Development of the Spectral CAMS System

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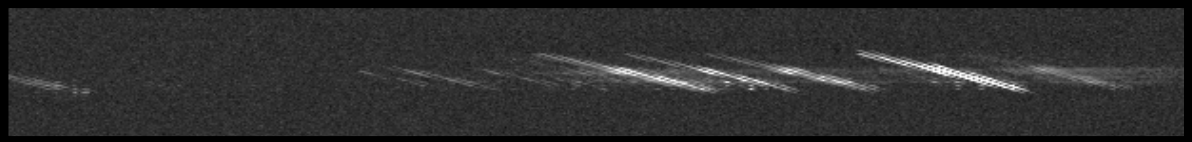
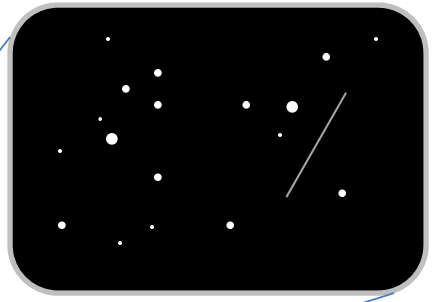


Support provided by
NASA's Near Earth Object
Observation Program Element

IMC 2013 – Poznan, Poland

Cameras for All-sky Meteor Surveillance (CAMS) - Overview

A collection of moderately narrow FOV and low-cost, non-intensified but low light sensitive video imagers to obtain meteor orbits.



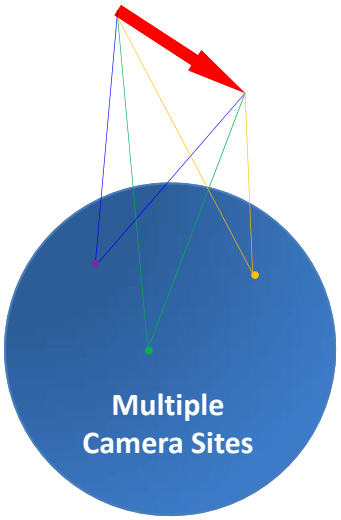
22° x 30°
2.8'/pixel

Affordable enough to mosaic the sky ?

CAMS Details Provided in Poster – Within Reach of Amateur Groups / Networks

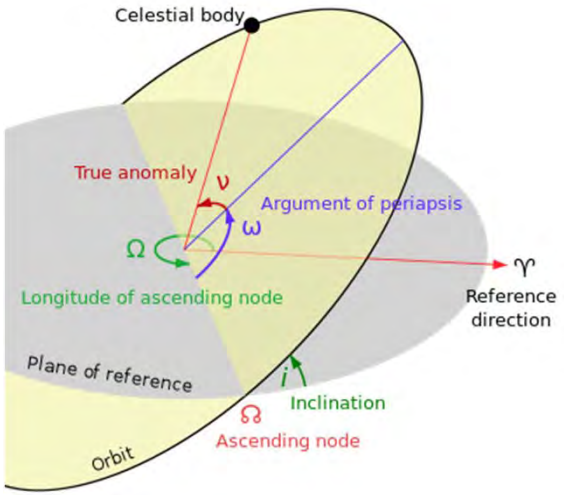
Cameras for All-sky Meteor Surveillance (CAMS) - Objectives

Trajectory …



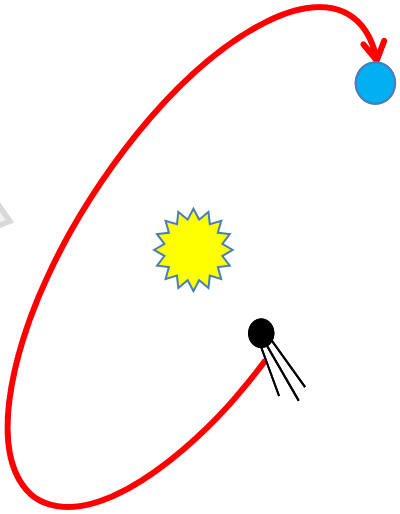
Solar System Orbit …

Stream Validation …



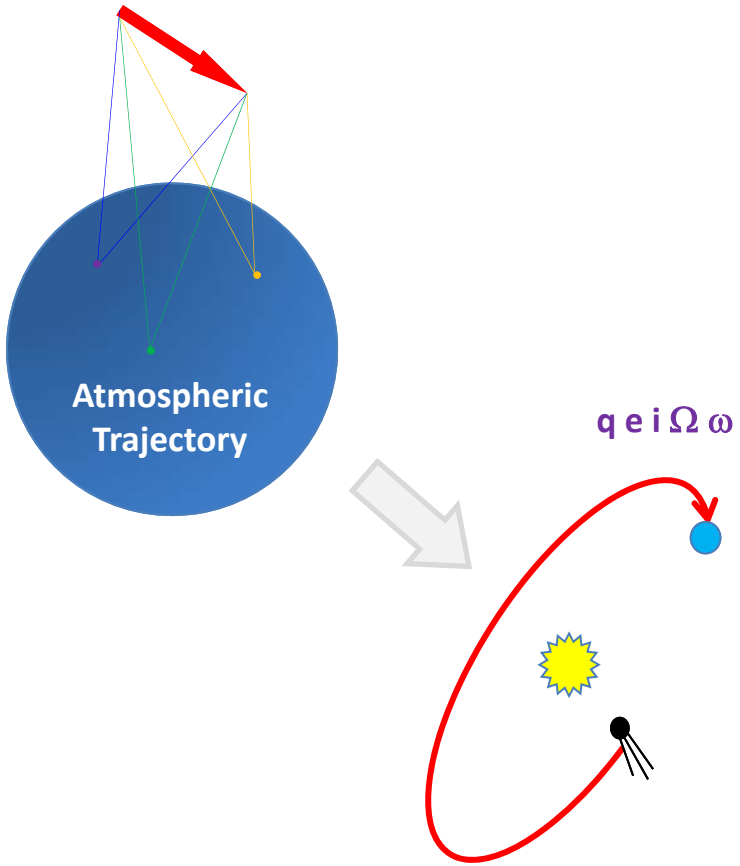
Solar System Keplerian Orbital Elements

Parent Body …

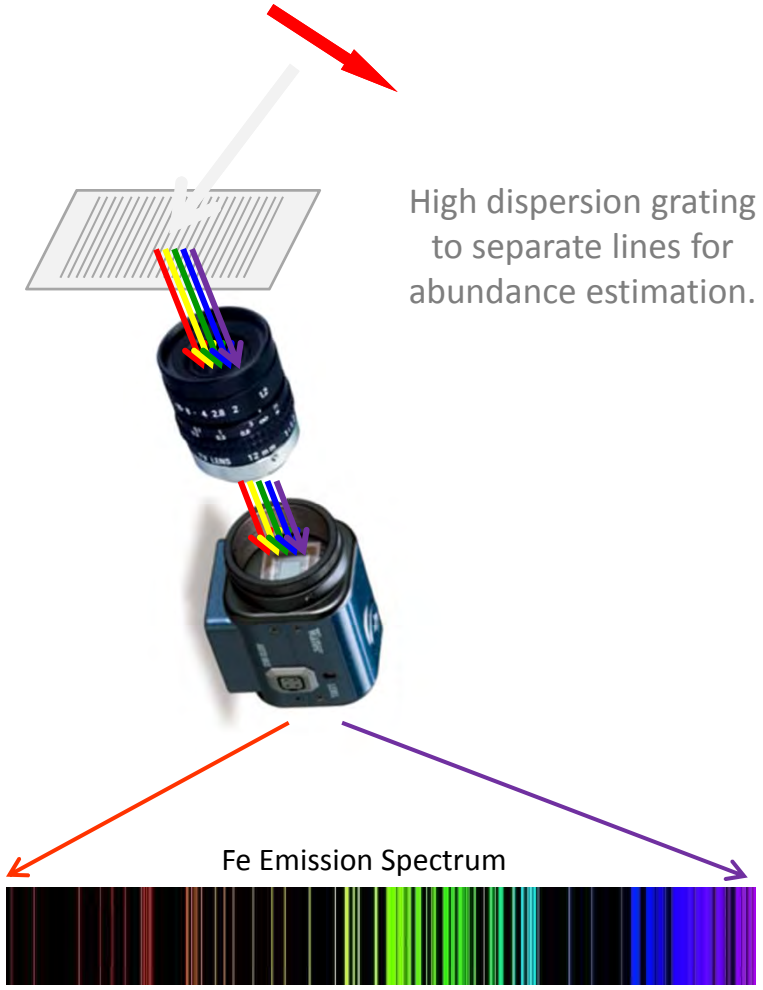


Next … Composition →

Cameras for All-sky Meteor Surveillance (CAMS) → CAMS Spectral (CAMSS)



CAMS obtains well defined orbits for major and minor streams which can be tied back to the parent body.

