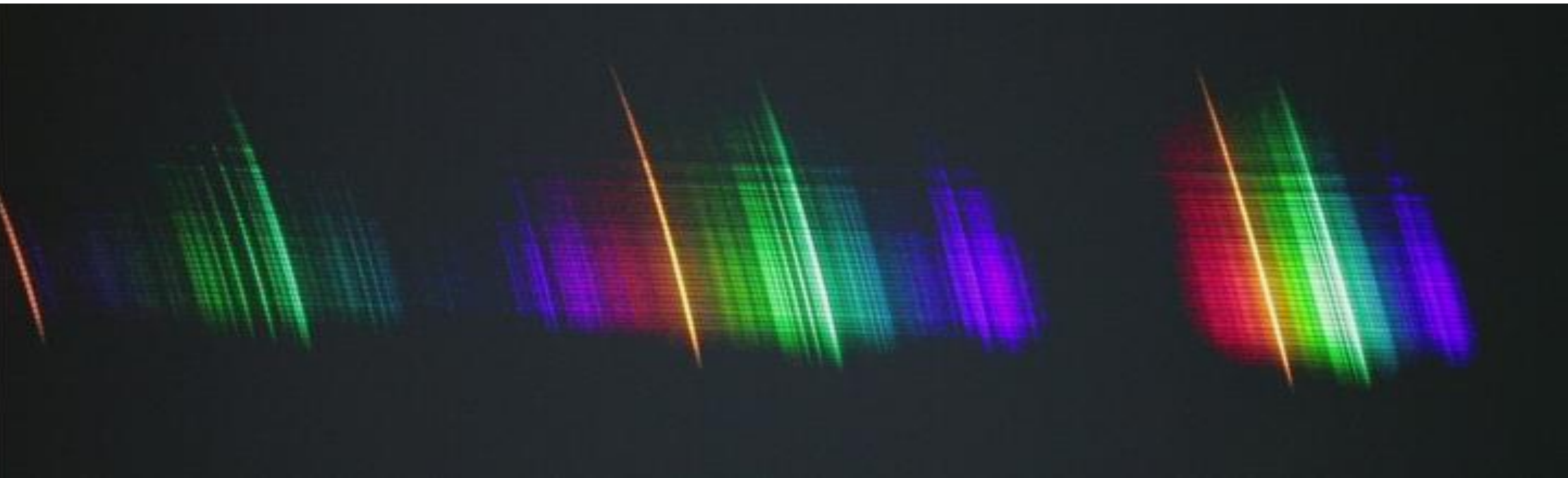
Fachgruppe Meteorastronomie

Meteor Spectroscopy, 2016

Martin Dubs, images by Koji Maeda

SAG, FMA

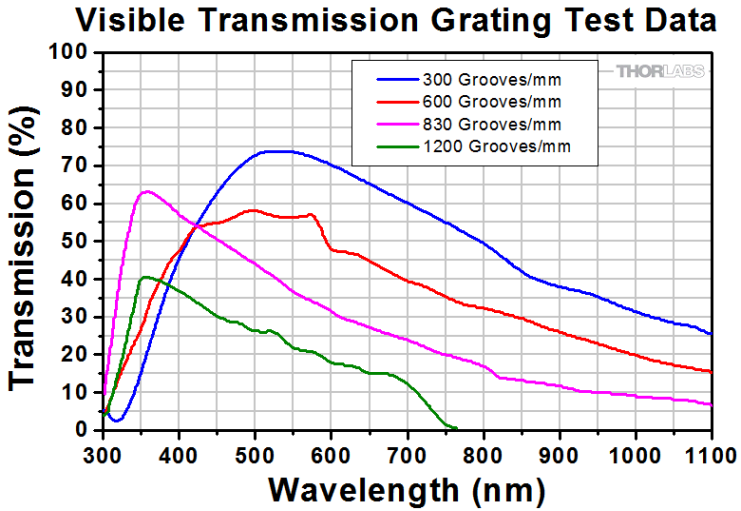


Inhalt

- Meteorspectroscopy
  - Hard- Software
  - Wavelength calibration
  - Spectrum extraction
  - Instrument response
  - Summary

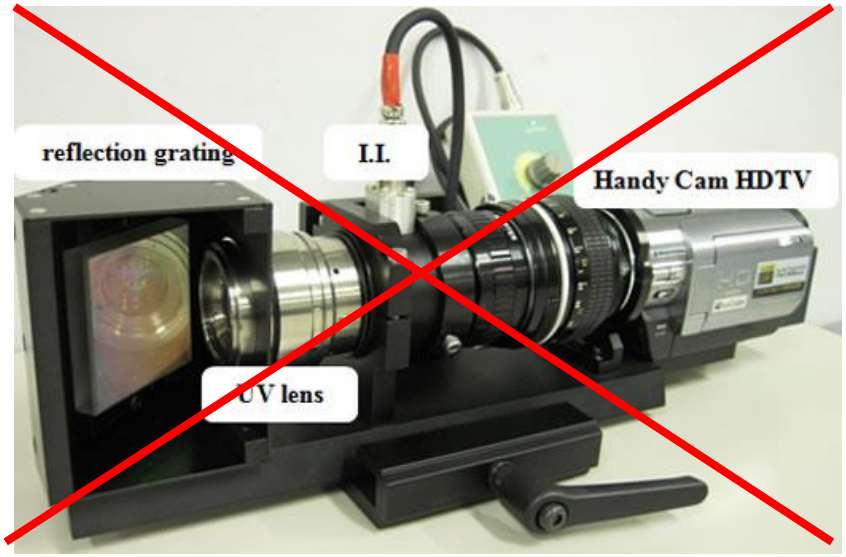
Hardware

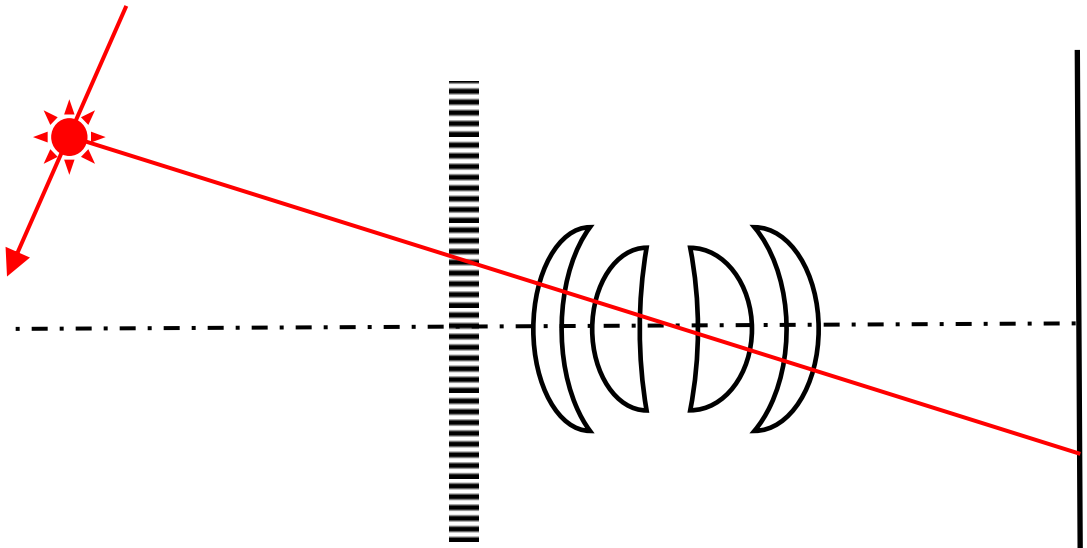
- Watec 902H2 ult. Computar HG2610AFCS-HSP F/1 2.6mm fl
- 902H2 ultimate (spectroscopy) Tamron 12VG412ASIR F/1.2, ≈7mm fl
- 2nd camera with transmission grating for spectroscopy
  Thorlabs
  300 L/mm → 600 L/mm

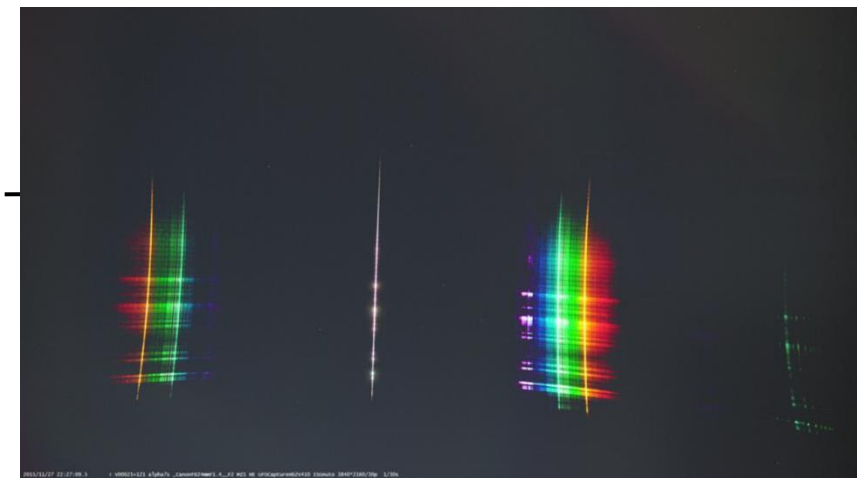


Grating in front of lens

- 300 – 600 L/mm transmission grating
- Grating perpendicular to optical axis!







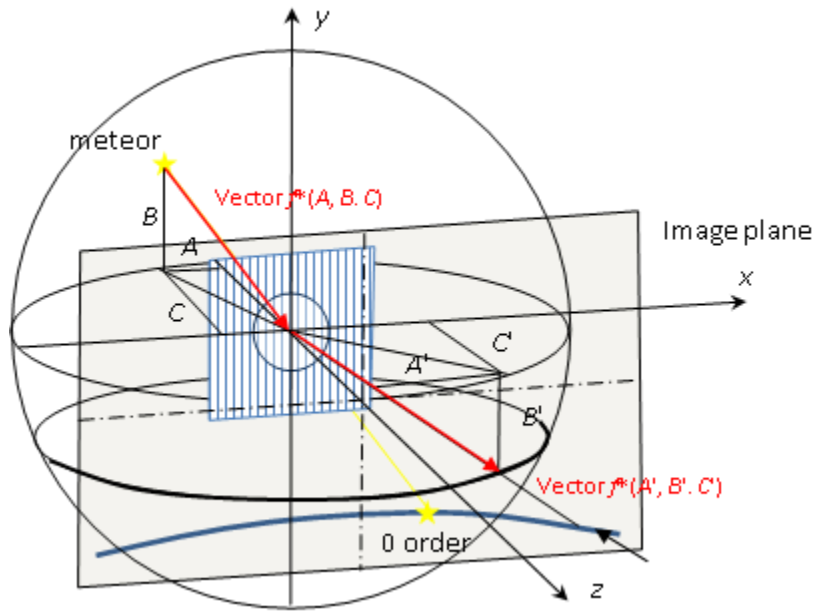
Vector theory wavelength calibration

- Grating in front of lens perpendicular to optical (z-)axis
- Unit vector (A B C) for incident direction
- Diffracted beam

