The American Meteor Society's filter bank spectroscopy project

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The American Meteor Society (AMS) has sponsored the development of an alternative method of meteor spectroscopy that relies on a set of eight very narrow band wavelength filters. The interference filters used are tuned to the dominant meteoric emission lines of Ca+, two Fe line regions, Mg, Na, Si+, the forbidden O line, and atmospheric O_{777}. Discussion will include the design trade-offs, construction of the instrument, first light testing, and initial results.

1 Introduction

Classical meteor spectroscopy has traditionally employed objective transmission or reflection gratings which are ruled substrates that spread light out into its component wavelengths. The resolution in wavelength is governed by the spacing of the grooves and impacts the system's sensitivity as the light can be either more or less distributed across the measurement focal plane. This trade-off is governed by the desire for increased or decreased wavelength resolution respectively, to help distinguish elemental meteor emission lines. Given sufficient resolution to separate the emission lines caused by neutral and ionized metal atoms originating from the meteor and the surrounding collision excited atmospheric elements, one can compute abundance ratios and determine the constituents of meteors. With concurrent multi-site "white" light measurements of the meteor, triangulation is possible and Keplerian orbital parameters may be calculated. This makes it possible to trace the meteor back to its parent body and effectively perform remote sampling of a comet or asteroid (Jenniskens et.al., 2013).

With grating type spectroscopy, the meteor's incident light is split up into orders and is governed by the standard grating equation. Zeroth order represents light that passes straight through the grating with no wavelength spread, which permits the background star field to pass through and be used as an image for astrometric pointing and calibration. First and higher orders spread the light across the focal plane in increasing wavelength resolution with the first order usually the primary response of the grating, whose efficiency of energy deposition is controlled by its blaze. For high quality gratings approximately 60% of the light ends up in first order.[1]

Meteor spectra are made up of emission lines (*Figure 1*) that are fairly well separated, spanning the visible wavelength range from the blue to the red end of the spectrum. The dominant emission lines typically seen are listed in *Table 1* and are comprised of those elemental species that have high transition probabilities when ionized during the meteor's ablation in the atmosphere. These ions reside within hot plasma of roughly 4500 degrees Kelvin (Borovicka et.al., 1999). Notice that the emission line wavelengths have good separation between most elemental species and thus lends itself to the concept that having low sensor resolution in wavelength could provide either a schema for meteor spectral classification or with sufficient resolution, perform direct abundance estimation.

Table 1 – Dominant emission lines seen in meteors.

Element	Wavelengths (nm)
Fe band #4	382.1 – 388.7
Ca+ H,K	**393.5, 397.0**
Fe band #3	**421.7**
Ca	**422.8**
Fe band #2	427.3 - 441.6, **438.5**
Mg	516.9, 517.4, **518.5**
Fe band #1	**527.1** - 545.7
Forbidden O	**557.9**
Na	**589.1, 589.8**
Atmospheric O	**615.8, 616.0**
Si+	**634.9**, 637.3
Atmospheric N	742.5, **744.4, 747.0**
Atmospheric O	**777.4, 777.6**, 777.8, 844
Atmospheric N	818-824, 857-868

For extremely bright fireballs and bolides, where many more emission lines are seen and their closer proximity in wavelength may cause mixing in a pass band, this concept breaks down. But the goal of this work is to push the limiting magnitude of spectra to the fainter meteor regime than typically captured with grating spectroscopy, thus operating at intensity levels where one is not expected to see a lot of the weaker emission lines.

2 Filter based spectroscopy

The concept of filter based spectroscopy employs the use of moderate to narrow bandwidth filters to target localized regions of the meteor spectrum. The band passes could be quite broad to actually include several

