American Meteor Society's

Filter Bank Spectroscopy Project

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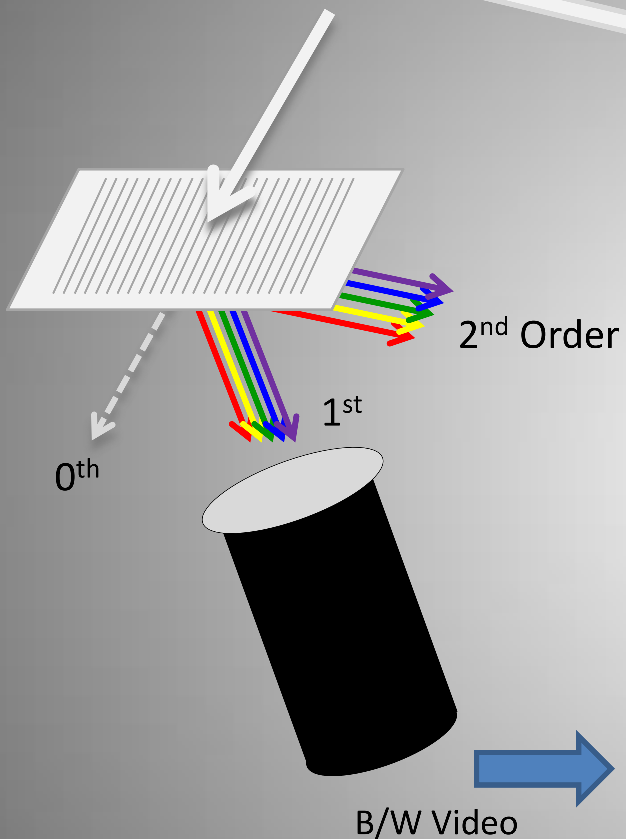
Co-I's: George Varros, Billy Smith, Jeff Jones

American Meteor Society Limited 1911 1993 2011

IMC 2015 - Mistelbach

Objective Grating Meteor Spectroscopy



Goal !

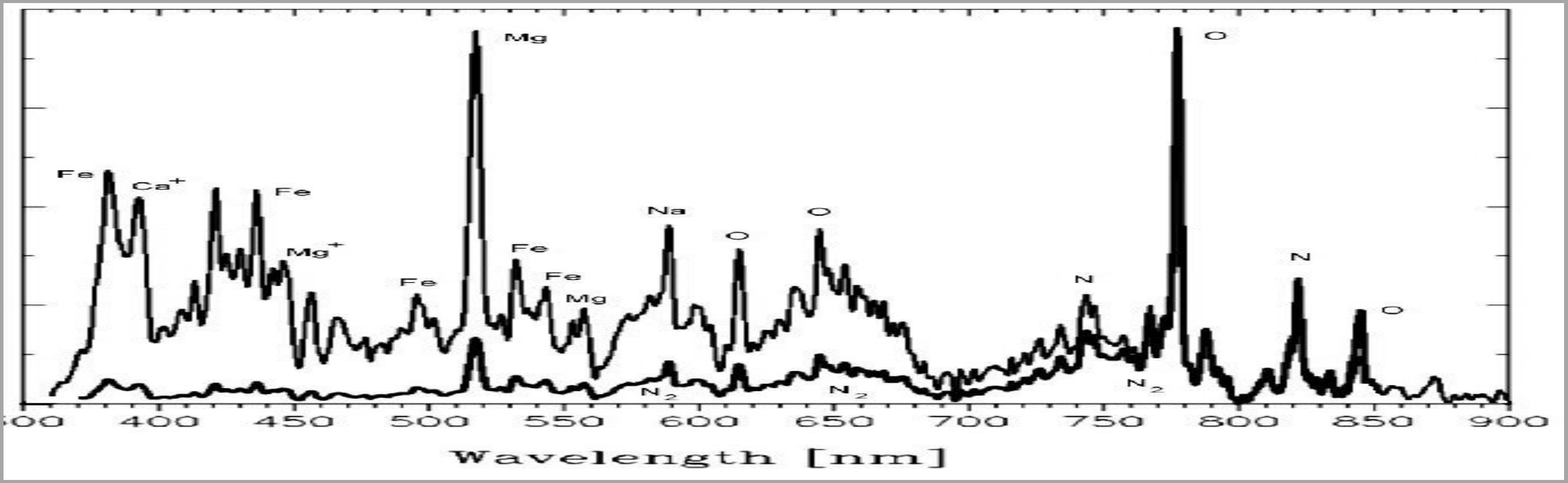
Ratio of Line Intensities = Metal Abundances

