Reminder from last lecture
Reminder from last lecture. The temperature of the source determines the wavelength of the produced light, and so what part of the electromagnetic spectrum is produced.

The higher the temperature of a blackbody, the more light it emits at all wavelengths.

- Low energy photons (e.g., 3000 K)
- High energy photons (e.g., 12,000 K)
ABSORPTION OF LIGHT

• “clear” doesn’t absorb
• “opaque” absorbs
• depends on frequency. Glass is clear in the visible but opaque in the infrared. Can cause greenhouse effect
• Microwave ovens work by operating at a frequency near a water absorption line
• atmosphere only clear in visible, radio, and part of infrared impacts observing using telescopes
• Absorption in atmosphere of stars used to help determine some star properties
Absorption vs Emission

- Absorption means photon “disappears” in gas as causes transition in atom/molecule to higher energy. Emission is when light is given off; an atomic transition is one example.
Absorption of Light in Atmosphere
100% means atmosphere completely absorbs
Absorption of Light in Atmosphere

Atmosphere is mostly “clear” in visible, radio and parts of infrared spectrum → Earth-based telescopes

Poor transmission in X-ray, UV, and parts of IR → space-based telescopes
Greenhouse Effect

Light from sun T=6000 K.

Peaks in visible

Glass. Opaque in infrared

Absorbs sunlight reemits at T=300 K (70 degrees F) in infrared which “bounces” off glass and keeps inside “warm”

Interior of greenhouse
Greenhouse effect in Earth’s Atmosphere
Some energy in Sun “trapped” by atmosphere and warms Earth (red lines going down)
Greenhouse Effect in Earth’s Atmosphere

- Infrared absorption in atmosphere → greenhouse effect
- Primary “greenhouse gas” in atmosphere is water vapor; it helps to keep Earth’s average temperature above freezing
- Water’s absorption frequencies depend mostly on the mass of a Hydrogen atom (see link on course web page)
- Carbon Dioxide absorption frequencies depend on the masses of C and O atoms → different than water and “fill in” parts of the spectrum and so add to the absorption in the Infrared. Methane also absorbs in the IR – byproduct of production especially fracking. Increased levels in these two gases are increasing the Earth’s temperature and we are already seeing significant and harmful effects
Transmission in IR mostly in “water hole” region

Infrared “water hole”

Partially filled in by carbon dioxide and a little bit by methane
Greenhouse effect in Earth’s Atmosphere

Note year of this figure is about 2004. Climate scientists had predicted trend in 1970s (and even earlier)

The recent warming trend correlates with the increase in CO₂ concentration since 1800 due to burning fossil fuels...

...and is clearly anomalous compared to changes in the climate over the last millenium.
Greenhouse effect and Carbon Dioxide

To slow the increase in temperature we (all humanity) want to reduce the amount of carbon dioxide released into the atmosphere. For a while the US trend was down, until 2018 where they increased.

Figure 1: Annual change in US CO₂ emissions
Energy combustion only

U.S. Carbon Dioxide Emissions Rose in 2018

Above, just energy
To right, all

By The New York Times | Rhodium U.S. Climate Service
Greenhouse effect and Climate Change

The increase in average temperature due to carbon dioxide will cause a large increase in the number of extremely hot days, in violent storms, and in droughts.
In 2010 most of the world is now desert. Canada, Siberia, and maybe Antarctica grow food (in green)
Greenhouse effect in Earth’s Atmosphere

Note year of this article is 1912, from Warkworth, New Zealand. The physics of atmospheric absorption and the greenhouse effect is relatively easy. The difficult is the climatology, for example the oceanography as most carbon dioxide is absorbed by the ocean.
Climate Change vs Special Interests

• In 1970s, two environmental problems understood by science (I learned about as undergrad ~1975. Have taught since 1990)
  - Freon $\rightarrow$ Ozone depletion, enhanced UV $\rightarrow$ quickly “solved”
  - Carbon Dioxide $\rightarrow$ climate change $\rightarrow$ still “not solved” but now see tangible impact predicted 40-100 years ago

• Carter started R&D national lab in 1978 on renewable energy (solar panels on White House), canceled/removed by Reagan. Could have had much larger fraction of US energy from renewables, less reliance on coal/oil, reduced greenhouse effect, fewer wars in Mideast. Now have a US administration which denies climate change and actively works against trying to solve the problem

• Not done. “I didn’t get it” then and still don’t but clearly due to influence of special interest groups. This is an astronomy class and so only give some info on renewable energy and links to “business” pages off our web page
Renewable Energy in 2019

• Large Scale electric: Quite cheap natural gas with wind turbine and solar competitive (>40% of electricity in Iowa from wind). Many cities and companies now installing large solar farms. A few 2 MW farms near DeKalb approved.

