(Astro)Physics 343 Lecture # 4:
Lab # 2 + Stars and Planets in the Radio

Some reassurances about Lab # 1

Response of SRT appears to be unstable: antenna temperature varies (by up to factor of 10!) between datasets, and in some cases within datasets as well. Reason(s) still to be determined (instability in receiver? pickup at low elevation?).

Some datasets look... strange. This is not your fault (or mine!).

The 20-25s “wait” appears not to have worked for the first offset in each scan.

Last week: 19 emails with questions about the lab. Don't be shy!

Lab # 2: more observations of the Sun...

First part of lab: measure the aperture efficiency of the SRT.

Second part of lab: assess level of solar variability.

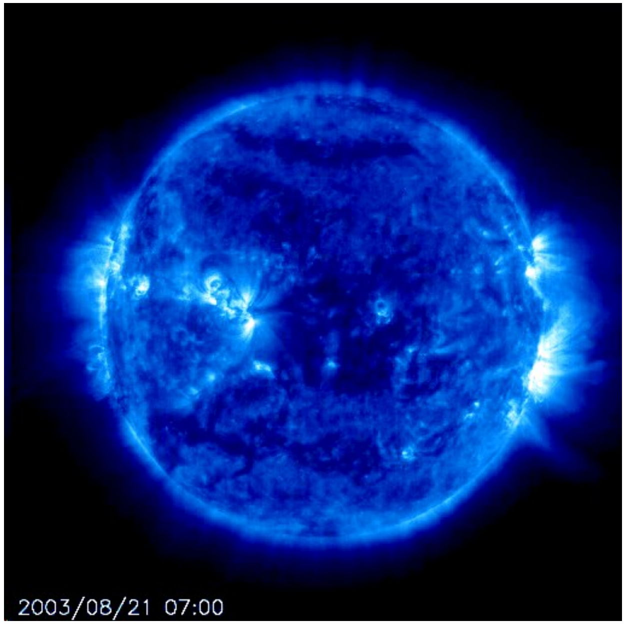
Most data will (again) be taken in service mode. For solar variability studies, you will create script fragments that will be merged to form a single master script. This will be run Wednesday, Thursday, Friday, Saturday, and Sunday, and the data for your specific slot (see instructions) will be emailed to you.

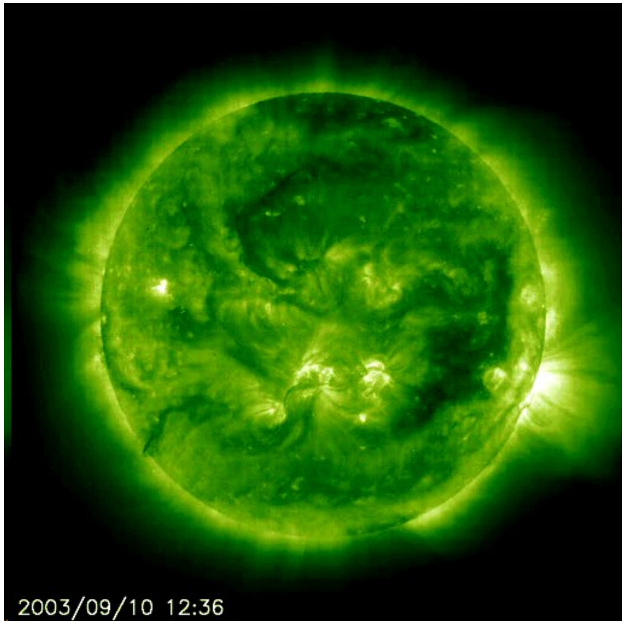
Quiz

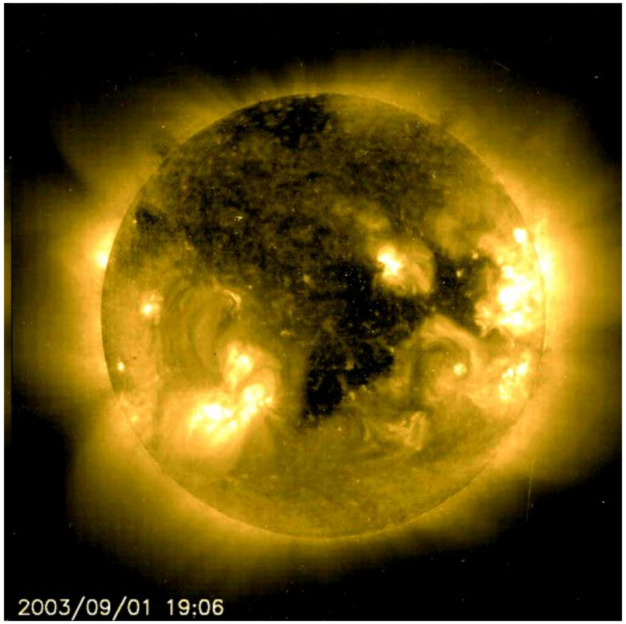
Size of the Sun

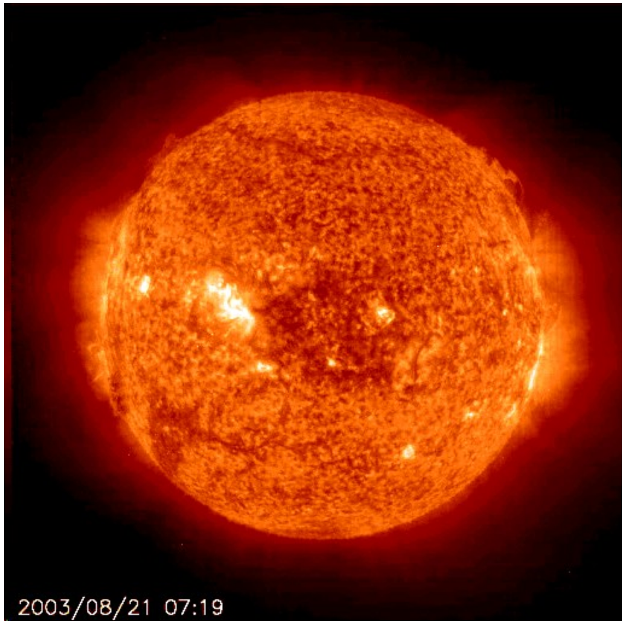
	Earth	Jupiter	Sun
Diameter	12,700 km 7,900 mi	140,000 km 87,000 mi	1,400,00 km 865,000 mi
Mass	6.0 x 10^{24} kg	1.9 x 10^{27} kg	2.0 x 10^{30} kg
Distance From Sun	150 x 10^{6} km 93 x 10^{6} mi	778 x 10^{6} km 483 x 10^{6} mi	---
Period	3.156 x 10^{7} s 1 year	3.74 x 10^{8} s 11.9 years	---

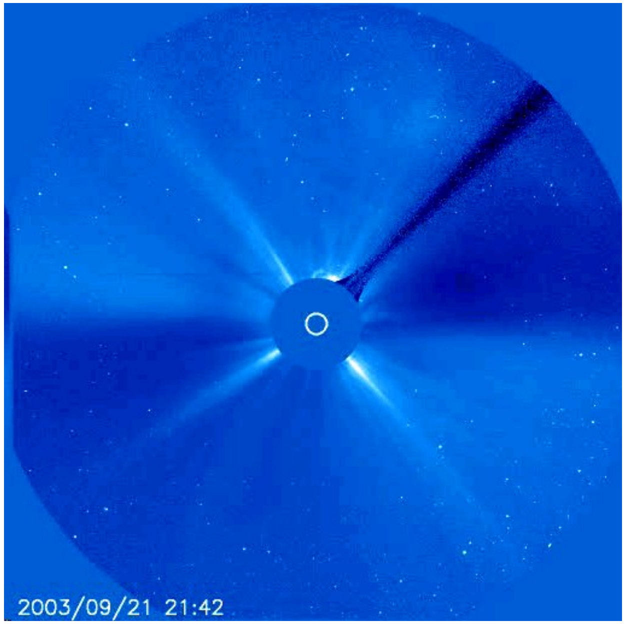
Solar Activity as seen by NASA and ESA missions

