

Solar Research with ALMA

Miroslav Barta
Marian Karlicky
Bartosz Dabrowski



EUROPEAN ARC
ALMA Regional Centre || Czech

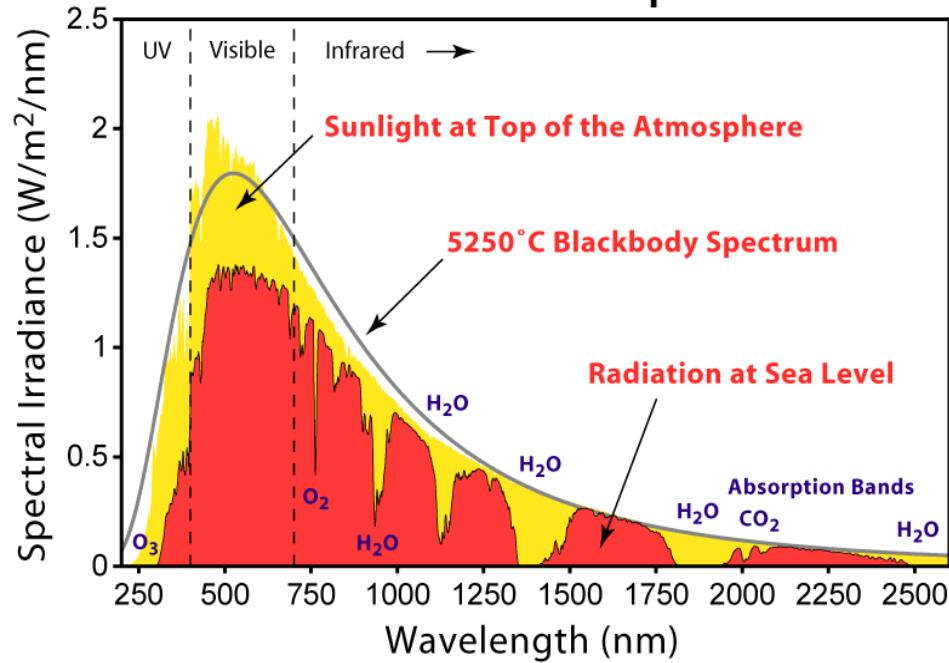
Why this talk?

- ✗ Solar research with ALMA is definitely minority subject among entire ALMA science: According to Design Reference Science Plan (DRSP) only ~20 hours will be devoted to the solar observations in next three years.
- ✓ However, the community of solar physicist has high expectations: Many key open questions of solar research might be answered with ALMA observations
- ✓ The Czech node of EU ARC devotes considerable effort to promoting ALMA in solar community and the solar research with ALMA belongs to its highlighted activities.