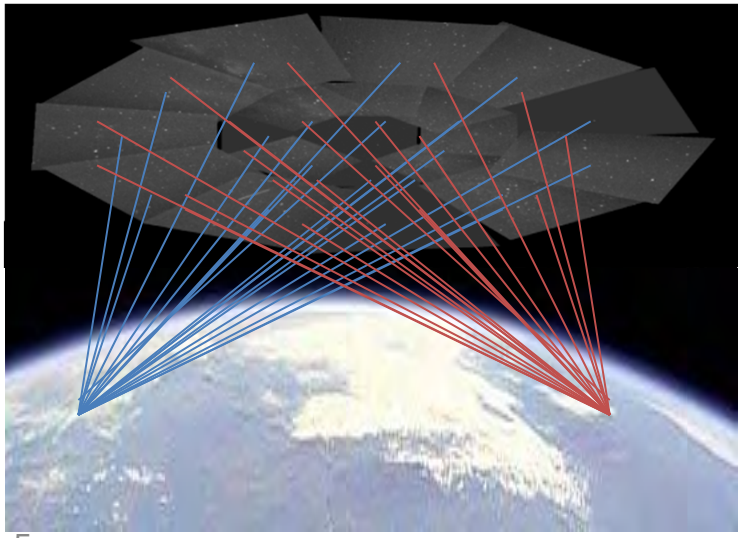


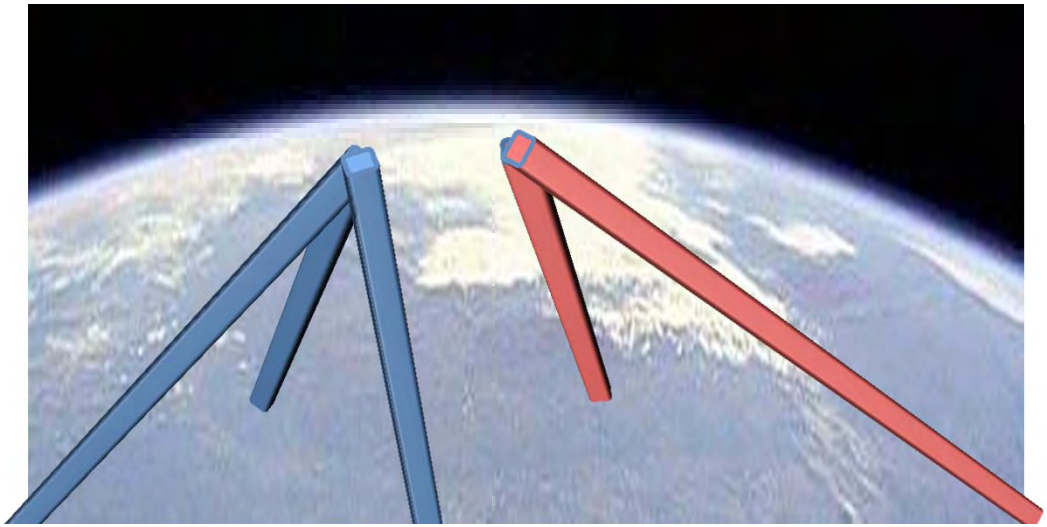
CAMSS adds composition and elemental abundance plus orbits as a effective sample return from the parent body.

