Abstract

The Sun shows a variety of transient surface features which are summarized as solar activity. Activity phenomena, apparently similar to the solar case, are also observed on stars other than the Sun. Stellar activity is closely related to magneto-hydrodynamic processes in a star's convection zone. A dynamo is believed to operate in the outer convection zone of solar-like stars, generating magnetic fields by complex motions of the convecting plasma under the influence of rotation. Differential (i.e. non-rigid) rotation of the stellar surface is an important indicator of the overall dynamics of a star's outer convection zone.

Sunspots are a conspicuous token of solar activity; dark spots can also be observed on the surface of stars other than the Sun. To which degree "starspots" are analogues of sunspots is presently only poorly known; the processes governing their lifetime and structure are largely unexplored.

Doppler imaging overcomes the diffraction-limitations of direct and interferometric imaging techniques by making use of information that is modulated into a star's spectrum due to its rotation. Doppler imaging is currently the only method to produce well-resolved images of solar-like stars.

After a selective review of the observational and theoretical foundation, the first part of this thesis describes a method for Doppler imaging called CLDI (CLEAN-like Doppler imaging). CLDI has been developed during this thesis, continuing the work of Kürster (1991). CLDI has been adapted to reconstructions at high surface resolution; its performance has been improved, as verified by extensive tests. Unlike maximum entropy Doppler imaging methods, CLDI is not an explicit optimization procedure; the resulting fundamental limitations of CLDI have been systematically studied. Due to the partial independence of CLDI's approach from other Doppler imaging methods, it is proposed as a means of checking the reliability of Doppler images reconstructed by other methods.

The second part presents the method sLSD (selective least-squares deconvolution), developed for the deconvolution of spectra of fast rotating stars; it is based on the method LSD introduced by Donati et al. (1997b). As an improvement compared to LSD, sLSD is well-suited for operating on relatively narrow wavelength ranges, allowing to account for individual characteristics of the deconvolved spectral lines. An important feature of sLSD is a Tikhonov-regularization which enables it to work on narrow spectral ranges. The consistency of the line profile extraction by sLSD has been verified by applying it to different spectral ranges and template spectra.

The third part of this thesis describes results concerning the ultrafast rotating, highly active, pre-main-sequence "solar-like" star "Speedy Mic" (= HD197890, K2 V, $P_{\rm rot} = 0.380$ days). CLDI was applied to a densely phase sampled spectral time series of homogeneous quality covering two complete rotations of Speedy Mic. These spectra have been observed as a part of this thesis using the spectrograph UVES mounted on the "Very Large Telescope" (VLT). The reconstructed Doppler images were verified to have a resolution of about ten degrees on the stellar surface by systematically comparing reconstructions based on different wavelength regions and data subsets. In contrast to many ultrafast rotating K-dwarf stars, the Doppler images of Speedy Mic do not show a polar spot.

The Doppler images of Speedy Mic show that many features of the spot pattern have been stable on large, intermediate and even small scales during the about thirteen rotations between them. However, a few spot reconfigurations have taken place on scales up to about 30° in stellar longitude and latitude.

These reconfigurations lead to an aperiodic behaviour of the lightcurve which has been confirmed by V-band photometry observed between the two Doppler images. An analysis of all photometric time series available for Speedy Mic was performed; its results indicate that Speedy Mic shows epochs of stable spot patterns for weeks as well as epochs of significant spot reconfigurations during a few days.

The differential rotation deduced from a cross-correlation of the Doppler images is weak compared to the Sun ($|\alpha| = \Delta\Omega/\Omega < 0.004 \pm 0.002$), i.e. less than five hundredth of the solar value. Only the evolution of the largest reconstructed spot group can be interpreted as caused by anti-solar differential rotation of the given strength. In this context, anti-solar means that the pole rotates faster than the equator in terms of the angular velocity Ω; anti-solar differential rotation of solar-like stars is not ruled out by fundamental arguments, but it contradics current theoretical predictions.

A study of the time-dependant core emission of the Ca II K line has been carried out for Speedy Mic. It has yielded indications of localized regions of chromospheric activity; there appear to be both stable and transient chromospherically active regions on Speedy Mic. A further study on the basis of the available data is suggested to allow a precise localization of these regions.