NEW OPTICAL FLUX ROUTINES
THE 2014 MAY CAMELOPARDALIDS

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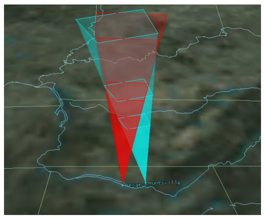
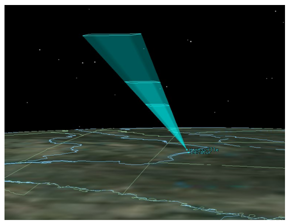
July 14, 2015

Optical Meteor Fluxes

Collecting Area

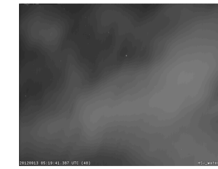




Weather

-when a system is clear and

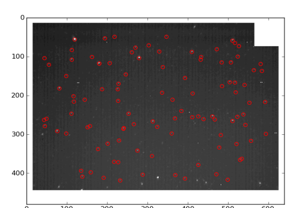
able to calculate fluxes

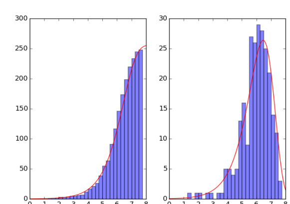


$$Flux = \#meteors / (area \bullet time)$$

to a limiting magnitude or mass

Limiting Stellar Magnitude





Limiting Absolute Meteor Magnitude

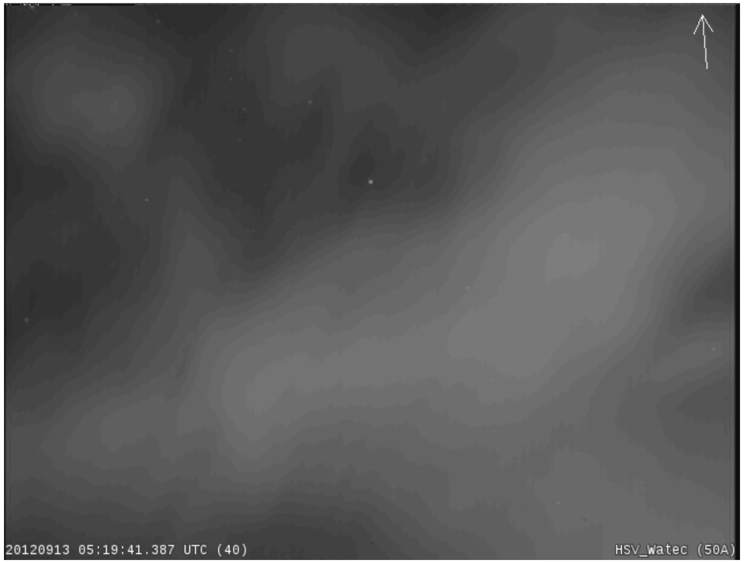
$$\boxed{m_m = m_S - 2.5\log(d)}$$

$$\boxed{M_M = m_m - 5\log(\frac{R}{100km})}$$

Outline

- Optical Fluxes:
  - Weather → clear times
  - Limiting Stellar Magnitude
  - Limiting Absolute Meteor Magnitude
  - Collecting Area
- May Camelopardalid Optical Fluxes
  - Electron Multiplied CCD (EMCCD)
  - Deep Gen 2
  - Wide Field
  - Romulan
  - All Sky

Weather

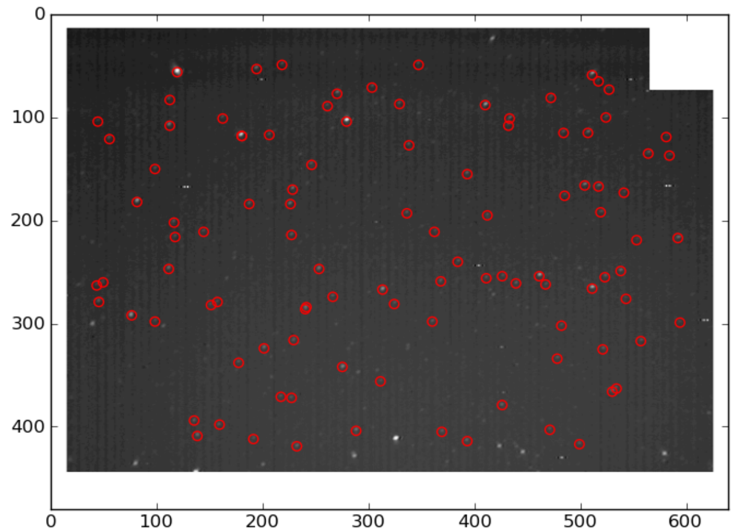


- Background + Standard deviation
- 98.8% identified correctly (over 9 nights)

Limiting Stellar Magnitude

Program written by Aaron Kingery

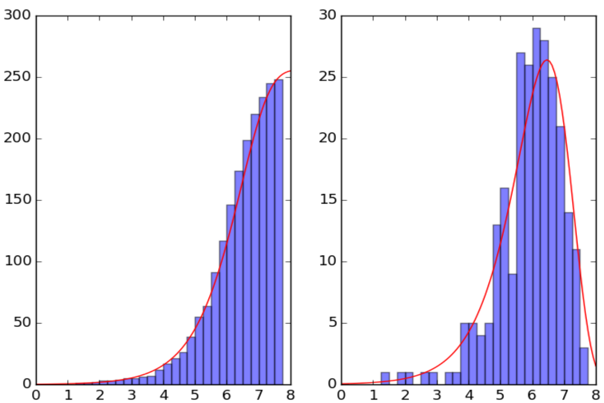
- The faintest stellar magnitude for which this image will detect all stars of greater or equal brightness

