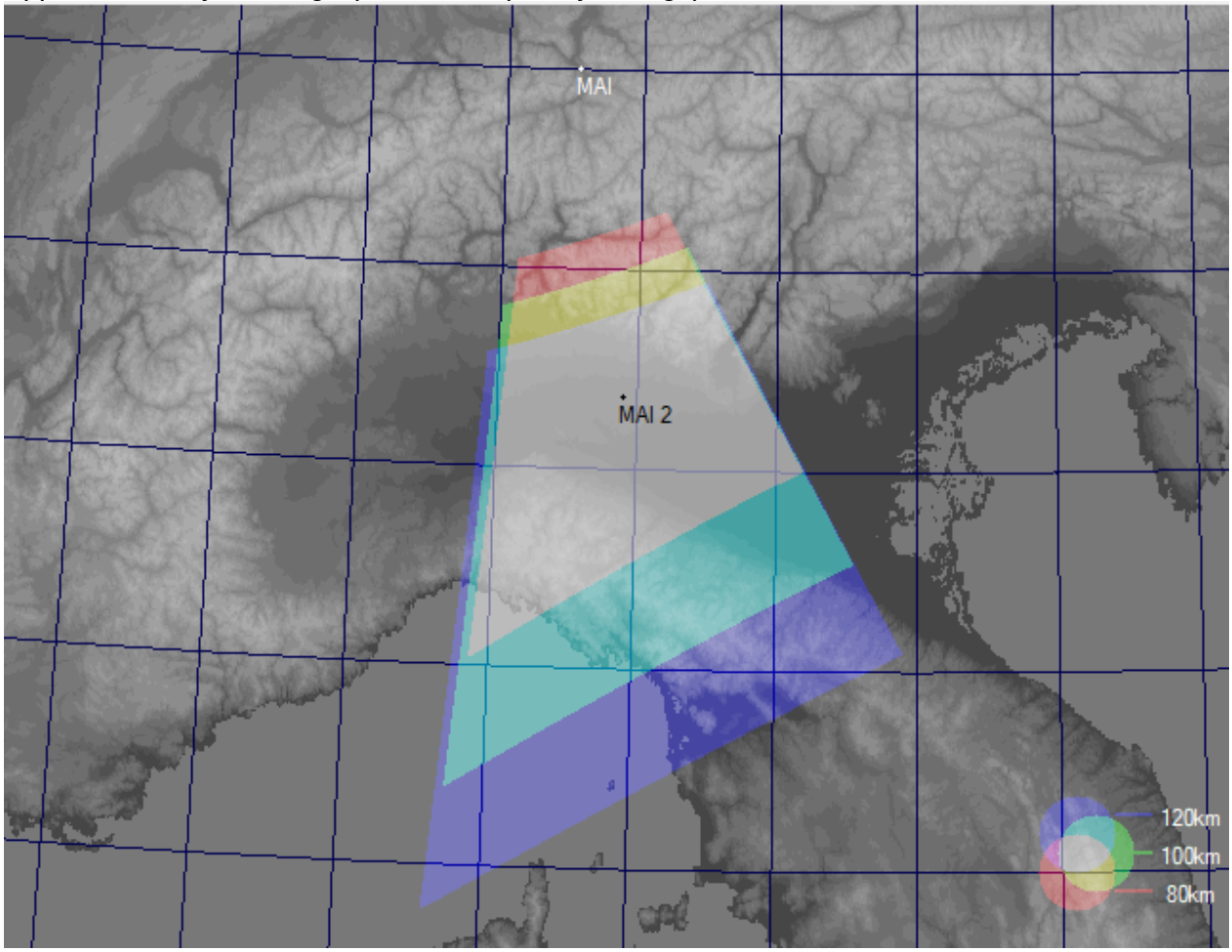
Meteor spectra 2023

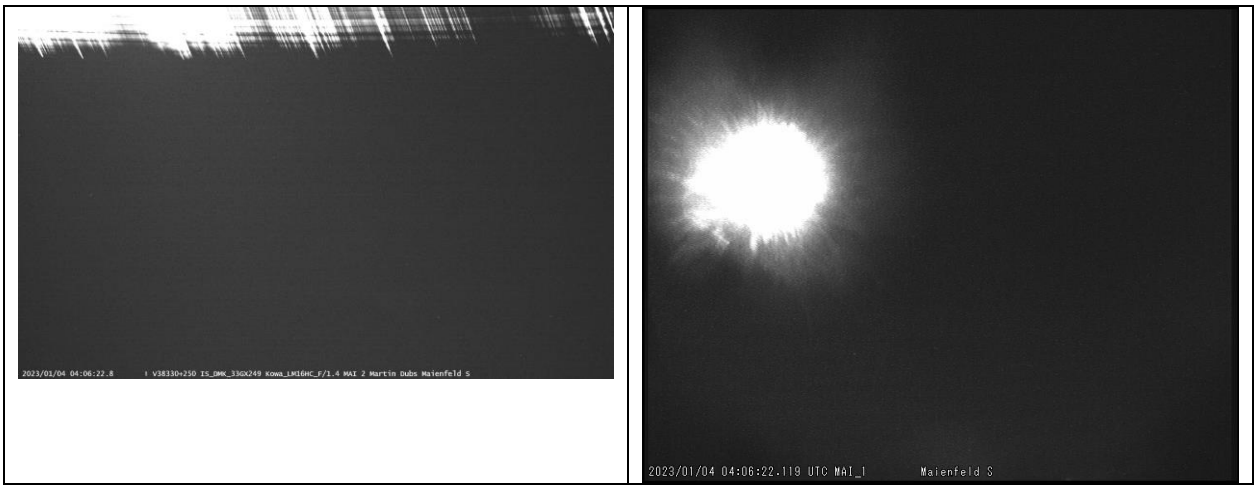
Overview

This is a collection of meteor spectra obtained at Maienfeld (station MAI_2, http://www.meteorastronomie.ch/stationen.html)
Setup:
Camera: **DMK 33GX249**
Resolution 1920x1200
Frame Rate: 25 Hz
Sensor Type Sony IMX249LLJ-C
Sensor Format 1/1.2 inch
Pixel Size **5.86 µm**
Lens
Kowa LM16HC f: 16mm F/1.4
Field of view horizontal: 39°
Approximate sky coverage (mobile setup, may change) for elevation 37°, Azimuth 170°



Grating: Thorlabs 600l/mm, dispersion: 0.598 nm/pixel
Spectra analyzed with Python M_SPEC.py.
1st order spectra were further analysed by fitting synthetic meteor spectra to the observed spectra
(https://meteorspectroscopy.org/2022/03/08/synthetic-meteor-spectra/).
In addition, meteors were recorded with a Watec 902H2 ultimate, equipped with a wide angle lens: Tamron VG412 ASIR at f ≅ 4mm, MAI_1.

M20230104_040622_MAI_2, DAD or QUA, -12.6m

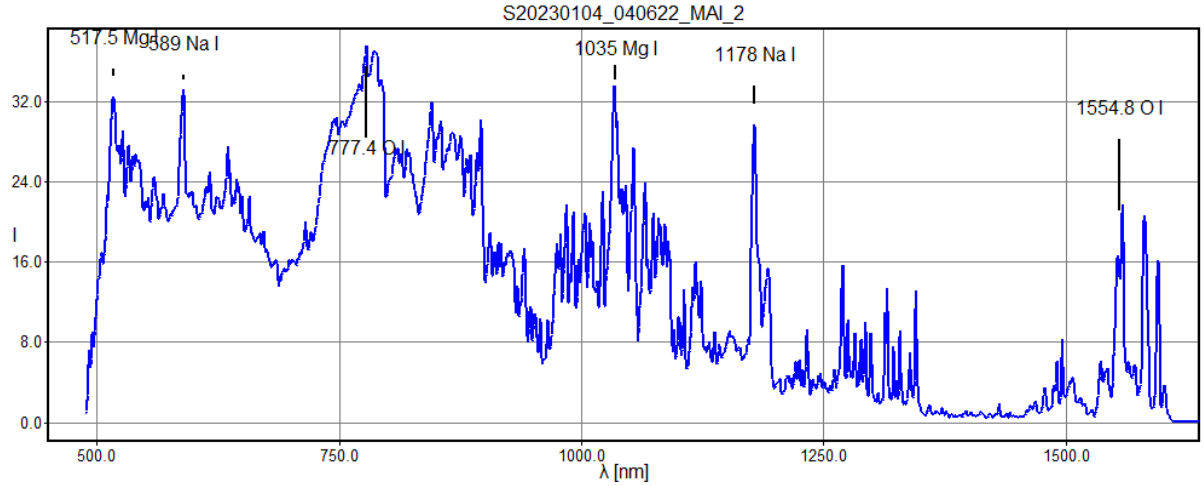


polynom for fit lambda c: [0.5996 488.989]

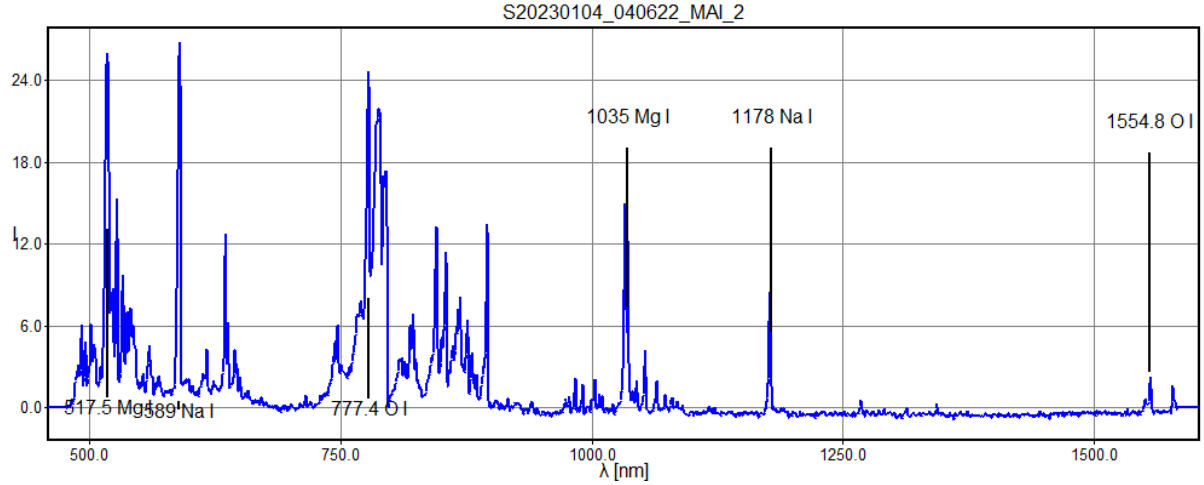
pixel	lambda	fit	error
47.24,	517.50,	517.32,	-0.1839
167.46,	589.00,	589.41,	0.4051
909.21,	1035.00,	1034.19,	-0.8105
1150.02,	1178.00,	1178.59,	0.5893

rms_x = 0.5482

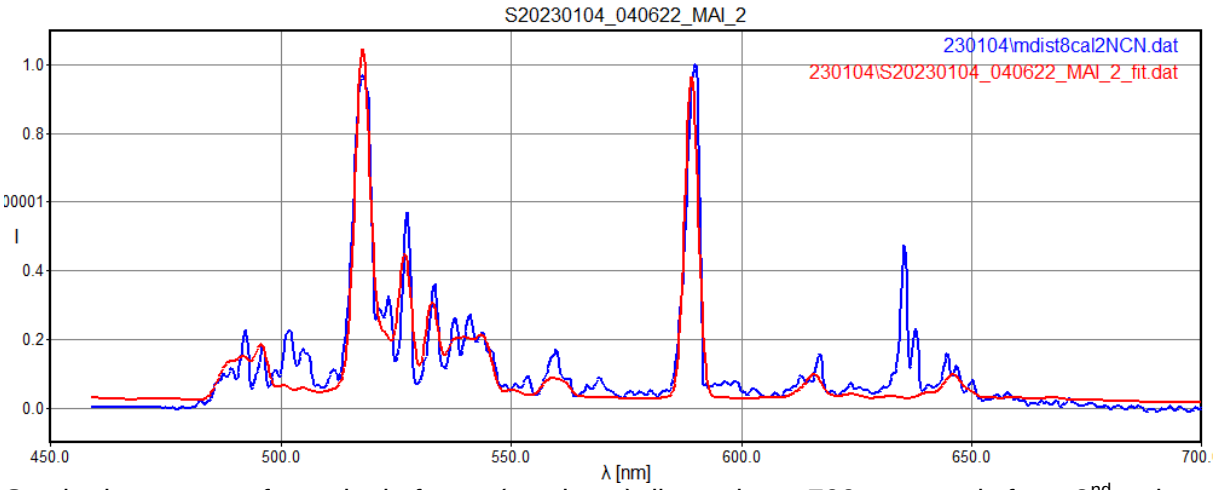
spectrum 230104\r_add6cal.dat saved



Spectrum mostly saturated, 1st and 2nd order

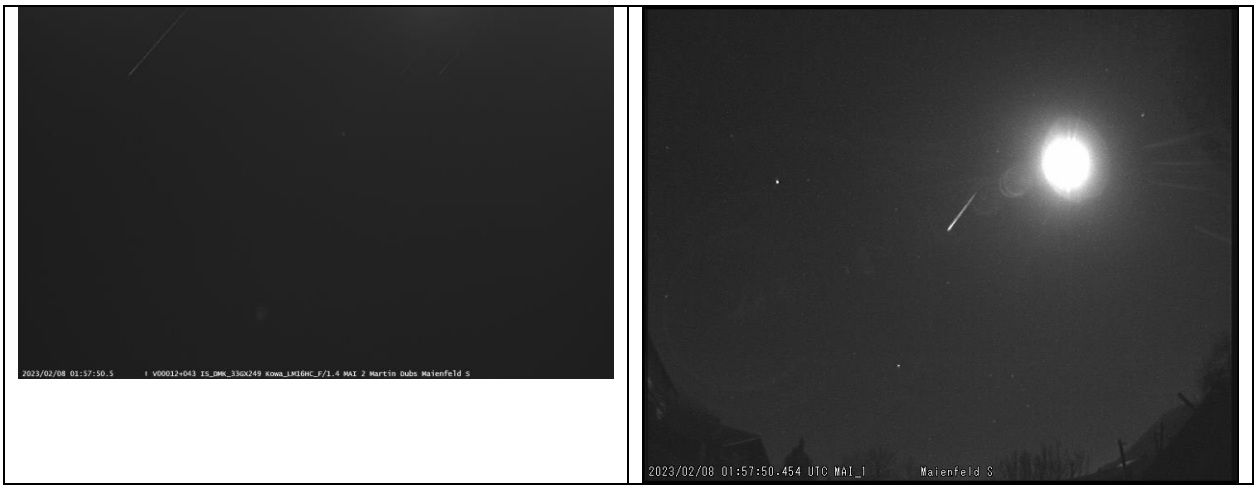


Single frame after most intense outburst



Synthetic spectrum from single frame (as above), lines above 700 nm mostly from 2nd order, excluded from fit, below 480 nm cutoff by frame edge.

M20230208_015750_MAI_2, spo, -1.1m

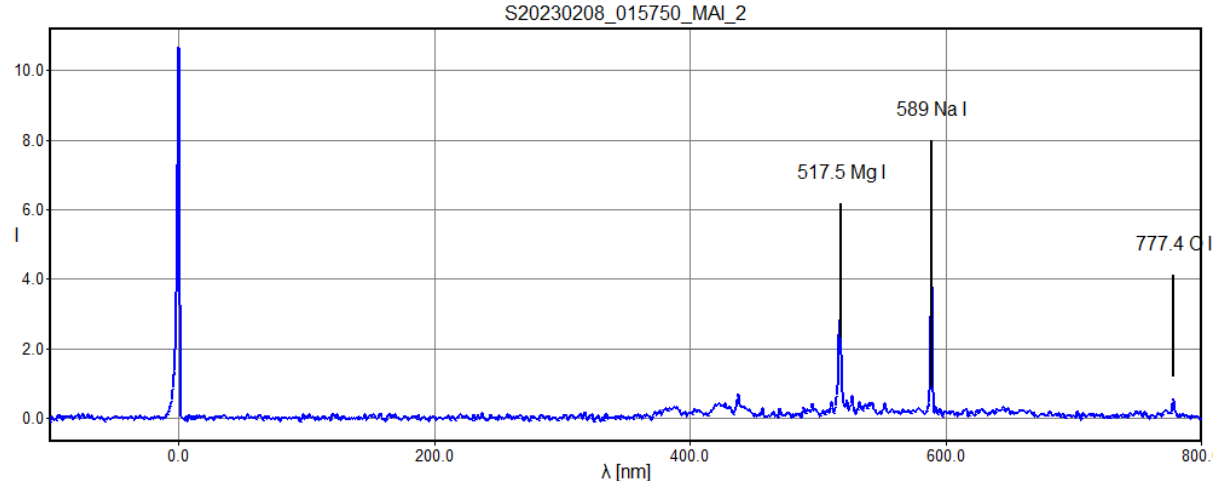


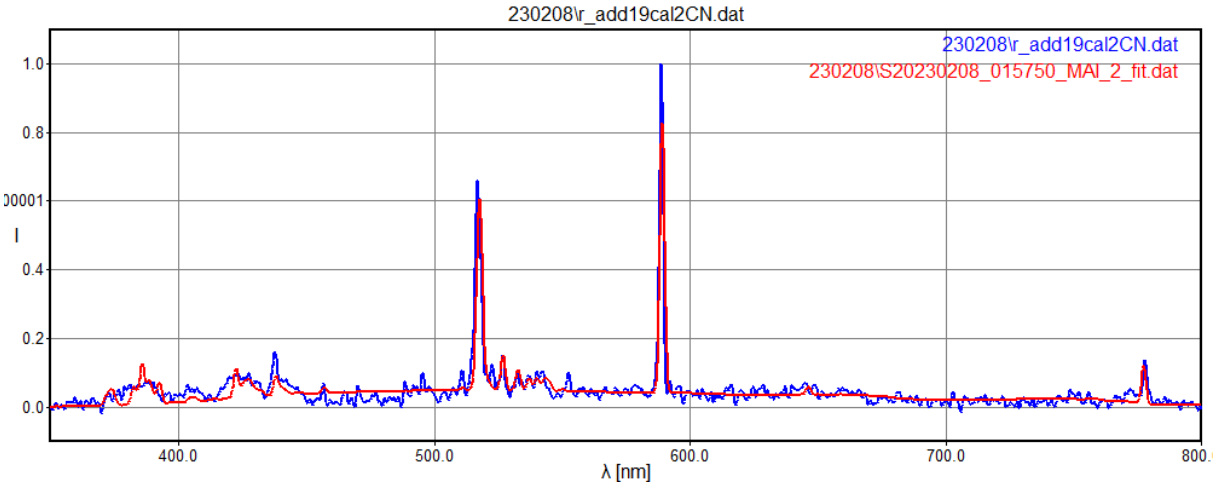
polynom for fit lambda c: [0.5991 -329.2067]

pixel	lambda	fit	error
549.88,	0.00,	0.21,	0.2072
1412.67,	517.50,	517.07,	-0.4254
1532.29,	589.00,	588.73,	-0.2653
1848.03,	777.40,	777.88,	0.4835

