Fachgruppe Meteorastronomie

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Meteor Spectroscopy, calibration

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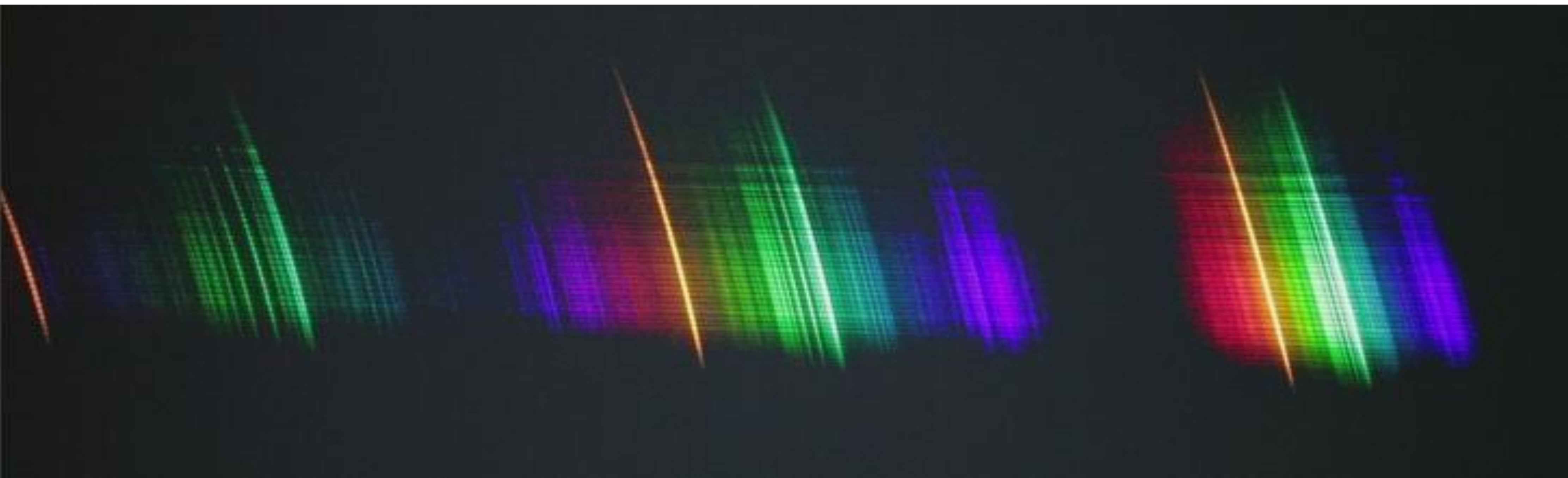
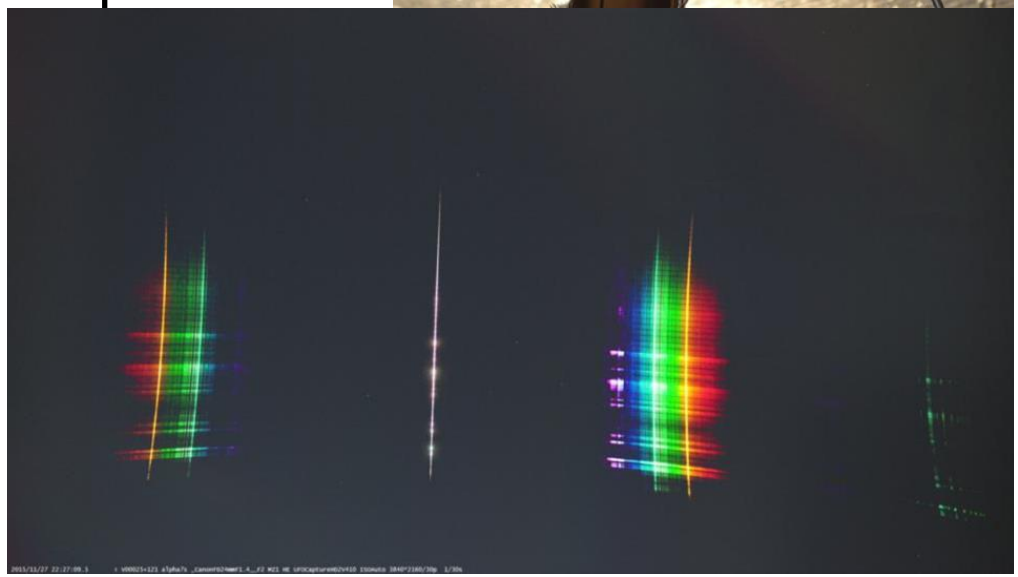


