4.1.2.6 Coronal active regions

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The active corona is characterized by magnetic loop structures of various sizes and temperatures [c, d, b, 96Low, 00Cha, f, 05Asc], (see also Fig. 2 of Sect. 4.1.2.1).

Many active-region loops have much higher electron densities than expected from theoretical considerations – they are called "overdense" loops [99Len, 01Asc, 03War1, 03War2]. The most active parts of the corona are magnetically connected to active regions (AR) on the Sun (cf., Sect. 4.1.2.1). The photospheric and coronal response to magnetic field emergence of twisted flux tubes was investigated by [06Mag]. Whenever an AR produces a flare (see Sect. 4.1.2.7) and/or a coronal mass ejection (Sect. 4.1.2.5.6) the active corona is severely affected and, in all likelihood, plays an active role as well. A flux rope formation in the outer corona was observed by [06Wan].

The coronal temperature above an AR was studied by [97Ste2], who found a steady plasma component with $T_e \approx 3$ MK, and a hotter, transient one caused by microflares. Relatively cool AR loops with a temperature near 1 MK in a hotter, diffuse environment were observed by [03Del]. The large-scale temperature structure of the corona for quiet and active conditions was investigated by [02Wil, 07Ben].

With increasing solar activity, equatorial coronal holes (CH) appear, which, in some cases, are still connected to the disintegrating polar CHs of the solar minimum corona. Reconnection events, as evidenced by enhanced magnetic activity at the CH boundaries, probably produce the required reconfiguration [04Mad]. At the same time, the solar X-ray and extreme-ultraviolet emissions increase substantially [97Har]. In general, the plasma parameters of equatorial CHs are not very much different from those of polar CHs [99Dob, 99Chi, 01Mir]. Both types are expanding super-radially.

Spectra of the active (and quiet) corona are presented by [96Bro, 07Bro]. X-ray observations of microflare activity in an AR rotating from the front side to the rear side of the Sun showed that the emission was restricted to low heights [97Ste1].

Coronal plasma flows and the magnetic field topology of ARs were studied by [04Mar]. Inter-connections between remote ARs are discussed by [03Sve]. Synchronous microwave brightenings of ARs more than 1 $R_\odot$ apart confirm the existence of such large-scale inter-connecting loops [04Gol]. The smallest coronal loops yet detected occur in coronal bright points (BP) treated in Sect. 4.1.1.5.2.4. The size distribution of X-ray emitting regions indicated that magnetic structures of all dimensions were present down to the instrumental resolution limit of ≈ 500 km [93Gom1, 93Gom2].

Heating of the active X-ray emitting corona is thought to be accomplished by the dissipation of many tangential discontinuities in the entangled magnetic field of the solar atmosphere. The related events have been called "nanoflares" by [88Par]. However, more work is required before a final answer can be given. Observations of the corona with the help of recent space missions have been reviewed by [a].

4.1.2.6.1 Coronal oscillations and waves

Magneto-acoustic oscillations had been expected in coronal inhomogeneities, for instance, in coronal loops [84Rob]. The idea of coronal seismology was that the physical conditions of the corona could be studied by investigating these oscillations. Transverse coronal-loop oscillations were later detected by [99Asc, 02Asc, 03Asc] and interpreted as global kink-mode oscillations with periods of ≈ 280 s, excited by strong flares, but occasionally also by filament eruptions [02Sch]. An estimate of the magnetic field strength in an oscillating loop is ≈ 1.3 mT [01Nak].

Studies of active-region loop oscillations indicated that certain periods are favoured for different emission lines [01She]. However, the 5 min period oscillations of the photosphere are in general present in all lines. Velocity oscillations are more prominent than radiance oscillations in coronal

