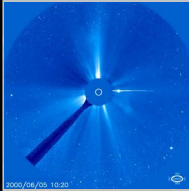


Physics of the heliosphere; an introduction

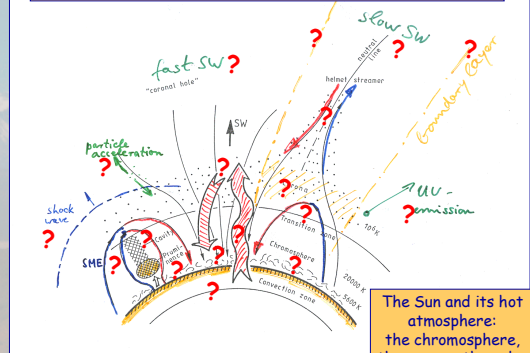
Lectures at the
International Max-Planck-Research School
October 2002

by Rainer Schwenn, MPAe Lindau

- 2. Corona and solar wind**
- The corona and its EUV spectrum
 - The four types of corona
 - The problem of coronal heating
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 - From the corona into the solar wind



Many basic problems are still unsolved!



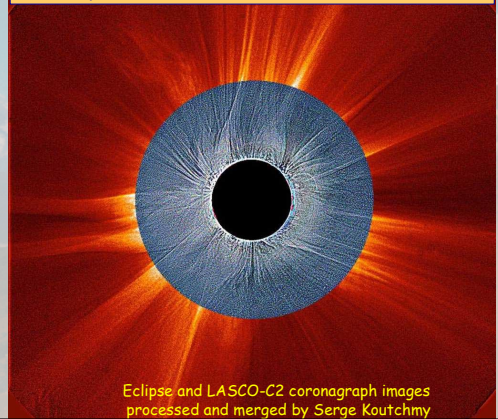
The Sun and its hot atmosphere: the chromosphere, the corona, the solar wind, and transient processes

Eclipses reveal an extended corona



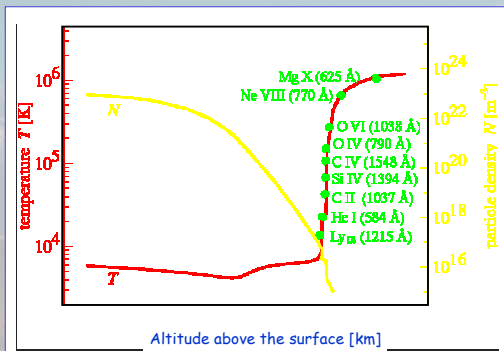
The Sun's outer atmosphere, the „corona“, must be very hot. Otherwise it could not be so extended

Eclipses reveal an extended corona



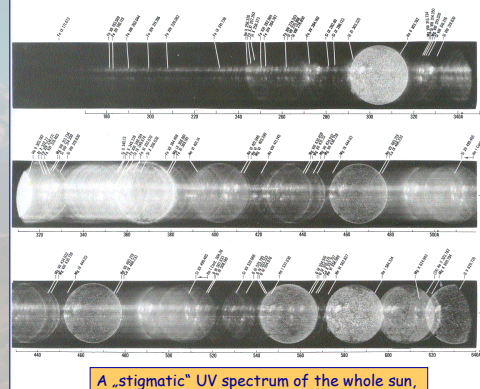
Eclipse and LASCO-C2 coronagraph images processed and merged by Serge Koutchmy