[1] http://www.newport.com/Grating-Physics/383720/1033/content.aspx

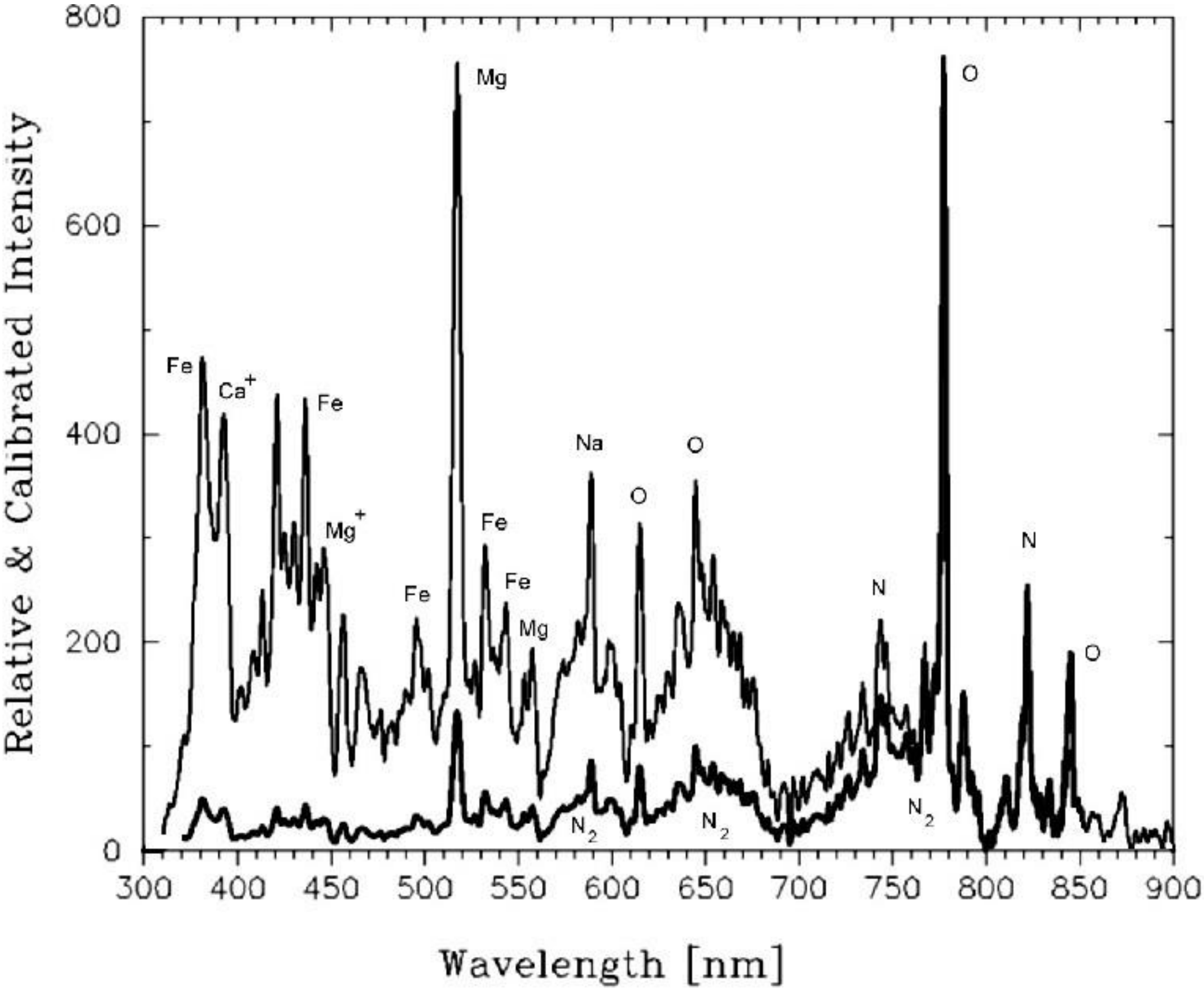

Figure 1 – Typical meteor emission line spectrum (Abe et al., 2000).

elements. By deploying a small set of these wide band filters, one could devise a classification scheme that is similar in nature to that used in stellar spectral classification. On the other hand, very narrow band filters could be used instead that target individual element emission lines to avoid mixing of element species in each filter's response. The objective would be to use filters rather than a grating to maximize the light passing through the system for each wavelength and thus achieve fainter limiting magnitudes without resorting to intensifiers.