Sun as radio source

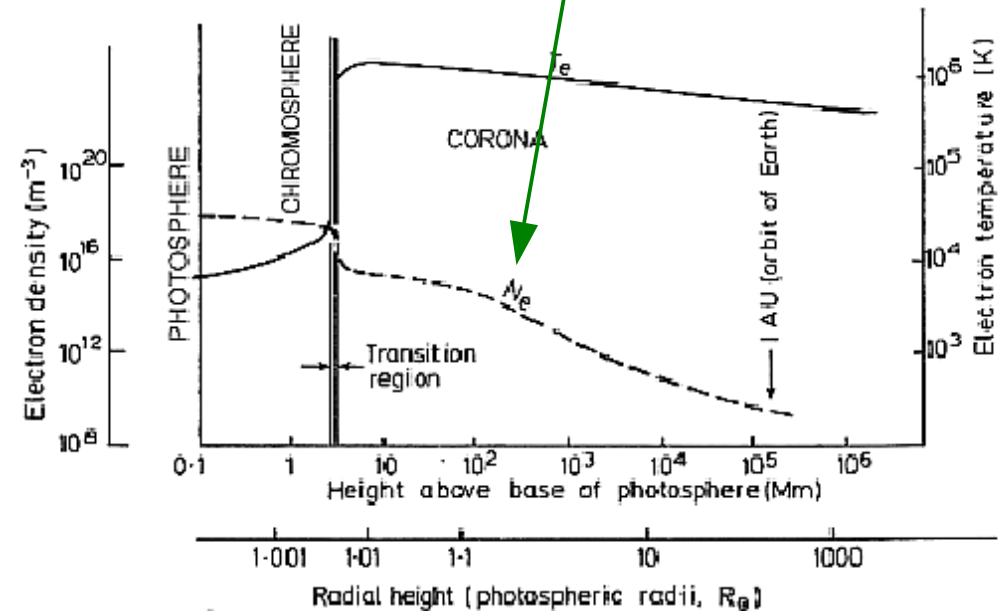
... in fact one of the oldest known

Solar Radiation Spectrum

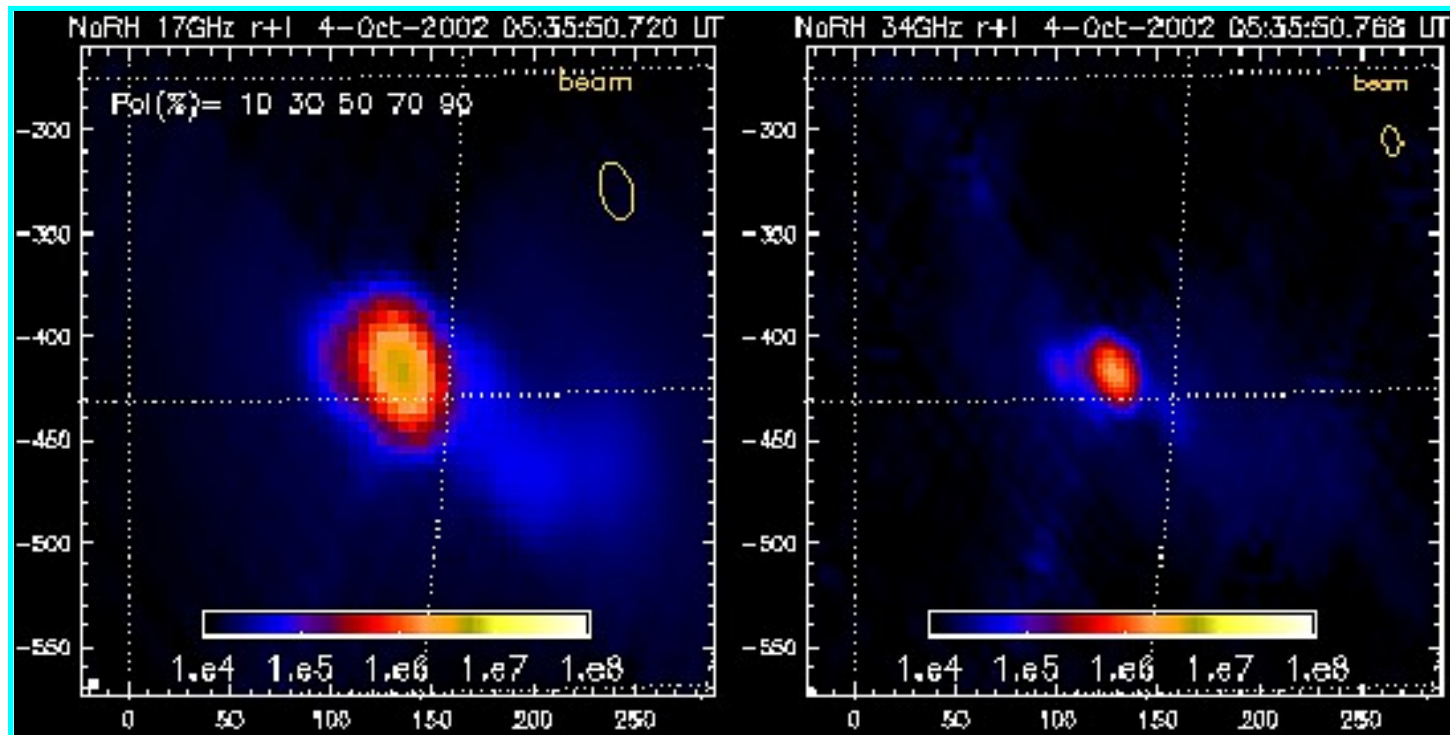
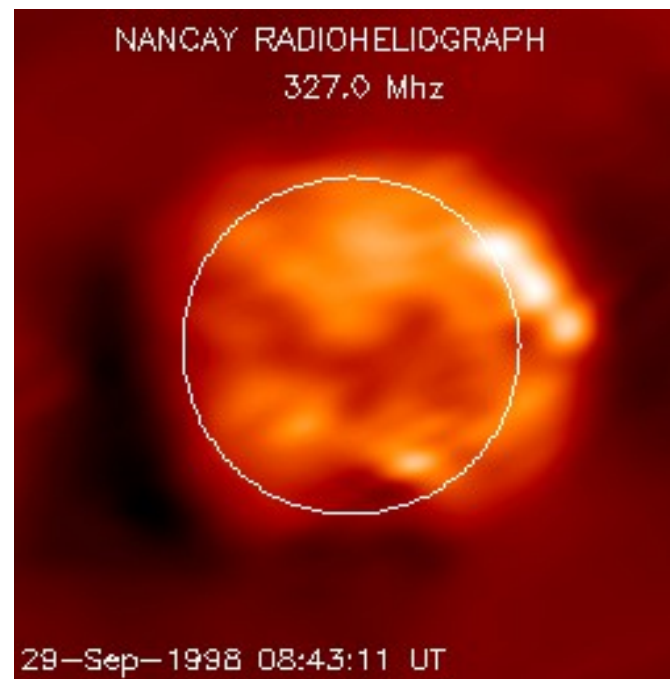