Temperatures in the solar atmosphere

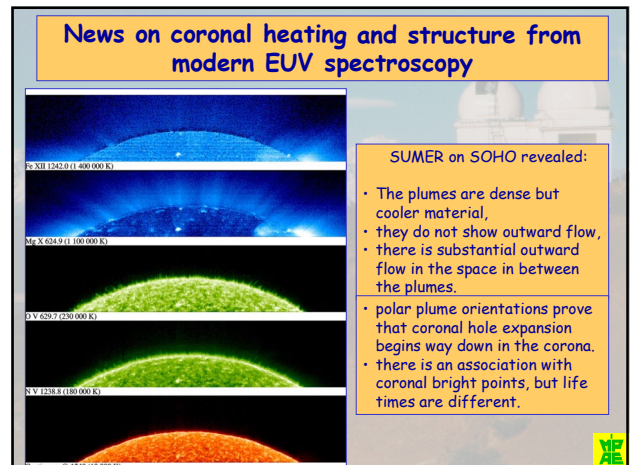
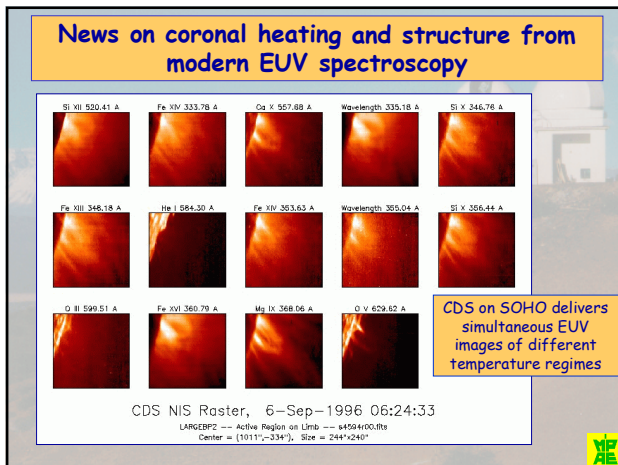
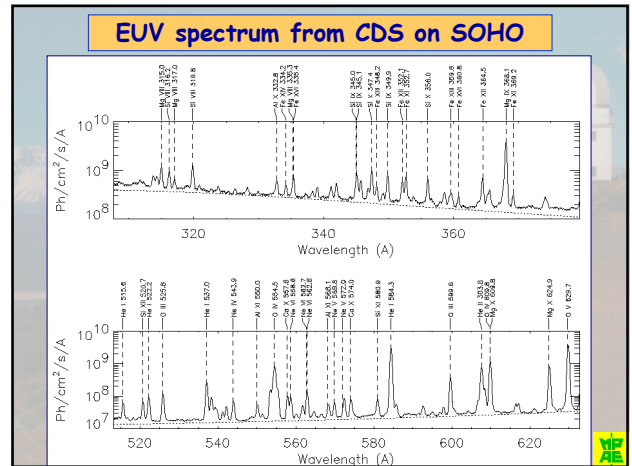
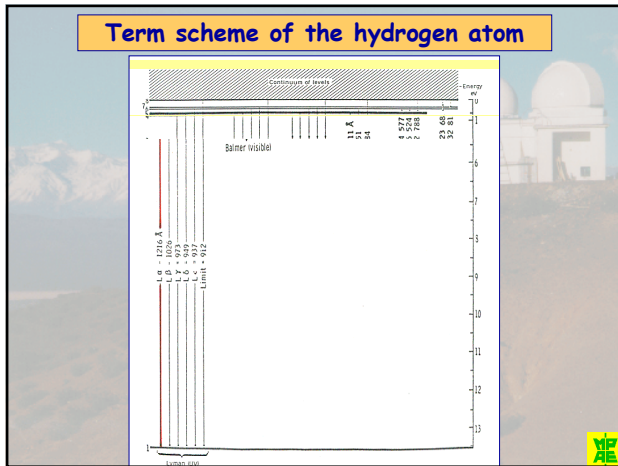
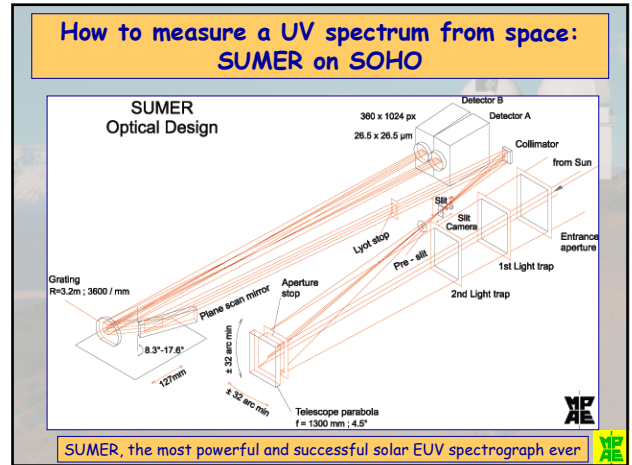
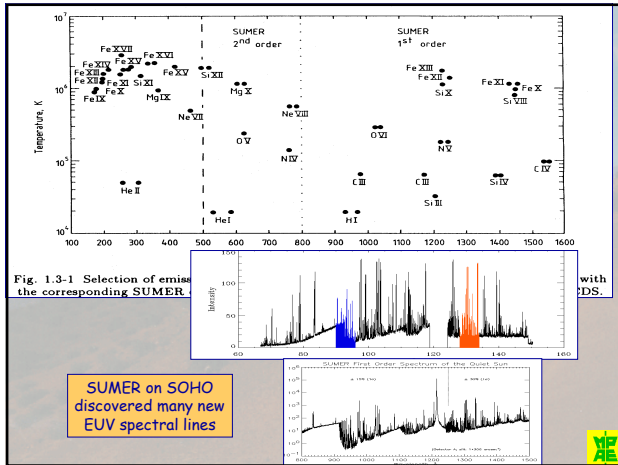