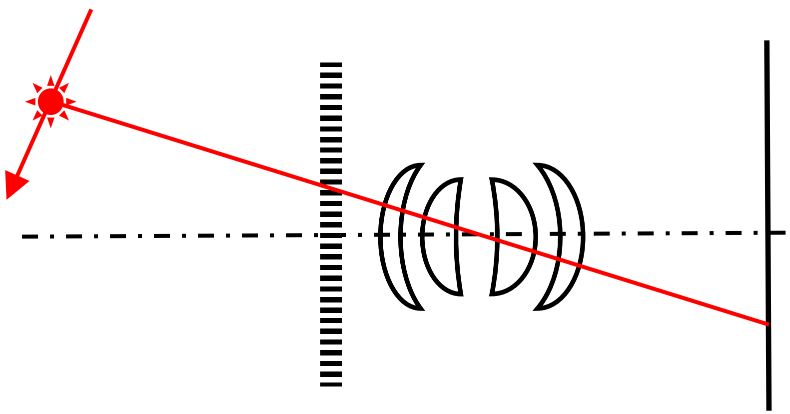
Content

- Wavelength calibration, linearization of spectra
- Processing and extraction of meteor spectra
- Instrument response, flux calibration
- Conclusions

Starting point

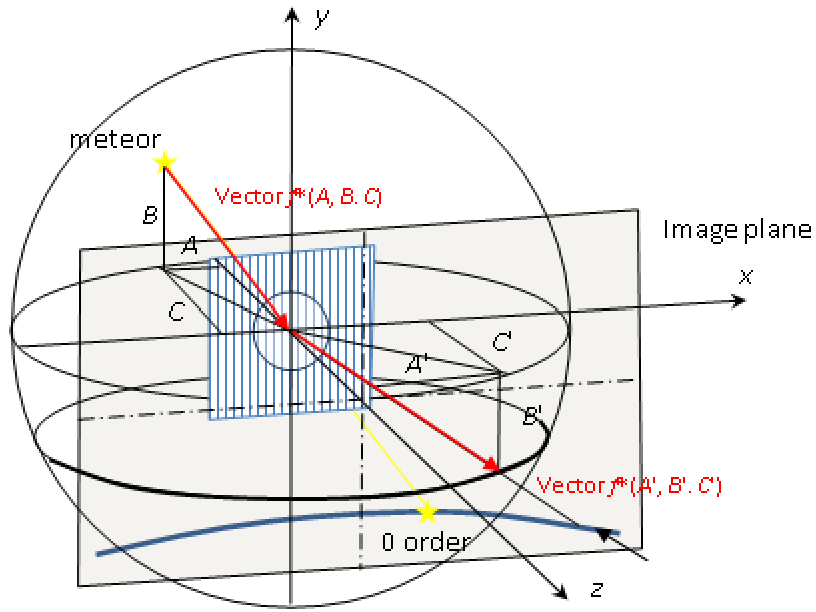
- Camera with wide angle lens
- Transmission grating
  - mounted perpendicular to optical axis!
- Problem:
  - Moving meteor
  - Curved spectra with nonlinear dispersion
  - Cannot be stacked