• Small scale: solar energy cheap if install on homes ~15% return on investment include taxes. DH home 50% solar and 50% wind for electricity since 2015. Geothermal good source for heat/AC but larger initial investment in older homes

DH home:10 solar panels. Will be paid for in < 7 years, then after just “profit” →

Rapidly changing technology. 2018 panels are about 30% more efficient (more energy produced for same cost). If US government was concerned about jobs would be aiding R&D for the next generation of technology. Instead imposed tariffs.
Renewables are the least expensive new sources.
Coal or Natural gas can both be used in many existing power plants and so “cost” (including need to pay for environmental damage) determines balance between the two. Renewables will keep increasing.
New US Electrical Energy 2010-2016 → driven by costs

Share of New U.S. Capacity
Solar energy beats both wind and gas for first time

Source: GTM Research, SEIA
US Electrical Energy 2002-2016 → driven by costs. Note retirement of expensive coal-fired plants

U.S. electric generating capacity increase in 2016 was largest net change since 2011
US Electrical Energy 2018 → cost of coal-fired plants vs renewable. If Red, renewable cheaper (does not include the cost due to damaging environment)
From April 2018 Smithsonian magazine (link on web page)
Wind farms very productive near ocean shore as essentially always windy. 140% of Denmark’s electrical energy produced by wind in 2017, sell excess to other countries. This (small) country is a world leader in wind turbine technology.
Renewables are now the largest source of electrical energy in Germany, at 40%, with a goal of 65% by 2030. Use solar and wind as primary renewable sources (last 3 entries above).
Lecture Feedback

E-mail me a few sentences describing one topic you learned from this set of presentations. Please include the phrase “Our atmosphere is transparent only in the visible, radio, and part of the infrared” in your mini-report but do not use that as your “one topic”.

25
Climate Change vs Electrical Energy Source

- Accounting firm Price Waterhouse Cooper “20 years from catastrophe” link on course web page. Accounting firm Ernst & Young helps businesses on “Global climate change and sustainability” issues. For insurance companies, climate change is their #1 risk factor for property/casualty losses (note recent hurricanes)

→ “easy” solution: eliminate coal-produced electricity. saves money for more than (probably) 98% of Americans while good for the climate, and health of people living in coal producing regions or near coal plants.

- Natural gas, solar, wind, and geothermal all cheaper than coal. In 2018 Trump placed tariff on solar panels. Even with this solar much more cost effective than coal; but the tariff reduced the solar/natural gas new production ratio in 2018 compared to 2017, and caused US job loss and increased electrical power costs, and in the long run increases carbon dioxide emissions. In 2018, US administration tried to use 1954 defense related law to force utilities to purchase from coal plants. In 1954, was in case of Soviet attack/invasion. In 2018, who is “attack” threat (Canada, aliens?, real threat is cyber with North Korea have world’s best hackers). Best solution for “attack” or hurricanes is local electrical sources, especially renewable plus battery storage. Coal requires transport, for instance all the trains going through DeKalb. US federal administration threatening to sue California and force them to use more coal/oil and reduce environmental protections. Why?
Historical Note on Acceptance of Science

• We saw that at the time of Galileo the Catholic Church “opposed” the new science discoveries. But today the Catholic Church says “trust the scientists” → the “world turned upside down”

• 2017 Pope Francis: "Anyone who denies [climate change] should go to the scientists and ask them. They speak very clearly ... climate change is having an effect, and scientists are telling us which path to follow. And we have a responsibility - all of us. Everyone, great or small, has a moral responsibility ... We must take it seriously ... history will judge our decision.”

• In 2017-2018, US withdraws from Paris Climate Accord (only country not in it), reduces dramatically future funding for much of science, stops using science as input to decisions (like at EPA), and in January 2018 imposes a 30% tariff on imported solar panels. After ~70 years of leading the world in science and technology, US unilaterally decides to give up that leadership. Why?

• Also in 2018 the world saw an increase in the amount of carbon dioxide being released to the atmosphere (with the US having about a 3.7% increase) and an increase in the rate of melting of the Greenland ice cap.