To Touch The Sun:
The Parker Solar Probe

a presentation for the
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Background Image: Joe Matus, NASA/MSFC, August 21, 2017
Outline

• A bit of history

• The Sun vs. a couple of stars
  - What is a Star?
  - What is the Sun like?

• The Parker Solar Probe

First Contact, August 21, 2017 Solar Eclipse

Image Credit: Mitzi Adams, NASA/MSFC, August 21, 2017 from Clarksville, Tennessee
History
"Simpson's Committee" of the Space Science Board (National Academy of Sciences, 24 October 1958) Interim Report, Long Range Plans:

-- a lunar satellite and a station on the Moon for the study of particles and fields;

-- a solar probe to pass inside the orbit of Mercury to study the particles and fields in the vicinity of the Sun;

-- probes to the planets to study their magnetospheres;

-- two kinds of Earth satellites, one in a highly eccentric orbit, the other in a geostationary orbit. Both satellites would be used to study the particles and fields in the Earth's magnetosphere and in interplanetary space outside the magnetosphere.

Professor Eugene Parker, S. Chandrasekhar Distinguished Service Professor Emeritus, Department of Astronomy and Astrophysics, University of Chicago

Image from: https://blogs.nasa.gov/drthomasz/2017/06/05/parker-solar-probe/
What is a Star?
What is a Star? -- Energy Production

A star is an astrophysical body that produces its own light by thermonuclear reactions in its core.

For solar-type stars, this is the proton-proton chain:

1. Two protons collide, form deuterium, a positron, and a neutrino.

2. A proton collides with the deuterium, forming helium-3 and a gamma ray.

3. Two He-3s collide to form He-4 plus two protons.
   Basically, Hydrogen converts to Helium.

(High-mass stars, greater than about 2 solar masses use a different procedure, the CNO cycle.)
What is a Star? -- Differences

Betelgeuse: A red-giant star, about 650 ly away, 3500 K, 862 R\(\odot\), 20 M\(\odot\), 8.5 million years old, ~100,000 years left.

Rigel: A blue-white star, about 8600 ly away, 12,000 K, 80 R\(\odot\), 23 M\(\odot\), 8 million years old.

Our Sun: A yellow star, ~8 lm away, 6,000 K, ~700,000 km (432,000 mi), 2 x 10\(^{30}\) kg, 4.5 billion years old, ~5M yr left.
α-Cen-A is G2, α-Cen-B is K1, Proxima (α-Cen-C) is M6, 4.2 ly

Sun is G2
8.5 light minutes away

Betelgeuse is M2
643 ly

Rigel is B8
860 ly
What is the Sun like?
Sunspots are regions that are cooler than their surroundings, produced by strong magnetic fields.

Sunspots have an Umbra surrounded by the lighter Penumbra.

Sunspots usually appear in groups, with lifetimes of days or weeks.

The earliest sunspot observations (c. 1609) indicated that the Sun rotates once in about 27 days.
The Sun: Sunspot Examples
The Sun: Sunspot - Magnetic Fields

(a) Yohkoh Soft X-ray Telescope, Corona
4 Jan, 1994 7:35 UT

(b) Line-of-Sight magnetic field from Kitt Peak National Observatory at 16:31 UT

(c), (d) Extrapolated Magnetic Field
The Sun: The Solar Cycle
The Sun: Sunspot Cycle Discovery

Sunspots observed > 230 years
1844 Heinrich Schwabe, amateur astronomer, Dessau, Germany

Cycle: increase and decrease over ~10-years
- number of sunspot groups and the
- number of days without sunspots

Schwabe’s data for 1826 to 1843
The Sun: 23 Full Cycles Observed

Rudolf Wolf 1849 -- “Relative”
Sunspot Number = 10 times
number sunspot groups + total
distinct spots

Average cycle: ~11 years, -2, +3

Average amplitude: ~100, with
range from 50 to 200
The Sun: Sunspot Latitudes

**DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS**

**SUNSPOT AREA IN EQUAL AREA LATITUDE STRIPS (% OF STRIP AREA)**

- > 0.0%
- > 0.1%
- > 1.0%

**AVERAGE DAILY SUNSPOT AREA (% OF VISIBLE HEMISPHERE)**

[Graph showing the distribution and average of sunspot areas over time and latitude.]