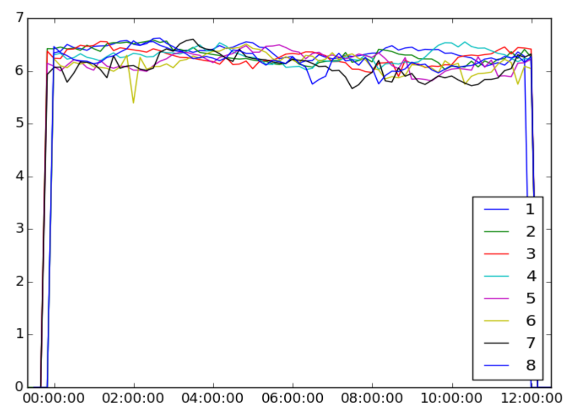


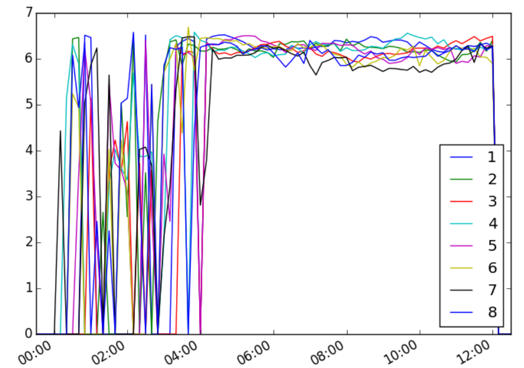
- Identifying stars in the calibration images with **astrometry.net**
- Finding their signal-to-noise ratio (aperture photometry)
- Compare with catalog data

Limiting Stellar Magnitude

- Program finds the limiting stellar magnitude by:
  - Identifying stars, find SNR, compare with catalog data
  - Plots cumulative histogram of how many stars are identified at various magnitudes
  - Gumbel distribution: peak = Limiting magnitude







Limiting Absolute Meteor Magnitude

- Definition: The faintest absolute meteor magnitude for which this system will detect all meteors of greater or equal brightness
  - Limiting absolute meteor magnitude → limiting mass

1) Δm: stellar limiting mag → apparent meteor limiting mag
2) ΔM: apparent → absolute meteor limiting magnitude

Limiting Absolute Meteor Magnitude

1) Δ m: stellar limiting mag → apparent meteor limiting mag

$$\boxed{m_m = m_S - 2.5\log(d)}$$

- d is the distance moved (in resolvable pixels) during a single video frame

$$\boxed{d = \frac{180 r_1 V \tau \sin(\zeta)}{pi * F_{OV} R}}$$

- r_1 - resolution of the detector
- V - geocentric velocity
- τ - CCD integration time
- ζ - angle between the radiant and camera pointing
- F_{ov} - field-of-view
- R - range to the meteors

Limiting Absolute Meteor Magnitude

2) ΔM: difference in apparent to absolute meteor limiting magnitude

$$\boxed{M_M = m_m - 5\log\left(\frac{R}{100km}\right)}$$

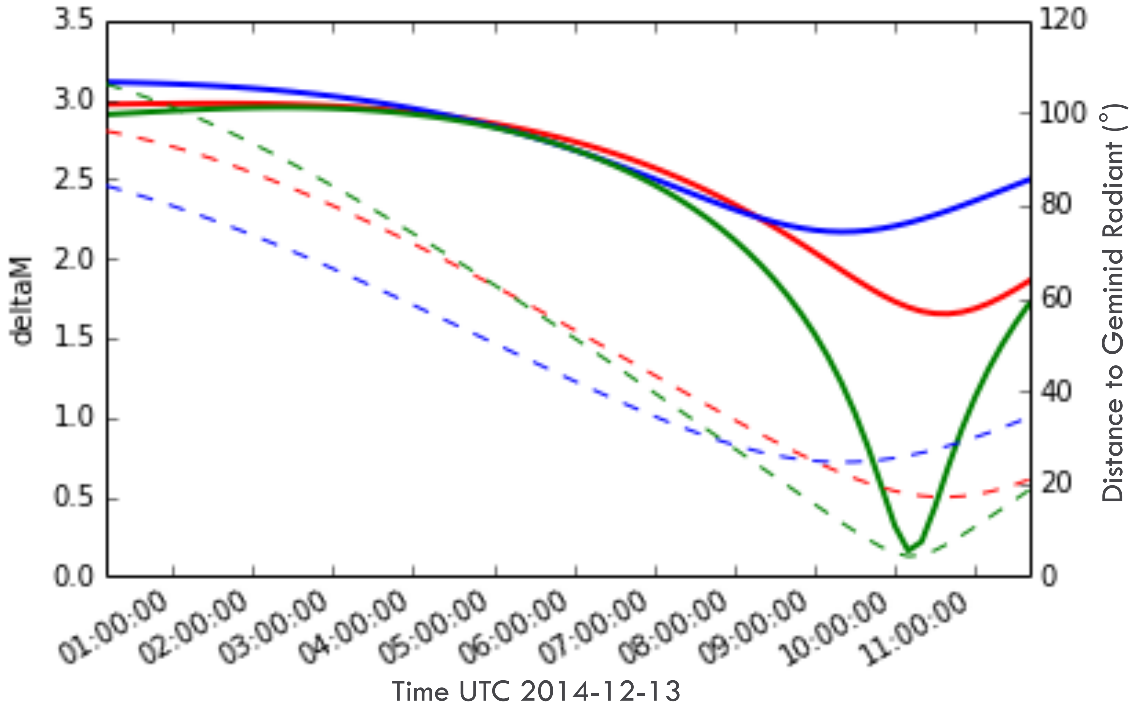
- Limiting absolute magnitude with range, based on stellar limiting magnitude

$$\boxed{M_M = m_m - 5\log\left(\frac{R}{100km}\right)} \qquad \boxed{m_m = m_S - 2.5\log(d)} \qquad \boxed{d = \frac{180 r_1 V \tau \sin(\zeta)}{pi * F_{OV} R}}$$

$$\boxed{M_M = m_s - 2.5\log\left(\frac{R}{100km}\right) - 2.5\log\left(\frac{180 r_1 V \tau \sin(\zeta)}{pi * F_{OV} 100km}\right)}$$