$$\omega^2 = \omega_p^2 + k^2 c^2$$

$$\omega_p = \sqrt{\frac{nq^2}{m\epsilon_0}}$$



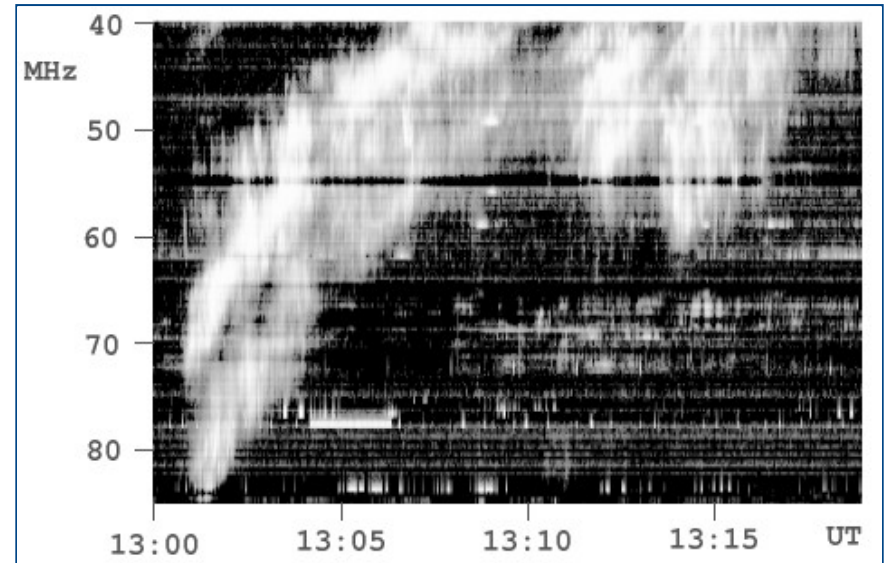
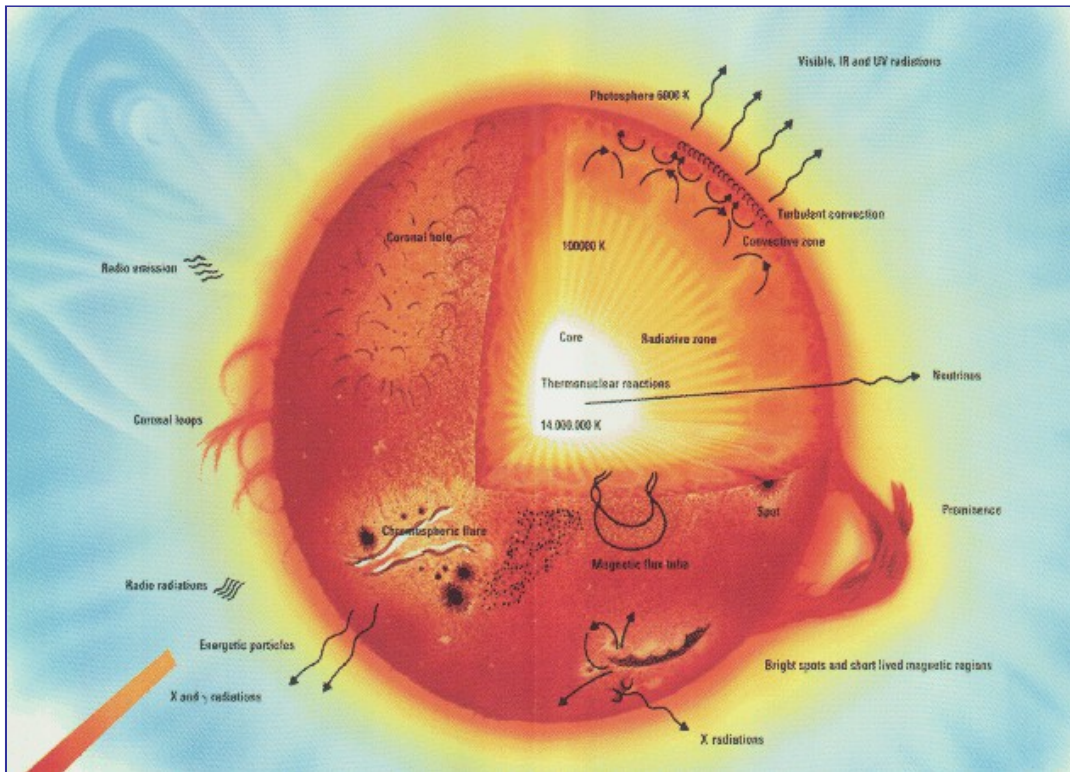
Sun as radio source