CAMS Camera Deployment Configurations → Trajectories & Orbits

Few Sites – Concentrated Batteries

Distributed Sites – Few Cameras per Site

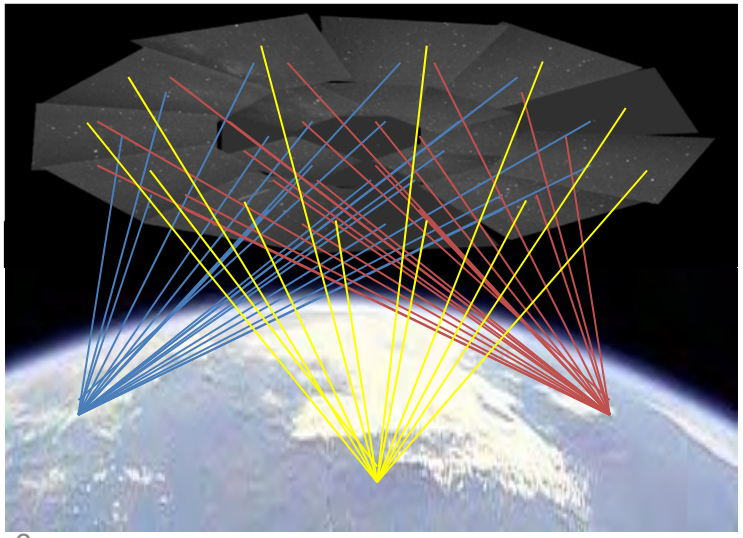


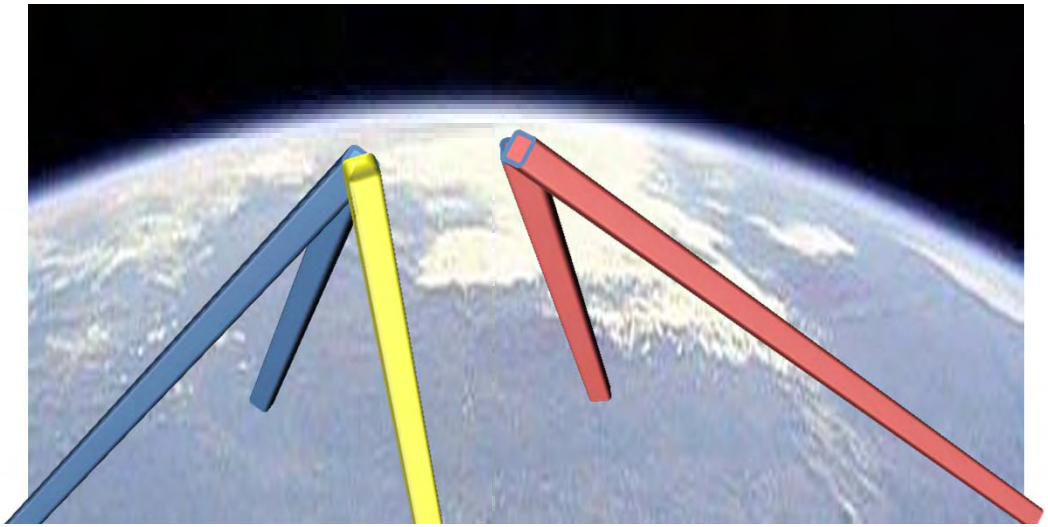


CAMSS Camera Deployment Configurations → Composition

Add a Dense Battery of Grating Cameras

Add a Objective Grating Camera to a Distributed Network





CAMSS Design Challenges to Automate Spectral Collection / Analysis

Grating Selection / Mounting ✓

Optimal Geometric Camera Pointing ✓

16 Video Channels Real-Time Capture ✓

Detection with Lossless Archiving ✓

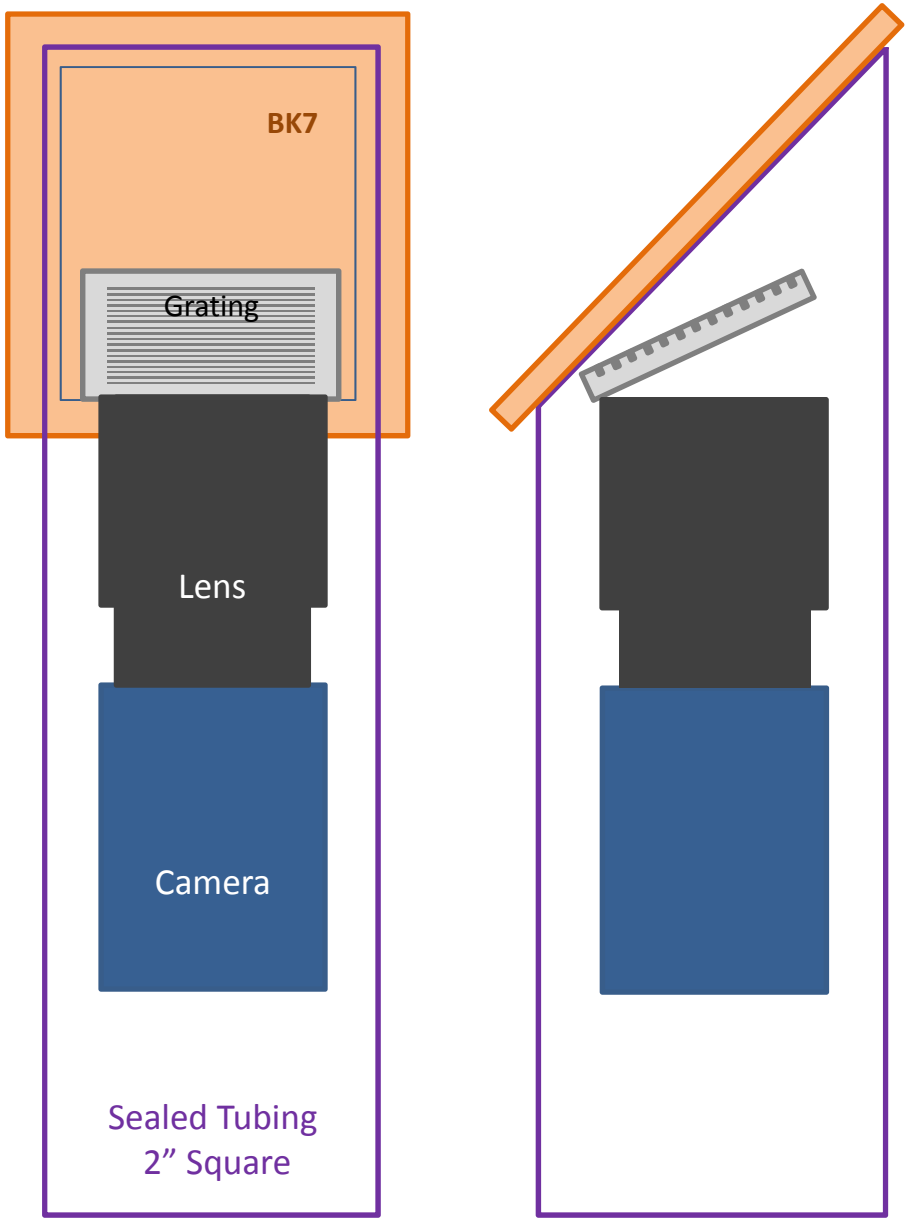
Coincidence to Known Trajectories ✓

Calibration – Astrometric, Atmospheric, Efficiency

Large Data Volume, Maximize Automation, Minimize HIL, Maintain Quality

Special thanks to Anthony Berdeu for proto-typing the pointing, extraction, and calibration

Objective Grating Configuration



← *BK7 - Protection of grating surface*
Broad spectrum transparency
Tilted 45° to be ~normal to 1st order incidence

← *Grating tilted 25° for max efficiency in 1st order*

High dispersion 1379 grooves/mm
Resolves critical emission lines
Measure Na/Mg, Fe/Mg, …

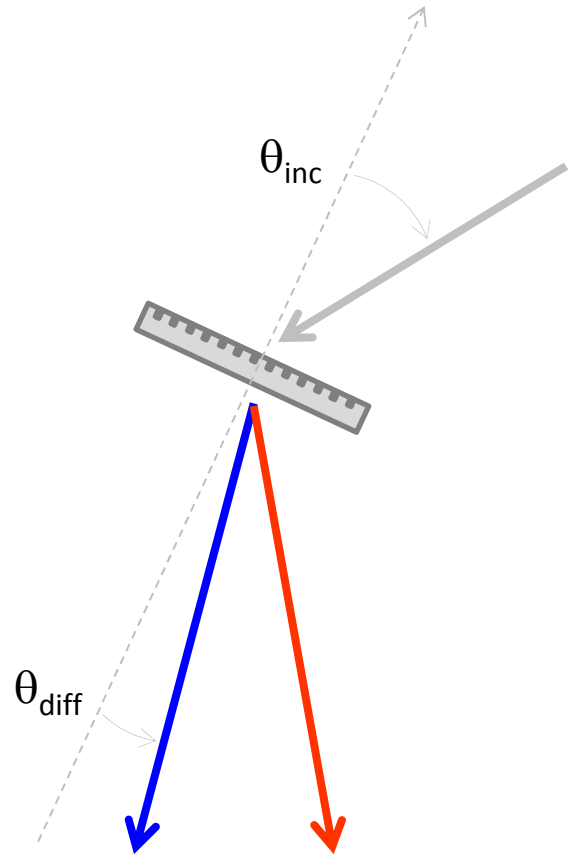
Aperture allows for 0, ±1, and +2 orders
Astrometric calibration obtained from 0th

← *Standard CAMS camera / lens setup*

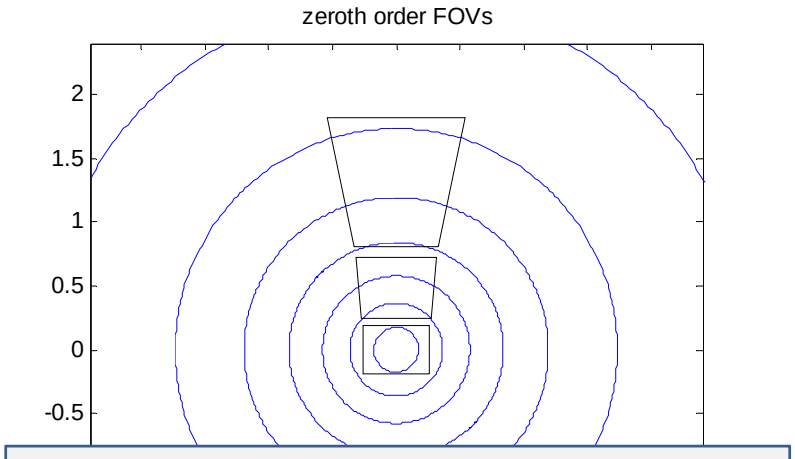
← *Keep out bugs and weather*

Effective Geometric Wavelength Coverage

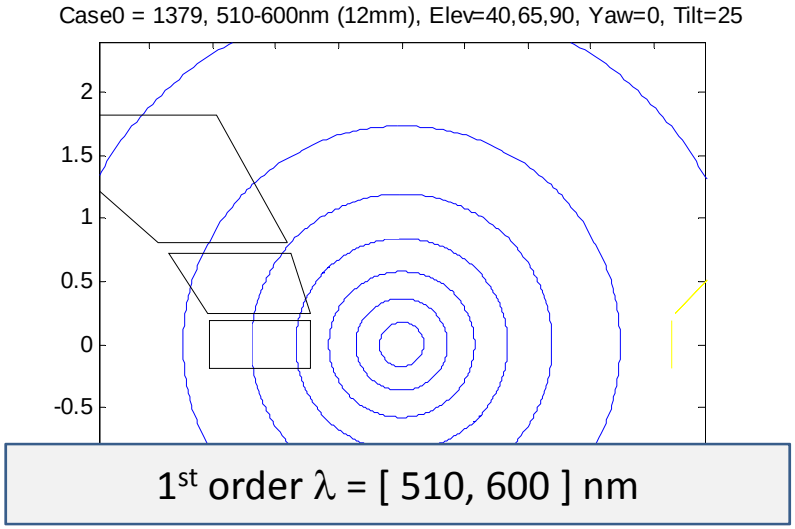
"Diffraction Grating Equation"