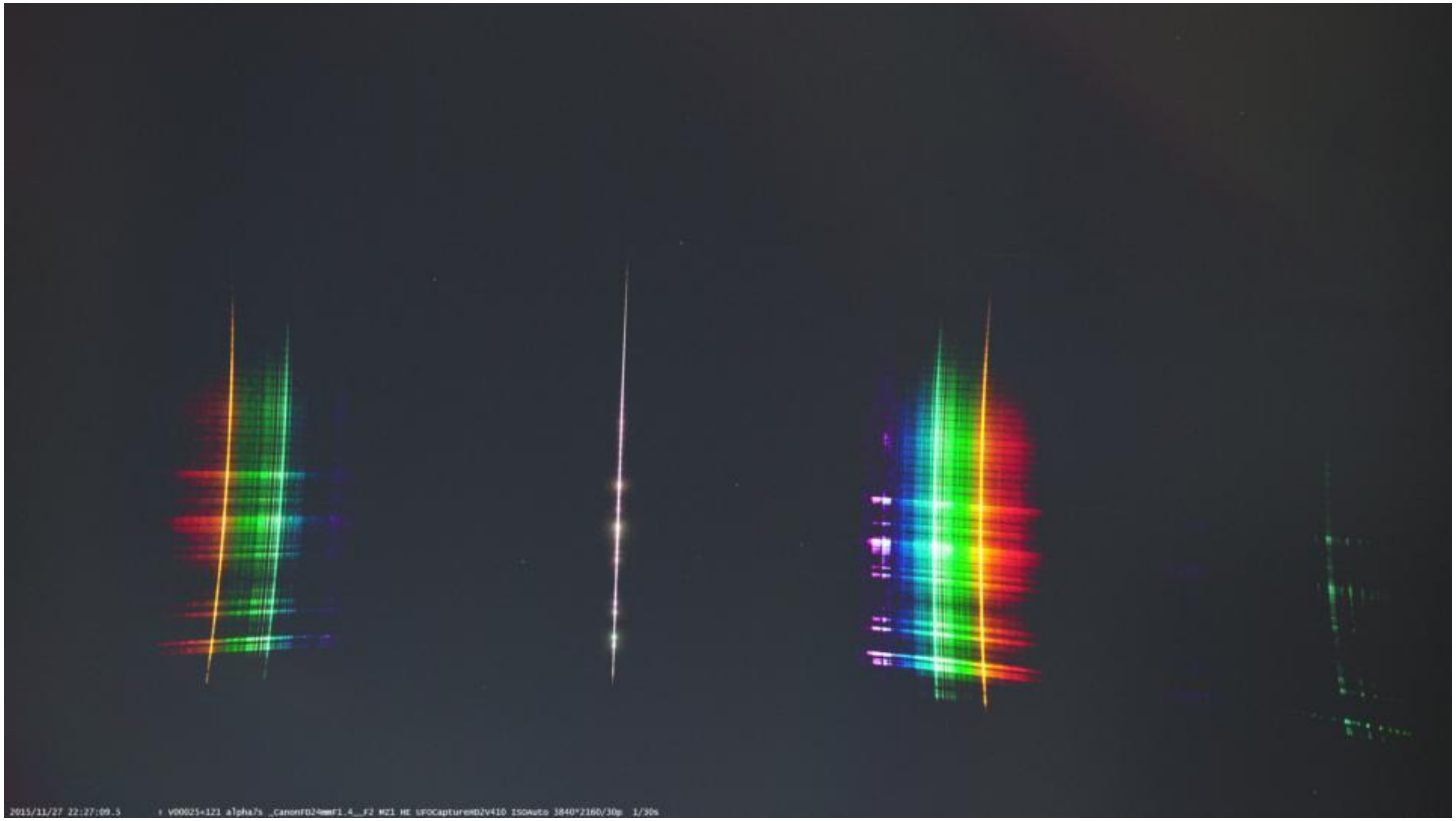
Vector notation, wavelength calibration*

- Grating perpendicular to optical (z-)axis, Rowland H. A. (1893),
- Unit vector (A B C) for incident direction
- Components of diffracted beam
  $A' = A + m\lambda G$ (x-axis)
  $B' = B$ (y-axis)
  $C' = \mathrm{sqrt}(1 - A'^2 - B'^2)$
- Spectrum on CCD plane
  – Nonlinear dispersion
  – Hyperbolic curvature
- Spectrum straight linear in A',B‘
- Rotational symmetry of transformation correction of lens distortion

