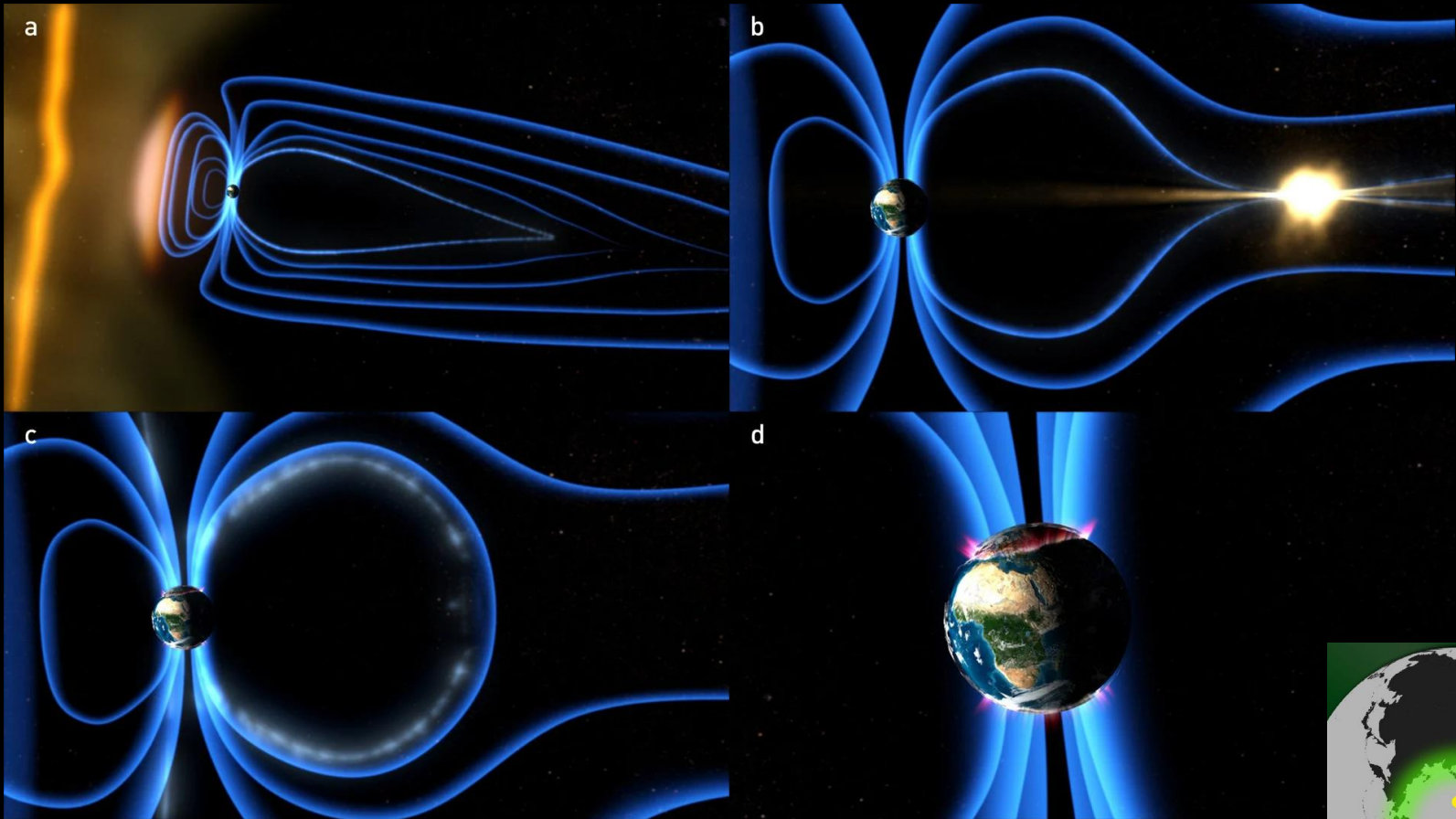
Credit: Aurora Guy

Specifically, Minnesota

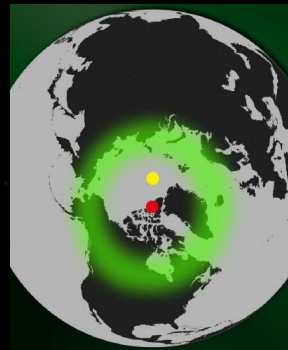
2 months in MN Sept-Oct 2024 (no tour, no plan, no experience)