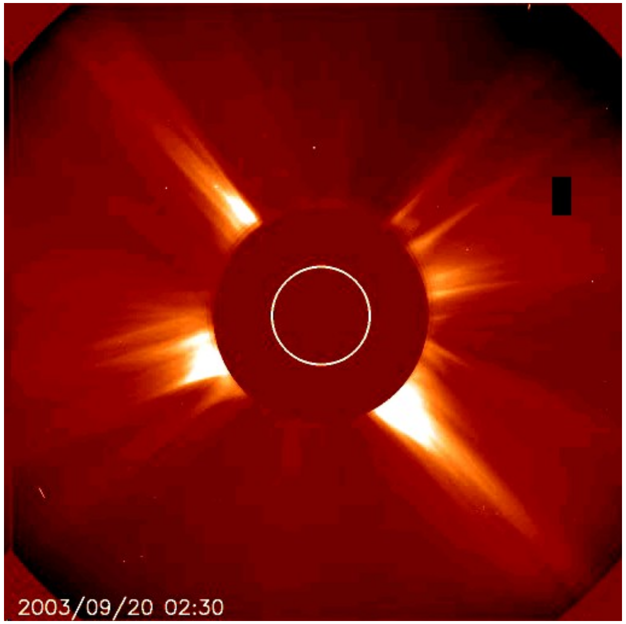






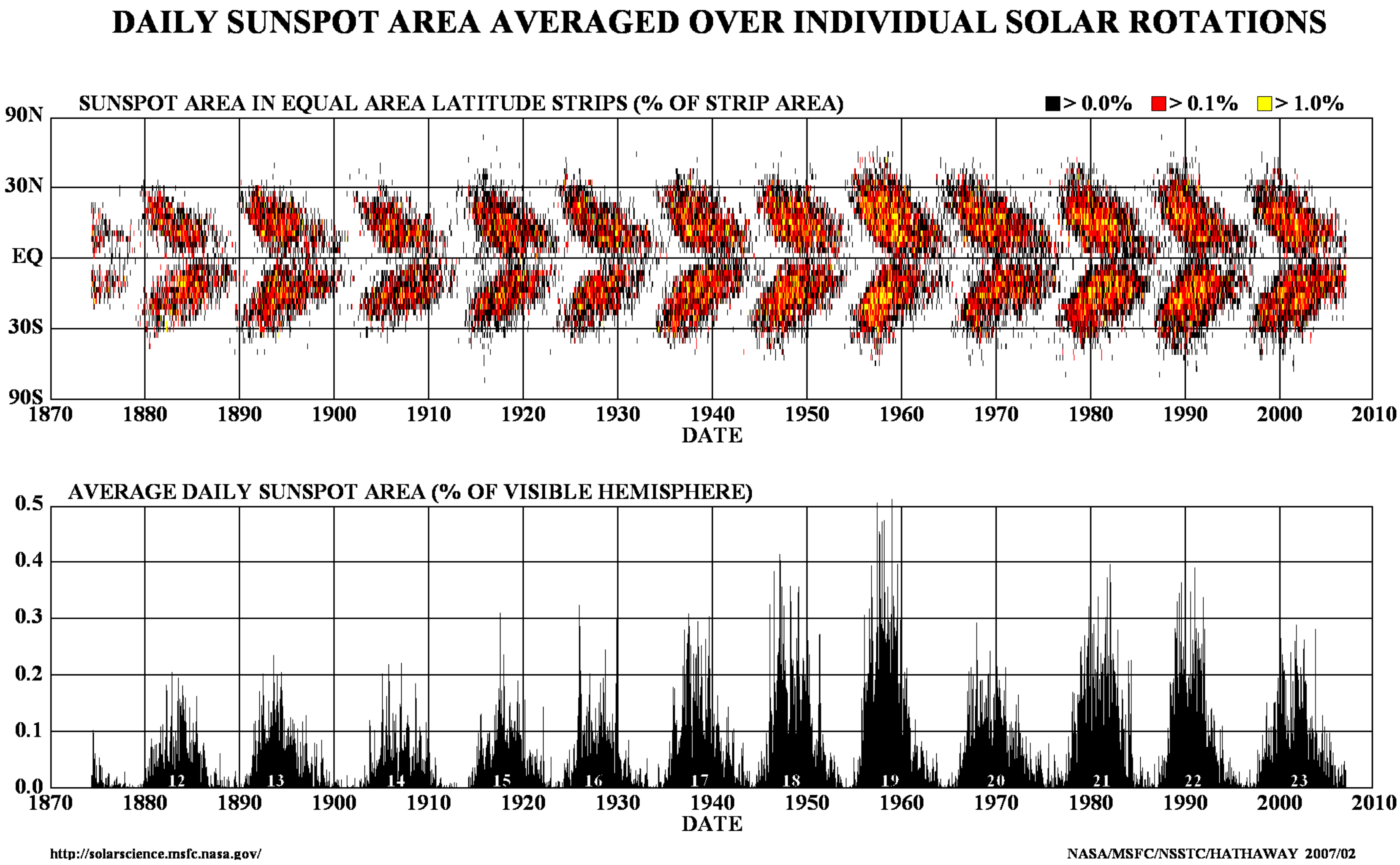




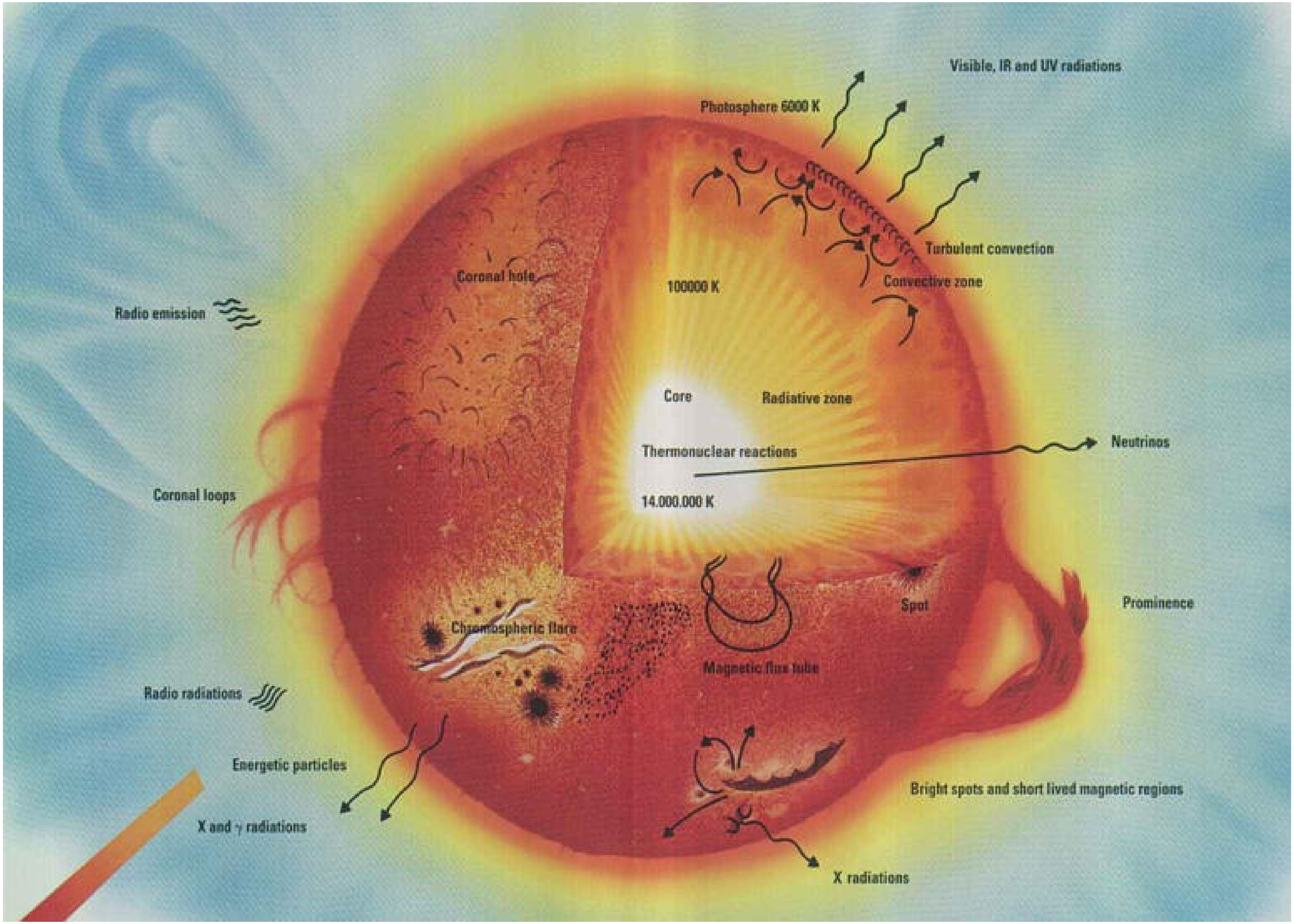


http://sohowww.nascom.nasa.gov/data/realtime/mpeg/

Long-Term Sunspot Cycles: 11 years



What's Happening in the Sun



Facts About Sun

- normal star of spectral type G2V which means:
  -- it is burning hydrogen in its core
  -- it has been doing this for the last 5 billion years
  -- it will continue to do for about another 5 billion years
- core temperature is about 14 million K
- temperature falls off with distance from the core
- surface temperature is 5800 K
- the photons generated in the core:
  -- take ~1 million years to reach the surface
  -- short mean free path -absorbed and re-emitted
  -- last scattering in the photosphere
- then they pass through tenuous gas at even lower temperature, ~4500 K, producing absorption lines in the spectrum
- At higher radius, temperature climbs steeply to several million degrees in a hot, tenuous plasma