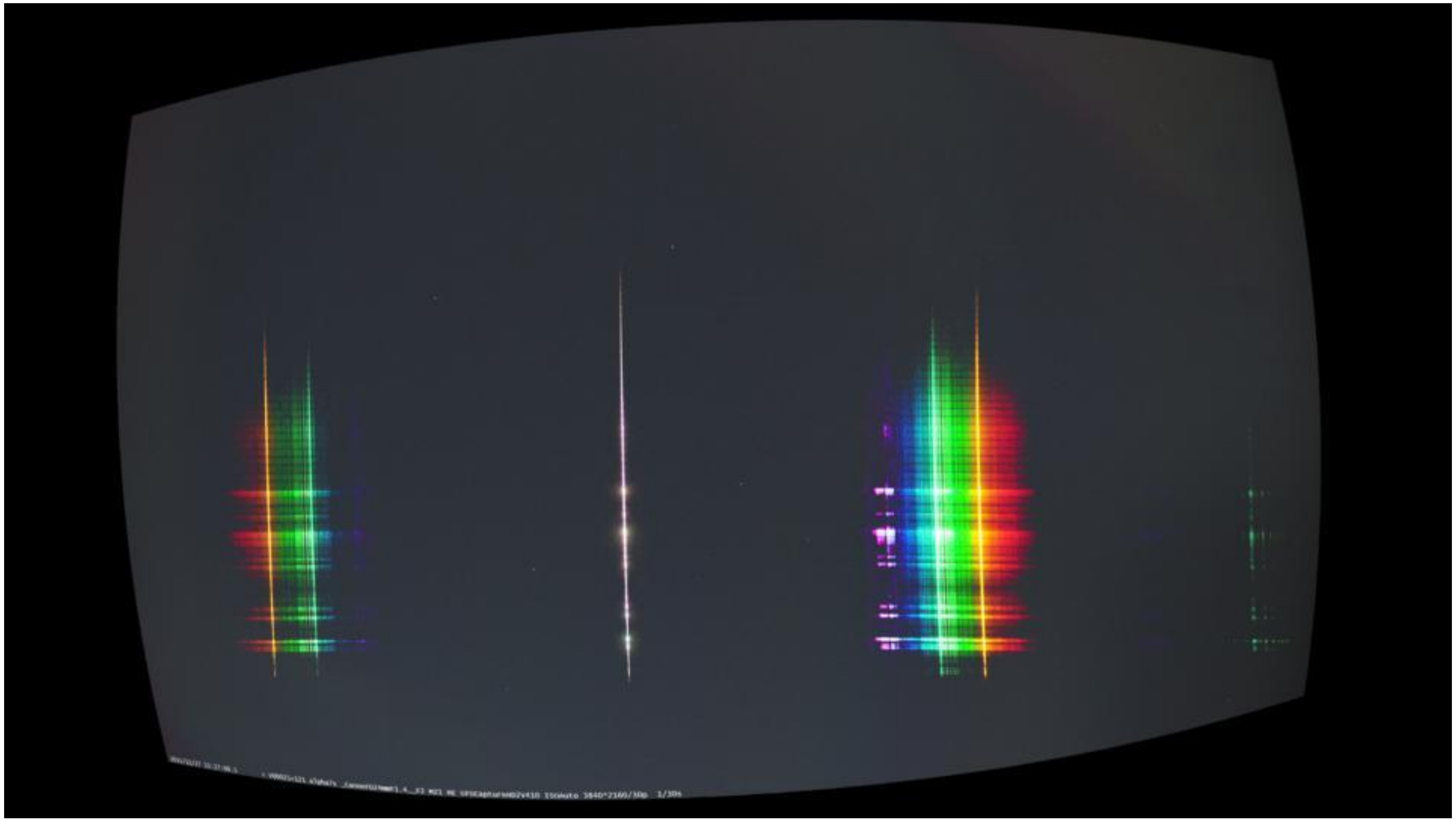


*Dubs, M. and Schlatter, P. (2015), A practical method for the analysis of meteor spectra, WGN, 43:4, p94