“seeing an aurora” \approx seeing a substorm:
when stretched magnetotail snaps back



but auroral oval is always there around the pole





magnetic
north



1 first "real thing" at Cass Lake near Bemidji, Sept 12 3:37am



1 too faint to see the color by eye; local guy just fished

When & Where

- solar maximum (2024/5)
- frequent clear skies (fall)
- more night (Sept+)
- less cold (Oct-)

Awesome free guide by "the Aurora Guy"



A Beginner's Guide to Aurora Chasing

Vincent Ledvina

2nd Edition

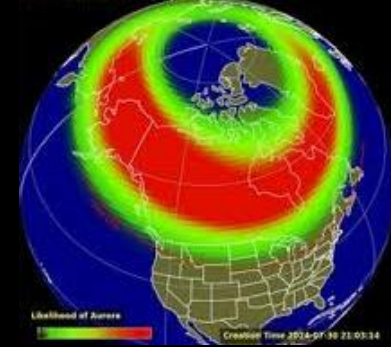


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- moon phase half full?
new: see fainter (rods)
full: see color (cones)
- when aurora is closest -
"magnetic midnight"
aurorasaurus.org =best visual
- when expect substorms

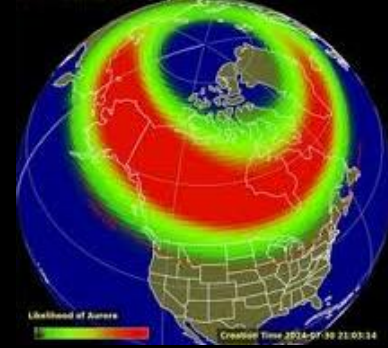


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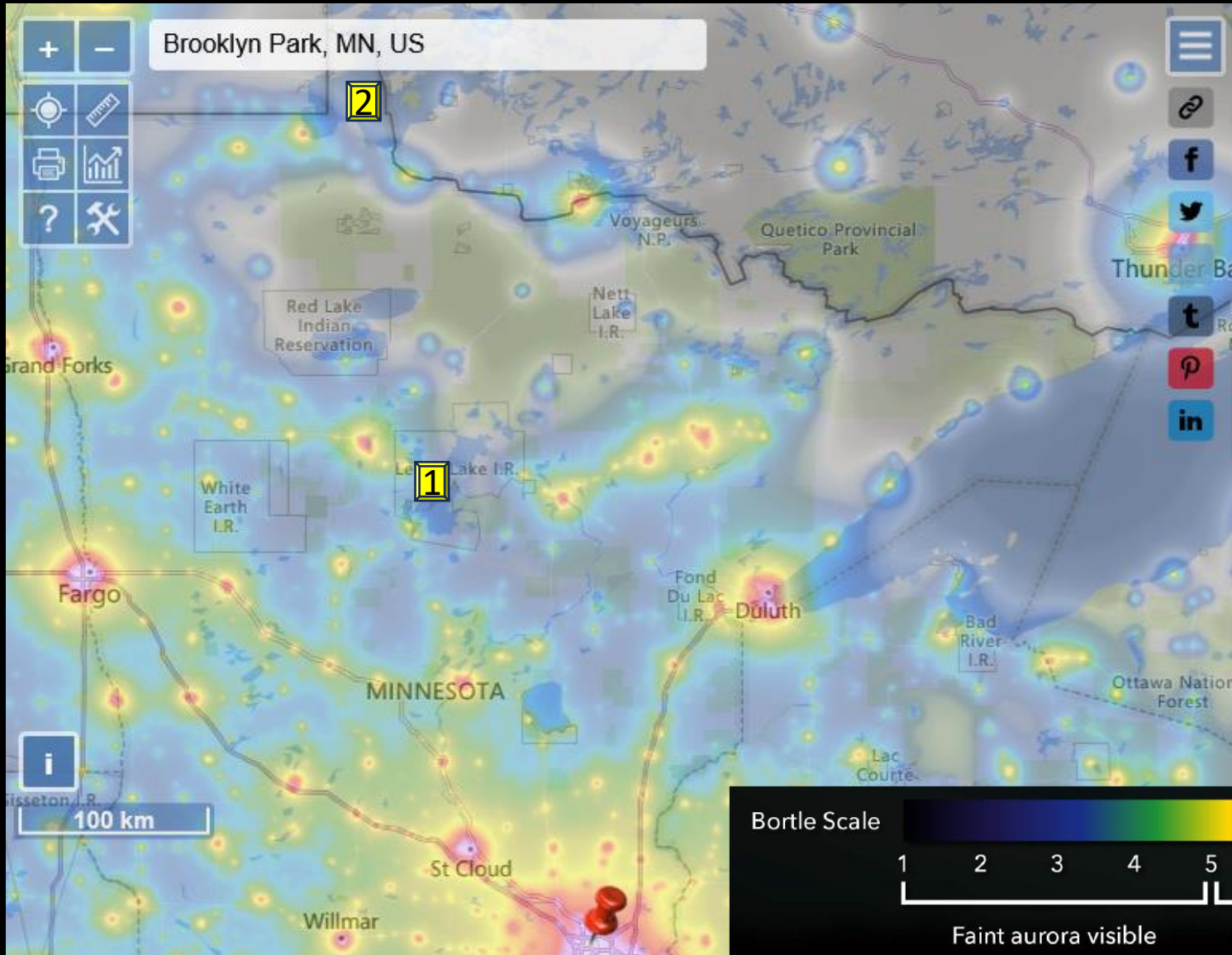
- north
- dark

