

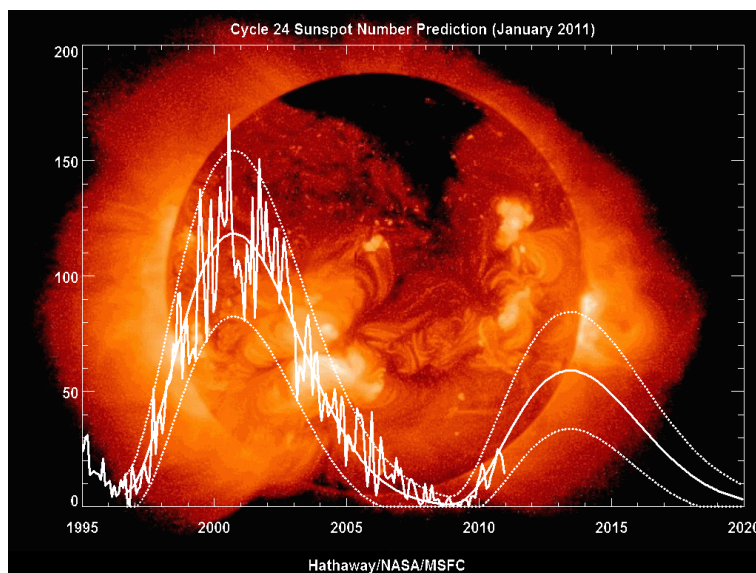
XFYS4280 Solar structure and activity

Silja Pohjolainen

Lecture Notes

Version 2.1.2

Updated Spring 2011



Course website:

<http://users.utu.fi/silpoh/xfys4280.html>

Contents

1	History of Solar Research	4
2	Solar and Stellar Structure	12
2.1	The Sun as a star	12
2.2	Energy production	14
2.3	Neutrino problem	16
2.4	Sun-like stars	17
2.5	Helioseismology	24
2.6	Solar magnetic fields	29
2.7	Hale's and Joy's laws	36
2.8	Differential rotation	37
2.9	Solar atmosphere	40
2.10	Plasma diagnostics	42
2.11	Atmospheric densities	43
2.12	Magnetic field strengths	45
3	Emission mechanisms	47
3.1	Radiation of atoms and molecules	47
3.2	Bremsstrahlung (free-free continuum emission)	52
3.3	Gyroemission	56
3.3.1	Gyrosynchrotron emission: mildly relativistic electrons	57
3.3.2	Gyrosynchrotron emission: thermal electrons	58
3.3.3	Synchrotron emission: ultrarelativistic electrons	58
3.3.4	How to distinguish between bremsstrahlung and gyrosynchrotron emission?	61
3.4	Masers	61
3.5	Absorption effects	63
3.6	Plasma emission	67
4	Radio astronomy fundamentals	71

4.1	Radio telescopes	72
4.2	Interferometers	76
4.3	Brightness temperature and flux density	78
4.4	Radiative transfer equations	83
4.5	Radio observations	86
4.5.1	Single dish antennas	87
4.5.2	Non-traditional antennas	91
4.5.3	Observed polarization	92
4.5.4	Multi-beam receivers in single dishes	94
4.5.5	Interferometers	95
4.5.6	Radio spectrometers	99
4.5.7	Solar eclipse observations using Fresnel diffraction	101
4.5.8	Burst classifications	105
5	Optical, EUV, and X-ray observations	107
5.1	Satellite orbits	107
5.2	X-ray and EUV instruments	109
5.3	Ground-based optical telescopes	119
6	Software and data archives	123
7	Shock waves in the solar corona	127
7.1	Moreton waves and EIT waves	127
7.2	Radio type II bursts	132
7.3	Solar energetic particles	137
8	Solar flares	139
8.1	Basic concepts	139
8.2	Flare models	145
8.3	Predictions for activity	150
8.4	Reconnection models	158
8.5	Accelerated particles	165
9	Coronal mass ejections	169
9.1	Basic concepts and observational constraints	169
9.2	Dimmings	176
9.3	CMEs, filaments, type IIs, and flares - all connected?	178

10 Small and large scale solar features	187
10.1 Coronal holes	187
10.2 Radio-bright coronal holes	189
10.3 Bright points	192
10.4 Plumes	194
10.5 Spicules	197
10.6 Photospheric network	197
10.7 Solar wind	199
10.8 Solar oscillations	201
10.9 Atmospheric models and coronal heating	203
11 Solar Physics in the Future	207
11.1 Instrumentation	207
11.2 Unsolved problems in solar physics	207
11.3 Solar activity	208
References and further reading	208