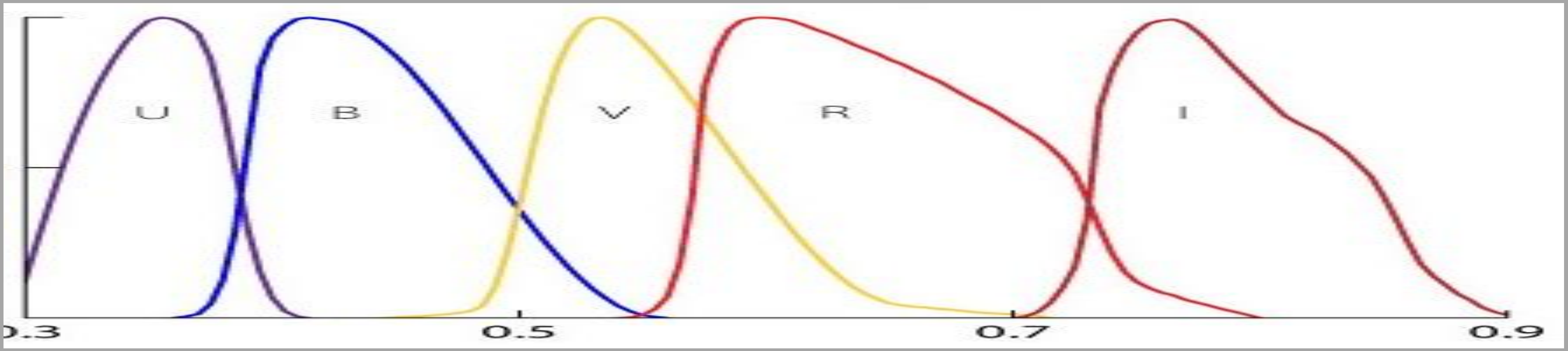
Great for bright meteors → lots of emission lines and λ resolution

Can we go fainter ? Can we simply classify using broader band filters ?

