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

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Outline

- **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

Project description

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

STARTED IN 2006

INSTITUTIONS INVOLVED

- ❑ Leaded 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

Project description

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 90x72º to 14x11º.
- ❑ Minimum brightness: apparent mag. of about -3.

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.

Main equipment

High-sensitivity CCD video cameras

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

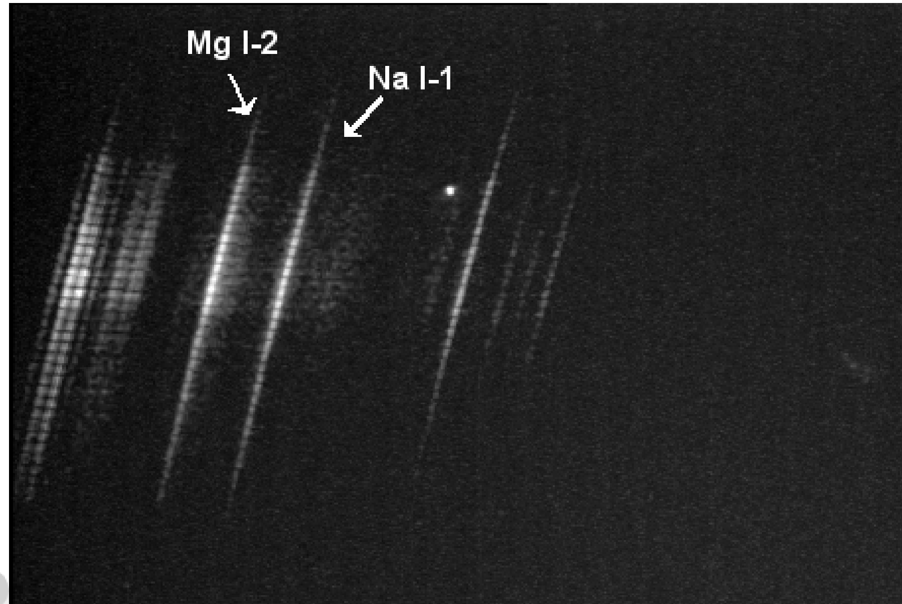
Station at Sierra Nevada Astronomical Observatory

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



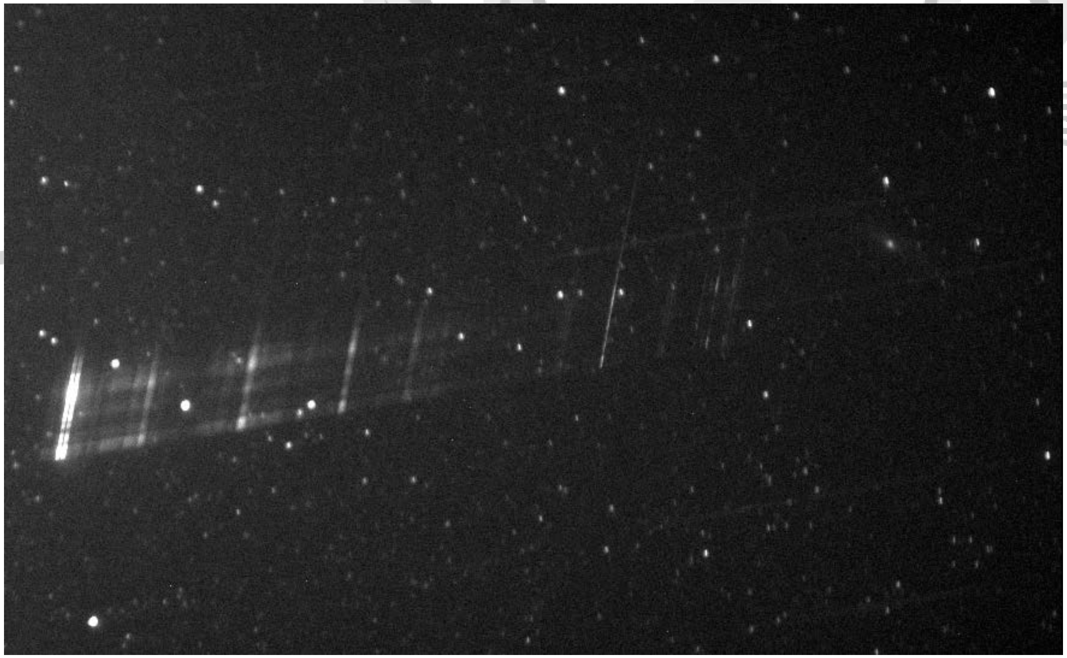
Typical video spectrum

Chemical species in videospectra

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

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**

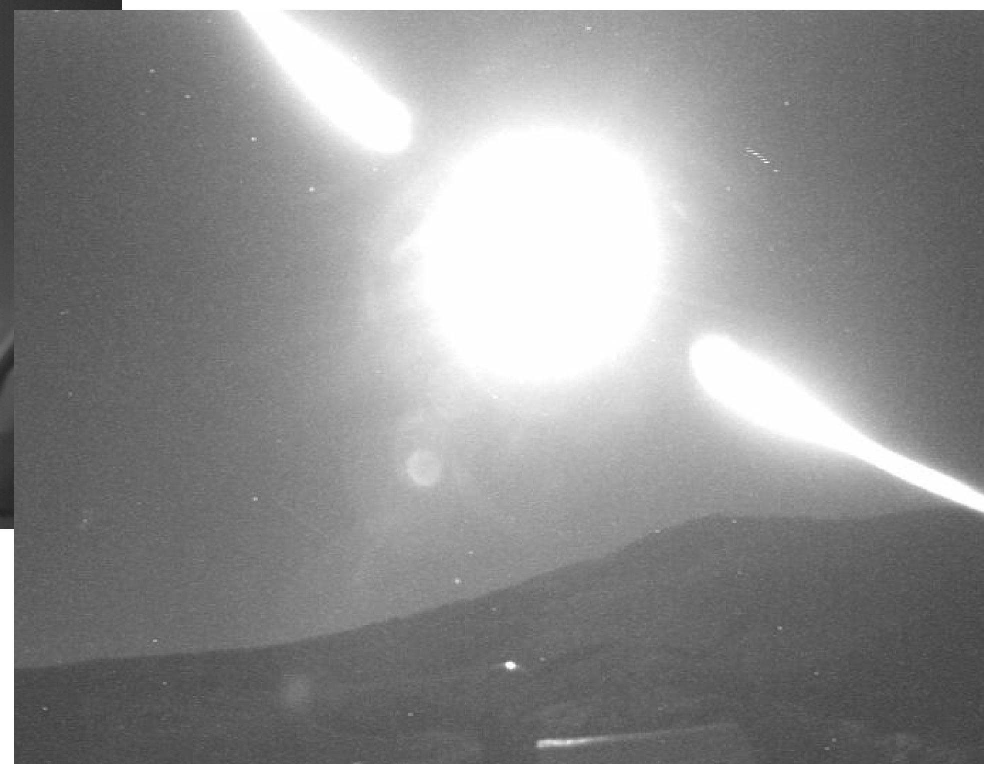


Perseid spectrum (ATIK 4000LE)

SOME PROBLEMS TO BE ADDRESSED

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

With grating

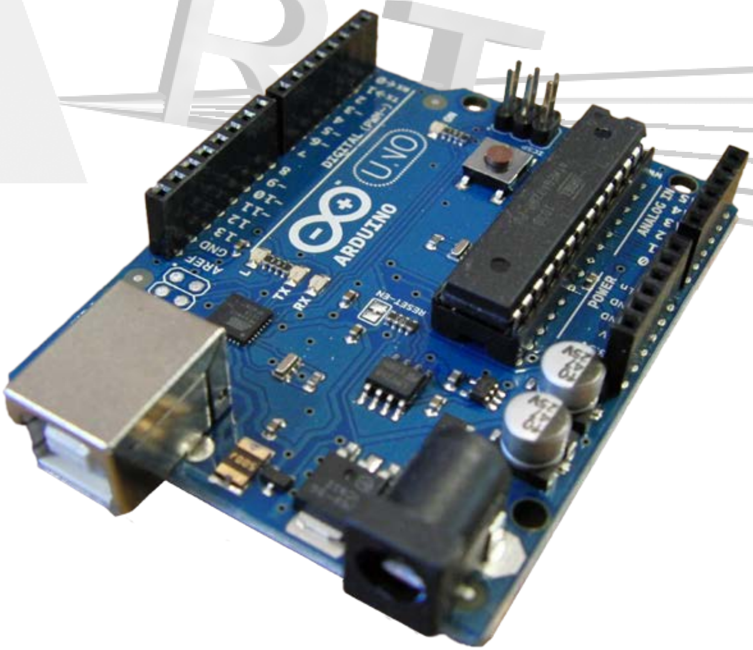


Without grating

Meteor spectra

SOLUTION

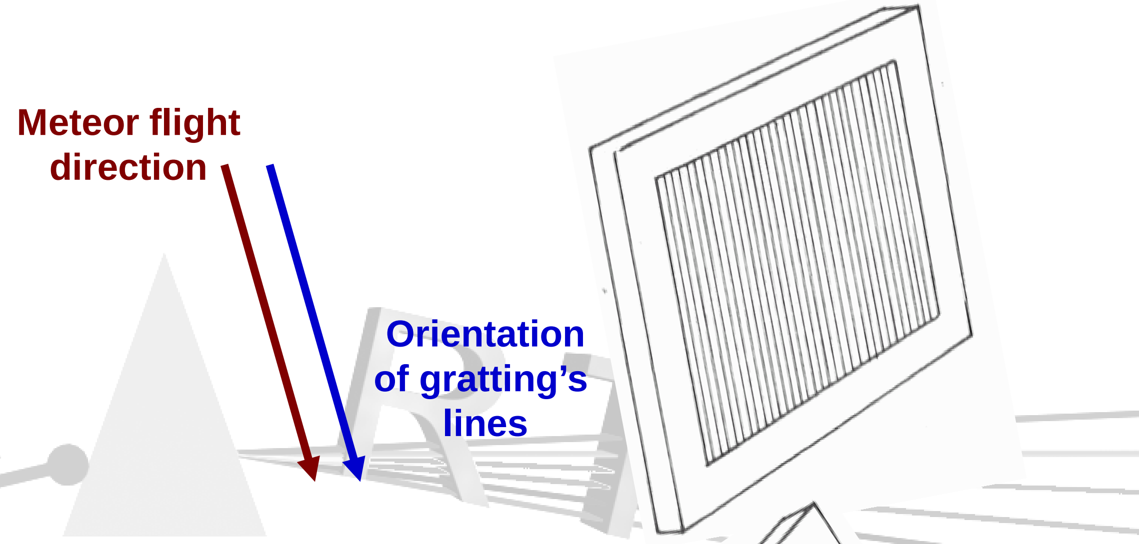
- ❑ Automated positional control by means of Arduino.
- ❑ ALT-AZ mount to avoid including the Moon in the FOV.