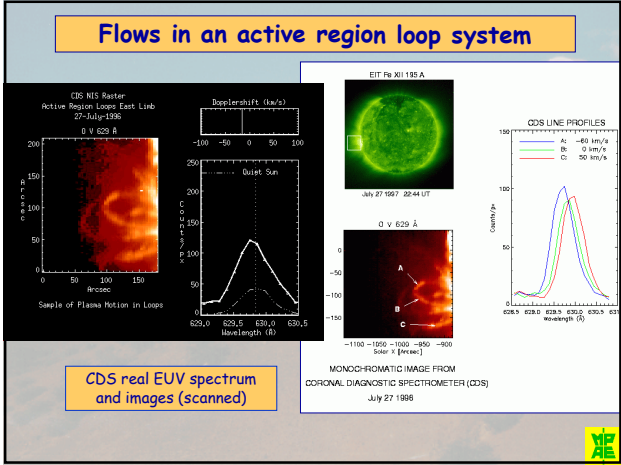
Solar images taken in the light of a certain emission line give a density map at the equivalent temperature

ATM/SKYLAB EXP 5082A SPECTROHELIOGRAPH



A „stigmatic“ UV spectrum of the whole sun, taken with a slitless spectrograph





The solar corona: four different types

Note: all coronal radiation is optically thin!

1. The K-corona (kontinuierliches Spektrum):

- White light from the photosphere, scattered on free electrons in the ionized corona (*Thompson-scattering*), i.e. a continuous spectrum like the photospheric spectrum, but
- no Fraunhofer absorption lines, because of high electron temperature in the corona causing *Doppler smear-out*,
- the intensity is proportional to the electron density, summed up along the line of sight,
- the light is strongly polarized, parallel to solar limb,
- visible from ground only during eclipses or using *coronagraphs* from very high mountains at extremely clear skies.

The solar corona: four different types

2. The F-corona (Fraunhofer corona)

- White light from the photosphere, scattered on dust particles (*Rayleigh-scattering*), i.e. a continuous spectrum like the photospheric spectrum, including Fraunhofer lines,
- very low degree of polarization,
- other name: *Zodiacal light*, visible by eye in dawn or dusk at favorable conditions.
- Note: The Fraunhofer line characteristics can be used for differentiating the two corona types!

3. The E-corona (emission line corona)

- Line emission from various atoms and ions in the corona,
- strongest line in visible spectral range: 530.3 nm of FeXIV ions (the *green line*), apart from H-alpha line at 656.3 nm of cold neutral hydrogen atoms (chromosphere),
- strongest line in UV: Lyman-alpha at 121.6 nm from neutral hydrogen atoms,
- very many lines in UV and EUV spectral ranges,
- strong radial gradients,
- many *forbidden lines*, therefore various polarization states,
- visible using spectrographs during eclipses, or coronagraphs.

4. The T-corona (thermal corona), barely visible

- Thermal radiation of heated dust particles,
- continuous infrared spectrum, according to temperature and color of dust particles,

How to heat the corona?

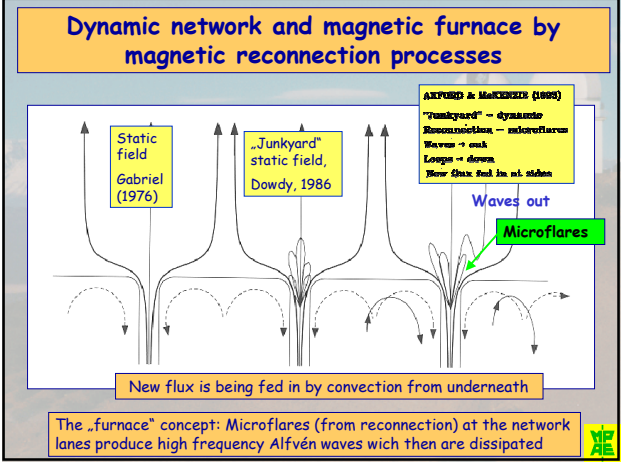
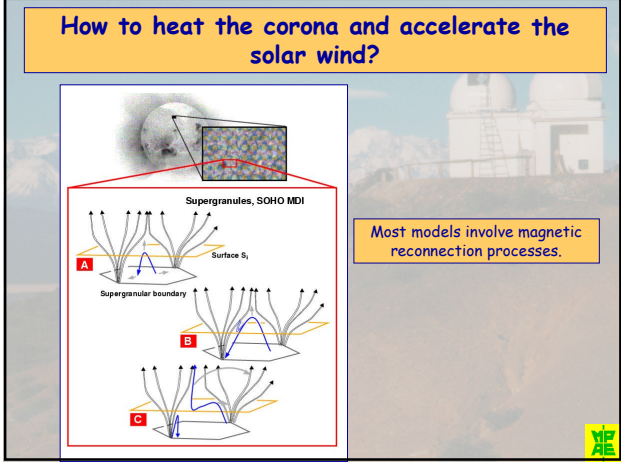
Types of waves potentially involved