The evolution of this concept for the AMS project started with an experiment run by the Croatian Meteor Network (Segon et.al., 2012) that captured meteors using extremely broad band filters. Deployed were a UV-cut plus IR-cut for 400–700nm coverage, an IR pass filter for the wavelength band >700nm, and a light pollution filter that mostly passed the atmospheric O line but excluded the Na line by the nature of its design. The first two showed that even with very wide filter pass bands there were distinguishable properties in the light curves between visible and near-IR that could be further exploited with tighter bandwidth filters. During the 2012 IMC, Gural and Segon had a private discussion about the use of a RGB triplet of filters but costs tabled further work. It was proposed at the IMC two years later (Gural, 2014) that a set of moderate bandwidth color filters could be used (such as the Johnson-Cousins UBVRI astronomical standard) to spectrally classify fainter meteors in a broadband sense. But closer inspection of that standard set found there would be a mixing of elements in the various bands and some dominant meteor emission lines such as Mg would fall into low filter response regions between bands.

While researching alternative color filter pass bands to find ones with high transmittance and good band pass properties, it was discovered that multi-layer hard-coated filters (interference filters) had made tremendous strides in bandwidth options, flatness in band, sharpness of cutoff, out of band rejection, and high transmission performance.

By using very narrow band filters one could target the well separated meteor emission lines with minimal to no mixing and take advantage that all the energy in band reaches the sensor rather than being split into various orders as in a grating. Thus such a "filter bank" system could allegedly see fainter meteor spectral components than a grating spectroscopic camera. However, the costs associated with using a multitude of video cameras and the logistics of processing multiple video streams simultaneously, needed to be considered as well.

Fortunately both low light cameras and multi-channel frame grabbers had dropped significantly in cost. The processing of up to 16 channels of video on a single PC had been both demonstrated (Gural, 2013) as well as functionally deployed as part of the Cameras for All-sky Meteor Surveillance (CAMS) system in New Zealand.

Concept of operations

Thus in early 2015, it was proposed to the AMS that an alternative method of meteor spectroscopy using very narrow band filters was technologically possible. Interference filters could be obtained at reasonable cost and selectively chosen around each dominant meteor emission band. The set of filters would be placed in front of a series of video cameras, all pointed in the same direction, and thus capture the same meteor, collecting only those wavelengths immediately surrounding each targeted meteor emission line.

The collection of multi-channel analog NTSC video signals would be streamed live to a digitizing board, stored directly onto computer memory, and immediately compressed using the standard CAMS compression algorithm (Jenniskens et.al., 2011). This compression approach takes 256 sequential image frames and forms the maximum temporal pixel, frame number of the maximum, the maximum excluded mean, and maximum excluded standard deviation per pixel. This results in a 64:1 compression of the video data. An extra image array containing the frame values after the maximum pixel, could be added for the filter bank project to try and capture the meteor's wake (assuming no discernable persistence in the sensor).

To minimize the computational loading of the CPU, the filtered cameras would only be captured and compressed to CAMS formatted files during the night. There would be included one camera without a filter (open), that would be captured/compressed, but also processed for meteor detection, and thus act as a cueing system for triggering the examination of the filtered camera files the morning after. In addition, one objective grating camera would be deployed with an orientation such that the unfiltered camera's meteor would show up in first order on the grating camera's sensor. The grating camera was also captured, compressed, and detection processed in real-time. The grating spectra would provide a comparison between methods on the brighter meteors captured.

The open/cueing camera would be processed on-the-fly for any potential meteor detections using the detection module library of MeteorScan (Gural, 2008; Molau et.al., 2005) and then visually reviewed the next day. This would confirm actual meteors in the data archive and eliminate false alarms (usually aircraft, lightning bugs, and clouds drifting through the scene). The astrometry for each camera would be automatically checked and only manually updated if no solution found. During meteor confirmation by the analyst, single-station stream association would be automatically performed and peak magnitudes estimated for those meteors declared real by the analyst.

The cueing camera's time stamps would then be searched across the filtered camera data folder and the temporally coincident filter files extracted along with the corresponding time stamped grating files. These would be examined for spectral signatures (which look like standard meteor traces in the filtered cameras). The elemental abundances in a meteor would then be determined from the relative strength of each spectral return after calibration for instrument responsivity, extinction, and ionization transition strength.

