Coronal multi-channel polarimeter at Lomnicky Peak Observatory

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Abstract: Coronal Multi-channel Polarimeter (CoMP-S), developed by HAO/NCAR, has been introduced to regular operation at Lomnicky Peak Observatory of the Astronomical Institute of SAS (Slovakia, 2633 m a.s.l.). We present here technical parameters of current version of the instrument and its potential for observations of the prominences in visible and near infrared spectral regions. First examples of results derived from observations of prominences in the H I 656 nm and Ca II 854 emission lines during a coordinated observing campaign of several instruments in October 2012 are presented. A planned upgrade of the instrument detectors for observations of the velocities and magnetic fields using near infrared emission lines is described as well.

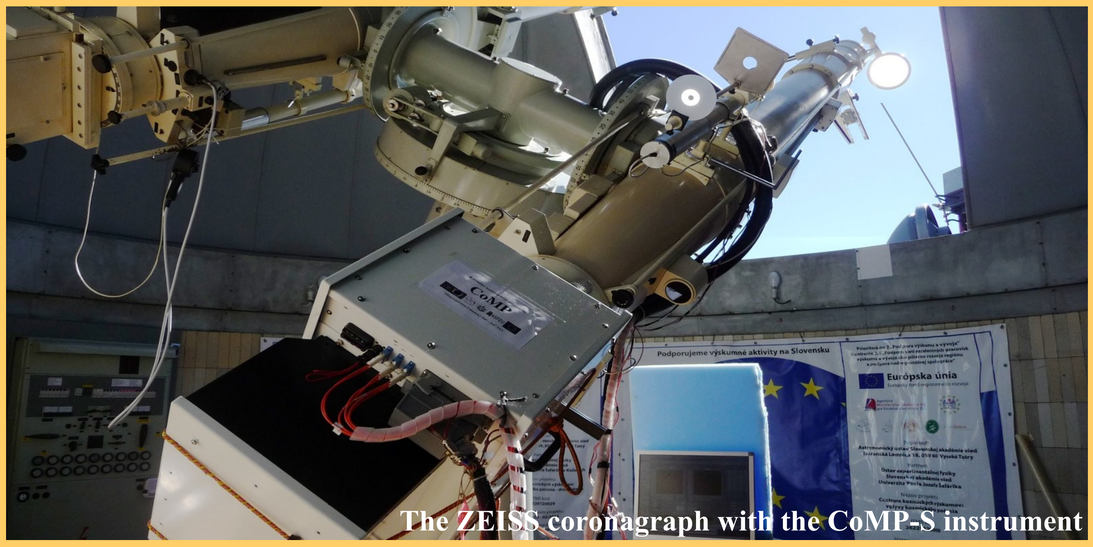
Observatory & coronagraph

Lomnicky Peak Observatory:

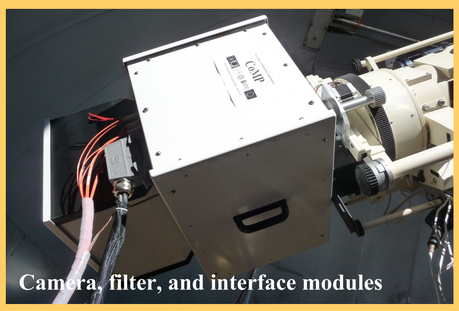
- observatory altitude 2633 m a.s.l.
- location: the High Tatras mountain range (boundary Slovakia/Poland) - 20°13' E, 49°11' N
- operated all year round, ~120 observing days per year in average
- access to the observatory exclusively by a cable car

Zeiss coronagraphs:

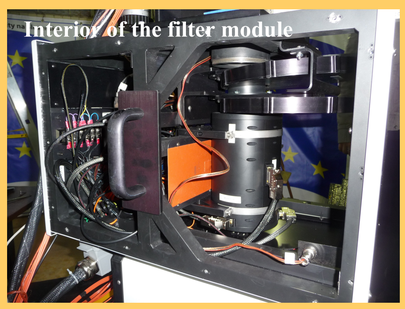
- 200/3000 CARL ZEISS Jena coronagraph - a Lyot type with some ZEISS inventions *(Lexa, 1963)*
- single objective lens: BK7, aperture = 19.6 cm, focus = ~3 m
- diffraction limited from 530 to 1100 nm by changing position of the objective lens
- spatial resolution: 0.67arcsec@530nm, 0.82arcsec@656nm, 1.36arcsec@1083nm
- secondary optics with a Lyot stop, final diameter of the solar image ~4 cm
- field-of-view (FoV): 1.02-1.84 of the solar radius
- post-focus instrument rotation around the optical axis and radial shift away from this axis
- on-line photoelectric pointing of the coronagraph



