Emission Spectra of Poorly Known Meteoroid Streams: the S.M.A.R.T. Project

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Description of the project

Spectroscopy of Meteoroids in the Atmosphere with Robotic Technologies (S.M.A.R.T.)

Selected results

Focus on poorly-known meteoroid streams
Spectroscopy of Meteoroids in the Atmosphere with Robotic Technologies (S.M.A.R.T.)

STARTED IN 2006

INSTITUTIONS INVOLVED

- Led by University of Huelva (UHU)
- Institute of Astrophysics of Andalusia Spanish National Research Council (IAA-CSIC)
- Calar Alto Observatory (CAHA)

AIMS

- Information about chemical nature of meteoroids
- Systematic monitoring of meteor activity
SCIENCE

- Monitoring of meteor activity.
- Chemical information about meteor plasmas and meteoroids ablating in the atmosphere.
- Atmospheric trajectories, radiant, orbital parameters.
- Determination of likely parent bodies.
- Chemical information about parent bodies.
- Correlation with information derived from our lunar impact flashes monitoring system (MIDAS).
Where?

**METEOR-OBSERVING STATIONS**

- 10 meteor stations.
- Fully automated systems.
- 70 CCD cameras (50 spectrographs).
  - 1 spectrograph in 2006
  - 10 spectrographs in 2009
  - 50 spectrographs in 2015
- Cover about 95% of the Iberian Peninsula and neighboring areas.
- Collaboration with 15 extra stations operated by the Spanish Meteor Network.
Main equipment

**High-sensitivity CCD video cameras**

- Watec 902H Ultimate.
- Fast optics (f1.0 – f1.2).
- Diffraction gratings (500 or 1000 lines/mm).
- FOV ranging from 90x72° to 14x11°.

**Slow-scan CCD cameras**

- ATIK 4000LE, SBIG ST10, ATIK 16HR.
- Optics: f1.0 – f2.8
- Diffraction gratings (1000 lines/mm).
- FOV 32x32 to 50x50.
- Minimum brightness: apparent mag. of about -5.
High-sensitivity CCD video cameras

- Continuous operation.
- No dead time between images.
- Located inside CCTV housings.

Station at Sierra Nevada Astronomical Observatory

Station at Calar Alto Astronomical Observatory
Main equipment

High-sensitivity CCD video cameras

- Continuous operation.
- No dead time between images.
- Located inside CCTV housings.
- Resolution ≥ 1.3 nm/pixel

Typical video spectrum

Chemical species in videospectra

- Neutral Fe, Ca, Mg, Na.
- Ca II lines (H and K lines, blended)
- Atmospheric oxygen and nitrogen.
- FeO.
Main equipment

Slow-scan CCD cameras

- Typical exposition time: 30 s (depending on sky conditions).
- Dead times: 10 – 30 s.
- Located either inside CCTV housings or inside domes.
- More detailed spectra. **Resolution: 0.5 nm/pixel**

*Perseid spectrum (ATIK 4000LE)*
SOME PROBLEMS TO BE ADDRESSED

- Moon near of within the FOV of the recording device.
SOLUTION

- Automated positional control by means of Arduino.
- ALT-AZ mount to avoid including the Moon in the FOV.
SOME PROBLEMS TO BE ADDRESSED

- Ideal situation: meteor flight direction is parallel to diffraction grating’s lines.
SOME PROBLEMS TO BE ADDRESSED

- Wrong orientation of fireball direction in relation to diffraction grating.
SOLUTION

- Rotator to get an optimal orientation of the diffraction grating with respect to the expected flight direction.
- Rotator motor: controlled by means of Arduino.
- Only practical for major showers.
Main software developed in the framework of SMART

- Code for Arduino systems.

- Software for the automatic operation of devices (MetControl).
  - Run and stop data acquisition.
  - Compress and FTP recorded data.
  - Check multi-station data.
  - Send email to the operator with list of recorded events.
  - Notify (email) the operator if important event is recorded.