The filter bank system would also be tied into the U.S. Mid-Atlantic States CAMS meteor triangulation project, by using the remotely sited and unfiltered video meteor cameras available in that network. The confirmed meteors would be triangulated, their orbits estimated, and ultimately associated with meteoroid streams and their parent bodies yielding information on cometary or asteroidal material constituents. This would also complement the activities underway at the State University of New York (SUNY) at Geneseo in characterizing and distinguishing meteorite versus terrestrial rocks with low cost X-ray analysis equipment (Stillman, 2015).

This filter bank concept was awarded a matching grant from the AMS in February 2015 to design and build a proof-of-concept filter bank system and try to characterize meteor abundances.

3 Design trades

The most critical design consideration was the availability of narrow band filters and their feasibility of use in a meteor monitoring system. Hard-coated multi-layer interference filters were the most promising in that the current technology yielded very flat pass bands of less than 2% ripple, high transmission levels of better than 95%, very sharp cutoffs on the band edges that were just 2–3 nm wide, and out of band rejection from 4 to 6 orders of magnitude down from the peak transmission level. They also came in bandwidths of 2, 10, 25, and 50 nm plus some targeted line florescence filters with non-standard widths. The hard coated filters were also considered more resistant to degradation over time, with a plan to have a BK7 window viewport to protect the system components from the outside environment (especially the grating).

The disadvantages of using interference filters is their off-axis behavior, which shifts the pass band down with increasing angle off normal incidence. For the red end of the spectrum this can amount to 4 nm for a 10 degree angle when using the standard formula (1) and given an index of refraction of n~1.8.

$$\Delta\lambda = \lambda \left[\sqrt{\left(1 - \frac{\sin^2\theta}{n^2}\right)} - 1 \right] \qquad (1)$$

Since the pass bands of the filters were flat, it was conceivable that by selecting filter center wavelengths such that the emission line sits at the low wavelength end of the filter pass band, one could accommodate the off-axis shift. But another concern was using the available filters already manufactured (to avoid the far higher cost for custom designed filter pass bands). This limited the pass band choices since the center wavelengths were spaced every 10nm for the most desired 10nm wide pass bands. It was a challenge to find a complete filter set that could cover each dominant emission line for both on and off-axis cases. Ultimately however, it was possible to identify a combination of 10nm, 25nm and florescence filters that were already in stock from Edmund Scientific Inc.

Selection of the number of specific filter bands to use for the system was driven by the planned use of a low cost US$200 8-channel PCI-express frame grabber built by Sensoray (model 812 PCIe or 1012 mini-PCIe small form factor board). By restricting the total filter count to eight, the pass band choices were down-selected to Ca+, Fe band #2, Mg, Fe band #1, O_f, Na, Si+, and one of the stronger atmospheric lines O_{777} (see *Table 1*). At the low wavelength range, the sensitivity of the camera was known to fall off significantly, so no attempt was made to target Fe band #4 or the Mg line in the 370–390nm range. Also avoided was the region around 422nm due to close proximity of two elemental species, the Fe and Ca lines at 421.7 and 422.8 respectively. Since only one atmospheric line seemed necessary, the O lines near 616nm and N lines near 744nm were also avoided. The reason for the two Fe bands is that their intensity ratio can give some idea of the plasma temperature if both bands are captured in the video.

Given the down selected eight filter center wavelengths and bandwidths that were available off the shelf, the optimal FOV needed to be defined. The choice was between a 12mm f/1.2 and 16mm f/1.2 lens option compatible with the expected use of a 1/3” format sensor chip. The 12mm maximum off-axis angle would be 14 degrees whereas the 16mm would produce 10.5 degrees worse case. Also the 16mm achieved 0.5 magnitude fainter limiting magnitude to a level of +6.2 stellar. Since the goal was to go as faint as possible, the initial trials were run with the 16mm lens, to minimize the impact of the off-axis pass band shift and strive for fainter meteors. The drawback was a loss of 40% in number of meteors captured relative to the 12mm lens due to the smaller coverage FOV and sensitivity difference. This was based on meteor count statistics gathered for both lens configurations over several nights pointing at the same patch of sky.

