RECENT DEVELOPMENTS IN METEOR SPECTROSCOPY IN THE FRAMEWORK OF THE S.M.A.R.T. PROJECT. J.M. Madiedo[1,2]. [1]Departamento de Fisica Atomica, Molecular y Nuclear. Universidad de Sevilla. 41012 Sevilla, Spain. [2]Facultad de Ciencias Experimentales, Universidad de Huelva, Huelva, Spain, madiedo@uhu.es.

Introduction: Meteor emission spectra provide an insight into the chemical nature of meteoroids ablating in the atmosphere, but also useful information about the mechanisms that control this ablation process [1, 2, 3, 4]. For this reason, an array of spectrographs has been deployed at several meteor observing stations operated by the University of Huelva, in Spain. These stations work in the framework of the SPanish Meteor Network (SPMN). The first of these devices, which were based on low-lux CCD video cameras endowed with holographic diffraction gratings, started operation in 2006 at the station in Sevilla and also at the Cerro Negro mobile station [5]. Later on, slow-scan CCD spectrographs were also employed at both locations. Nowadays, these spectral cameras operate in a fully autonomous way at 7 meteor stations in the framework of the SMART project, which is the acronym for Spectroscopy of Meteoroids in the Atmosphere by means of Robotic Technologies. Favorable weather conditions in Spain play a key role in the successful development of this systematic spectroscopic campaign. A description of the main developments performed during 2013 is given here.

Instrumentation: The spectrographs work in a fully autonomous way thanks to the MetControl software, which was developed in the framework of the SMART project and is described below. Some or these systems are based on low-lux monochrome CCD video cameras (models Watec 902H and 902H Ultimate). These employ aspherical fast lenses (f1.0) covering fixed fields of view ranging from 90 to 8º. To disperse light emitted by bright meteors, a holographic transmission diffraction grating is attached to the objective lens. Emission spectra produced by events brighter than mag. -4/-5 can be obtained by these video spectrographs. On the other hand, five slow-scan CCD cameras manufactured by ATIK and SBIG are also employed as imaging devices. These cover a field of view of ~50º and are placed on automated alt-az mounts. In this way, they can be pointed to an arbitrary region of the sky. They can image emission spectra for fireballs brighter than mag. -6/-7.

Software for robotic device operation: The MetControl software was initially developed to control the operation of remote meteor observing stations at sites where human intervention was not always possible [6]. Later on, it was modified to achieve a fully automatic operation of the spectrographs employed in the framework of the SMART project. The software can work in client and server modes. The client mode corresponds to data acquisition. Under this configuration the application starts the data acquisition software when the observing session must begin. Then, MetControl checks periodically if a new meteor trail has been recorded and checks if an event brighter that mag. -3/-4 has been detected, since these can produce bright enough emission spectra to be recorded by the spectrographs. The software keeps a list of these events, and this list is emailed to the operator when the observing session is over. When the observing session is over, MetControl compresses the data recorded during the night and transfers them to a FTP server, where the information obtained by each device operating at the different stations is gathered and stored for further processing. Another instance of MetControl running in server mode (or data processing mode) on this FTP server checks the incoming data. In this way, the software identifies which meteor trails have been simultaneously recorded from at least two different locations.

Figure 1. One of the new 6-videospectrographs arrays employed at the Cerro Negro mobile station.

The spectra analysis software: CHIMET is a Windows compatible application designed within the SMART project to analyze meteor spectra recorded by both video and slow-scan CCD spectrographs [7]. The spectrum is initially obtained as an intensity profile (pixel brightness, in device units, vs. pixel number). This signal is then converted to intensity versus wavelength by identifying typical lines appearing in meteor spectra. At this stage, the spectral resolution is also calculated. Most lines are produced by neutral Fe, but prominent lines produced by chemical species such as Mg, Ca and Na can also be very helpful for this calibration. Then, the spectrum is corrected by taking into consideration the spectral response of the spectrograph. Finally, the relative abundances are calculated, together with the temperature and the electronic density in the meteor plasma. An alternative analysis implies measuring the relative intensities of the contributions from Na I-1, Mg I-2 and Fe I-15 multiplets. These relative intensities provide information about the likely chondritic or achondritic nature of the progenitor meteoroids [8].