Limiting Absolute Meteor Magnitude

- Geminid radiant. Widefield camera #1 (pointed NW)
- center of FOV
- left of FOV
- right of FOV

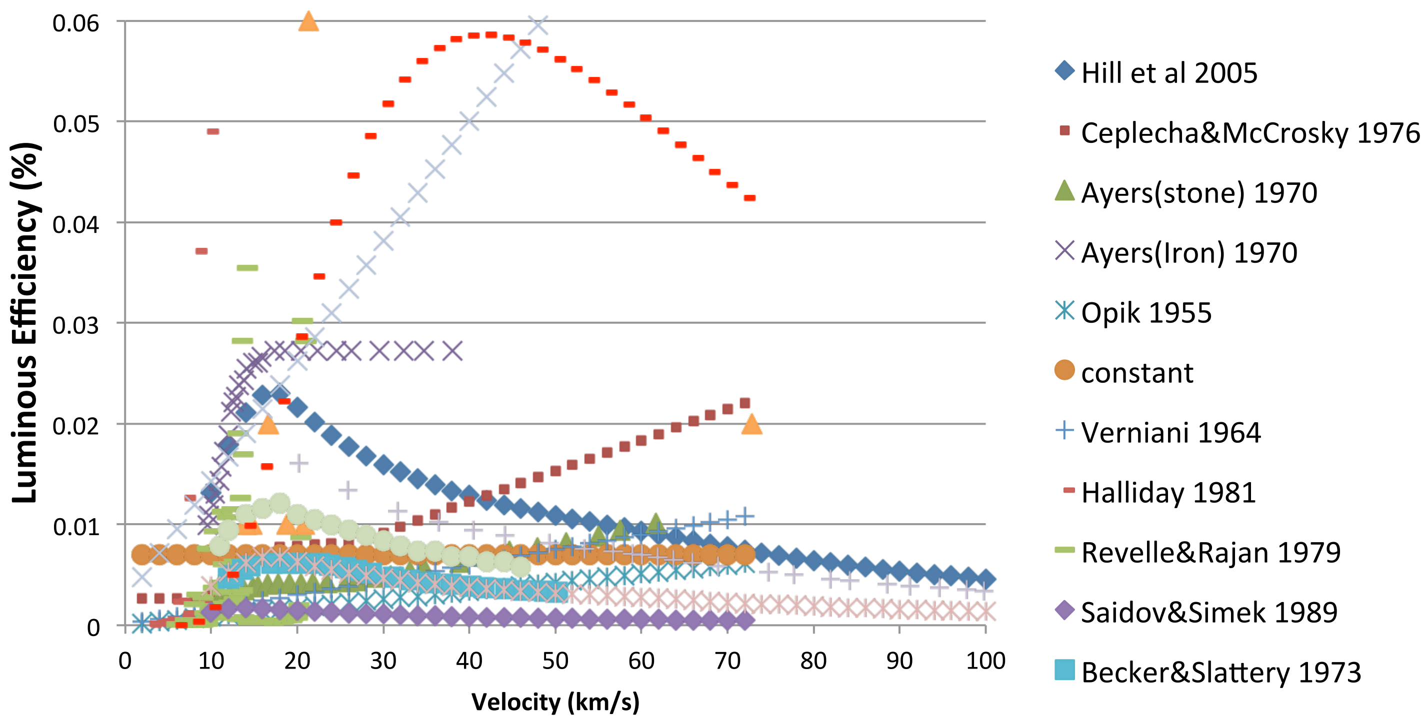


Limiting Absolute Meteor Magnitude

- Determined using a point at the center of the FOV and an average range at that point
  - Difference in angular velocity across FOV is accounted for in the collecting area

$$M_M = m_s - 2.5\log\left(\frac{R}{100km}\right) - 2.5\log\left(\frac{180 r_1 V \tau \sin(\zeta)}{\pi * F_{OV} 100km}\right)$$

Magnitude to Mass



$$Mass = 10^{5.14-3.9*\log(velocity)-mag/2.25}$$

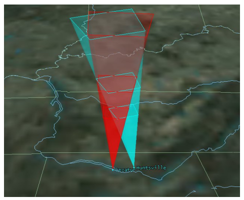
(Peter Brown)

$$Mass = \frac{0.04*10^{-0.4*mag}}{velocity^2}$$

(Margaret Campbell-Brown)

Optical Meteor Fluxes

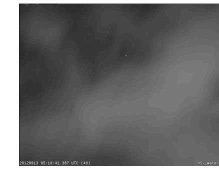
Collecting Area



$$EffectiveArea = (area)\frac{(sensitivity * \cos(zenith))}{angularVelocity}$$

Weather

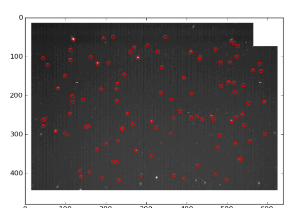
-when a system is clear and
able to calculate fluxes

