Introduction to the Sun and its Activity

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The Solar Atmosphere

The Outer layers (Atmospheres) of the Sun:

• Photosphere

• Chromosphere

• Corona
Chromosphere
Chromosphere in Hydrogen-alpha
Corona – The Sun’s outermost atmosphere
August 21, 2017 Total Solar Eclipse Path
Credit: E. Avrett (from K. Lang: The Sun from Space, 2000)
Research Topic: What Causes the Corona to be Hot?
We have to go to *space* to see the Sun’s outer atmosphere with regularity.
The Electromagnetic Spectrum

Increasing wavelength, $\lambda$

Increasing energy, $E$

$E = \frac{hc}{\lambda}$

ELF Radio Microwave Infrared Ultraviolet X-ray Gamma Ray

Visible: 700 nm - 400 nm

$\lambda$: 1000 Å - 1 Å - 0.1 Å

$E$: 10 eV - 100 eV - 1 keV - 10 keV - 100 keV

Extreme Ultraviolet Soft X-ray Hard X-ray
At around $T \sim 10^5$ K:

\begin{align*}
H - R &= C \\
-R &\approx C \\
R &\approx \frac{d}{dz} \left[ \kappa_0 T^{5/2} \frac{dT}{dz} \right]
\end{align*}

(E.g., Golub & Pasachoff, “The Solar Corona.”)

Strong radiation in this temperature range means a steep temperature gradient is needed for energy balance. This leads to a “thin” transition region.
By the way...

There are many ways to observe the Sun (but never directly with unaided eyes!!). Ground-based telescopes have long been used. But in recent decades, the biggest breakthroughs are from satellites. Here are some recent ones:

- ...Several earlier missions....
- SOHO (1996 -- present; US, Europe)
- TRACE (1998 -- 2010; US)
- RHESSI (2002 -- present; US)
- Hinode (2006 -- present; Japan, US, UK, Europe)
- Solar Dynamics Observatory; SDO (2010 -- present; US)
- IRIS (2014 -- present; US)
Research Topic: Large-Scale Solar Activity (CMEs)
• The Sun is the nearest star to the Earth. It is the only star that we can study in great detail.

• The Sun’s atmosphere is loaded with dynamic activity. We use a combination of theory (including basic physics), data from the ground, and data from space, to try to understand the processes causing this activity.

• From (“night time”) astronomical data, it is inferred that similar types of activity occur on other stars as well, and also in other astronomical objects. Therefore the Sun can serve as a nearby laboratory for understanding various astronomical objects.
A Key Example of Solar Activity: Coronal Mass Ejections (CMEs)

• Expulsion of coronal material, etc., into space.

• CMEs are the main contributor to “space weather.” Can affect the environment around the Earth.

• In rare and extreme cases, they are capable of killing astronauts. (This is one reason why we want to understand them!)
Research Topic: Sources of CMEs at the Sun
Solar Sources of CMEs; Filaments and Flares

• CMEs start from the corona.
• Often start with filament eruptions; filaments are cool material (coronal material) suspended in the corona.
• Flares also often (always?) occur in conjunction with filament eruptions and CMEs.
What causes eruptions on the Sun?
(a) Temperature?
(b) Magnetism?
(c) Gravity?

Hint: It’s the same thing that results in the “clumpiness” of the corona.
Yohkoh Soft X-ray Telescope, Soft X rays
November 11, 1999 at 15:40
Solar Eruptions at the Sun

• Eruptions in the solar atmosphere are the sources of CMEs.
• Eruptions are due to the magnetic field.
• The energy for the eruption comes from the magnetic field; that is, the magnetic field provides the energy needed to drive the eruption leading to the flare, CME, etc.
• BUT, we still do not understand the details of these processes!!

One of my jobs: Study the onset of solar eruptions; specifically, their magnetic origins.
(Moore, Sterling et al. 2001)
(Moore, Sterling et al. 2001)
Research Topic: Smaller-Scale Eruptions (Coronal Jets)
Revised View of Jets (Sterling et al. 2015, Nature)
Research Topic: Solar Cycle
The Solar Cycle

• The amount of solar activity varies systematically over time.

• The activity variation is cyclic, with an (approximately) 11-year period. (And there are other periods too.)

• This “solar cycle” was first identified by the variation in the number of sunspots each year (count the total number of spots, e.g., each month).

• Cycle also can been seen in other ways, e.g. the intensity of the corona, the number of CMEs, etc.
Summary of Solar Science

- Main atmospheres of the Sun: photosphere, chromosphere, and the corona; each region has specific properties.
- The Sun is alive with activity!
- Magnetic fields are responsible for much (if not all) of the activity.
- Some manifestations of this activity are sunspots, flares, filament eruptions, and CMEs.
- Activity undergoes an approximately 11-year cycle.
Science Funding

Pure research funds - *Extremely* competitive!! Two ways (among others) to supplement are:

- Teaching + Research
- Satellite support + Research

- ...Several earlier, and current, missions....
- SOHO (1996 -- present; US, Europe)
- TRACE (1998 -- 2010; US)
- RHESSI (2002 -- present; US)
- Hinode (2006 -- present; Japan, US, UK, Europe)
- Solar Dynamics Observatory; SDO (2010 -- present; US)
- IRIS (2014 -- present; US)
- Parker Solar Probe (2018 -- present; mainly US)
- Solar Orbiter (mainly Europe, but also US)
Hinode (ひので)
Some Places for Solar Physics Graduate Studies

• UAH; Alabama A&M (via NASA/MSFC)
• Catholic U; George Mason U. (Washington DC)
• Several Boston area schools (through Smithsonian Astrophysical Observatory - SAO)
• U of Hawaii
• U of Montana
• U of New Hampshire
• NJ Institute of Technology
• UC Berkeley; Stanford
• Rice U
• Etc!!