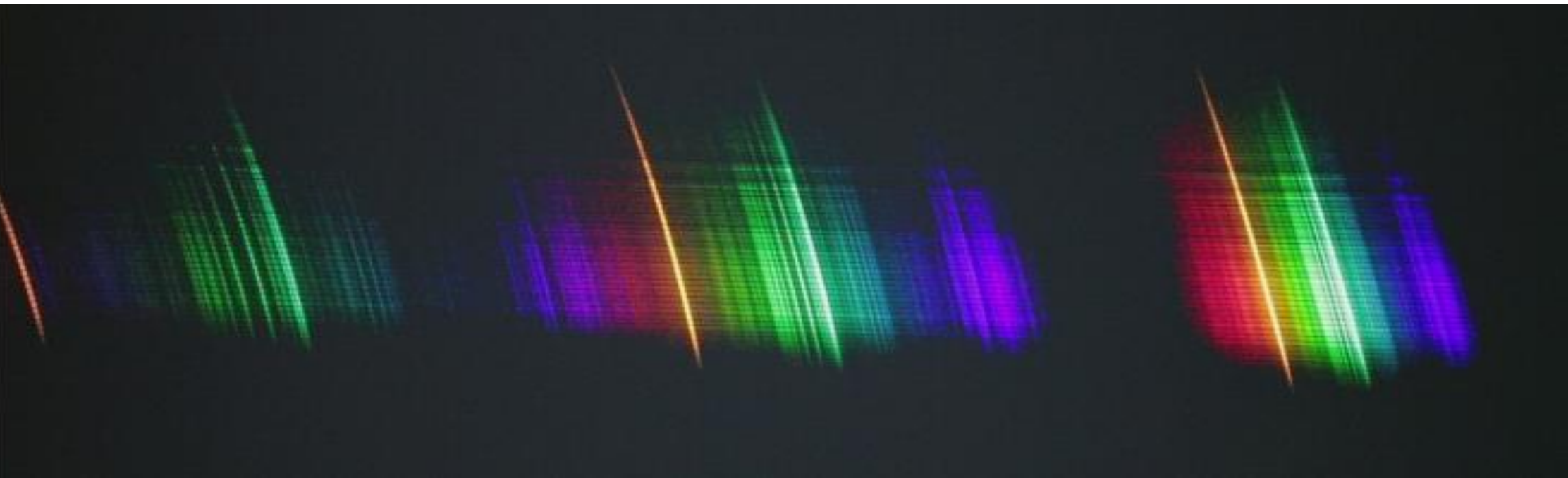
Fachgruppe Meteorastronomie

Meteor Spectroscopy, Aspekt 2015

Martin Dubs

SAG, FMA



Meteor Spectroscopy, Content

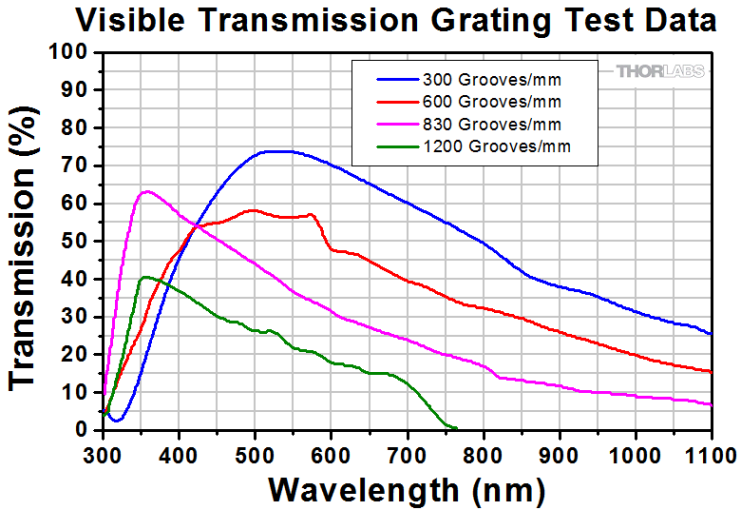
- Introduction
- Hardware
- Software
- Wavelength calibration
- Spectrum extraction
- Examples
- Summary

Meteor spectroscopy

- Additional information
  - Composition of the meteoroid
  - Temperature
  - Interaction with atmosphere
  - Meteor trail
- Problems
  - Reduced sensitivity
  - analysis
  - Compromise between spectral resolution, field of view and sensitivity
  - Saturation

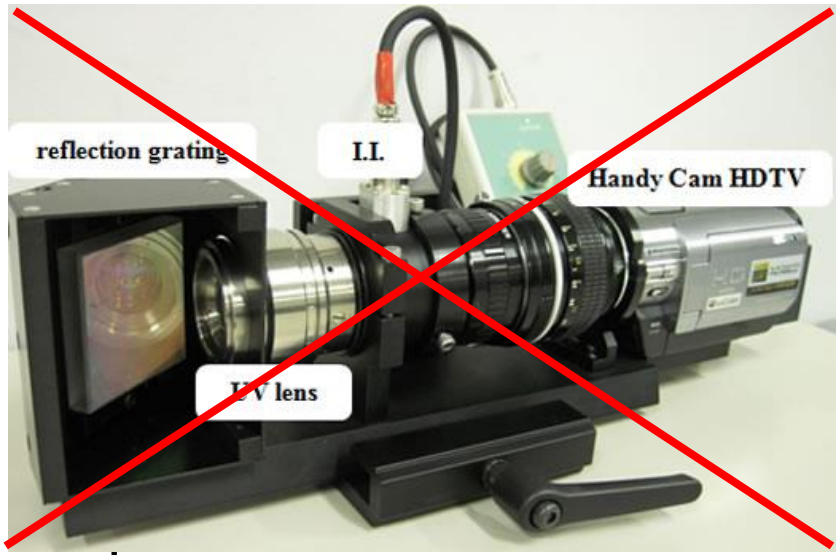
Hardware

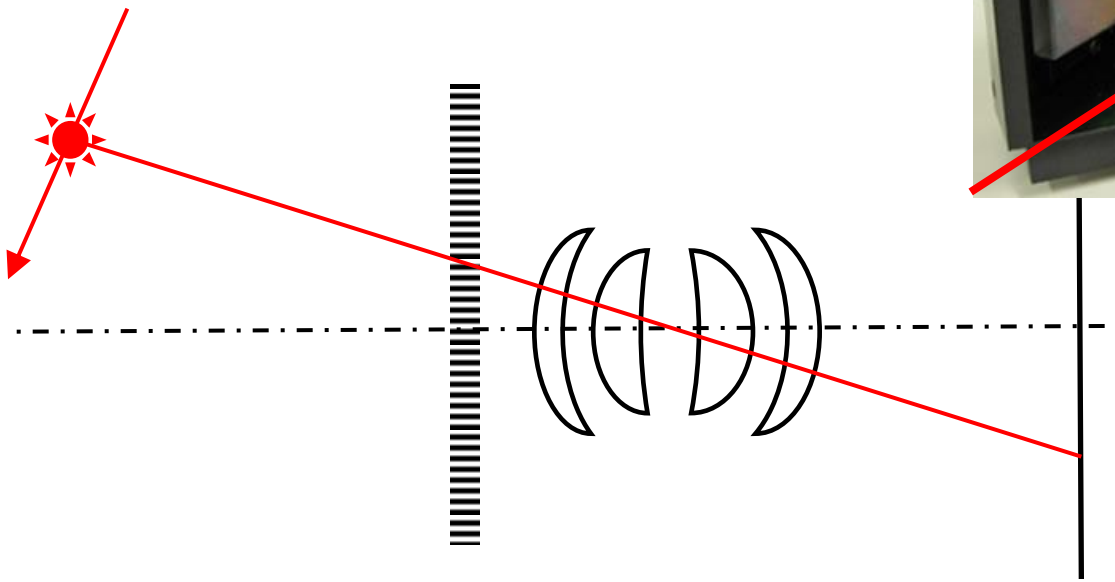
- Watec 902H2 ult. Computar HG2610AFCS-HSP F/1 2.6mm fl
- 902H2 ultimate (spectroscopy) Tamron 12VG412ASIR F/1.2, ≈7mm fl
- 2nd camera with transmission grating for spectroscopy
  Thorlabs
  300 L/mm → 600 L/mm