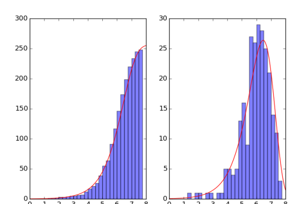


$$Flux = (\#\,meteors)\,/\,area\,/\,time$$

to a limiting magnitude or mass

Limiting Stellar Magnitude





Limiting Absolute Meteor Magnitude

$$\boxed{m_m = m_S - 2.5\log(d)}$$

$$\boxed{M_M = m_m - 5\log\left(\frac{R}{100km}\right)}$$

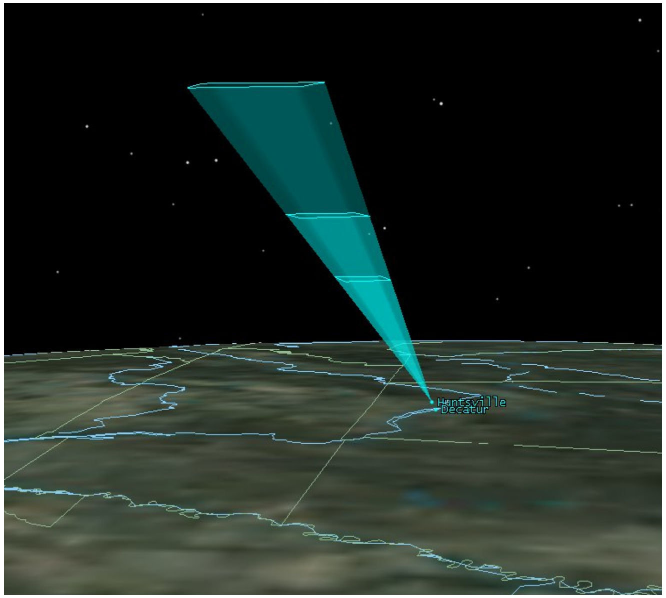
Collecting Area

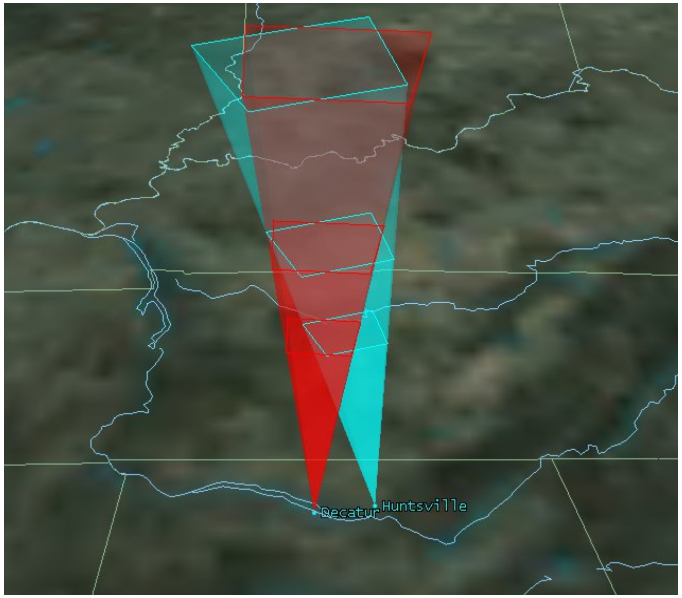
Program by Margaret Campbell-Brown

- Description: The effective area, per height, over which meteors from a specific meteor shower or sporadic source can be seen.
- Two steps:

  1) Find true area of sky seen at each height

  2) Apply corrections to find the effective collecting area per shower or source





Collecting Area

Raw area

1) Loops through all azimuths
   - If seen, finds lowest/highest elevation seen by camera
2) 2D → 3D: Each height (2 km) filled with blocks
   - It is determined if the block is seen by the camera

Wide field cameras:

16° x 24° FOV

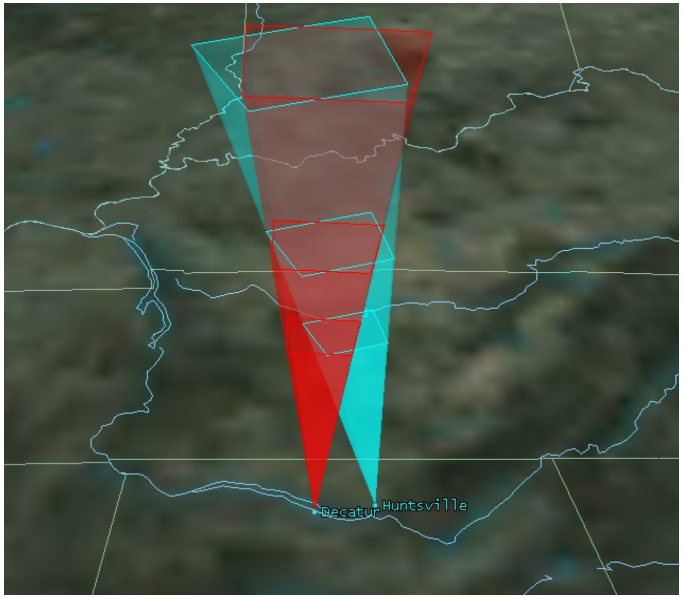
Single station: 1300 – 2800 sq km/height

Double station: 900 – 1800 sq km/height

Deep Gen II's w/ 155mm f/1.2 Catadioptric lens:

5.3° x 5.3° FOV

Single station: 128 – 256 sq km/height



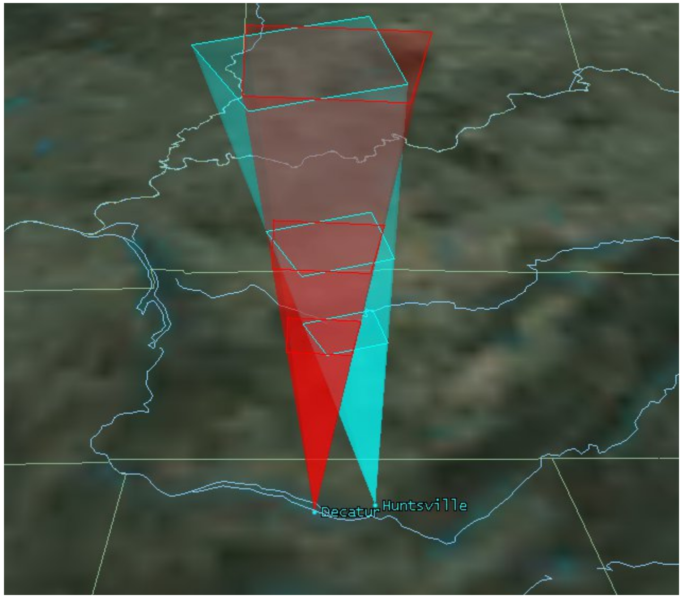
Collecting Area

$$EffectiveArea = area \frac{k * \left(\frac{sensitivity * \cos(zenith)}{d} \right)}{k * \max\left(\frac{1}{d} \right)}$$

- *d*– the number of pixels covered, from the angular velocity of the meteor
- Accounts for difference in angular velocity across FOV…
  - Find value @ center of the FOV/range
  - Normalize all other #pix for each area cube, to that

$$m_M = m_S - 2.5\log(d)$$

$$d = \frac{180 r_1 V \tau \sin(\zeta)}{pi * F_{OV} R}$$



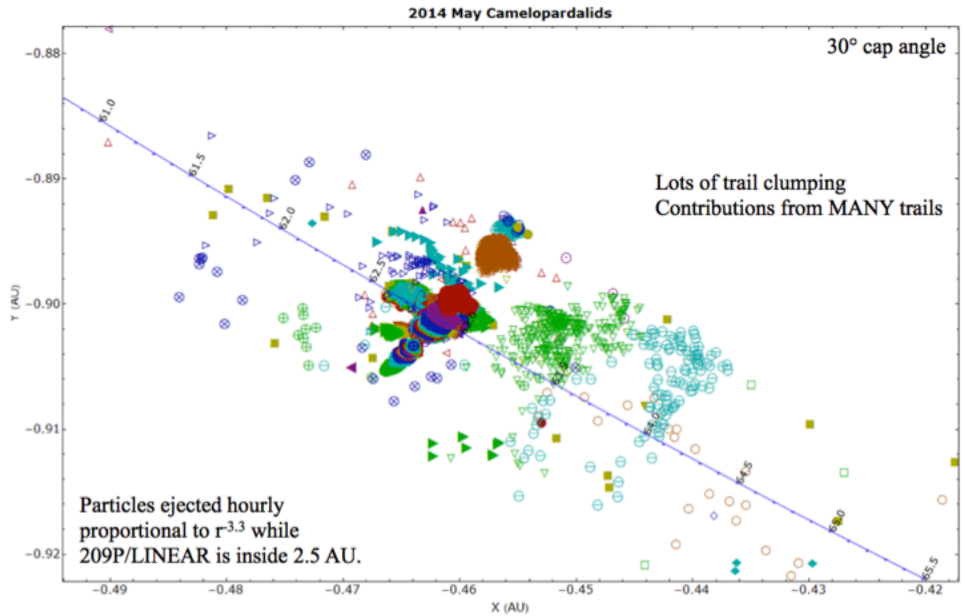
Outline

- Optical Fluxes:
  - Weather → clear times
  - Limiting Stellar Magnitude
  - Limiting Absolute Meteor Magnitude
  - Collecting Area
- May Camelopardalid Optical Fluxes
  - EMCCD
  - Deep Gen 2
  - Wide field
  - Romulan
  - AllSky

The 2014 May Camelopardalids – a new meteor shower

Bill Cooke (NASA Meteoroid Environment Office), Danielle Moser (MITS/Dynetics Technical Services)

- On May 24, 2014 Earth will encounter trails of debris laid down by Comet 209/P LINEAR over the past 3 centuries.
- This will produce a meteor outburst between 6 and 8 UTC (favorable from North America), with rates between 100 and 1000 per hour (200 – 400 hr^{-1} most likely).
- Difficult to calibrate model because no past observations of this shower exist.
- Particles from 209P/LINEAR have a very high transfer efficiency to Earth in 2014 - ~1 % of simulated particles, compared to 0.02% for 1998 Leonids.