Temperature Above Solar Surface

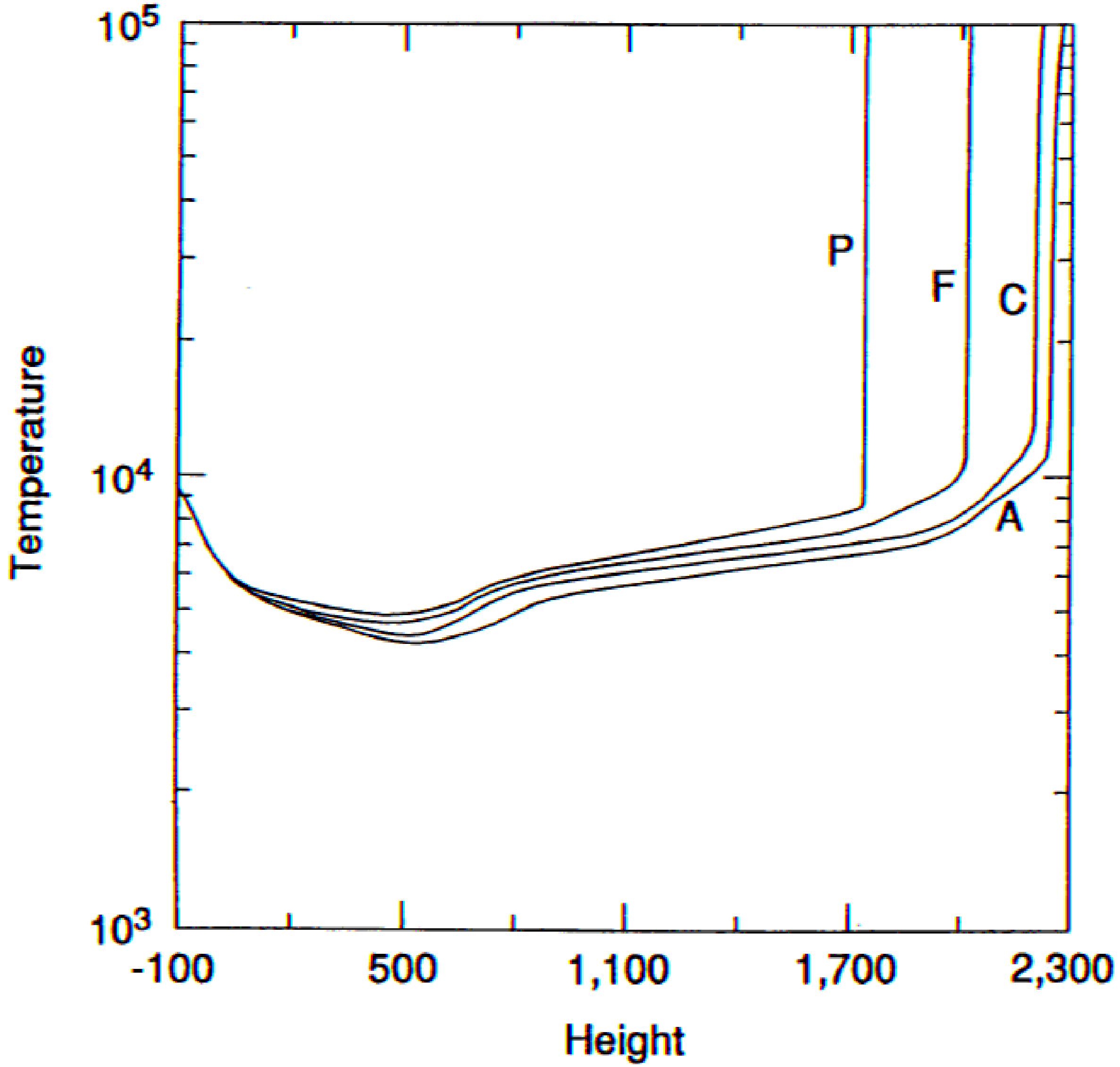


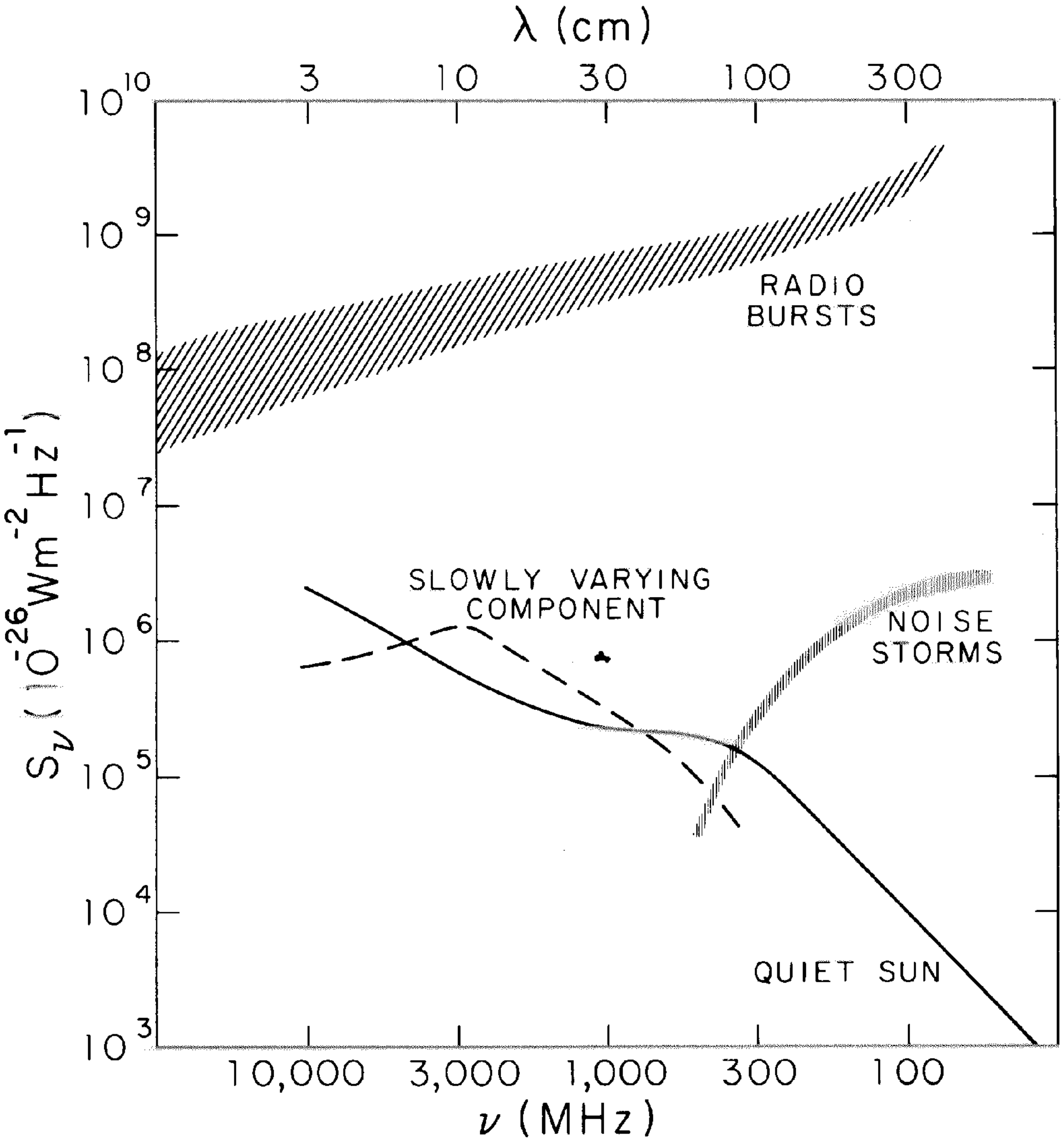
FIG. 3.—Temperature structure of our models A, C, F, and P. The height is measured in kilometers from the level; the temperature is in kelvins.

Types of Radio Emission from the Sun

Composition of the Sun:

- The matter in the Sun is mostly Hydrogen and Helium
- The physical state of this matter is a plasma:
  an ionized gas of electrons (- charge)
  and ions (+ charge)
- There are four broad categories of radio waves from the Sun:
  - Quiet Sun Emission
  - Slowly Varying Component
