The 2014 May Camelopardalid Meteor Shower

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On May 24, 2014 Earth will encounter multiple streams of debris laid down by Comet 209P LINEAR.

This will likely produce a new meteor shower, never before seen.

Rates predicted to be from 100 to 1000 meteors per hour between 2 and 4 AM EDT, so we are dealing with a meteor outburst, potentially a storm. Peak rate of ~200 per hour best current estimate.

Difficult to calibrate models due to lack of past observations.

Models indicate mm size particles in stream, so potential risk to Earth orbiting spacecraft.
Meteoroids
• Chunks of rock and ice out in space left behind by comets and asteroids.
• About the size of a boulder or smaller.
• Smaller than an asteroid.

Meteors
• Streaks of light that you see as a meteoroid ablates, or burns up, in the Earth’s atmosphere.
• Commonly called a ‘shooting star’ or ‘falling star’.

Meteorites
• What is left of the meteoroid if it survives the trip through the atmosphere and hits the Earth.
• Made of silicate minerals and/or iron-nickel.
Risk to Spacecraft

**Penetration**
Meteoroids travel fast, 11-71 km/s.

They have a lot of energy.

BEFORE being shot with a 5 cm aluminum ball moving at 6 km/s

AFTER being shot with a 5 cm aluminum ball moving at 6 km/s

**Plasma**
A meteoroid generates a charged plasma capable of producing a current pulse or spike.
Spacecraft Affected by Meteoroids

**Mariner IV**
NASA planetary exploration spacecraft
Encountered meteoroid stream between the orbits of Earth and Mars in Sept 1967
Thermal shield damage

**Olympus**
ESA communication satellite
Struck by a Perseid near the time of the shower peak in August 1993
Sent tumbling, fuel exhausted, end of mission

**Chandra**
NASA X-ray observatory
Struck by a Leonid or sporadic(?) near the time of Leonid shower peak in November 2003
Temporary wobble
Meteoroid Streams

- Consist of particles ejected from the parent comet during its orbit around the Sun.

- Over time
  - slight differences between the velocities of the comet and particles and
  - perturbations caused by planetary gravity and solar radiation pressure change the orbit of the stream so that it no longer follows the exact path of the comet.

- When Earth passes through a meteoroid stream it produces a meteor shower on Earth.
What
Model of particle ejection and subsequent evolution from comets.

Why
To provide accurate meteor shower forecasts to spacecraft operators for hazard mitigation and mission planning purposes.

How

Create particles
- 1μg – 1kg
- 37.8M ejected from 209P within 2.5 AU from epochs 1703-2014
- Prod rate varies w/ $r_h^{-3.3}$
- Particle vel given by Jones & Brown (1996)

Evolve particles
- RADAU 15th order integrator
- Include rad pressure, PR drag, gravity from 8 planets, Pluto & Moon, 1st order GR correction
- Computation w/ 48 proc

Extract particles
- Particles within 0.01 AU of Earth within 1 week before/after shower peak
- Node-Earth dist and impact parameter calc’d
- Analyze results

Meteor Shower Forecast
2014 May Camelopardalids
Meteoroid Stream Locations

Lots of stream clumping
Contributions from MANY streams

Streams (Year of particle ejection)

Earth's path

600,000 p/stream

Space parameter = 0.01 AU
Time parameter = 2014,05-18 to 05-30
2014 May Camelopardalids
Heat Map
2014 May Camelopardalids
Activity Profile
Meteor Shower Activity Comparison
209P Efficiently Delivers Particles to Earth in 2014

<table>
<thead>
<tr>
<th>Shower</th>
<th>% Simulated particles at Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 209Pids</td>
<td>0.96%</td>
</tr>
<tr>
<td>1970 209Pids</td>
<td>0.02%</td>
</tr>
<tr>
<td>2003 Leonids</td>
<td>0.00%</td>
</tr>
<tr>
<td>2002 Leonids</td>
<td>0.00%</td>
</tr>
<tr>
<td>2001 Leonids</td>
<td>0.01%</td>
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<tr>
<td>2000 Leonids</td>
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</tr>
<tr>
<td>1999 Leonids</td>
<td>0.00%</td>
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<tr>
<td>1998 Leonids</td>
<td>0.02%</td>
</tr>
<tr>
<td>1966 Leonids</td>
<td>0.00%</td>
</tr>
<tr>
<td>2011 Draconids</td>
<td>0.01%</td>
</tr>
</tbody>
</table>
Modeling Difficulties

• This shower has never been seen before
  – The model can’t be calibrated
  – We don’t know how well the model describes the shower time or, critically, the rate

• Despite model post-predictions of activity in the past, no historical observations matching this shower have been found

• The parent comet doesn’t appear to be very active now; we don’t know how active the comet was in the past
Agreement with other Models

Ye & Wiegerter

mm-sized particles pose hazard to spacecraft

Vaubaillon

\[ \alpha = 125^\circ \]
\[ \delta = +79^\circ \]
## May Camelopardalids Modeling Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>Time on May 24 (UT)</th>
<th>ZHR (#/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyytinen &amp; Jenniskens (1929)</td>
<td>3:19</td>
<td></td>
</tr>
<tr>
<td>Lyytinen &amp; Jenniskens (1979)</td>
<td>6:04</td>
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</tr>
<tr>
<td>MSFC (Mar/Dec 2013, peak 1)</td>
<td>6:11</td>
<td>200</td>
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<tr>
<td>Ye &amp; Wiegert (2013)</td>
<td>6:29</td>
<td>200 storm unlikely</td>
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<tr>
<td>Lyytinen &amp; Jenniskens (1818, 1853)</td>
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<tr>
<td>MSFC (Dec 2013, roughfit)</td>
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<tr>
<td>MSFC (Mar 2013, peak 2)</td>
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<tr>
<td>Lyytinen &amp; Jenniskens (1903, max)</td>
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<tr>
<td>Lyytinen &amp; Jenniskens (1909)</td>
<td>7:15</td>
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</tr>
<tr>
<td>Maslov (1898-1919; 1903)</td>
<td>7:18</td>
<td>200-300</td>
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<tr>
<td>Maslov (max)</td>
<td>7:21</td>
<td>100</td>
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<td>Vaubaillon</td>
<td>7:40</td>
<td>100-400</td>
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<tr>
<td>Lyytinen &amp; Jenniskens (1914)</td>
<td>7:49</td>
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</tr>
<tr>
<td>Maslov (1763-1783)</td>
<td>7:55</td>
<td>50-150</td>
</tr>
<tr>
<td>MSFC (Mar 2013, peak 3)</td>
<td>8:10</td>
<td></td>
</tr>
</tbody>
</table>

### Radiant
- \( \alpha = 125^\circ \)
- \( \delta = +79^\circ \)

### Speed
- \( V_g = 16 \text{ km/s} \)
Take-aways

• The May Camelopardalids are a new meteor shower, never observed before.
• Expected to peak May 24, 2014 06-08 UTC.
• Meteor rates may be high, best estimate is a peak rate of ~200 per hour.
• Models are difficult to calibrate due to lack of observations.
• May potentially pose a risk to spacecraft.