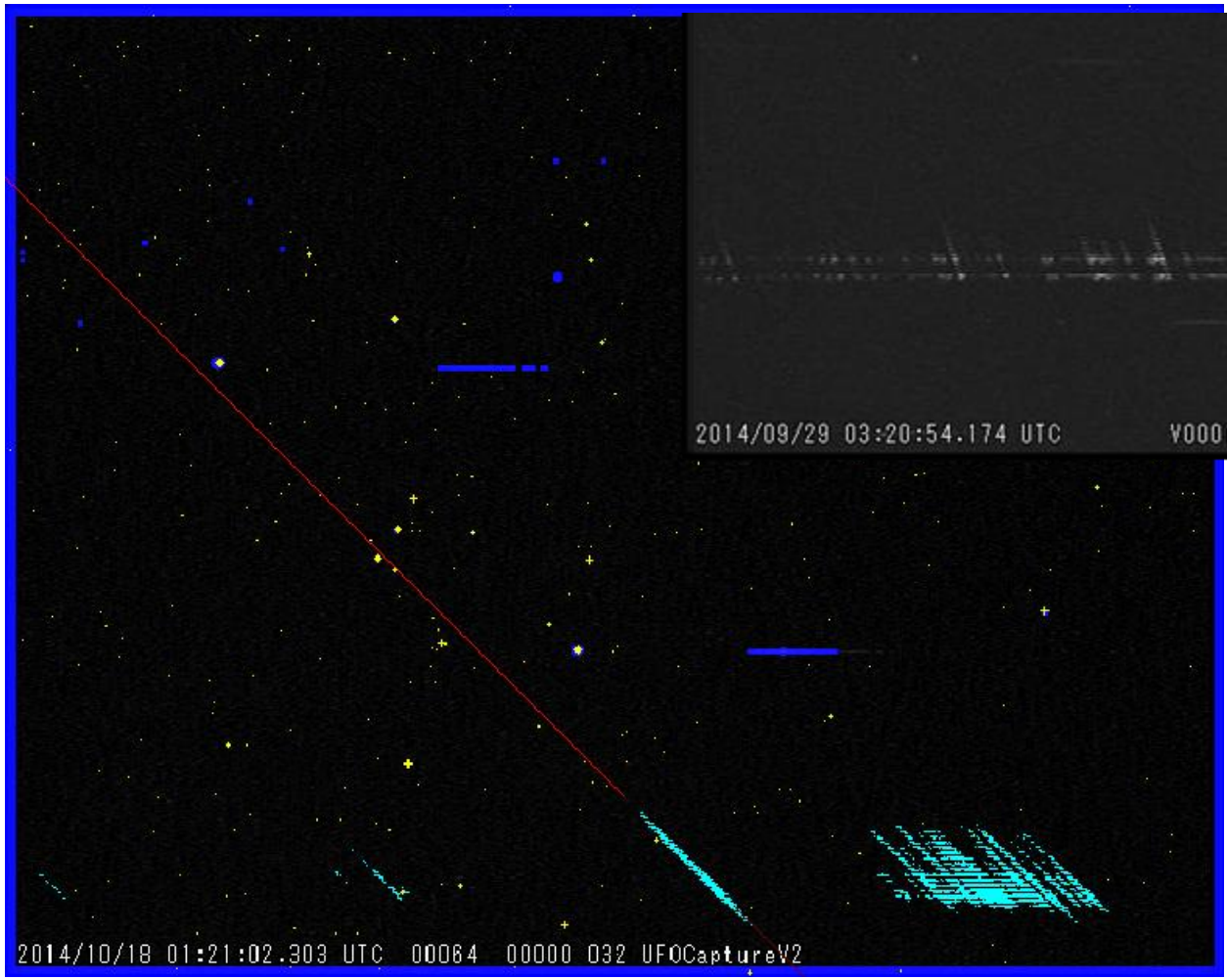
Objektivgitter

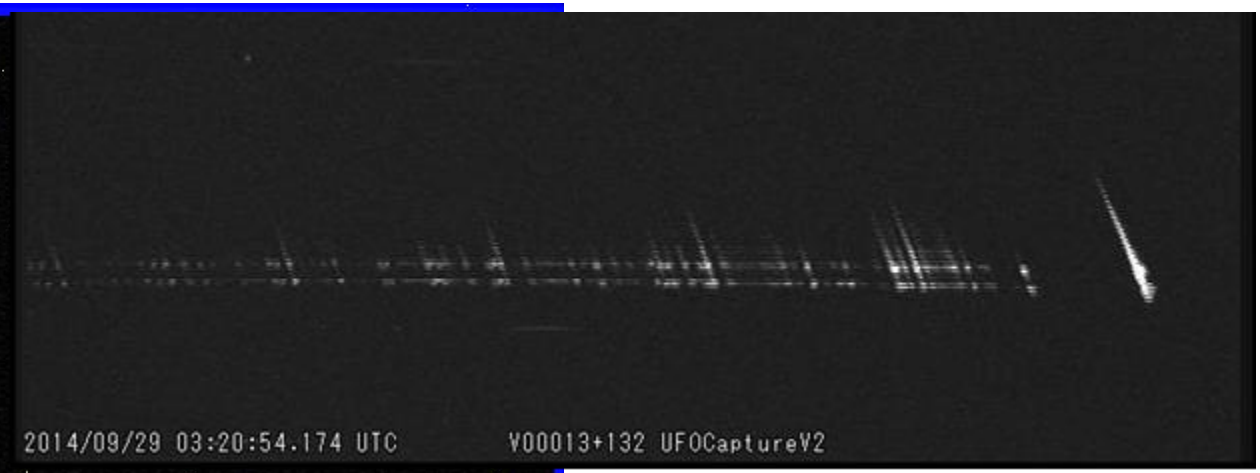
- 300 – 600 L/mm Transmissionsgitter
- Gitter senkrecht zu optischer Achse!





Meteor spectra



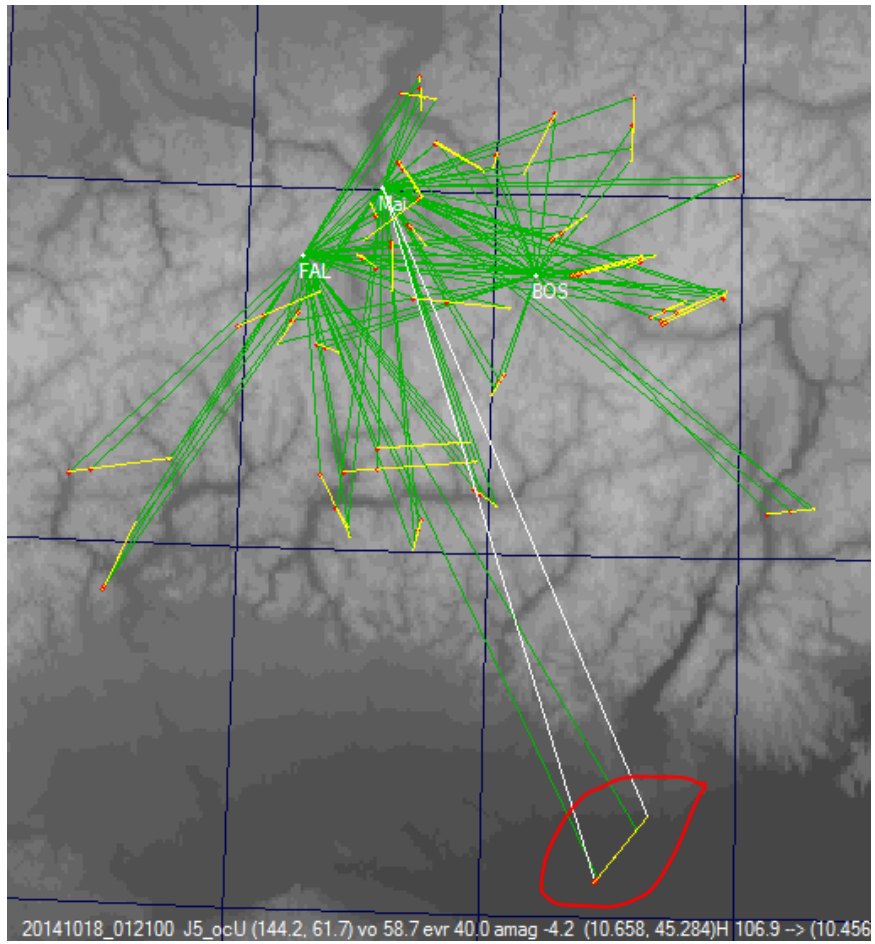


f = 4mm, -4mag

f = 7mm, -2mag, 300L/mm

Meteor 20141018_012100

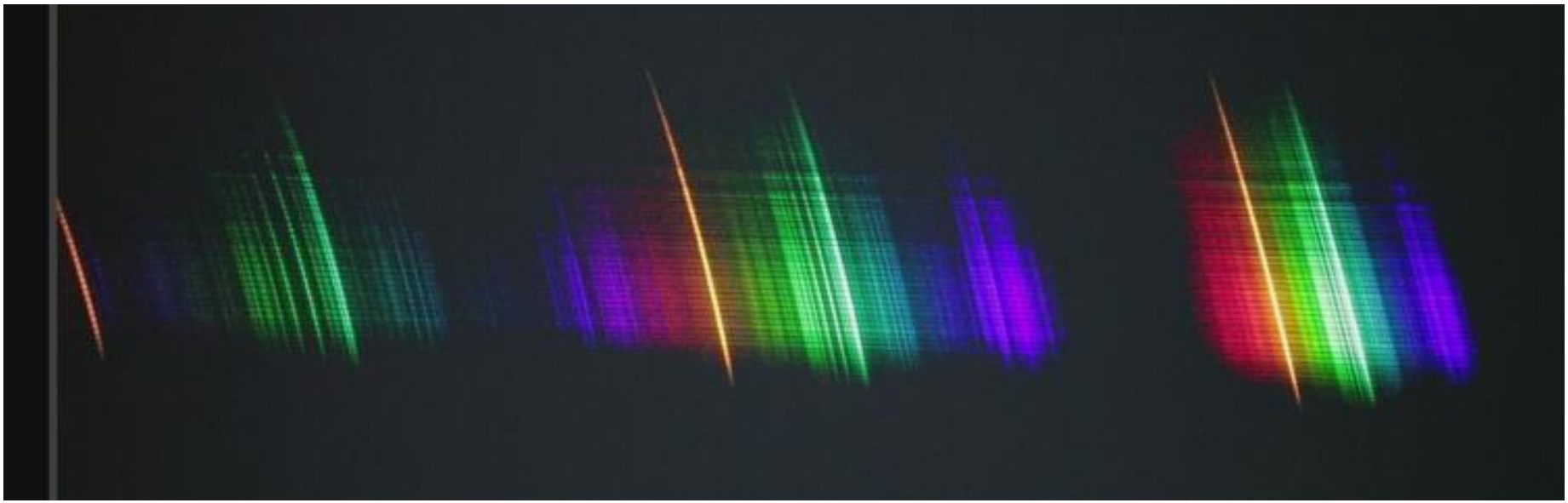
- Ground Path from FMA Database Data 1. – 18. Oct.
- Calculated with UFO Orbit October Ursae Majorids
  v_g = 58 km/sec (54.4 km/sec ocU)
  v_s = 42.0 – 43.3 km/sec
  (parabolic, hyperbolic)



