# Varying Optical Depth and Albedo as a function of Time throughout the Ejecta Cone of 9P/Tempel 1

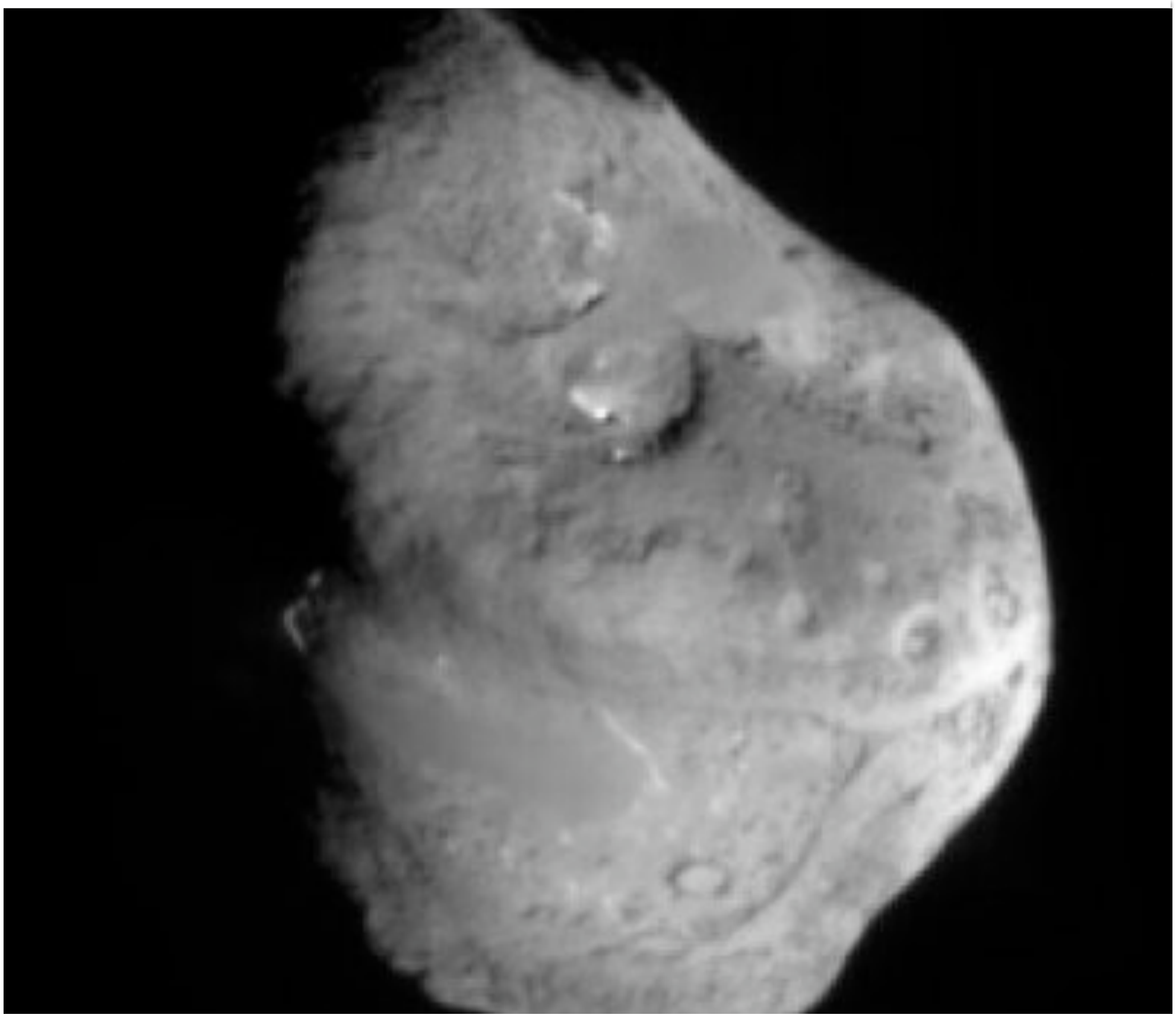
By: Wil Barnett
1/26/08

# Abstract/Overview

- Layering of materials in the nucleus at the impact site of Tempel 1
- Use images from the Medium Resolution Instrument (MRI) from before and after the collision
  - Measure brightness of the shadow cast on the nucleus
  - Allows for a calculation of optical depth ($\tau$)
    - $I = I_o e^{-\tau}$
- Then, using the brightness values in conjunction with optical depth, the albedo of the particles in the cone can be estimated
  - Ultimately allows for an educated guess as to the composition of the ejecta cone