  $A' = A + m\lambda G$ *(x-axis)*

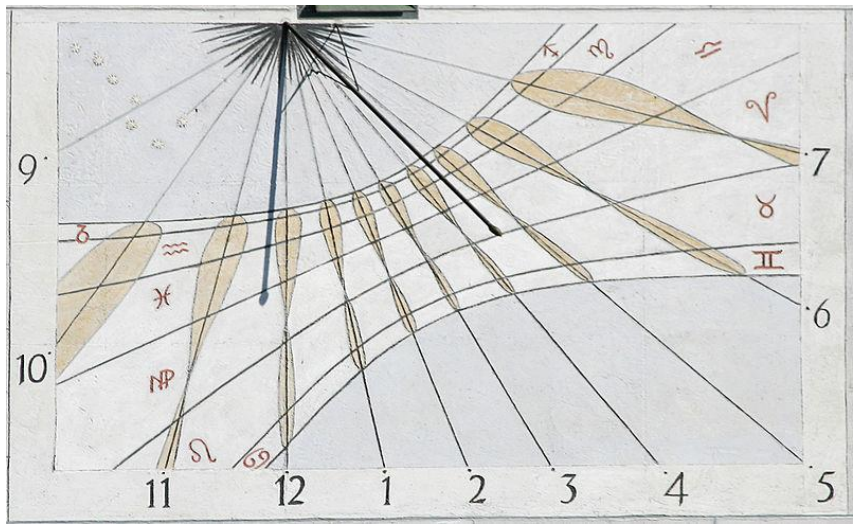
  $B' = B$ *(y-axis)*

  $C' = \mathrm{sqrt}(1 - A'^2 - B'^2)$
- Spectrum on CCD plane
  - Nonlinear dispersion
  - Hyperbolic curvature
- Spectrum straight linear in A',B'

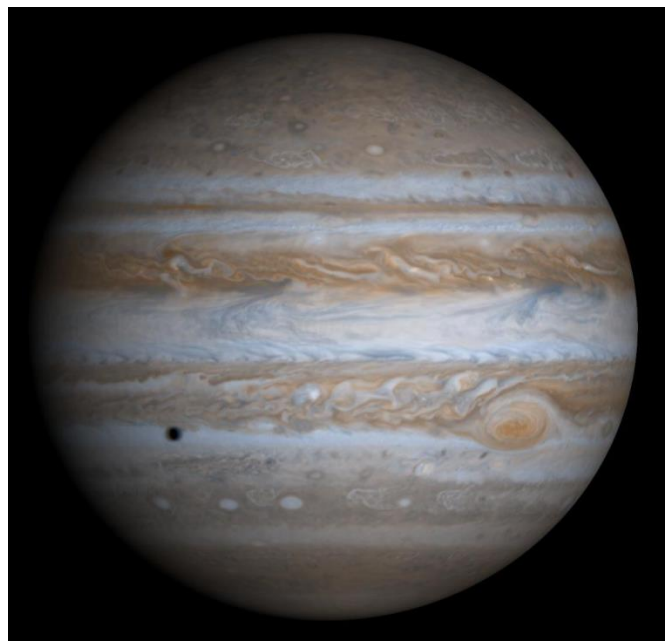


Gnomonic and orthographic projection

- Gnomonic, TAN
  - R = f*tan(ρ)
  - Great circles → straight
  - Optimum for path, radiant
  - Latitude circles → hyperbola



- Orthographic, SIN
  - R = f*sin(ρ)
  - Great circles →ellipses
  - Latitude circles → straight
  - Optimum for spectroscopy

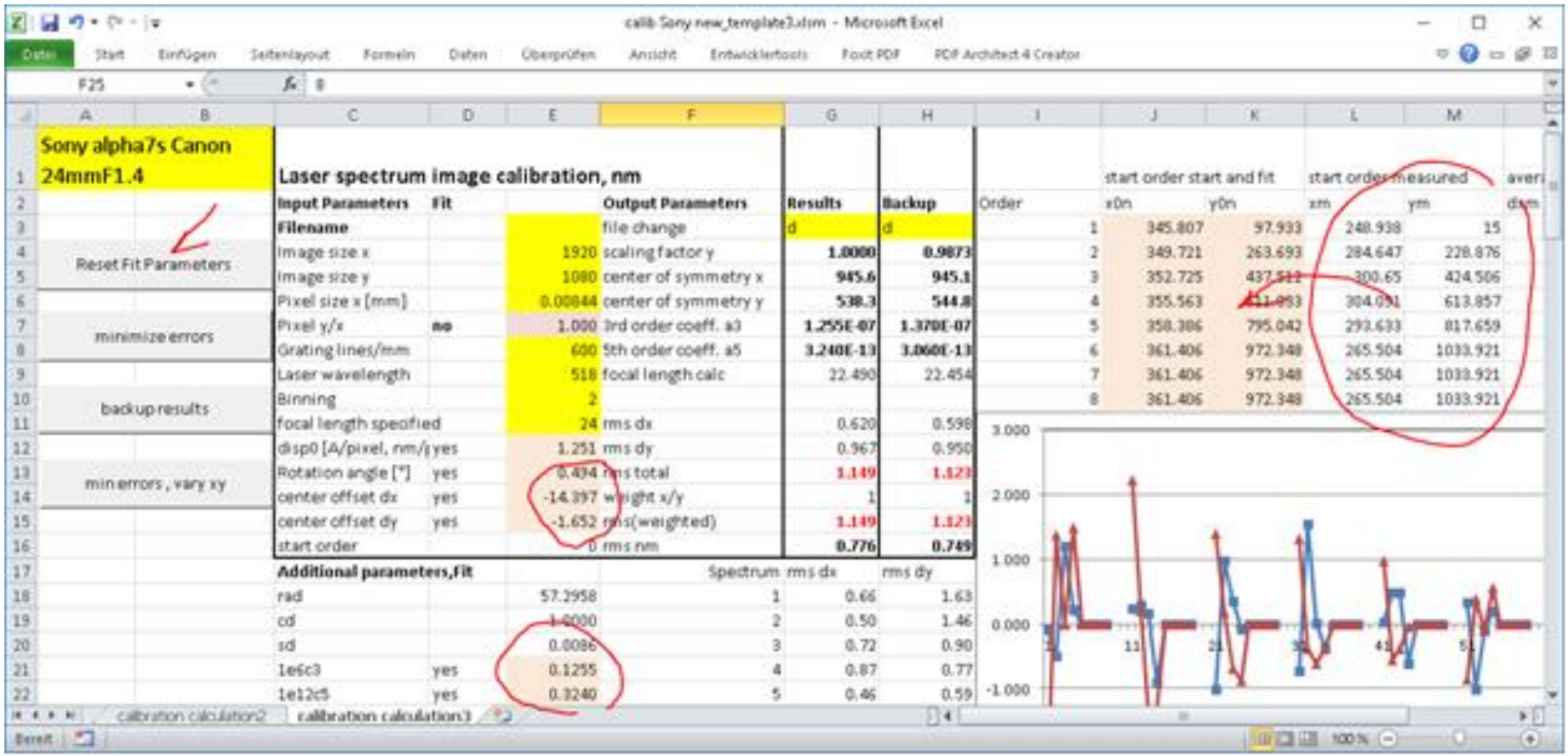


Calibration image

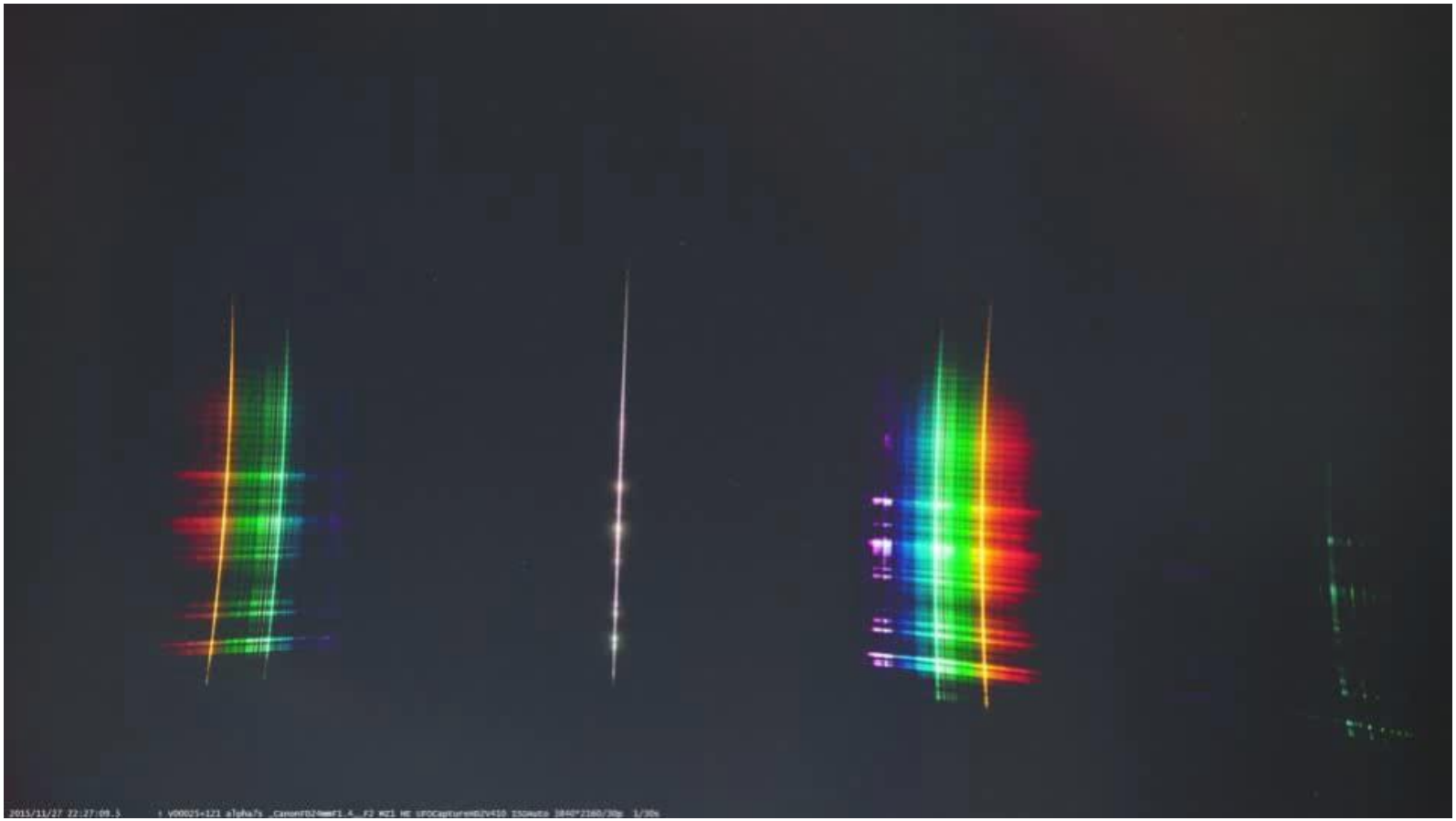
- Watec 902 H2 ultimate
- Tamron 12VG412ASIR,
- grating 600 L/mm
- Violet laser 405 nm