$$n\lambda/d = \sin\theta_{inc} + \sin\theta_{diff}$$



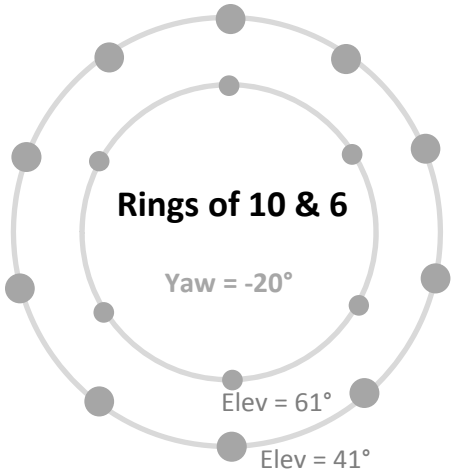
0th order FOV for 40, 65, 90 Elevation



1st order λ = [510, 600] nm

How to Optimally Point 16 Cameras ?

Optimizing the 16 Grating Camera Pointing Directions

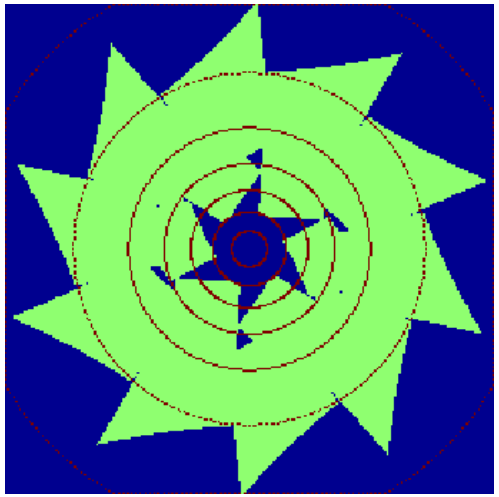


Design Goals:

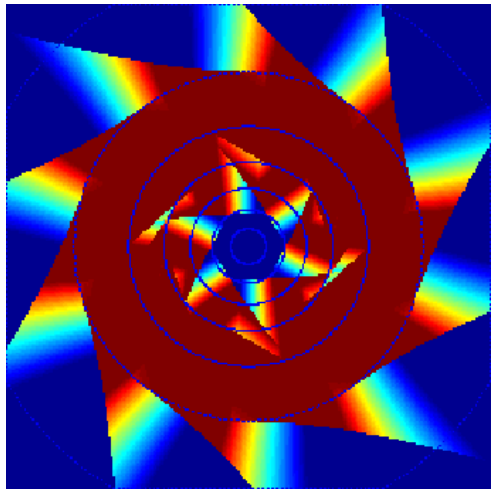
- Realizable mounting scheme
- Maximize sky coverage above 30°
- Maximize spectral coverage λ = [380, 600] nm
- Overlap zeroth and first order sky coverage

Observations:

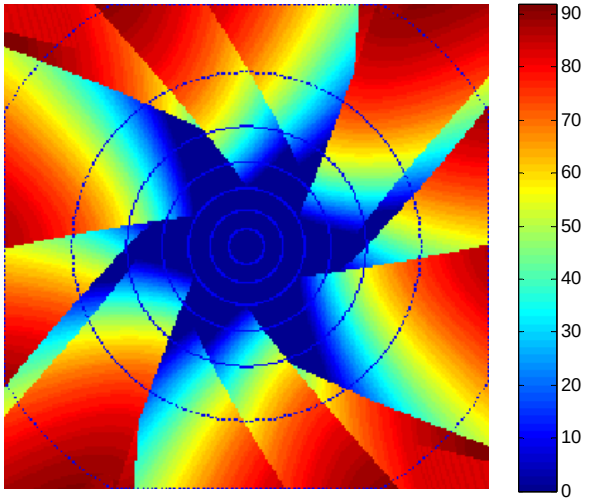
- Introduced mounting yaw for n=0 & n=1 overlap →



Zeroth Order FOV

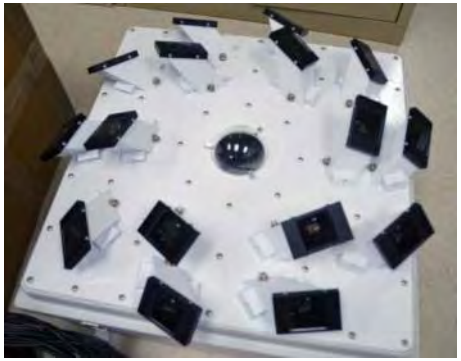


First Order Coverage



Second Order Coverage

Real-Time Capture Across 16 Video Channels



16 Objective Grating Cameras

Watec 902 H2 Ultimate
Pentax 12mm f/1.2
Grating 1379 grooves/mm

640x480 @ 30 fps

Capture 16 Video Channels → Memory

Full resolution monochrome
Simultaneous and asynchronous
NTSC or PAL video frame rates

Sensoray 817
PCI Express x1
Ribbon cable to BNC box

Multi-Threaded Software

Must function in real-time at video rates
Support asynchronous processing

Run 16 capture/detection threads
Run 1 compress thread per channel per minute
Detection only halts one camera for buffer write

Single PC w/ 64-bit Windows 7

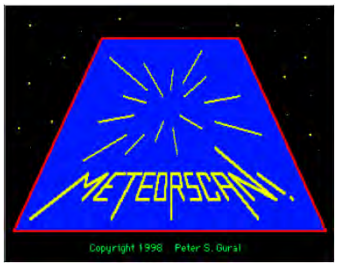
HP Pavilion HPE h8-1360t
Intel i7-3770 Quad-core
3.4 GHz, 8 Gbyte, 1 Tbyte HD

Currently 25% utilized

Advantage: Lower overall system cost with one PC
Disadvantage: Single point of failure – spectral data loss for the night

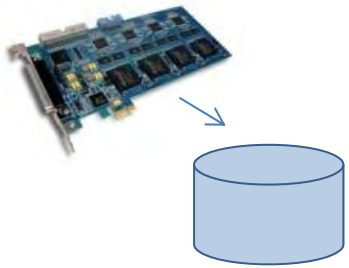
Options Considered for Processing

Detect on the fly ?



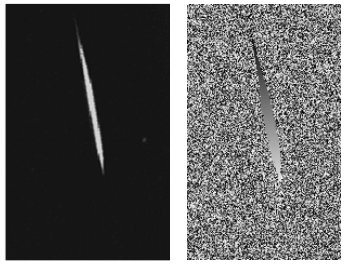
1 channel real-time, modularized, but not thread safe

Save it all ?