northern wilderness of MN:
International Dark Sky Park



<https://www.lightpollutionmap.info/>

doesn't tell you about high beams in your eyes!



1 Cass Lake Bortle 4, but lights blocked

2 Arnesen Bortle 2, but bright security light

2 Arnesen, near
Warroad, northern
coast of MN,
Sept 12 10:50pm:
first aurora seen
reflected in water,
color just a hint by eye

*downside: so far north
we barely had enough
dog food to make it
back to Minneapolis*

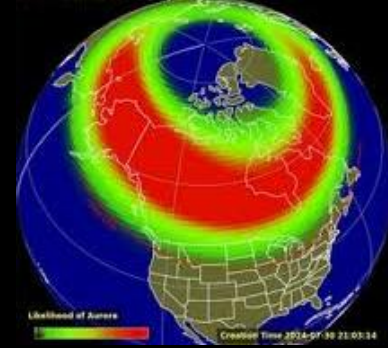


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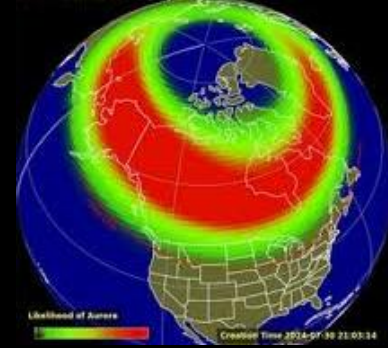
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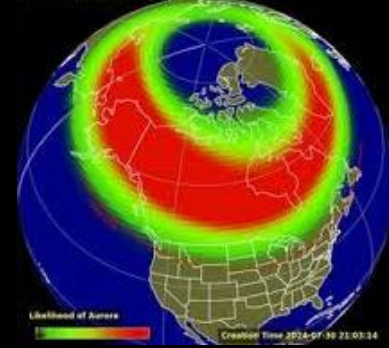


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- north
- dark
- northward vista, such as south shore of lake
- scenic for photography
- safe, near a bathroom
- accessible on short notice