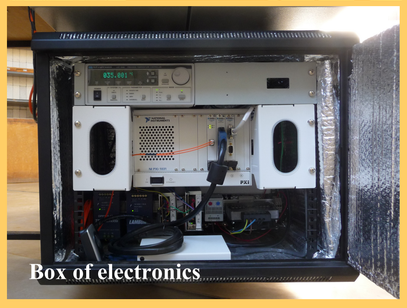
The ZEISS coronagraph with the CoMP-S instrument



Camera, filter, and interface modules


Interior of the filter module

Interior of the camera module


Box of electronics

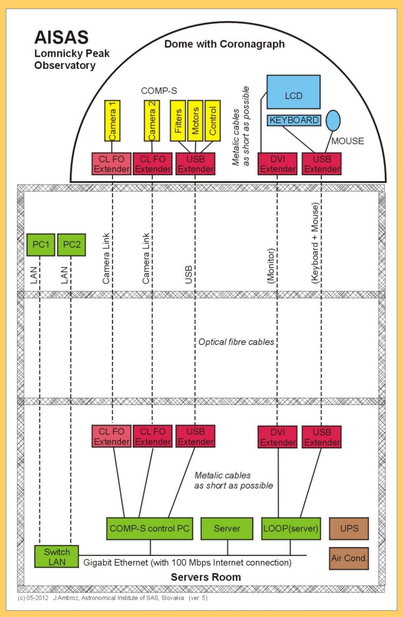

Computers in the server room

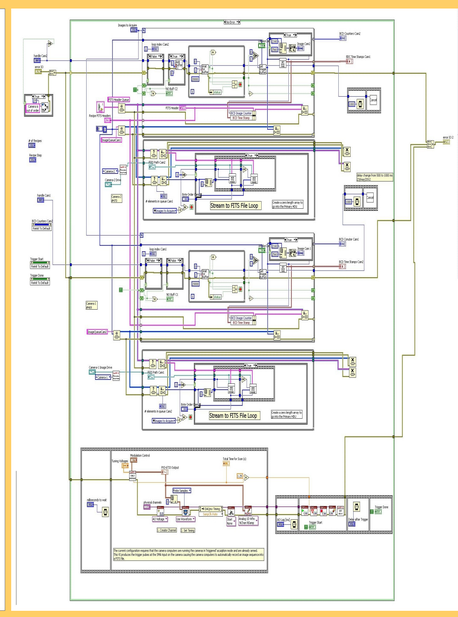
CoMP-S instrument

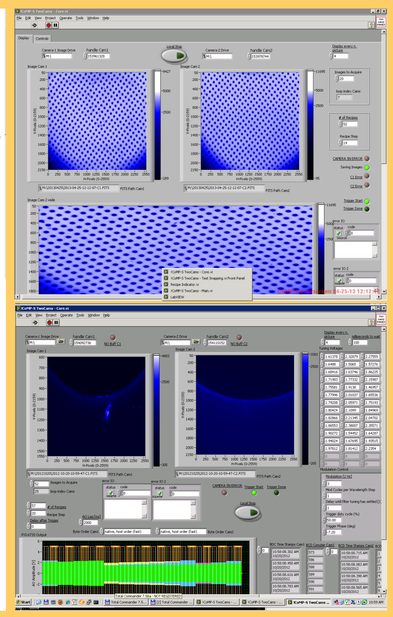
- based on the CoMP instrument concept *(Tomczyk et al., 2008, Kučera et al., 2011)*
- A tunable 4-stage Lyot filter and Stokes polarimeter: diameter 30 mm
- visible and near IR wavelength ranges from 500 to 1100 nm
- polarizer material: VIS700BC4 by CODIXX, more than ~70% transmission
- super-achromatic APSAW λ/2 plates by ASTROPRIBOR (range: 0.7- 1.5 $\lambda_{nominal}$)
- the selected emission lines: corona: Fe XIV 530.3nm, Ca XV 569.5nm, Fe X 637.5nm, Fe XI 789.2nm, Fe XIII 1074.7 and 1079.8 nm; prominences: He I 587.6nm, H I 656.3nm, Ca II 854.2nm, He I 1083.0 nm
- bandpass width (FWHM): 0.028 - 0.13 nm, free spectral range: 0.50 – 2.5 nm (500–1100 nm)
- strategy: 2 orthogonal polarization states acquired simultaneously in two bandpasses shifted in wavelength by two separate detectors for a subtraction of scattered light
- polarization modulation: 2 ferroelectric liquid crystals (FLC): fixed retarder followed by a linear polarizer (analyzer) – a scheme from HAO PromMag *(Tomczyk et al., 2010)*
- detectors for the visible light: pco.edge sCMOS detector by PCO, 2560x2160 pixels, , 60% QE (500nm), 6.5 μm pixels, readout: 16bit, 50 frames per second, 2 e^- readout noise
- final image sampling: 0.33 arcsec/pixel @ 656.3 nm
- final FoV: ~860 x ~680 acrsecs