Sun as radio source

Radio emission is highly variable - we recognise three components:

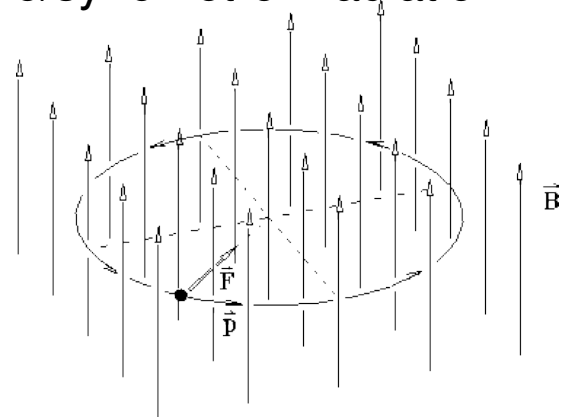
- Quiet-Sun radiation
- Slowly varying component
- Radio bursts



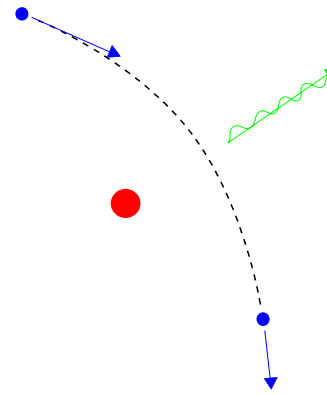
Radio emission mechanisms

■ Bremsstrahlung (thermal emission)

■ Gyro/synchrotron radiation



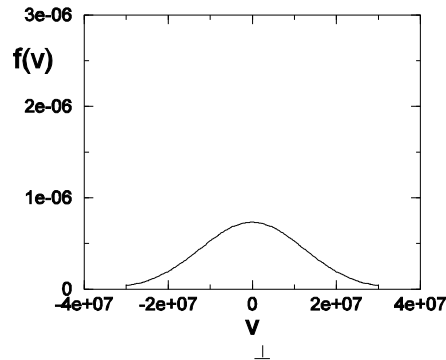
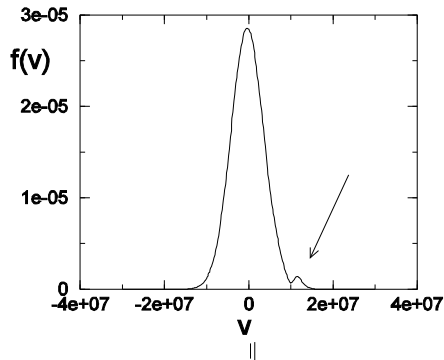
$$\omega_c = \frac{qB}{m}$$



■ Plasma emission process

a)

b)