boat launches & fishing piers abundant in MN - land of 10,000 lakes



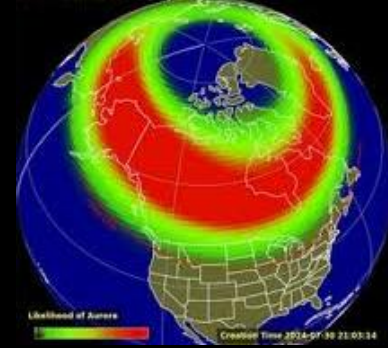
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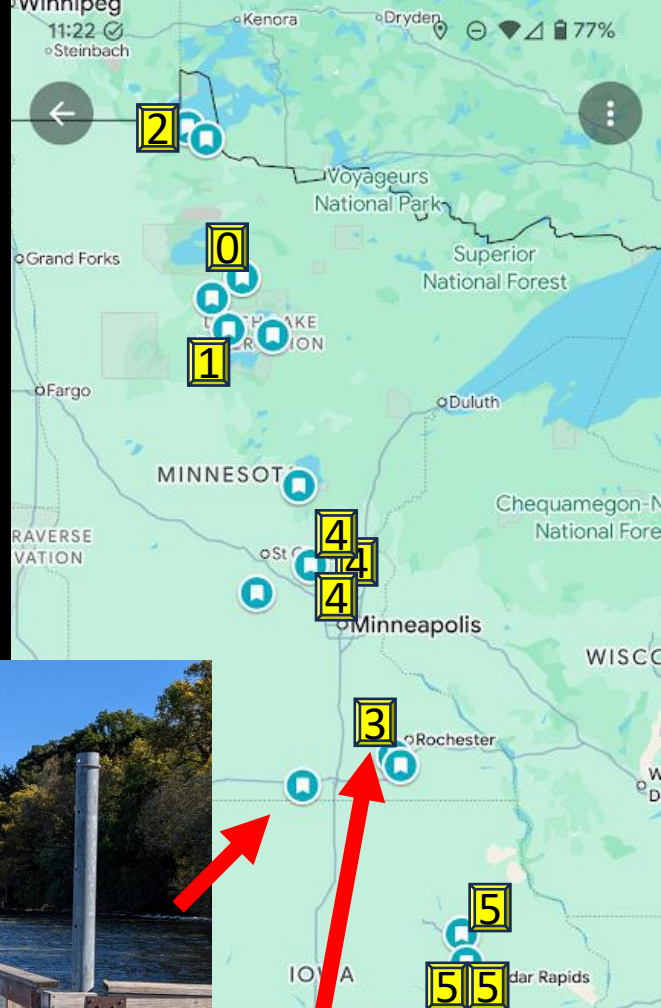
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boat launches & fishing
piers abundant in MN:
land of 10,000 lakes

- away from clouds
<https://digital.weather.gov/>
<https://graphical.weather.gov/>



We got "lucky" - almost no rain for 2 months. But we drove as far as Iowa to dodge clouds!



Pihls Park, Faribault County - the perfect aurora viewing site where we never saw an aurora

Instead raced to random country road for aurora #3



3 field southeast of the Twin Cities, Sept 16 10:24pm
nearly full moon → full-color aurora - 6 sec exposure

When will there be an aurora?

free, better
science info,
includes coronal
holes/streams

- first warning = M,X solar flare alerts
(spaceweather.com or spaceweatherlive.com)
- but the coronal mass ejection (CME) is what matters... +wild card equinox effect (9/22 in 2024)
- Kp forecast = 3-day heads up for entire Earth
<https://www.swpc.noaa.gov/products/3-day-forecast> (2x / day)
NOT <https://www.swpc.noaa.gov/products/3-day-geomagnetic-forecast>

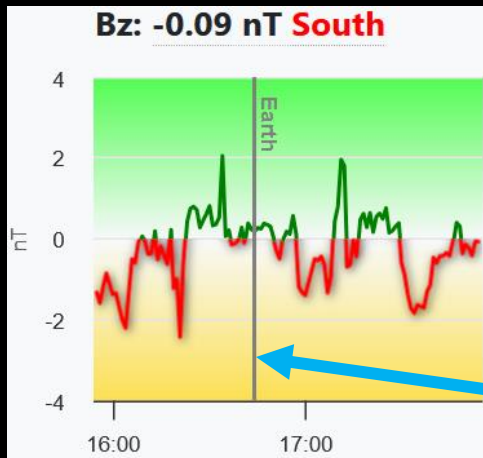
Kp < 5	Kp = 5 (G1)	Kp = 6 (G2)	Kp = 7 (G3)	Kp = 8, 9- (G4)	Kp = 9o (G5)
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Sept 15 - woke in city to X-class flare alert, fast CME direct hit *in the news*, clouds → frantic site research

Sept 16 - no CME all night, nap in afternoon, woke to alert: Kp 6 then 7, 8 as we drove! speeding to escape clouds/lights to rural vista: **15 min of magic** 📺

But really, when?