- Software for the analysis of meteor spectra (ChiMet).
ChiMet: Chemical Information about Meteoroids

- Image processing (apply darks and flats, video deinterlacing, etc.).
- Spectra calibration.
- Identification of emission lines.
- Monochromatic lightcurves (evolution of specific lines with height and time).
- Chemical nature of meteoroids (normal composition? Na rich? Na depletion?).
- Conditions in meteor plasmas (Temperature, electron density).
- Relative abundances of main chemical elements.
General analysis procedure

- Get intensity profile from video or FITS.

![Emission spectrum graph](image)
General analysis procedure

- Get intensity profile from video or FITS.
- Lines identification (calibration in wavelength).
- Database of emission lines.
General analysis procedure

- Get intensity profile from video or FITS.
- Lines identification (calibration in wavelength).
- Database of emission lines.
- Spectral response of recording device.
ChIMet Software

General analysis procedure

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General analysis procedure

- Get intensity profile from video or FITS.
- Lines identification (calibration in wavelength).
  - Database of emission lines.
- Spectral response of recording device.
- Chemical data about the meteoroid.
- Relative abundances.
- Info about the nature of the meteoroid.
Information about the chemical nature of the meteoroid

- Relative intensities of Na, Mg and Fe.
Spectra recorded between 2006 and 2016

- Large number of meteor emission spectra
  - Several hundreds useable (non saturated, non overlapping lines, no Moon effect, ....).
- Correspond to meteors with luminosity > mag. -3.
- Most of these obtained with Watec cameras (video spectra).
  - Most of them from major showers and sporadics.
  - About 200 spectra of multi-station meteors associated to poorly known streams.
- Afterglow spectra have been also recorded.
Information about the chemical nature of the meteoroid


- Relative intensities of Na, Mg and Fe.
March Lyncids (MLY)

- $V_{\text{inf}} \sim 15 \text{ km/s}$.
- Asteroidal ($T_j=3.8$).
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The diagram shows the emission spectrum of March Lyncids with peaks at various wavelengths corresponding to different elements:

- Mg I-3
- Na I-1
- Fe I-42
- Fe I-37
- Fe I-15
- Fe I-16
- Fe I-1
- Mg I-2
- Fe I

The intensity is plotted against wavelength (nm).
March Lyncids (MLY)

- $V_{\text{inf}} \sim 15 \text{ km/s}$.
- Asteroidal (Tj=3.8).
- Normal composition.
\(\lambda\)-Ophiuchids

- \(V_{\text{inf}} \sim 20\ \text{km/s.}\)
- Cometary stream (JFC, P/2005 JQ5 (Catalina)).
- Na depletion.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{spectrum.png}
\end{figure}

\begin{itemize}
\item Mg I-2
\item Na I-1
\item Fe I
\item Fe I-4
\item Fe I-5
\item Fe I-21
\item Fe I-37
\item Fe I-41
\end{itemize}
Results

\( \lambda \)-Ophiuchids

- \( V_{\text{inf}} \approx 20 \) km/s.

- Cometary stream (JFC, P/2005 JQ5 (Catalina)).

- Na depletion.
Northern $\gamma$-Virginids (NGV)

- $V_{\text{inf}} \sim 18$ km/s.
- Asteroidal ($T_j=3.36$).
Northern γ-Virginids (NGV)

- $V_{\text{inf}} \sim 18$ km/s.
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Northern $\gamma$-Virginids (NGV)

- $V_{\text{inf}} \sim 18$ km/s.
- Asteroidal (Tj=3.36).
- Normal composition.
September $\varepsilon$-Perseids (SPE)

- $V_{\text{inf}} \sim 66$ km/s.
- Cometary stream ($T_j=-0.7$).
- Normal composition.

Results
We have set up a system record meteor spectra

- Ten stations in operation
- CCD video cameras and slow-scan CCD cameras.

Automated positional control by means of Arduino.

- ALT-AZ mounts to avoid Moon in the FOV.
- Rotators for optimal orientation of meteor direction and diffraction grating.

Software has been developed to

- Automatic operation of the recording devices.
- Analysis of meteor spectra.

Several hundreds of meteor spectra were obtained.

- Mostly for major showers and sporadics.
- About 200 spectra for events belonging to poorly-known meteoroid streams.

Fireball afterglow spectra have been also recorded.
Thank you for your attention