Calibration

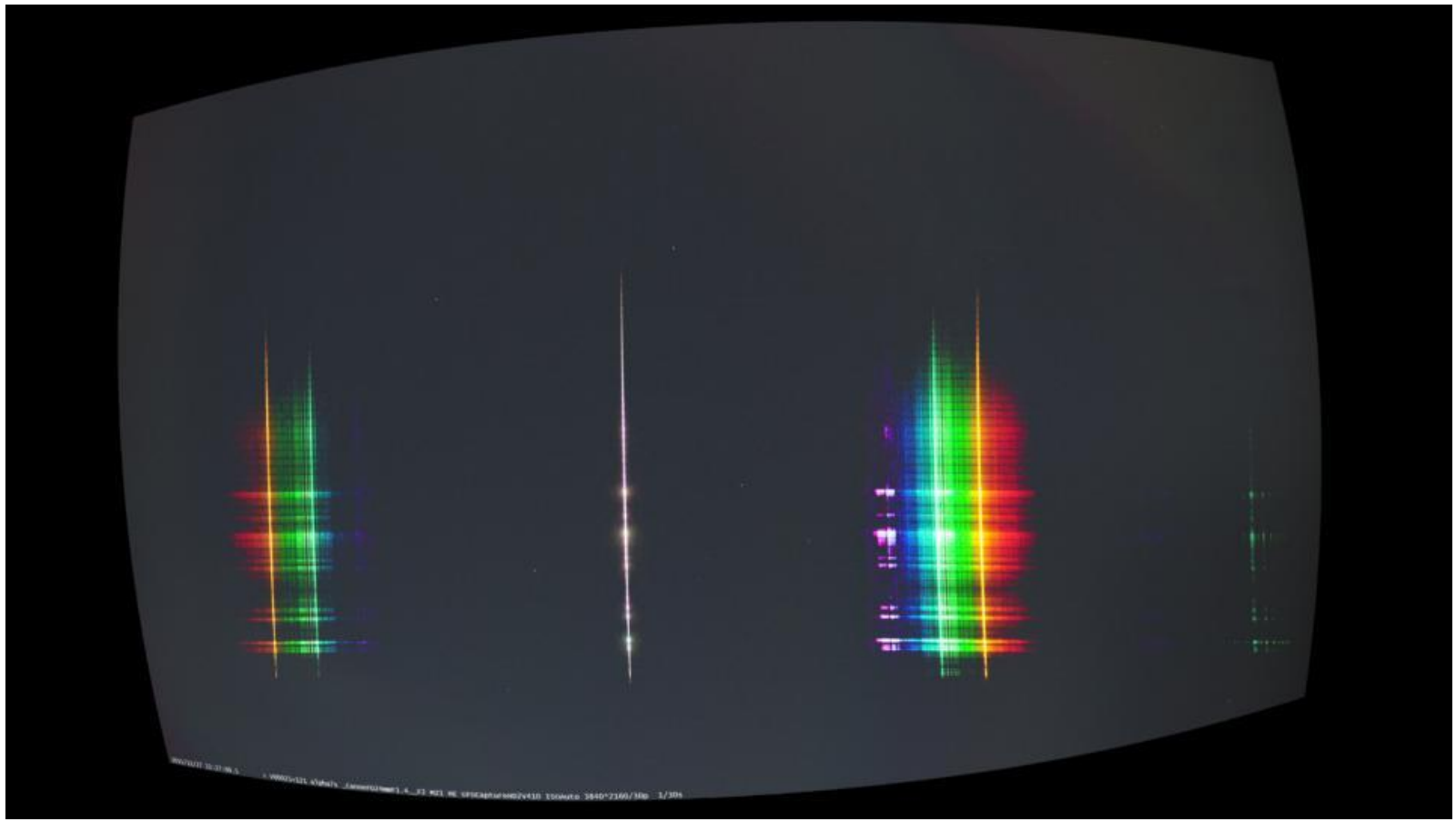
- EXCEL worksheet



Orthographic transformation (1st price IMC)

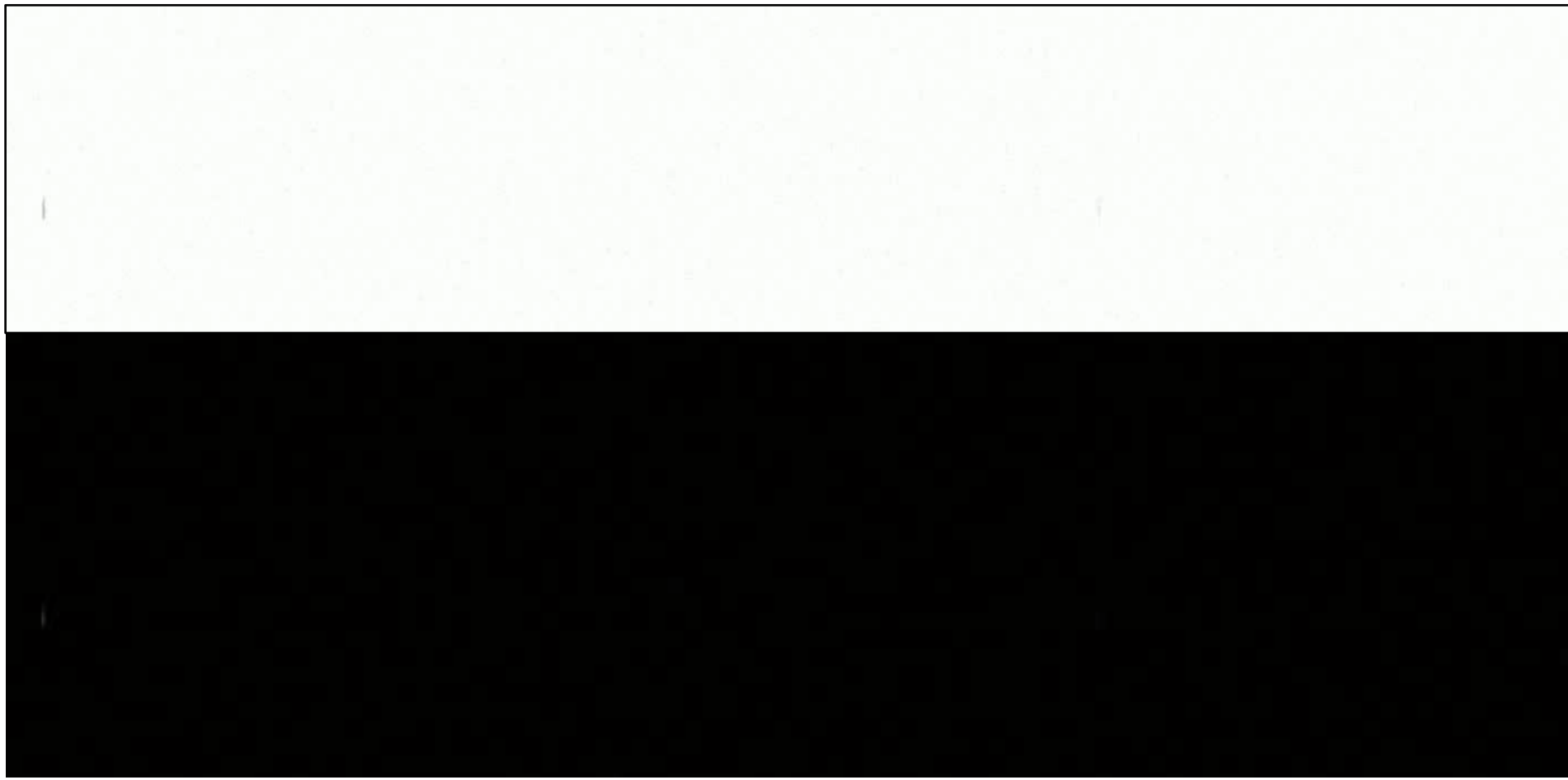


Orthographic transformation, result



Orthographic transformation, result

- Frames converted to b/w, linearized,registered, M20151127_222709
- color



Full processing

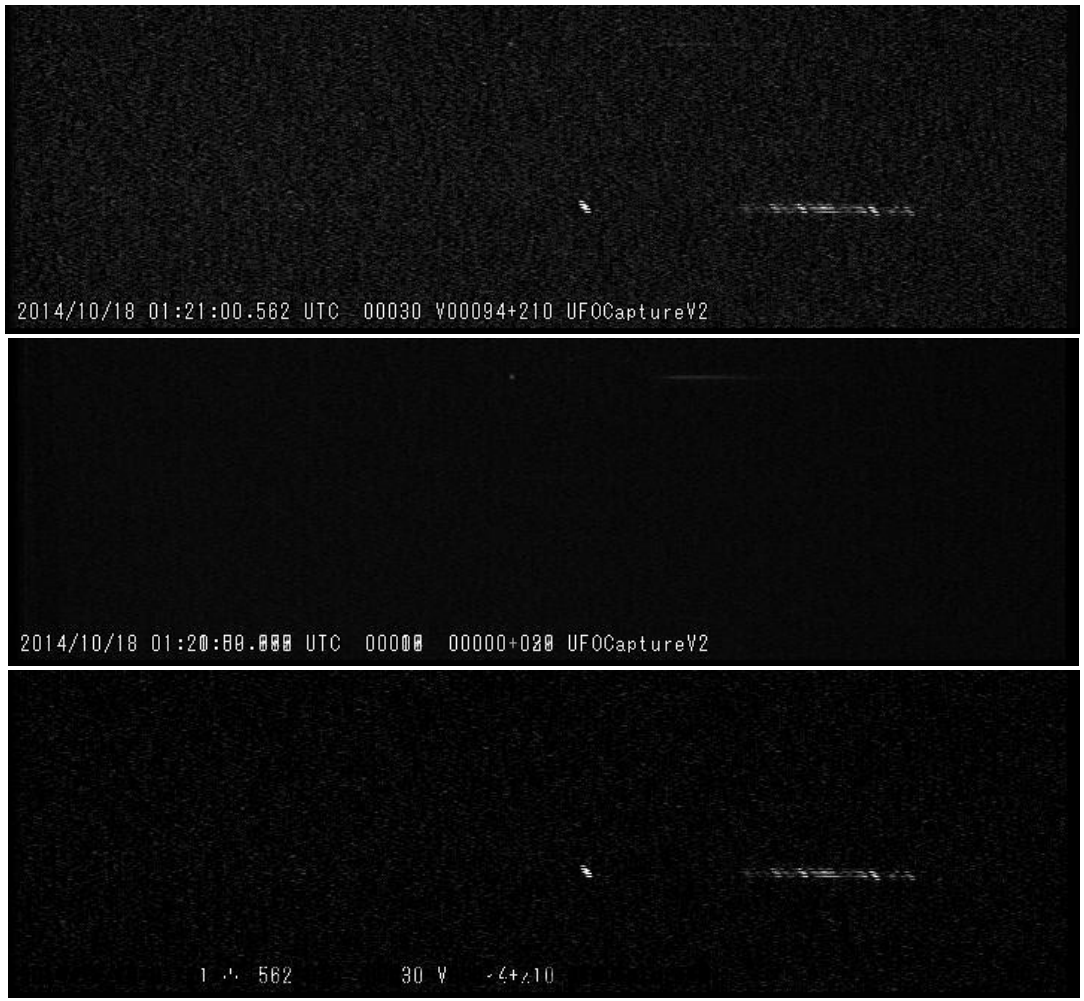
- Lens calibration √
- Preprocessing
  - Extract images from video
  - Background subtraction!
  - Vignetting, field of view
  - Correction for image transformation