Broad Band Filter Concept – IMC 2014

Multiple Monochrome Cameras with Johnson-Cousins Filters

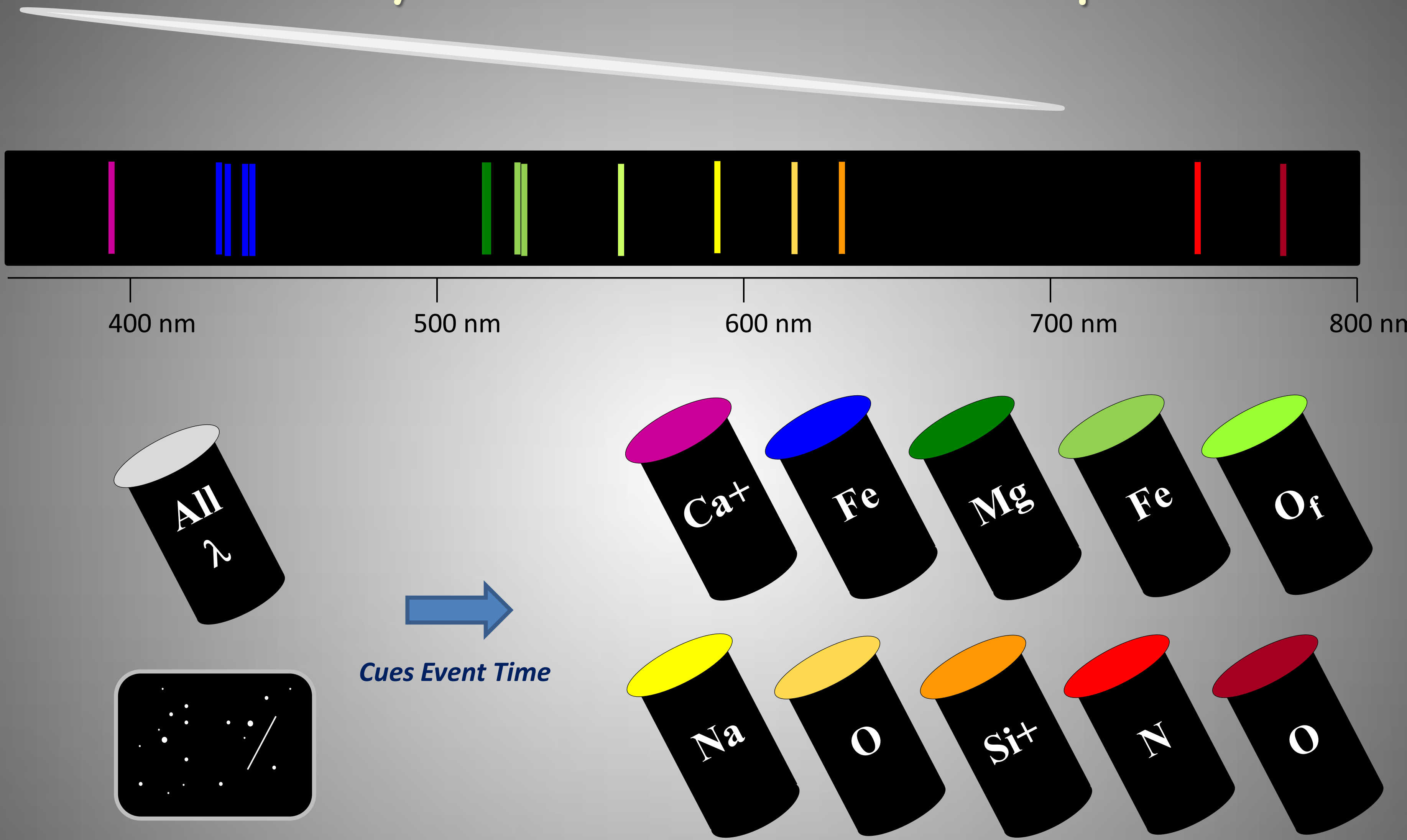




Color Index for <u>fainter</u> meteors and no incidence angle limitation

Some emission lines not well covered plus mixing of elements

Very Narrow Band Filters Concept



Target the Well-Separated Dominant Meteor Emission Lines

<u>*Low-Cost*</u> Cameras and 8-Channel Frame Grabber ✓ *<30 nm Filters ?*

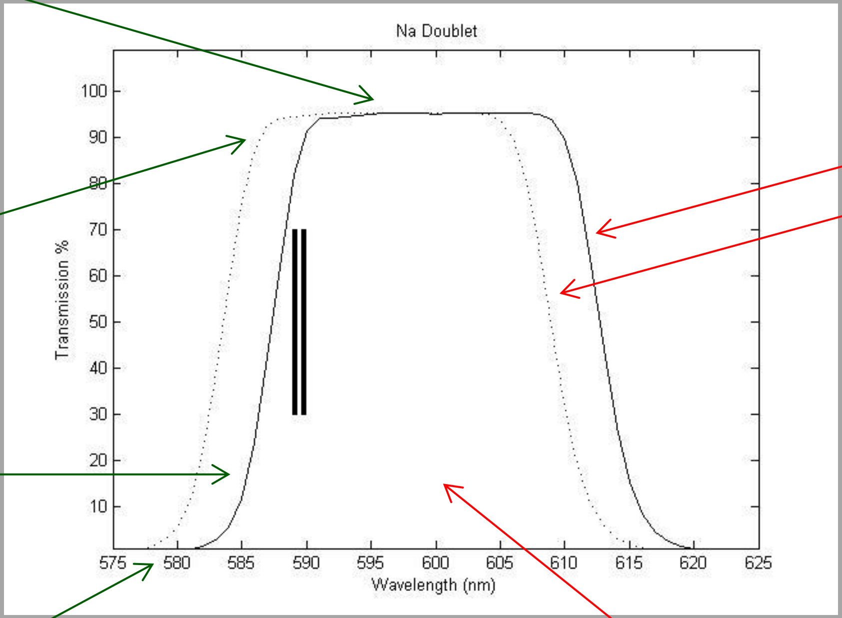
Hard-Coated Band-Pass Interference Filters