  - Noise Storms
  - Bursts

Intensity of Solar Emission Types



Quiet Sun Emission

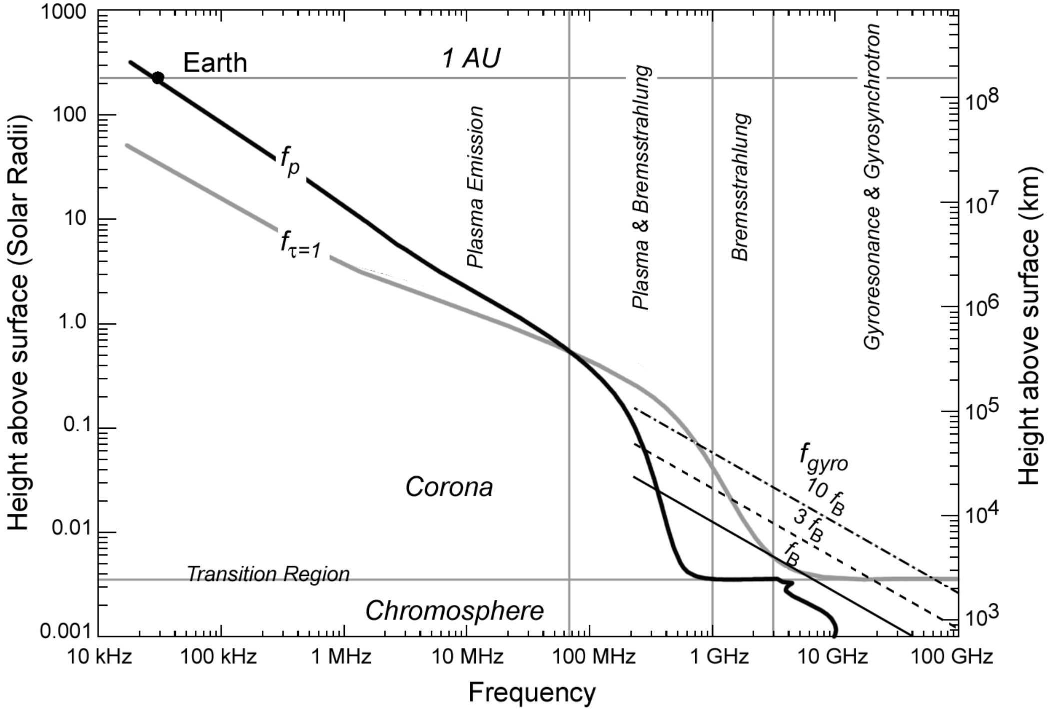
Radio emission from the “quiet” Sun is always present,
and it is relatively stable in time.
The mechanism is thermal bremsstrahlung,
i.e. “braking” radiation due to collisions
between particles in or near outer Sun’s outer surface.

Quiet Sun Processes

Electron density, n_e, tends to increase with altitude above solar surface.

Observations at different frequencies tend to “see” different depths.

Higher frequency = deeper penetration into Sun’s surface.