- the Aurora Guy's Beginner's guide taught us to pay attention to [aurorasaurus](#) (moving oval, social media) and the graphs at [spaceweatherlive](#) (solar wind data: speed/density/Btot/Bz from NASA/NOAA satellites)



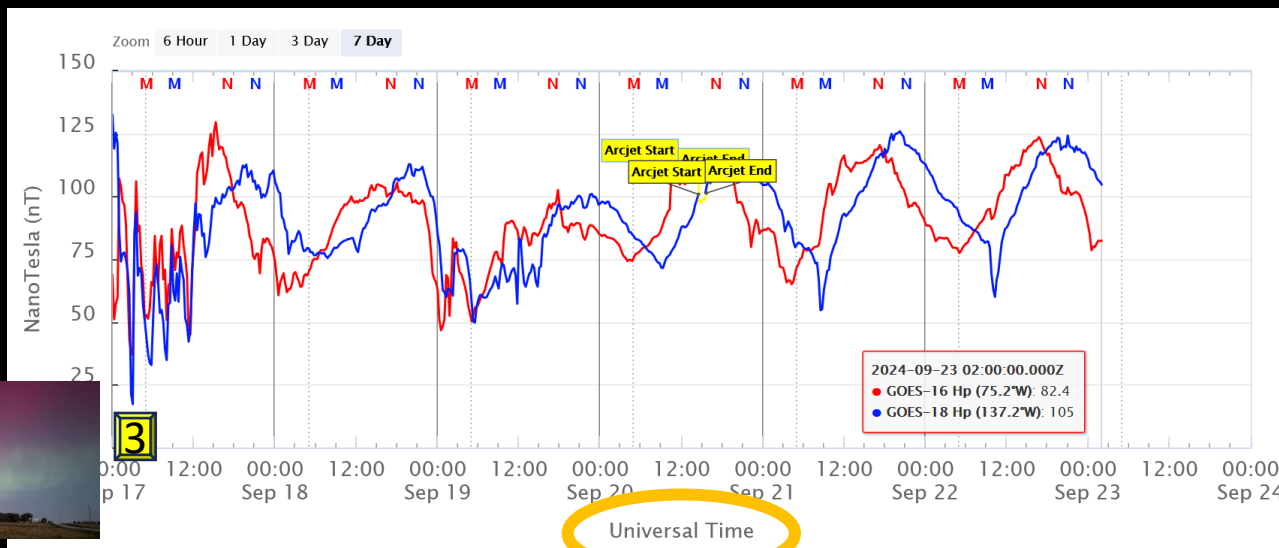
magnetic field Bz is most critical –
“on/off switch for the aurora” –
when < -5 for 30+ min, heads up!

vertical line = should be hitting Earth now

- graphs show conditions *incoming* ~40+ min away
- density *rises and falls* when CME shock arrives
- but graphs only forecast conditions for a substorm

No really, when are the substorms?

- GOES: North America has magnetometers hovering over the East & West Coasts – geostationary GOES satellites
- Aurora Guy's blog: "out in the field, it's the main thing I pay attention to"
<https://theauroraguy.com/blogs/blog/how-to-use-the-goes-magnetometers-to-master-aurora-chasing>
- downspikes in sine wave show magnetotail pulling back, ready to snap – and the moment of snap (substorm)



"I have seen many chasers quit early after seeing the aurora at a standstill"

Missed more!

Another gotcha! 10pm 9/16 in MN = 3am 9/17 Universal Time (UTC)

October...