rms_x = 0.3634

spectrum 230208\r_add19cal.dat saved





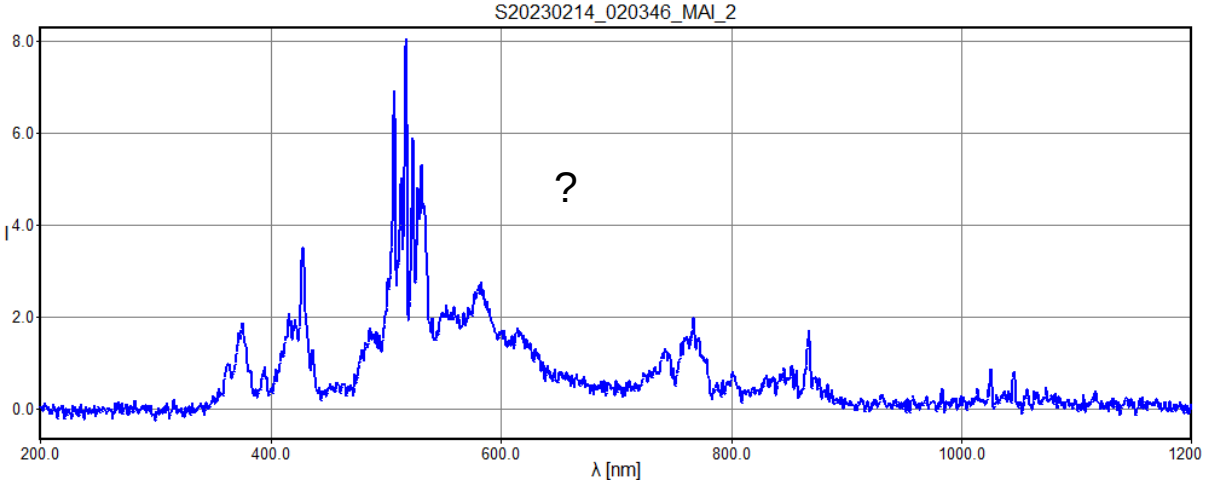
M20230214_020346_MAI_2, spo, -1.9m

polynom for fit lambda c: [0.59996, 197.0193668]

pixel	lambda	fit	error
534.17,	517.50,	517.50,	0.0000

rms_x = 0.0000

spectrum 230214\r_add7cal.dat saved



Calibration uncertain, spectrum does not fit

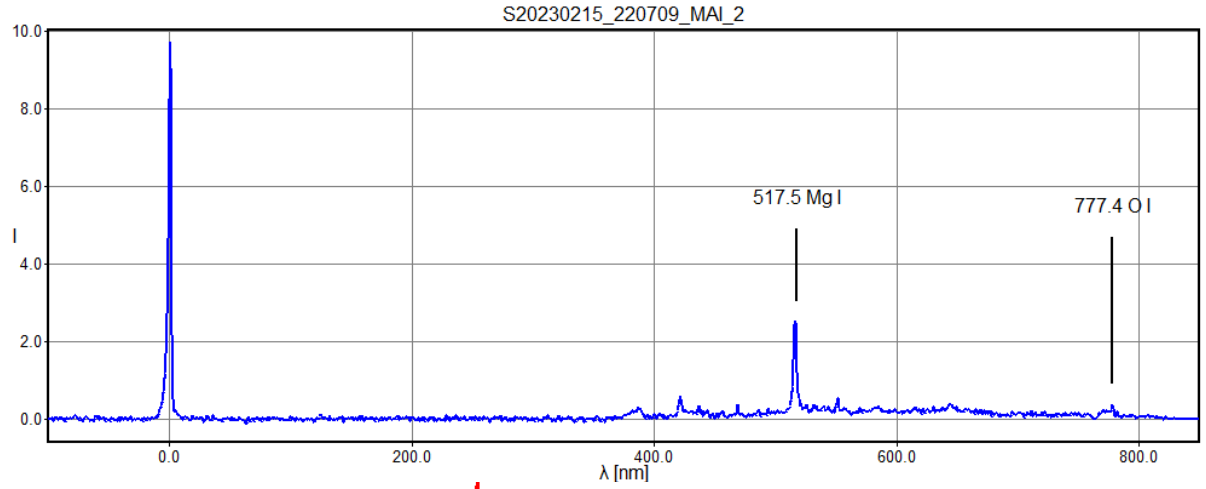
M20230215_220709_MAI_2, spo, -1.4m

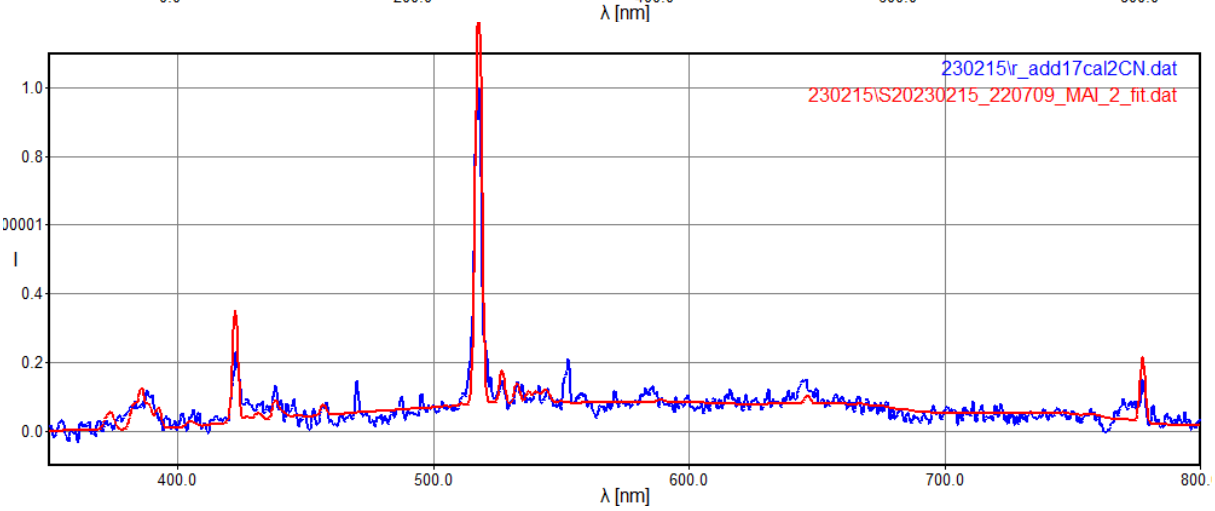
polynom for fit lambda c: [-5.1760e-06 6.0876e-01 -2.9946e+02]

pixel	lambda	fit	error
494.00,	0.00,	0.00,	0.0000
1357.69,	517.50,	517.50,	0.0000
1796.39,	777.40,	777.40,	0.0000

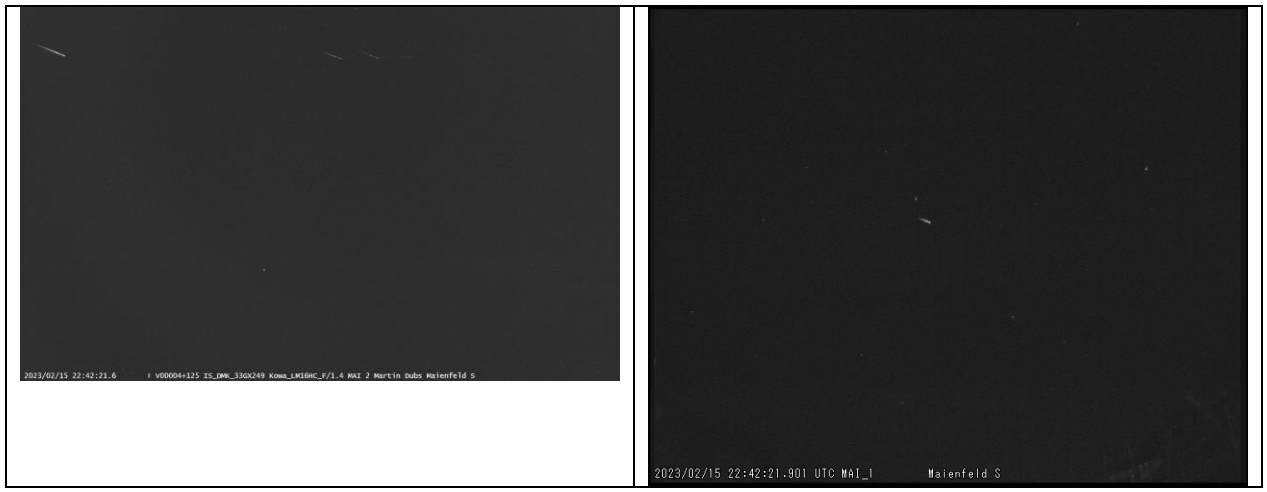
rms_x = 0.0000

spectrum 230215\r_add17cal.dat saved





M20230215_224221_MAI_2, spo, -1.2m

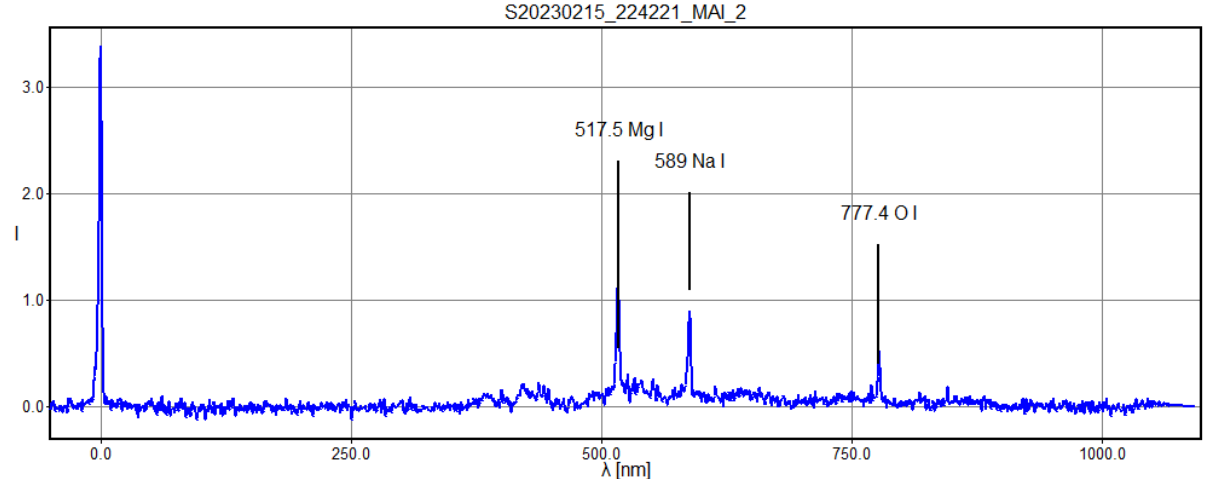


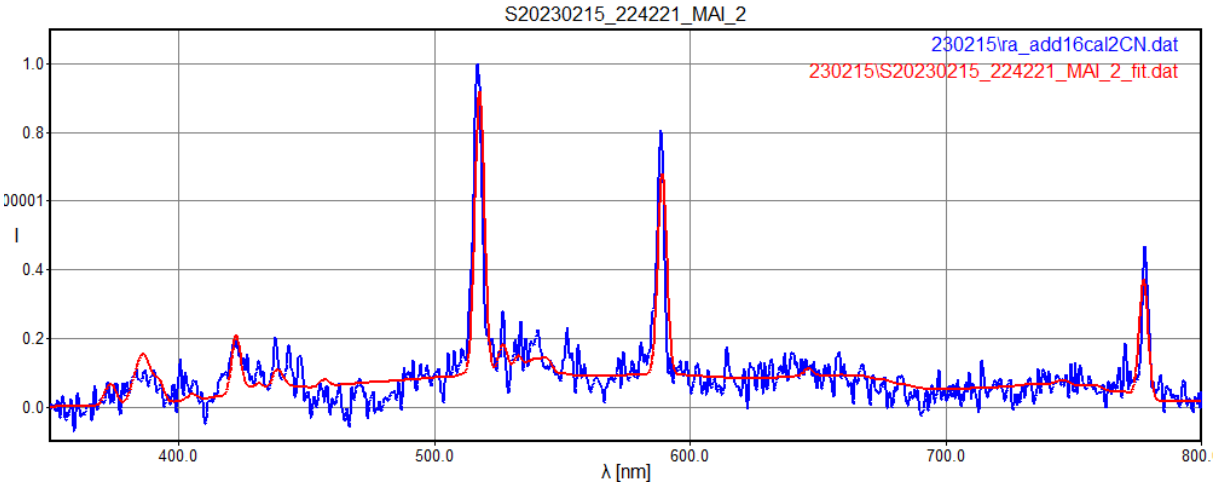
polynom for fit lambda c: [0.5975 -52.5834]

pixel	lambda	fit	error
88.36,	0.00,	0.22,	0.2159
953.39,	517.50,	517.11,	-0.3868
1073.10,	589.00,	588.65,	-0.3543
1389.86,	777.40,	777.93,	0.5251

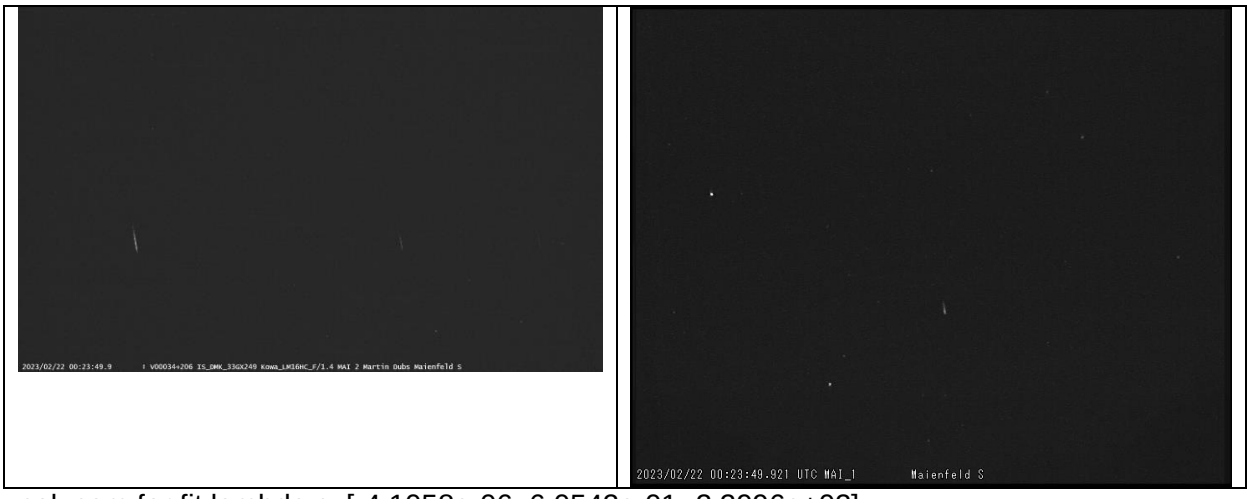
rms_x = 0.3865

spectrum 230215\ra_add16cal.dat saved





M20230222_002349_MAI_2, spo, -0.3m

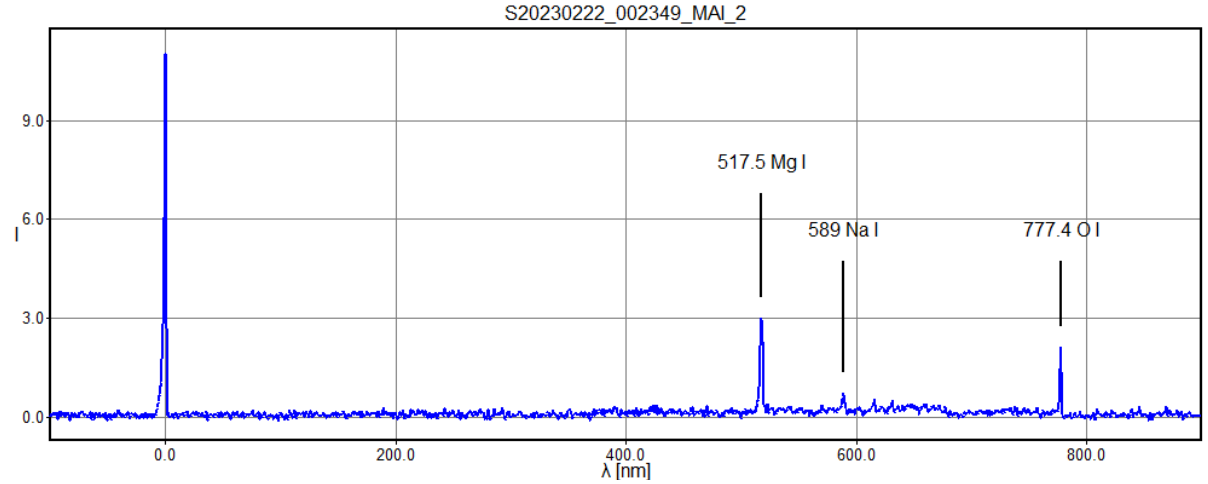


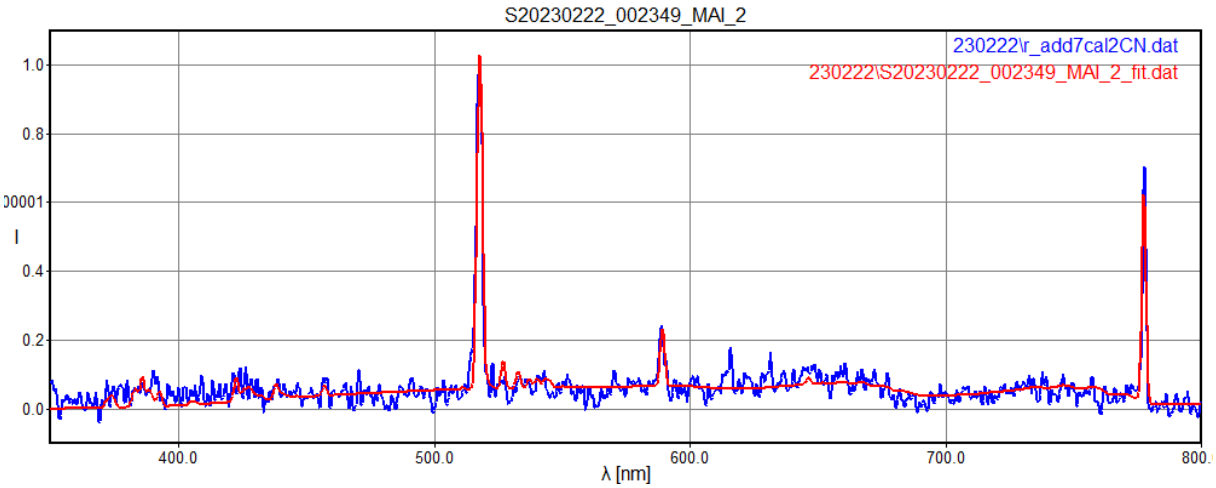
polynom for fit lambda c: [-4.1058e-06 6.0542e-01 -2.2996e+02]

