C/2013 A1 (Siding Spring) vs. Mars

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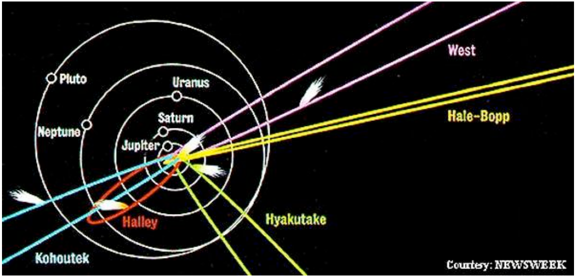
Outline

Comet Types: Classed by Orbit



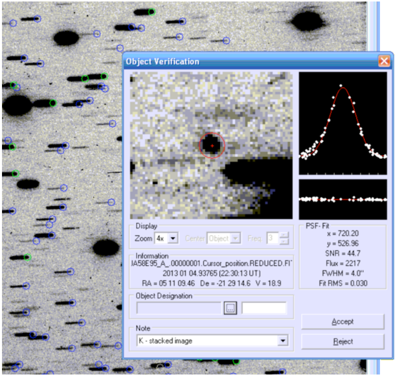
Type	Orbit	Origin	Examples
Short period	$P < 200$ yrs	Kuiper Belt	Halley
Long period (Oort cloud)	$P \sim 1000$s yrs	Oort cloud	Hale-Bopp, C/2013 A1
Sungrazers	Pass near or plunge into the Sun		C/2012 S1 (ISON)

Comet Types: Classed by Orbit

Comet Hartley 2

- Comets are the least reflective objects in the Solar System:
  - Halley has an albedo of about 4%.
  - Asphalt has a albedo of 7%.
- Long period comets contain more volatiles, as short period comets lose much of these in frequent passages around the Sun.

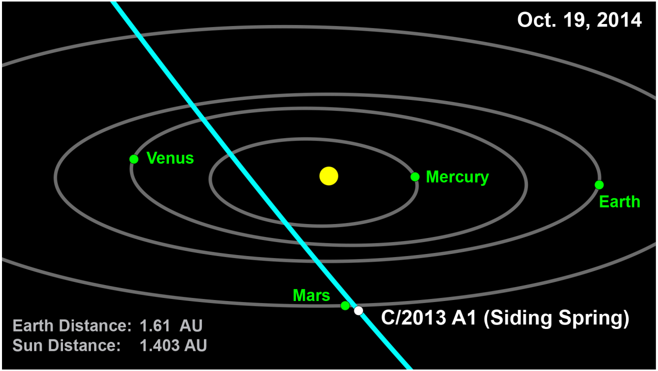
C/2013 A1 (Siding Spring)



- Discovery:
  - January 3, 2013
  - Rob McNaught
  - 0.5 meter telescope (same size as our scope in New Mexico)
  - Siding Spring, Australia
- Pre-discovery images located in Catalina Sky Survey (December 8 2012 images)

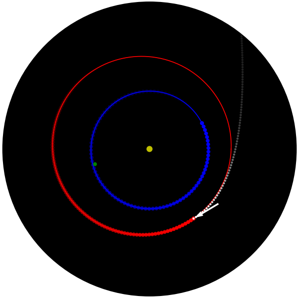
C/2013 A1 (Siding Spring)

- Long period comet, with perihelion at 1.4 A.U. (just inside Mars' orbit) and inclination of 129° (retrograde)
- Perihelion on October 25, 2014, after Mars encounter
- Nucleus size estimates range from 1 to 40 km.