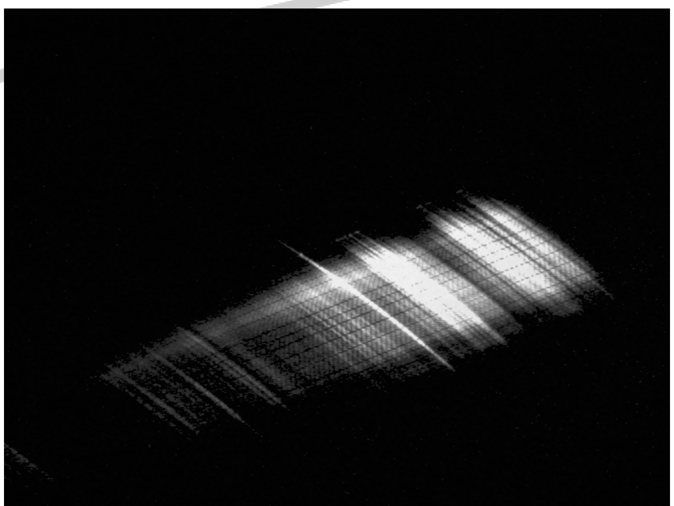


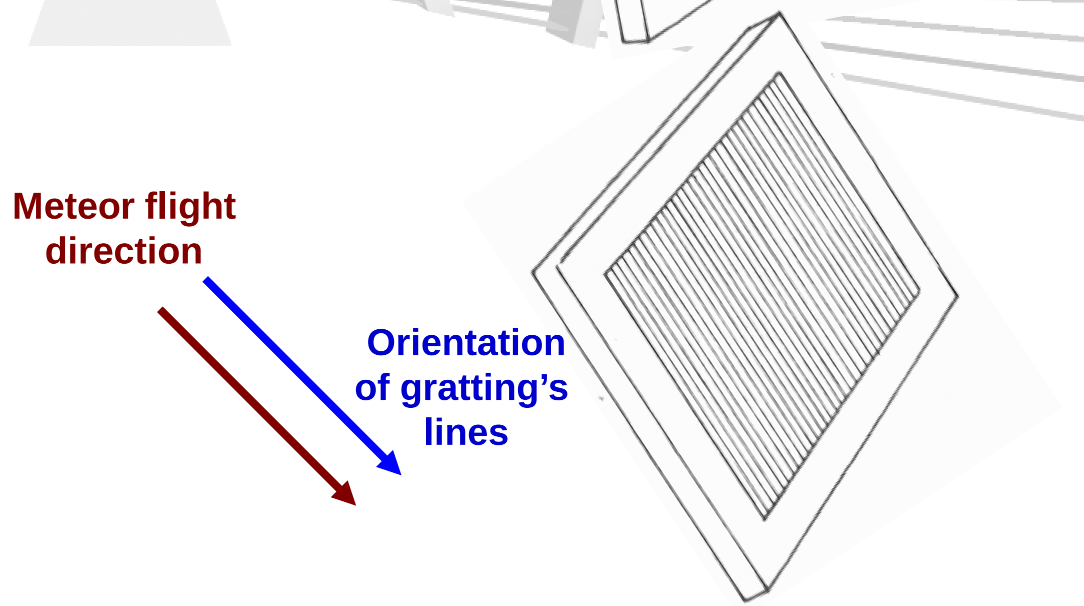
Meteor spectra

SOME PROBLEMS TO BE ADDRESSED

- Ideal situation: meteor flight direction is parallel to diffraction grating's lines.

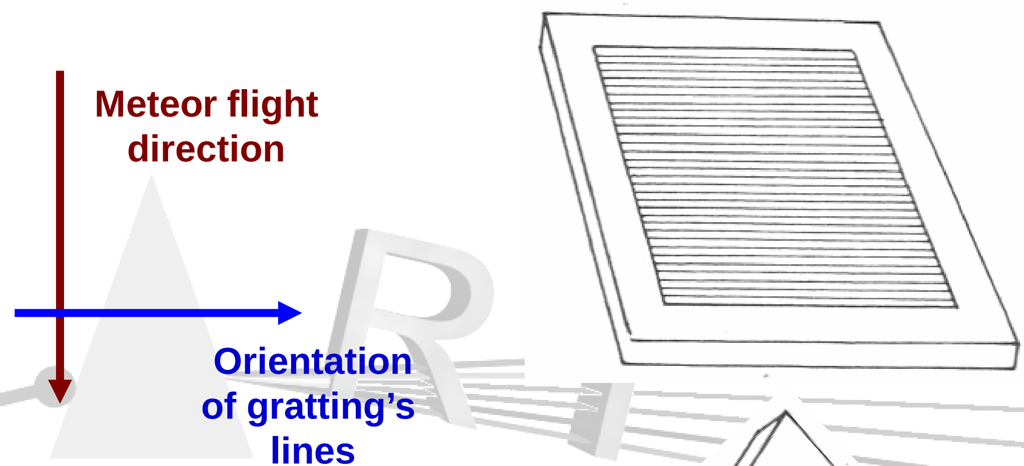


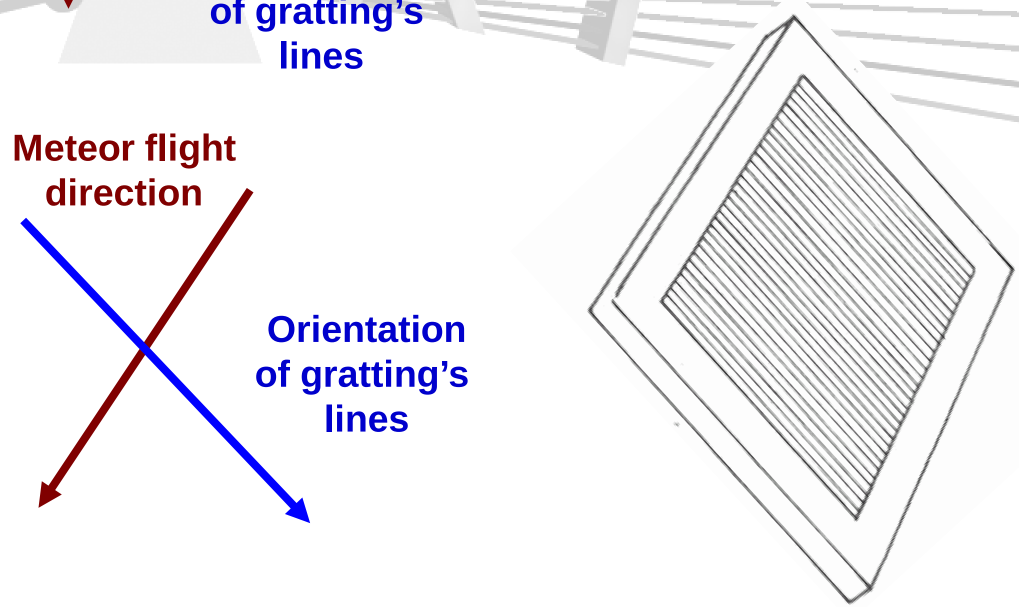




SOME PROBLEMS TO BE ADDRESSED

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

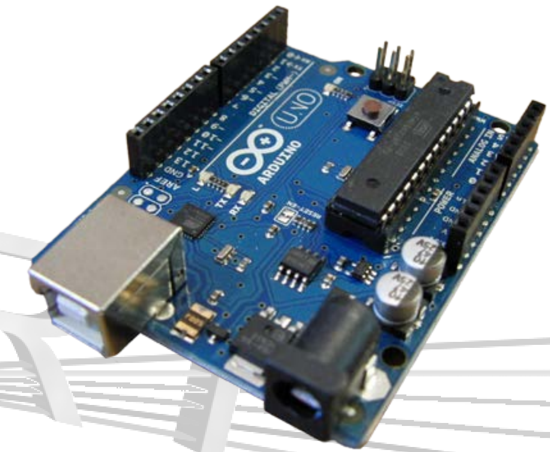




Meteor spectra

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.