1 X7 flare - glancing CME

2

3 X9 flare - better CME

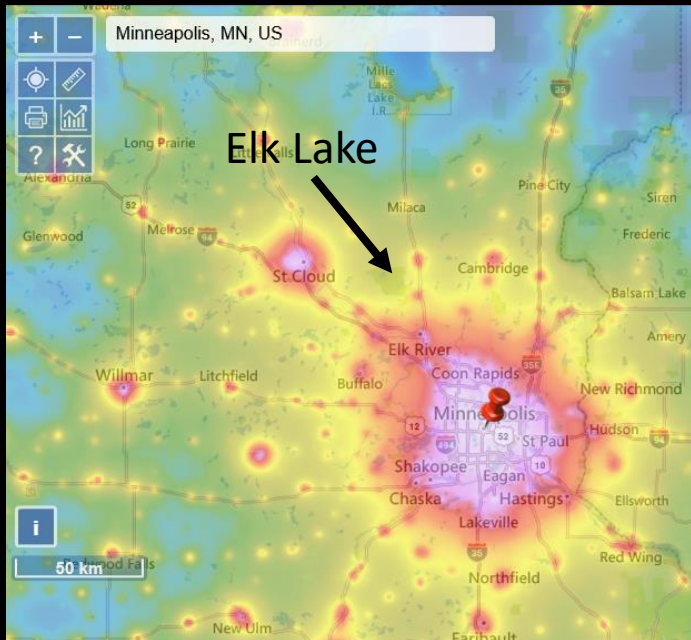
4

5

6

7 *surprise alerts...*

- X** camped @ Mille Lacs
- X** roundtrip to Pihls Park
- X** camped at Pihls Park
- X** tired/too late/gave up
- ✓** to Elk Lake 📱📱📱



photos nonstop 10:20-11:43pm



faded, crowd left, got cold, GOES said stay...





















4 min compressed into 1 second





12:24 am



After 3 hours
(+ 4 nights) of
aurora chasing,
my driving was
a little erratic...

1:25 am



October...

1 X7 flare - glancing CME

2

3 X9 flare - better CME

4

5

6

7 surprise alerts...

8 X2 flare - "perfect" CME

9

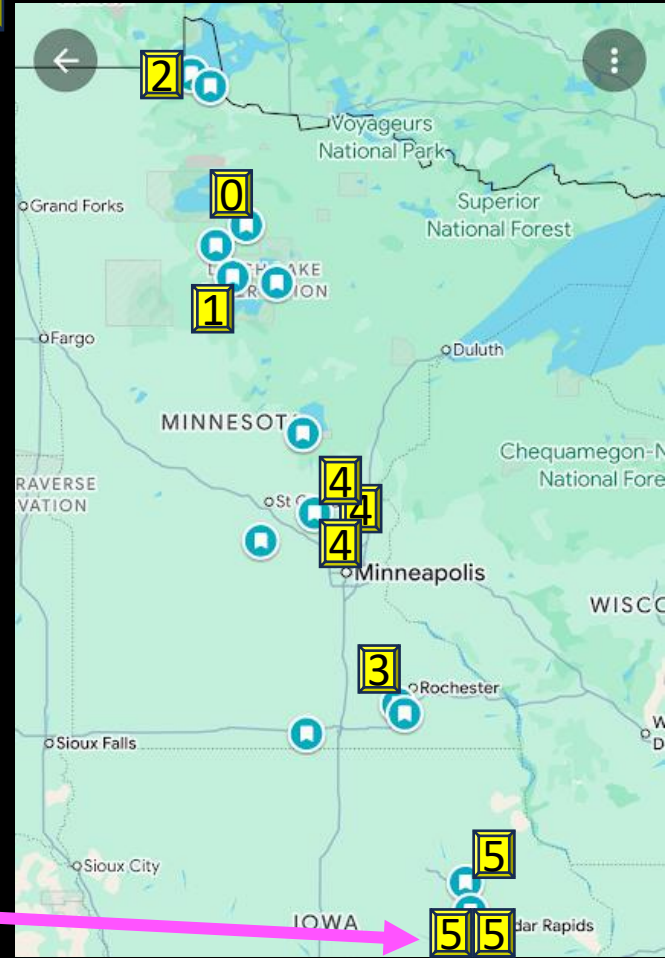
10

X camped @ Mille Lacs
X roundtrip to Pihls Park
X camped at Pihls Park
X tired/too late/gave up
✓ to Elk Lake **444**

✓ to Iowa! **555**



9 pm - first substorm





midnight -
second
substorm



2:30am -
third
substorm





What did I learn?

I can't cross aurora chasing off my bucket list

Will 2025 be even more exciting than 2024?

Solar maximum
continues...

