

Center-to-Limb Variation of the Velocity Field in and around a Sunspot with Light-Bridges

Carsten Denker¹, Meetu Verma¹, Horst Balthasar¹, Andrea Diercke^{1,2}, Sergio J. González Manrique^{1,2}, Johannes Löhner-Böttcher³, Christoph Kuckein¹, and Michal Sobotka⁴

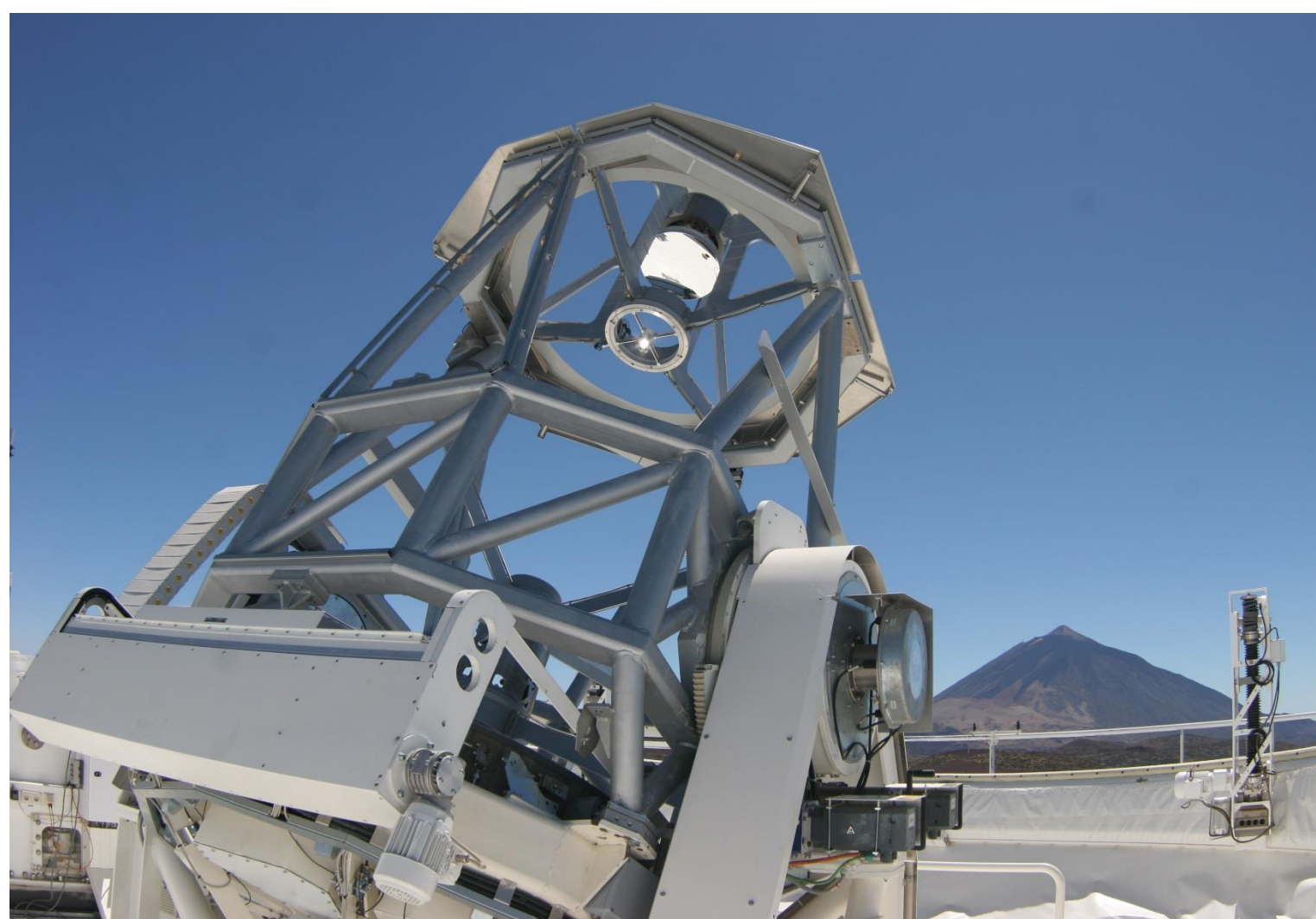
¹ Leibniz-Institut für Astrophysik Potsdam (AIP), Germany