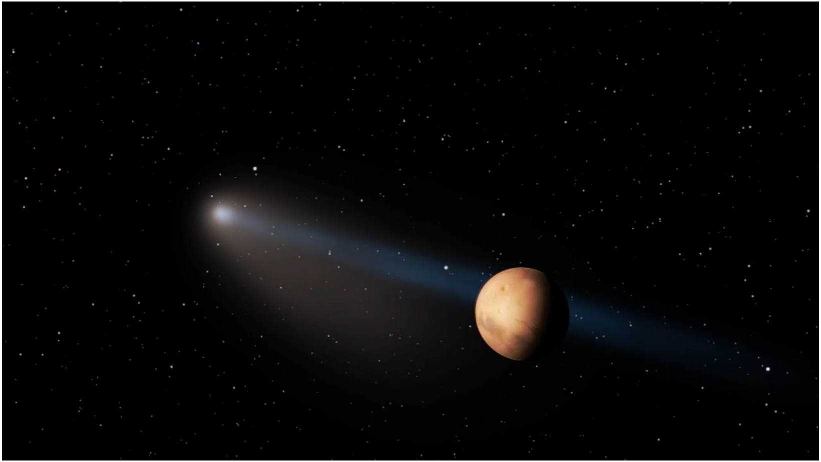
Close Encounter with Mars

Details



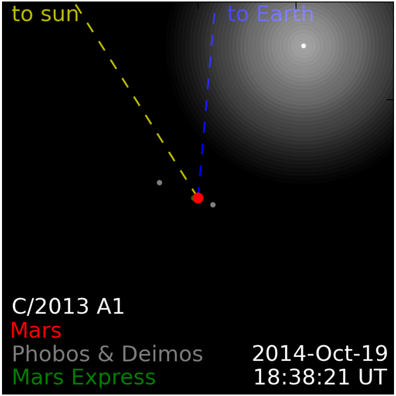
- C/2013 A1 (Siding Spring) will closely approach Mars on October 19, 2014, 18:51 UTC ($\pm$ 0:47)
- Will approach from below the ecliptic and in a head-on direction (retrograde orbit, $i = 129^\circ$)
- Close approach distance is 113,000 km
- Relative speed is 55 km/s
- Sun to Mars vector is nearly orthogonal to C/2013's velocity vector

Close Encounter with Mars



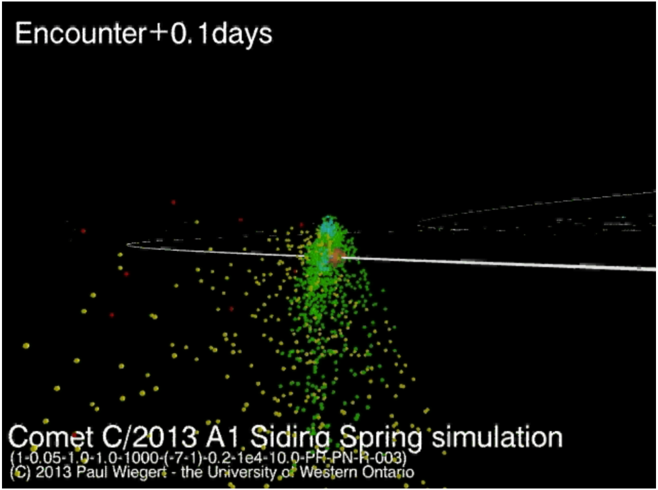
Movie credit: Leonid Elenin using SpaceEngine software

Close Encounter with Mars



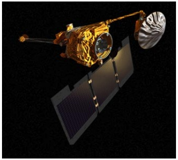
- C/2013 A1 will be slightly north of the ecliptic at the time of closest approach.
- Note that a 100,000 km coma will not reach Mars.
- 9,000 km $< b <$ 300,000 km, nominal value is 113,000 km
- Tail will almost certainly envelop Mars

Close Encounter with Mars

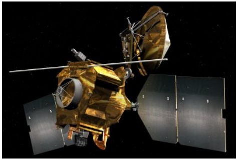


Movie credit: Paul Wiegert, UWO

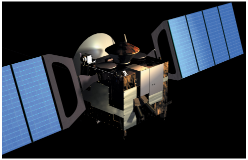
Mars Satellites



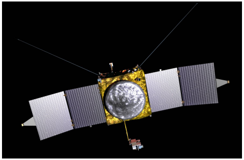
Mars Odyssey (NASA)
400 km, 2 hour orbit



Mars Recon Orbiter (NASA)
300 km, 2 hour orbit



Mars Express (ESA)
300 - 10,000 km, 7.5 hour orbit



MAVEN (NASA)
150 - 6,200 km, 4.5 hours
Arrives September 2014

Cometary Comae

- As comets approach the sun, volatiles sublimate and produce a coma of gas and dust.
- Effect varies with heliocentric distance.
- Light scattering off these dust particles dominates brightness.

$$m = \mathrm{M1} + 5 \log \Delta + 2.5 n \log r$$

The Giotto Flyby of 1P/Halley

- We have detailed coma data for one comet: Halley.
- Giotto recorded 12,000 dust impacts.
- Model fits to these data yield:
  - Dust density and albedo: $\rho/a \sim 2.5$ g/cc
  - Dust size distribution: $f(s) \propto s^{-k}$, $k = 2.6$
  - Dust spatial distribution, $\nu(r) \propto r^{-2}$

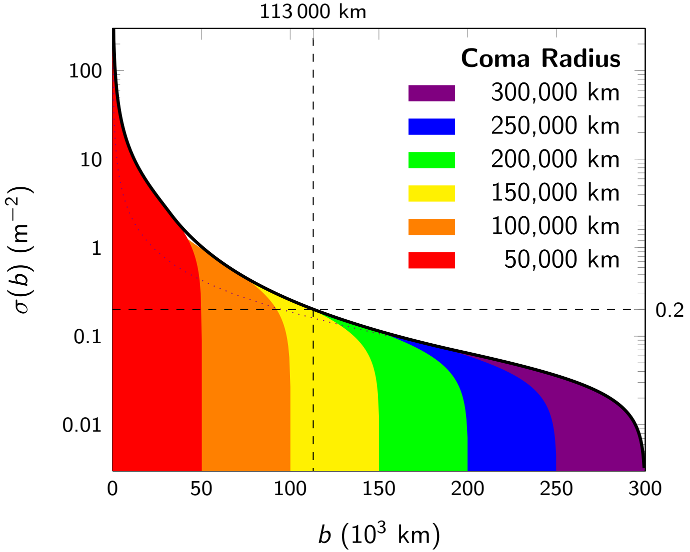
(Fulle et al., 2000)