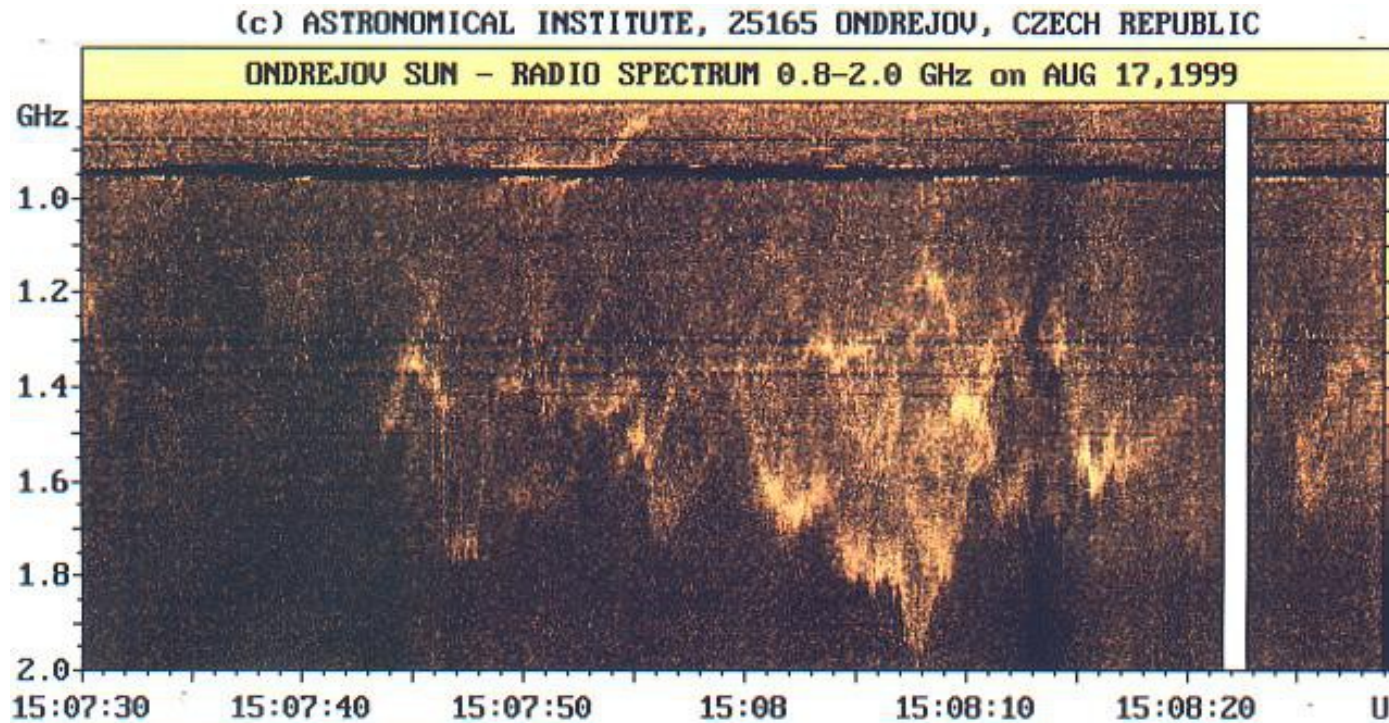


1. Generation of various plasma modes
2. Conversion to radio waves

Radio emission mechanisms

- Resonant processes (similar to plasma emission)

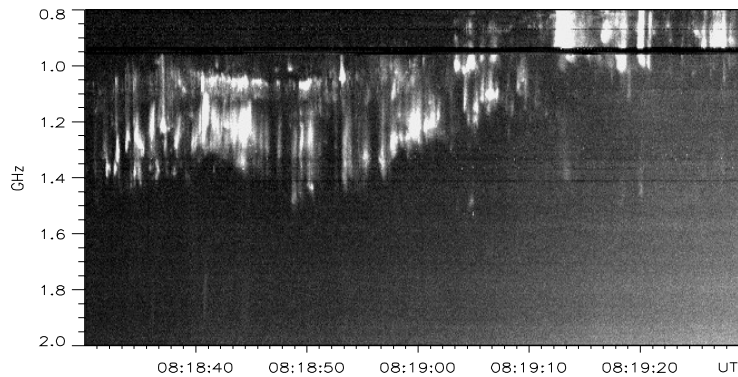
$$s\omega_c = \sqrt{\omega_p^2 + \omega_c^2}$$