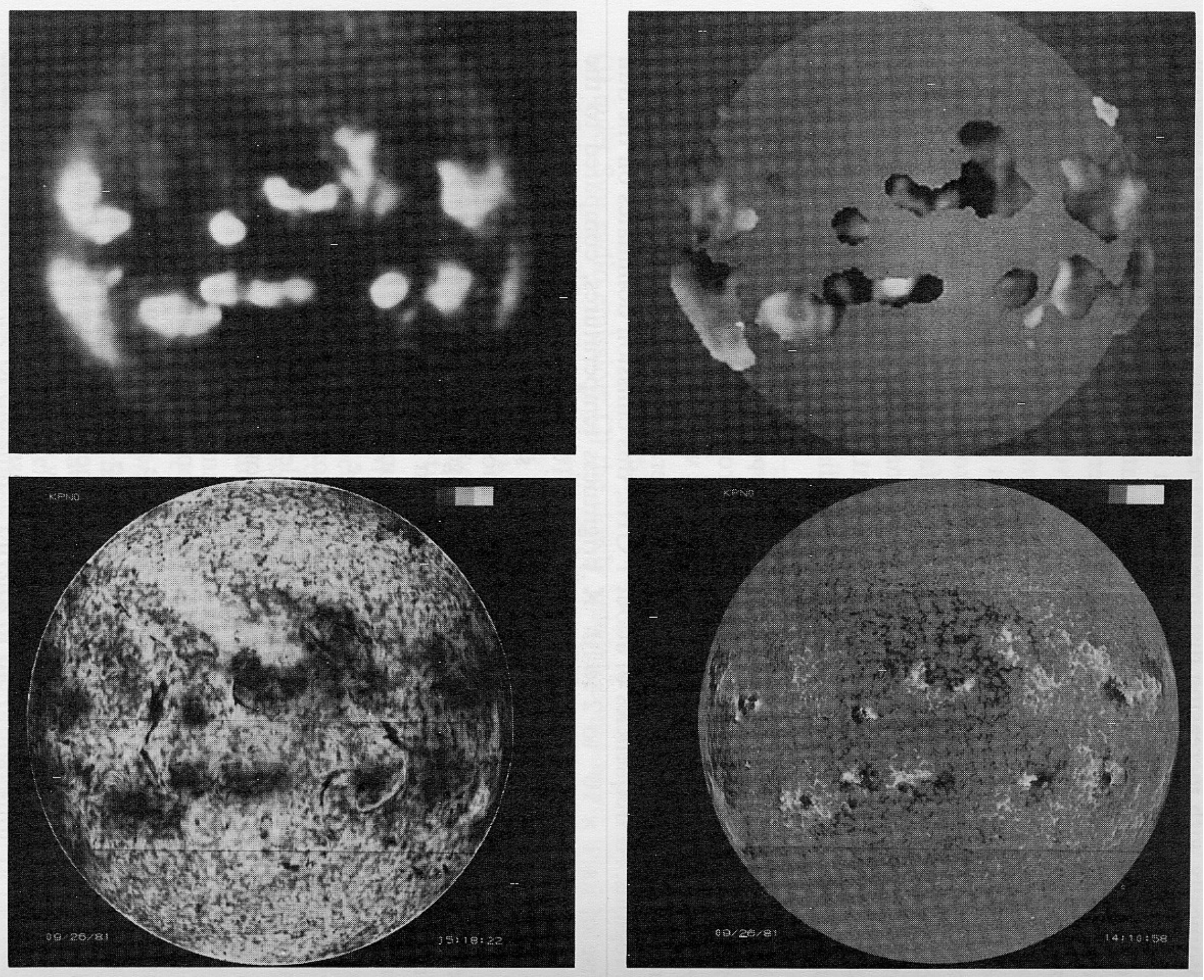
Highest curve: emission mechanism dominant at different frequencies in the solar atmosphere.

Based on the dependence of different emission mechanisms on the plasma parameters of temperature, density, and magnetic field strength.

Slowly Varying Component

Dominates radio emission at ~1 GHz

With effective temperatures of 1- to 2-million deg-K



1.4 GHz

1.4 GHz
Circ. Pol.
Dark = LH
Light = RH

1083 nm
Wavelength
He line

Magnetogram

Dulk & Gary, 1983

Noise Storms

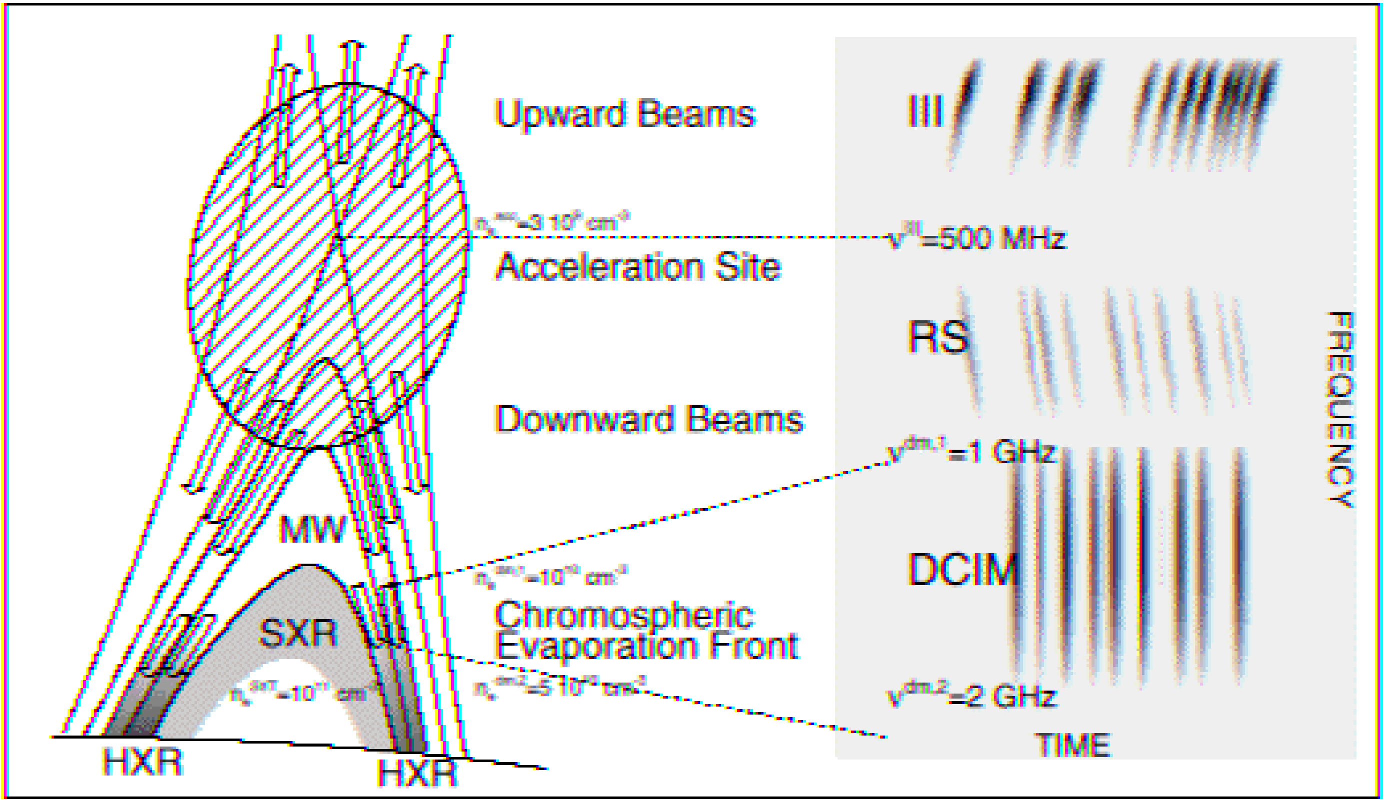
Solar noise storms frequently dominate
radio emission in 1- to 10-m wavelength
and they last a few hours to a few days.
There are various types, but we won’t discuss distinctions

Near the maximum of solar sunspot cycle
they are in progress ~10% of the time.

They originate 0.1 to 1 solar radius above the photosphere
and they are beamed ~radially outward.