Image transformation, original

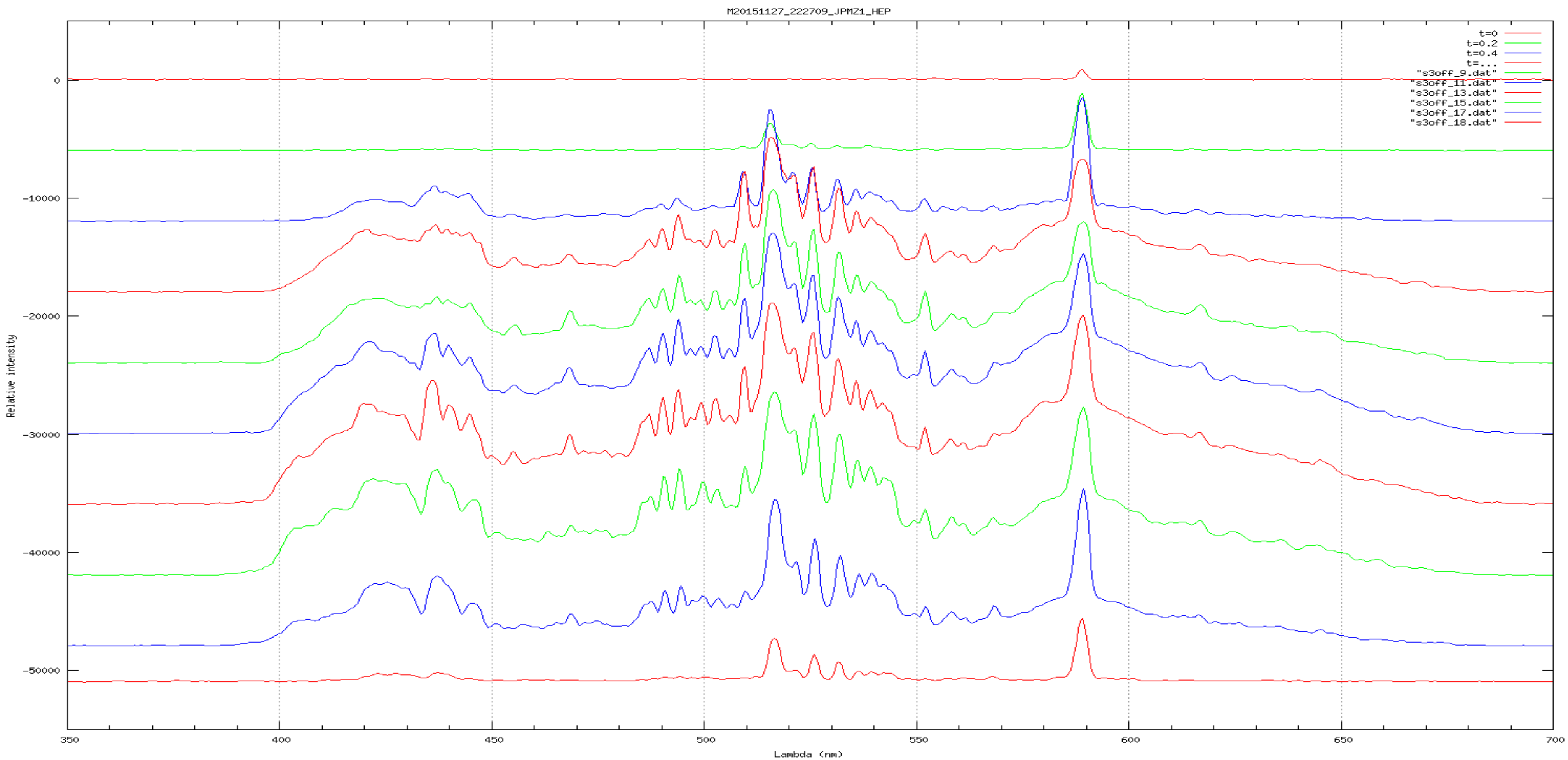


Orthographic projection, result



Extraction of spectra

- Use of standard spectroscopy software to extract spectra



Full processing

- Wavelength calibration √
- Flux calibration
  Correct for:
  - Background subtraction!
  - Vignetting, field of view
  - Correction for image transformation

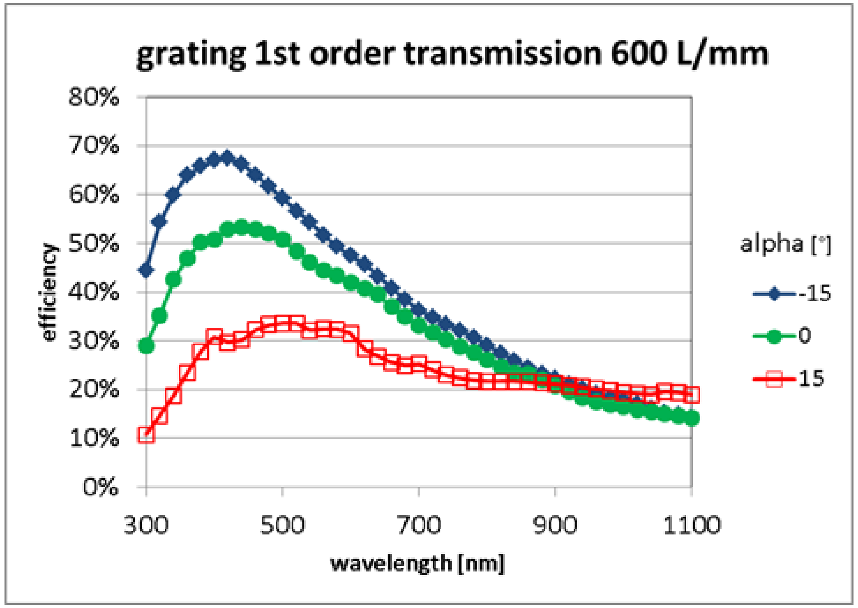
  } flat field correction in pre-processing