Narrow
Δλ = 10nm, 25nm
& Fluorescence

Flat pass band
with T>90%

Sharp cutoff

10^4 out of band
rejection



Off-axis incidence
shifts pass band
0° = FOV center
12° = FOV corner

λ center spec ±2 nm
caveat emptor

λ centers every 10 nm
→ Using COTS limits low cost options

Selection of the Filter Pass Bands – COTS Limited

Figure 1. Dominant Meteor and Atmospheric Emission Lines

Element	λ (nm)	n	λ @0°	λ @10°	λ @12°	Comments
~~Fe~~	382.1 - 388.7	1.68	382 - 392	380 - 390	379 - 389	F 387 / 11 nm Low Watec sensitivity
Ca+ H,K	393.5, 397.0	1.68	388 - 412	386 - 410	385 - 409	400 / 25nm
Fe	427.3, 430.9, 432.7, 438.5, 440.6, 441.6 Fe 421.7 but avoid Ca 422.8	1.71	426 - 450	424 - 448	423 - 447	F 438 / 24nm
Mg	516.9, 517.4, 518.5	1.78	516 - 524	513 - 521	512 – 520	520 / 10 nm
Fe	527.1, 533.0, 539.8, 540.7, 543.1, 545.7 Fe 537.2 is very weak ✓	1.78	524 - 544	521 - 541	520 - 540	F 534 / 20 nm
O forbid	557.9	1.78	556 - 564	553 - 561	552 – 560	560 / 10 nm
Na	589.1, 589.8	1.72	588 - 612	585 - 609	584 - 608	600 / 25 nm
~~O~~	615.8, 616.0	1.72	616 - 624	613 - 621	612 - 620	620 / 10 nm Only need 1 atmo set
Si+	634.9, 637.3	1.72	633 – 647	630 – 644	628 - 642	F 640 / 14 nm
~~N~~	742.5, 744.4, 747.0	1.84	738 - 762	734 - 758	733 - 757	750 / 25 nm Only need 1 atmo set
O	777.4, 777.6, 777.8	1.84	776 - 784	772 - 780	771 - 779	780 / 10 nm

1) Fe (421.7) and Ca (422.8) too close to separate
2) FWHM of filter specified but λ range trims 1 nm from edges of the band pass for flat transmittance bandwidth (except Fluorescence filters)
3) 34 deg FOV for 8mm with 1/3" Effio, 22 deg FOV for 12mm with 1/3" Effio
4) 12mm f/1.2 lens has aperture = 10mm so might be able to use 12.5mm diameter filters (check for blockage from filter's axial position offset)
5) Wavelength shift = λ [sqrt($1 - \sin^2 \theta / n^2$) - 1]