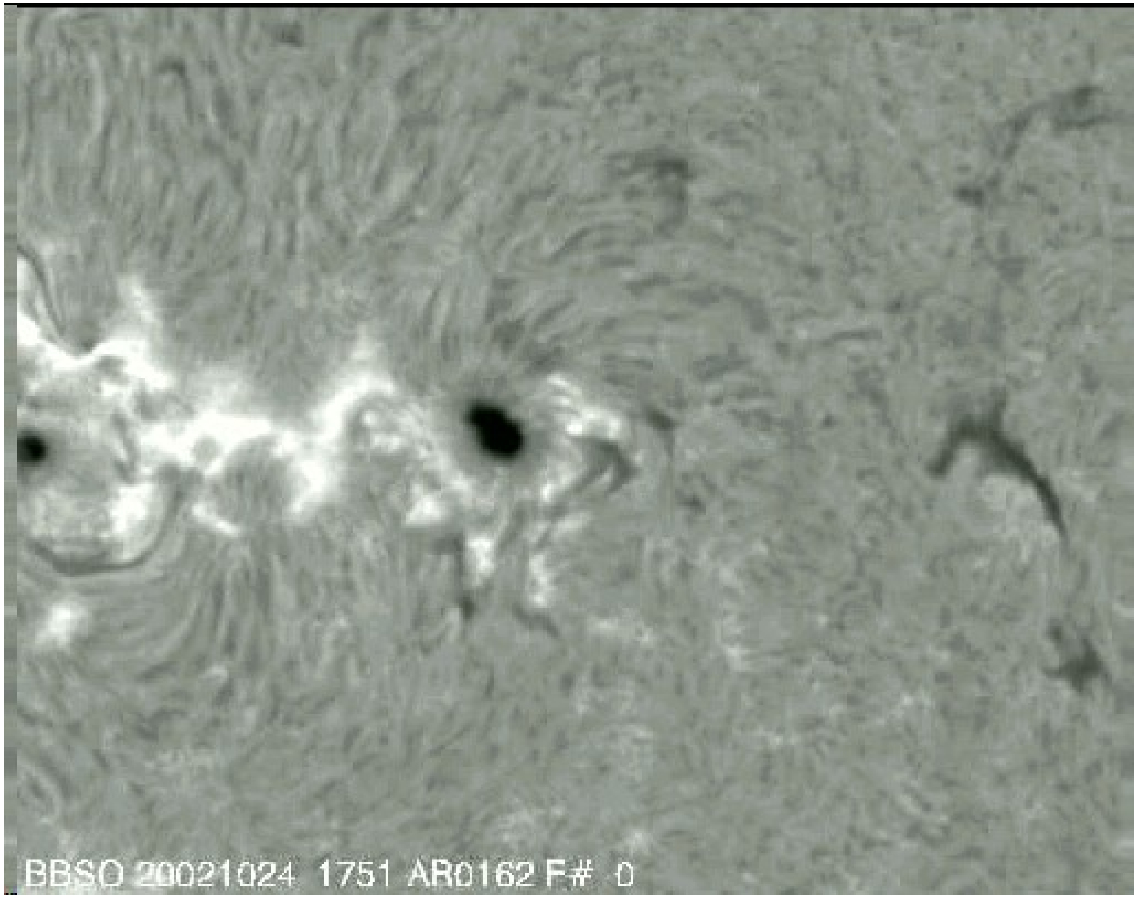
Solar Radio Bursts

Strongest and most complex solar radio events.
Usually associated with solar flares.
Brightness temperatures up to 10^{12} K.
Non-thermal spectra.
Duration: a few minutes to a few hours.



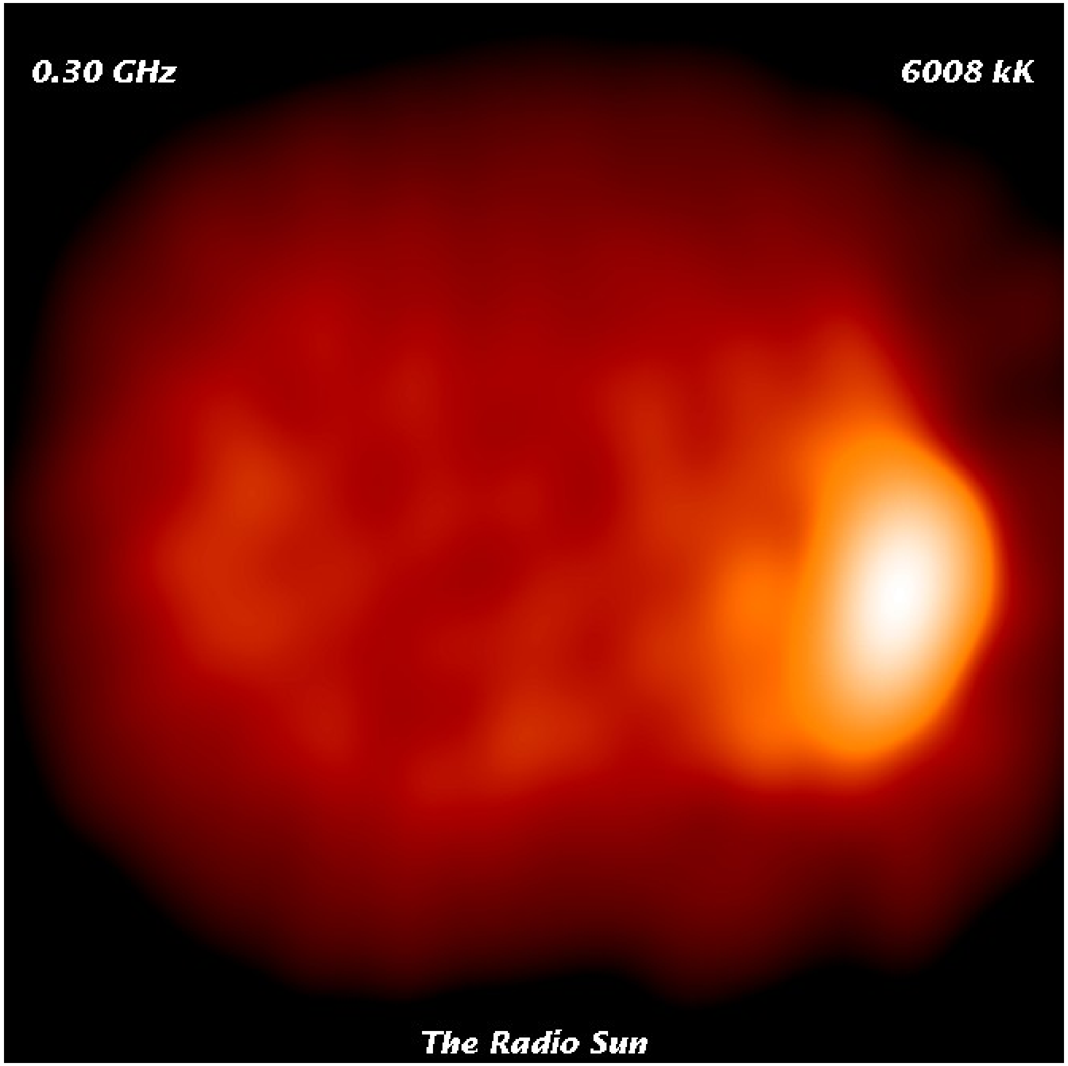
Solar Flare

X-ray flare and Optical flare observed in H-alpha and several eruptive centers



http://www.bbso.njit.edu/Research/Events/2002/10/24/event_20021024_1810/

Solar Appearance vs. Radio Frequency



http://physics.njit.edu/~dgary/728/montage_anim.gif

Radio observations of *other* stars

The Radio Interferometric Planet (RIPL) Search:
http://astro.berkeley.edu/~gbower/RIPL/

Use the VLBA+GBT to detect wobbles of stars due to planets in orbit about them.