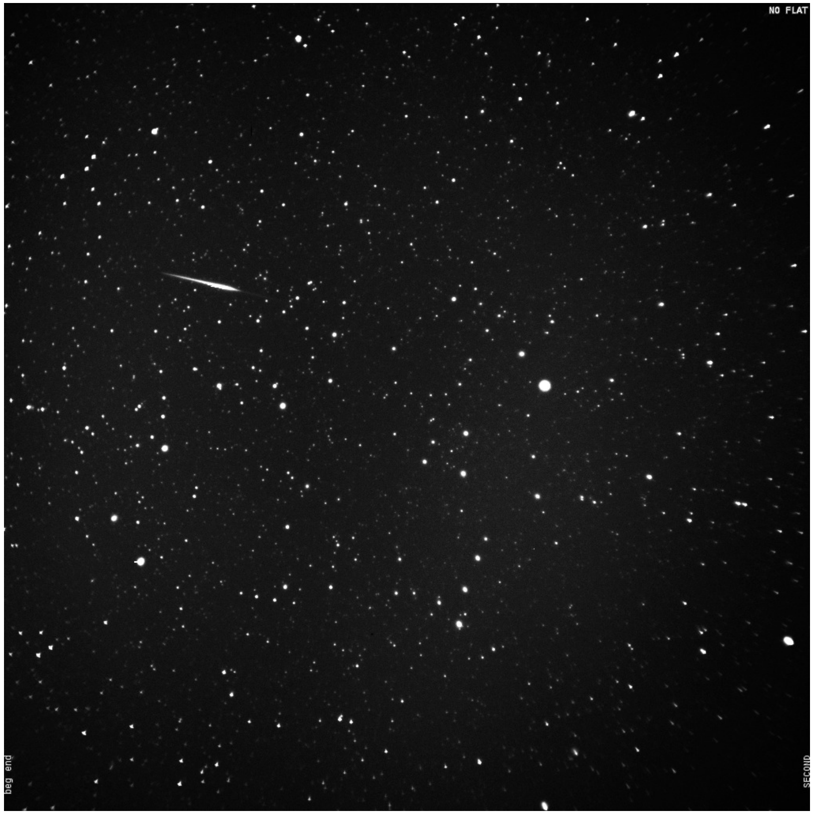


Model	Time on May 24 (UT)	ZHR (#/hr)	RA, Dec (°)	V_g (km/s)
Lyytinen & Jenniskens (1929)	3:19			
Lyytinen & Jenniskens (1979)	6:04			
MSFC (Mar/Dec 2013, peak 1)	6:11			
Ye & Wiegert (2013)	6:29	200 storm unlikely	122, +79	
Lyytinen & Jenniskens (1818, 1853)	6:33			
MSFC (Dec 2013, roughfit)	6:42			
MSFC (Mar 2013, peak 2)	6:56			
Lyytinen & Jenniskens (1903, max)	6:59	15.86	125, +78	15.86
Lyytinen & Jenniskens (1909)	7:15			
Maslov (1898-1919; 1903)	7:18	200-300	122.8, +79.1	16.2
Maslov (max)	7:21	100	122.8, +79.0	
Vaubaillon	7:40	100-400	~125, +79	
Lyytinen & Jenniskens (1914)	7:49			
Maslov (1763-1783)	7:55	50-150	122.8, +79.0	16.2
MSFC (Mar 2013, peak 3)	8:10			
Jenniskens (general)			123, +79	16

May Cam Fluxes – Overview of Cameras

EMCCD (electron multiplying CCD)

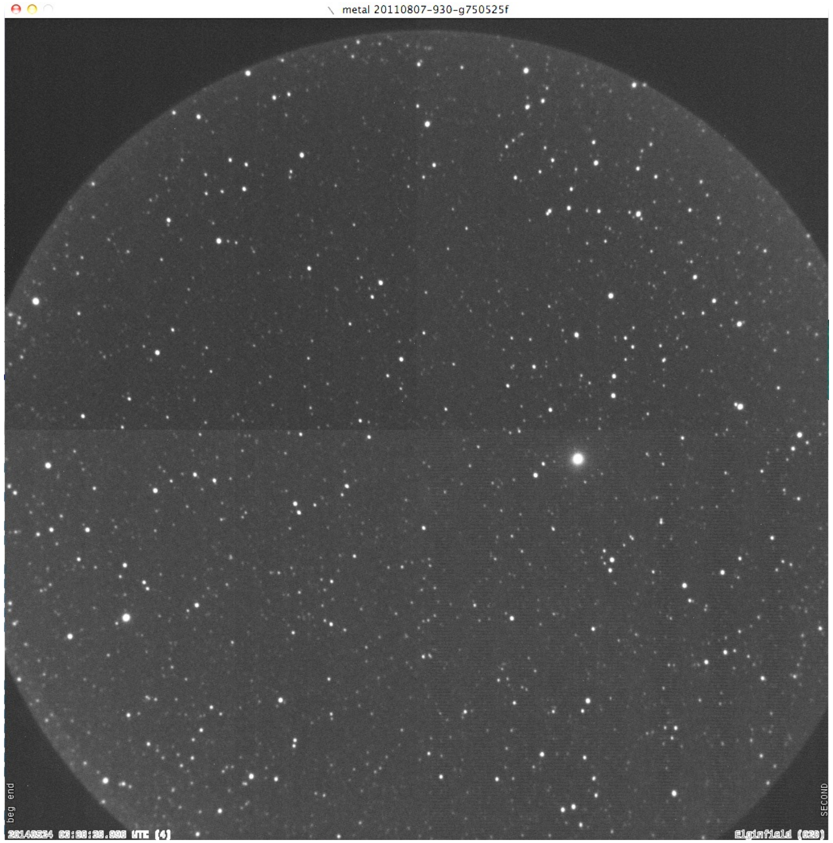
- Liquid nitrogen cooled, low light camera, running @ 10 frames/sec
- ~313 single-station meteors seen in 6 hours (14 Cams)
- 10.25° x 10.25° FOV
- 1024 x 1024 chip
- Stellar limit ~+11 (R band)