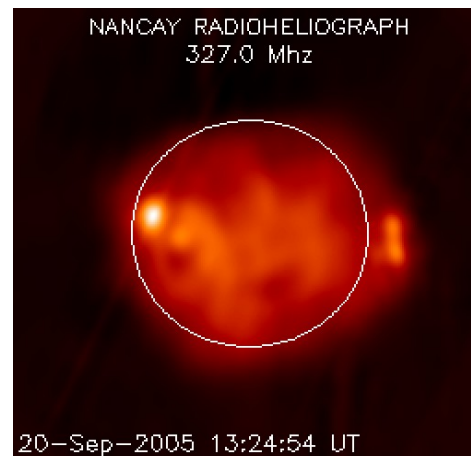
- Recombination lines
- Transition radiation
- + some undiscovered / not yet considered...

Solar radio observation so far

- Dynamic radio spectroscopy:
ranging from kHz (in-situ measurements in solar wind) to ~10GHz
+ a few single-frequency channels up to THz range, **no spatial resolution.**



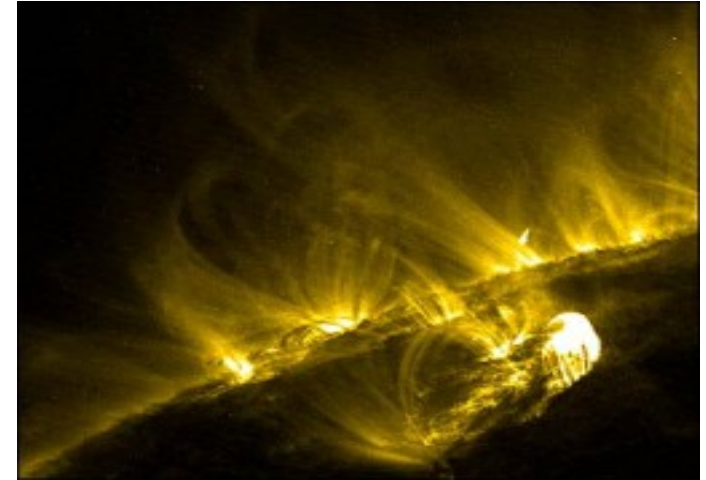
- Radio imaging:
At a few channels, **no spectral information** available



What open key questions might be answered with ALMA?

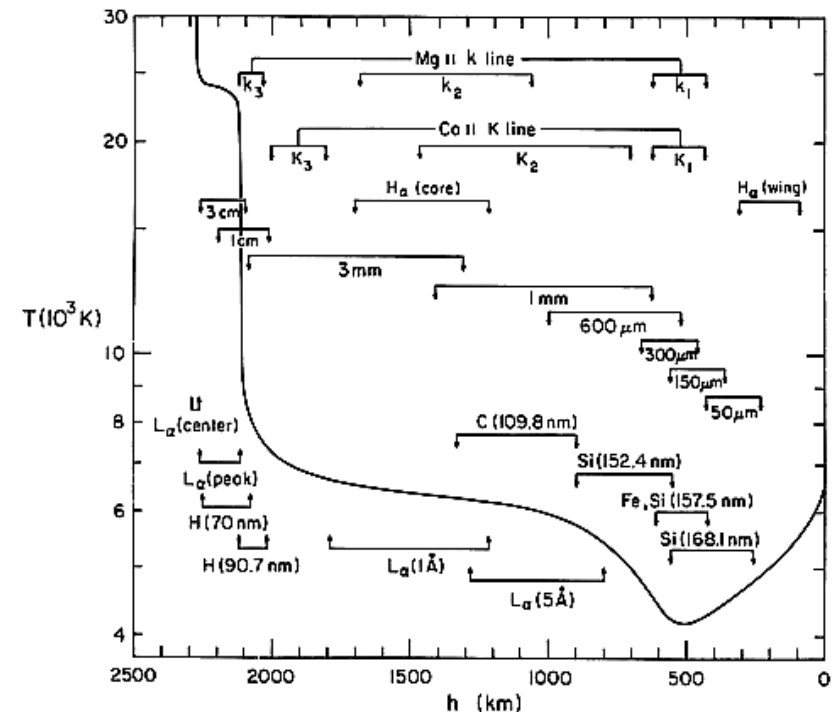
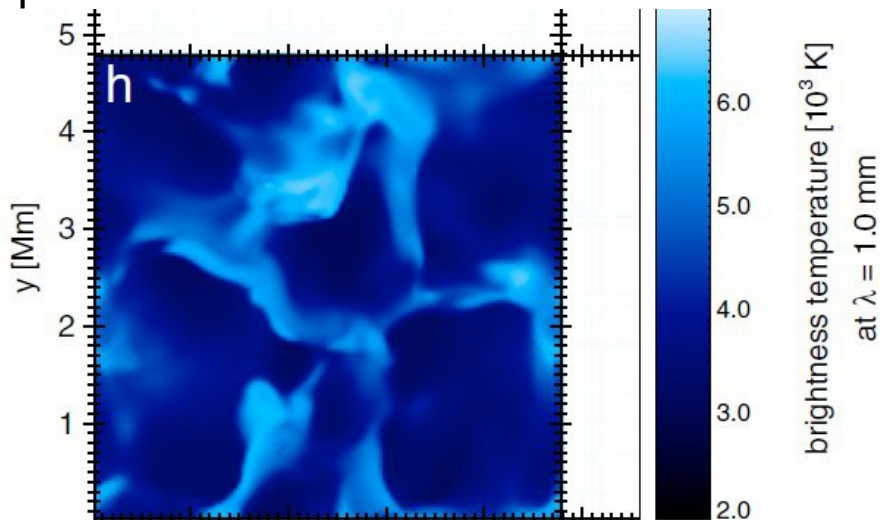
■ Particle acceleration in solar flares