6.4 Terabytes per night

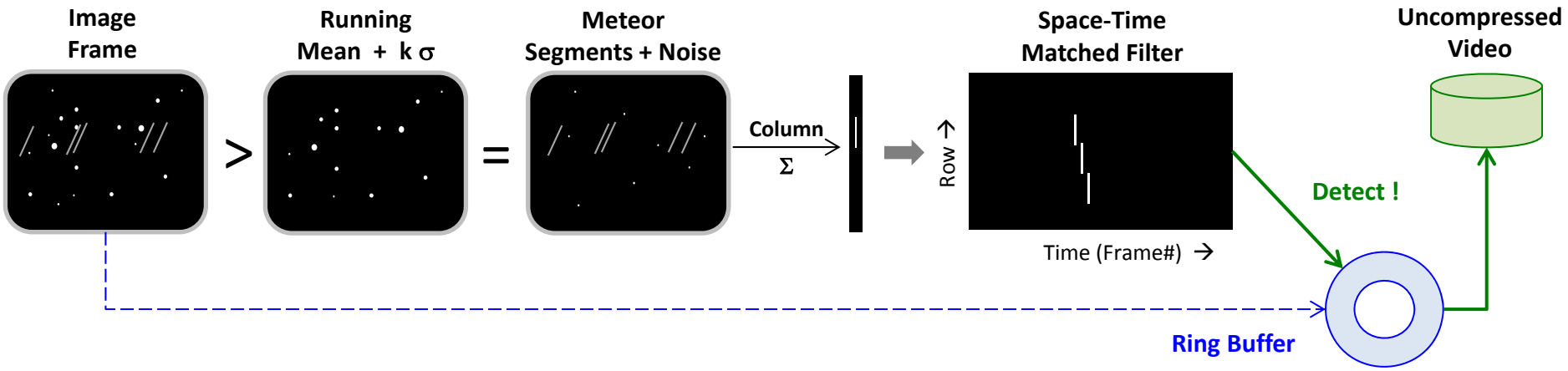
Compress it ?



Max Temporal Pixel Value | Frame# of Max Pixel

Potential loss of weak spectral lines in background

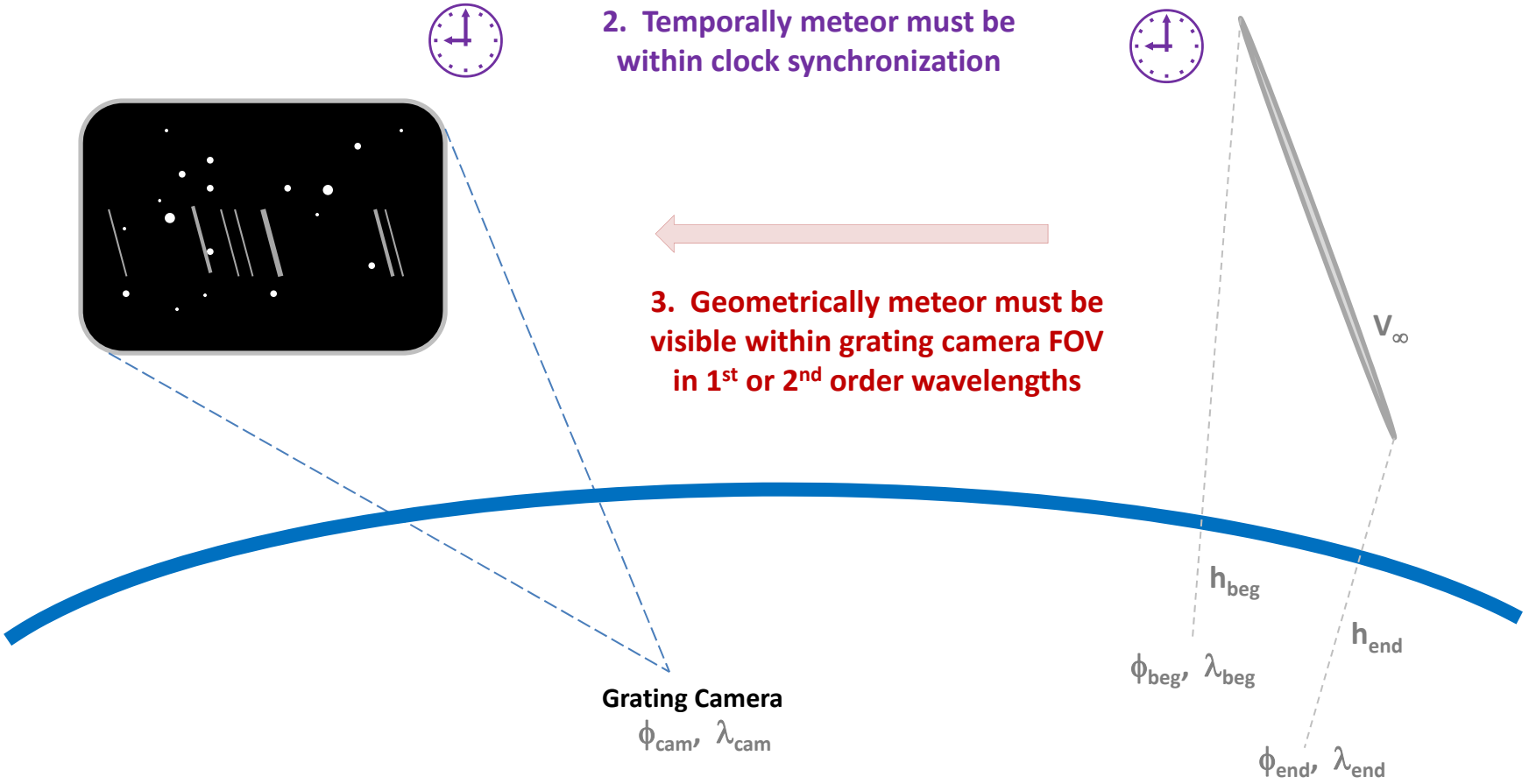
Detect in Real Time with Lossless Archiving



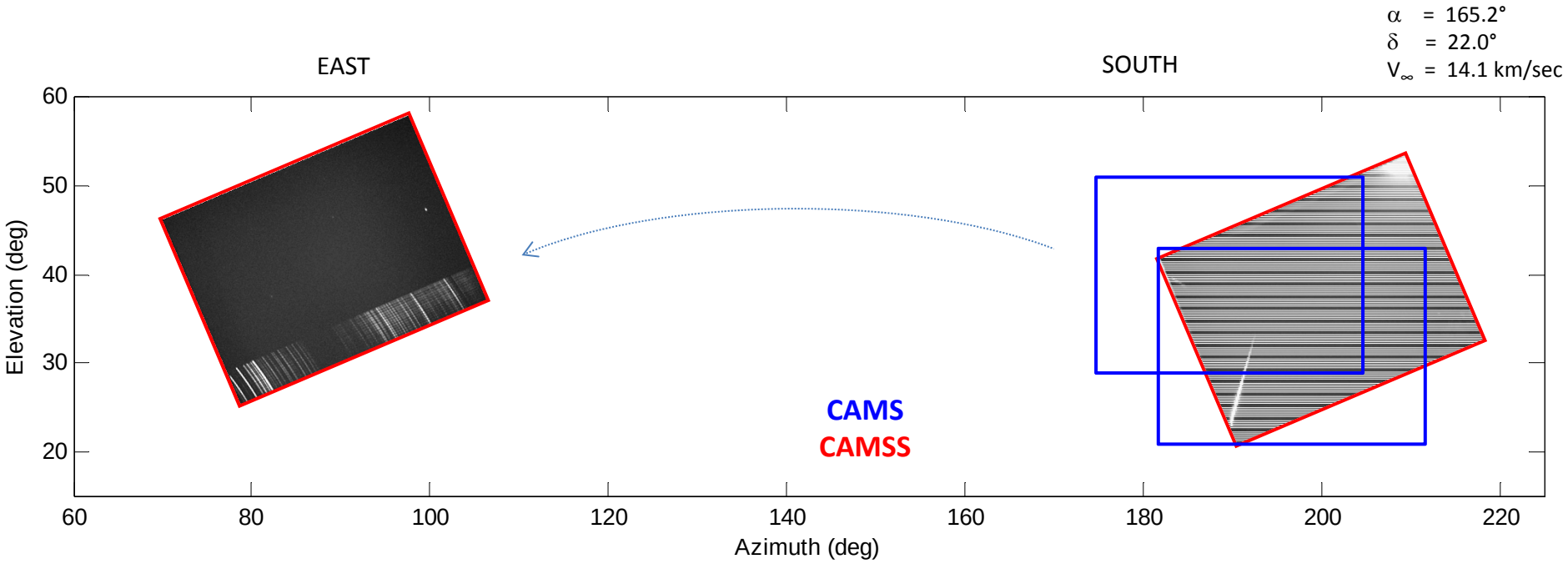
Alternatives: MeteorCue meteor tracker low latency cluster detector
Striation detection via 2D FFT – FFTW fits in timeline
MeteorScan trigger on wide field zenith camera → dump the 16 ring buffers

Space-Time Coincidence to "Known" CAMS Trajectories

1. Trajectory obtained from standard CAMS processing on ALL cameras (*spectral included*)



Geometric Example from April 21, 2013 - but not a Lyrid !