Major Equipment Components

Effio-E, no IRcut
Exview HAD II
16mm f/1.0
US$40

30 fps lm = +6.2 stellar
12.6° x 16.7°

Sensoray 812/1012
8-channel
Frame grabber
US$200

240 fps @ 640x480 to memory
w/ CPU asynchronous processing

Edmund Scientific
Hard Coated OD4
25mm diameter
US$200

10nm – 25nm $\Delta\lambda$

HP Slimline
Intel i5-3450
Quad-core
US$700

8 chan cap/comp/detect
+ 8 chan cap/comp ONLY

CAMS capture/compression, MeteorScan detection = Free

~US$3500 equipment cost meets specifications for a prototype…

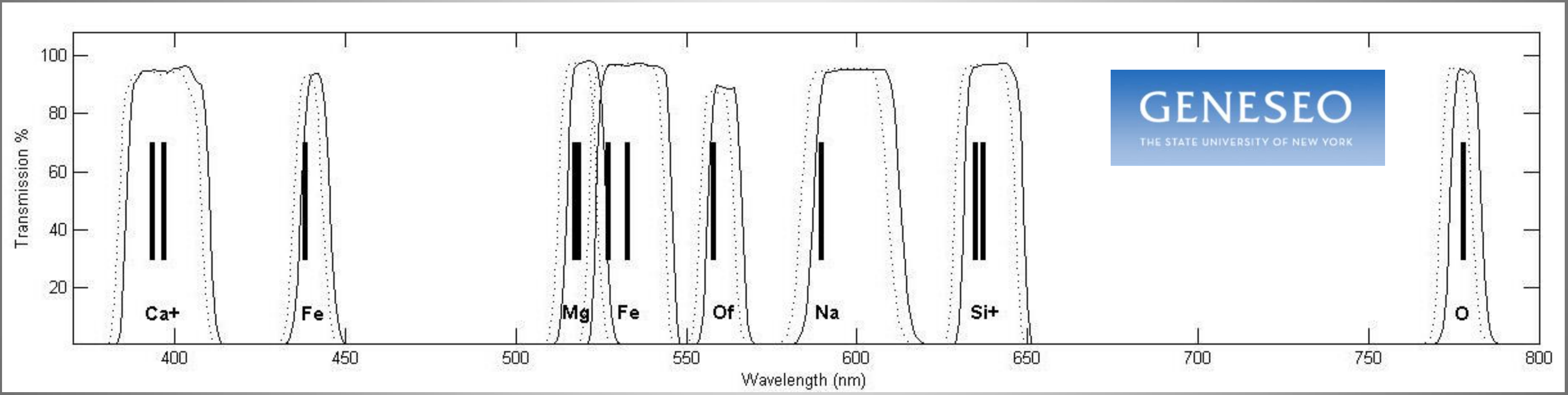
Filter Bank Concept Proposed to the AMS Jan 2015 → Awarded a Matching Grant

Verification of the Filter Pass Bands

Some filters ordered were on the band edge given the nominal specs

Dr. David Meisel requested the SUNY at Geneseo Chem Dept. scan the filters

Dr. Jeffery Peterson and his undergrad team used a
Cary 5000 UV-VIS-NIR spectrophotometer

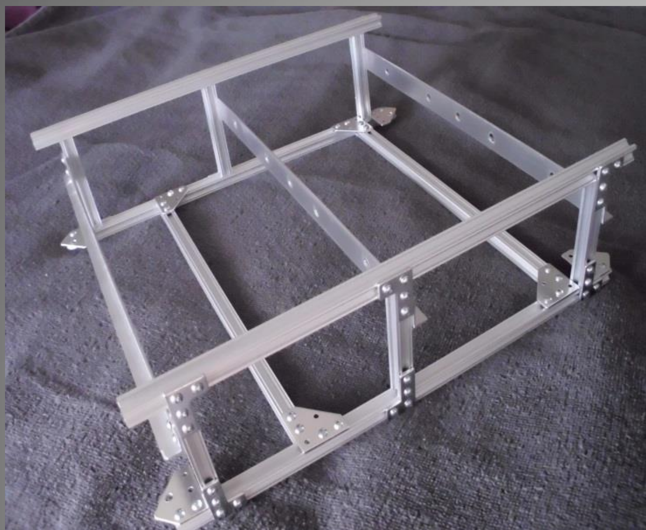


Two filters had centers shifted 2+ nm higher in λ → emission line out of band !