The CoMP-S operation

- the mechanical interface is used to attach the filter and camera modules to the coronagraph,
- electronics in the box mounted to the pier of mount, computers are placed in the server room
- the instrument adapted to dome environment conditions: ambient temperature in range from -20°C to +20°C while the Lyot filter temperature tuned to 35.000°C and the air temperature inside the filter and camera modules to 23.0°C
- CoMP-S FoV can be placed to any position angle along the solar limb
- LabVIEW code for operation of the Lyot filter, polarimeter, detectors, data acquisition and coronagraph peripheries (diffuser motion, focusing of the objective lens, revolution in the position angle around the solar limb)
- due to two separated detectors used for data acquisition of the same FoV a calibration mode TARG was introduced with a fixed chromium dot pattern inserted into primary focal plane
- data calibration to absolute energetic units is performed by a light flux reduction occulter placed in front of the coronagraph objective lens while observing the solar disk directly
- typical operation timescales: exposure time - chromospheric lines 50-100 ms, coronal lines ~2s; filter tuning time: 250ms; polarimeter setup change: 30ms
- an analysis of the polarimetric properties of the instrument is in progress

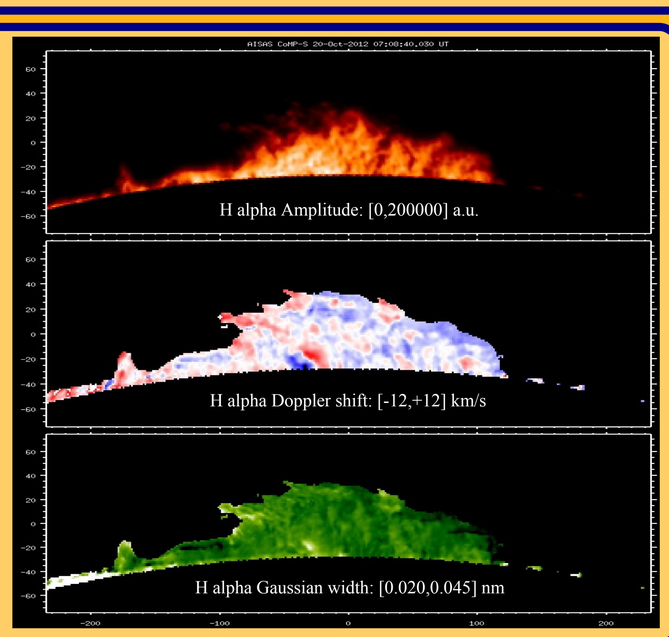






The CoMP-S observations

- example of the CoMP-S observations taken during the HOP186 coordinated campaign “Mass loading of quiescent prominences from multi-wavelength observations” of several instruments (XRT/Hinode, Ondřejov,...) led by P. Schwartz (AISAS)
- a quiescent prominence – 20/10/2012 07:06 UT, PA=170°
- CoMP-S observing run: 2 chromospheric lines (Ca II 854 nm, H I 656nm) and 2 coronal lines (Fe XIV 530nm, Fe X 637nm)
- H alpha line: 11 positions across the spectral profile, 4 individual polarizations per wavelength, exposure time = 50 ms, total line scan time = 20.75 s
- reduction procedure: only Stokes I profile, binning of 4x4 pxs leading to the final 1.3”x1.3” spatial sampling of the results
- line profile fitting: Gaussian fitting of line profiles in each point deriving the line profile amplitude, the velocity shift (km/s), and the Gaussian line width (nm)
- graphics: square-root of amplitude used for a clearer display



The CoMP-S extension

- data acquisition for wavelengths longer than 900 nm requires an incorporation of IR detectors to the camera module in addition
- selected IR detector: Goodrich GA1280J by Sensors Unlimited (1280x1024 15μm pixels, sensitivity: 950-1650nm)
- two light channels created by a dichroic beam splitter
- selection of a visible or a near IR emission line without any mechanical action needed
- expected time of installation to the instrument: Jan - Feb 2014

References

- Lexa, J., 1963, *Bulletin of the Astronomical Institutes of Czechoslovakia* **14**, 107
- Kučera, A., Ambróz, J., Gömöry, P., Kozák, M., Rybák, J., 2011, *Contributions of the Astronomical Observatory Skalnaté Pleso* **40**, 135
- Tomczyk,S., Card,G., Darnell, T., Elmore, D., Lull, R., Nelson, P., Streander, K, Burkepile, J., Casini, R., Judge, P..: 2008, *Sol Phys.* **247**, 411
- Tomczyk, S., Casini, R., de Wijn, A.G., Nelson, P.: 2010, *Applied Optics* **49**, 3580

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