May Cam Fluxes – Overview of Cameras

Deep Gen II

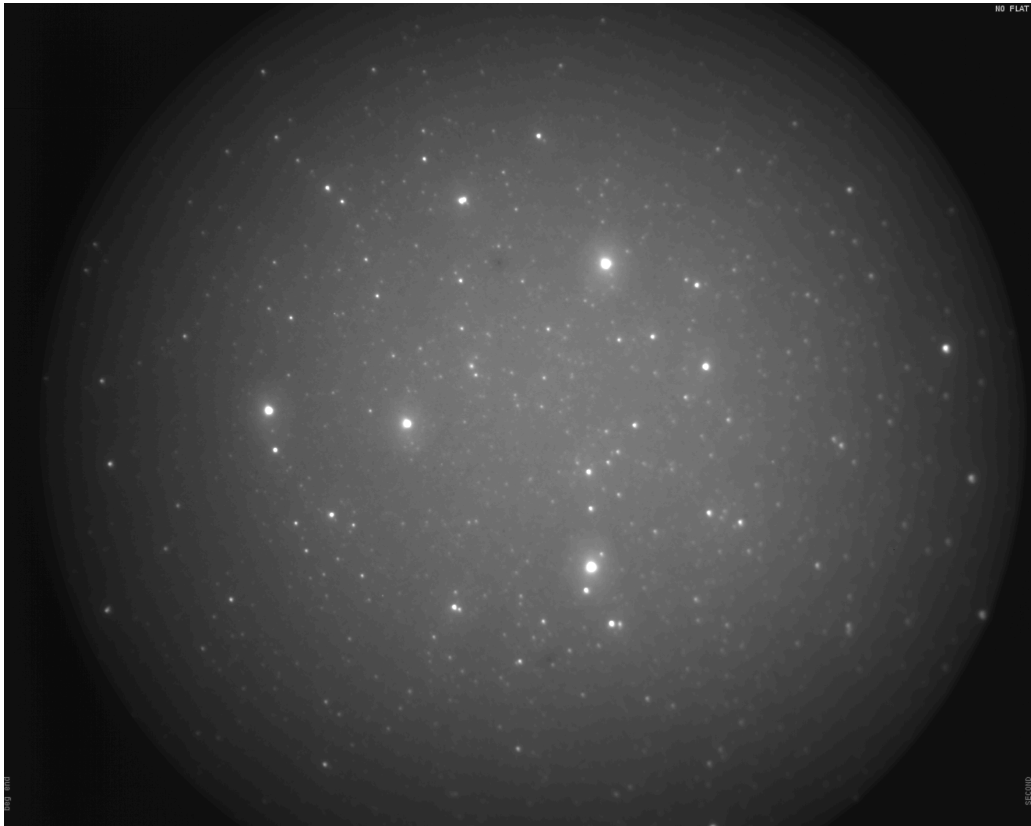
- Litton 25 mm Generation 2 image intensifier w/155mm f/1.2 Catadioptric lens
- 5.34° x 5.34° FOV
- 50 frames/sec
- 1024 x 1024 chip
- Stellar limit of +11.5 (V band)



May Cam Fluxes – Overview of Cameras

Romulan Cameras

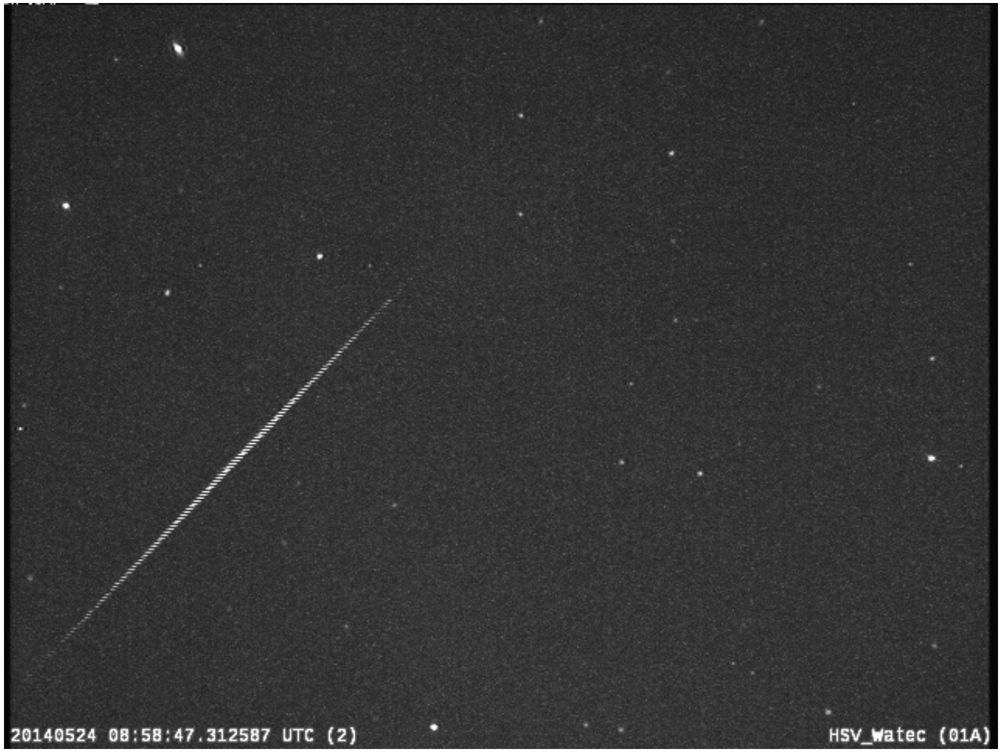
- 29° X 23° FOV
- 1.6K x 1.2K chip
- Gen III image intensifier
- 20 fps
- 14 bit optical depth
- Stellar limit ~+8 (R band)