Software development

Main software developed in the framework of SMART

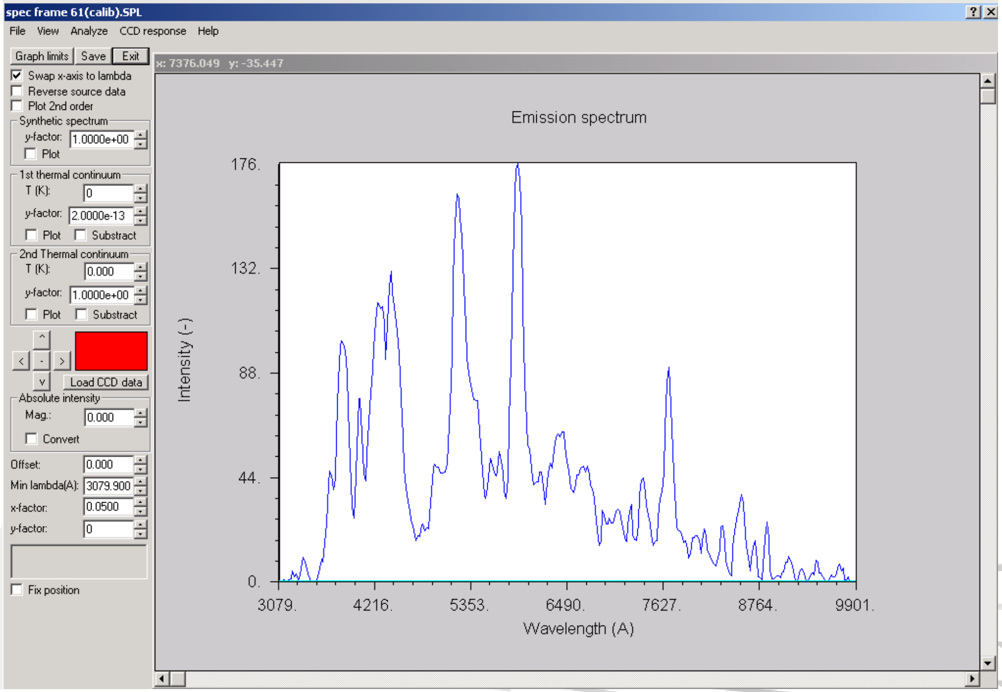
- ❑ Code for Arduino systems.
- ❑ Software for the automatic operation of devices (**MetControl**).
  - ❑ Run and stop data acquisition.
  - ❑ Compress and FTP recorded data.
  - ❑ Check multi-station data.
  - ❑ Send email to the operator with list of recorded events.
  - ❑ Notify (email) the operator 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.

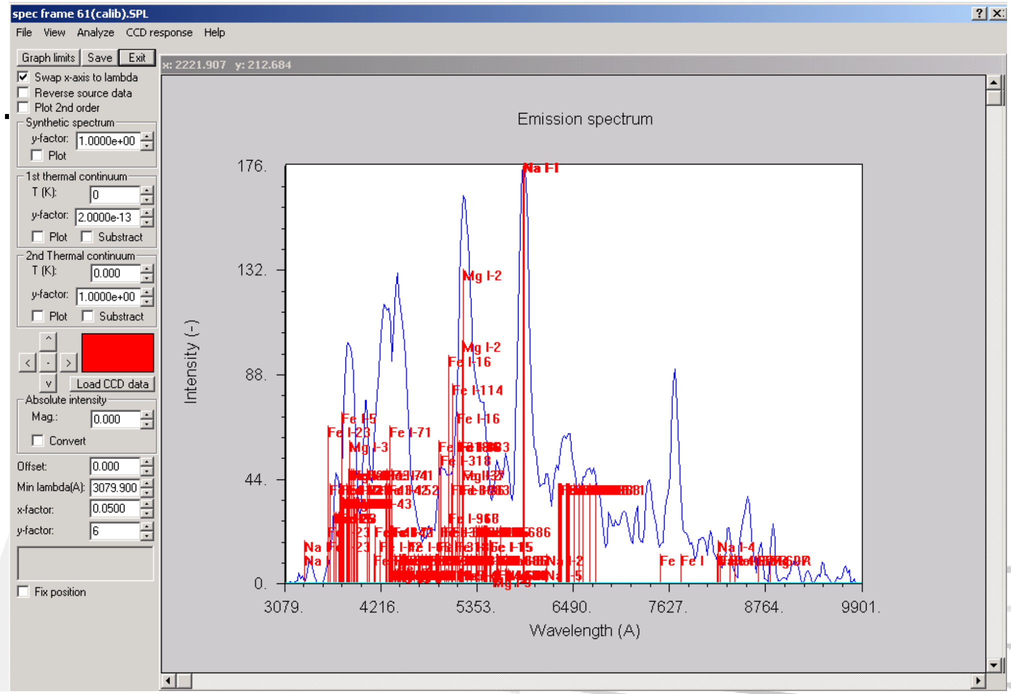
General analysis procedure

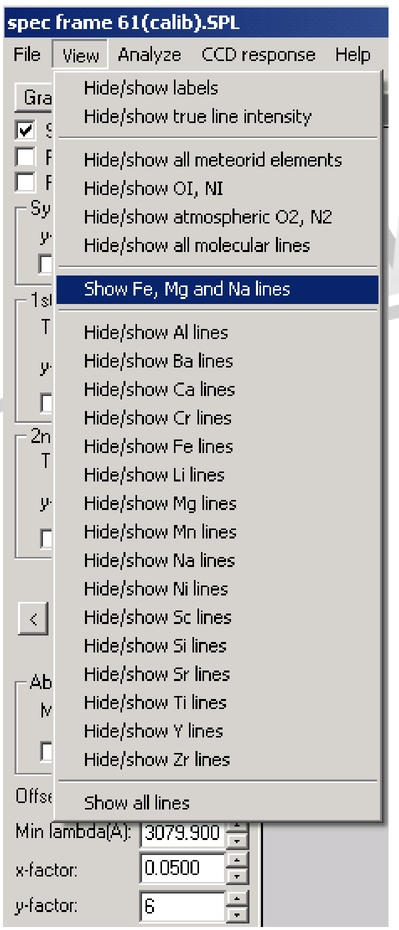
- Get intensity profile from video or FITS.



General analysis procedure

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





General analysis procedure

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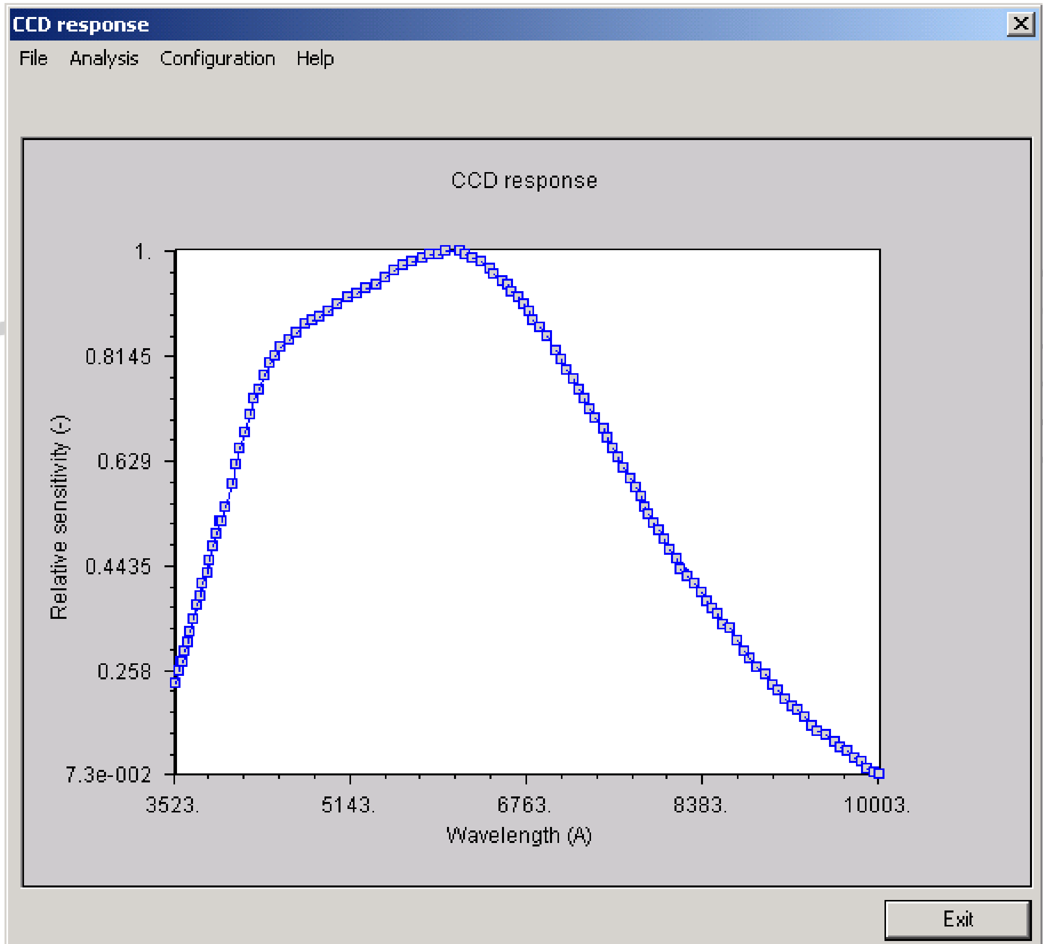
- Spectral response of recording device.



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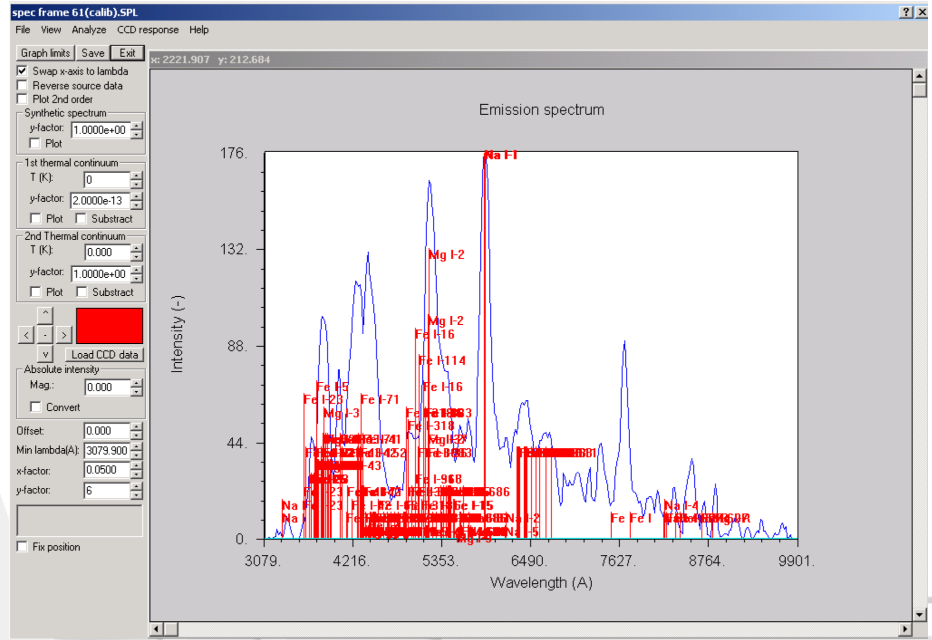