Precision radial velocities measure wobble along line of sight.
Precision astrometry measures wobble in plane of sky.

RIPL is looking for companions to lower-mass stars than can be studied with radial velocities.

Planetary Astronomy: Radar and Radio Observations

Planets and other solar system objects are generally cold relative to stars:
~700 K for Mercury … ~30 K for Pluto … >6000 K for the Sun.

For the visible spectrum, see only reflected light.

But planets are thermal emitters, producing radio emission
due to black body radiation from their surfaces.
This thermal radiation is in the radio spectrum.

Jupiter has a very large magnetosphere.
Larger in angular size than the Moon if we could see it in visible light.
This traps high-energy electrons that then emit synchrotron radiation.

Emission Spectra of Solar System Bodies

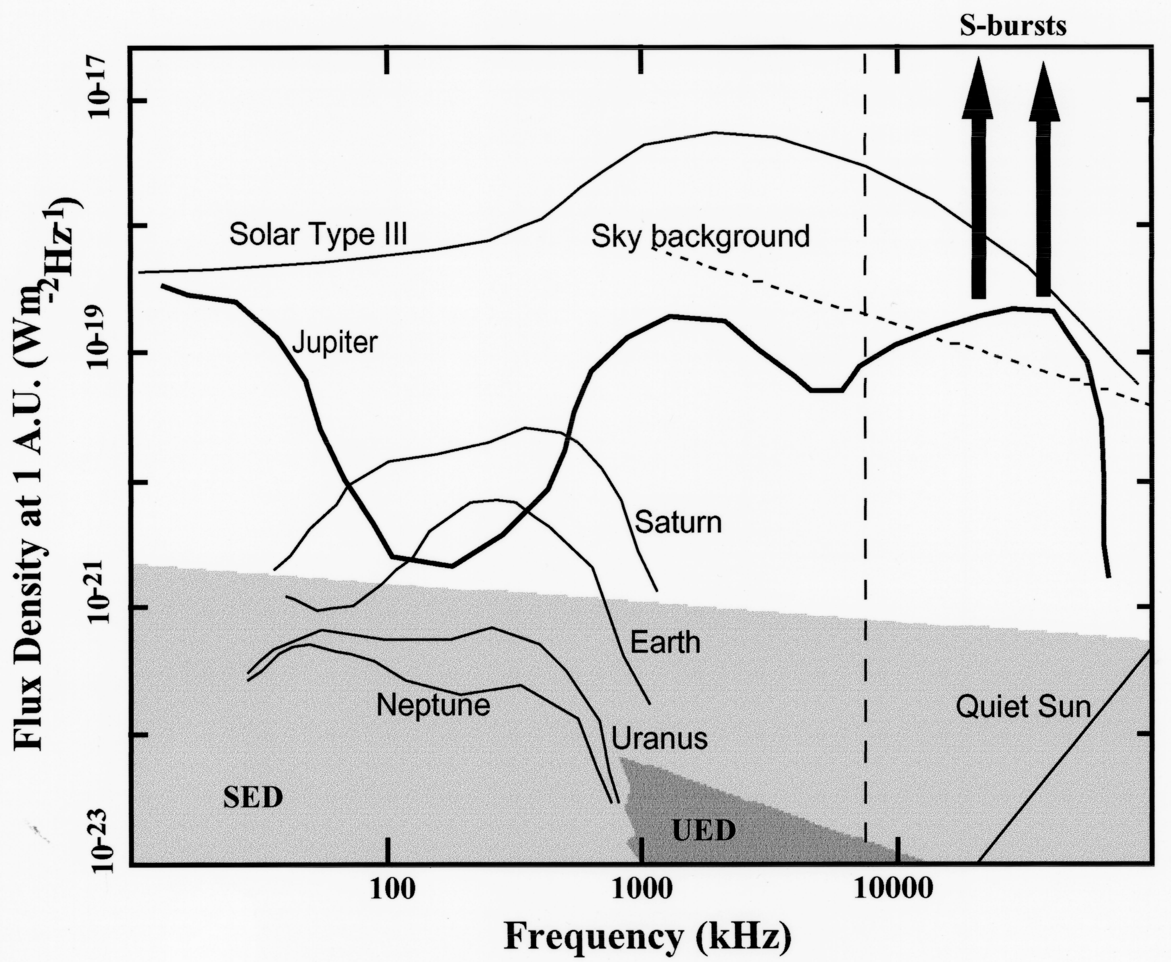
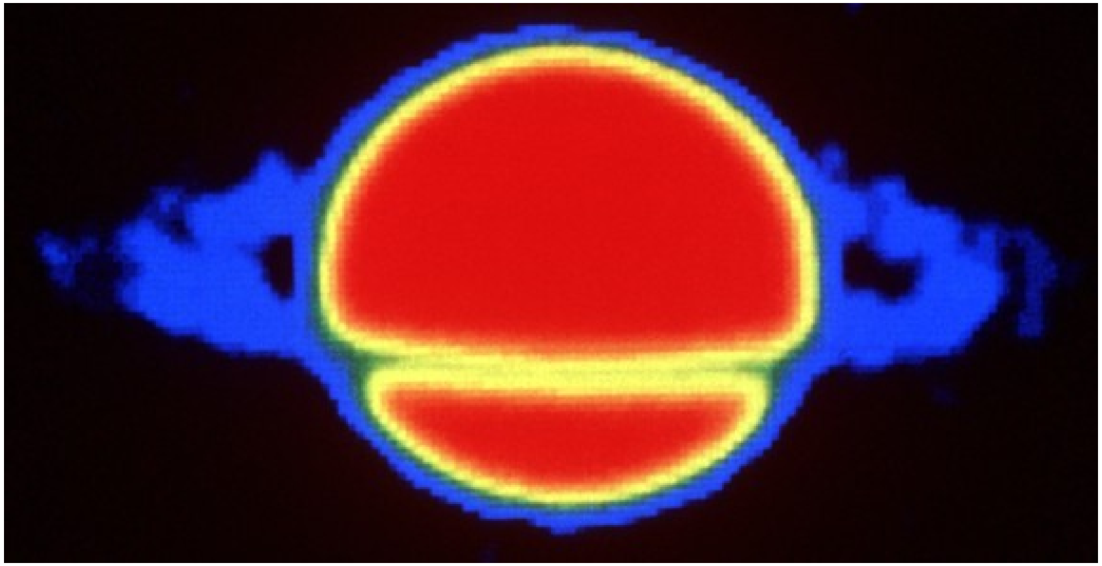
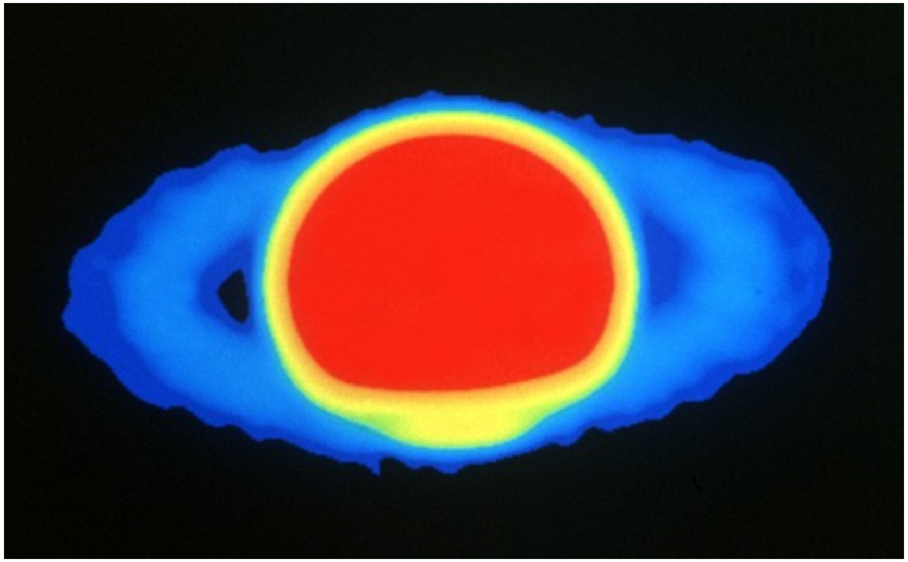