  } 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

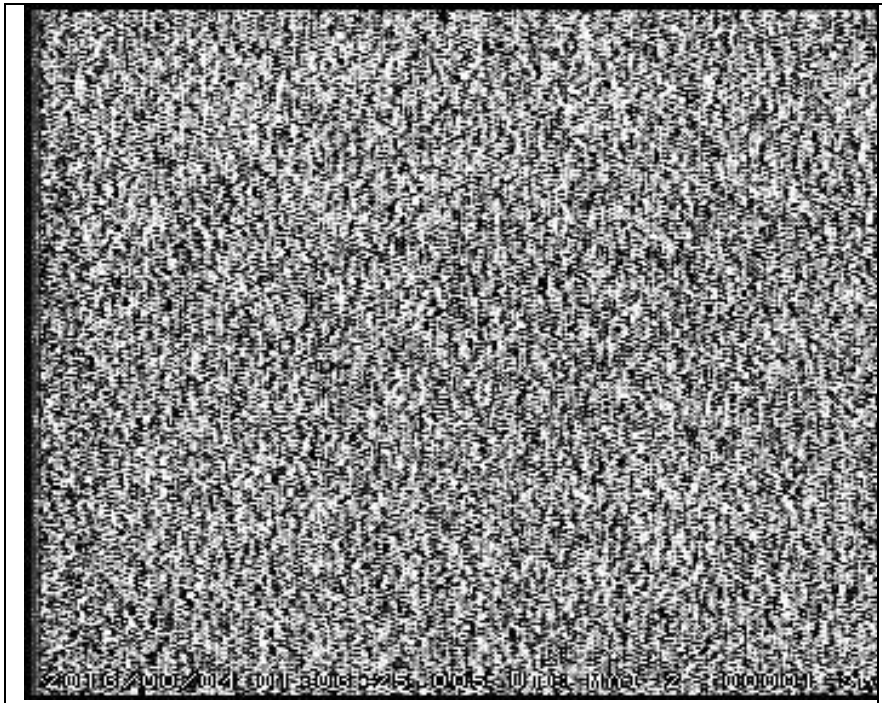
Preprocessing

- Extract image (i30)
- Background (ADD_MEAN) better: ADD2 MULT < I1 … I20 >
- Subtraction SUB2

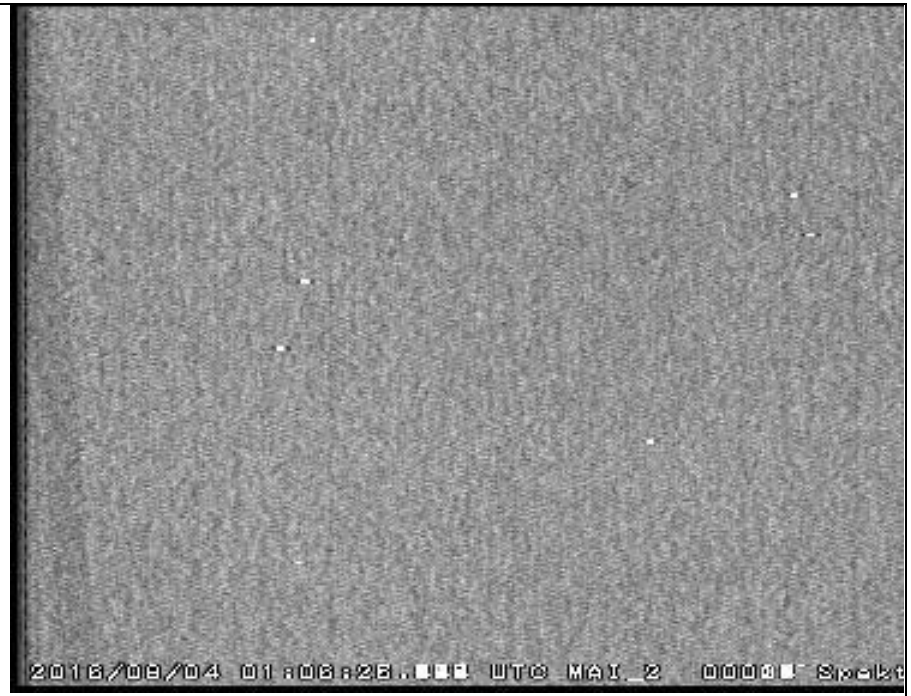


Preprocessing new

- RUN M_BACK: create background image
- RUN M_ DARK: subtract background



M_1 visu 10 0 sigma = 4.4 ADU



Back visu 10 0 sigma = 0.75 ADU, some stars, hot pixels visible

Flat field

- Border not illuminated, same f-stop as meteor recordings (Nikon)

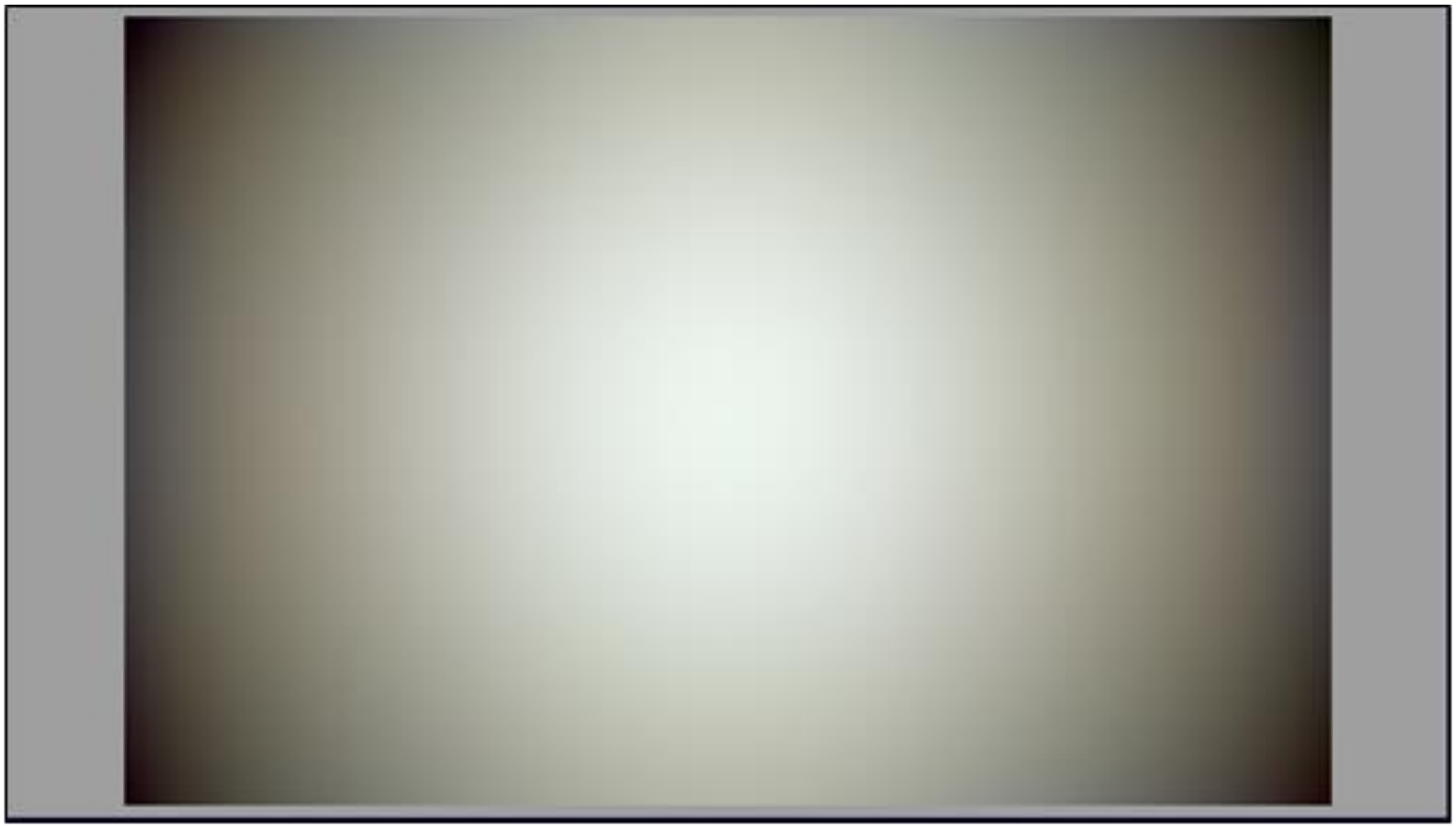
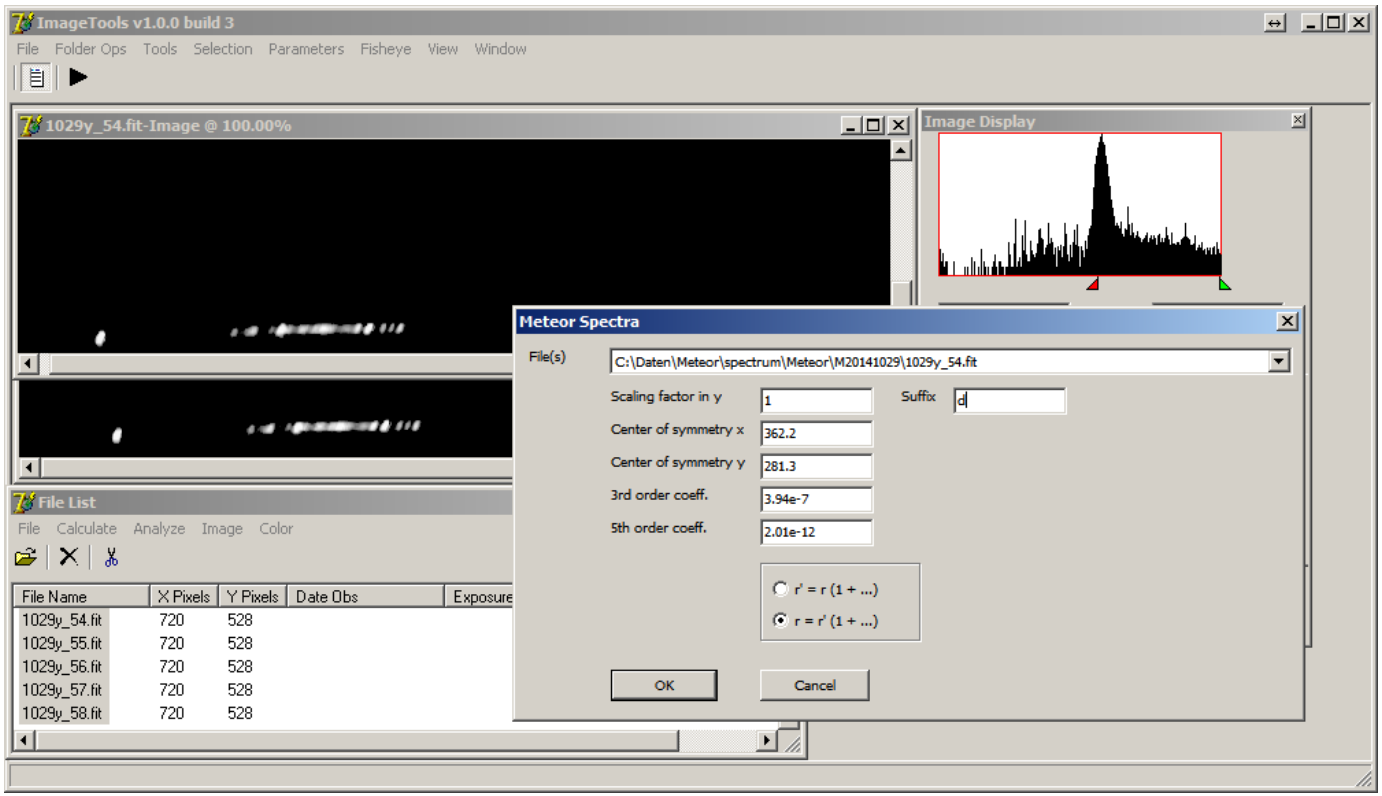
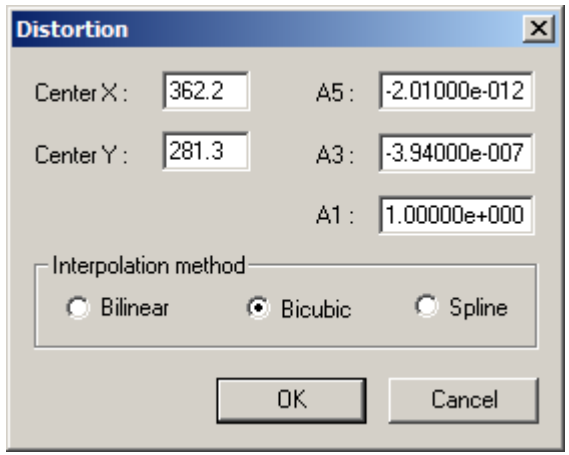