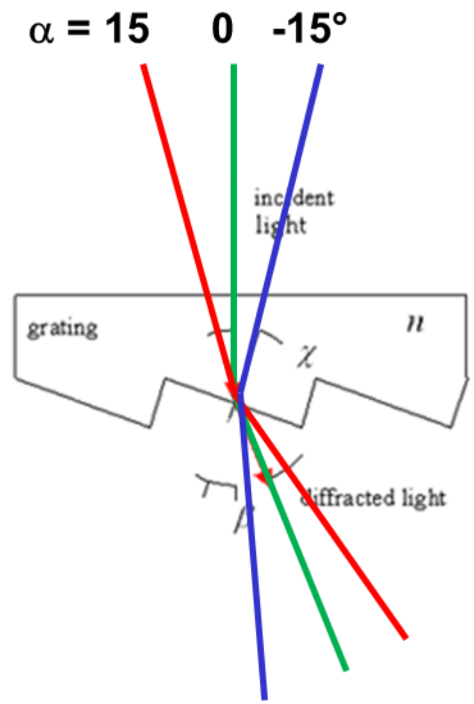
    - Apply image transformation
    - Extract spectrum, calibrate wavelength
- Instrument response
  - Grating efficiency
  - Camera spectral sensitivity (lens, CCD)
  - Atmospheric transmittance

  } instrument response

Instrument response, theory

- Grating efficiency, dependent on incidence angle:
  (Gsolver V4.20b, http://www.gsolver.com/)