pixel	lambda	fit	error
380.81,	0.00,	-0.01,	-0.0079
1245.45,	517.50,	517.69,	0.1932
1364.96,	589.00,	588.77,	-0.2334
1683.19,	777.40,	777.45,	0.0482

rms_x = 0.1534

spectrum 230222\r_add7cal.dat saved





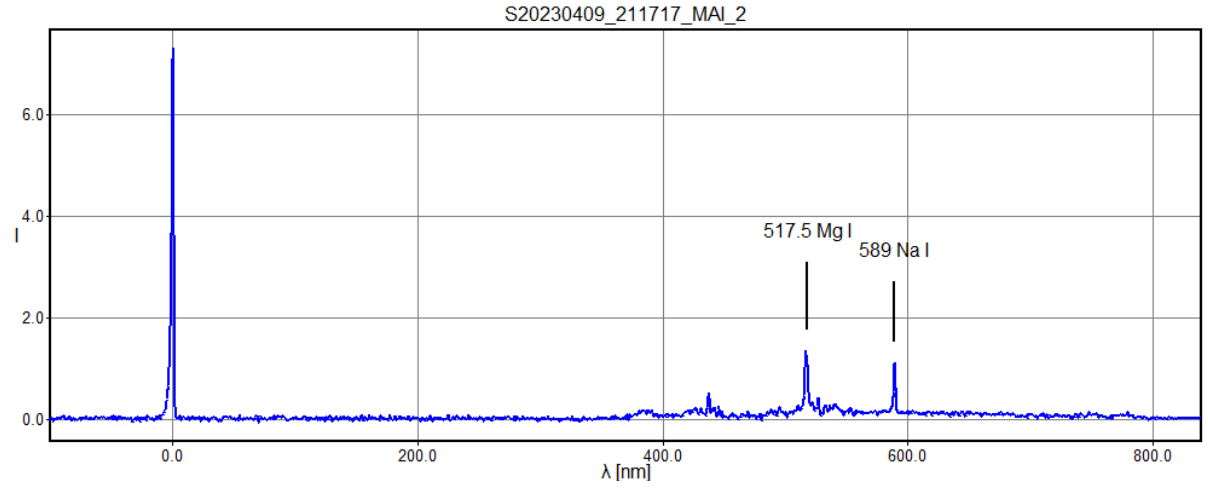
M20230409_211717_MAI_2, spo, -0.1m

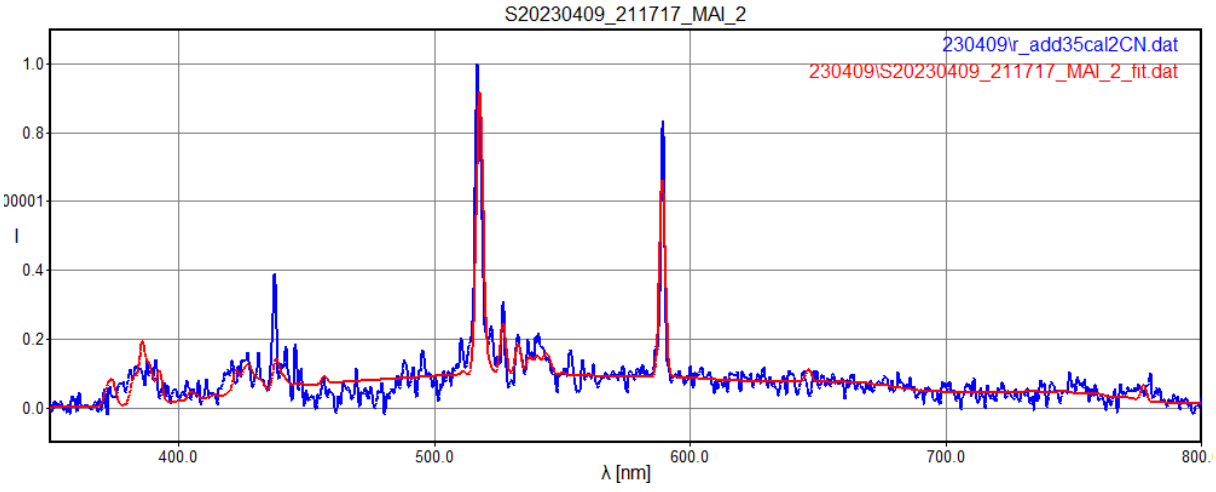
polynom for fit lambda c: [0.598 -305.9936]

pixel	lambda	fit	error
511.76,	0.00,	0.04,	0.0416
1376.50,	517.50,	517.16,	-0.3395
1497.13,	589.00,	589.30,	0.2979

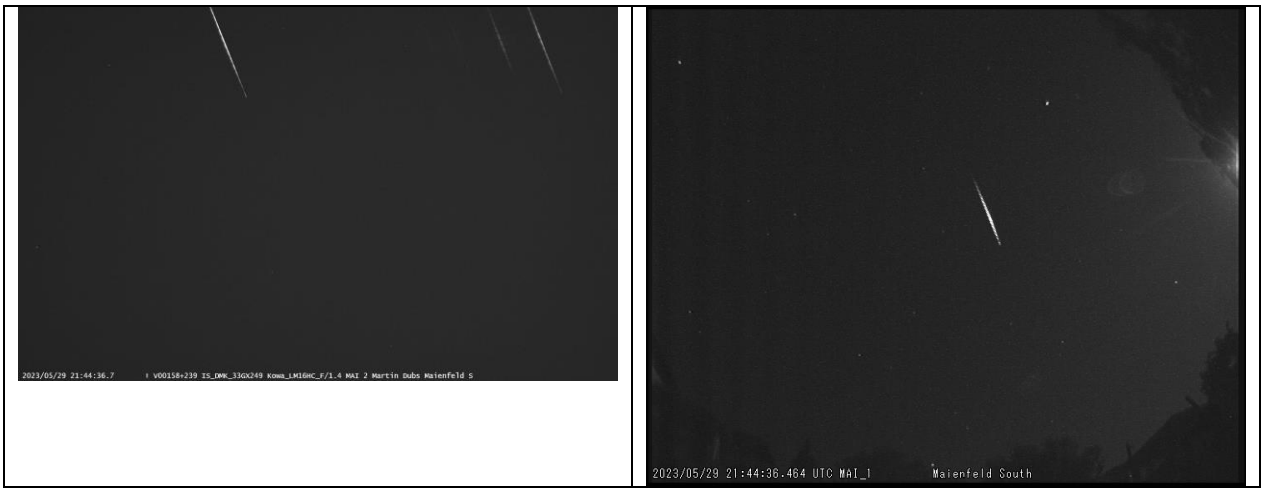
rms_x = 0.2619

spectrum C:\Daten\Python\spyder\ 230409\r_add35cal.dat saved moved to C:\Daten\Python\meteor-spectrum\230409





M20230529_214436_MAI_2, spo, -2.6m

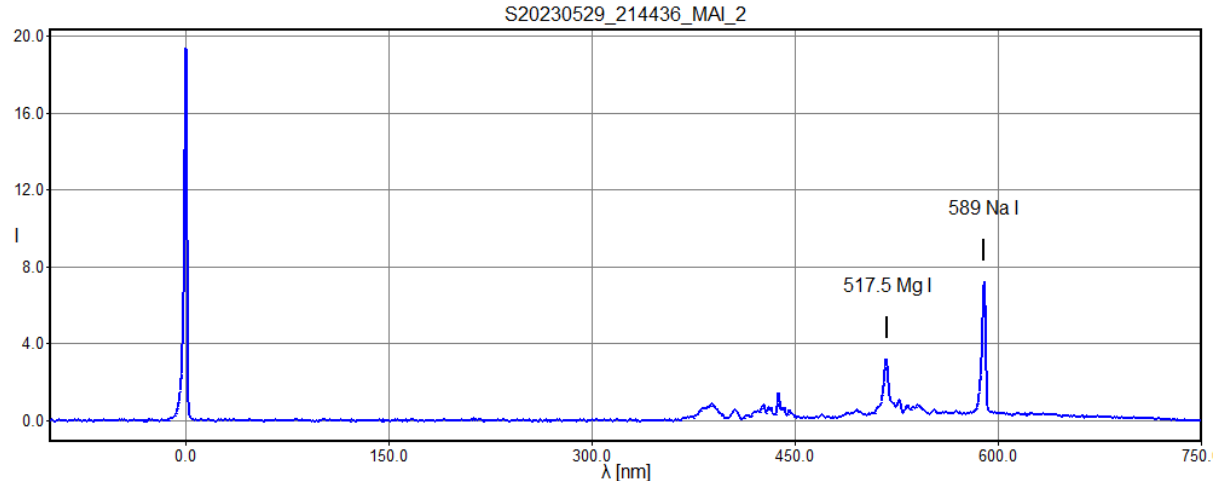


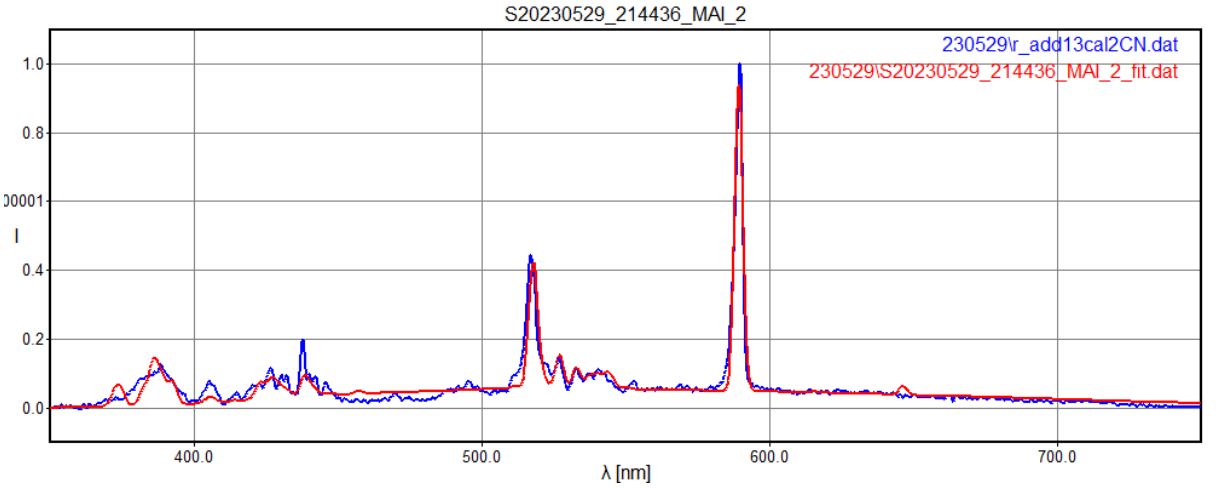
polynom for fit lambda c: [0.5979 -374.8916]

pixel	lambda	fit	error
627.14,	0.00,	0.05,	0.0519
1491.93,	517.50,	517.08,	-0.4227
1612.85,	589.00,	589.37,	0.3708

rms_x = 0.3260

spectrum 230529\r_add13cal.dat saved





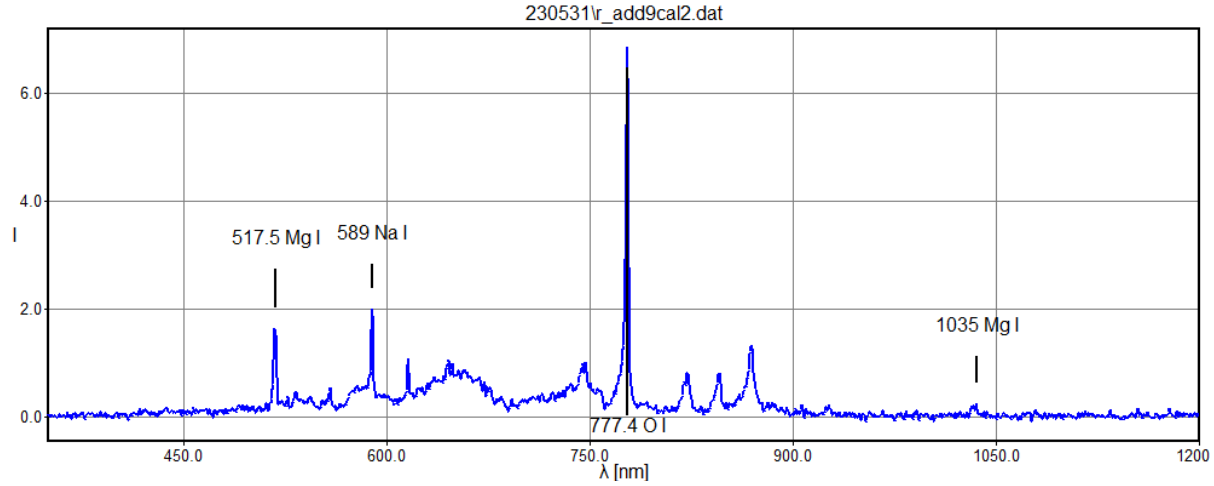
M20230531_021909_MAI_2, spo, -2.1m

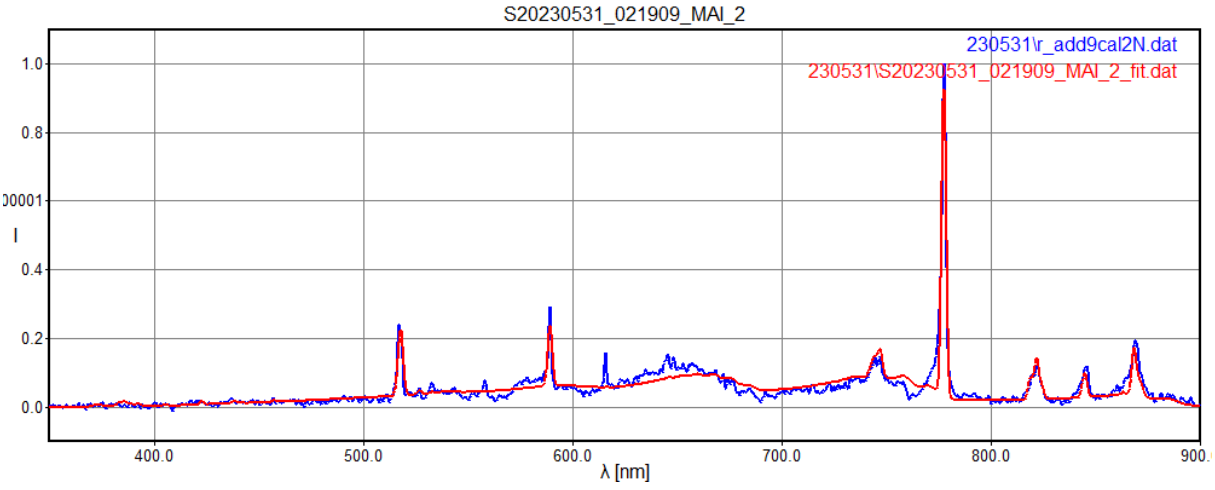
polynom for fit lambda c: [0.5973 314.7031]

pixel	lambda	fit	error
339.49,	517.50,	517.49,	-0.0057
459.17,	589.00,	588.98,	-0.0160
774.66,	777.40,	777.44,	0.0391
1205.81,	1035.00,	1034.98,	-0.0174

rms_x = 0.0230

spectrum 230531\r_add9cal.dat saved





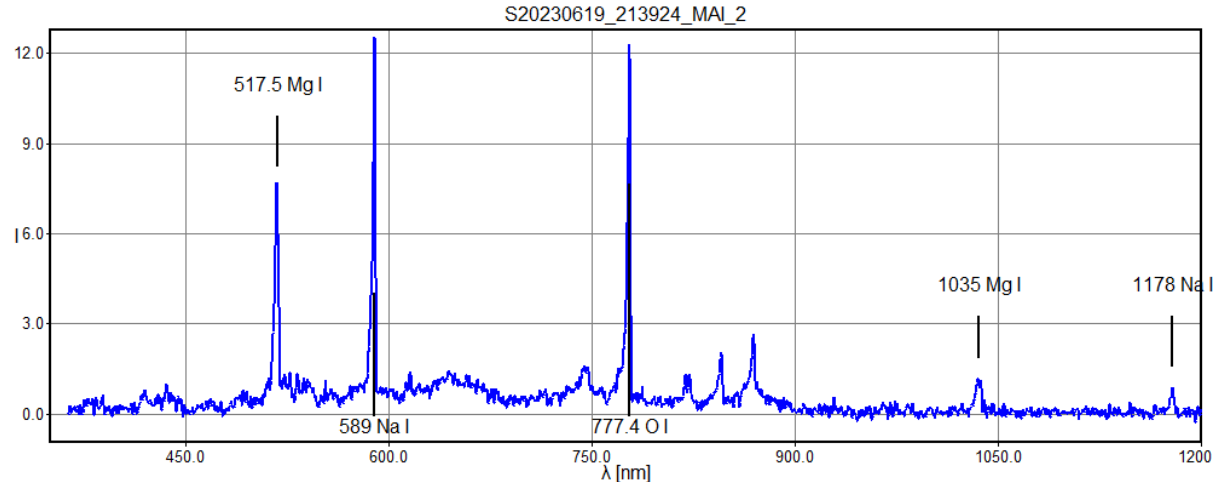
M20230619_213924_MAI_2, spo, -2.6m

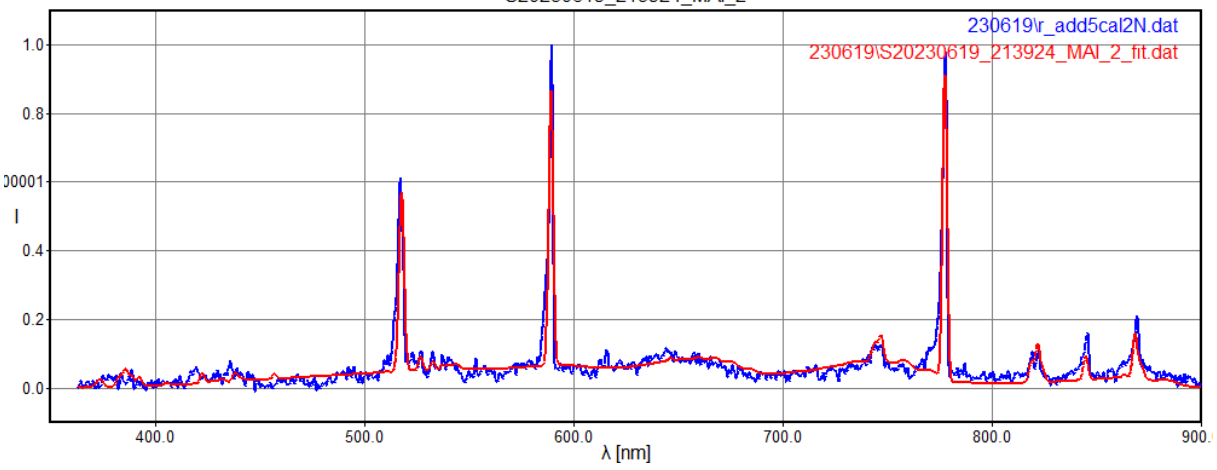
polynom for fit lambda c: [0.598 362.4407]

pixel	lambda	fit	error
258.90,	517.50,	517.25,	-0.2475
379.46,	589.00,	589.34,	0.3425
693.80,	777.40,	777.31,	-0.0949