Image transformation

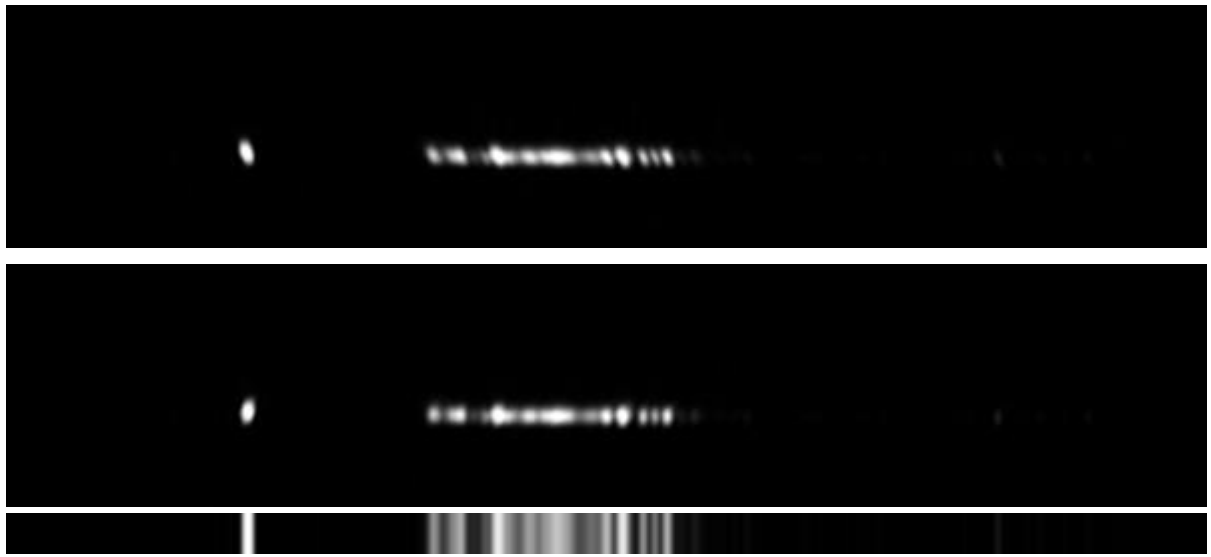
- Transformation to square pixels
- Transformation to orthographic projection IRIS → ImageTools →



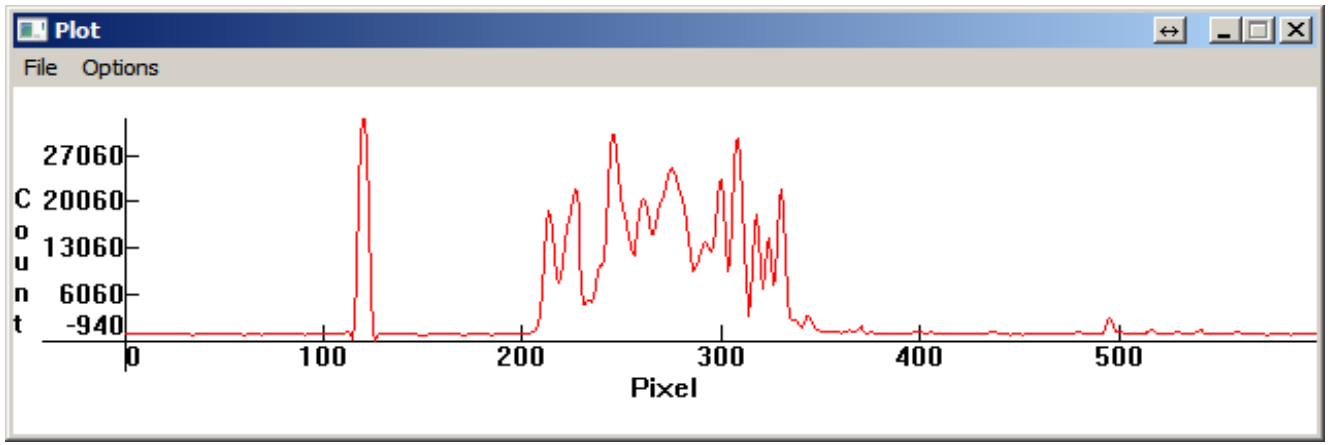


Processing 2, stacking

- REGISTER
  ADD2
  d1-15

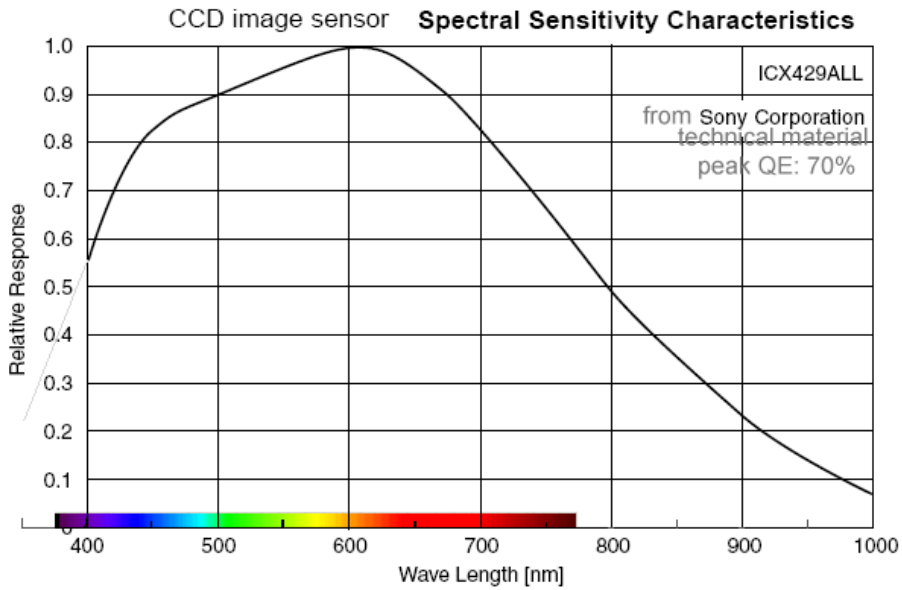


- SLANT 472 24
- L_ADD
- L_PLOT
  save file.dat



Instrument response

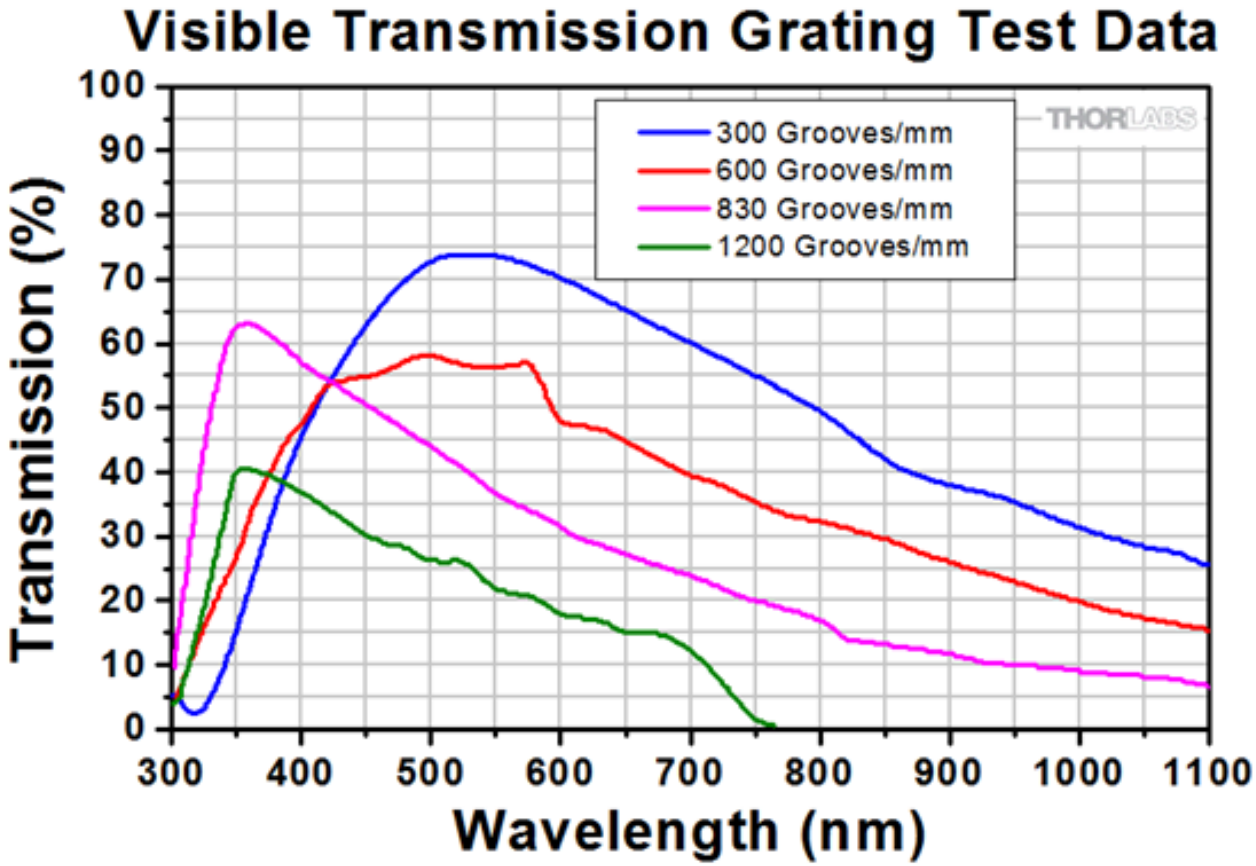
- Correction of
  - Camera spectral sensitivity (CCD, lens transmission)
  - Grating efficiency
  - Atmospheric transmission