Figure 1 : *Comparative spectra of solar system radio emissions in the decameter-to-kilometer range, normalized to a distance of 1 A.U. (except for the sky background - Kraus, 1986). Average spectra of the auroral radio emissions of the five "Radio-planets" are displayed (adapted from Zarka, 1992). That of Jupiter (boldface) is often as intense as solar type III radio bursts. Peak levels are about one order of magnitude above these averages. Jovian S-bursts fluxes can reach* 10^{-16} $Wm^{-2}Hz^{-1}$*. The grey-shaded regions labeled "SED" and "UED" (standing for Saturn/Uranus Electrostatic Discharges) show the range of intensities of these planetary lightning-associated radio emissions*

Our telescope
operates at
much higher frequency
1420 MHz
= 1,420,000 kHz

Saturn





1982-01-25 **VLA Telescope** **1986-12-00**

Red is hot,
Blue is cool.

Bright disk with a gradual fading toward the edge - limb darkening
illustrates a gradual cooling outward in Saturn's atmosphere
Rings are seen in emission outside the disk
but in front of the planet they absorb radiation from disk behind
In visual light they appear bright everywhere - reflect the incident sunlight.
At radio wavelengths the sunlight is fainter.
Emission from Saturn dominates.

Jupiter

Jupiter has a strong magnetic field.
Gives rise to huge Van Allen belts of radiation around the planet.

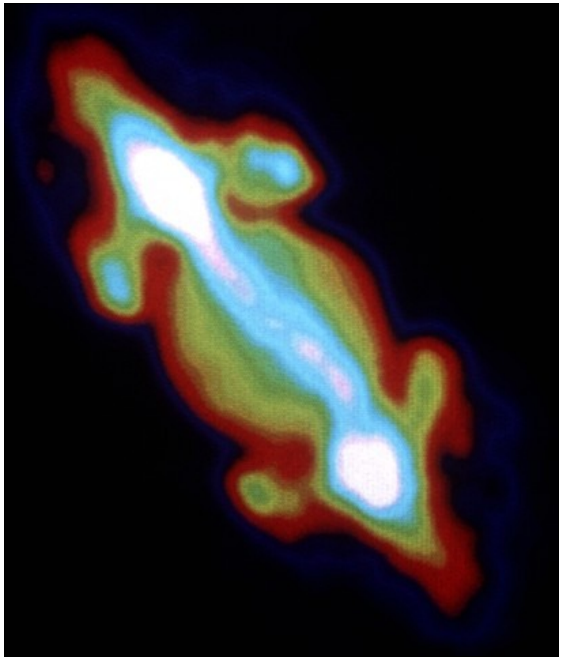
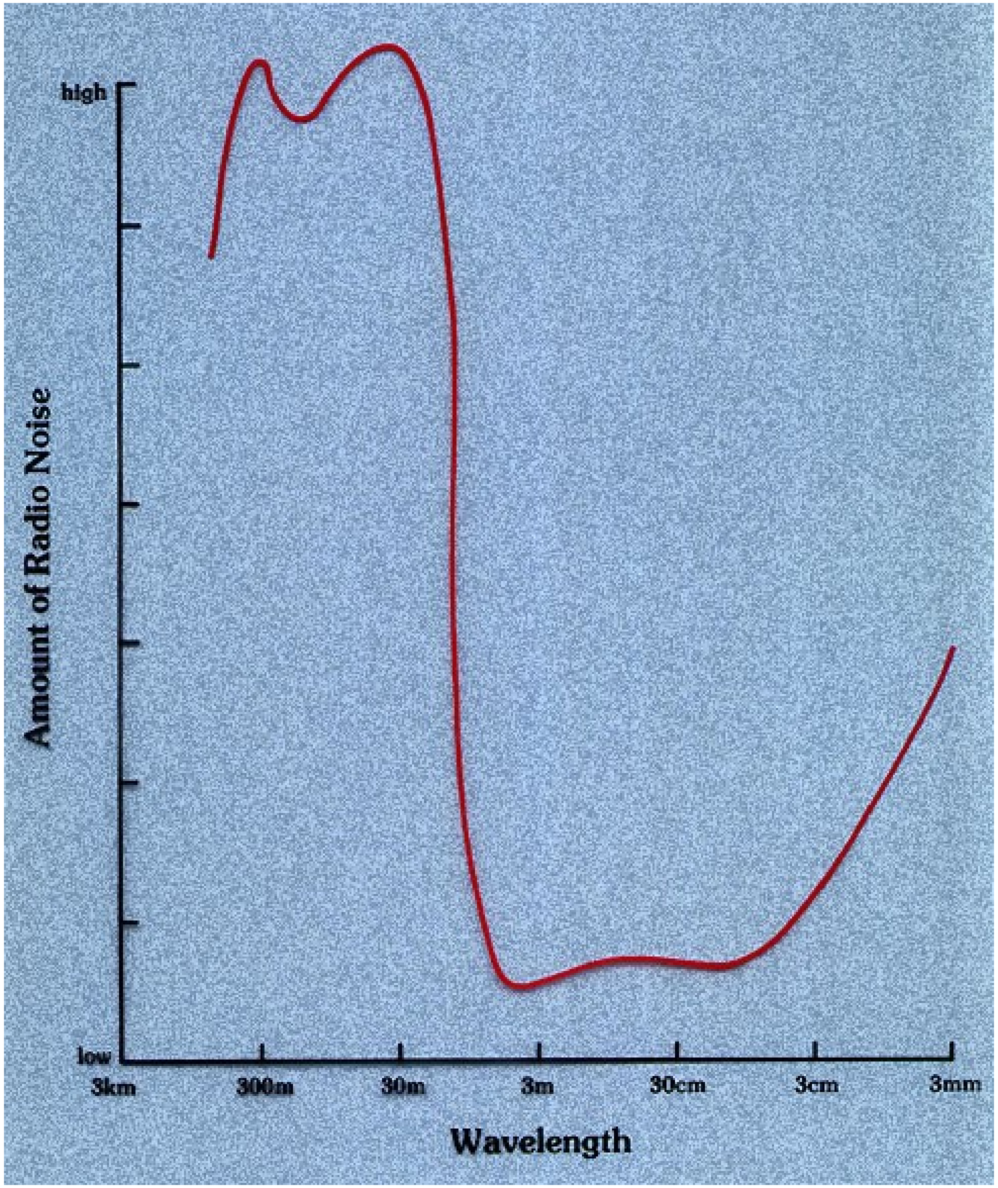


Image courtesy of NRAO/AUI

Charged particles travel in circular orbits around magnetic field lines.
Electrons give rise to synchrotron radiation.

Jupiter



λ ~ 3cm: bremsstrahlung

= free-free in atmosphere

λ ~ 10cm: synchrotron

from magnetosphere

λ > 3m: radio bursts due to Io

building up a huge charge

(potential difference ~ 400,000 V)

before violently discharging