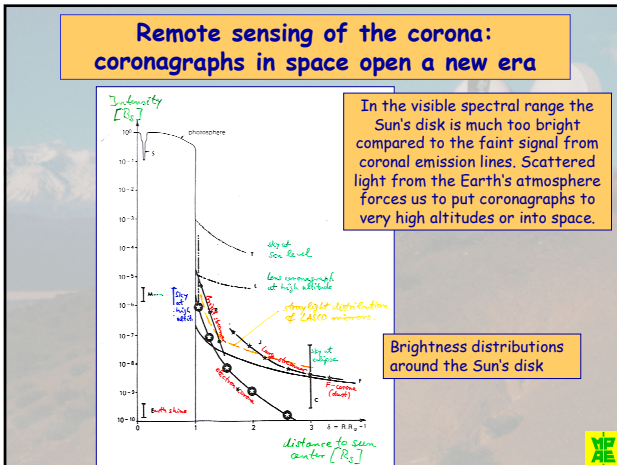
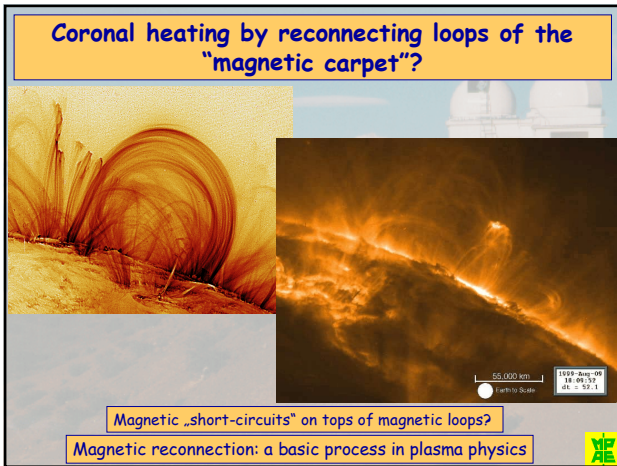
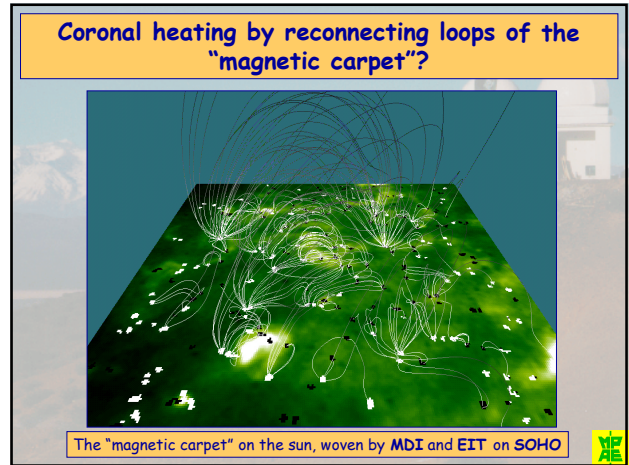
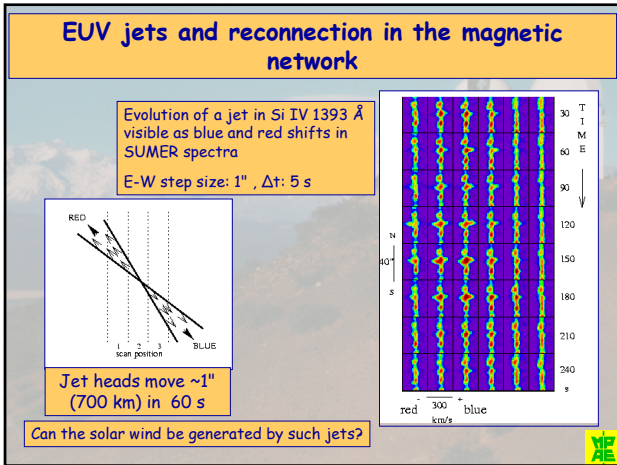
- sound waves, shock waves,
- fast and slow magneto-acoustic (MHD) waves,
- Alfvén waves,
- surface waves,
- torsional Alfvén waves,
- turbulence,
- plasma waves