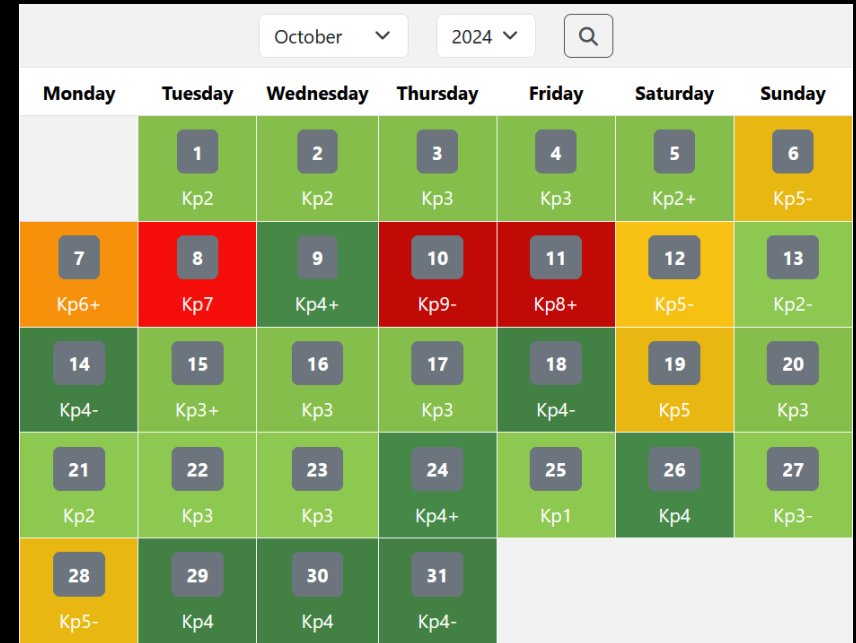
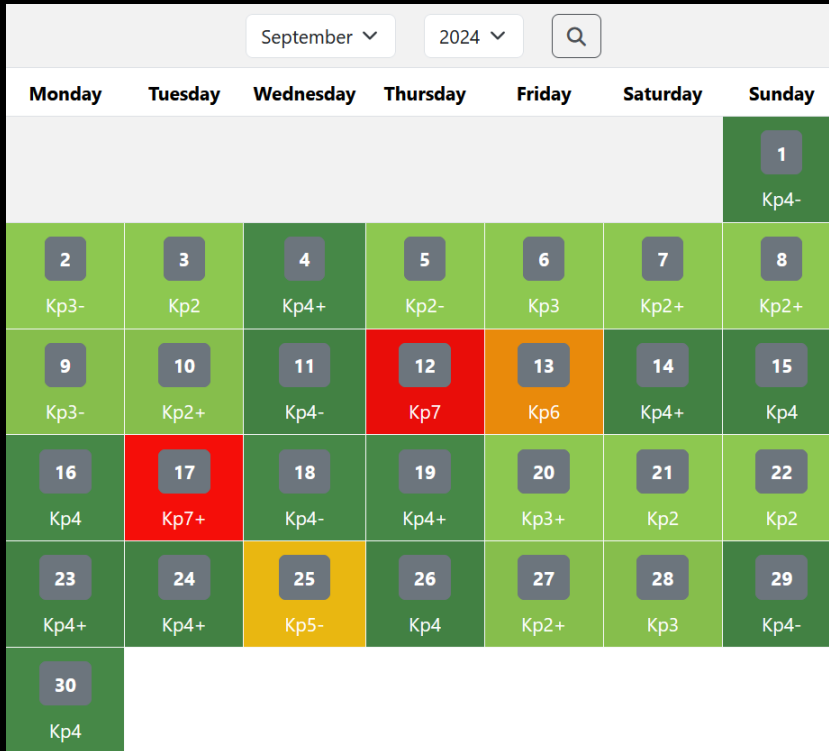
and
NASA is set to
launch LEXI this
month!



Tips from Our Experience

- **Duration:** even during solar maximum, 2 weeks will NOT ensure Kp6+/G2+ (moderate+) activity

Saw auroras on all but one Kp 6+ night...