As this system deploys nine cameras (1 open and 8 filtered), the cost for low-light sensitive cameras was a crucial concern. Fortunately, the Effio-E line of cameras equipped with the Exview HAD II sensor was obtainable for US$35 each. Please note that the terminology “Effio” refers to the image processing chip on the camera’s board, and that a second sensor chip is also mounted, which can be a Super HAD I or II or Exview HAD I or II – so buyer beware. Also note that the Effio’s had to be special ordered without the IR cut filter, as that was found to reduce sensitivity by 1 magnitude. The Exview HAD II sensor is equivalent to that used in the Watec 902H2 Ultimate, except for the use of a 1/3” format rather than the ½” used in the Watec. The smaller format produces a smaller FOV but the lens costs for a 1/3” format f/1.2 lens was only US$4.

With 9 video channels for the filter bank system, a grating video camera, and several CAMS cameras, the specifications for a PC and capture board were also critical. The Sensoray 812 can frame grab 8 channels at 240 full frames per second NTSC (also supports PAL) and dump the raw 8-bit digitized images directly to CPU memory for asynchronous image processing. Two or more 812 boards can be mounted in the same PC given available PCIe slots. To perform the minimum desired 2 channels of capture, compression, and detection, plus another 8 channels of capture and compression only, required the use of a quad-core processor. In actual fact the i5-3450 PC employed was able to easily handle the 8 filter bank camera capture/compression plus 6 channels on the capture/compression/detection side. Note that 4 CAMS cameras were included in the total system configuration to stress test PC throughput performance and monitor for frame drops.

Lastly, having so many cameras and the PC not closely co-located, meant that there would be a large number of long video cables connecting the outdoor filter bank system to an indoor computer. Long cable runs, even if coax, can pick up A/C line interference and need to be electronically filtered. For this project a set of 4-channel video baluns were used at either end of the cables runs. These particular baluns block any induced line interference as well as bundle four coax cables into one CAT5 twisted pair cable thus reducing total cable costs. At the other end is another 4-channel balun to convert the CAT5 back to 4 coax video channels for connection to the frame grabber patch panel.

4 Filter response validation

The filter band centers and widths were selected to ensure the desired meteor emission lines would theoretically stay within the pass band for each filter obtained. The manufacturer only provides a nominal response curve for each filter and did not measure it uniquely for each one delivered. To ensure that the filters purchased had the desired response characteristics, Dr. David Meisel of the AMS requested that the State University of New York at Geneseo’s chemistry department do both on-axis and off-axis scans of the filters. Thus each purchased filter was carefully measured by Dr. Jeffery Peterson and his undergraduate research team at Geneseo using a Cary 5000 UV-VIS-NIR spectrophotometer. As seen in *Figure 2*, which is a composite plot of all eight filters purchased, the dominant meteor emission lines are superimposed on the zero angle incidence response measurement as well as the 12° off-axis measurement.

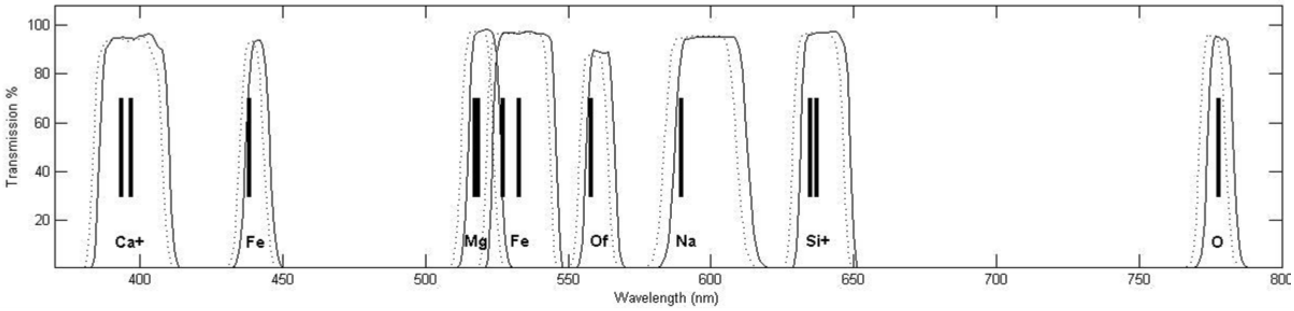

Figure 2 – Composite of filter scans for both normal incidence (solid) and 12 degrees off-axis incidence (dotted) with targeted meteor emission lines (bold vertical lines).