http://solarcyclescience.com/solarcycle.html

HATHAWAY 2017/09
The Corona and the Solar Cycle

Source: Yohkoh/NOAA/HAO
The Corona, August 21, 2017

Image by Joe Matus, NASA/MSFC from Hopkinsville, KY
Solar Eruptions
Filament Eruptions

October 2000
Filament around AR 9182
C-7 flare triggered
Halo coronal-mass ejection (CME)
Image Credit: NOAA/SEC

August 31, 2012
Filament eruption, CME
Plasma Speeds: > 900 mi/s
Normal Solar Wind Speed: ~250 mi/s
Image Credit: SDO/AIA in 304 Å.
More Solar Eruptions

SDO plus Soho C2
X2-flare and halo CME

Three distinct CMEs
1. To right in both images, from a filament eruption,
2. From North Pole,
3. From far side of Sun.
All three eruptions happened within hours of each other.

Image Credit:
SDO and SOHO/LASCO
Solar Flare Classification

Sept. 6, 17:59 UT
Hinode XRT
X9 flare

Sept. 6, 18:46 UT
SDO/HMI
Parker Solar Probe (PSP)
PSP: What Do We Know and Why Do We Care?

-- The Sun produces a wind composed of electrons and ions and
-- The wind carries the magnetic field with it.

-- Anti-parallel magnetic field reconnects
-- Plasma is redirected backwards to the magnetotail...more active when Bz is southward

Events: Coronal Mass Ejections and Corotating Interaction Regions

PSP: Why Do We Care?

Energetic Electrons → Damage to Spacecraft Electronics → Ionospheric Currents

Solar Flare Protons

GPS Signal Scintillation

Radiation Effects on Avionics

Geomagnetically Induced Current in Power Systems

Induced Effects in Submarine Cables

Telluric Currents in Pipelines
1. Why is the corona so hot?
2. What accelerates the solar wind?
3. What are conditions like in the corona at 9 solar radii?
4. How are energetic particles accelerated and what is their origin?
5. How is the magnetic field there structured and how does it change?

Images From: https://sdo.gsfc.nasa.gov/gallery/main
Parker Solar Probe: Science Objectives

- Trace flow of energy that heats and accelerates the corona and solar wind

- Determine structure and dynamics of plasma and magnetic fields at solar wind sources

- Explore mechanisms that accelerate and transport energetic particles

Image Credit: Johns Hopkins University Applied Physics Laboratory, Artist’s Concept
Parker Solar Probe: Approaching the Sun

Closest Approach: 3.83 million miles

Fastest Speed: 450,000 mph
Philadelphia to D.C. in one second

Image Credit: Johns Hopkins University Applied Physics Laboratory, Artist's Concept
Parker Solar Probe: Investigations
Fields Experiment
Measurements of: electric and magnetic fields and waves, Poynting flux, absolute plasma density and electron temperature, spacecraft floating potential and density fluctuations, and radio emissions.
Parker Solar Probe: Investigations
Integrated Science Investigation of the Sun (ISIS)
Observations of: energetic electrons, protons, and heavy ions (10s of keV to 100 Mev)
Correlates with: solar wind and coronal structures
Parker Solar Probe: Investigations
Wide-field Imager for Solar PRobe (WISPR)
Images of: solar corona, inner heliosphere, solar wind, and shocks
Parker Solar Probe: Investigations
Solar Wind Electrons Alphas and Protons (SWEAP)
Counts: electrons, protons, helium ions
Measures: velocity, density, and temperature
Parker Solar Probe: Spacecraft

Mass: 685 kg  
S/C height: 3 m  
TPS max diameter: 2.3 m  
S/C bus diameter: 1 m

Actively cooled solar arrays  
388 W at encounter  
Solar array area: 1.55 m²

Radiator area under TPS: 4 m²  
Wheels for attitude control

Science downlink rate: 167 kb/s at 1AU
Parker Solar Probe: Launch

Launch Window: July 31 - August 19, 2018

Delta IV-Heavy with Upper Stage
Image Credit: ULA
Parker Solar Probe: Trajectory

- 24 Orbits
- 7 Venus Gravity Assists
- Temps at Closest Approach: 
  - 1400° C at shield
  - ~25° C behind shield
- First Close Approach
  - December 19, 2024
- Last Close Approach
  - June 14, 2025
Send Your Name to the Sun

Submissions Accepted until April 27, 2018
Go Here: http://go.nasa.gov/HotTicket

Image from: http://parkersolarprobe.jhuapl.edu/News-Center/Show-Article.php?articleID=70