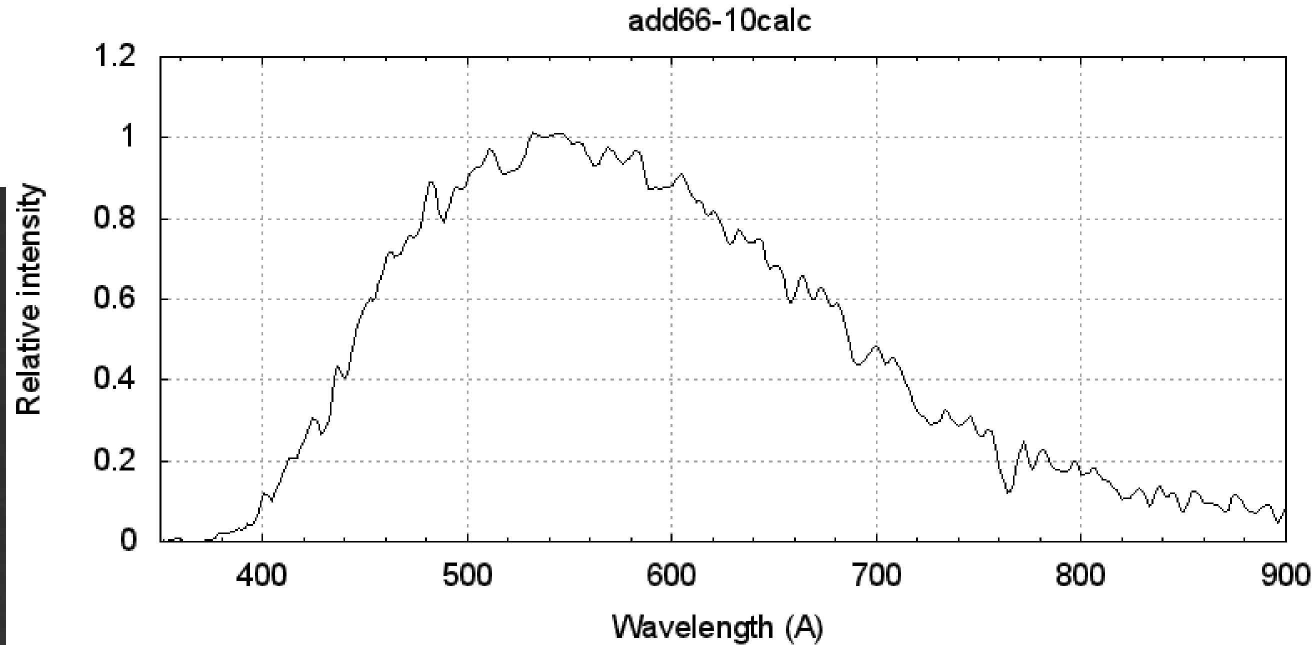


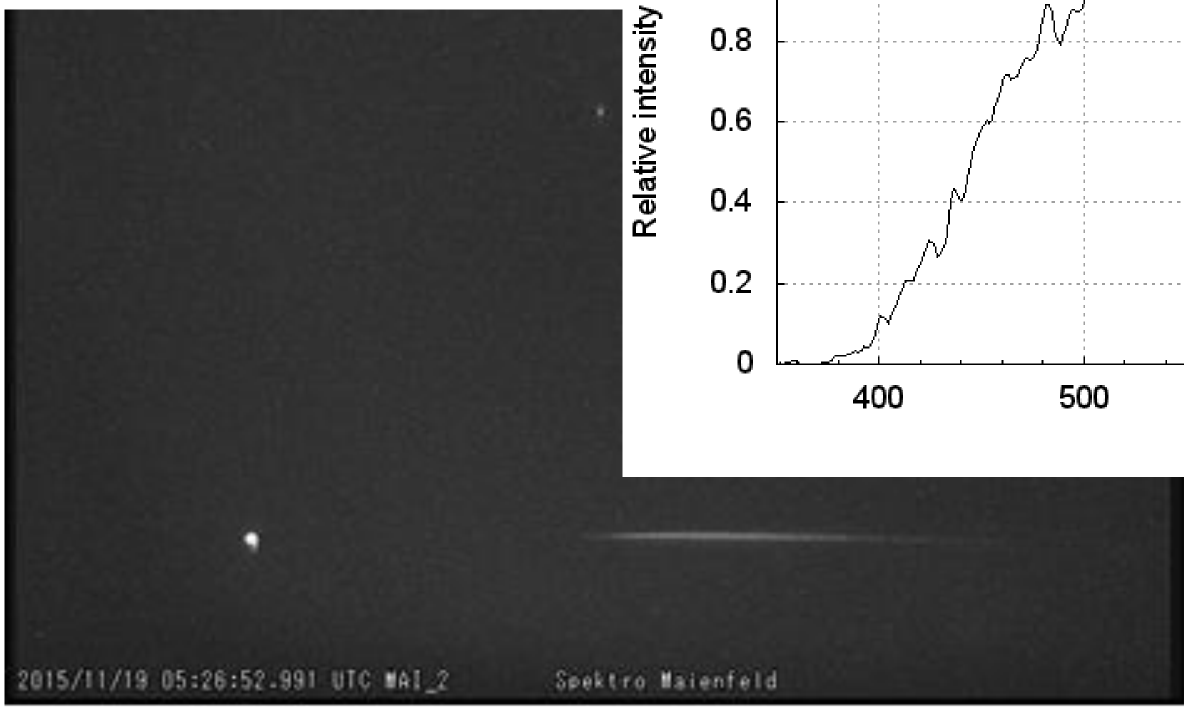


- CCD efficiency: quantum efficiency from manufacturer
  – Convert to flux by dividing by wavelength ($E = hc/\lambda$)
- Atmospheric transmission: $Ta(\lambda) \approx \exp[-\tau(\lambda)/\cos(z)]$