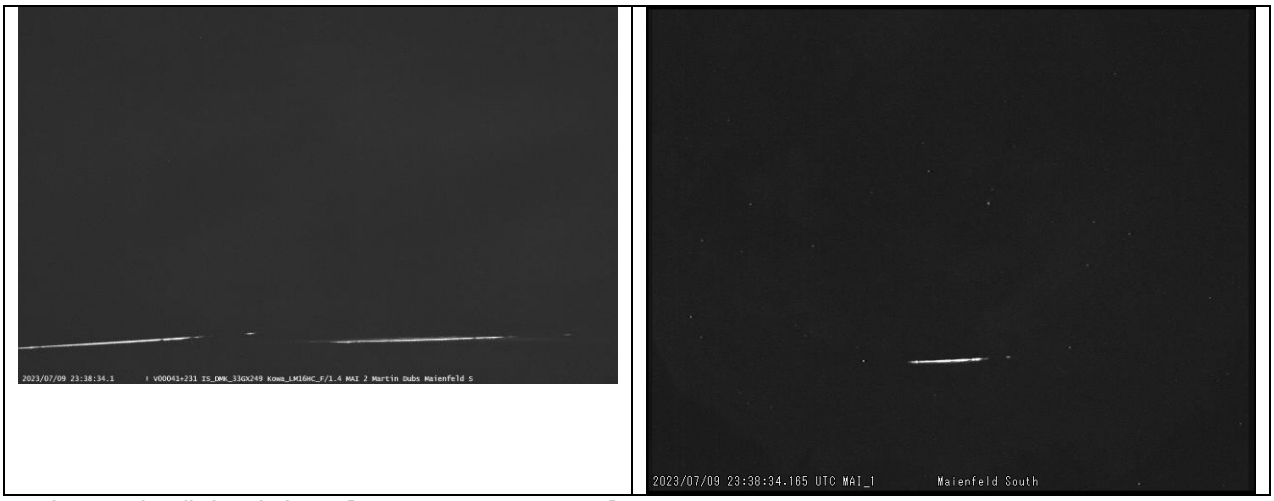
rms_x = 0.2500

spectrum 230619\r_add5cal.dat saved





M20230709_233834_MAI_2, spo, -2.2m

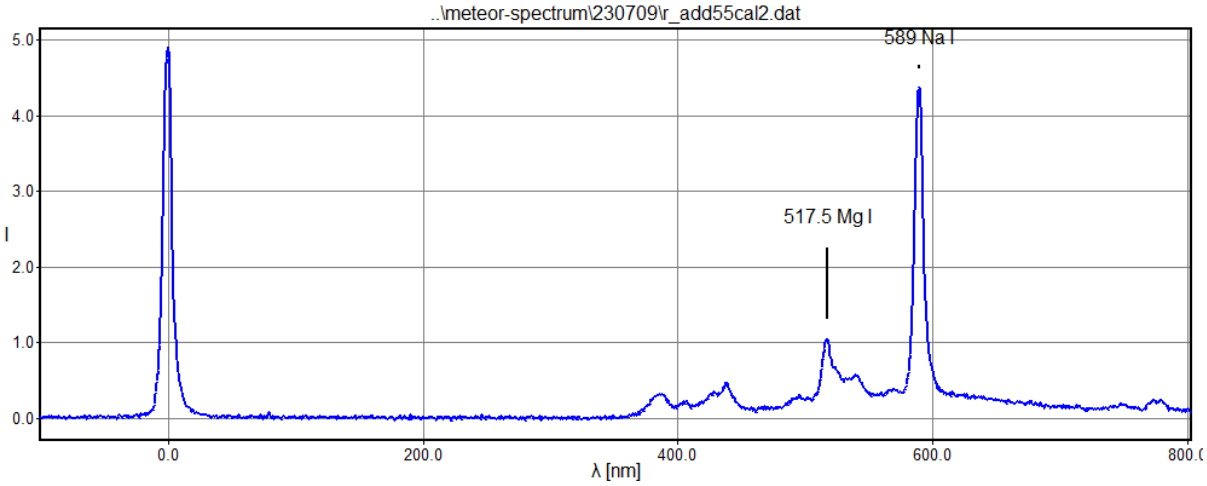


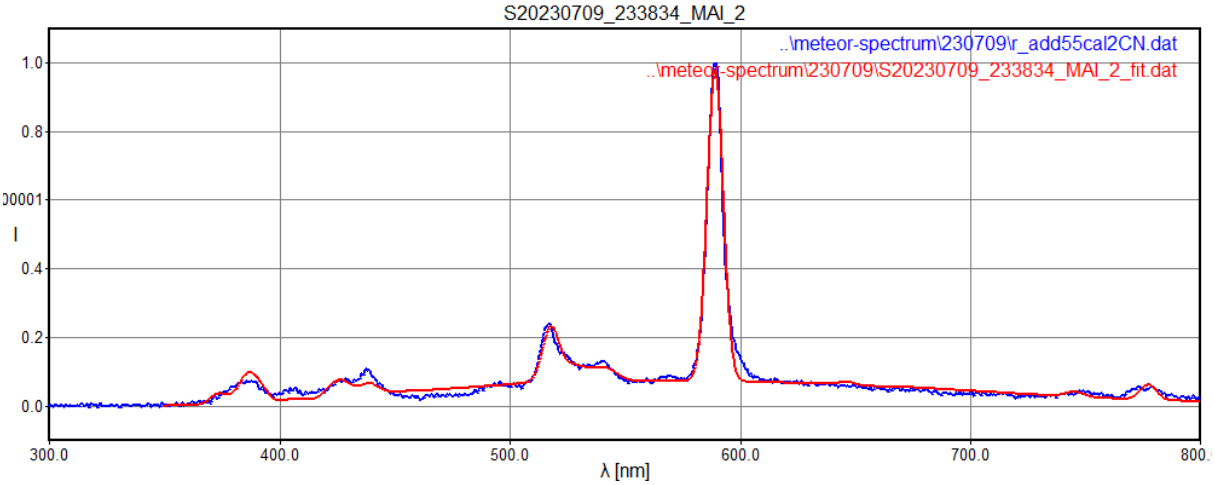
polynom for fit lambda c: [0.5982 -342.4655]

pixel	lambda	fit	error
572.60,	0.00,	0.04,	0.0384
1437.17,	517.50,	517.19,	-0.3141
1557.69,	589.00,	589.28,	0.2757

rms_x = 0.2423

spectrum ..\meteor-spectrum\230709\r_add55cal.dat saved





Low resolution caused by movement along dispersion direction. Cannot correct slant.

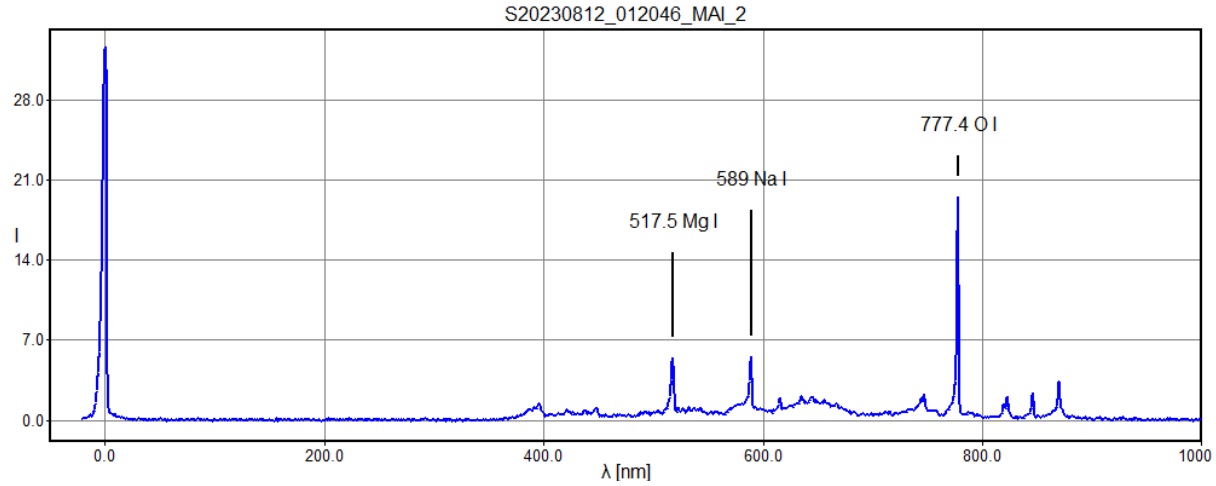
M20230812_012046_MAI_2, PER, -2.8m

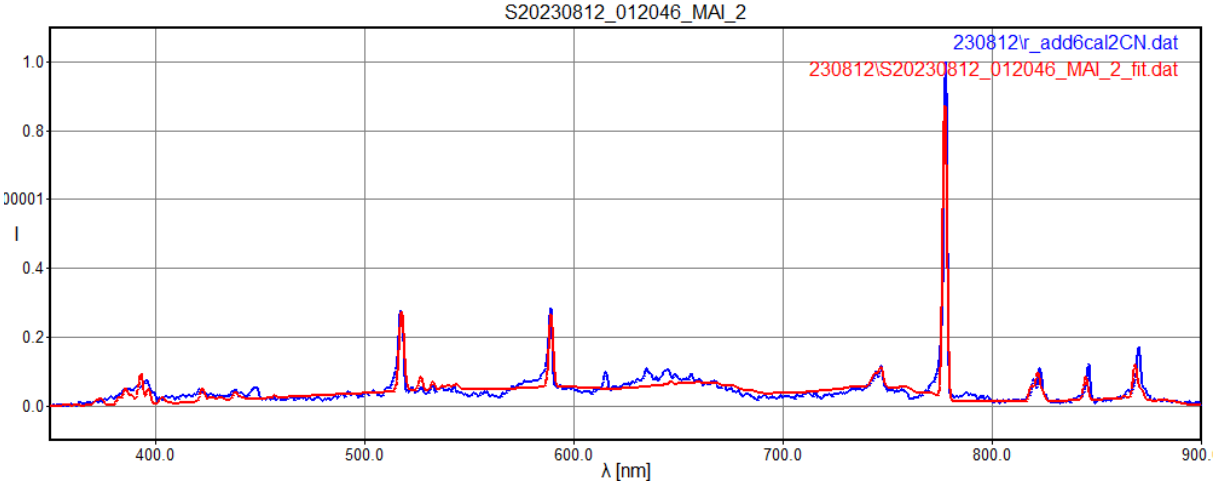
polynom for fit lambda c: [0.5972 -22.1659]

pixel	lambda	fit	error
37.21,	0.00,	0.05,	0.0547
903.64,	517.50,	517.46,	-0.0415
1023.16,	589.00,	588.83,	-0.1680
1339.19,	777.40,	777.55,	0.1548

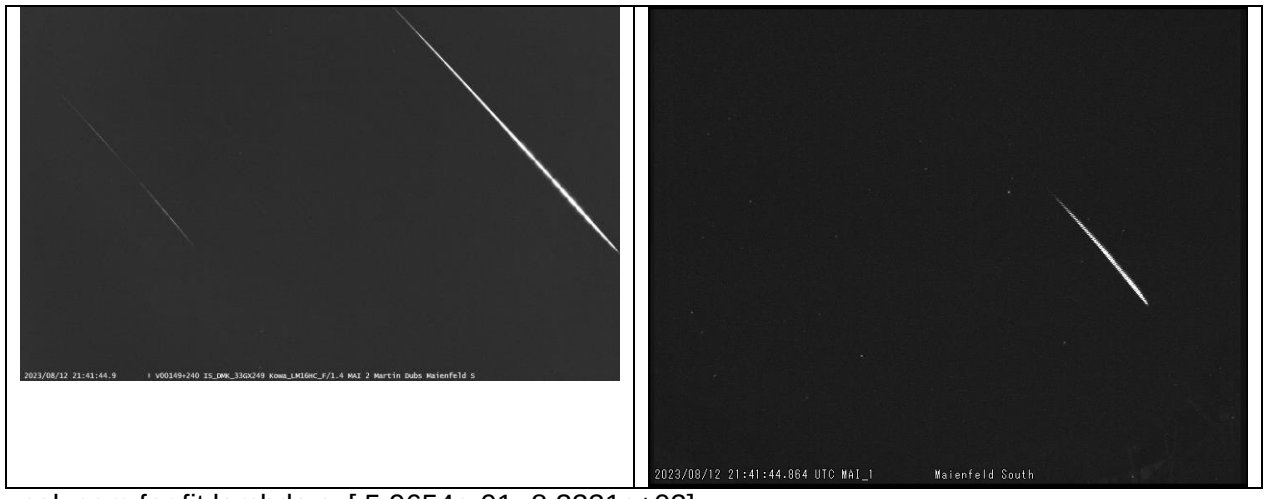
rms_x = 0.1193

spectrum 230812\r_add6cal.dat saved





M20230812_214144_MAI_2, PER, -3.4m

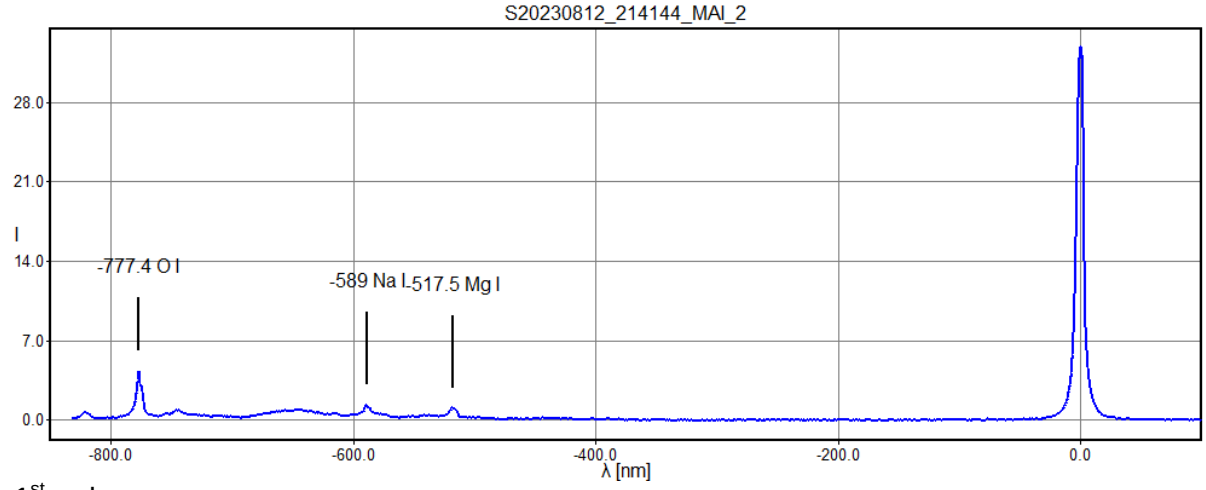


polynom for fit lambda c: [5.9654e-01 -8.3331e+02]

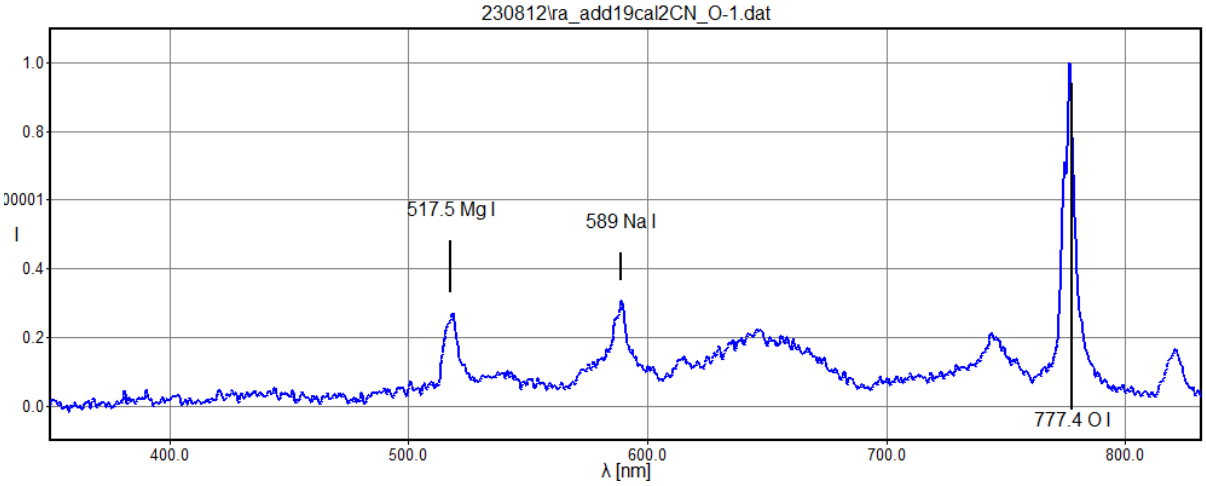
pixel	lambda	fit	error
1397.38,	0.00,	0.29,	0.2853
528.15,	-517.50,	-518.24,	-0.7448
409.28,	-589.00,	-589.16,	-0.1555
94.75,	-777.40,	-776.79,	0.6149

rms_x = 0.5095

spectrum 230812\ra_add19cal.dat saved



-1st order:



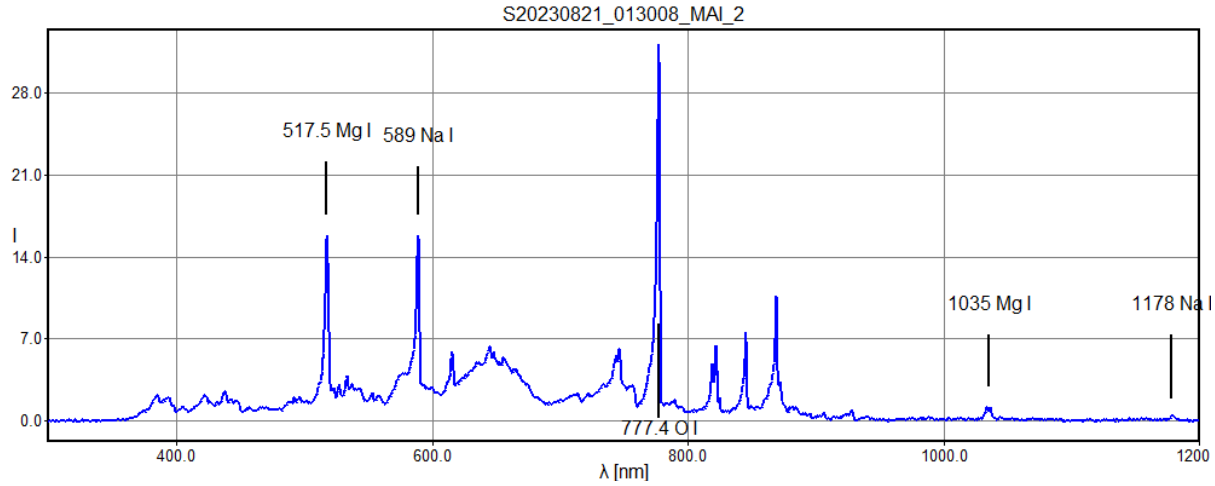
M20230821_013008_MAI_2, PER, -3.3m

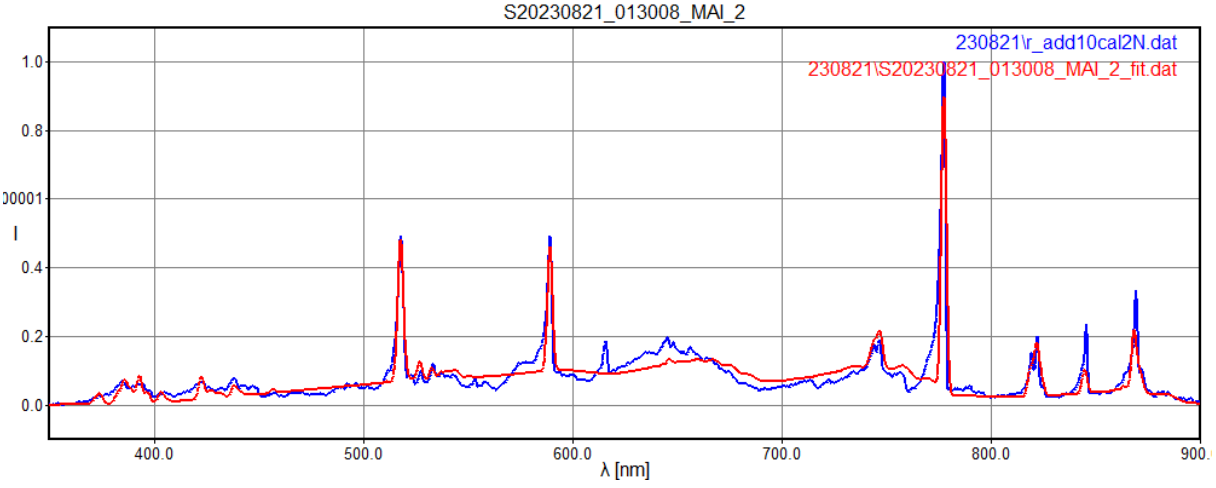
polynom for fit lambda c: [0.5981 213.6816]

pixel	lambda	fit	error
508.60,	517.50,	517.90,	0.3969
627.60,	589.00,	589.08,	0.0759
941.88,	777.40,	777.06,	-0.3398
1371.15,	1035.00,	1033.82,	-1.1751
1613.93,	1178.00,	1179.04,	1.0420

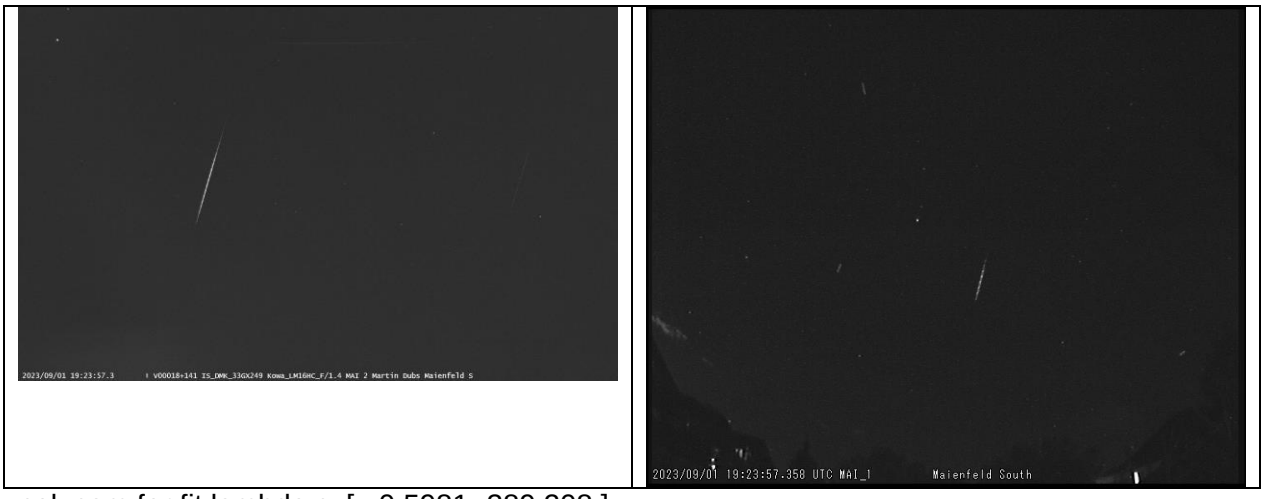
rms_x = 0.7410

spectrum 230821\r_add10cal.dat saved





M20230901_192357_MAI_2, spo, -0.9m

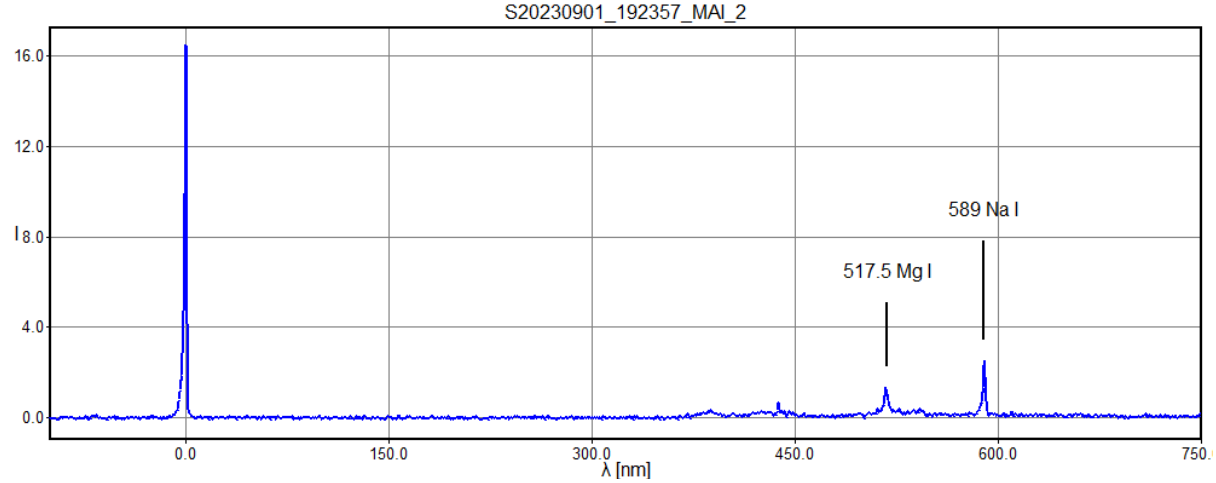


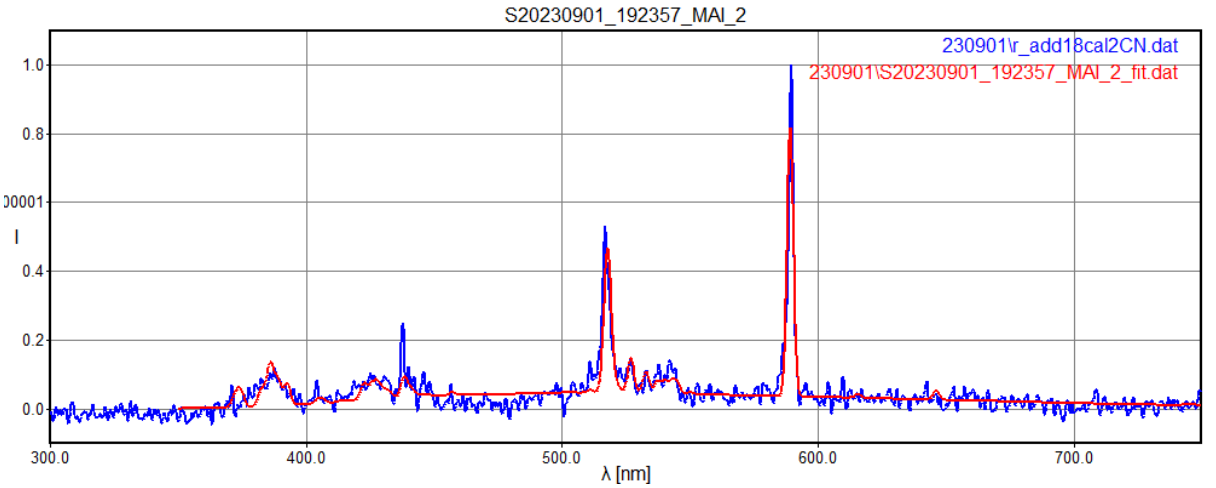
polynom for fit lambda c: [0.5981 -389.208]

pixel	lambda	fit	error
650.85,	0.00,	0.06,	0.0620
1515.15,	517.50,	517.00,	-0.5046
1636.28,	589.00,	589.44,	0.4426

rms_x = 0.3892

spectrum 230901\r_add18cal.dat saved





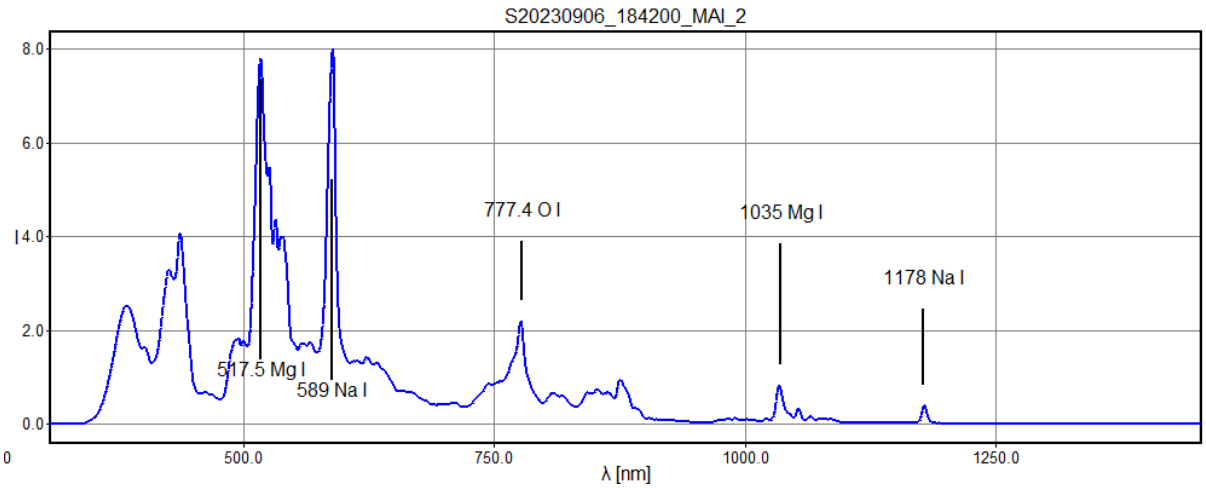
M20230906_184200_MAI_2, spo, -3.7m

polynom for fit lambda c: [0.5988 307.7832]

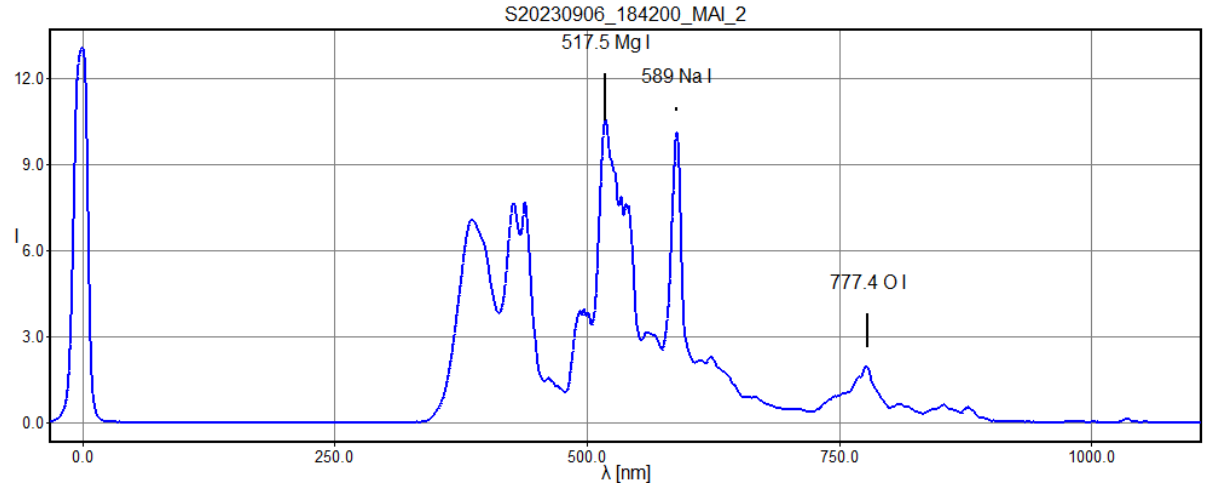
pixel	lambda	fit	error
350.53,	517.50,	517.66,	0.1649
470.35,	589.00,	589.41,	0.4077
783.37,	777.40,	776.83,	-0.5699
1213.16,	1035.00,	1034.17,	-0.8309
1454.76,	1178.00,	1178.83,	0.8283

rms_x = 0.6156

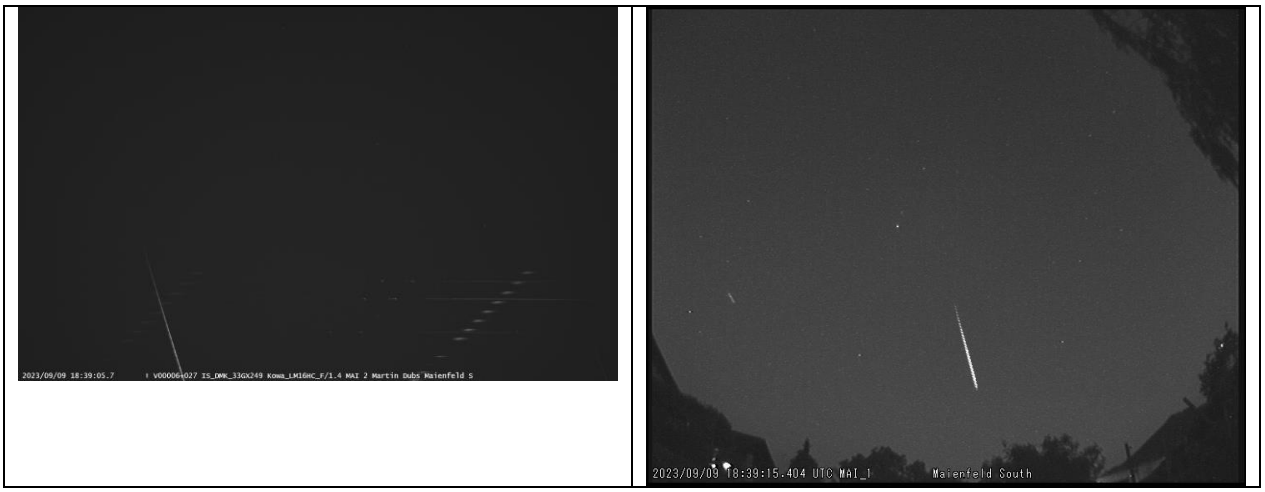
spectrum test\r_add50cal.dat saved



Later frames, with first order, meteor started to fragment:



M20230909_183905_MAI_2, spo, -2.0m

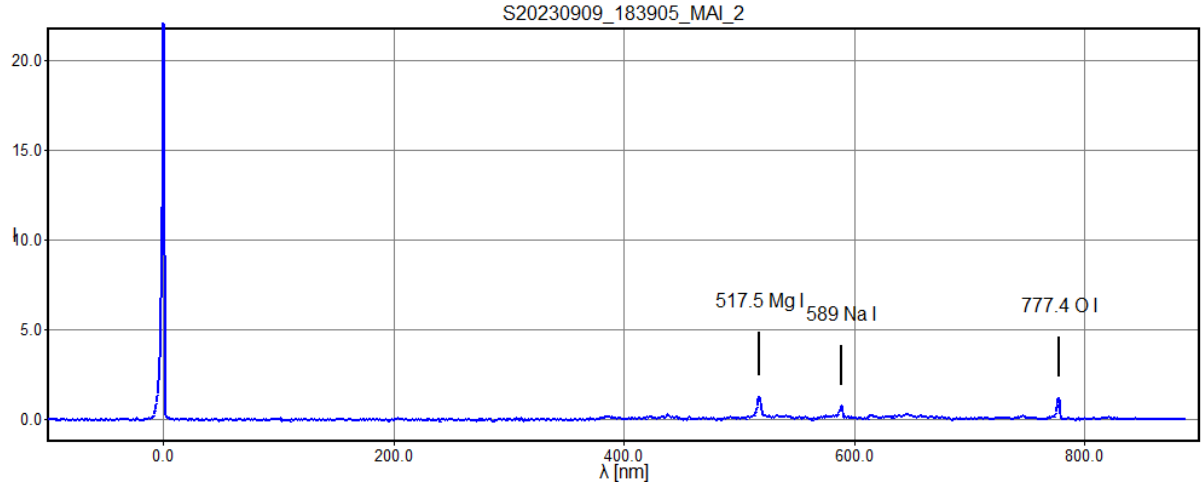


polynom for fit lambda c: [-5.2860e-06 6.0648e-01 -2.5520e+02]