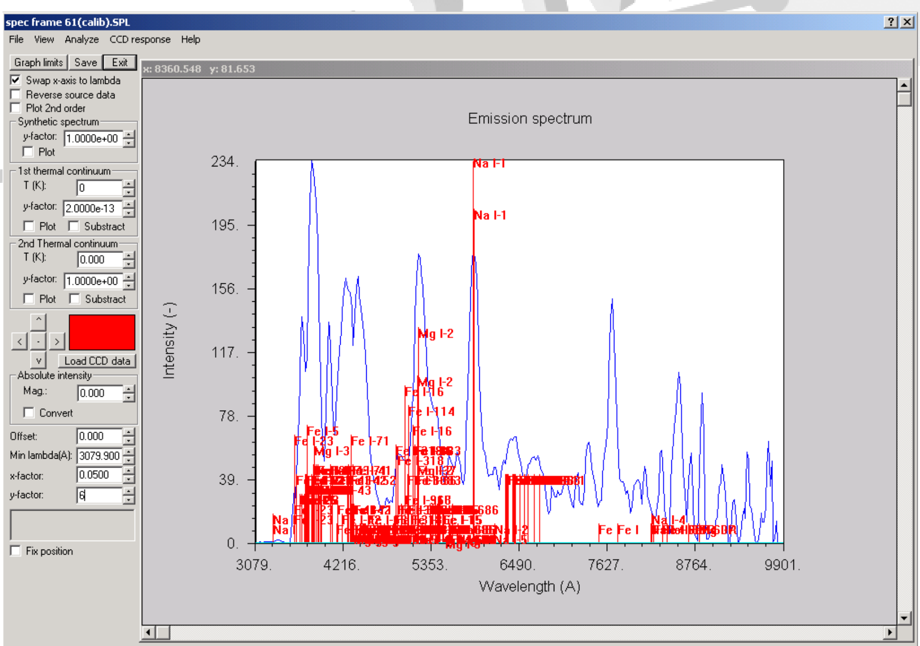

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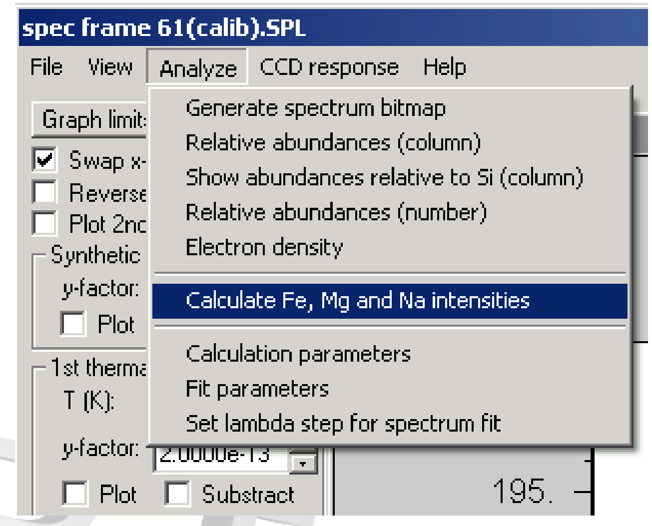
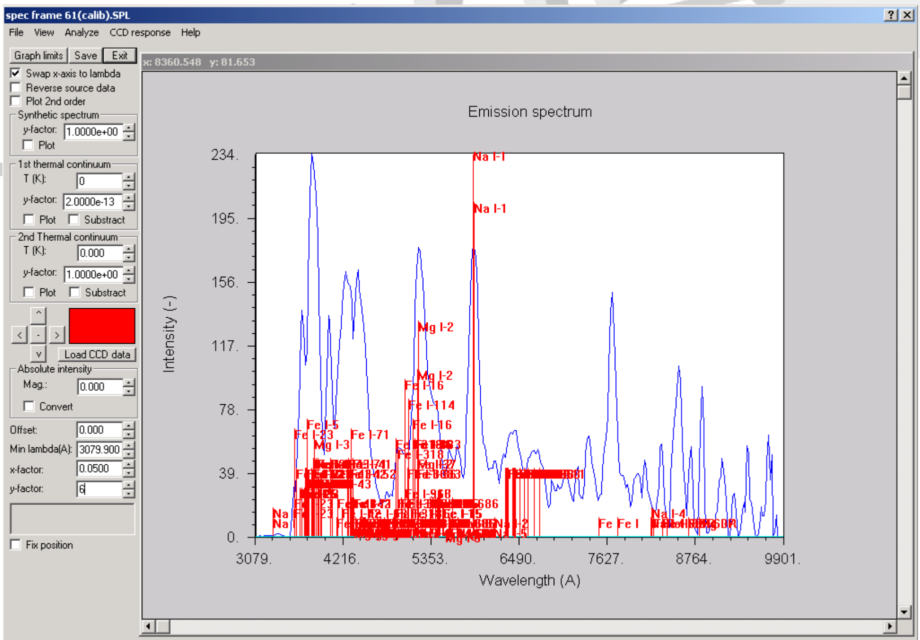
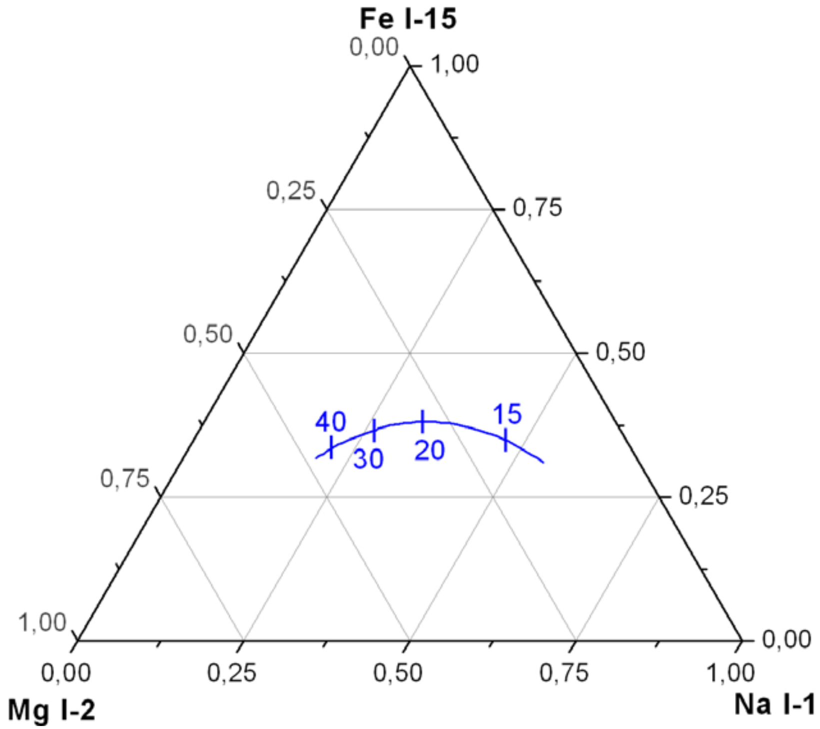


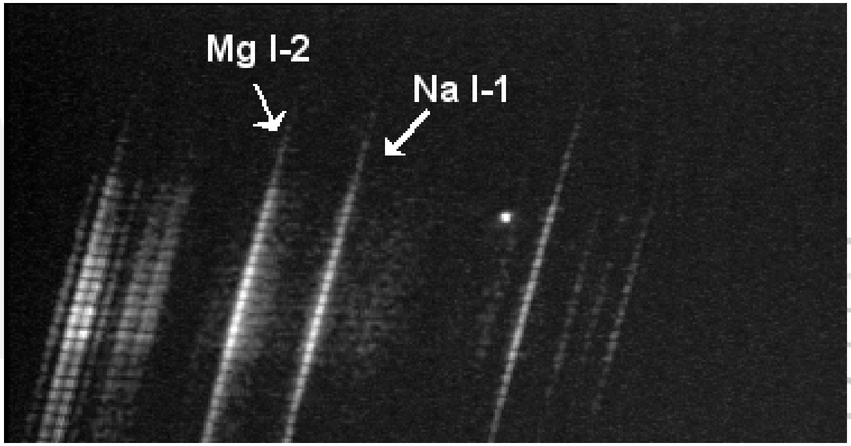


- ❑ Chemical data about the meteoroid.
  - ❑ Relative abundances.
  - ❑ Info about the nature of the meteoroid.

Information about the chemical nature of the meteoroid

- ❑ Method described in Borovička J. et al., 2005, Icarus, 174, 15.
- ❑ Relative intensities of Na, Mg and Fe.