Ultra energetic electrons can produce synchrotron radiation in mm range. With ALMA we would reach unprecedented spatial imaging of energetic particles.



■ Structure and dynamics of solar chromosphere

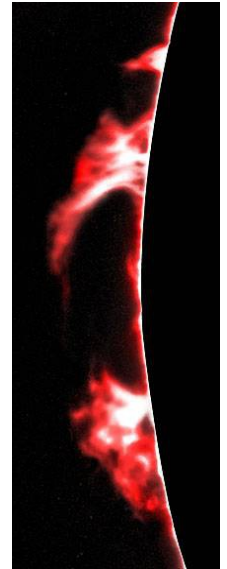
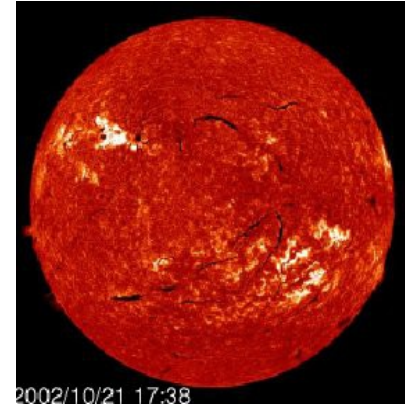
Temperature structure remains unclear. What is the role and nature of oscillations and waves? Thermal emission in ALMA range can provide an answer.



What open key questions might be answered with ALMA?

■ Structure of solar prominences

Internal structure of prominences and filaments remain unclear. ALMA can look through with very high resolution.



■ Study of recombination lines in solar atmosphere

It still unclear whether these can be observed in the mm wavelength range. If yes, an important diagnostic tool for measurement of magnetic field in the part of the solar atmosphere where it is otherwise difficult would emerge.

■ Probably many more open issues...

Solar community should look. Numerical modelling combined with CASA simulation tool can represent a way how to find out.

Specifics of solar observations (and related issues)

■ The Sun is very bright radio source

- + Good S/N can be reached with very short observing times
- ALMA is sensitive, do we need attenuation?
- How does it compare to relatively much weaker calibrators?

■ The Sun is very VARIABLE source

- + ALMA sensitivity and Sun's brightness enable study of dynamics at short timescales
- How to cope with unpredictable but extremely interesting transient events?
- Current version of AOT seem not to support 'movie' regime

■ The Sun rotates – even differentially

- Need for ephemeris/coordinate transform calculations.

References

Solar research with ALMA

Karlicky, M. et al. (2011): Solar Physics 268, pp. 165-173
<http://adsabs.harvard.edu/abs/2011SoPh..268..165K>

Science with ALMA

<http://www.eso.org/projects/alma/science/alma-science.pdf>

ALMA Science portal

<http://almascience.eso.org/alma-science/completed-alma>

ALMA Design Reference Science Plan

<http://www.eso.org/sci/facilities/alma/documents/drsp.html>