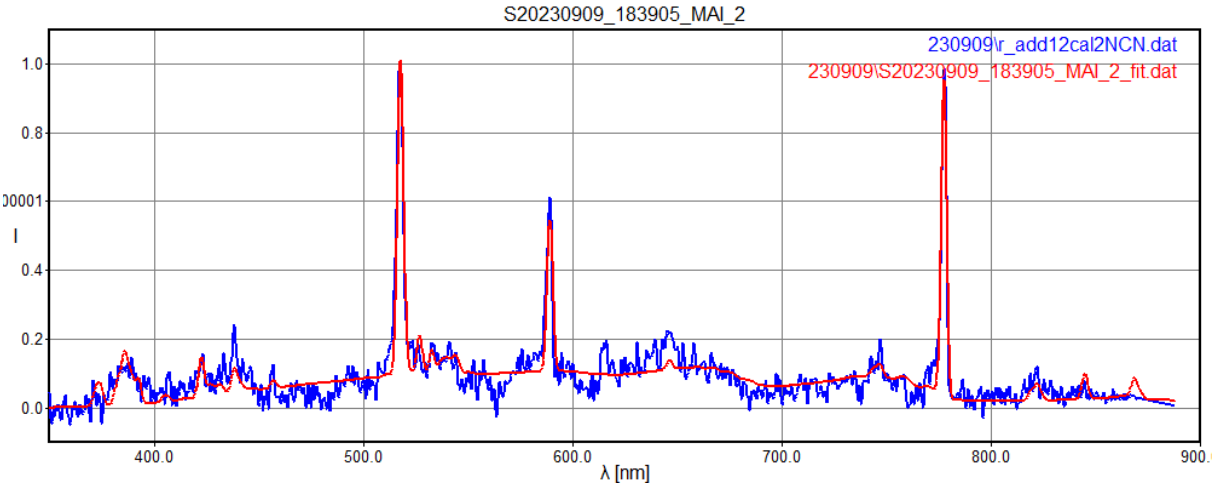
pixel	lambda	fit	error
422.34,	0.00,	0.00,	0.0006
1288.51,	517.50,	517.48,	-0.0156
1409.30,	589.00,	589.02,	0.0189
1728.64,	777.40,	777.40,	-0.0039

rms_x = 0.0124

spectrum 230909\r_add12cal.dat saved

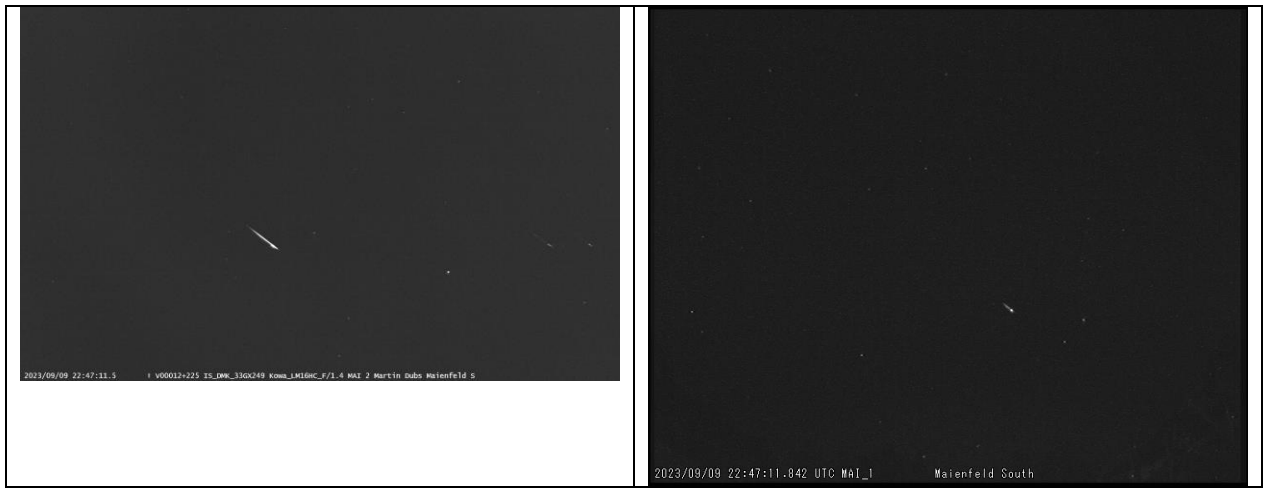


Poor grating efficiency, end of lifetime



video saved: \M20230909_183905_MAI_2part230-300.avi from frame 230, meteor 260

M20230909_224711_MAI_2, spo, -1.3m

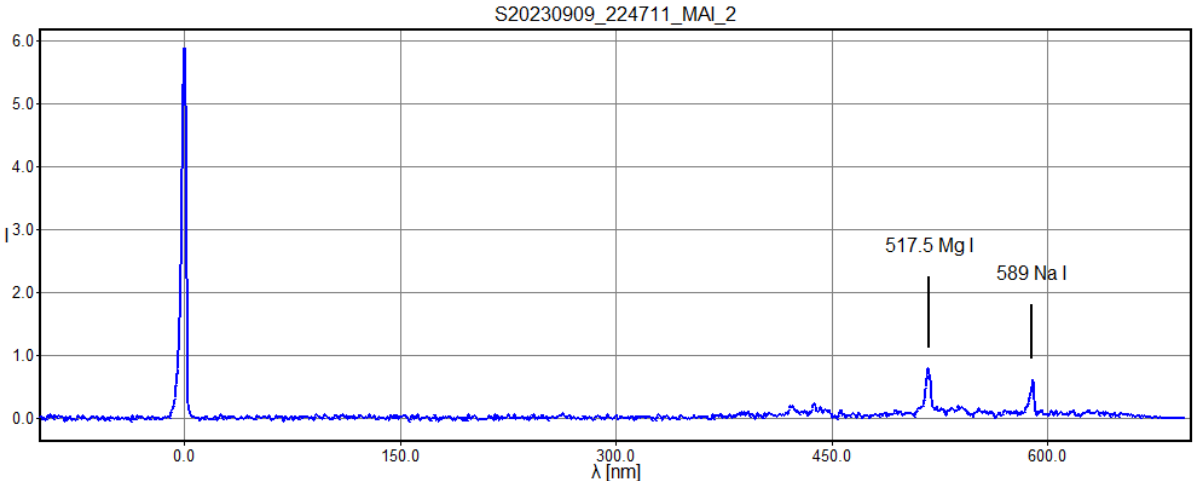


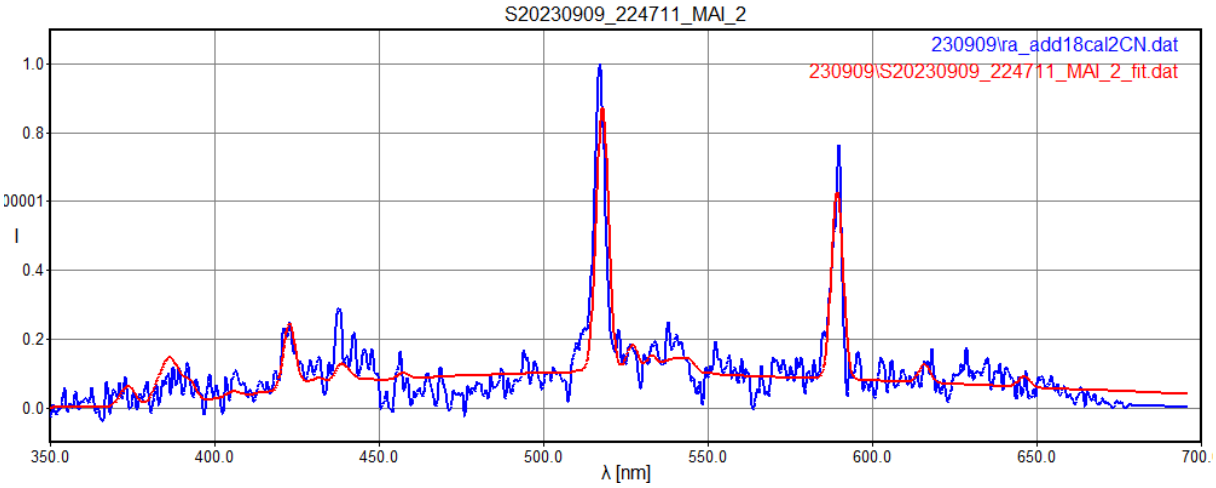
polynom for fit lambda c: [0.5964 -446.5888]

pixel	lambda	fit	error
748.91,	0.00,	0.05,	0.0547
1615.79,	517.50,	517.05,	-0.4455
1737.08,	589.00,	589.39,	0.3908

rms_x = 0.3436

spectrum 230909\ra_add18cal.dat saved





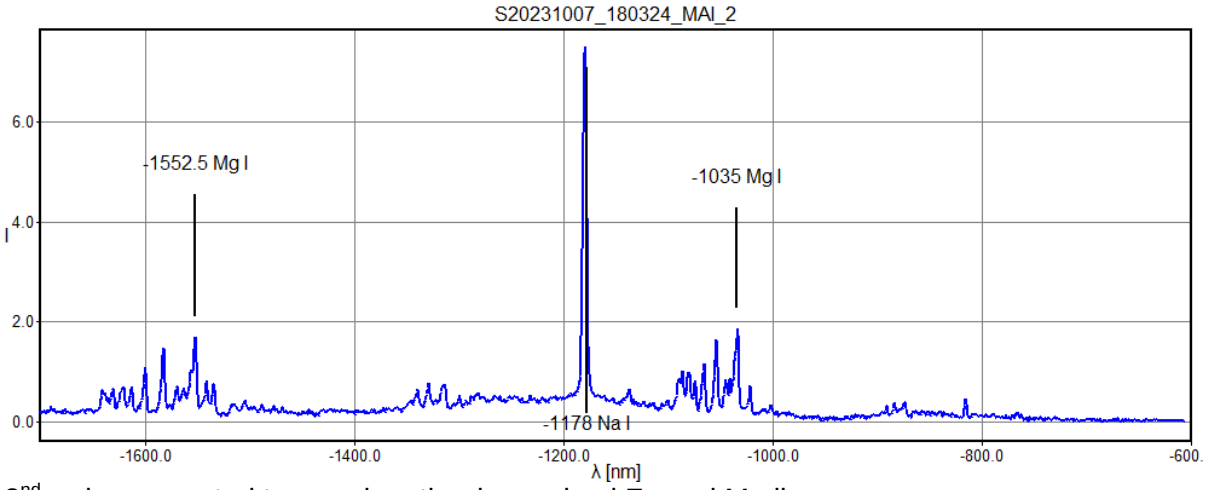
M20231007_180324_MAI_2, spo, -3m

polynom for fit lambda c: [6.0132e-01 -1.7590e+03]

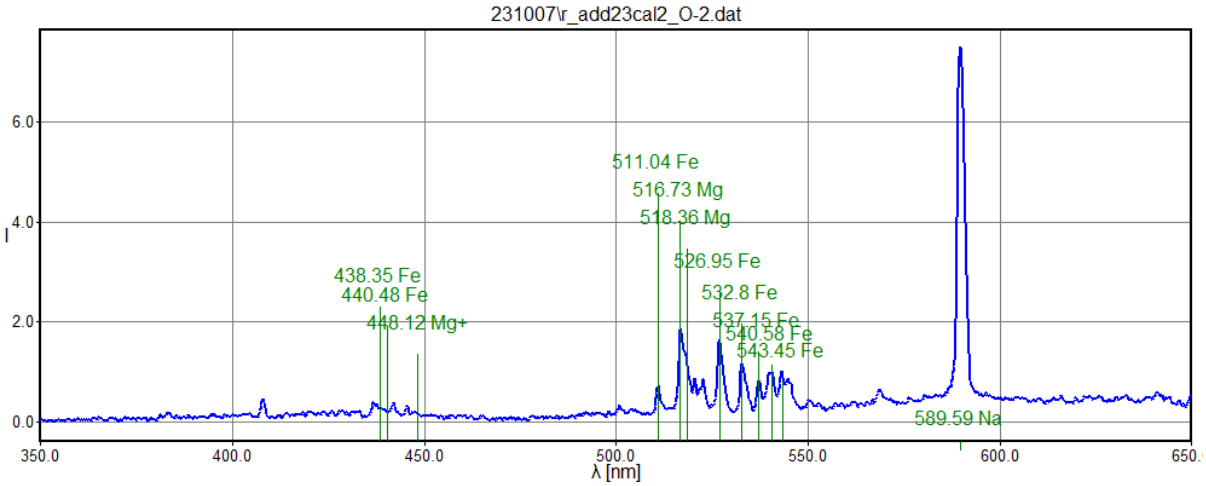
pixel	lambda	fit	error
963.77,	-1178.00,	-1179.48,	-1.4828
1205.82,	-1035.00,	-1033.93,	1.0663
344.13,	-1552.50,	-1552.08,	0.4165

rms_x = 1.0815

spectrum 231007\r_add23cal.dat saved



-2nd order converted to wavelength, nice rsolved Fe and Mg lines:



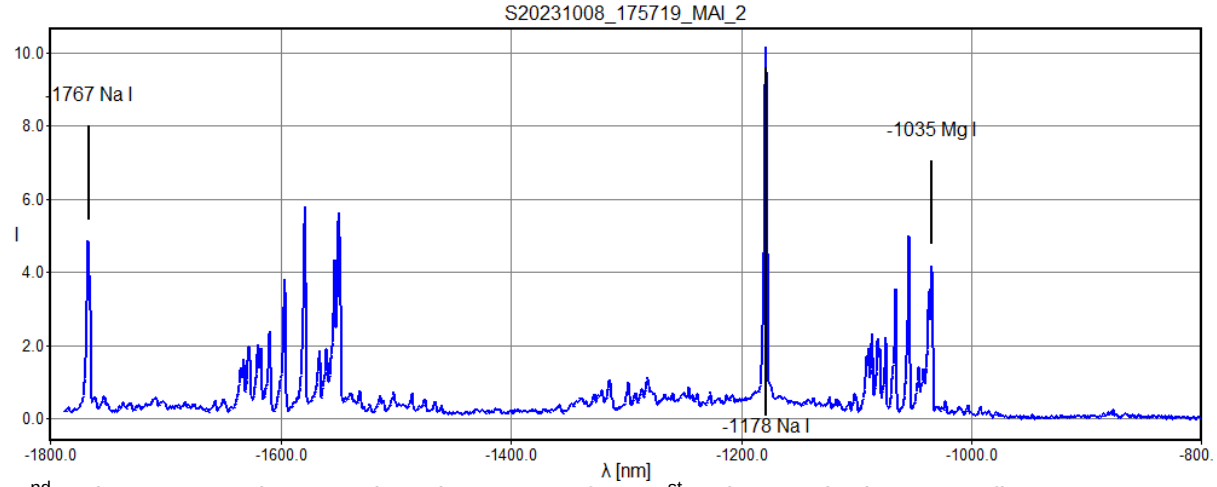
M20231008_175719_MAI_2, spo, -0.8m

polynom for fit lambda c: [5.9734e-01 -1.7890e+03]

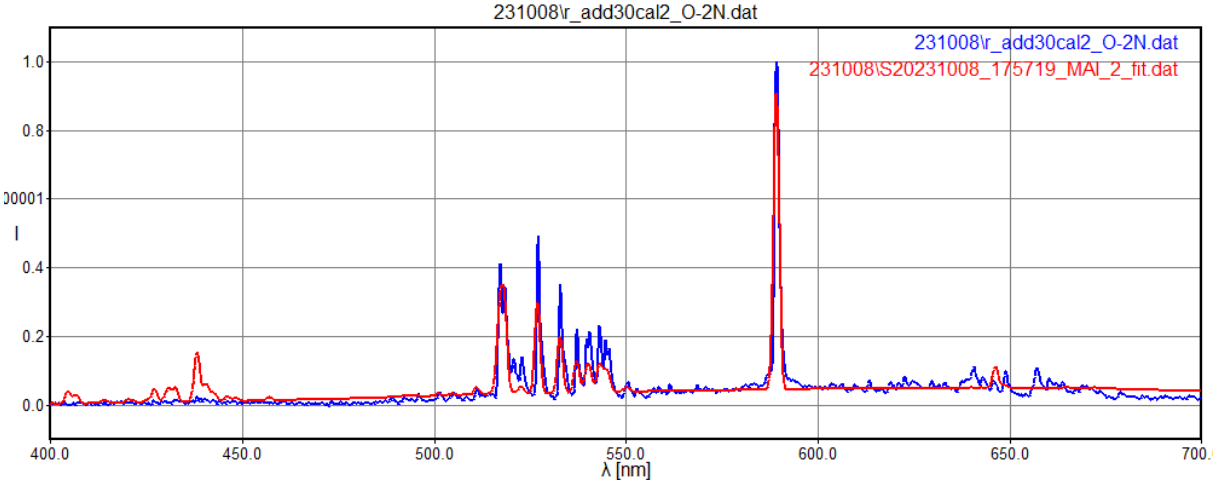
pixel	lambda	fit	error
37.05,	-1767.00,	-1766.90,	0.0973
1022.10,	-1178.00,	-1178.50,	-0.4950
1262.99,	-1035.00,	-1034.60,	0.3977

rms_x = 0.3709

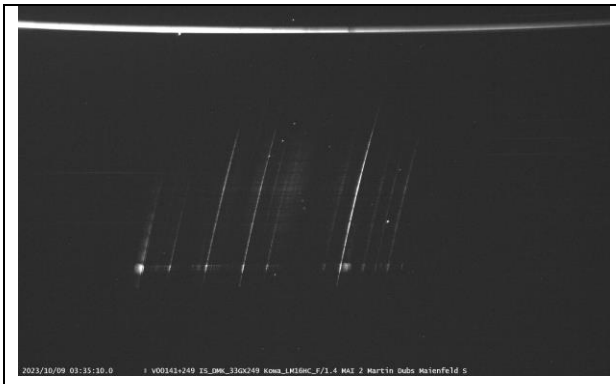
spectrum 231008\r_add30cal.dat saved



-2nd order converted to wavelength, reponse from 1st order used, gives poor fit:



M20231009_033510_MAI_2, spo, -3.2m

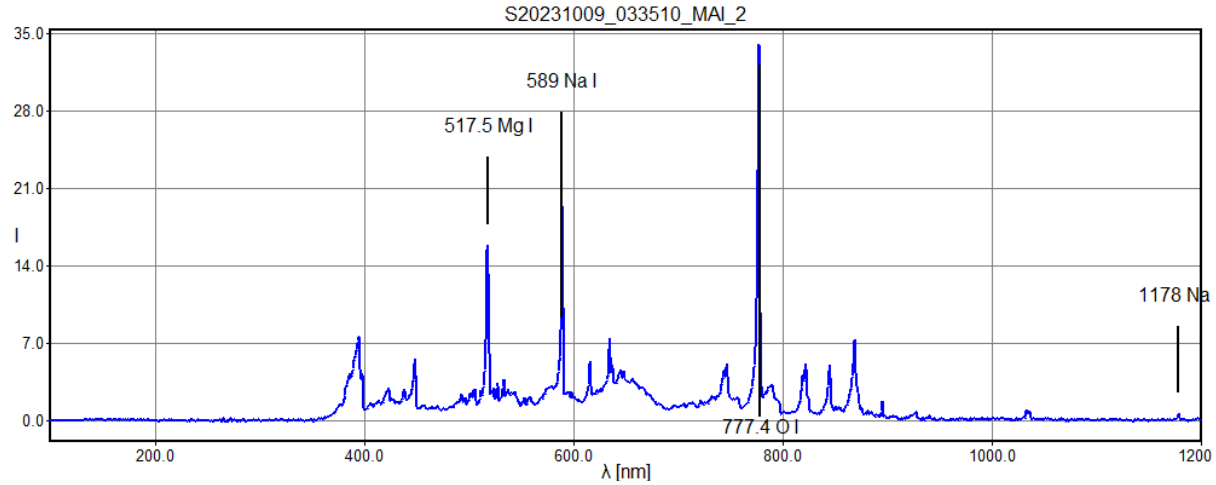


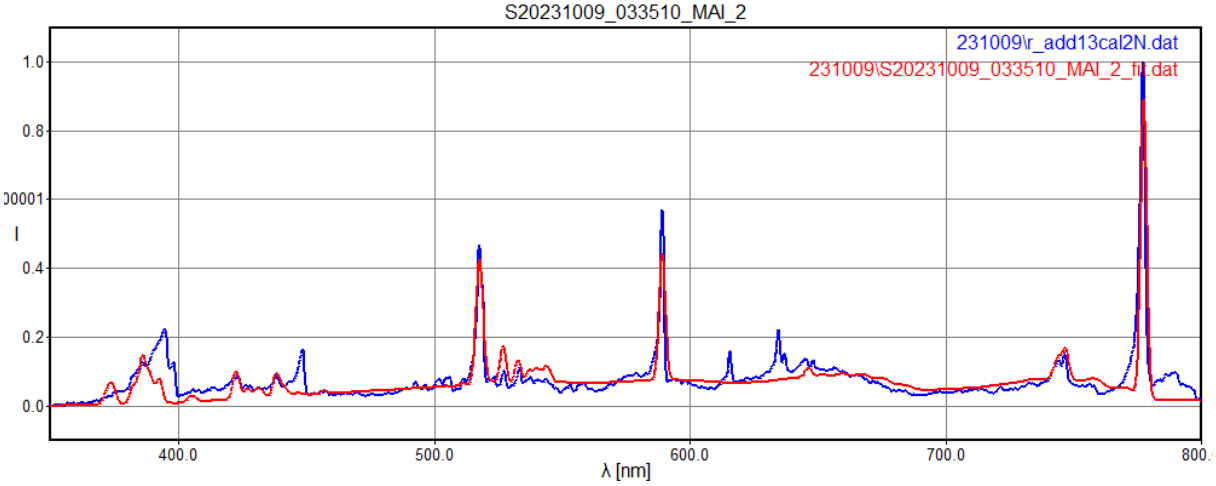
polynom for fit lambda c: [0.5966 92.0475]

pixel	lambda	fit	error
713.62,	517.50,	517.78,	0.2793
833.05,	589.00,	589.03,	0.0289
1147.96,	777.40,	776.90,	-0.5020
1820.62,	1178.00,	1178.19,	0.1938