Results

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

- Method described in Borovička J. et al., 2005, Icarus, 174, 15.
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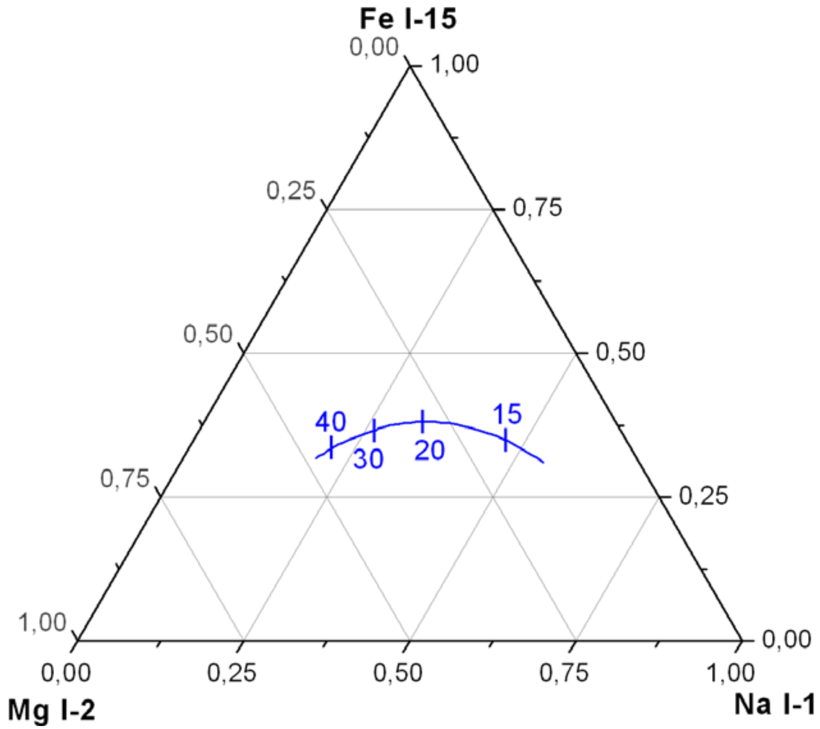
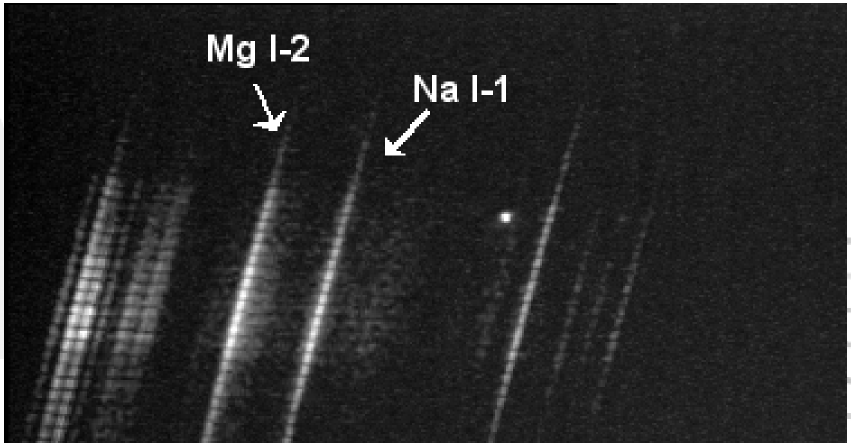
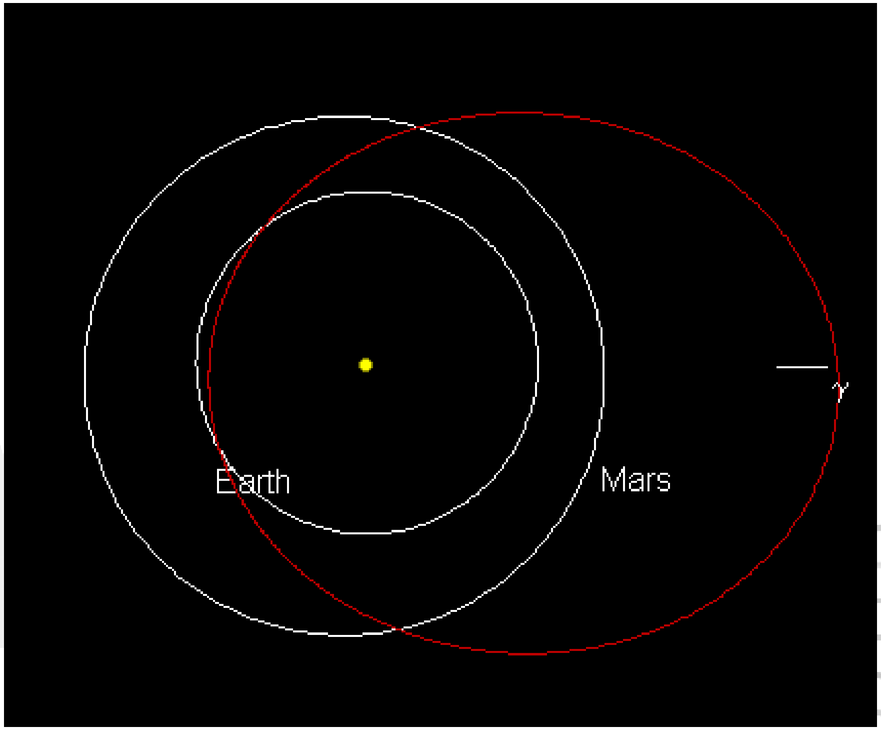
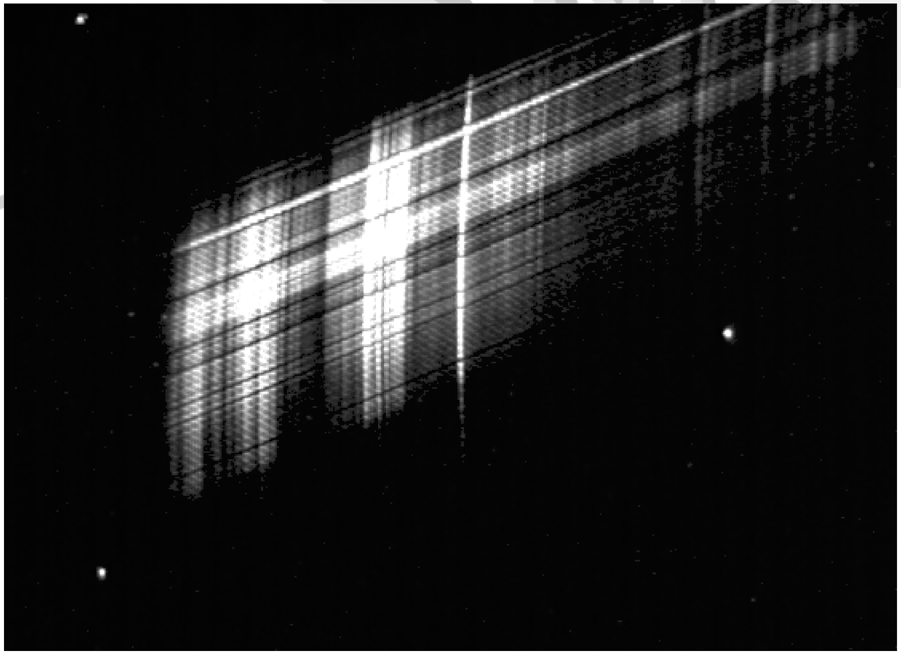




March Lyncids (MLY)

- ❑ V_{inf} ~ 15 km/s.
- ❑ Asteroidal (Tj=3.8).





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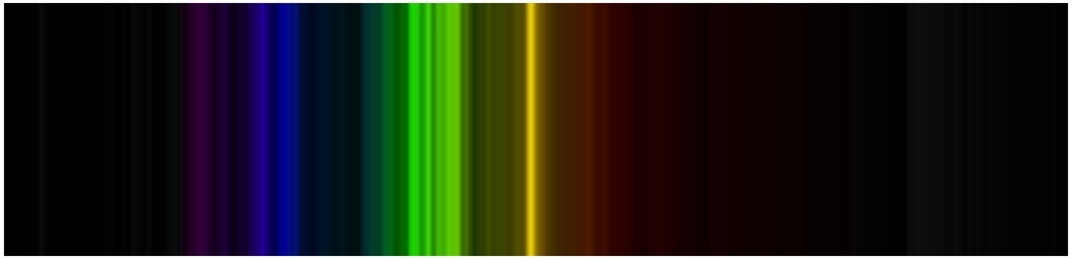

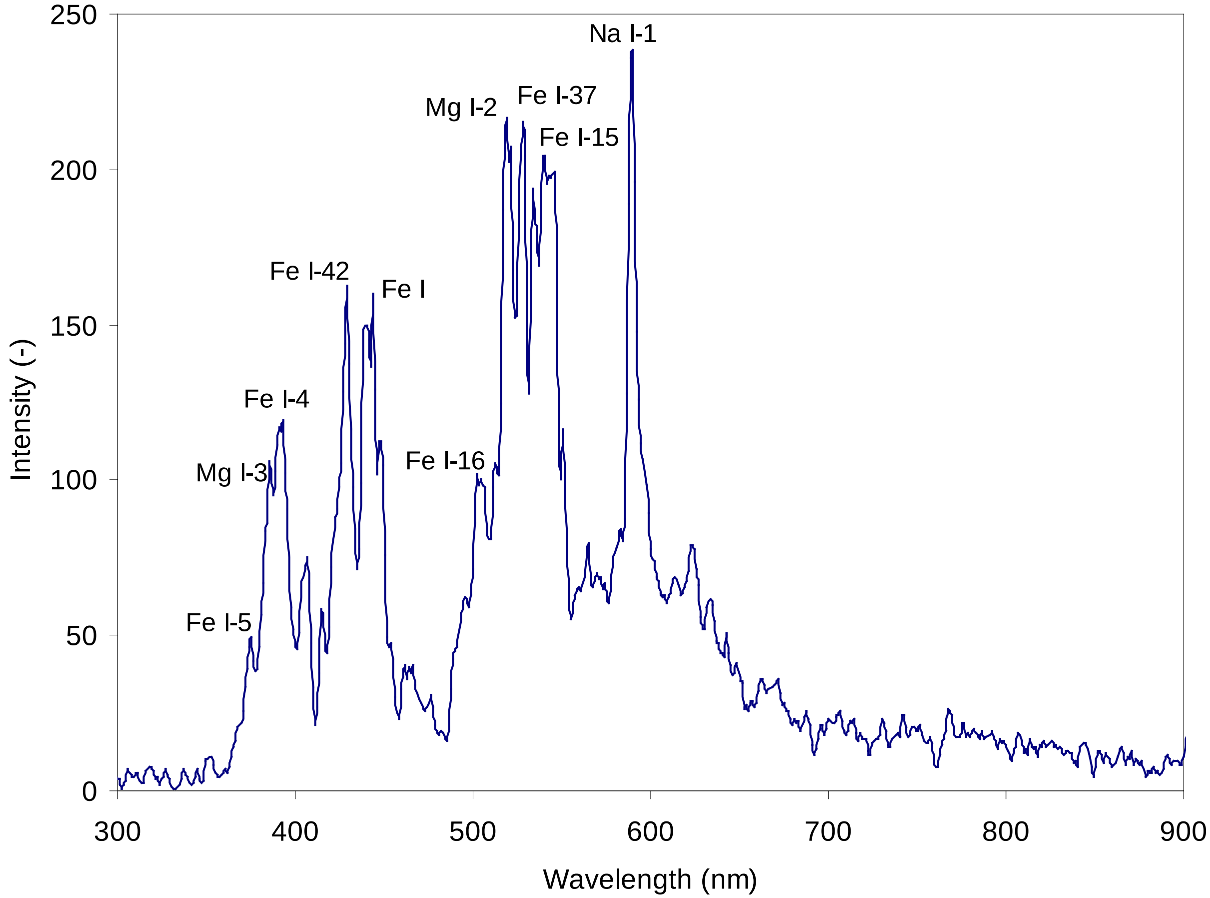

March Lyncids (MLY)