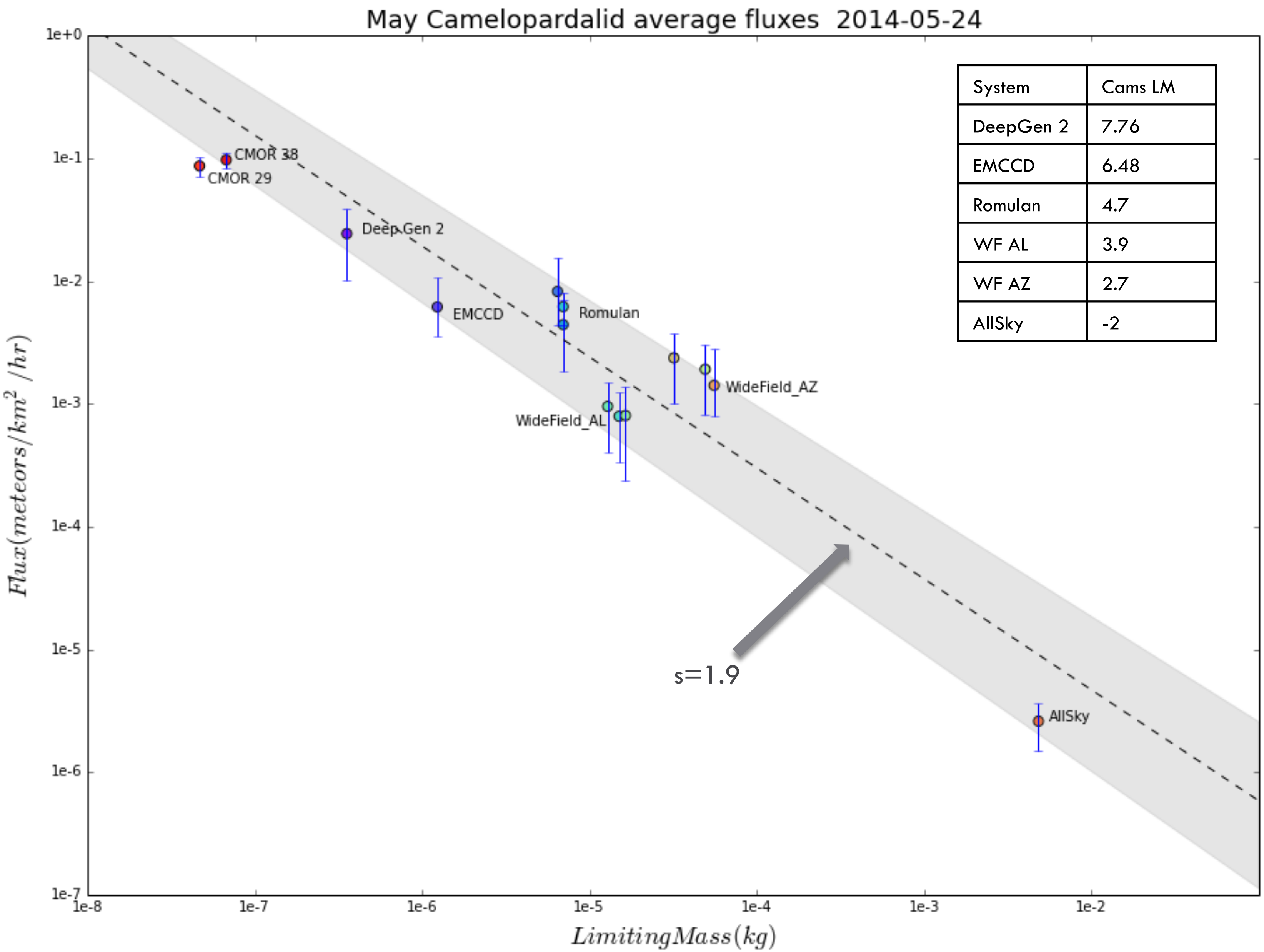


May Cam Fluxes – Overview of Cameras

Wide Field cameras

- 640 x 480 Watec ccd
- 17 mm Schneider lens
- Stellar Limit ~+6.5 (R band)
- Located in AL and AZ





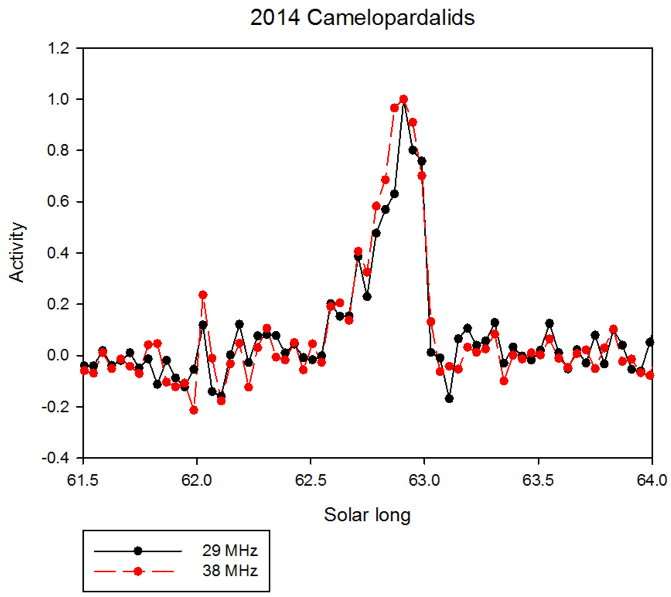
System	Cams LM
DeepGen 2	7.76
EMCCD	6.48
Romulan	4.7
WF AL	3.9
WF AZ	2.7
AllSky	-2

Other May Cam thoughts:

- Correctly predicted Earth encountering a new meteor shower!
- AND the peak time was right on.
- BUT:

ZHR	Mass index
27.8	1.85
22.7	1.9
19	1.95
16	2.0

- Using EMCCD flux (LM was +6.48)



Questions?

Additional Results - Geminids

Geminid Results:

Source	Date	Flux (meteors/km^2/hr)	+/-	Meteors	Limiting Mag	Limiting Mass (g)	ZHR	Mass Index
GEM	20141212	0.003255	0.001615	40	3.5	0.00389	**97.7**	2.0
GEM	20141213	0.002139	0.000803	85	3.0	0.00666	**104.0**	2.0

Compare this to CMOR (Canadian Meteor Orbit Radar)'s results:

Source	Date	Flux (meteors/km^2/hr)	Limiting Mag	Limiting Mass (g)	ZHR	Mass Index
GEM	20141212	0.0444	7.04	1.8e-04	**76.5**	2.0
GEM	20141213	0.0626	7.04	1.8e-04	**107.8**	2.0