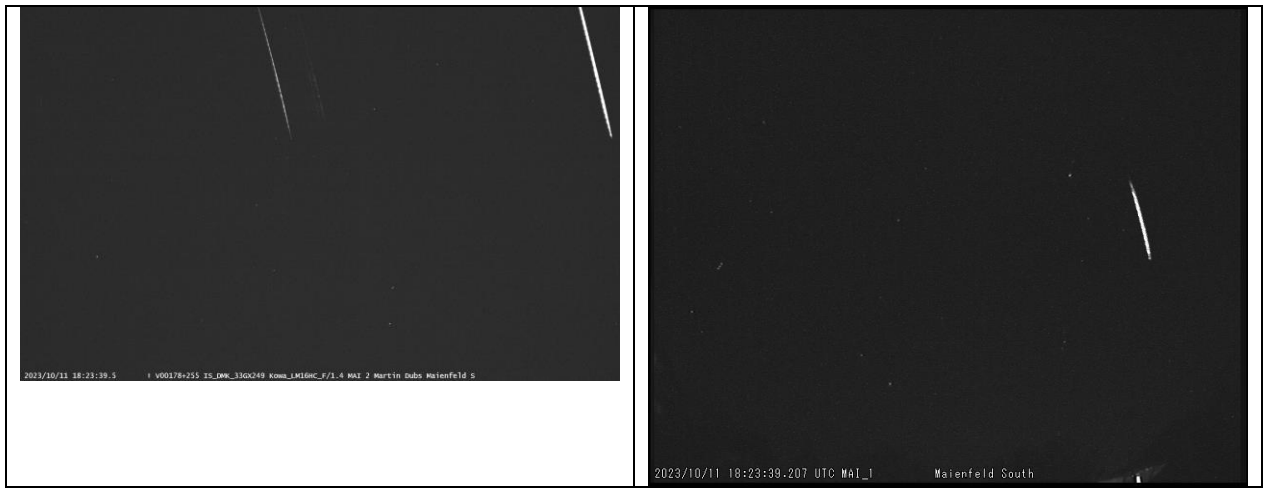
rms_x = 0.3035

spectrum 231009\r_add13cal.dat saved





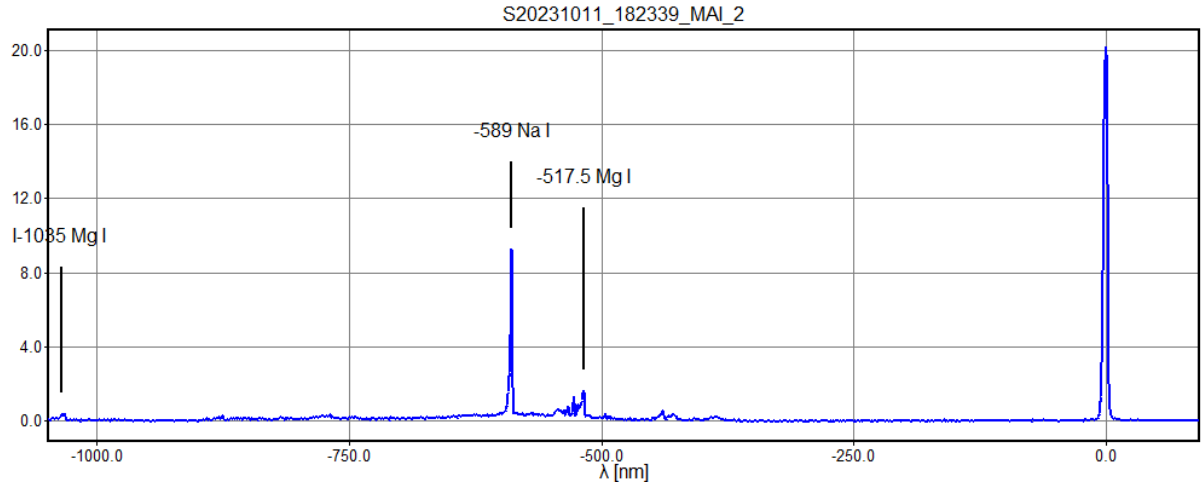
M20231011_182339_MAI_2, spo, -2.4m



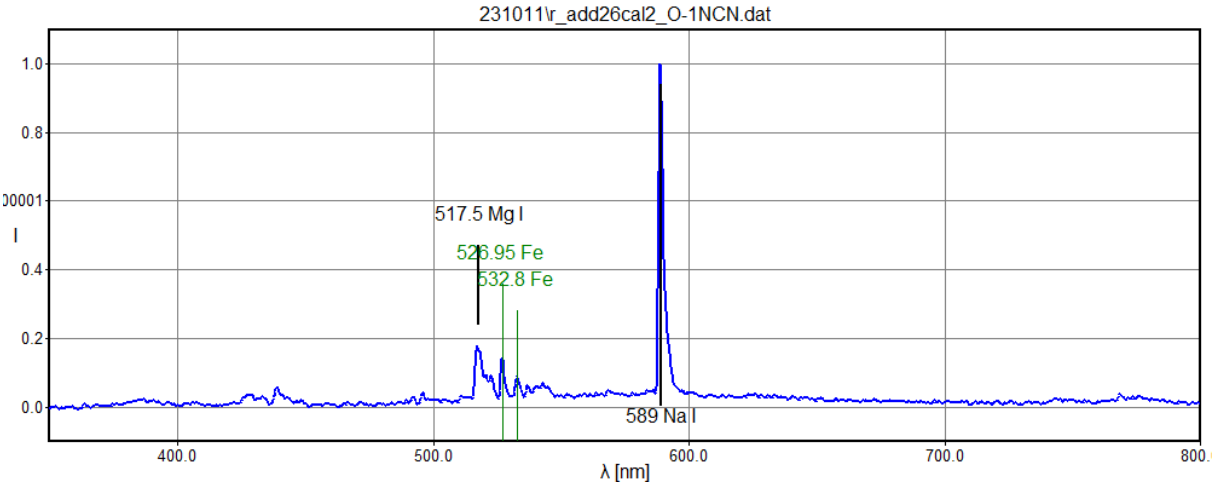
polynom for fit lambda c: [5.9619e-01 -1.0496e+03]

pixel	lambda	fit	error
1760.49,	0.00,	0.01,	0.0115
892.30,	-517.50,	-517.59,	-0.0946
772.67,	-589.00,	-588.92,	0.0832

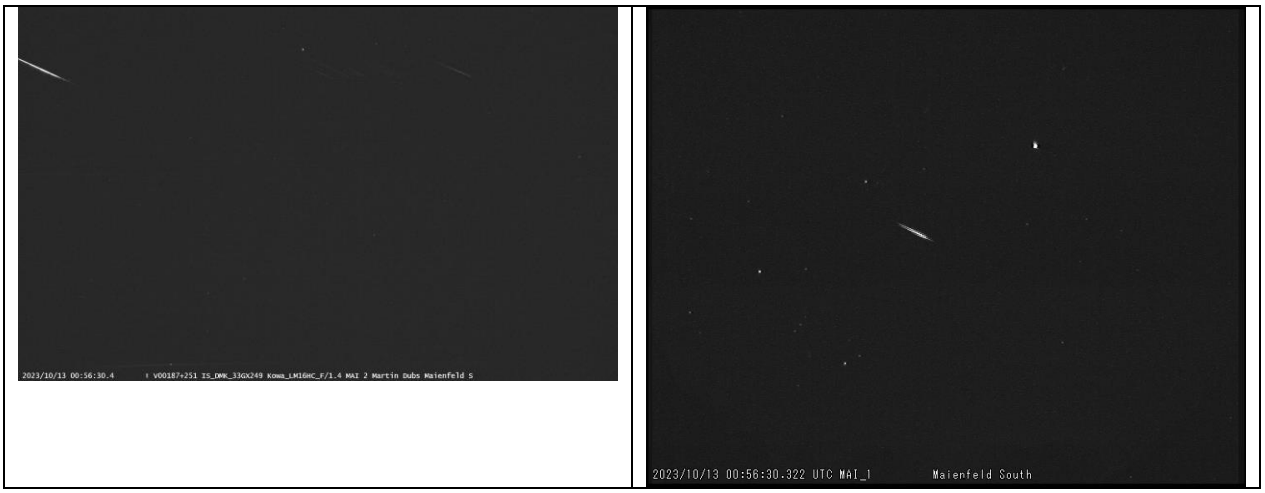
rms_x = 0.0730
spectrum 231011\r_add26cal.dat
saved



-1st order converted to wavelength:



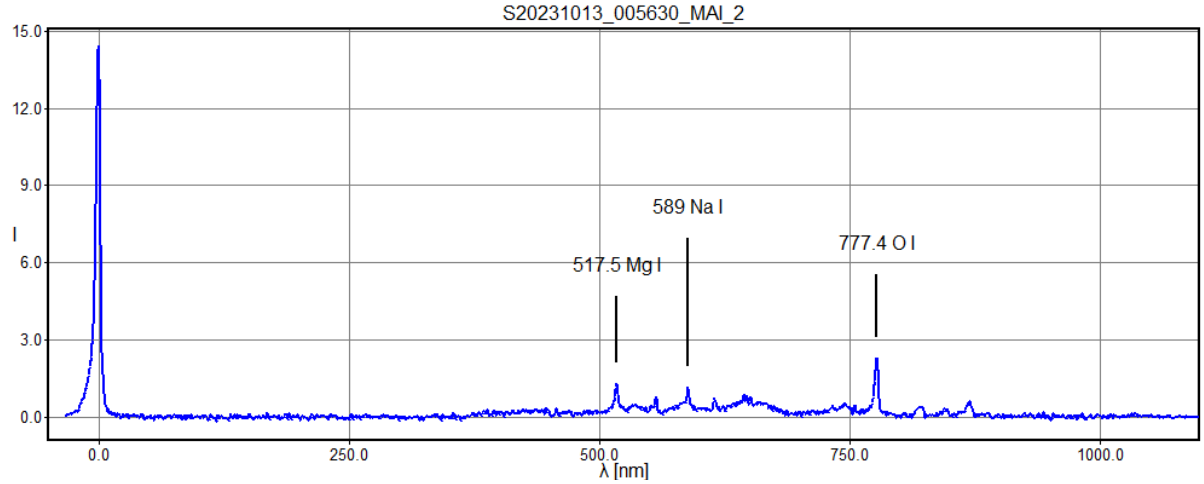
M20231013_005630_MAI_2, spo, -2.4m

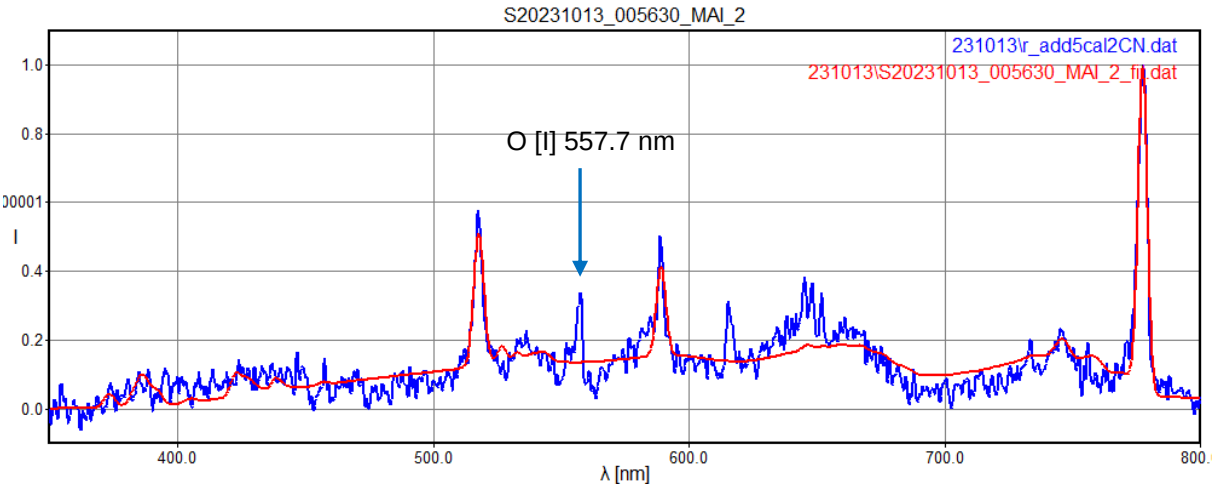


polynom for fit lambda c: [-6.9468e-06 6.1249e-01 -3.3113e+01]

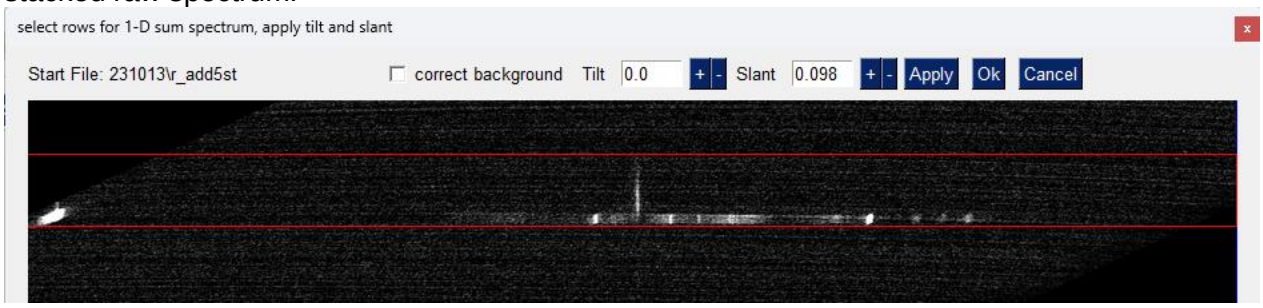
pixel	lambda	fit	error
54.09,	0.00,	-0.00,	-0.0038
908.48,	517.50,	517.59,	0.0914
1027.50,	589.00,	588.89,	-0.1104
1343.82,	777.40,	777.42,	0.0228

rms_x =
0.0726

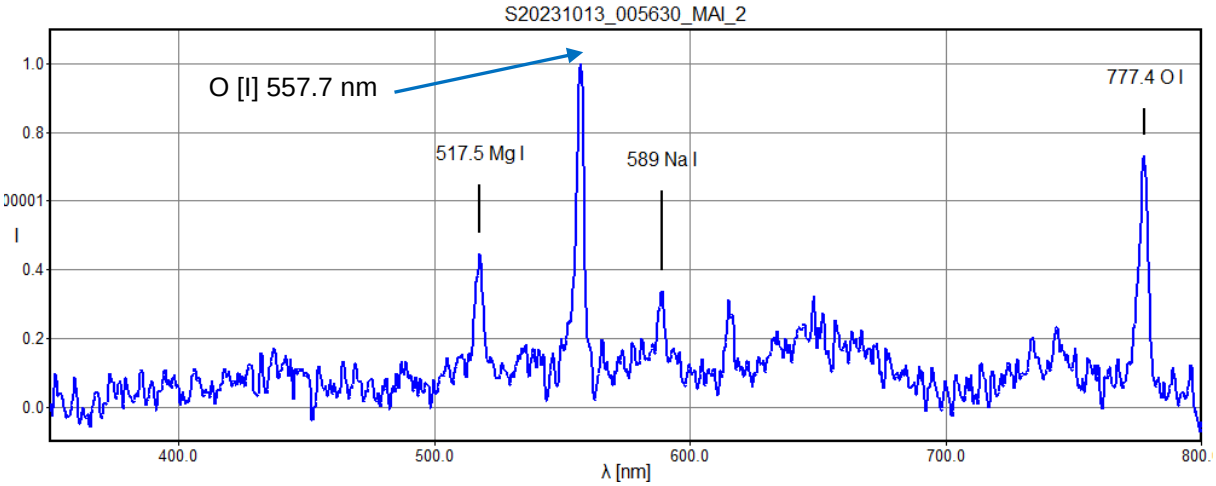




Not fitted is the telluric train line of forbidden oxygen O[I] at 557.7 nm, well visible in the stacked raw spectrum:



Adjusting the slant of the train and adding over the rows containing the train increases ist visibility:



The forbidden line is actually the most intense line of the meteor spectrum!