Grating order overlap

- Na and Mg line
- Order

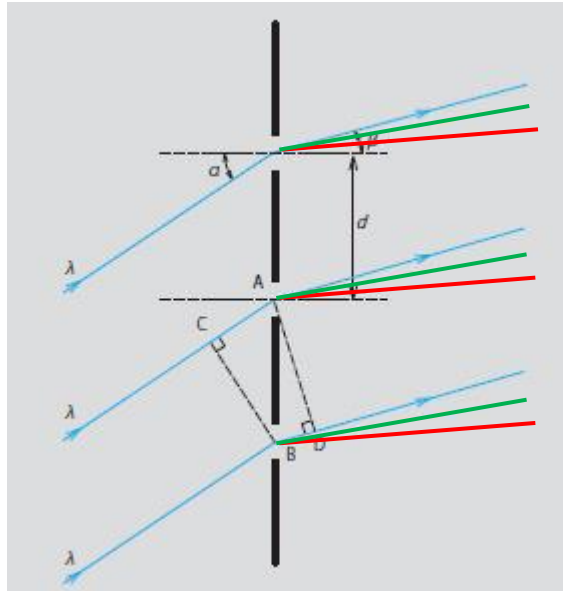
-3 -3 -2 -2 -1 -1



- Koji Maeda, M20150104_032315, Canon EOS6D 1/30s, 35 mm F/1.4 UFO CaptureHD

Spectrograph, theory

- Video camera with transmission grating in front of lens
- Grating equation:
  - **$m * \lambda * G = (\sin \alpha - \sin \beta) * \cos \gamma$**
  - m: grating order, G: grating lines / mm
  - λ: wavelength
  - α, β: angle of incidence, transmitted beam
    γ: cross, out of plane angle
- Inverse dispersion per pixel:
  $d\lambda/dx = (\cos \beta \cos \gamma)/(m*G*f)*p$ (p: pixel size)
  - Example: f = 7 mm, p = 8.6 µm, G: 300L/mm β = 0 → dλ/dx = 41A/pixel



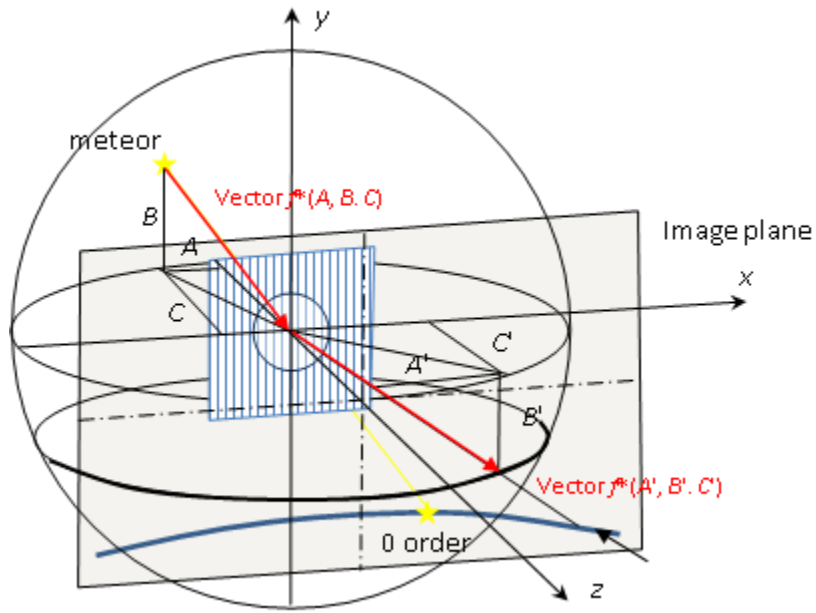
Vector theory wavelength calibration

- 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)*

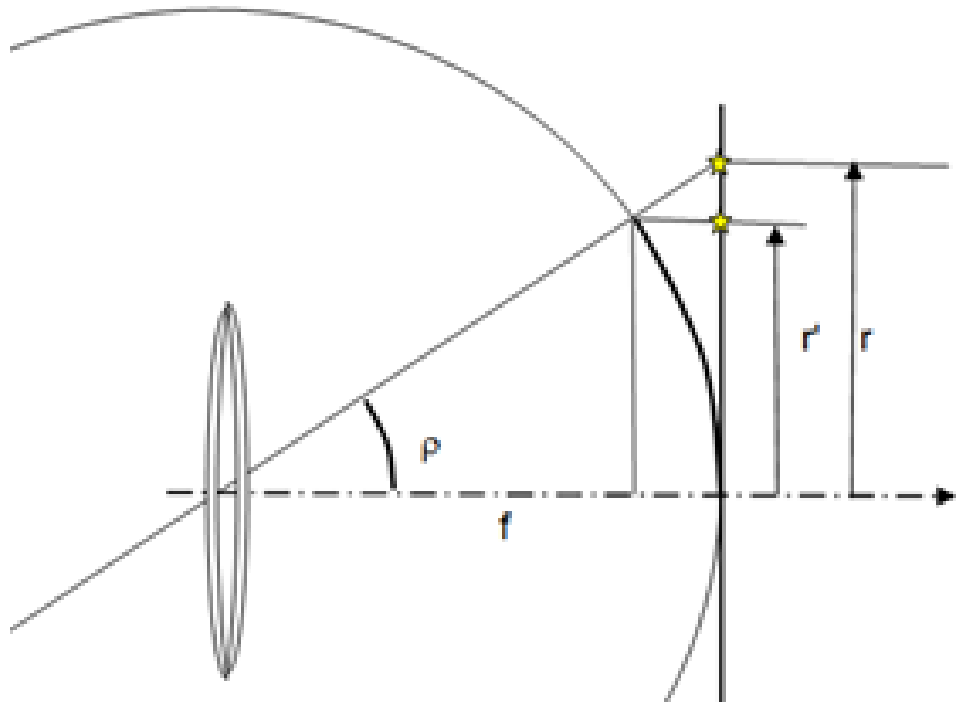
  $B' = B$ *(y-axis)*

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



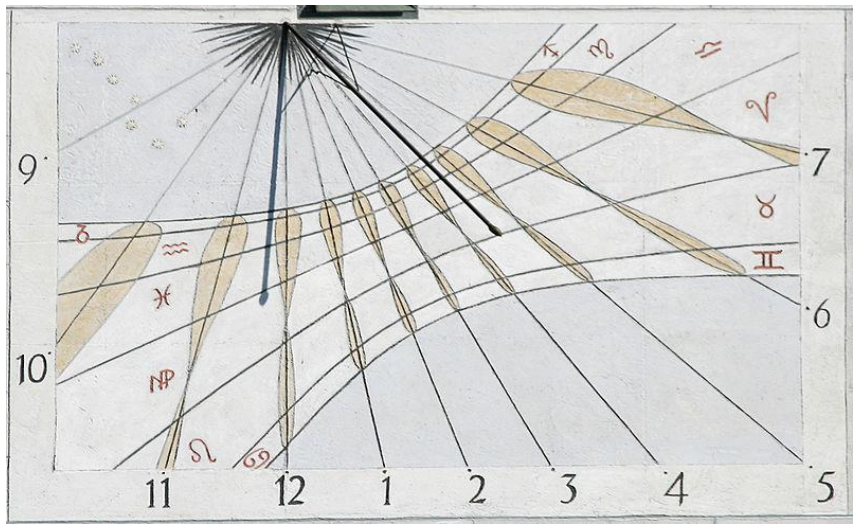
Spectrum linearization

- Grating in front of lens perpendicular to optical axis
- CCD: tangential or gnomonic projection
- Orthographic projection r →r'
  $r' = r/\mathrm{sqrt}[1 + (r/f)^2]$
  $r = r'/\mathrm{sqrt}[1 - (r'/f)^2]$
- Spectrum straight, linear constant dispersion everywhere
- Include lens distorsion with modified equation

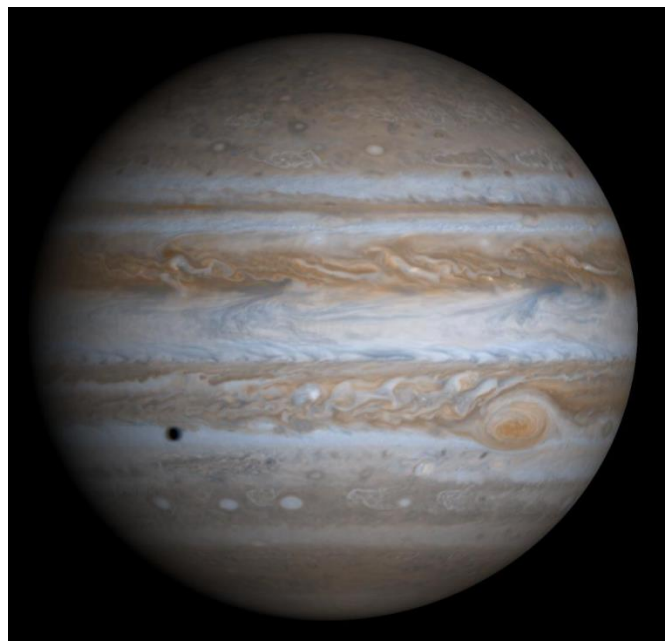


Gnomonic and orthographic projection

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

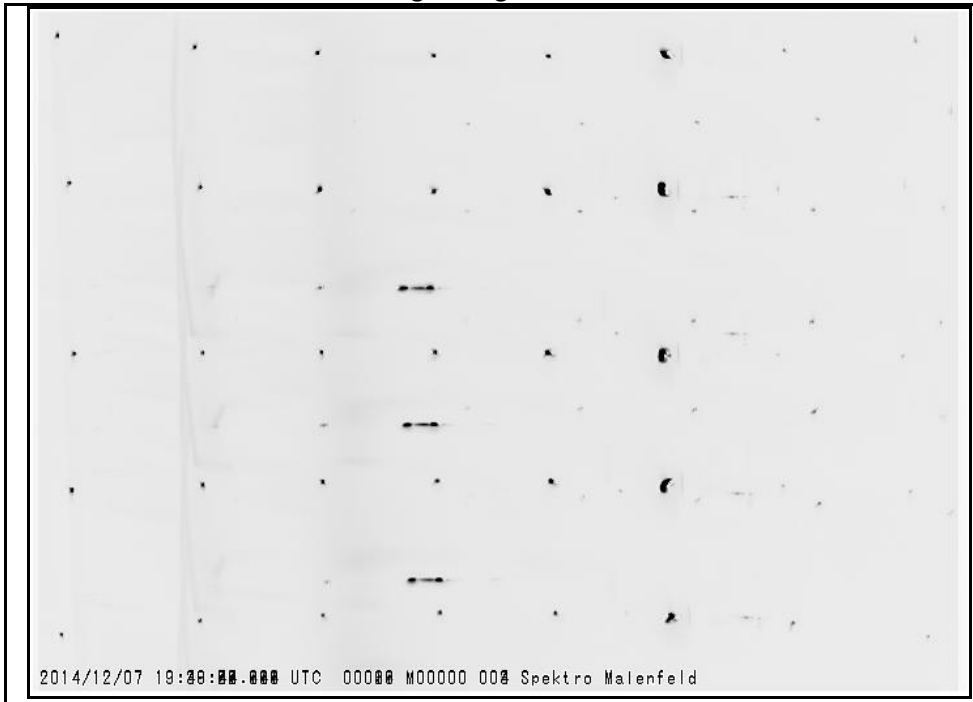


- Orthographic, SIN
  - R = f*sin(ρ)
  - Great circles →ellipses
  - Latitude circles → straight
  - Optimum for spectroscopy