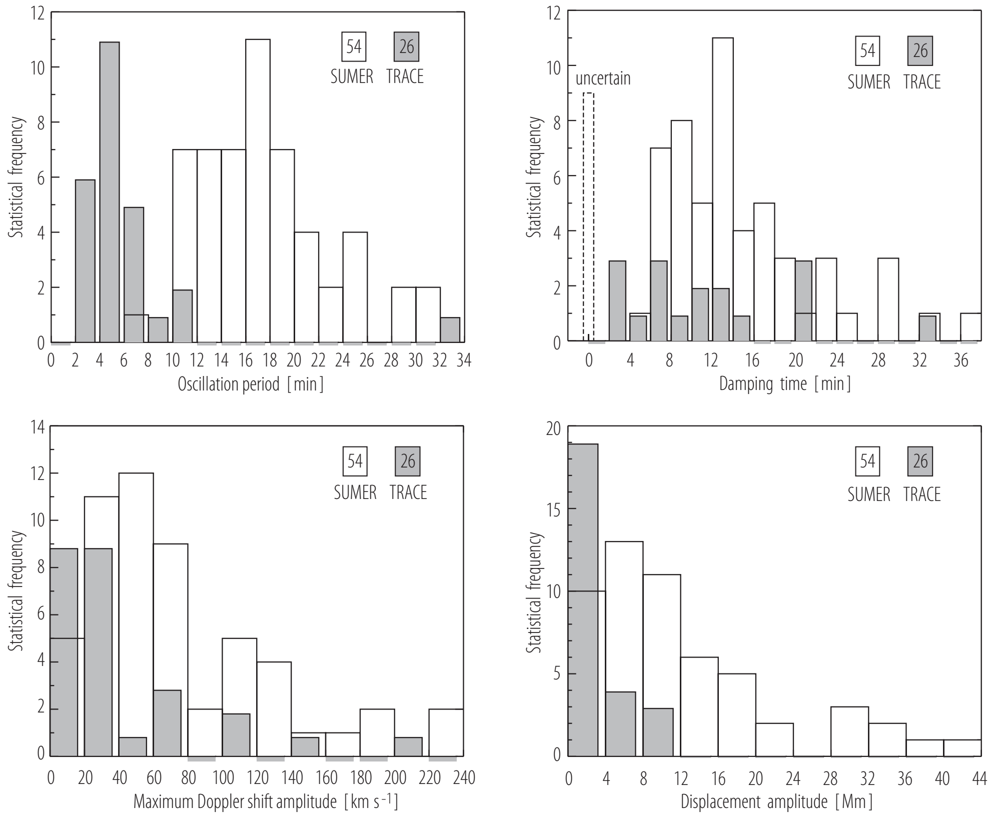

Fig. 1. Comparison of SUMER and TRACE loop-oscillation parameters. The TRACE oscillations (26 cases) have much shorter periods and smaller displacement amplitudes than the SUMER oscillations (54 cases) (from [04Wan1]).

lines, in contrast to transition-region lines. Consequently. non-compressive modes, which do not affect the radiance, appear to be generated in the corona and not in the transition region.

Slow magneto-acoustic disturbances propagating with speeds of roughly 100 km s^{-1} have been observed in active-region loops [01Rob]. LOS velocities of ± 150 km s^{-1} were found in C II and Fe XXI lines during an M3 flare with damped velocity oscillations with periods from 4 min to 8 min [02Kli, 02Wan, 03Wan, 02Ofm]. A phase shift of 90° prevailed between the radiance and velocity oscillations, consistent with the signature of standing slow-mode waves in hot loops. Vertical oscillations of coronal loops could be observed by TRACE in its 19.5 nm channel [04Wan2].

Observations and interpretations of coronal loops oscillations have been reviewed by [04Wan1], who compared the physical parameters of the oscillations observed by SUMER[1] and TRACE. The results are summarized in Fig. 1. Coronal magnetic field determinations from loop oscillations have also been performed by [07Wan].

Initiated by flares, large-scale coronal transients were propagating at a speed of ≈ 250 km s^{-1} across the solar disk [99Tho]. Later studies, cf. [05Che] indicated that the waves are all associated with Coronal Mass Ejections (CME; see Sect. 4.1.2.5.3), but have different characteristics. Active regions or coronal holes seem to inhibit the wave propagation.

Reviews of coronal oscillations and the related coronal seismology can be found in [e, 03Nak].

[1]Solar Ultraviolet Measurements of Emitted Radiation instrument [95Wil] on the SOlar and Heliospheric Observatory (SOHO).

4.1.2.6.2 References for 4.1.2.6

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