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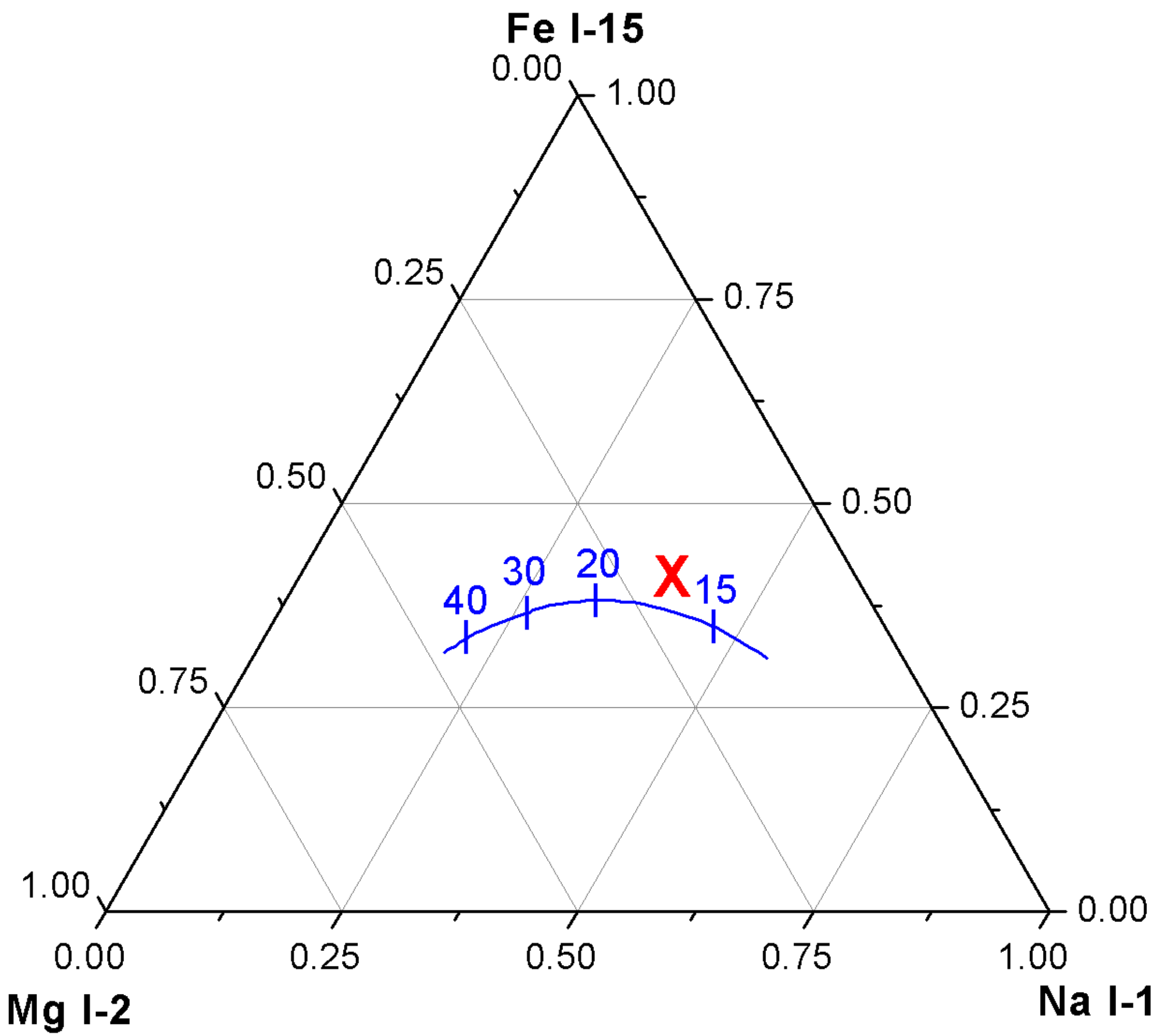
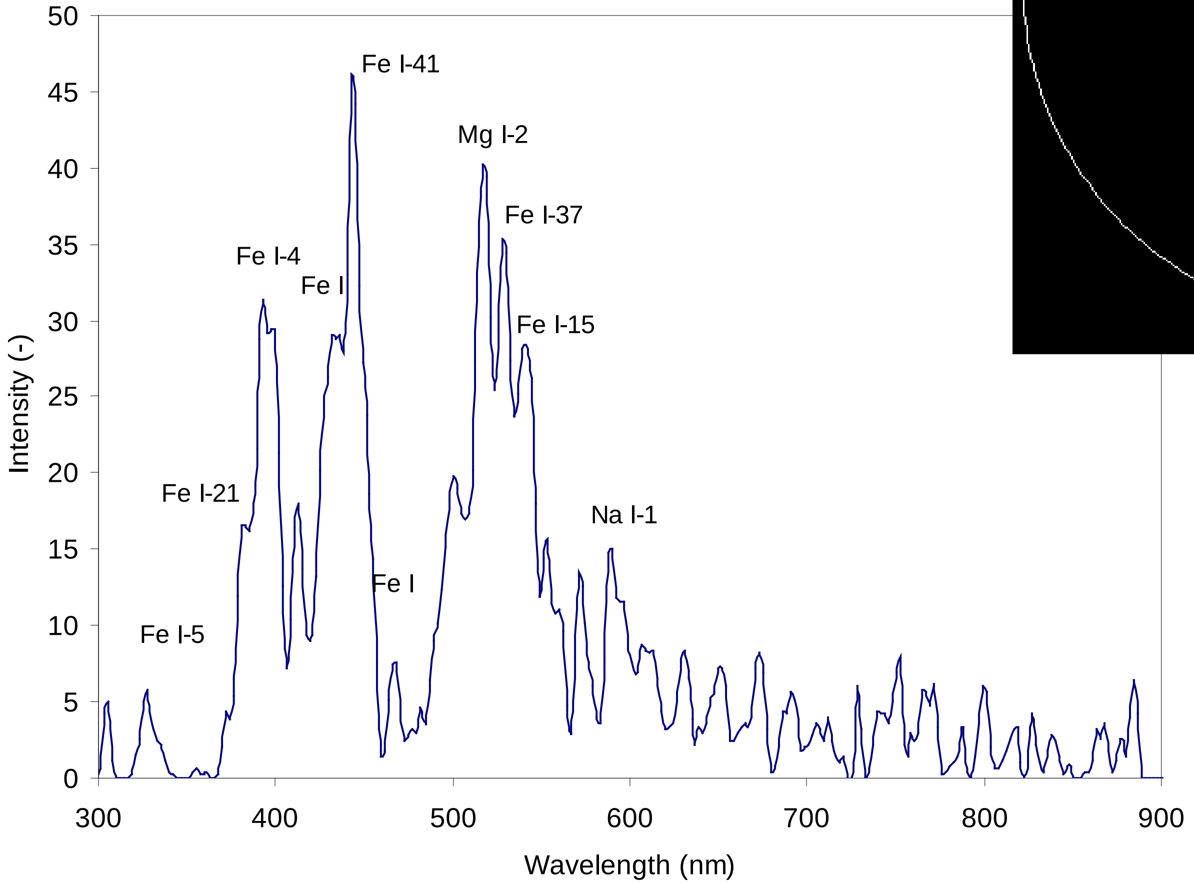
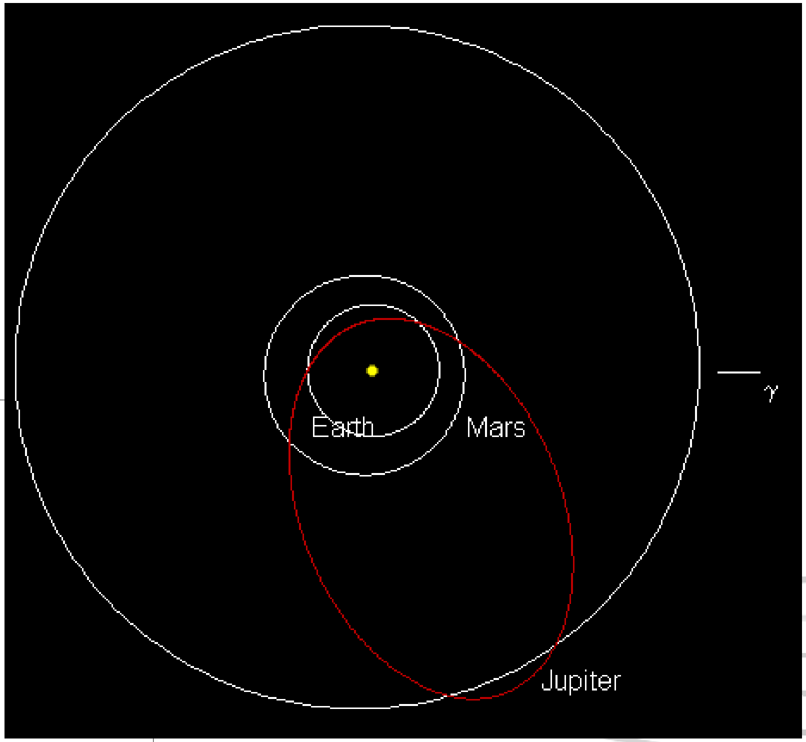
- ❑ Asteroidal (Tj=3.8).
- ❑ **Normal composition.**