Obtained replacement filters with different lot numbers which met spec

Final scans shown are for 0° and 12° incidence → index of refraction

Photos During Construction



MicroRAX

Shortening the Cameras

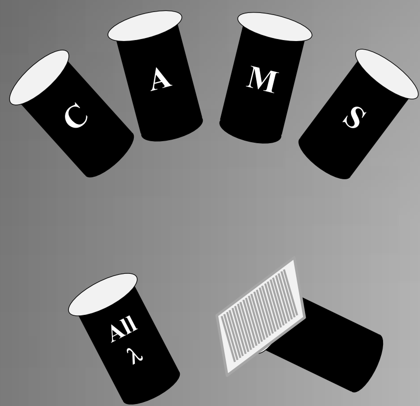
9 Effio-E and 1 Watec

Power, Video feeds, Balun→CAT5

Mounted Filters & Grating

Waterproof Polycase w/ BK7 windows

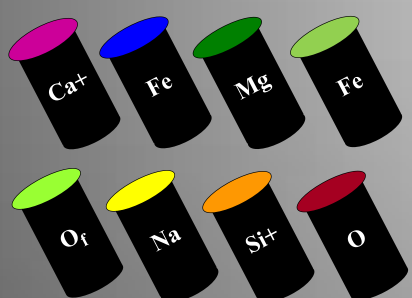
Collection and Processing CONOPS



Capture, Compress, Detect, Triangulate, Orbit

14 channels compressed
- ***6 channels run detection***
- ***8 channels compress only***

Astrometric cal update
User confirmation
All-λ cues detection
- ***Check radiant & m_V***
- ***Check filter bank***
- ***Check grating***
- ***Check CAMS for orbit***