Estimating the Dust Enhancement

Quantifying the dust:

1. Determine the brightness at the time of interest.
2. Assuming an albedo/reflectivity, compute the dust surface area.
3. Assuming a size distribution and material density, compute the number of dust particles.
4. Assuming a spatial distribution, compute the number density.
5. Integrate along the trajectory to get total fluence.

Dependence on Coma Size, Approach Distance



Dependence on Dust Properties, Cometary Magnitude

$$\sigma_*(113{,}000\text{ km}) \lesssim 0.2\text{ m}^{-2} f_k \cdot g \cdot (1.4\text{ AU})^{-(n-4.4)} \times \left(\frac{a}{0.04}\right)^{-1} \left(\frac{\rho}{0.1\text{ g/cc}}\right)^{\frac{2}{3}} 10^{-0.4(\mathrm{M1}-5.2)}$$

- ρ, a, and g tend to cancel each other out (Fulle et al., 2000), but together could add up to a factor of 2 difference.
- Dependence on size distribution (f_k) can also produce a factor of 2.
- Magnitude, especially n, can make a large difference.
  - Halley had $\mathrm{M1} = 3.88$ rather than 5.5 during Giotto encounter.

Dynamical Simulations

- Dust is ejected from nucleus with velocity

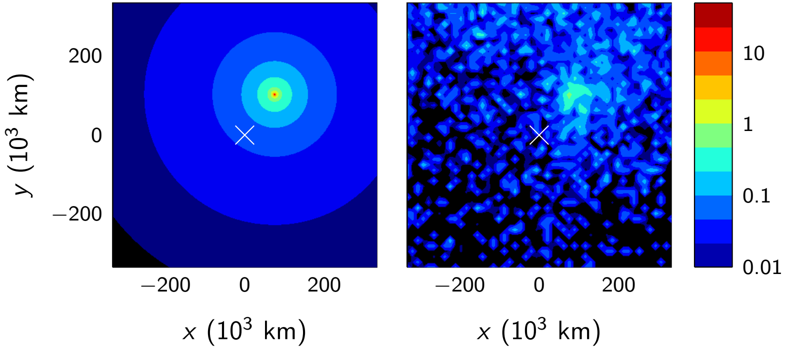
$$v_{ej} = 41.7\mathrm{m/s}\ R_N^{1/2} m^{-1/6} \rho^{-1/3} r^{-1.038}$$

- Activity is assumed to begin at 10 AU
- Dynamical evolution due to gravity, radiation pressure
- Fluence is normalized by

$$f_N = \frac{N_{theory}}{N_{sim}}$$

Comparison: Theory and Simulations

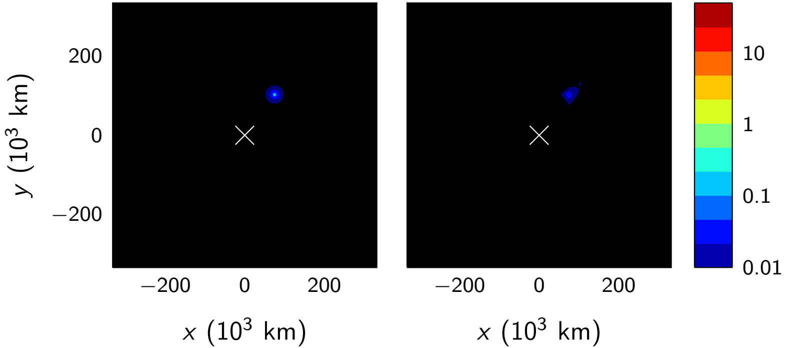
100 + μm particles



- Analytical model (left) and normalized simulations (right) in plane containing Mars, perpendicular to trajectory.
- Simulations performed and data provided by Paul Wiegert, UWO

Comparison: Theory and Simulations

$1000+\mu$m particles



- Larger mass particles only ($s > 1000\mu$m)
- Simulations include coma asymmetry and tail
- Note that $r_c \simeq 800,000$ km (to match simulations) results in a lower σ compared to slide 15.

Summary

- Comet C/2013 A1 (Siding Spring): recently discovered long period comet
- Will have close encounter with Mars on October 19, 2014
  - Collision is extremely unlikely
  - Passing through the coma and/or tail is likely
- Increases risk to Martian spacecraft
  - Meteoroids (100 μm or larger): $\lesssim$ 20% chance of impact per square meter due to coma and tail
  - Gas may also affect Martian atmosphere