λ-Ophiuchids

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





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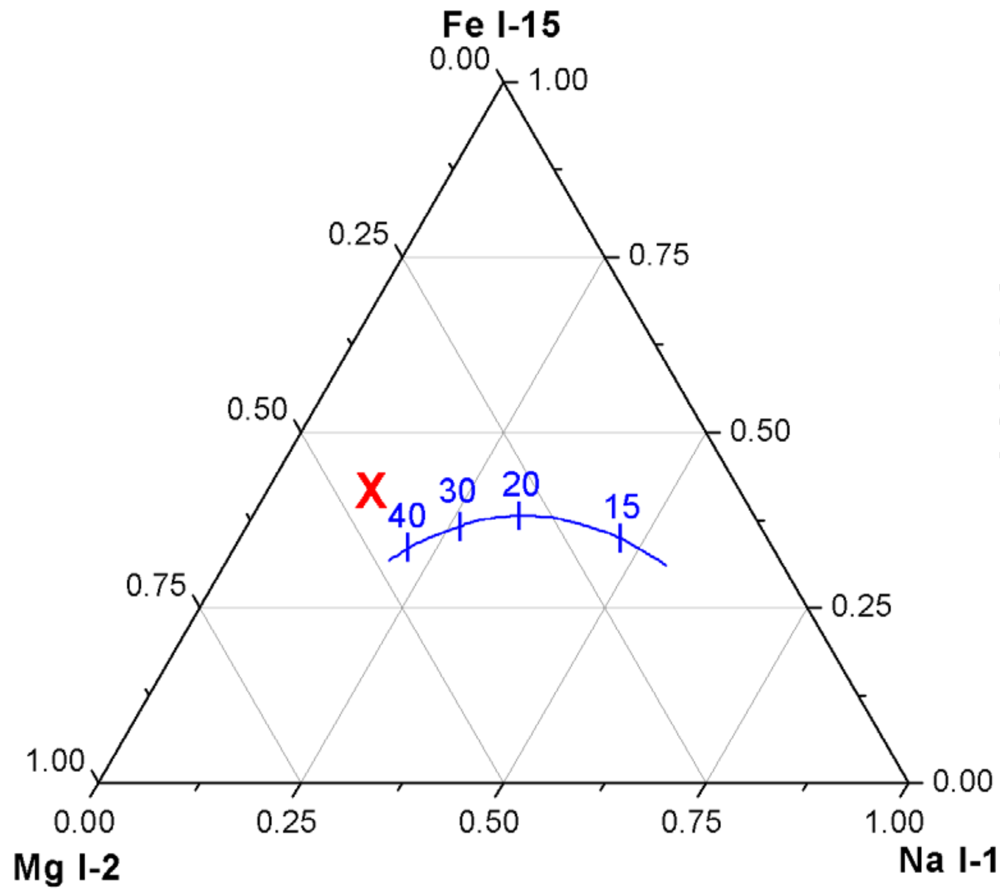
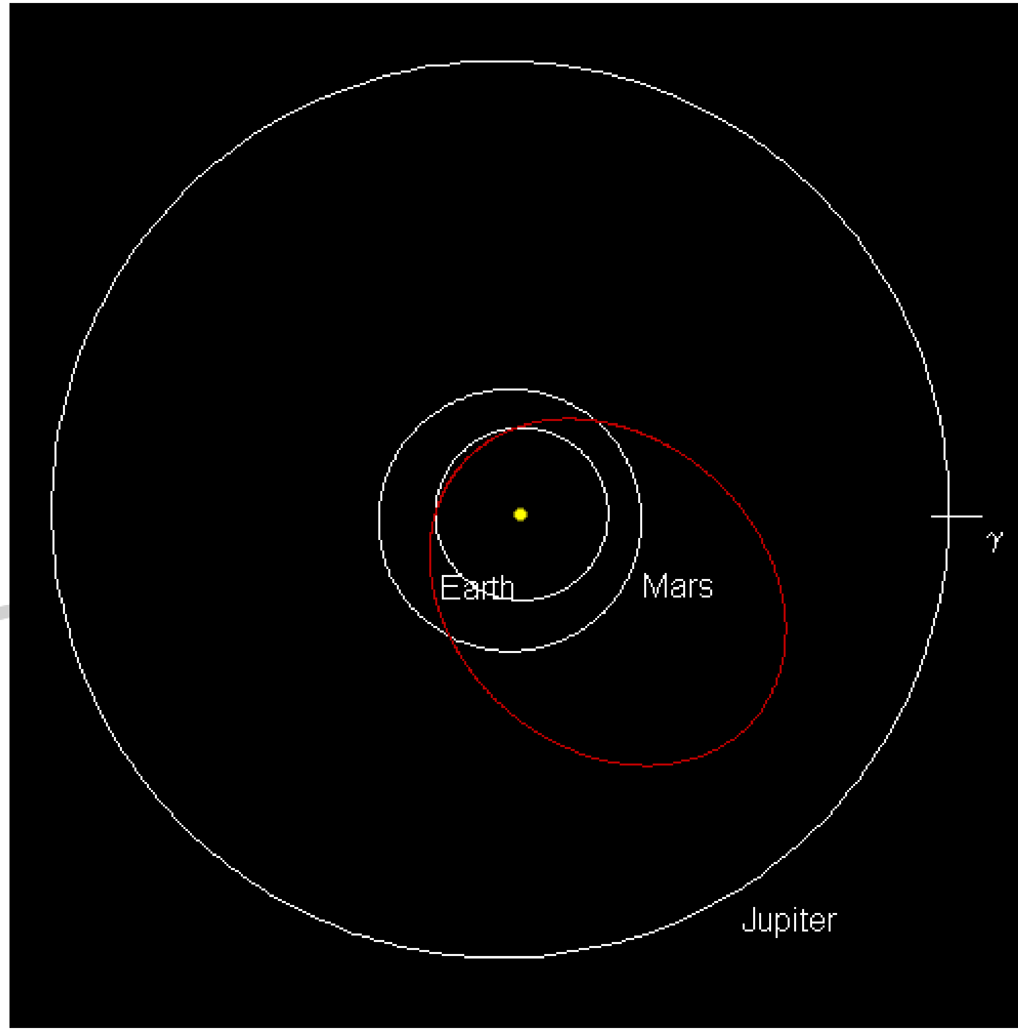


Northern γ-Virginids (NGV)

- V_{inf} ~ 18 km/s.
- Asteroidal (Tj=3.36).