Through this process it was discovered that two filters had their pass bands actually 2nm higher in wavelength than the nominal manufacturer specification, which would have resulted in the targeted emission lines being outside the bandwidth of the filters (recall the emission lines were set close to the low wavelength edge of the pass band so any shift higher in wavelength is bad). These filters were replaced by other lot numbers, which after scanning, showed they better conformed to the nominal specification. It was fortunate that the manufacturer allowed us to swap filters, as their quoted tolerance specification for band centers was plus/minus 2nm. It was a concern however, that we would not find suitable replacements, and to keep costs down we had to use whatever they had in stock without custom ordering.

The measurements verified the band pass ranges of the final set of filters purchased, the flat response in-band, and the constancy of transmission levels between on-axis and off-axis incidence. For this prototype system, the resultant filter band coverage was acceptable without the higher costs of filter band pass customization.

5 System construction

The AMS filter bank instrument shown in *Figure 3* was constructed during the spring and early summer of 2015. First a rigid framework was built using the MicroRAX extruded aluminum and connector system. On this framework was mounted the cameras whose bodies were shortened to 8cm to fit inside the Polycase weatherproof box. The cameras were originally 12cm in length, not counting lens and filter, with essentially empty volume between the camera's front lens-mount/Effio-board and the rear panel controls/connectors. The mounted cameras were then wired to a power distribution bus (12 VDC) and the video lines connected to three internal 4–channel video baluns. The one power lead and three CAT5 cables carrying up to 12 video channels were run through waterproof penetrators out of the enclosure. The Watec grating mounted camera was attached at a 45 degree angle to permit imaging of the first order induced spectra of any meteors that would be seen nearly on-axis to the filter bank system. The filter bank cameras were aligned to within 1 degree of each other, optimal camera settings saved on the each camera's internal EPROM, and the grating oriented so the dispersion direction would be aligned with the rows of the Watec camera's focal plane sensor.

The next assembly was the cover where the options were one large and therefore thick piece of BK7 glass for high transmission at any visible wavelength, or a series of small 30mm x 30mm x 1mm thick BK7 covers placed over holes drilled in the enclosure's lid. The latter approach was chosen due to a major cost savings. Lastly a 16 channel patch panel for the incoming video lines was interfaced to the two digitizer boards. Two BNC penetrators were added to allow the filter bank station to have two additional external video cameras operating and utilize the two free video channels of the three 4-channel baluns.

Figure 3 – Completed system of filter bank and grating.

The major system components are as follows:

- 9x Exview-HAD-II 1/3" format B/W NTSC video cameras equipped with 16mm f/1.2 lenses
- 8x Edmund Scientific hard coated interference filters of nominally 10 or 25 nm pass bandwidths
- 1x Watec 902H2 Ultimate and 12mm Pentax f/1.2 lens mounted with a 1379 lines/mm grating
- 3x four-channel video baluns to convert the ten video signal coax cables to just three CAT5 cables
- 1x HP Slimline PC with quad-core i5-3450 processor
- 2x Sensoray 1012 eight-channel small form factor capture cards with custom built patch panel

During the writing of this paper for the proceedings and after the AMS instrument was built, it was discovered that a similar narrow band system had been previously designed and tested (Ocana et.al., 2011). It targeted fireballs and reached a limiting magnitude of -2. It used wide field of view (FOV) optics of up to sixty degrees and placed interference filters behind the objective lens in the converging part of the light path, which can make calibration challenging if the filters do not have a flat pass band. That work provides a good complement to the design trades and performance results that are achievable.

6 Initial results

Preliminary statistics

Initial night operations began on July 28, 2015 after pre-aligning cameras, adjusting gains, and testing the capture, compression, and detection throughput of the i5 processor. Feeding one of the capture boards was the unfiltered cueing sensor, the grating camera, plus four standard CAMS cameras, resulting in a total of 6 video channels of capture, compression, and detection processing. The second frame grabber was fed the 8 video channels of the filter bank, which were only captured and compressed such that without detection there was very little additional CPU loading. The unfiltered camera would be the detection cue to look at the filter bank files. Virtually no frames were dropped of the 14 video channels ingested over the course of eight hours, each channel running at 30 fps NTSC (640x480 pixels). Note that the detection processing threads wrapped up a few minutes after the capture processing had ceased during morning twilight.