Capture, Compress, Extract

First Multi-Band Detection   July 30, 2015 m_v=+1.5

Open

Mg

Fe

Na

Si+

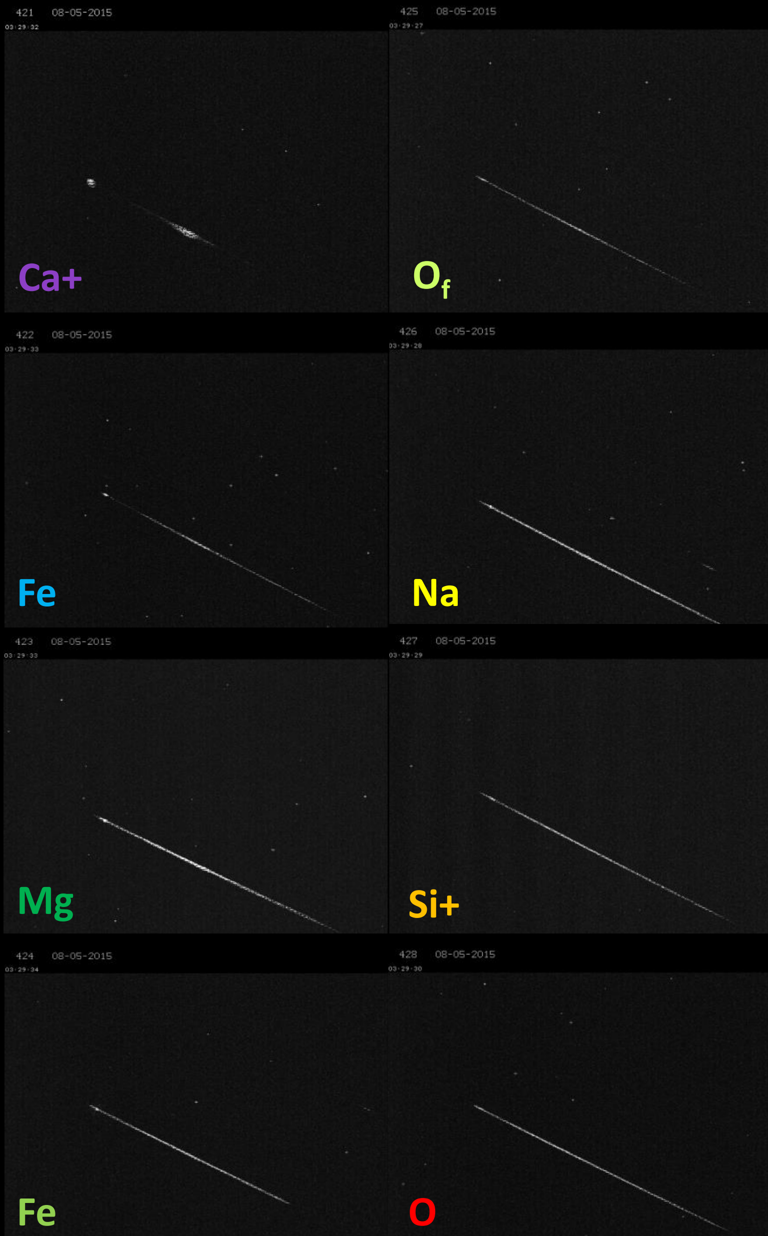
O

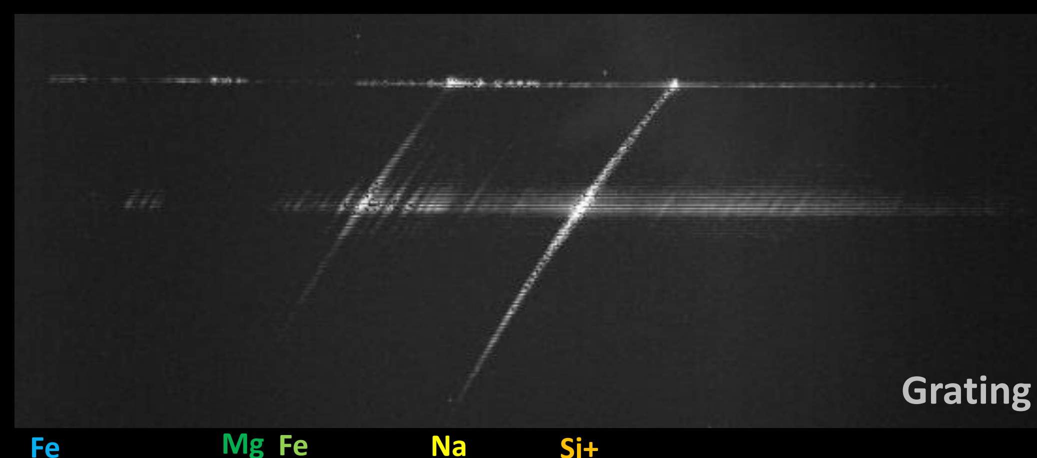
Early Statistics: July 28 – August 15, 2015

m_V	# OPEN	# Shower	# Sporadic	Grating	Ca+	Fe #2	Mg	Fe #1	O_f	Na	Si+	O_{777}
-2	1	1		1	1	1	1	1	1	1	1	1
-1				2								
0				2								
+1	16	8	8				4	4	1	5	5	11
+2	42	24	18			1	3	4	1	4	8	19
+3	72	39	33								2	13
+4	28	12	16									
+5	1	1										

Shower	km/sec		Grating	Ca+	Fe #2	Mg	Fe #1	O_f	Na	Si+	O_{777}
NDA	42					1	1		1	1	2
SDA	41										1
CAP	25		1	1	1	1	1	1	1	1	1
PAU	35					1	1		1	1	2
PER	59		3		1	3	3	2	3	10	22
KCG	25					1	2		2	1	1
SPO	-		1			1	1		2	2	15

