International team of astronomers will investigate mechanisms of the global coronal heating

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The dazzlingly bright solar disk, seen every day in the sky, is an image of the solar photosphere, which is only the lowest layer of its enormously vast solar atmosphere. The external, biggest and hottest part of the atmosphere is called, very aptly, the solar corona. Unfortunately, a brightness of the solar corona is so minute, that it can be perceived with the naked eye only during total solar eclipses, when the bright light of the solar disk is blocked with an opaque disk of the Moon. The brightness of the solar corona depends on a phase of the famed 11-year solar activity cycle and on an actual structure of the solar magnetic fields penetrating the whole solar corona. Apart from these secondary factors, one can state a typical brightness of the solar corona in the visible light is of two hundred-millionths of the brightness of the solar disk just one solar radii above the solar limb.

The magnificent images of the solar corona, recorded in the visible light during total solar eclipses show an enormously complicated system of brighter and dimmer, semi-transparent structures, shaped by local magnetic fields: loops, arcades of loops, helmets, streamers and many other features. During the totality, just outside the lunar limb, one can see pink, bright clouds of prominences, formed of relatively cold and dense plasma and shaped and supported by hammocks of the local magnetic fields. With any luck it is possible to perceive a momentary phase of a prominence eruption or even of a coronal mass ejection.

Despite the solar photosphere’s temperature being only 5800 Kelvin, quiet regions of the solar corona have temperatures of the order of 1-2 million Kelvins, while its active regions, where magnetic fields are concentrated, have temperatures of 3-4 million Kelvins. The local temperature of the solar coronal plasma does not depend only on the altitude, but also on variable processes of interactions between magnetic field and plasma, especially spectacular in the active regions. Thus, the relative cold prominences of 10-20 thousands Kelvin can be right next to hot coronal loops of many million Kelvins and flaring kernels of 10-20 million Kelvins. It is interesting, the total energy losses of the corona by radiation, conduction and the solar wind are up five hundred-thousandths of the total solar emission power, which is a monstrous $2 \cdot 10^{22}$ W – equivalent to the energy of five millions megaton bombs released every second.

Though these energy losses are so huge, the solar corona as a whole maintains a more or less constant mean global temperature. Undoubtedly, its energy losses are compensated by a continuous process or simultaneously occurring processes of so called global coronal heating. The strict nature of these processes is not explained so far, but two hypotheses are most commonly accepted. The first one assumes that the corona is heated by numerous but tiny magnetic reconnections, so called “nano-flares”. The nano-flares are so small that they are not individually observable. Nevertheless its energies are still of the order of 10^{16} J per flare, i.e. five megaton bombs per event! The second possible process of the global heating is based on dissipation of the energy carried by waves.

The past three decades have seen the launch of a number of large dedicated spacecraft solar telescopes, mostly working in the visible and ultraviolet and performing in-situ measurements of the solar wind plasma. However, ground-based observations are still very important in investigations of the solar corona structure, energy transfer, corona heating or interactions of plasma and magnetic fields, due to high time resolution and ability to collect huge amounts of data in short periods of time when imaging over even small portions of the solar corona, more than can generally be taken with spacecraft instruments. The solar corona is emitting numerous strong spectral lines of highly ionized elements in the visible part of the spectrum, between other: „green” line (λ=530.3 nm, iron FeXIV), „yellow” line (λ=569.5 nm, calcium CaXV) and „red” line (λ=637.5 nm, iron FeX).

International team of leading world-class heliophysicists from United Kingdom (Queen’s University Belfast), France (Observatoire de Paris) and Poland (Astronomical Institute of the University of Wrocław) is preparing a novelty experiment, aimed at solving the problem of how the wave processes participate in global heating of the solar corona, with the special interest in analysis of the so-called Alfven waves.

The investigations will be based on the numerical analysis of unprecedented observations of wave-like local variations of the plasma velocities to be collected during the total solar eclipse on 21 August 2017 with the use of state-of-the-art, innovative Solar Coronal Dopplerometer instrument, which is based on revolutionary concept of the double line Multi-channel Subtractive Double Pass spectrograph with mirror-slicer and high cadence single-camera recording system. The Solar Coronal Dopplerometer will have an exceptionally wide two-dimensional field of view of 5 x 14 arcmin square. The associated multi-channel spectrograph will produce simultaneously 2D images and spectra for all points in the field of view, at the same time in “red” and “green” coronal lines with the very high time cadence of 10 exposures per second. The instrument being proposed here will search not for local intensity fluctuations in the corona but rather moving material as revealed by Doppler shifts in the green and red coronal lines. The observational capabilities of the instrument surpass those of any previous instrument observing solar corona during eclipses.

Polish astronomers from the Astronomical Institute of the University of Wrocław are responsible for construction of the heliostat and horizontal telescope, preparation of the spectrograph’s box, adjustments and tests of the whole instrument; construction of the auxiliary power supply system, preparation of the raw data processing software and basic scientific data analysis software, transportation of the instrument to the observing sites. All similar tasks were performed by them very successfully during previous eclipse expeditions in 1999, 2001, 2006 and 2009.

Detection and investigations of the short-period wave motions along magnetic field lines, would make significant contributions to the field of the coronal heating processes, but will be also important in the field of the physics of the solar active regions and solar magnetic loops. The results will be published in leading astronomical periodicals and if the results are very significant may lead to papers in Nature or Science. The astronomers from AI UWr will also exploit the opportunities for popularization of the astronomical science, public relations and publicity for all groups involved, while total solar eclipses always attract a good deal of positive public attention.

It may be worth briefly describing the 2017 eclipse. The path of the total solar eclipse on 21 August 2017 will travel across the whole continental USA between 17:15 UT (11:15 CST on the west coast of US) to 18:45 UT (12:45 CST on the east coast), with longest duration of $2^m40.3^s$ (in the region of Kentucky, Tennessee, and Missouri) and the Sun having a high altitude -- 63.8° (Fig. 8). The eclipse magnitude (ratio of apparent lunar diameter to apparent solar diameter) will be equal to the relatively high value of 1.0306. The best weather conditions are likely towards the west coast. The exact location of our observing site has not yet been decided, but it is therefore likely to be towards the West Coast of the USA to maximise the chances of clear weather.