On the first night, six meteors were captured in the open "cueing" camera, of which two showed atmospheric oxygen lines, but the metal emission was too faint to be seen in the other filters. The next night a +1.5 magnitude PAU meteor was captured with spectral components of O, Si+, Na, Fe, and Mg. There was no corresponding grating spectrum found, thus supporting the conjecture of lower magnitude sensitivity for the filter bank system. Preliminary operations continued through August 16 and statistics were accumulated as seen in *Table 2*.

Table 2 – Statistics of spectral bands seen versus magnitude from July 28 through August 16, 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										

Several observations can be made from the statistical results thus far:

- The limiting magnitude to pick up spectral components in the filter bank system is +2 whereas the limiting magnitude of the grating is 0. In both cases one needs to go one magnitude brighter to have good quality measureable signal.
- Just where the filter bank system becomes sensitive to multiple bands, the limited FOV at brighter magnitudes hurts the statistics. Note the four meteors at 0 and -1 that were seen by the grating camera but were just outside the FOV of the filter bank system. The next phase of operations will swap in 12mm f/1.2 lenses to buy back a 40% increase in meteor counts. The center and pass bands of all the filters but one will support this. The exception is the O_{777} filter where the response will cut off for meteors on the edges of the FOV.
- The O_{777} line is usually the most significant component visible especially for fainter meteors, followed by the Si+ emission line. This opens up the possibilities of daylight observations of meteors at the O line since the sky brightness is only 10% of the intensity in the middle of the visible band.
- There is difficulty picking up the Ca+ and lower wavelength Fe band which is likely due to several causes ranging from lower camera sensitivity below 450 nm, initial tests run near sea-level in humid summer conditions, plus other low wavelength optical component limitations.

Fireball of August 5, 2015

On August 5, 2015 at 3:29:29 UT an alleged Alpha Capricornid (CAP) of magnitude -1.5 with two flaring events, showed a signature in all 8 filter bands. It also produced a grating spectrum and was captured in 3 unfiltered cameras. Unfortunately, the triangulation site did not start operations until an hour later due to clouds. However, the three open cameras all independently associated the meteor as a CAP based on single station analysis.

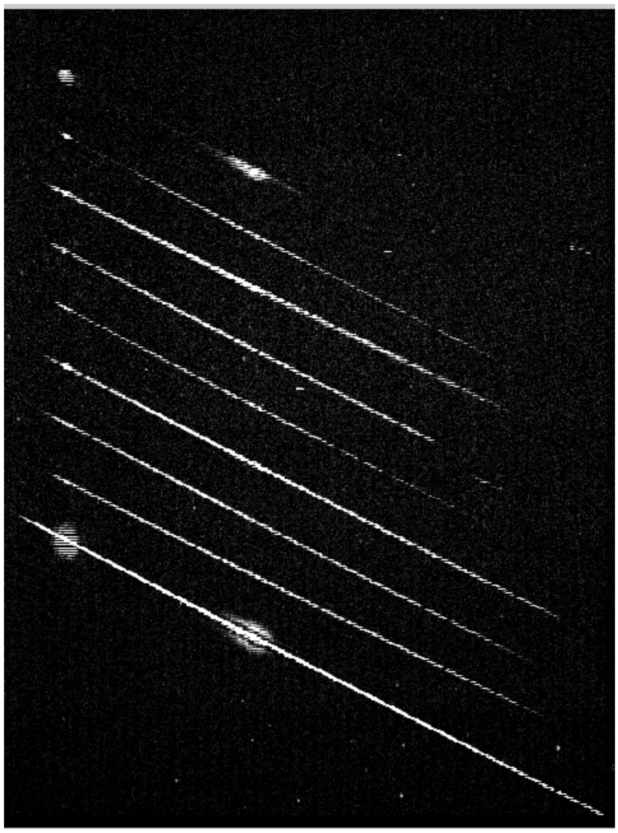

Figure 4 – Multi-frame, multi-camera, stacked-offset composite of the eight filtered light profiles plus one unfiltered track of the CAP with m_v = -1.5 collected on August 5, 2015.