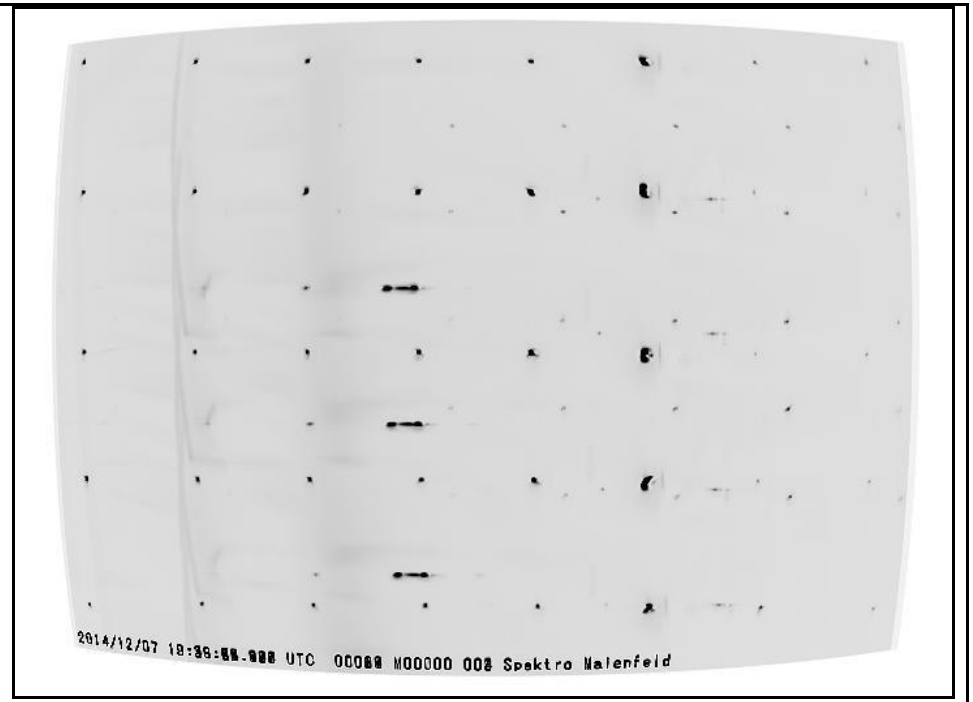


Calibration spectrum HeNe laser

- HeNe laser λ = 633 nm, f = 4 mm
- Fit with polynom r = r' * [1 + 3.94E-07*r'2 + 2.01E-12*r'4]
- Fit center x_0, y_0



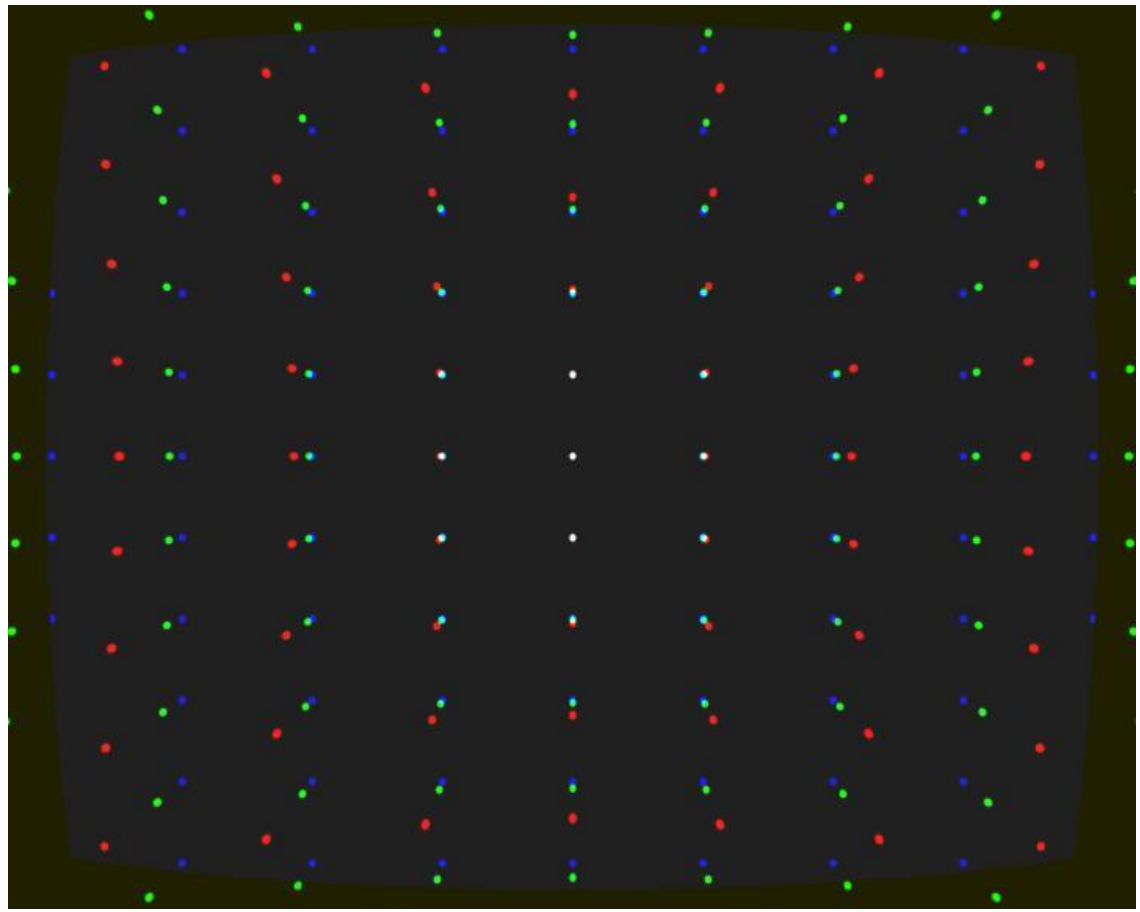
Composite spectra original



After applying transformation

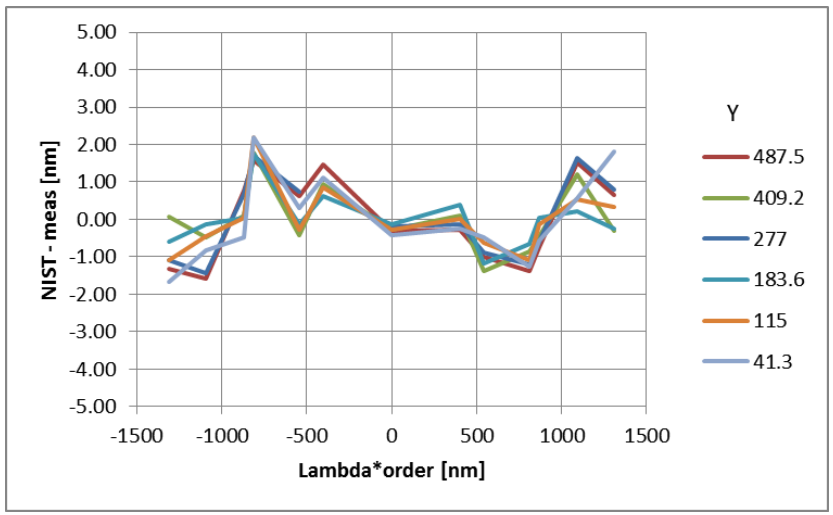
Calibration spectrum simulation

- HeNe laser λ = 633 nm, f = 4 mm
- Red: tangential projection
- Green:
  included lens distorsion
- Blue: orthographic projection
- Created with ImageTools
  (Peter Schlatter)



Calibration spectrum HgAr

- f = 7 mm
- Fit with x = x0 + (λ - λ0)*disp0/sqrt[1 – ((λ - λ0)*c_2))2]
- Lens distorsion included in c2
  - x_0 = 362.2
  - $disp_0$ = 4.14 nm/pixel
  - c_2 → f_2 = 13.42 mm



$m*\lambda_{NIST}$	x	fit x [pixel]	error	Line
-1307.498	13.238	13.38	-0.14	Hg 3rd order
-1092.147	68.753	68.58	0.18	Hg 2nd order
-871.666	124.254	124.03	0.23	Hg 2nd order
-809.313	139.373	139.54	-0.17	Hg 2nd order
-546.074	204.431	204.41	0.02	Hg
-404.656	238.747	238.90	-0.16	Hg
0	336.798	336.80	-0.00	zero order
404.656	434.218	434.38	-0.16	Hg
546.074	468.829	468.62	0.21	Hg
809.313	532.868	532.77	0.09	Hg 2nd order
871.666	548.128	548.08	0.05	Hg 2nd order
1092.147	602.454	602.65	-0.20	Hg 2nd order
1307.2951	656.771	656.72	0.05	Hg 3rd order