Potential mechanisms leading to coronal heating

- wave dissipation,
- resonance absorption of waves (e.g., ion cyclotron resonance),
- current sheets and their dissipation,
- Ohmic heating by field-aligned currents,
- micro- and nanoflares,
- heating by spicules,
- magnetic reconnection,
- heating by microturbulence (electrostatic waves),
- heating by MHD turbulence (magnetic helicity).

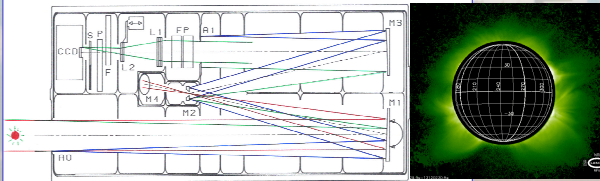
Note: The coronal magnetic field plays the crucial role!





Remote sensing of the corona: coronagraphs in space open a new era

LASCO-C1/MICA coronagraph scheme



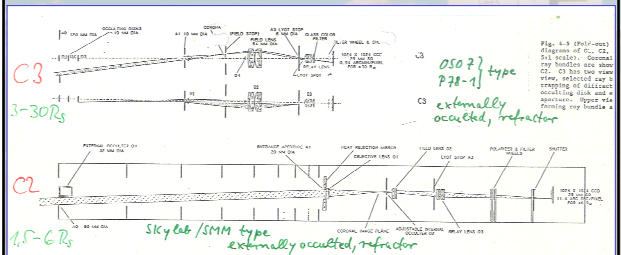
Occulting disk: 1.1 kg 3 DL, 200mm diam
 COC Kamera: 1024 x 1024 Pixel
 Max. Auflösung: 8.5µm
 Spektralbereich: 589.8 nm, 589.4 nm, 507.4 nm, 505.8 nm, Weißlicht
 Spektrale Auflösung: 0.8 Å
 Streulicht bei 2 R_s: unter 10⁻⁷

— Korona, Eklip
 — L1-L3 für Sonnenstrahl
 — Streulicht von Ap.

Internal occulter system avoids vignetting of inner corona and allows very high spatial resolution, but it has high instrumental straylight levels.

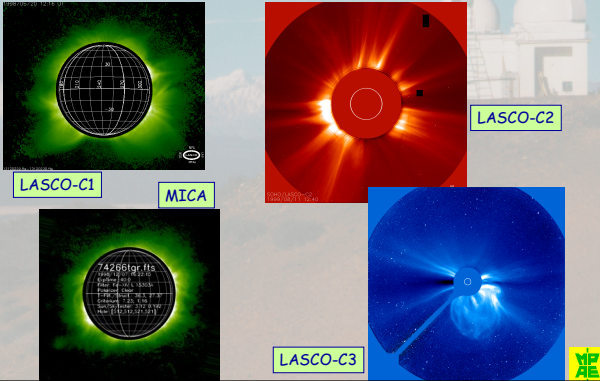
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LASCO-C2/C3 coronagraph scheme

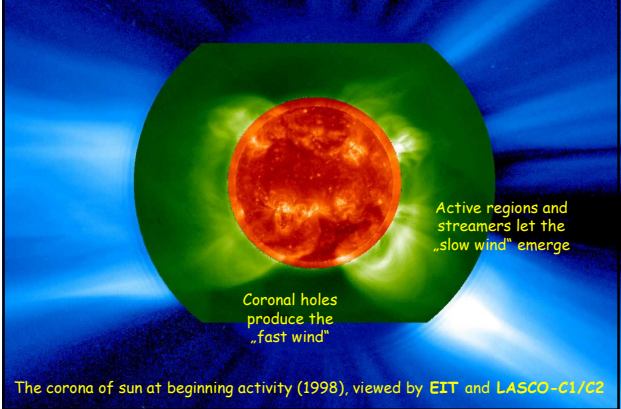


External occulter system is perfect to view the very outer corona, but near the inner edge it suffers from vignetting and allows no more resonable spatial resolution

Remote sensing of the corona: coronagraphs in space open a new era



The two states of corona and solar wind



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