Recent developments and preliminary results: The use of moving platforms (alt-az mounts) for the slow-scan CCD spectrographs operating at Sevilla and Cerro Negro meteor stations is one of the improvements that have been recently implemented. In this way, these devices can be oriented to an arbitrary location or can avoid direct moonlight during the whole observing session. In addition, the spectral resolution of the video spectrographs operating at Cerro Negro has been improved. From 2012 this mobile station employs two arrays containing a total of 12 video spectrographs (6 per array), with each device covering a field of view ranging between 90 and 8º (Figure 1). Other significant improvements include the establishment in Nov. 2013 of a new spectroscopic station in the south of Spain (La Pedriza) and a new higher-resolution CCD video spectrograph operating since Aug. 2013 at La Hita Astronomical Observatory, in central Spain. As an example, Figure 2 shows an emission spectrum obtained by the new video spectrograph setup in 2013 at La Hita Astronomical Observatory, in the center of Spain. It corresponds to a sporadic fireball recorded on Dec. 8, 2013 at 2h50m12s UTC. This device improves the resolution of the video spectrographs previously employed by a factor of ~2.

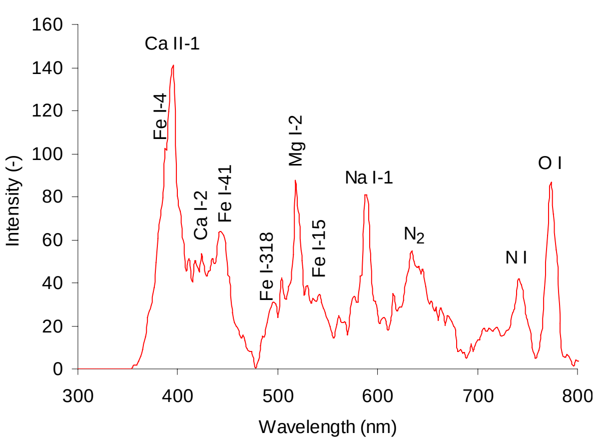

Figure 2. Emission spectrum produced by a sporadic fireball imaged on Dec. 8, 2013 from La Hita meteor station.

Most lines identified in meteor spectra correspond to neutral Fe. Thus, several multiplets of this element have been identified. Calcium is also observed, although H and K lines of Ca II are usually blended with Fe I lines. Multiplet Ca I-2 (422.7 nm) is in many cases easily identified. Two typical features in these spectra are the usually prominent emission lines of the Na I-1 doublet (588.9 nm) and the Mg I-2 triplet (516.7 nm). The contribution of Mg I-3 (382.9 nm) is also seen, although it appears blended with Fe I lines. The triplet O I at 777.4 nm is often recorded in the infrared for fast meteors. The forbidden O I line at 557.7 nm has also been identified in our spectra. On the other hand, the contribution of atmospheric N_2 is present in most of them. The analysis of these spectra by means of the CHIMET software allows obtaining the relative abundances of the main metals in the meteoroid, but also the physical conditions in the meteor plasma (temperature and electron density). This analysis provides an insight into the chemical nature of the progenitor meteoroids.

Conclusions: Since 2006 the University of Huelva is performing a systematic monitoring campaign to obtain meteor emission spectra. This research, which is performed in the framework of the SMART project, employs both low-lux CCD video and slow-scan CCD spectrographs. These systems work in a fully autonomous way by means of software developed for this purpose. These meteor spectra are providing information about the chemical composition of meteoroids ablating in the atmosphere.

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References: [1] Borovicka, J. (1993) *Astron. Astrophys*. 279, 627-645. [2] J.M. Trigo-Rodríguez et al. (2003) *MAPS* 38, 1283-1294. [3] Trigo-Rodriguez, et al. (2009) *MNRAS* 392, 367–375. [4] Madiedo, J.M. et al. (2013) *MNRAS* 433, 571. [5] Madiedo, J.M. & Trigo-Rodriguez, J. M. (2008) *EMP* 102, 133. [6] Madiedo, J.M. et al. (2010) *Advances in Astrononmy* 2010, 1. [7] Madiedo, J.M. et al. (2013) *MNRAS* 431, 2464. [8] Borovicka, J. et al. (2005) *Icarus* 174, 15.