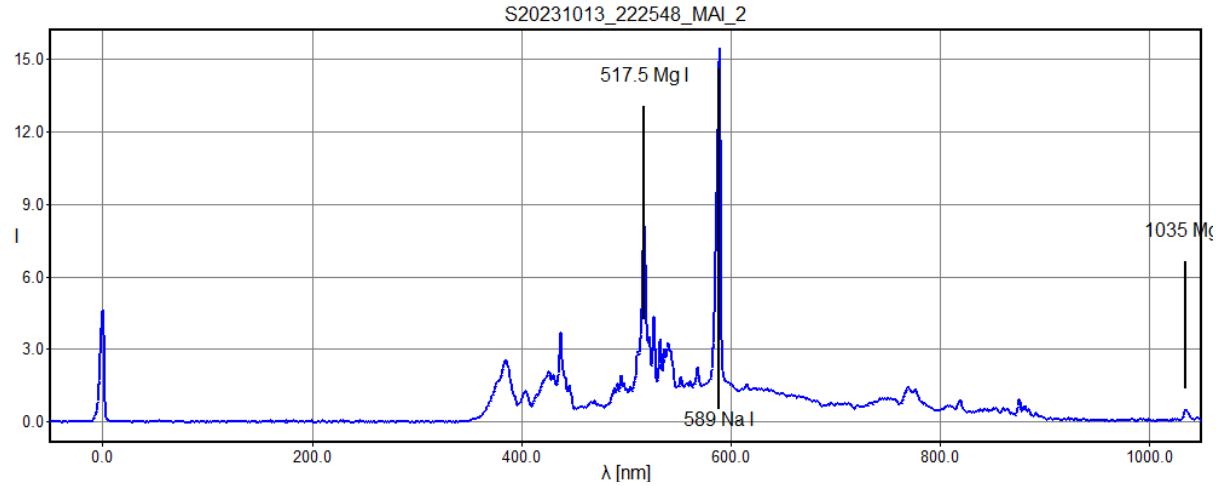
M20231013_222548_MAI_2, spo, -3.0m

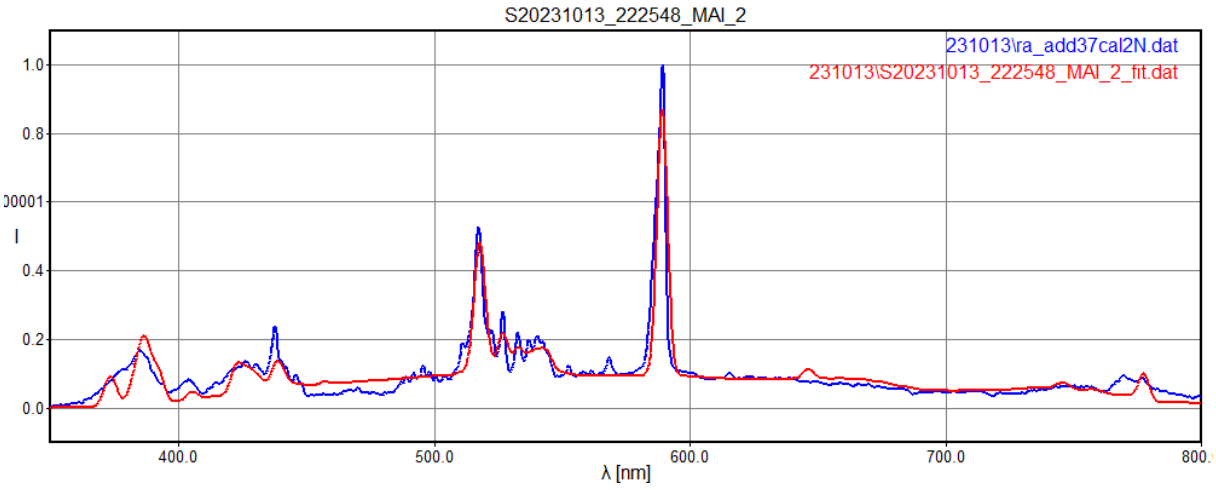
polynom for fit lambda c: [2.3833e-06 5.9319e-01 -8.2128e+01]

pixel	lambda	fit	error
138.39,	0.00,	0.01,	0.0093
1006.52,	517.50,	517.35,	-0.1539
1126.55,	589.00,	589.16,	0.1571
1869.19,	1035.00,	1034.99,	-0.0125

rms_x = 0.1103

spectrum 231013\ra_add37cal.dat saved





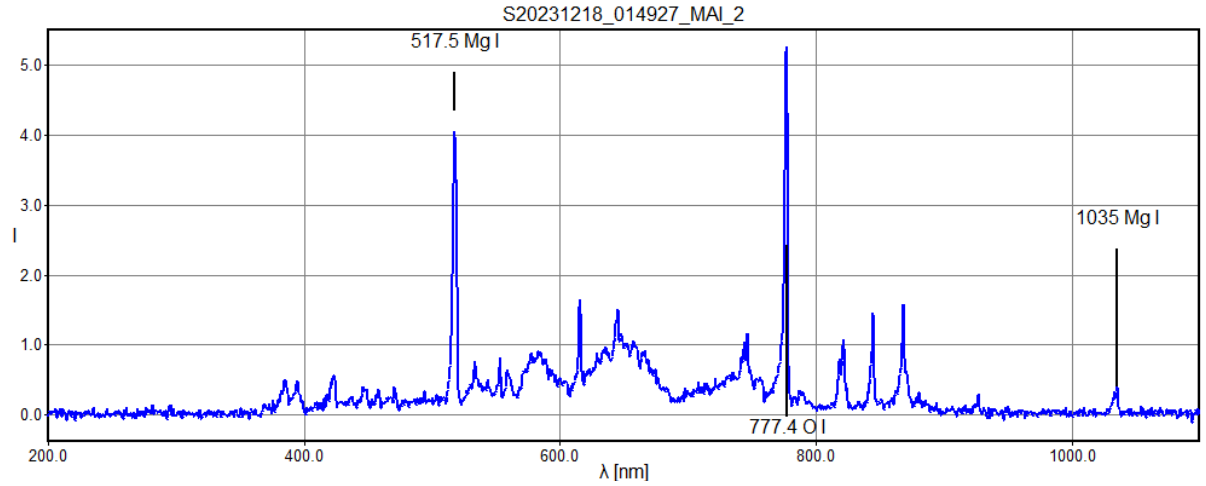
M20231218_014927_MAI_2, spo, -1.5m

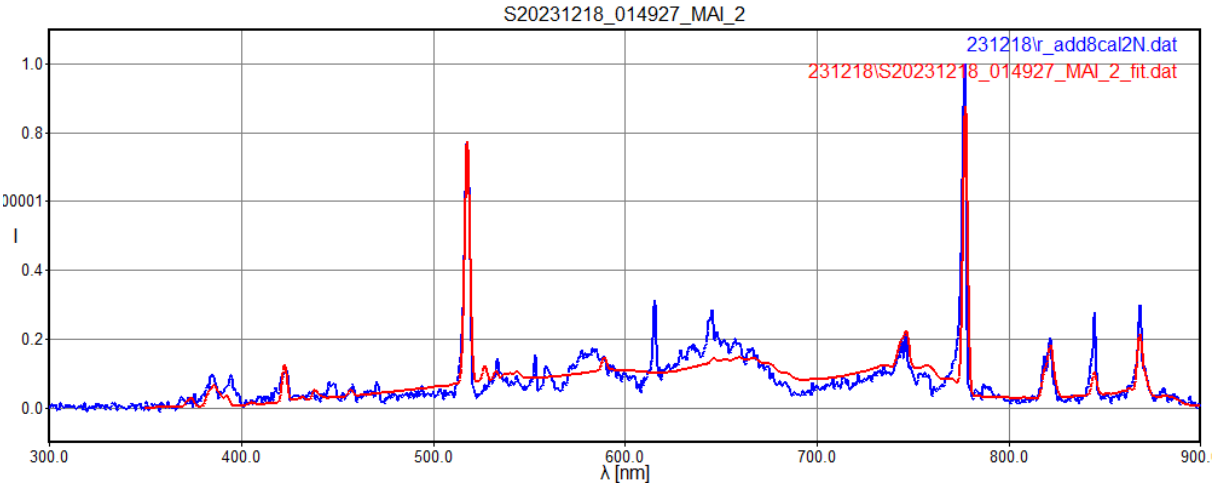
polynom for fit lambda c: [0.5962 81.0876]

pixel	lambda	fit	error
732.45,	517.50,	517.80,	0.2986
1166.85,	777.40,	776.80,	-0.5977
1600.40,	1035.00,	1035.30,	0.2992

rms_x = 0.4227

spectrum 231218\r_add8cal.dat saved





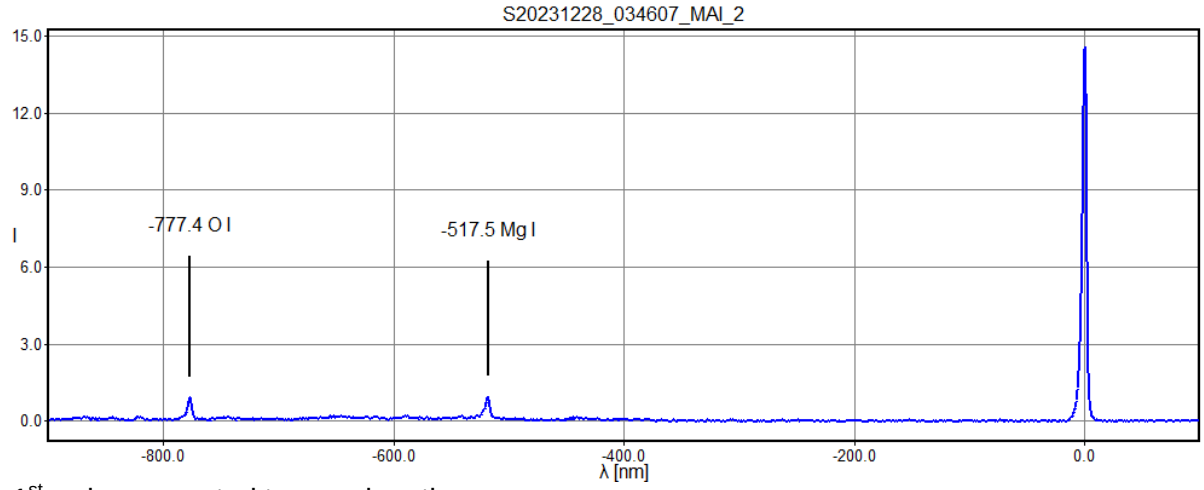
M20231228_034607_MAI_2, QUA, -1.9m

polynom for fit lambda c: [5.9530e-01 -9.0042e+02]

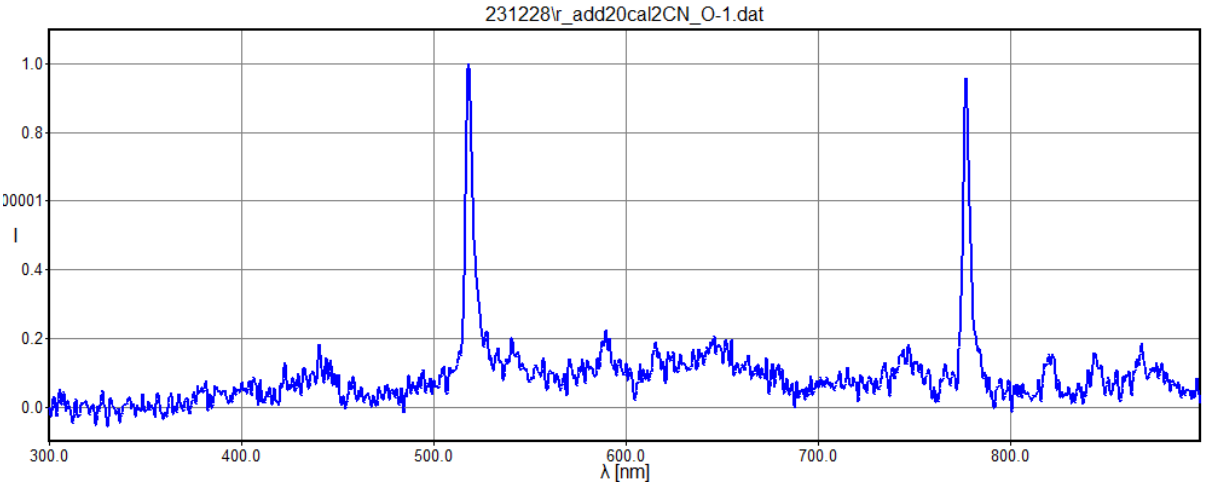
pixel	lambda	fit	error
1512.97,	0.00,	0.24,	0.2413
642.03,	-517.50,	-518.22,	-0.7250
207.47,	-777.40,	-776.92,	0.4836

rms_x = 0.5221

spectrum 231228\r_add20cal.dat saved



-1st order converted to wavelength:



Meteor spectral lines

Table 3-7: List of spectral lines frequently found in meteor spectra and their relative intensities. Th
tification of the lines (numbers) in our example is also given. Lines marked with an asterisk appear b
spectra of fast meteors, such as the Perseids, but much fainter in spectra of slow meteors.

Laboratory data			ident.	Laboratory data			ident.
λ_{lab}, [Å]	atom/ion	intensity	number	λ_{lab}, [Å]	atom/ion	intensity	number
3719.9	Fe	10	2	4923.9	Fe^+	2*	
3734.9	Fe	8		4957.6	Fe	4	
3737.1	Fe	9	3	5012.1	Fe	1	
3745.6	Fe	8		5018.4	Fe^+	3*	
3749.5	Fe	8		5110.4	Fe	1	
3820.4	Fe	9		5167.3	Mg	17	
3825.9	Fe	8		5172.7	Mg	25	
3829.4	Mg	10		5183.6	Mg	28	
3832.3	Mg	11		5208.4	Cr	10	
3838.3	Mg	12		5227.2	Fe	5	
3859.9	Fe	11		5269.5	Fe	14	
3886.3	Fe	9		5328.0	Fe	12	
3933.7	Ca^+	40*	8	5371.5	Fe	9	
3968.5	Ca^+	35*	9	5397.1	Fe	5	
4030.8	Mn	10		5405.8	Fe	6	
4045.8	Fe	10		5429.7	Fe	6	
4063.6	Fe	9		5434.5	Fe	4	
4131.0	Si^+	1*		5446.9	Fe	4	
4226.7	Ca	11	12	5455.6	Fe	4	
4254.4	Cr	9		5528.4	Mg	2	
4271.8	Fe	10		5615.7	Fe	1	
4274.8	Cr	8		5890.0	Na	40	
4289.7	Cr	7		5895.9	Na	35	
4307.9	Fe	10		6156.8	O	1*	
4325.8	Fe	10		6162.2	Ca	1	
4383.5	Fe	14	15	6347.1	Si^+	6*	
4404.8	Fe	11		6371.4	Si^+	3*	
4481.2	Mg^+	15*		6495.0	Fe	1	
4920.5	Fe	3		6562.9	H	2*	

From: Spectral lines, (IMO PhotographicHandbook 03 Spectra, p 47)
http://www.imo.net/docs/03spectra.pdf

Another list from Borovicka, 2005
https://ui.adsabs.harvard.edu/abs/2005Icar..174...15B/abstract
Free access from:
https://sci-hub.st/https://doi.org/10.1016/j.icarus.2004.09.011

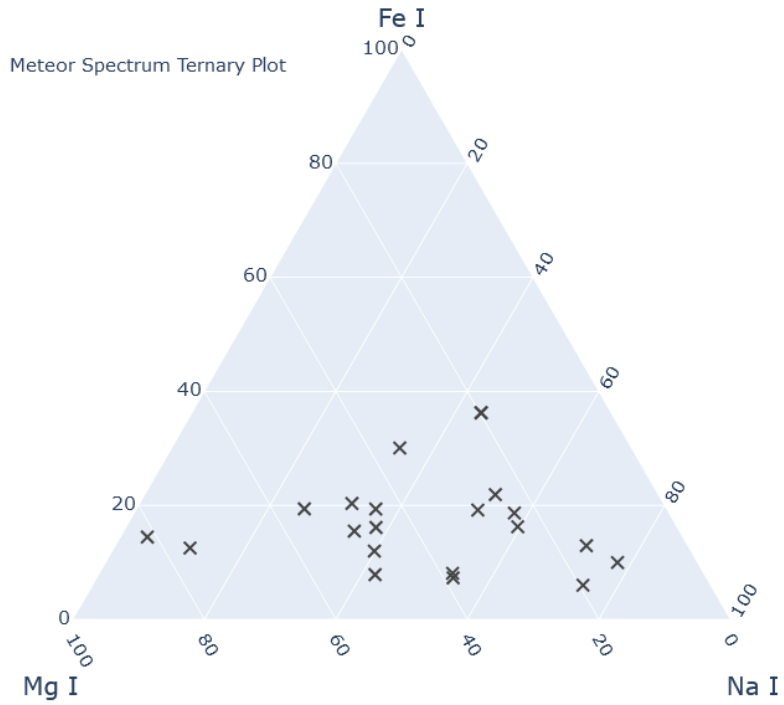
Table 1
List of the most important atomic lines used to fit the spectra in the 4200–8500 Å range, ordered according to line groups

λ (Å)	Atom & multiplet		Typical intensity	λ (Å)	Atom & multiplet		Typical intensity
Low temperature lines				*Wake lines*[a]			
4226	Ca I	2	80	4216	Fe I	3	16
4273	Fe I	42	30	4376	Fe I	2	26
4308	Fe I	42	25	4427	Fe I	2	21
4326	Fe I	42	25	4462	Fe I	2	12
4384	Fe I	41	45	4482	Fe I	2	7
4405	Fe I	41	25	4571	Mg I	1	17
4920	Fe I	318	11	5110	Fe I	1	9
4957	Fe I	318	16	5169	Fe I	1	8
5047	Fe I	114	13	5205	Fe I	1	5
5182	Mg I	2	200	*Atmospheric lines*			
5269	Fe I	15	23	5330	O I	12	47
5328	Fe I	15	19	5436	O I	11	34
5371	Fe I	15	17	6157	O I	10	150
5404	Fe I	15	15	6455	O I	9	17
5431	Fe I	15	13	6484	N I	21	27
5449	Fe I	15	11	7424	N I	3	60
5528	Mg I	9	22	7442	N I	3	120
5589	Ca I	21	5	7468	N I	3	150
5892	Na I	1	150	7774	O I	1	1400
6163	Ca I	3	4	8186	N I	2	400
6439	Ca I	18	3	8218	N I	2	700
6463	Ca I	18	2	8243	N I	2	280
8194	Na I	4	3	8446	O I	4	800
High temperature line				*Train line*			
4481	Mg II	4	36	5577	[O I]	3*F*	31

[a] Wake lines are low excitation intercombination lines with a small transition probability. They are so named because they are prominent in meteor wakes, i.e., in the radiation forming a "tail" just behind the meteor head. They may be, nevertheless, present also in meteor heads, in particular when the collisional deexcitation rate is low.

Ternary plot 2023

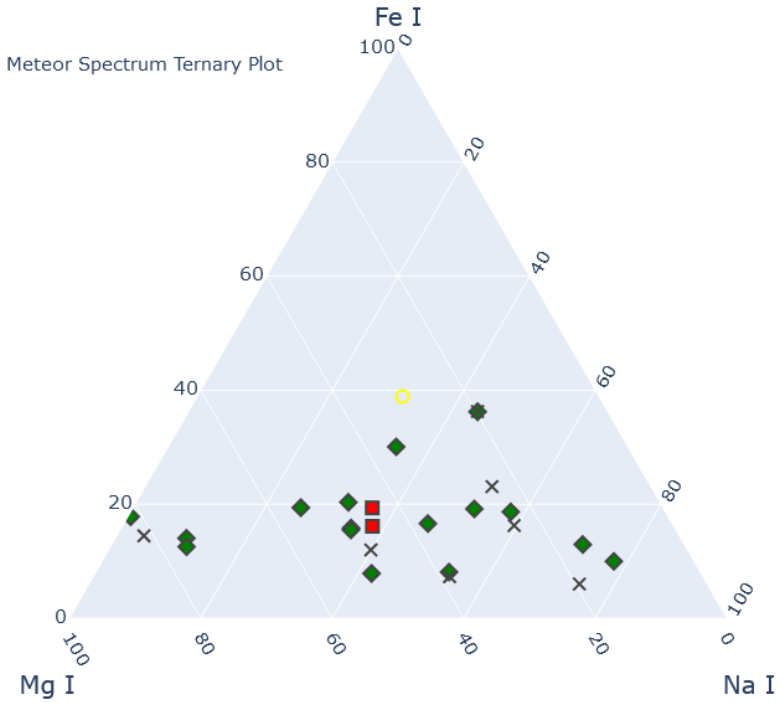
All analyzed spectra



ternary Plot 2023 raw.htm,

created from all logfiles or 2023log.log

Annotated and added missing spectra:



SPO: Green diamond
PER: red square
Other meteors: yellow circle
Other spectra: x
ternary Plot 2023 annotated.htm

Content