ICX429ALL: Watec 902H2ultimate

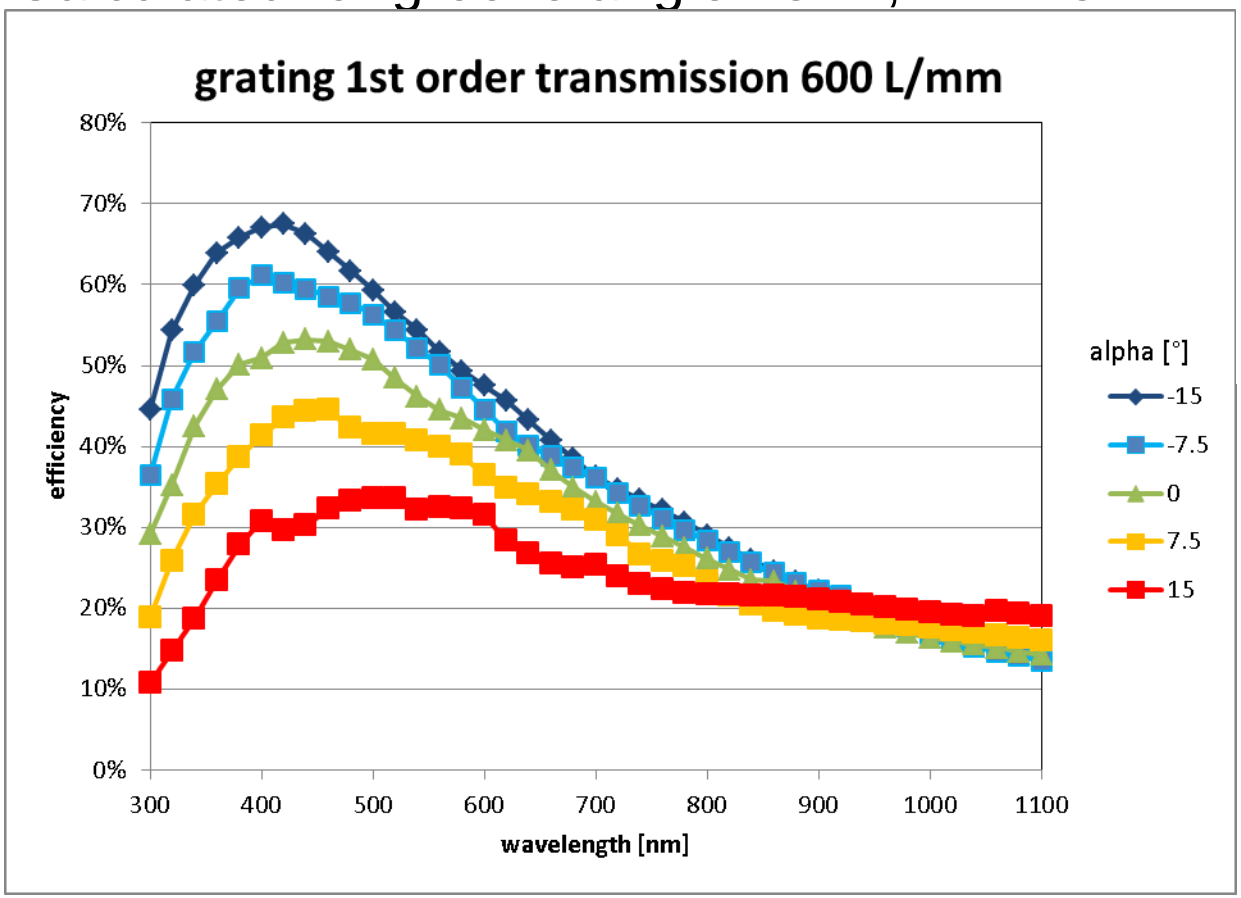
Grating efficiency

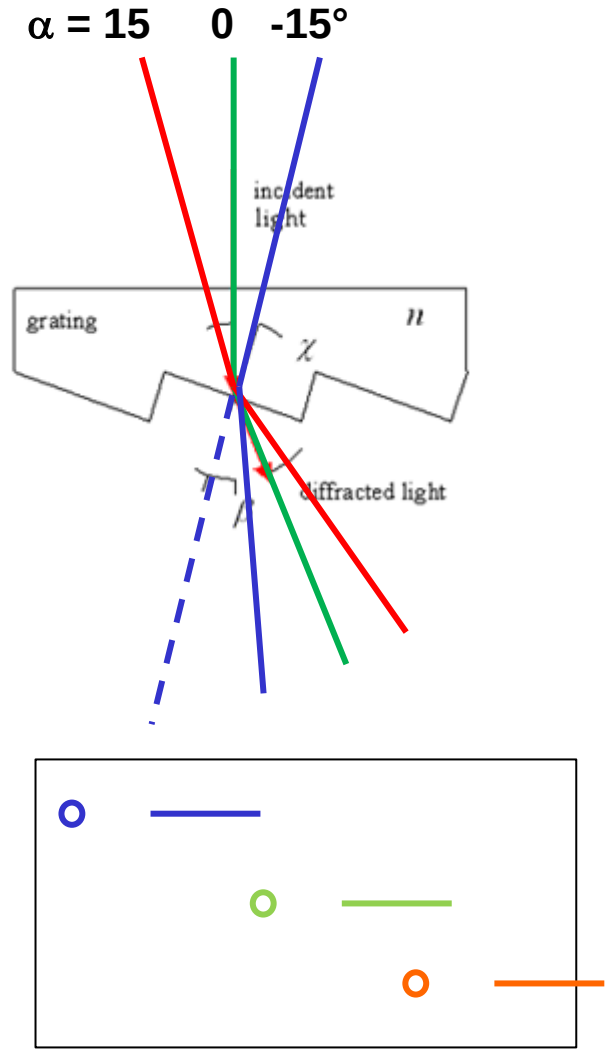
- Depends on grooves/mm and groove angle
- Thorlabs:



Grating efficiency 2

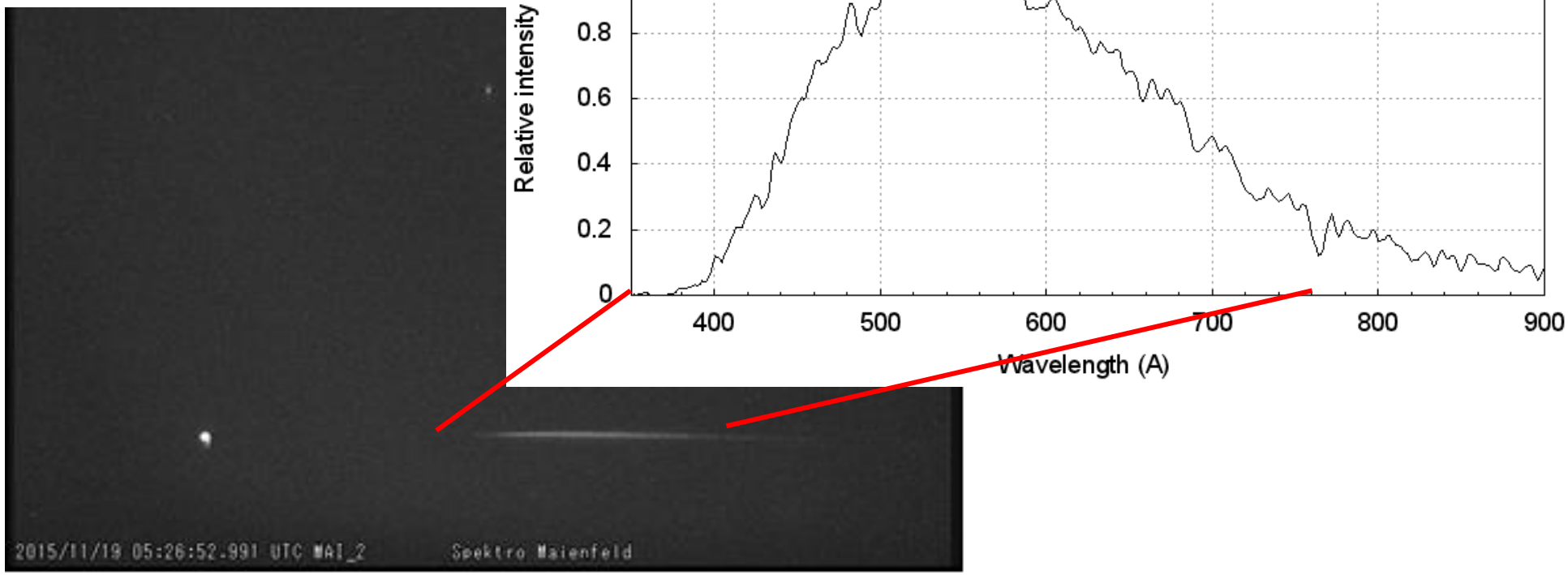
- Grating efficiency dependent on incident angle!
  Calculated for groove angle 28.7°, n = 1.52