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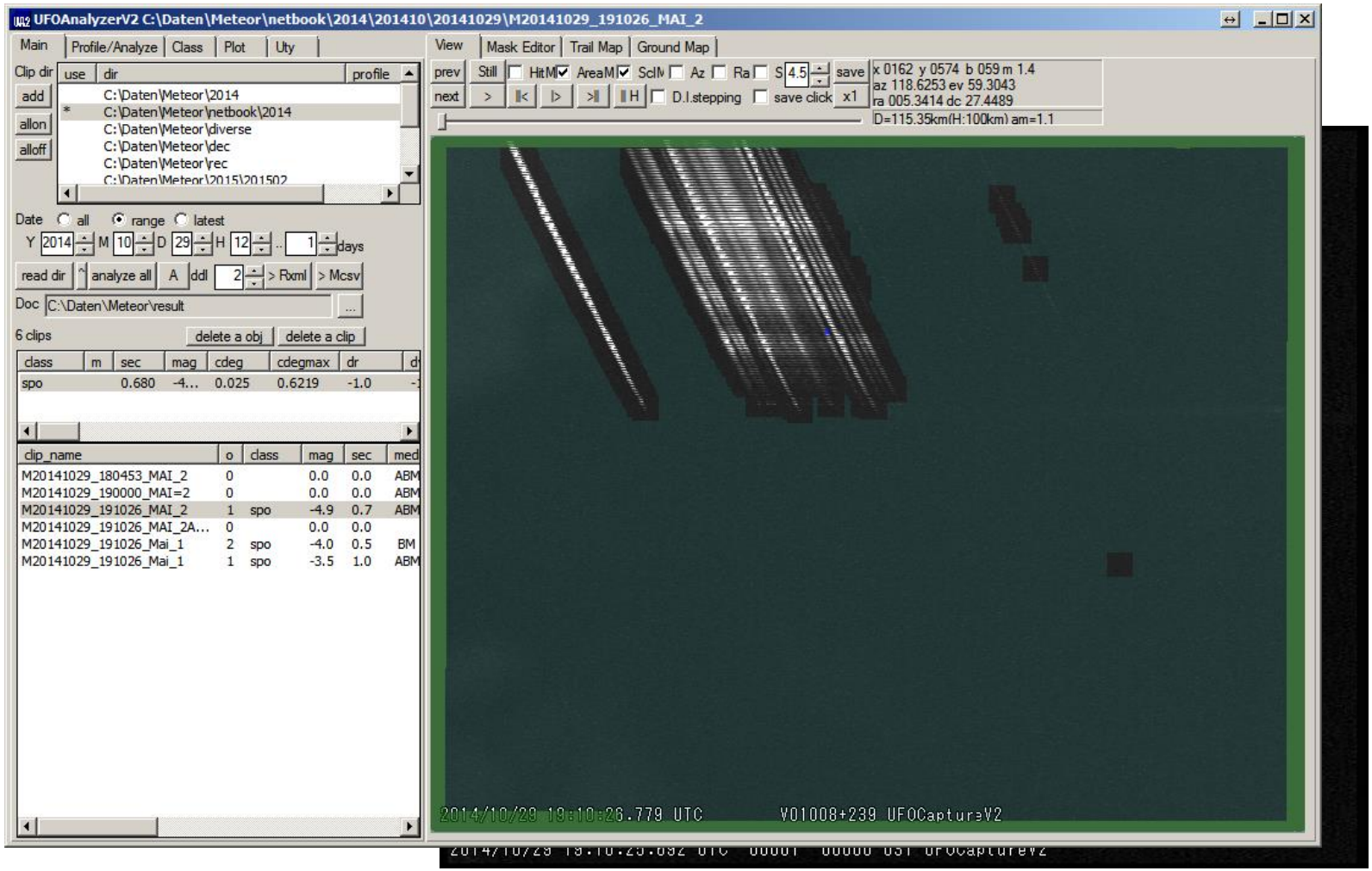
Spectra processing overview

- IRIS
  - Extract images from uncompressed AVI (File – AVI conversion)
  - Measure background image with stars only (ADD_MEAN)
  - Subtract background from meteor images (SUB2)
  - Linearize spectra with orthographic projection (ImageTools preferred)
  - register meteor images
  - Extract raw spectrum, whole range (2D image → 1D spectrum) (L_ADD, L_PLOT)
- Linear Wavelength calibration (zero point, dispersion)
- (Spectral response)
- Analyze spectrum (assign chemical elements)

AVI clip M20141029_191026



Preprocessing

- Extract image (i30)
- Background ADD_MEAN < I1 … I20 >
- Subtraction SUB2

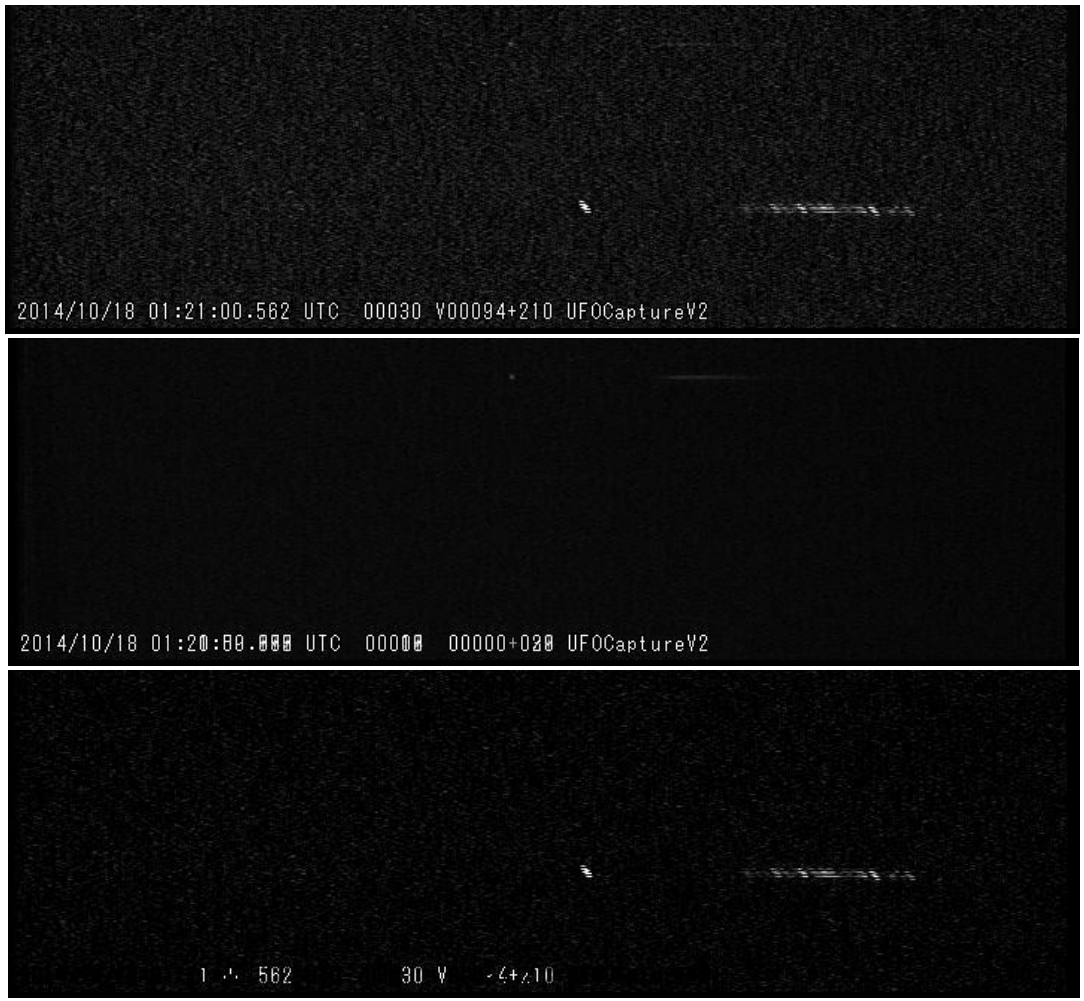
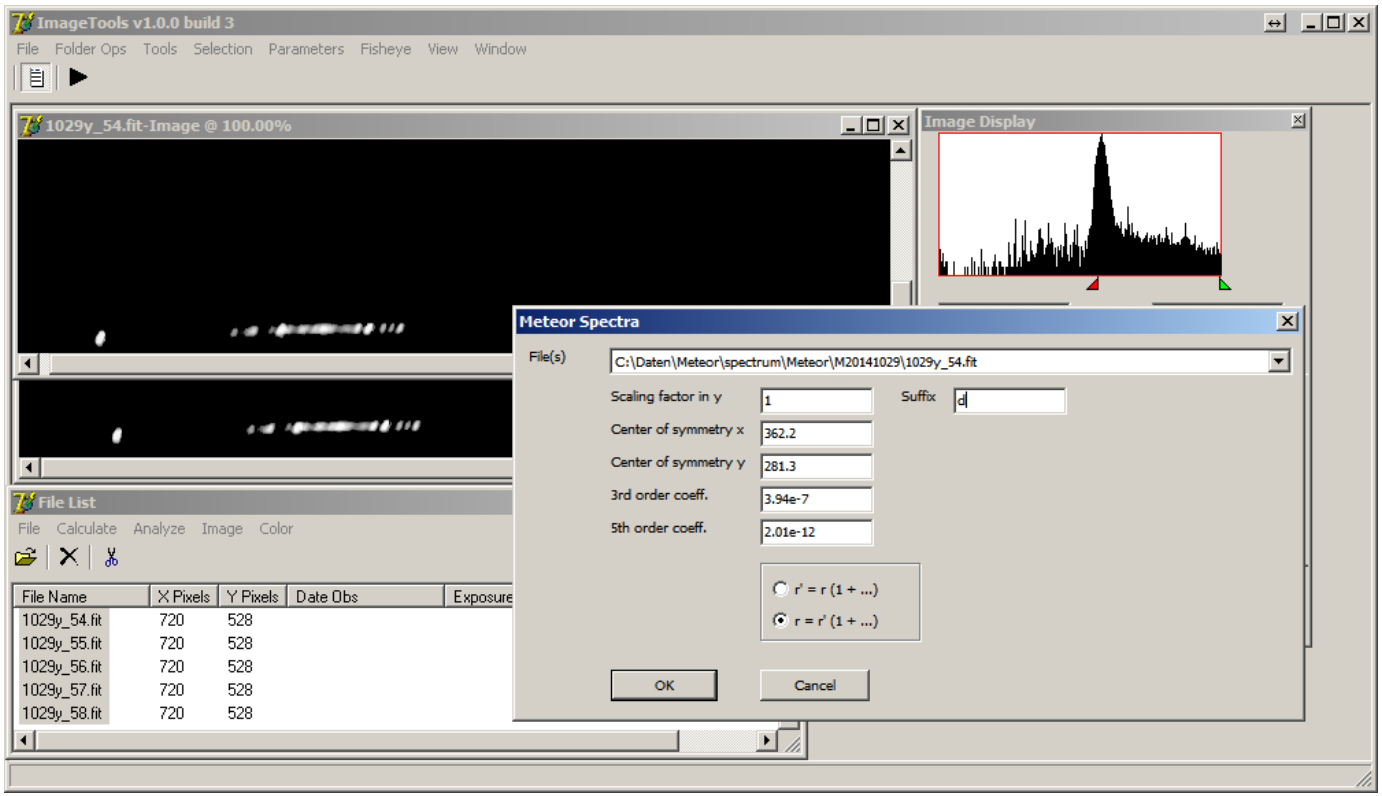
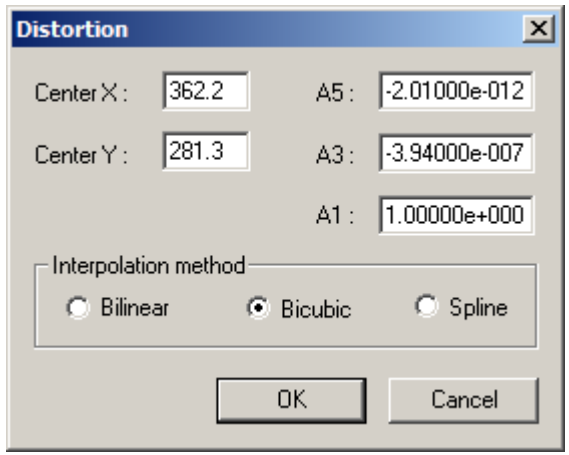