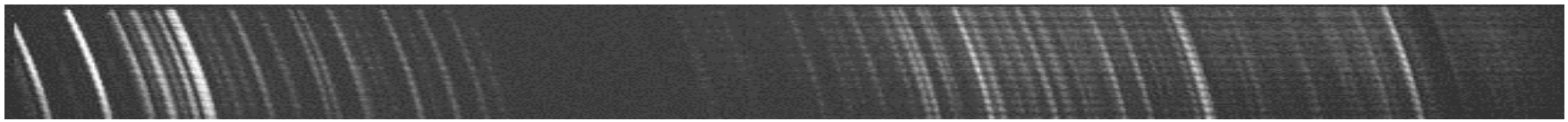
Mg
517

2nd Order

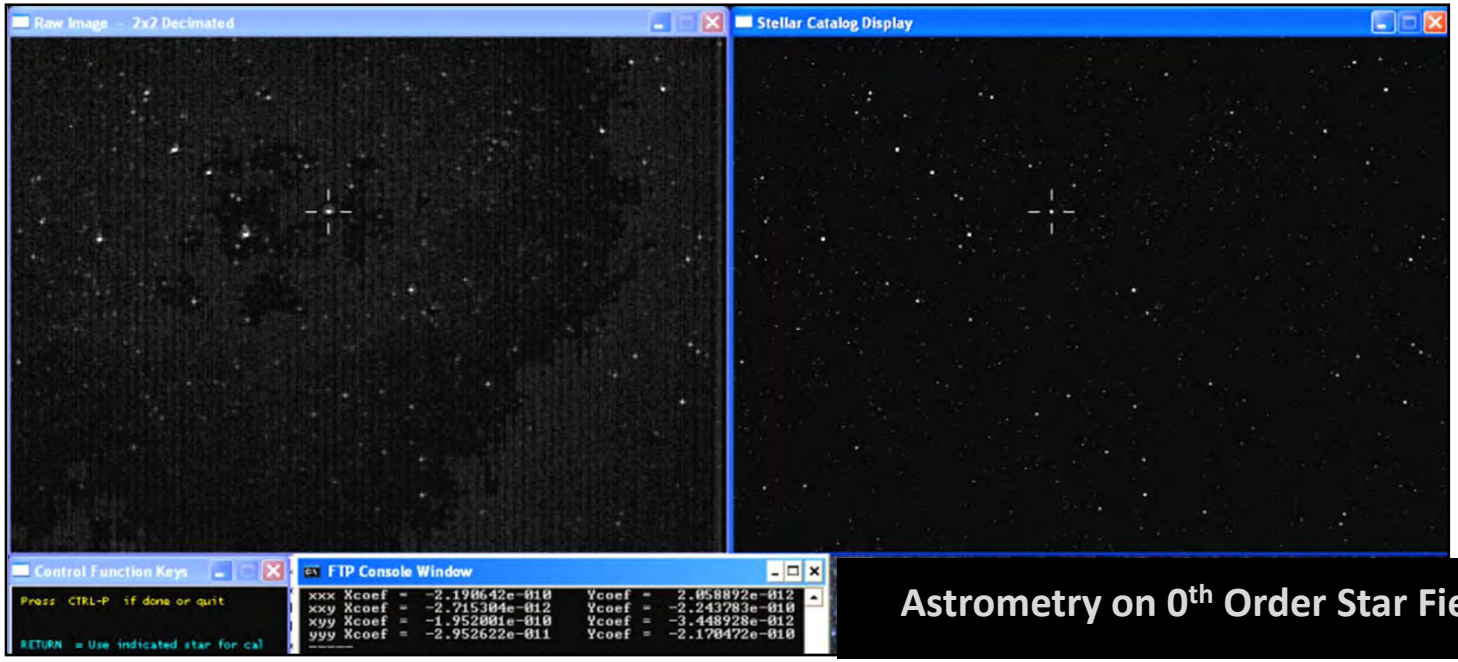
Iron Content Meteor !