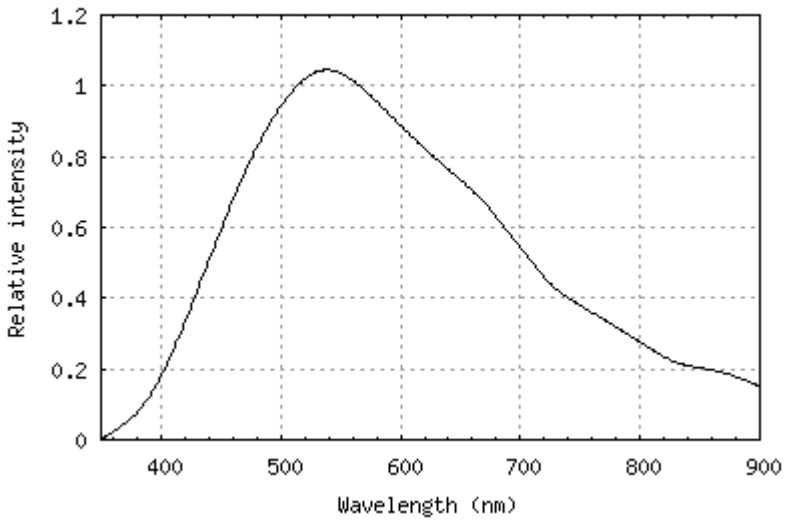
Measured spectrum, Watec 902H2ultimate

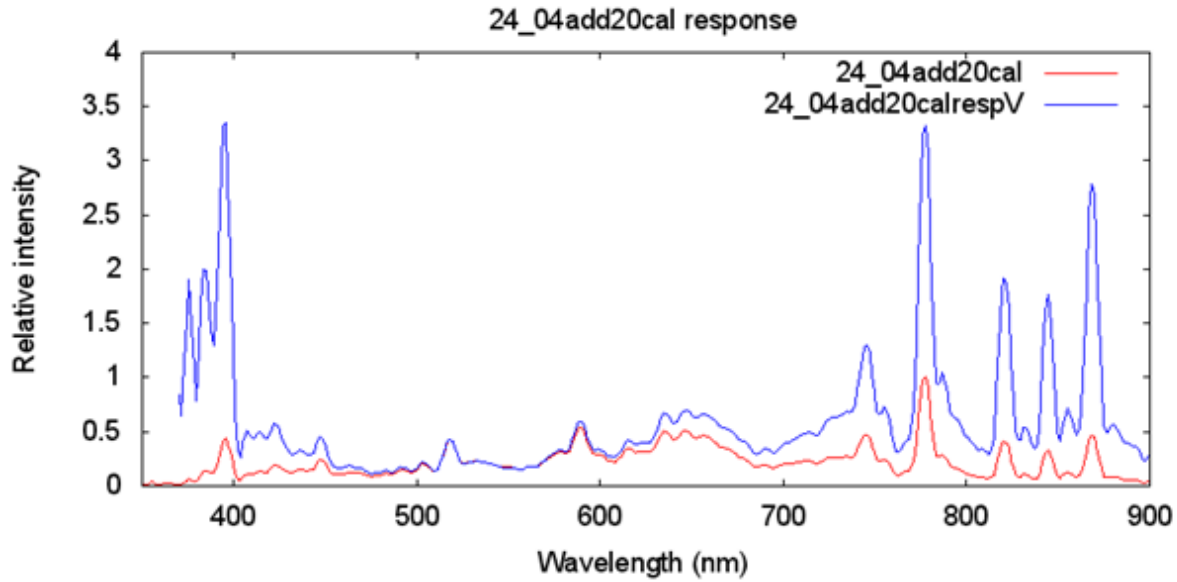
- Venus spectrum



Instrument response

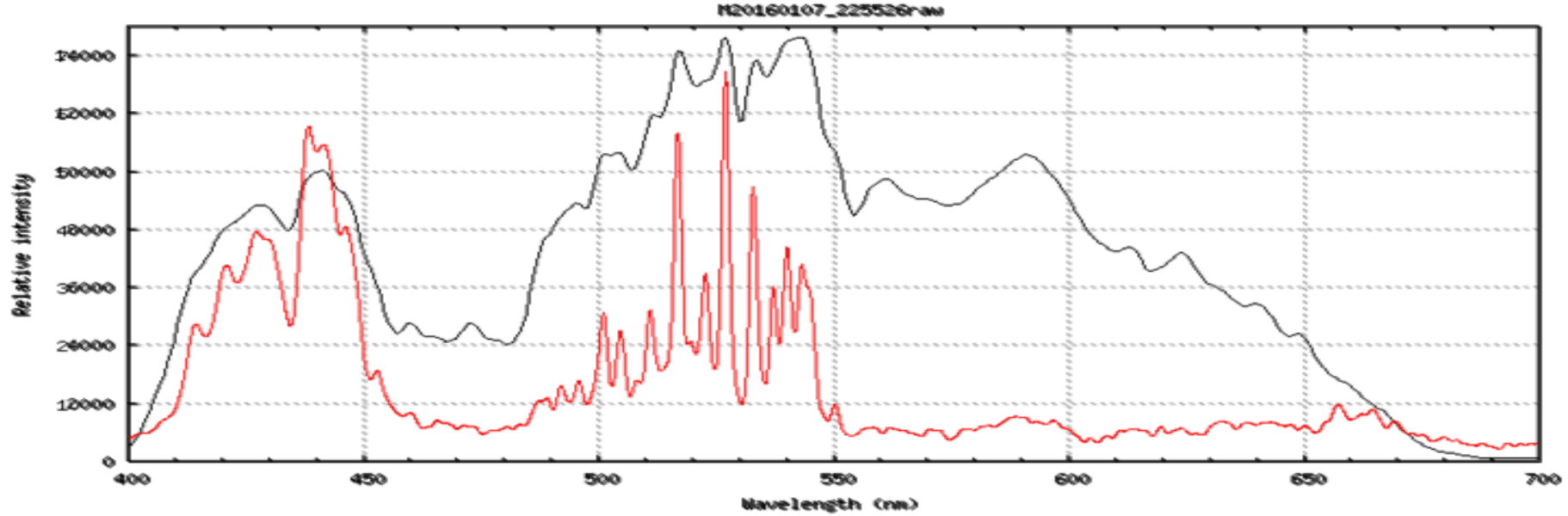
- Spectrum of known object (Venus, Sirius)
  - IR(λ) = measured spectrum(λ) / flux calibrated reference spectrum(λ)
- Meteor spectrum, wavelength calibrated → flux calibrated spectrum
  - Flux calibrated spectrum(λ) = meteor spectrum(λ) / IR(λ)