In *Figure 4* is shown a composite of the eight filter bank tracks for Ca+, Fe#2, Mg, Fe#1, O_f, Na, Si+, O_{777} and the open camera running from top to bottom of the figure respectively. Notice the appearance of the Ca+ emission line during the brightest flare portions near the end of the ablation. In *Figure 5* is shown the corresponding grating spectrum that is a composite of all frames in the sequence with the meteor propagating upwards (the grating camera is rotated 90 degrees with respect to the filter bank cameras).

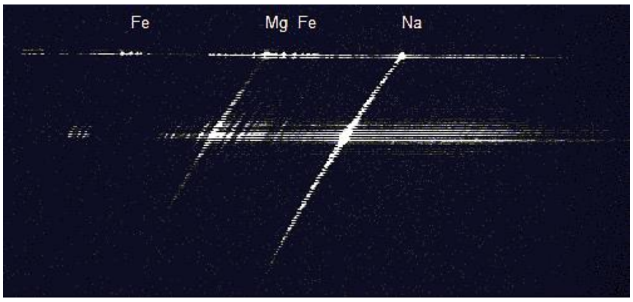

Figure 5 – Multi-frame composite of the grating camera's view of the m_v = -1.5 CAP meteor of August 5, 2015. The two brightest lines are Mg and Na. Also visible are several lines from Fe bands #1 and #2. Grating system based on the CAMSS design (Jenniskens et.al, 2013).

Note that the grating camera could not capture the full spectrum from 400–800 nm in the non-vignetted portion of its focal plane due to the wide spread induced by the 1379 lines/mm ruling. Whereas the filter bank cameras effectively covered the entire spectral range. Of course a lower dispersion grating would mitigate this and still have better resolution than the filter bank's 10 nm bandwidth of its narrowest filters. On the other hand there is the preliminary two magnitude sensitivity gain of the filter bank that must be further assessed with additional operational time of the instrument.

Other issues to work on immediately are the lack of stars in some of the filter bank cameras due to the use of such narrow pass-bands. The system will need to be pointed at some very bright star region to determine the relative pointing offsets between cameras (although a scheme to use an aircraft strobe and the millisecond time stamping could do the relative astrometry despite the unsynchronized cameras deployed). This will allow temporal alignment of the light curves once the tracks are extracted for abundance analysis.

7 Conclusion

The AMS has helped support an investigation into an alternative method of meteor spectroscopy that from a first look, appears to provide lower magnitude sensitivity than using a grating. The design, construction, and initial test collections have been completed for a filter bank system of video meteor cameras covering the dominant meteor emission lines.

There is a trade-off that must be further analyzed in that the limited FOV of an interference filter based system may hurt the statistics needed at just the point where the system is sensitive to elemental signatures across multiple bands. This begs the question: is it better to deploy the same number of cameras equipped with low resolution gratings pointing in many different directions similar in nature to CAMSS (Jenniskens et.al., 2013), that would yield more sky coverage and perhaps more spectra, despite having a brighter limiting magnitude.

Since the off-axis wavelength shift of the interference filters are the restriction on FOV for the filter bank, another alternative may be to reconsider use of colored filters without angle restrictions, resulting in even wider FOV and higher meteor statistics. This however would result in operating at a brighter limiting magnitude and there is the potential to mix elemental signatures. This would move away from abundance calculations to a more general color index characterization for meteors.

Further testing with a wider FOV lens using the same interference filter set will help to shed light on these various design trades. Nevertheless the filter bank system does initially appear to provide a probe into fainter meteor spectral composition. Other next steps include automating the coincident filtered file extraction for examination, hot pixel removal which are prevalent in the Effio-E Exview HAD II sensors, collections made against several bright stars to build the responsivity for the cameras, implement the calibration software and meteor extraction from the imagery, and finally make relative abundance estimations. After the software is established and the processing becomes routine, the system will be deployed to a darker sky site located at George Varros' residence in Mount Airy, Maryland.

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Pete Gural during his lecture (Photo by *Christoph Niederhametner*).