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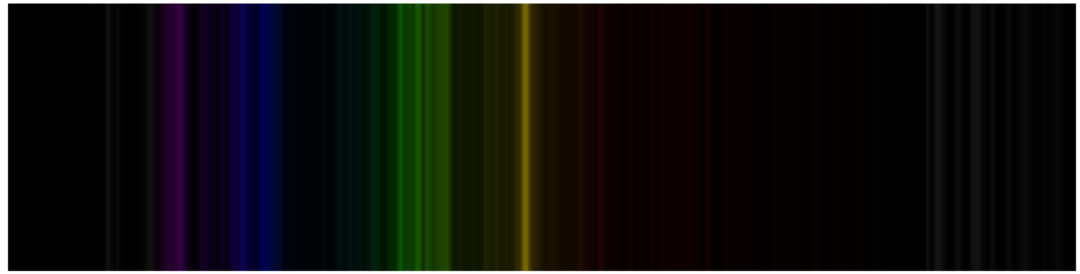
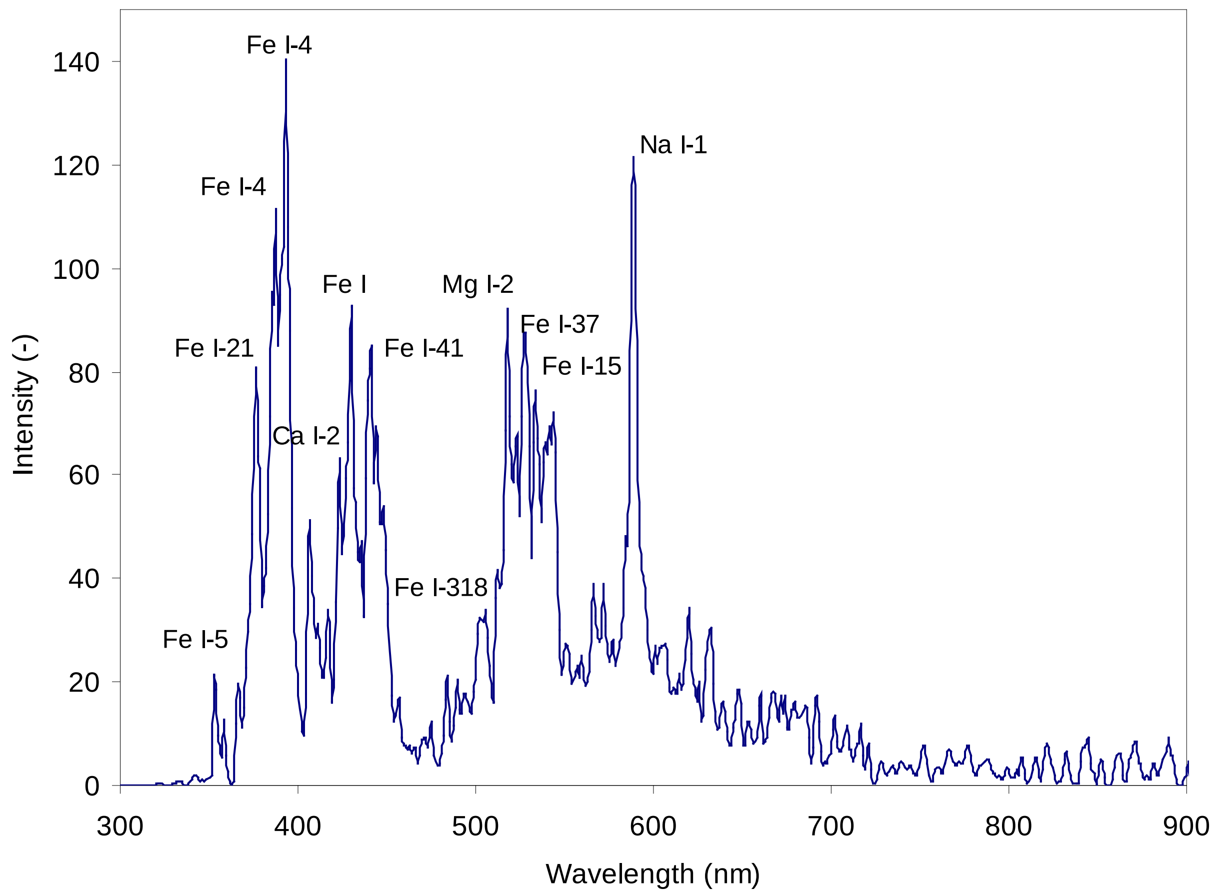
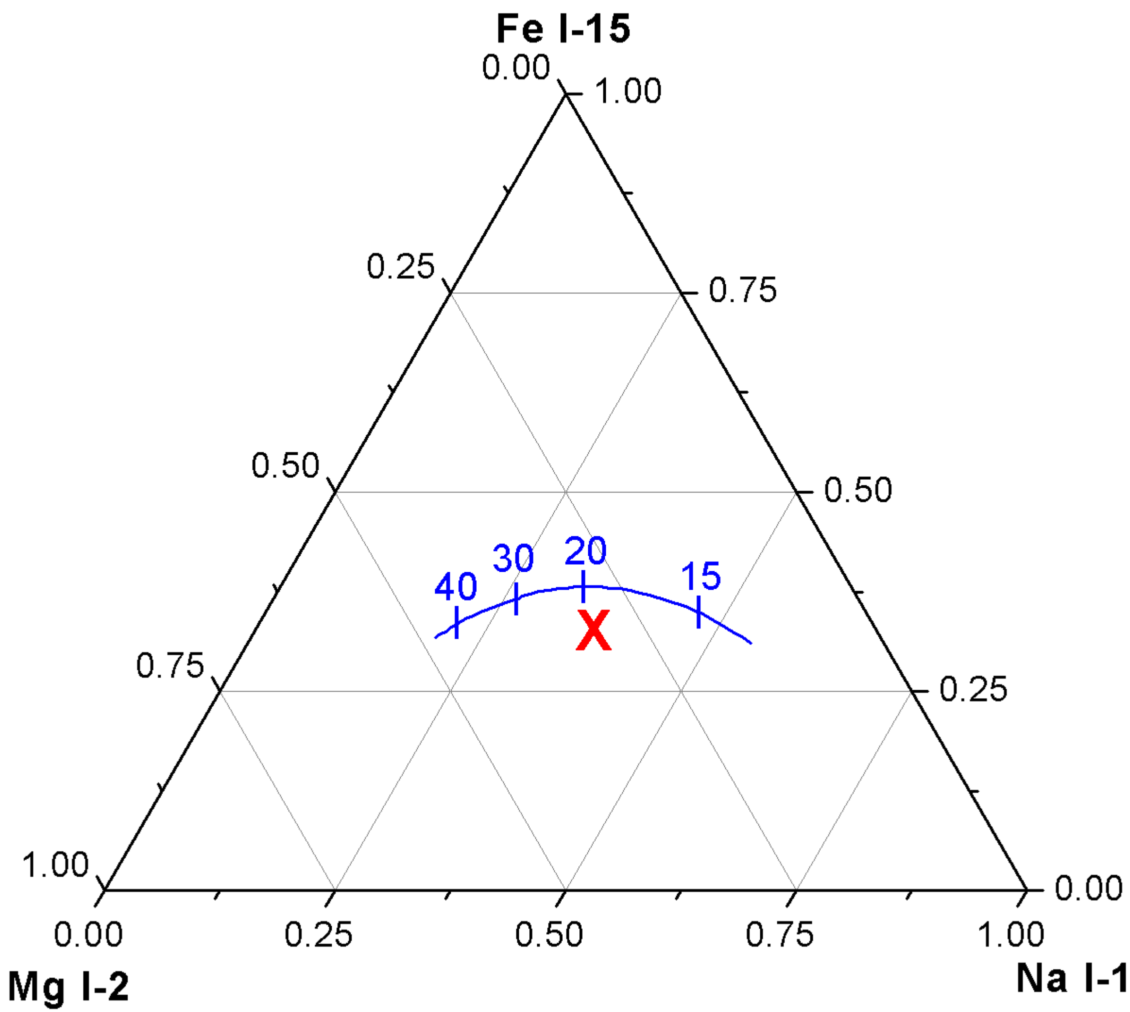




Results

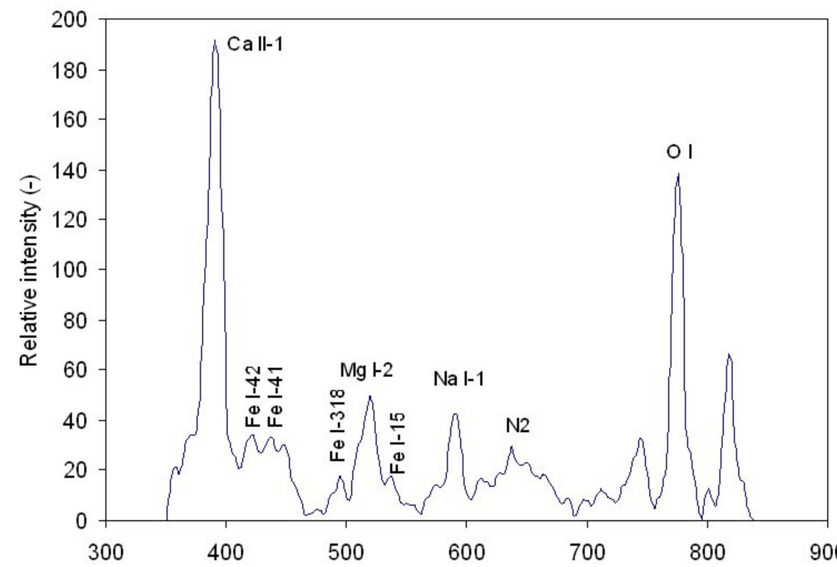
Northern γ-Virginids (NGV)

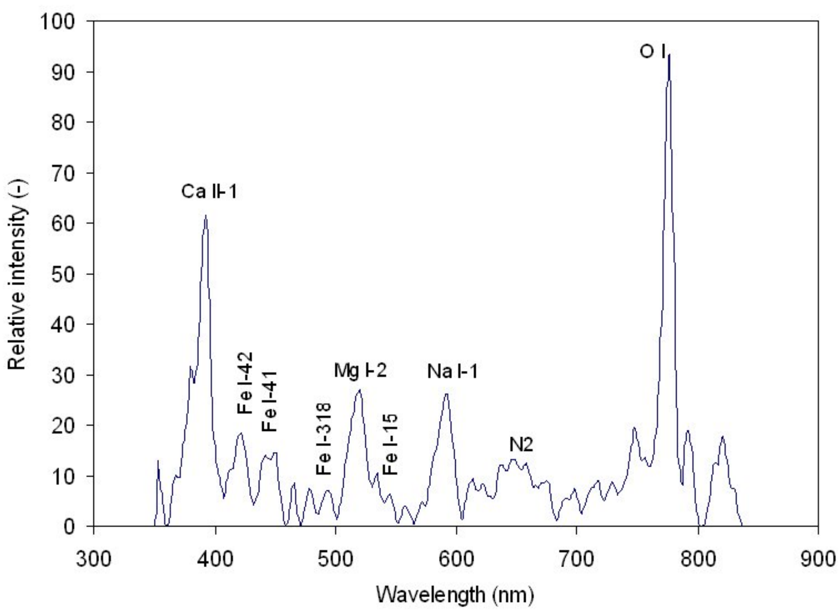
- ❑ V_{inf} ~ 18 km/s.
- ❑ Asteroidal (Tj=3.36).
- ❑ **Normal composition.**

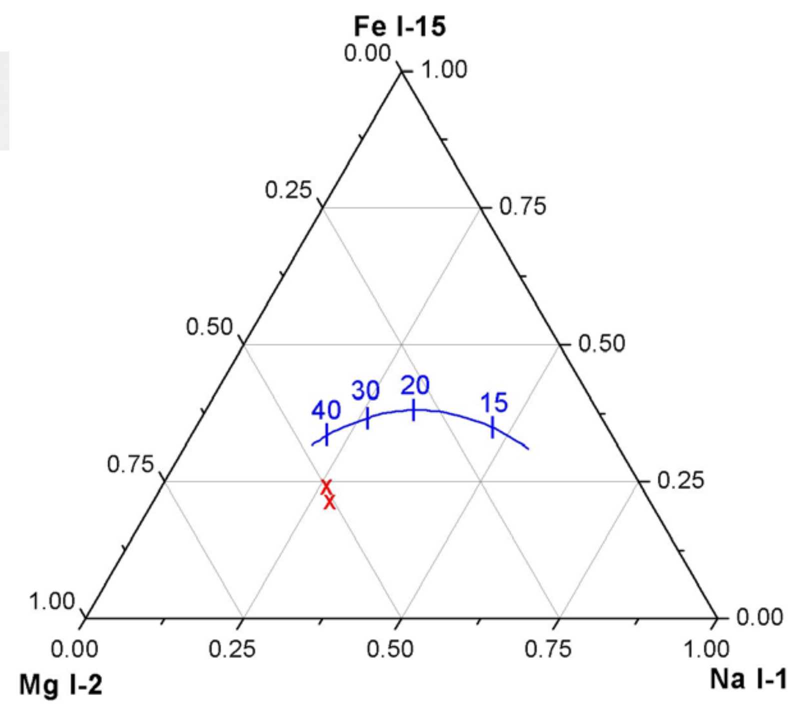


September ε-Perseids (SPE)

- V_{inf} ~ 66 km/s.
- Cometary stream (Tj=-0.7).
- **Normal composition.**







Conclusions

- 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