Measured reference spectrum

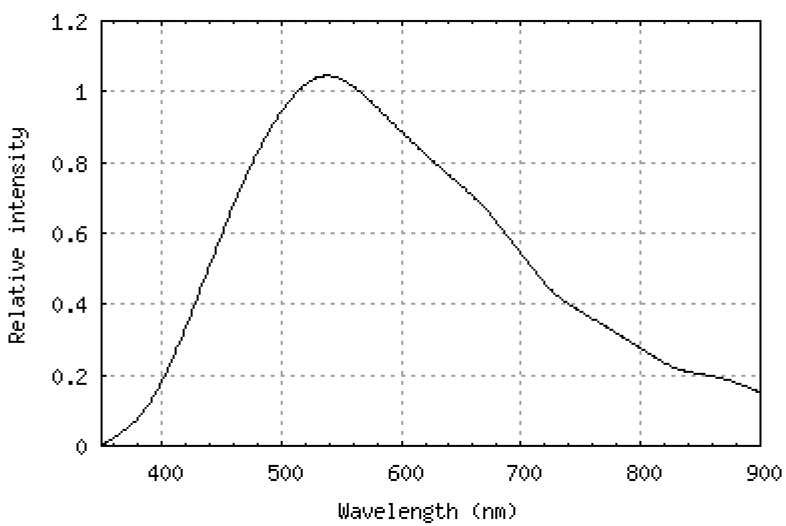
- Venus spectrum

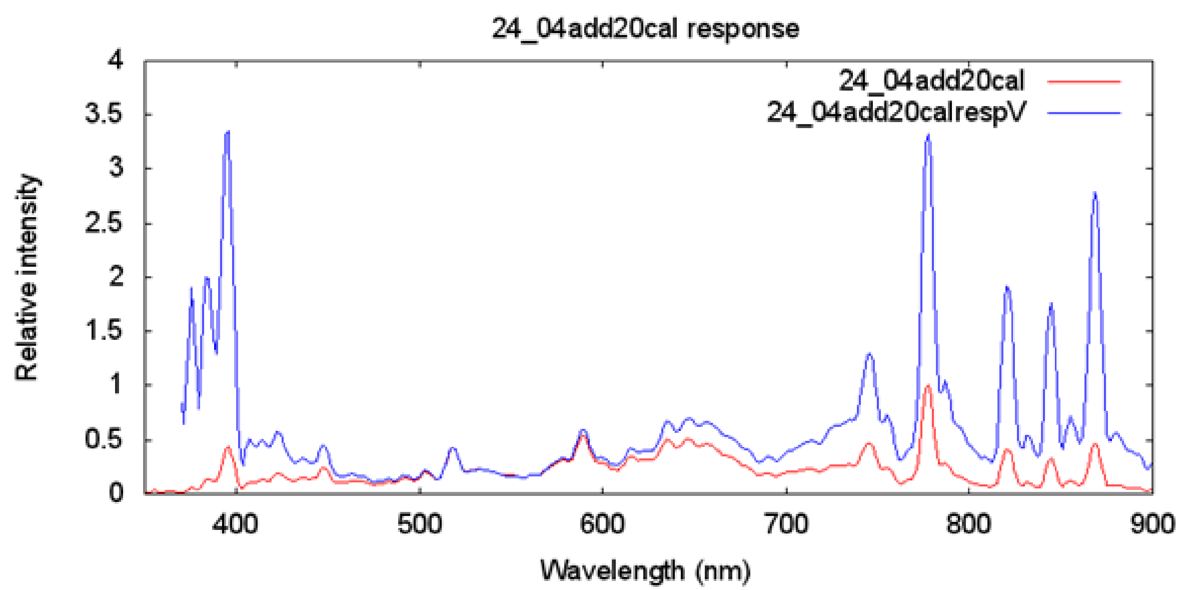




Instrument response

- Spectrum of known object (Venus, Sirius)
  - IR(λ) = measured spectrum(λ) / flux calibrated reference spectrum(λ)
- Meteor spectrum, wavelength calibrated → flux calibrated spectrum
  - Flux calibrated spectrum(λ) = meteor spectrum(λ) / IR(λ)





Conclusion

- Grating mounted perpendicular to camera axis
- Image transformation gives linear spectra!
- Precise flux calibration depends on many factors, approximations used
- Looking for low cost, sensitive, high resolution, high dynamic range video camera
- Full format colour camera (e.g. Sony)
  - \+ Color → easy interpretation
  - \+ Orders can be separated
  - \+ High resolution
  - – Bayer matrix lower sensitivity
  - – Difficult to analyse (Instr. Resp.)
  - – cost
- Video camera (e.g. Watec)
  - \+ High sensitivity
  - \+ Spectral range
  - \+ Low cost
  - – Small field of view or
  - – Low spectral resolution
  - – Overlapping orders

Spectrum recording and processing software

- UFO Capture for trigger and record video (http://sonotaco.com/e_index.html)
- IRIS and ISIS (http://www.astrosurf.com/buil/us/iris/iris.htm) astronomical image processing and spectroscopy software
  - Both by Christian Buil
- ImageTools by Peter Schlatter (private communication)

Links

- Linear calibration: http://arxiv.org/abs/1509.07531 or http://www.meteorastronomie.ch/images/Meteor_Spectroscopy_WGN43-4_2015.pdf

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- FMA (division of Swiss (Amateur) Astronomical Society) for data, discussion
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  - Network of stations (Photo, Video, All sky fireball detection, Radio, Seismic), complementing Spectroscopy
  - Linked with EDMOND database
- Peter Schlatter (Image tools)

Thank you!