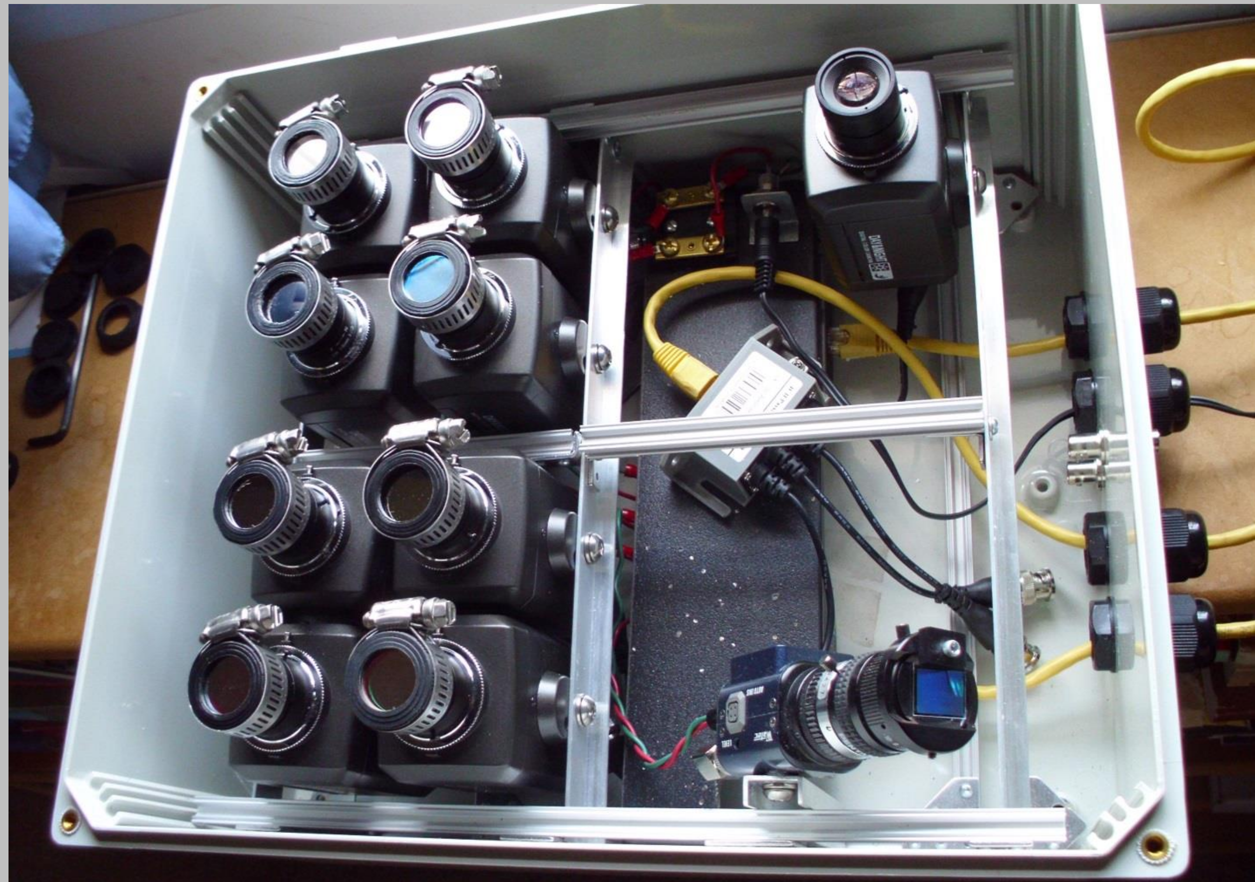
-1.5 CAP on August 5, 2015 @ 3:29:32 UT





Next Steps

- Change to 12mm and 30° wide FOV
- Need more automation !
- Hot pixel identification and removal
- Responsivity based on very bright stars
- Extinction estimation
- Extract tracks
- Compute abundances
- Deploy to dark sky site → Mount Airy, Maryland, USA
- Tie into triangulation network (Mid-Atlantic CAMS)



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Questions ?

Additional support
provided by the
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GENESEO
THE STATE UNIVERSITY OF NEW YORK

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