Credit: SpaceWeatherLive

...on a 2-week trip, could have seen no Kp 6+

Tips from Our Experience

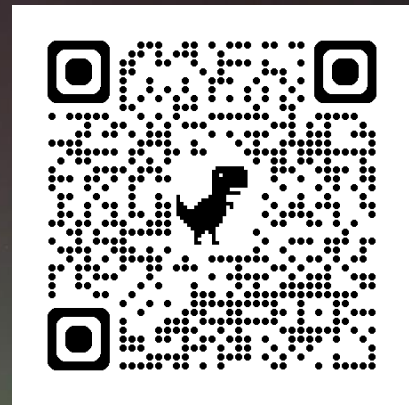
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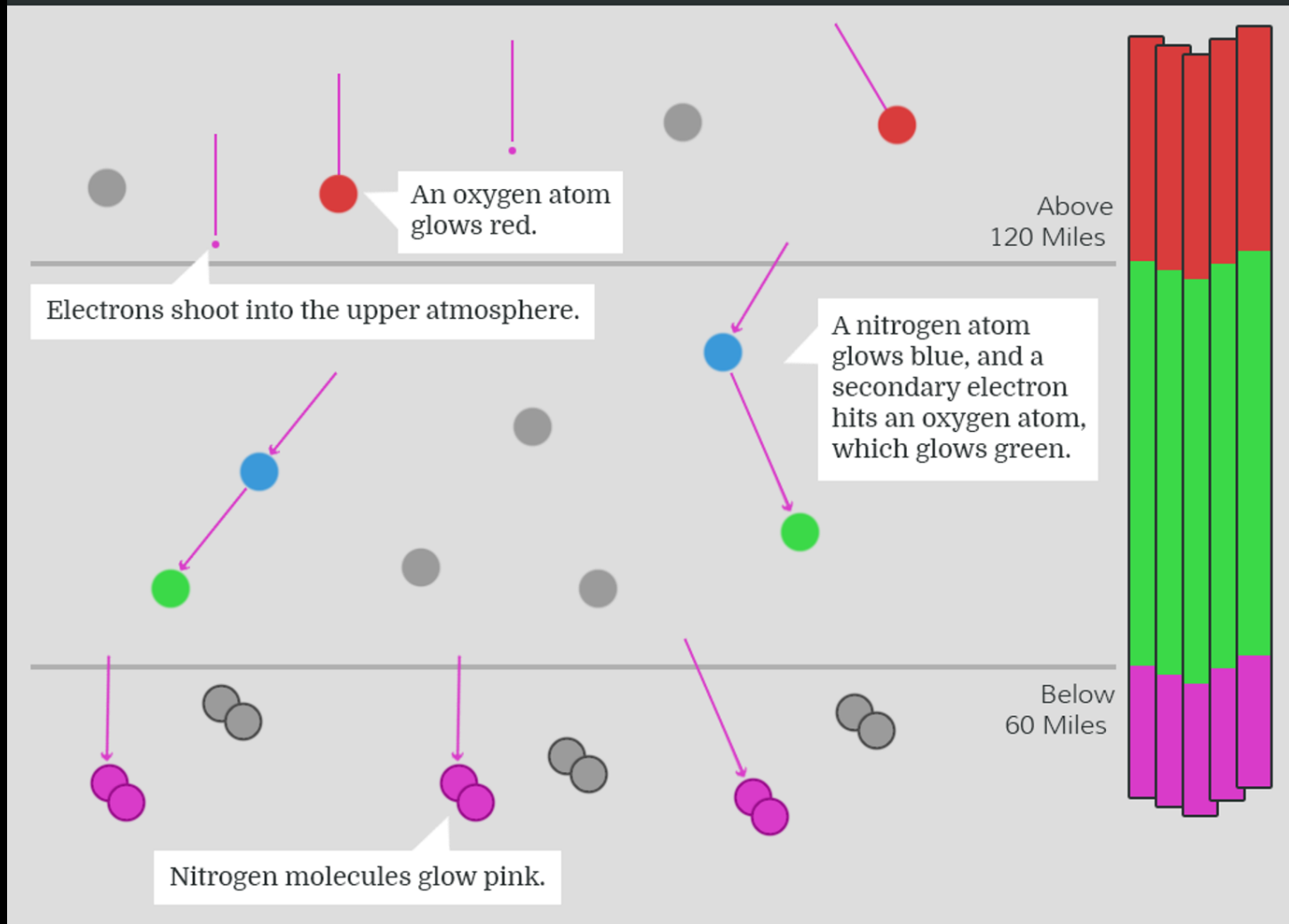
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- **Photography:** cameras see more color but eyes see more motion; not all cell phones deliver true color



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Auroral Colors Vary with Altitude



Credit: NASA