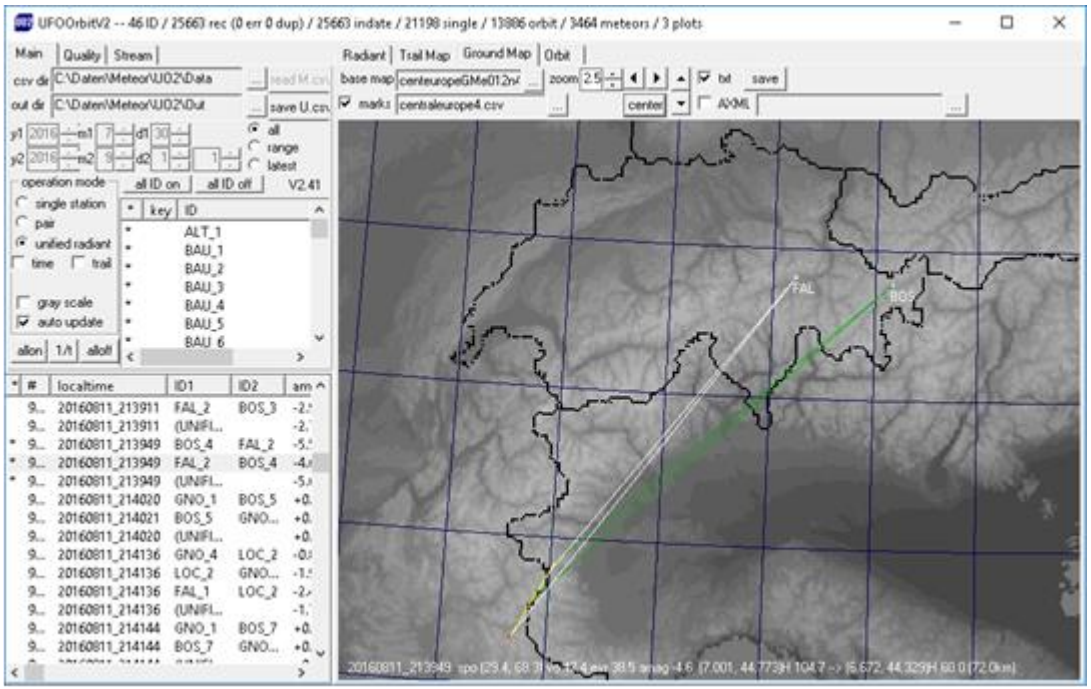
Saturation

- 1st and 2nd order on same wavelength scale



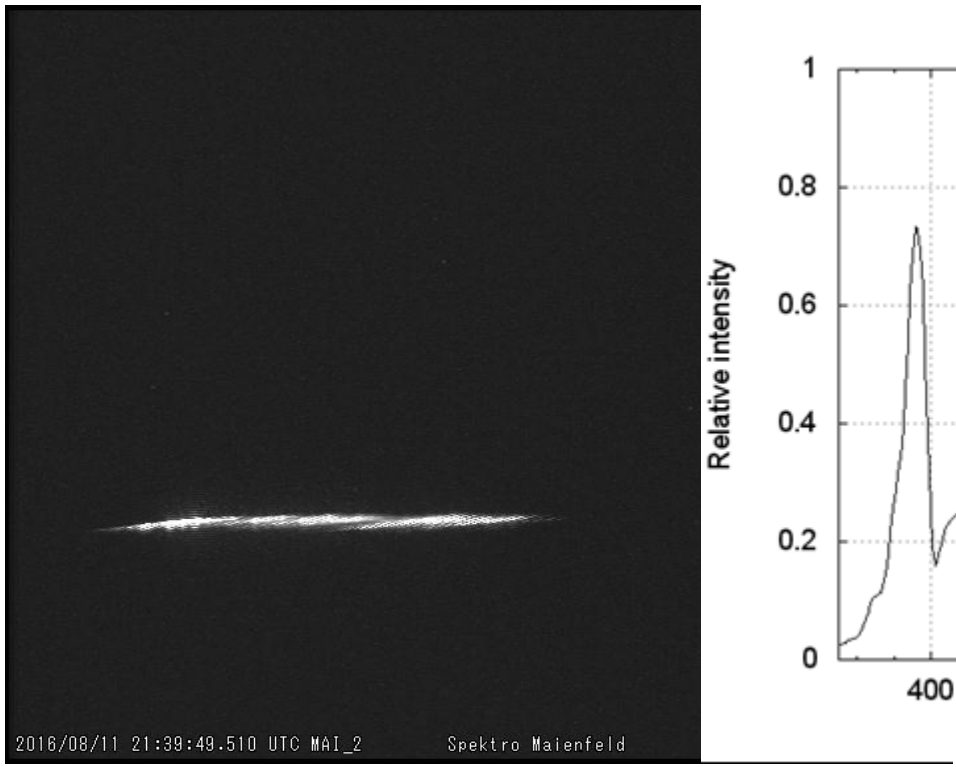
M20160811_213949_OHP_2, Per, ≅ -2.0m

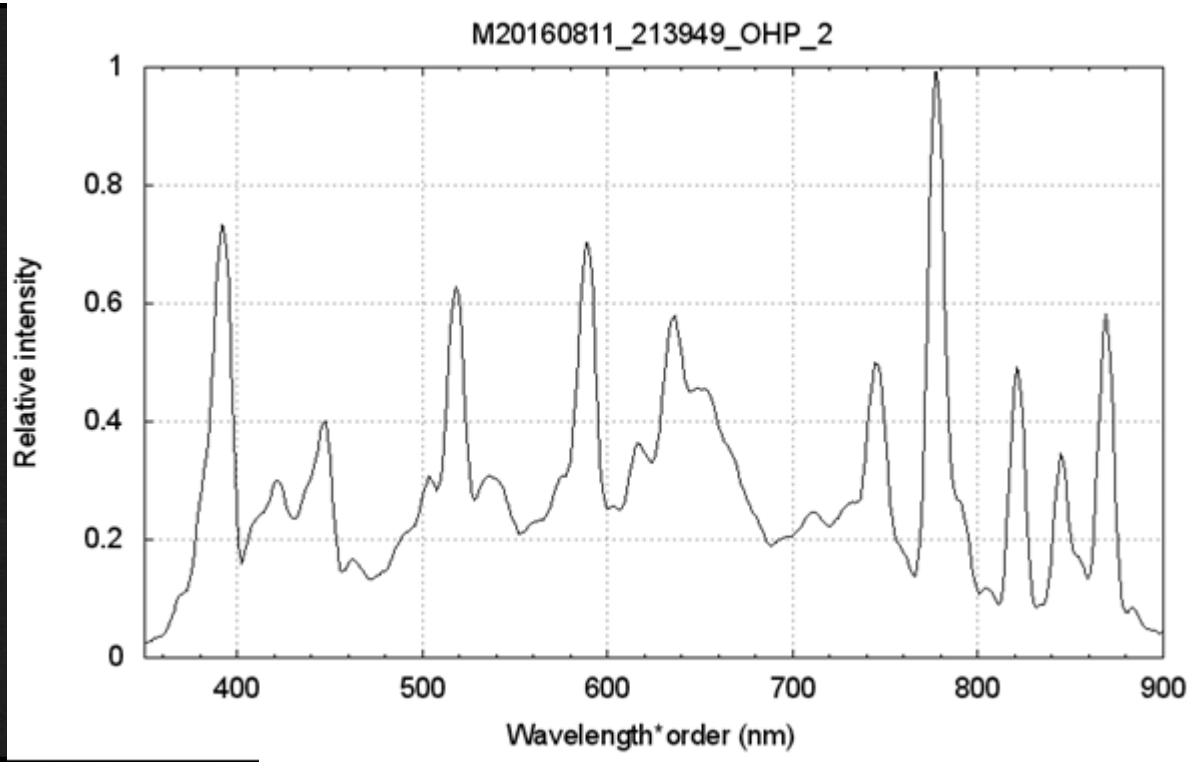
- Spectrum from OHP, triangulation from Switzerland



M20160811_213949_OHP_2, Per, ≅ -2.0m

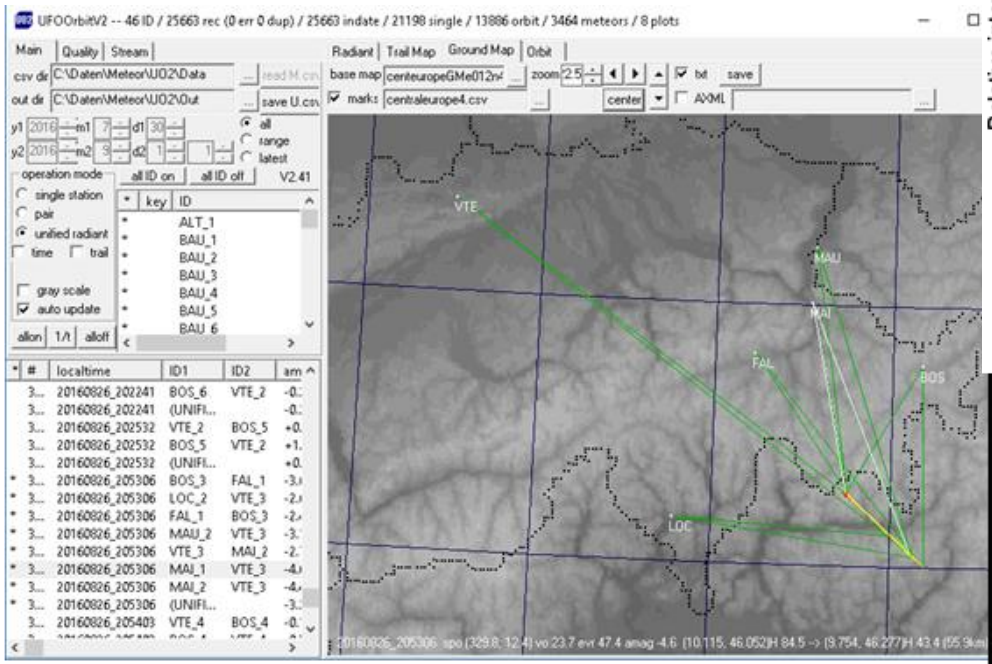
- Spectrum from OHP, triangulation from Switzerland

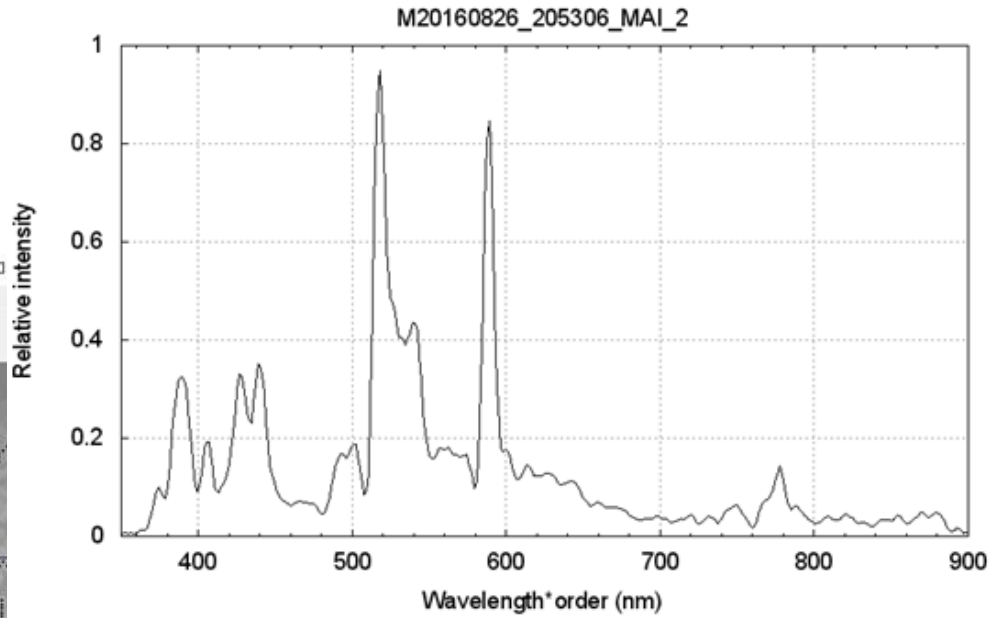


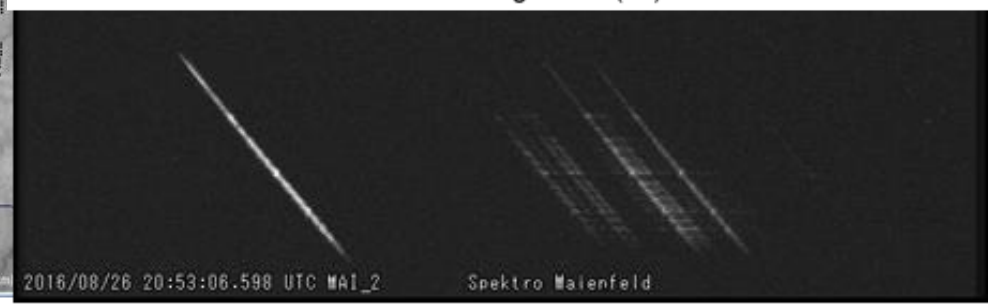


M20160826_205306_MAI_2, spo, -4.2m

- Very little atmospheric lines
- Observed by 6 stations







Trade-off focal length

- Short focal length
  - Large field of view
  - Low spectral resolution
  - Low sensitivity
  - Different orders visible
  - Many meteor spectra
- Grating with 300 to 1000L/mm mounted perpendicular to axis

- Long focal length
  - Small field of view
  - High spectral resolution
  - High sensitivity
  - Few meteor spectra of higher quality
- 6 – 12mm focal length for ½" CCD
- Limit magnitude -1 … -2

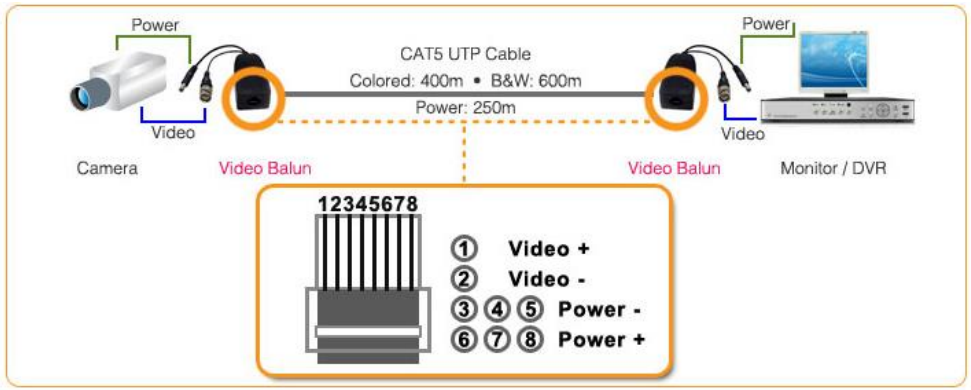
Waiting for next meteor spectrum, patience required!

Conclusion

- Grating mounted perpendicular to camera axis
- Image transformation gives linear, parallel 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

Camera connection

- Video Balun 15$/5 Paare (alibaba)
- Ethernet Flachbandkabel (Alibaba) (5$/10m)
- USB 5 → 12V converter (ebay)



Spectrum recording and processing software

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

Acknowledgment

- FMA for data, discussion
  - Jonas Schenker, Roger Spinner (website, database)
  - Stefano Sposetti, Jose de Queiroz (equipment, data)
  - All others (data, discussions)
- Peter Schlatter (Image tools)
- Koji Maeda (HD color videos)

Links

- SonotaCo Forum
  http://sonotaco.jp/forum/viewtopic.php?t=3065
- Thorlabs grating
  http://www.thorlabs.de/newgrouppage9.cfm?objectgroup_id=1123
- Linear wavelength calibration: http://arxiv.org/abs/1509.07531 or
  http://www.meteorastronomie.ch/images/Meteor_Spectroscopy_WGN43-4_2015.pdf
- IMC:
  http://www.meteorastronomie.ch/images/20160605_Calibration_of_Meteor_Spectra_Dubs_IMC2016.pdf

Danke für Ihre Aufmerksamkeit!