O
777

1st Order

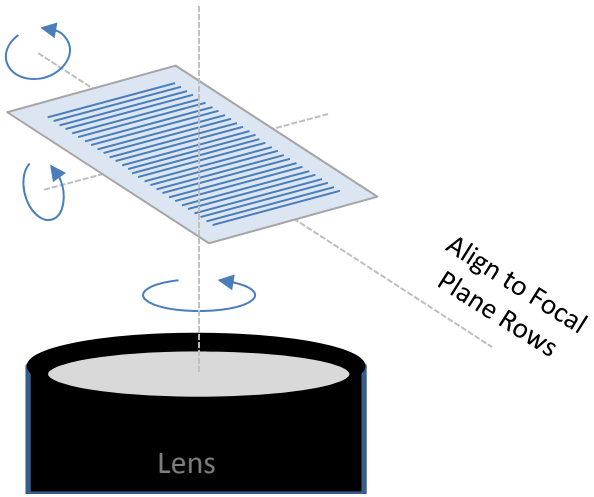


Calibration Components



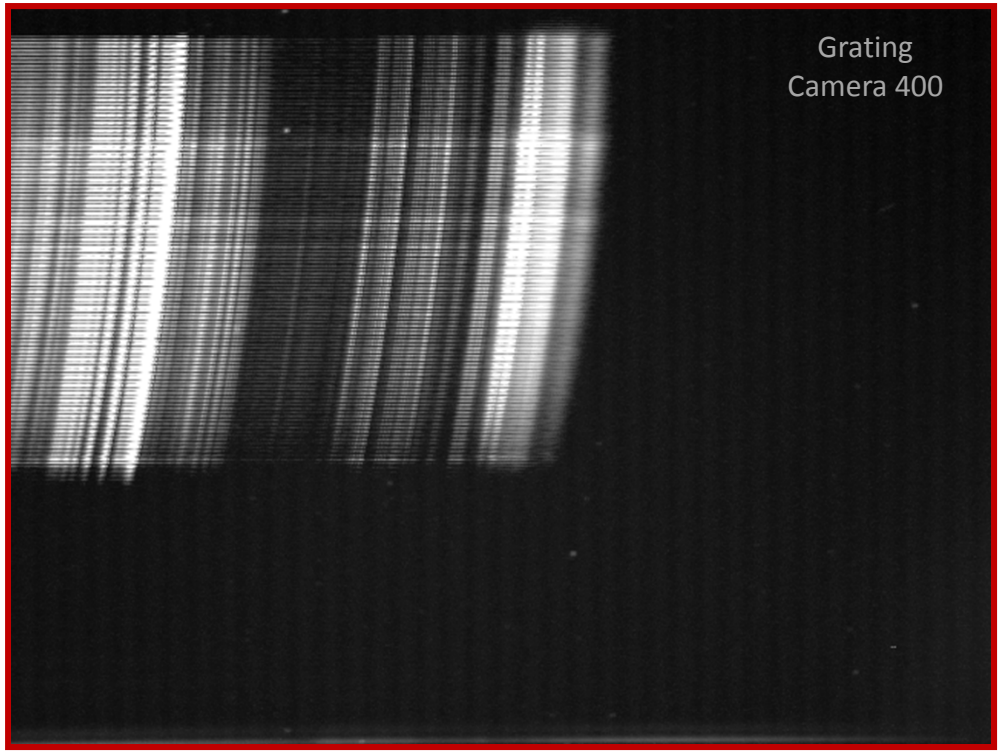
Astrometry on 0th Order Star Field

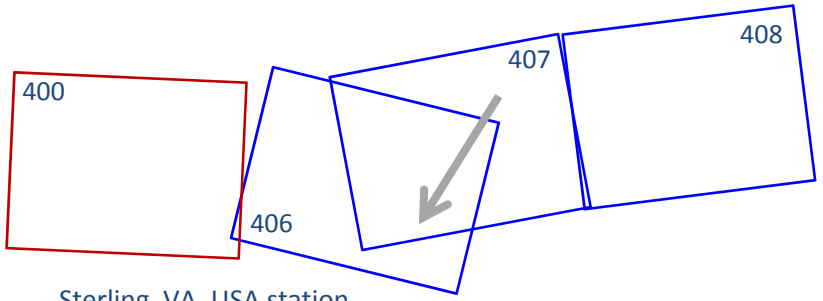
Grating Roll, Pitch, and Yaw



Star Spectrum Calibration for Frequency Response

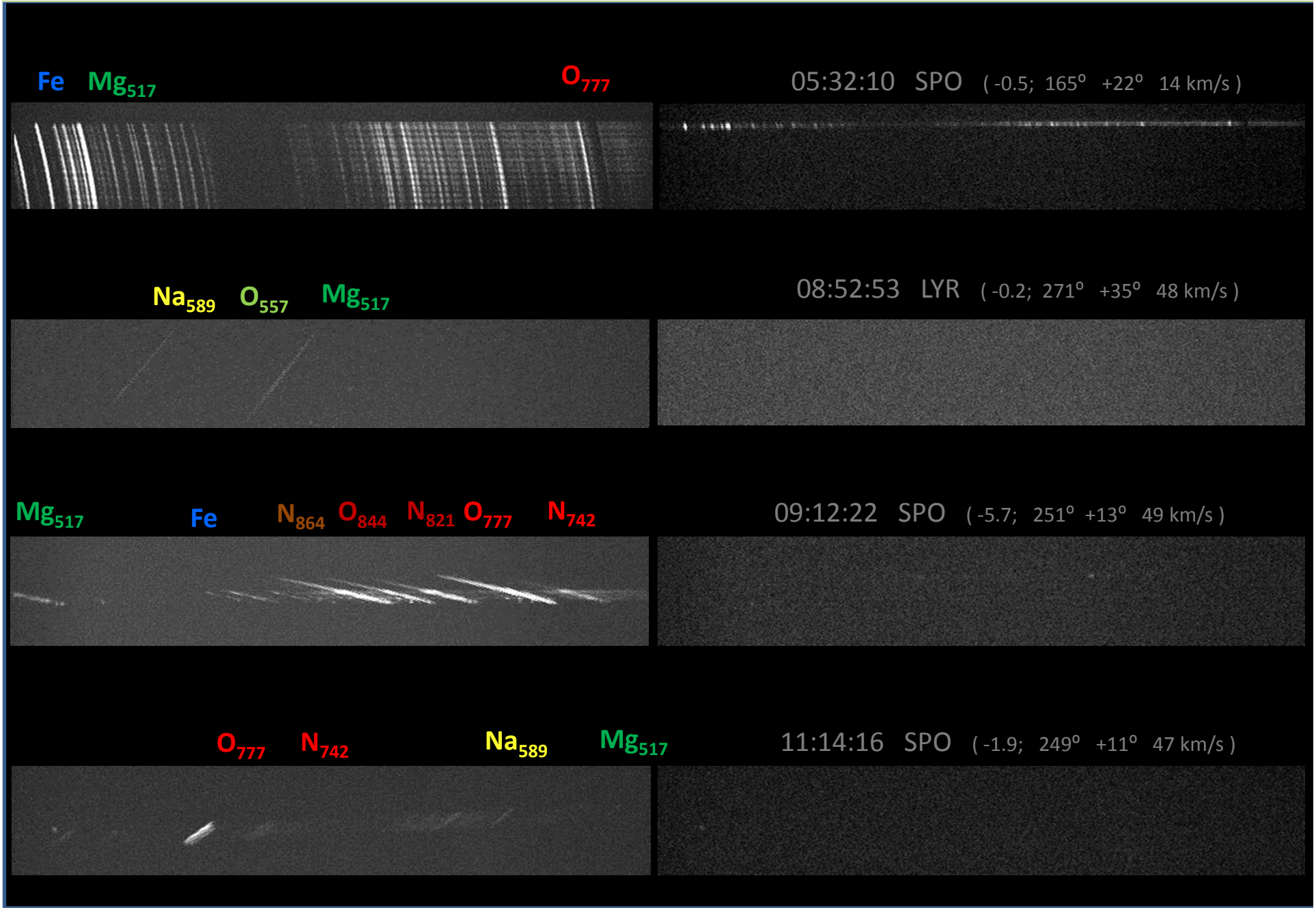
First Fireball Spectrum during the Geminids - 14 Dec 2012 04:43:49 UT