Image transformation

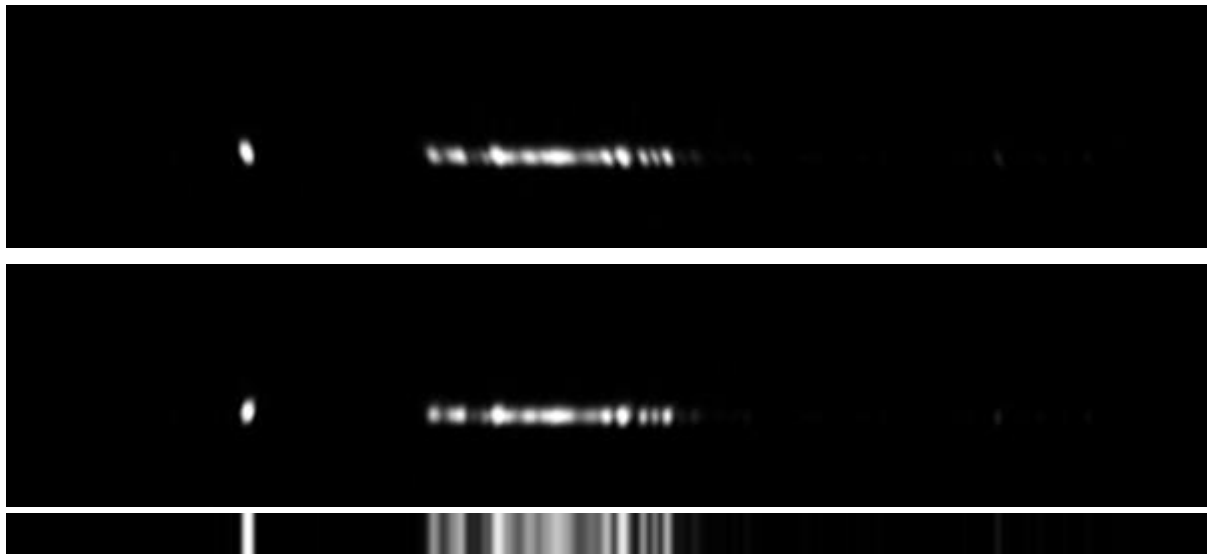
- Transformation to square pixels
- Transformation to orthographic projection IRIS → ImageTools →