² Universität Potsdam, Institut für Physik und Astronomie, Germany

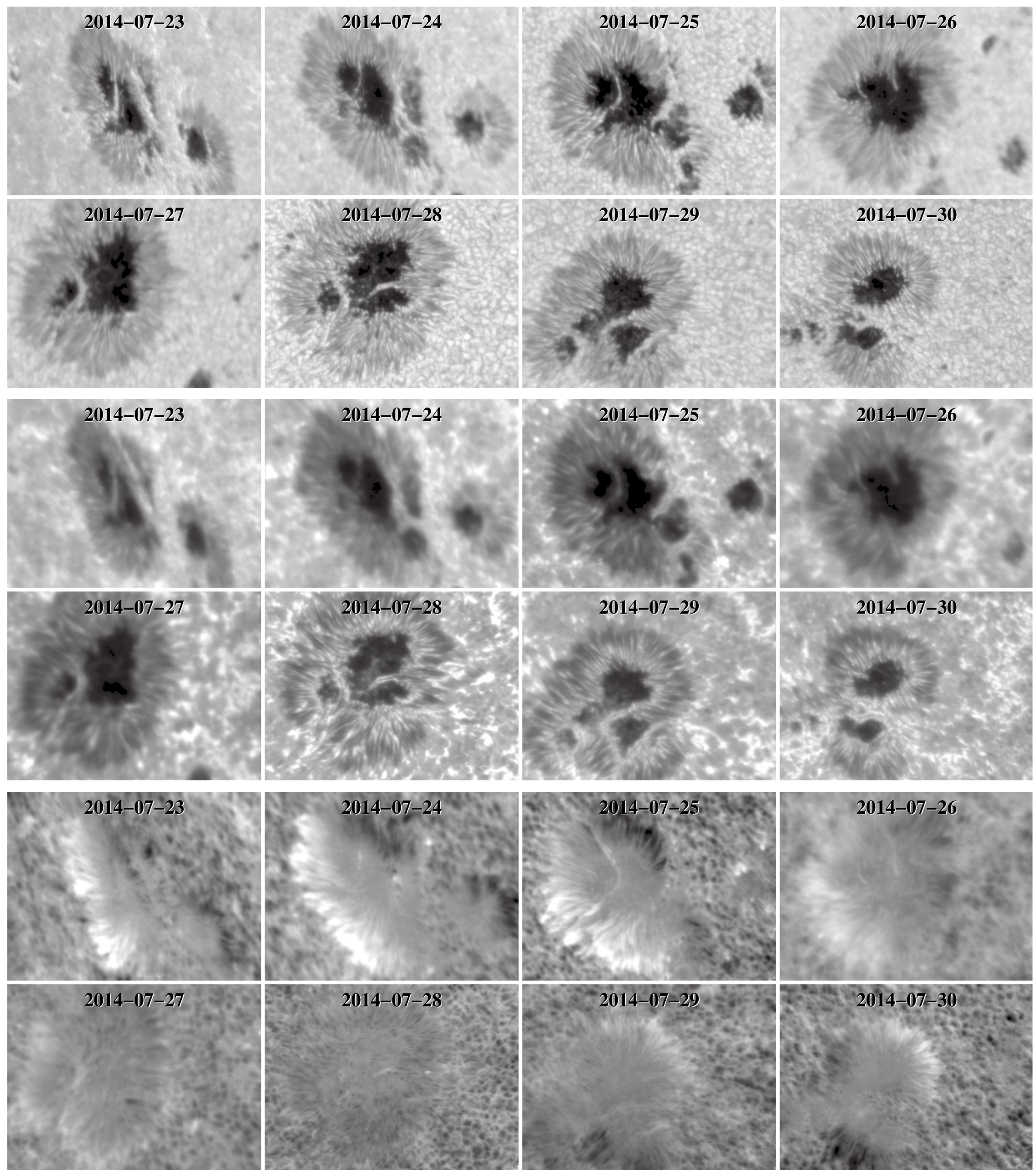
³ Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany

⁴ Astronomical Institute, Academy of Sciences of the Czech Republic, Ondřejov

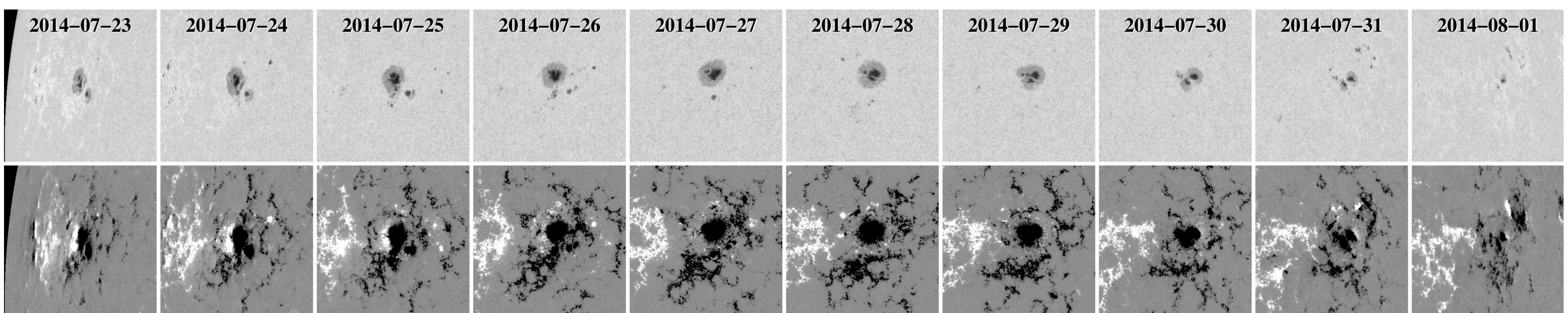
Abstract. The disk passage of active region NOAA 12121 was observed with the 1.5-meter GREGOR solar telescope (Schmidt *et al.* 2012, AN 333, 796) during the time period 2014 July 22–30. On 2014 July 25 and 28, the seeing conditions were excellent so that longer time-series (30–90 min) were recorded approaching the diffraction limit of the telescope. The seeing conditions on the other days were variable ranging from mediocre to very good so that only snap-shots of high-quality images and imaging spectroscopy were possible. On each day, data were acquired with the GREGOR Fabry-Pérot Interferometer (GFPI, Denker *et al.* 2010, Proc. SPIE 7735, 77356M; Puschmann *et al.* 2012, AN 333, 880), initially in the spectral line Fe I $\lambda 630.15$ nm and on the last two days in the spectral line Fe I $\lambda 617.34$ nm. Imaging spectroscopy based on spectral scans restored with Multi-Object Multi-Frame Blind Deconvolution (MOMFBD, van Noort *et al.* 2005, SoPh 228, 191) delivered high-resolution line-of-sight (LOS) velocity maps for a field-of-view (FOV) of $50'' \times 38''$. In addition, we present speckle reconstructed images obtained with a G-band filter ($\lambda 430.7$ nm) in the Blue Imaging Channel (BIC) of the GFPI. These images cover a FOV of $75'' \times 93''$ and were obtained with a cadence of about 30 s. These data serve as input for Local Correlation Tracking (LCT, November & Simon 1988, ApJ 333, 427; Verma & Denker 2011, A&A 529, A153) to investigate horizontal proper motions in and around the sunspots. The high-resolutions data are complemented by data from the Solar Dynamics Observatory (SDO, Pesnell *et al.* 2012, SoPh 275, 3) and Interface Region Imaging Spectrograph (IRIS, de Pontieu *et al.* 2014, SoPh 289, 2733). We study the evolution of the sunspots with an emphasis on growth and decay of individual sunspots, formation and dissolving of (rudimentary) penumbrae, and fine structure of light-bridges and umbral dots.



The 1.5-meter GREGOR solar telescope at Observatorio del Teide, Izaña, Tenerife, Spain. The telescope structure holds the primary, secondary, and tertiary mirrors, the prominently illuminated heat stop, and the polarization calibration unit. Pico del Teide is visible in the background next to the closing mechanism of the foldable-tent dome (courtesy J. Rendtel).



Maps of physical parameters derived from spectral scans with the GFPI using the Fe I lines at $\lambda 617.34$ nm and $\lambda 630.15$ nm. The spectral line scans were restored with MOMFBD. The temporal evolution of active region NOAA 12121 is shown for the broad-band images (top), the line core intensity maps (middle), and the line-of-sight-velocity maps derived with the center-of-gravity method. The velocities were scaled between ± 1.8 km s⁻¹, where black and white refers to up- and downflows, respectively. Image rotation introduced by the alt-azimuth mount of the GREGOR solar telescope was not corrected.



The disk passage of active region NOAA 12121 observed with SDO during the time period 2014 July 23 – August 1. The top row shows continuum images of the Helioseismic and Magnetic Imager (HMI, Scherrer *et al.* 2012, SoPh 275, 207) and the bottom row comprises line-of-sight magnetograms scaled between ± 250 G. The FOV is $200'' \times 200''$ in each panel and the time is always 08:30 UT.