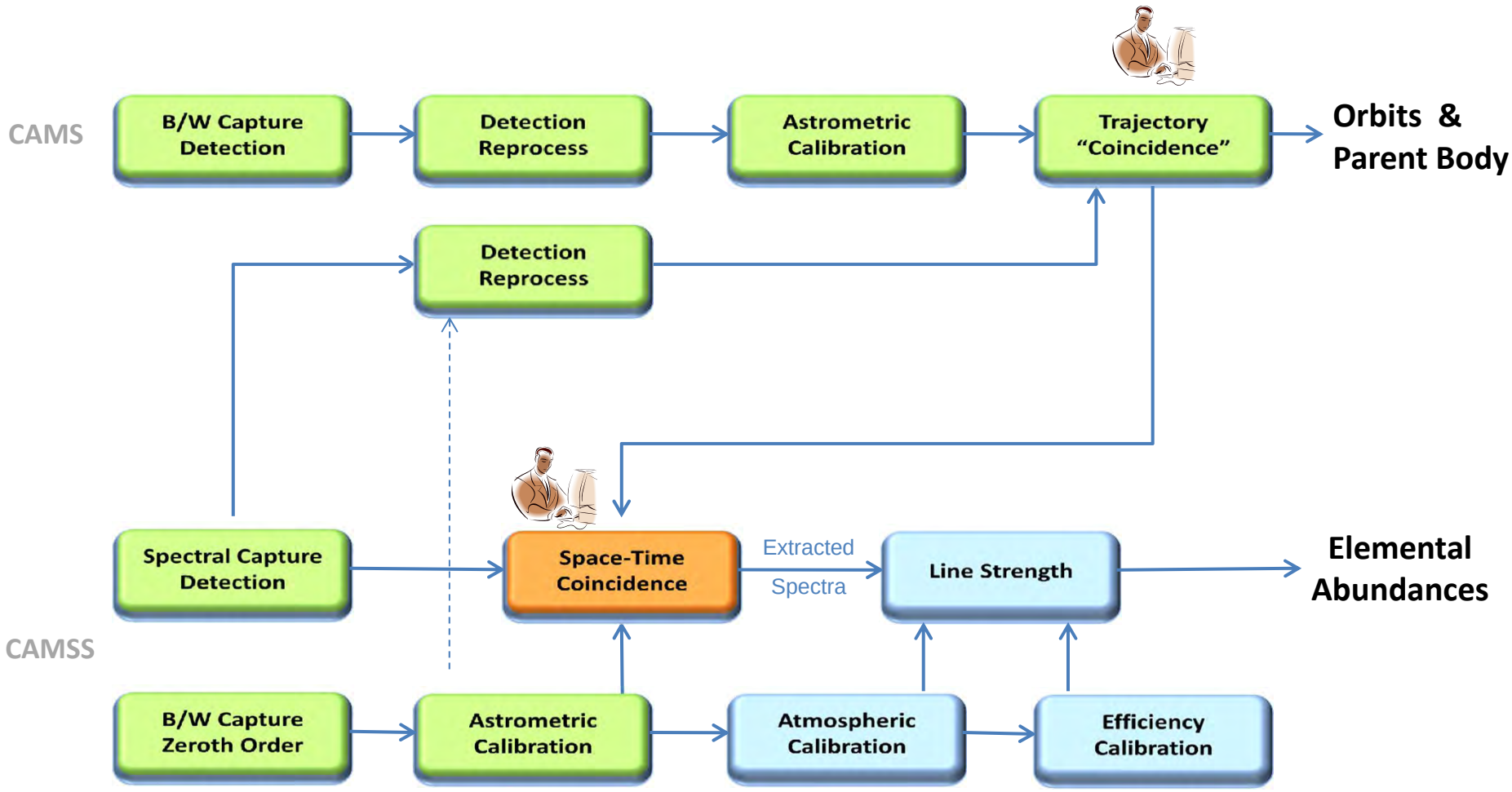


Sterling, VA, USA station

Sample Spectra and Videos - April 21, 2013



CAMS + CAMSS Module Development and Work Flow



Amateurs can Contribute by Setting up a Grating Camera in a CAMS Network

Still need to finish end-to-end software – then build single camera spectral capture

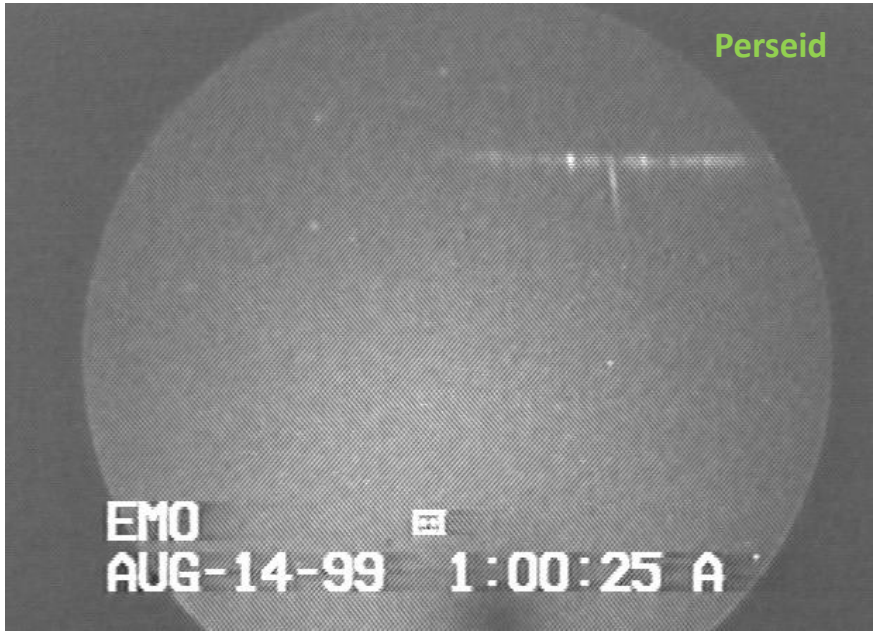
Amateur Contributions to this Field

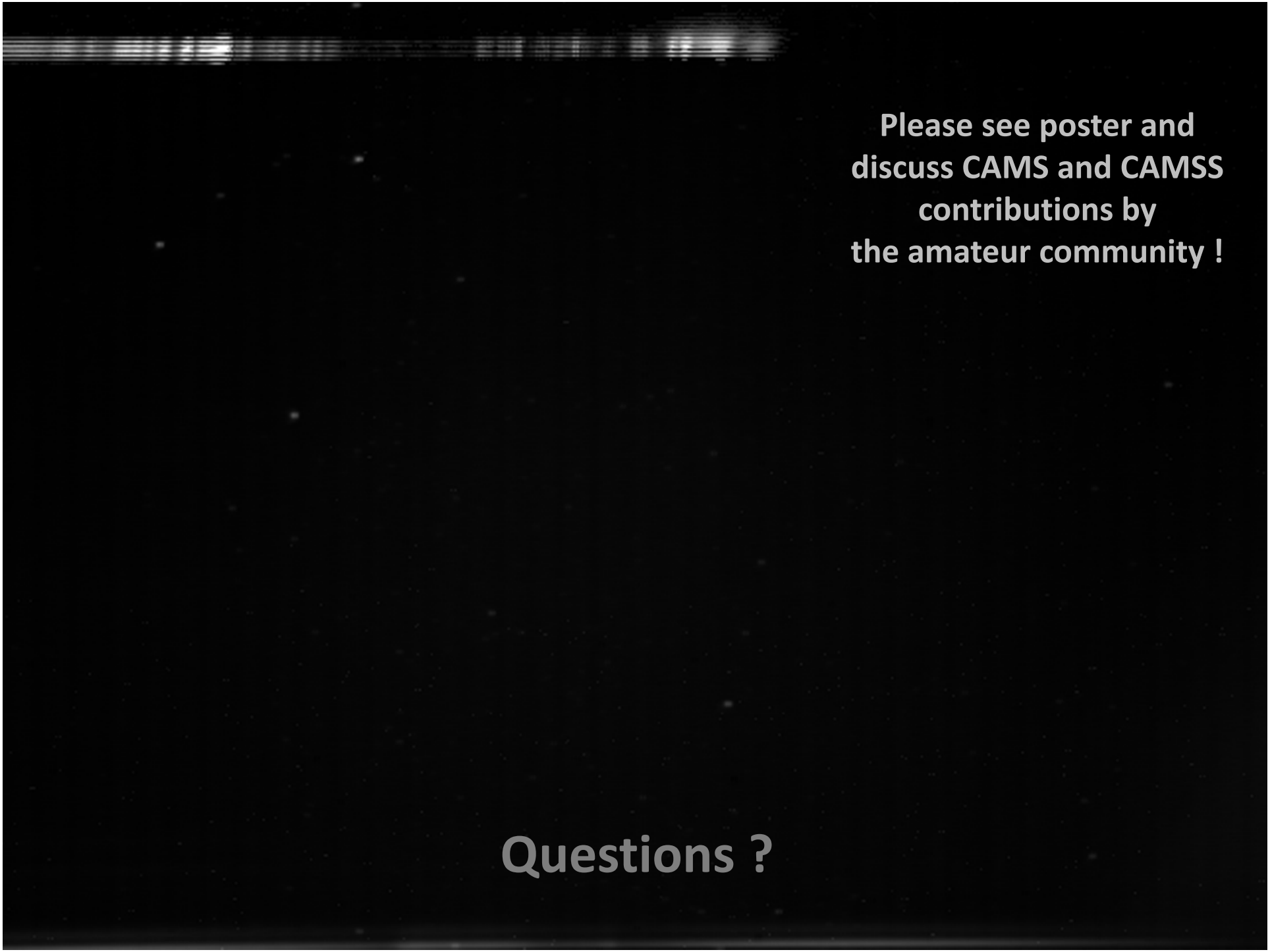
Ed Majden's
Meteor Spectra

Objective Prism
4"x5" film

Objective Grating
2.25" roll film

Objective Grating
Gen II Intensifier
Canon L2 Super-8 Video




Please see poster and
discuss CAMS and CAMSS
contributions by
the amateur community !
Questions ?