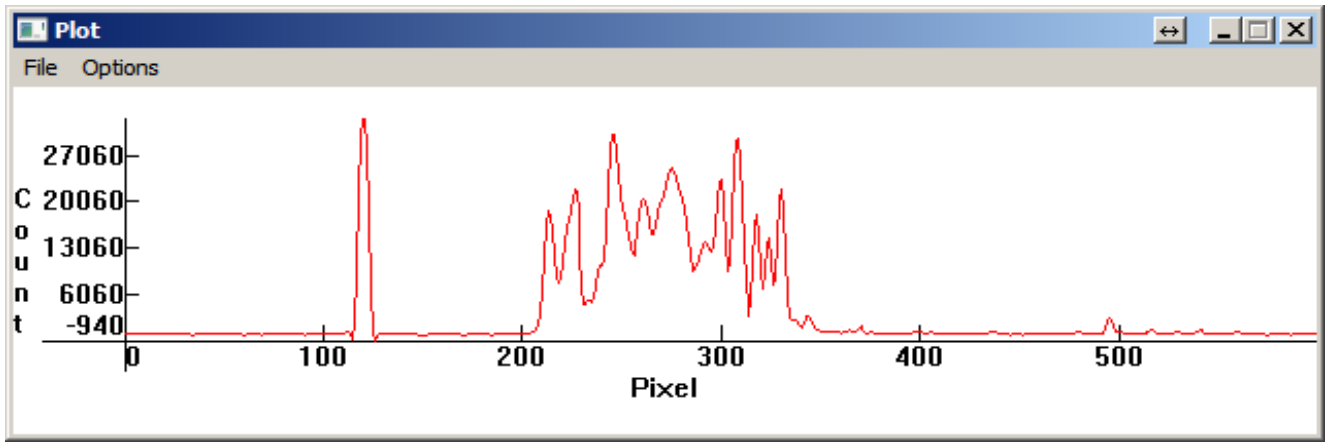


Processing 2, stacking

- REGISTER
  ADD
  d1-15

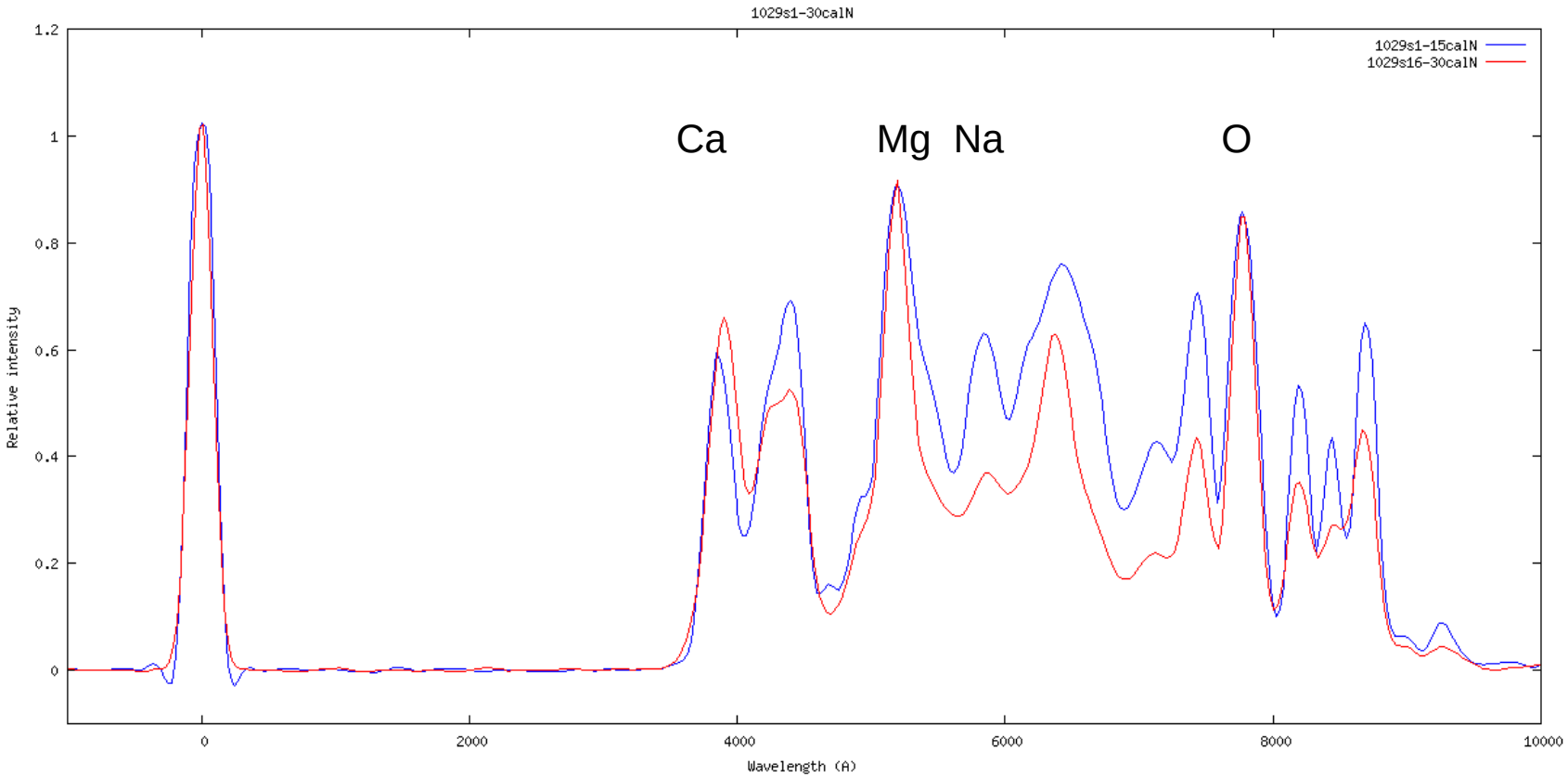


- SLANT 472 24
- L_ADD
- L_PLOT
  save file.dat



Result M20141029_191026

- S1-15 first half more saturated, s16-30 second half



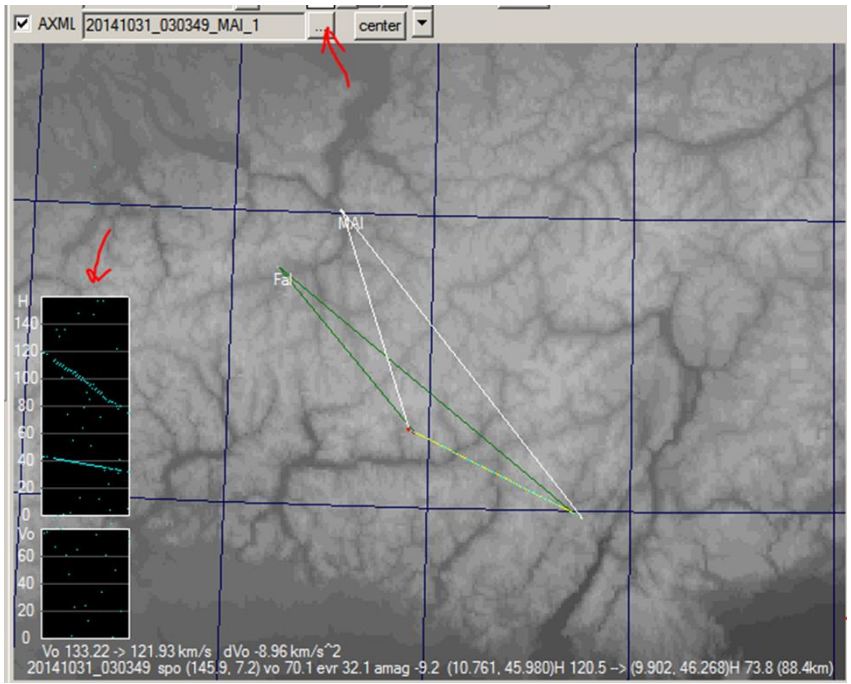
Spectrum Oct. 31, 030349

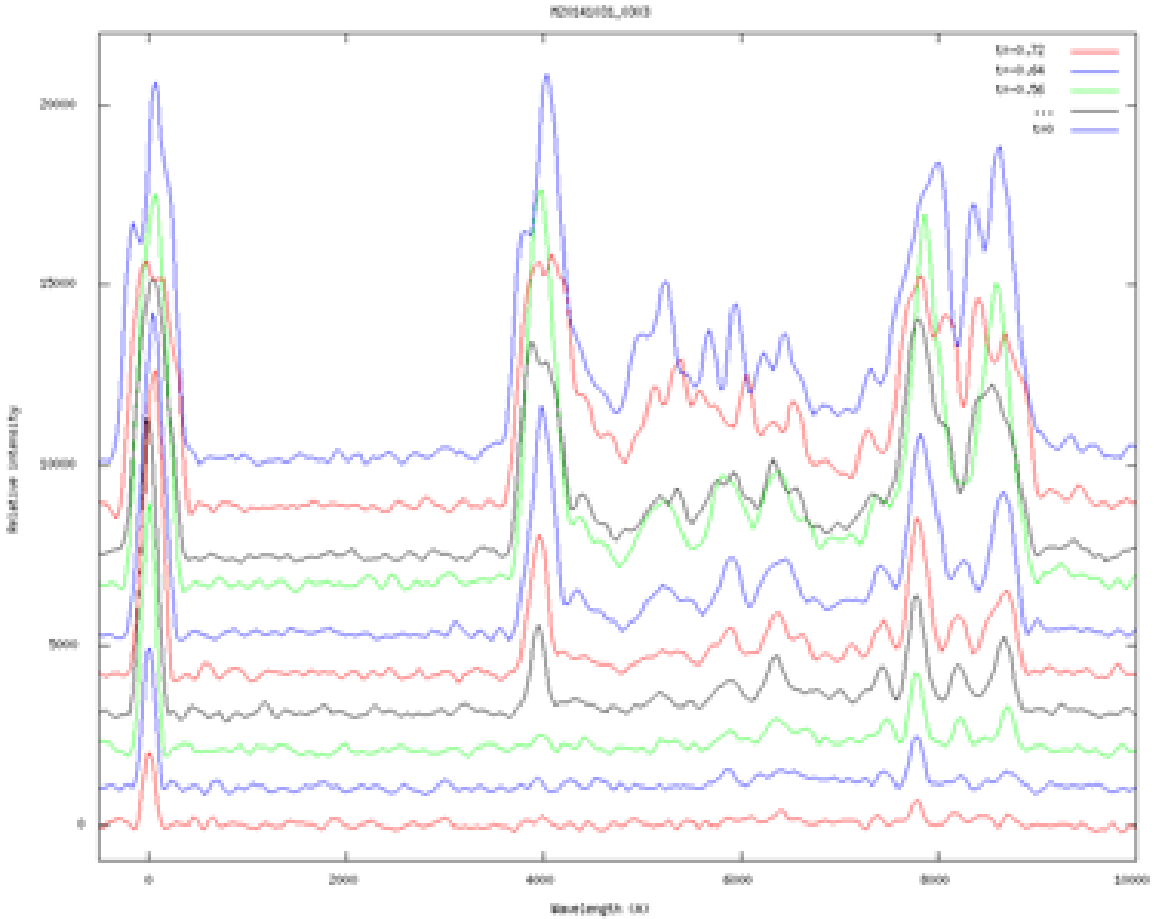
Watec 902B

Watec 902H2 ultimate

Result M20141031_0303

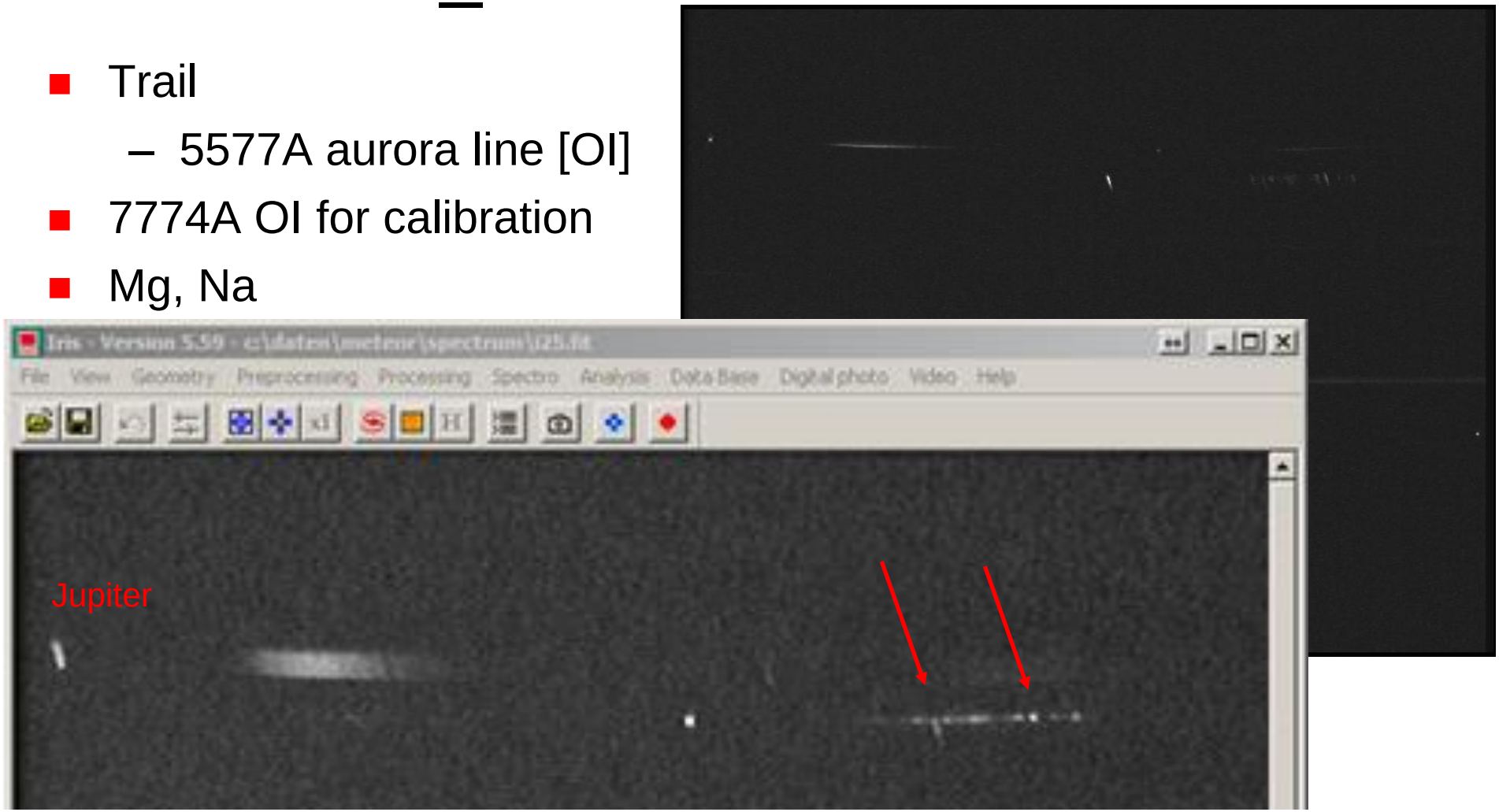
- saturation





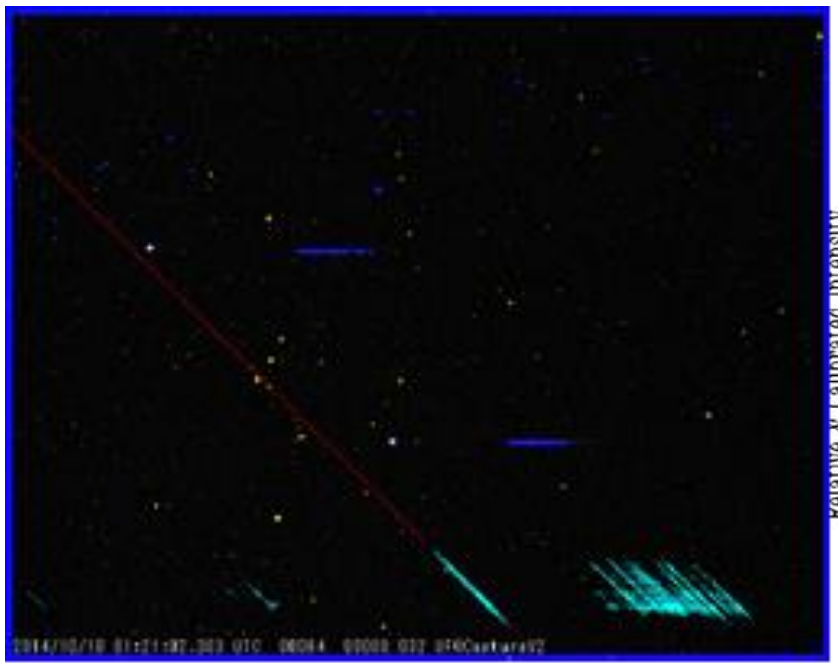
M20141019_0426

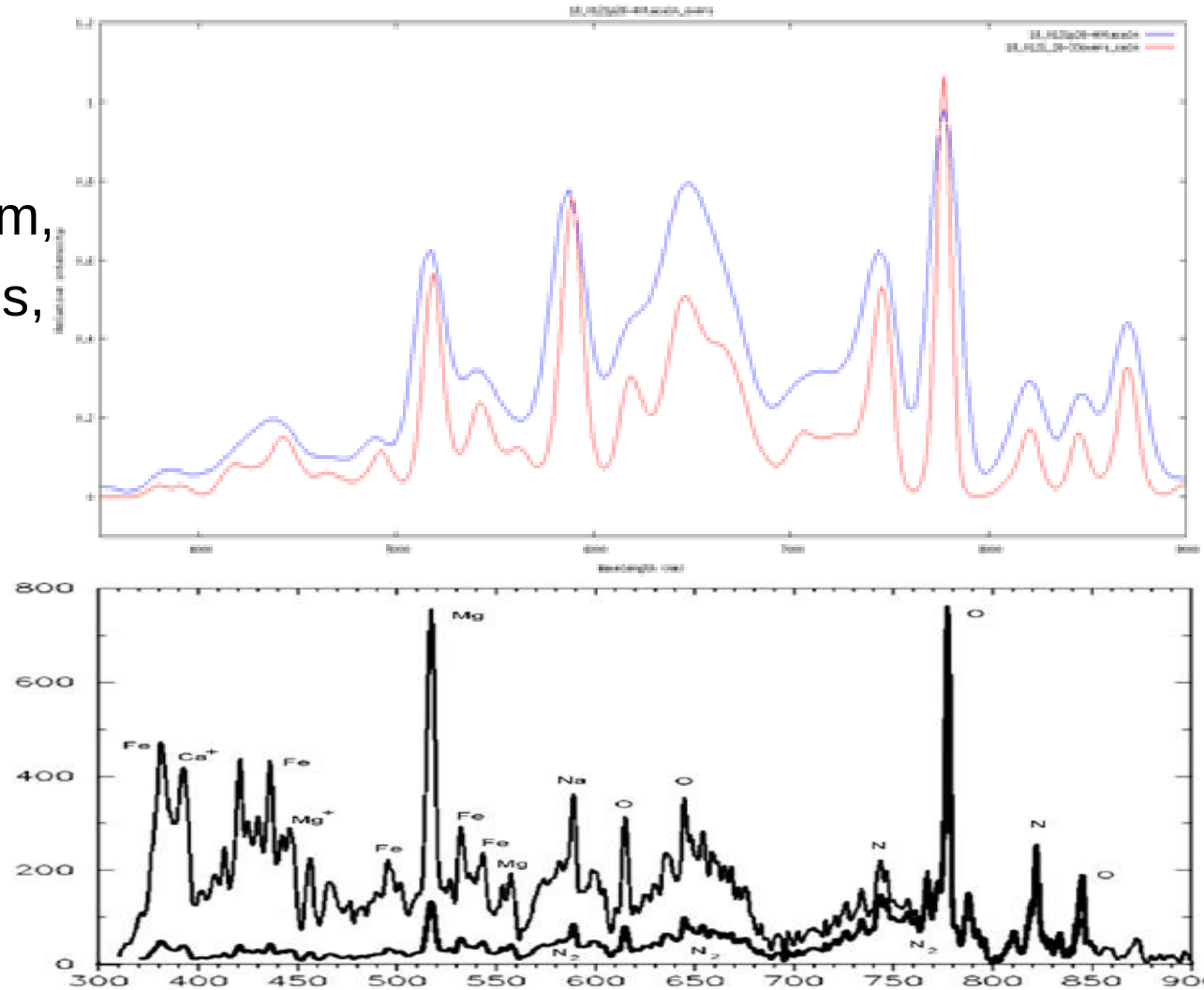
- Trail
  - 5577A aurora line [OI]
- 7774A OI for calibration
- Mg, Na



Example

- M20141018_012100, -3.7m,
  - October Ursae Majorids,
  - 54.4 km/sec



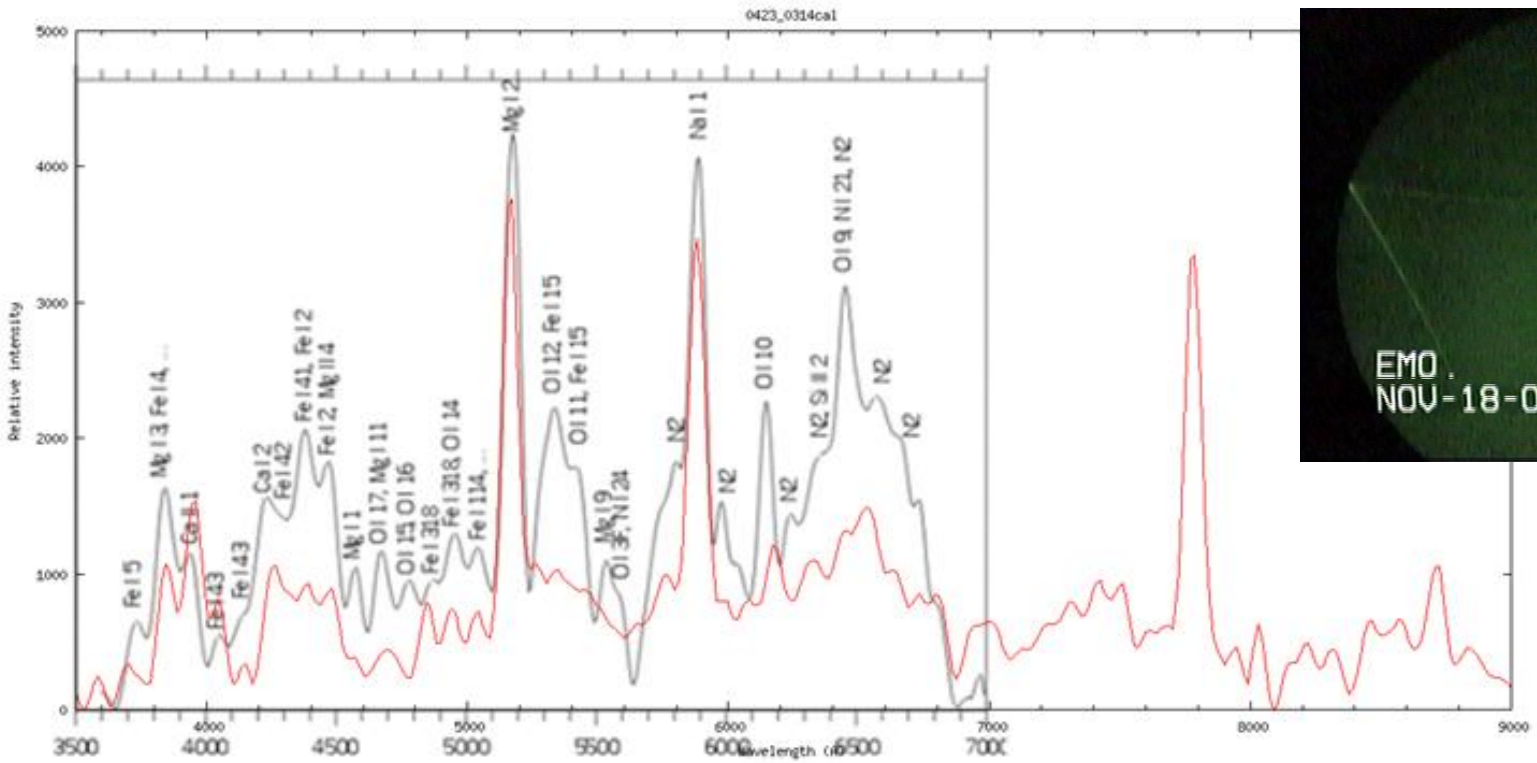


1999 Leonid spectrum

http://meteorobserver.proboards.com/thread/24/meteor-spectroscopy

600L/mm grating, first spectrum

- Red: M20150423_031405, Lyrid, -3.0m, vg = 49 km/sec
- Black:: Leonid spectrum http://members.shaw.ca/epmajden/



Conclusion

- Image transformation gives linear spectra!
- Short focal length
  - Large field of view
  - Low spectral resolution
  - Low sensitivity
  - Different orders visible
- Long focal length
  - Small field of view
  - High spectral resolution
  - High sensitivity
  - Few meteor spectra of higher quality
- Grating with 300 to 1000L/mm mounted perpendicular to axis
- 6 – 12mm focal length for ½" CCD
- Limit magnitude -1 … -2
- Next: Spectral response

Waiting for next meteor spectrum, patience required!

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)

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)
- Bill Ward (discussion Sonotaco forum, IMC)

Links

- www.meteorastronomie.ch
- http://www.meteoros.de/
- http://www.imo.net/
- SonotaCo Forum
  http://sonotaco.jp/forum/viewtopic.php?t=3065
- Thorlabs grating
  http://www.thorlabs.de/newgrouppage9.cfm?objectgroup_id=1123

Thank you!
Danke für Ihre Aufmerksamkeit!