# Comet 9P/Tempel 1

This is an image of the comet 5 minutes before the collision occurred. The image is taken with the MRI



# Background and Relevance of Research

- Discovered by Wilhelm Tempel on April 3,1867
- Deep Impact mission collided with the comet on July 4, 2005 at 5:52 UTC
- Crater formed is 200 m wide and 50 m deep
- Previously, no spacecraft of any kind had touched the surface of a comet
  - Knowledge gained from DI mission can be used as a clue as to the composition of other short period comets

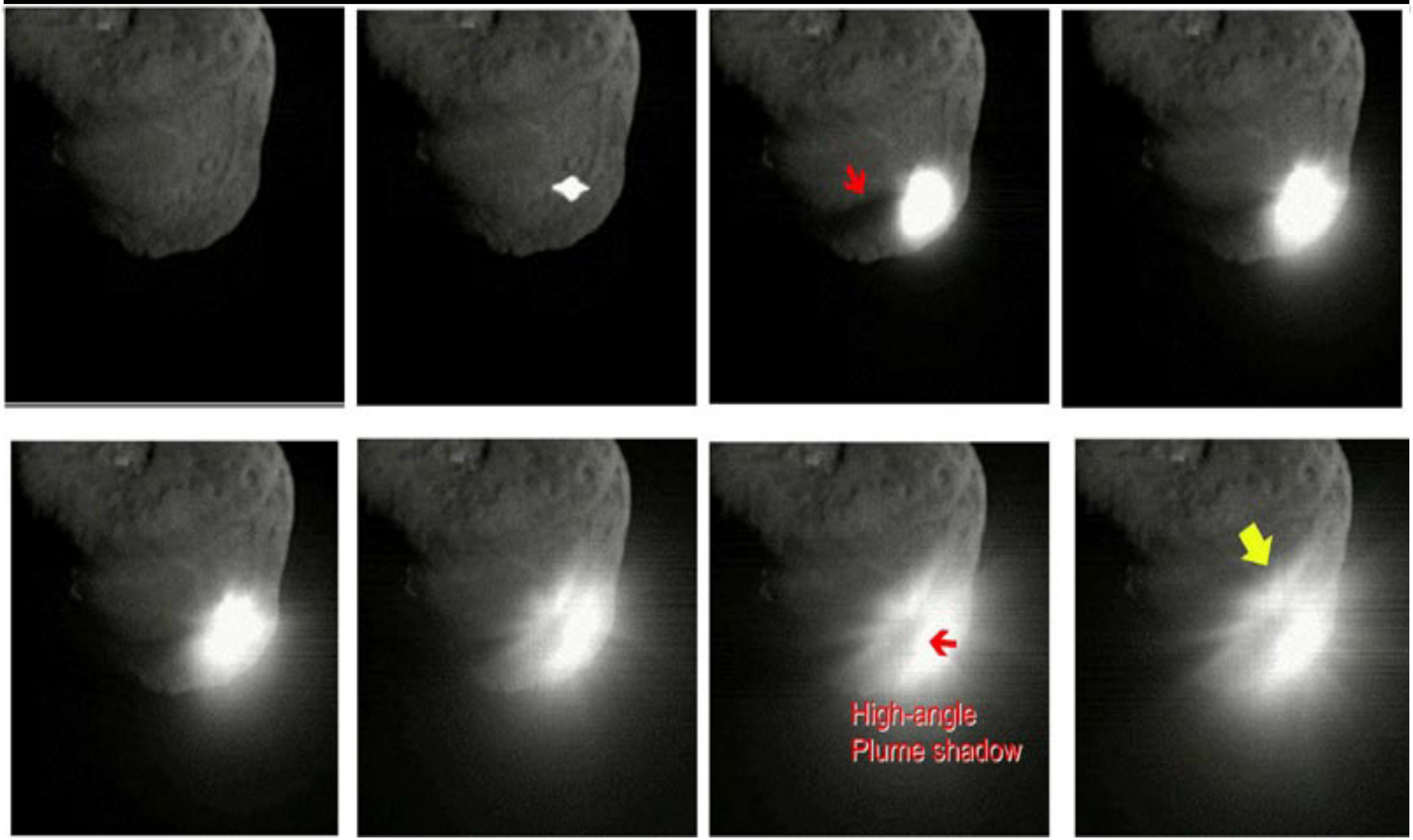
# Background and Relevance of Research, cont'd

- Three main goals of DI mission
  - Gain info about the nucleus of Tempel 1
  - Learn more about the composition of the sub-surface layers
  - Discover the history and evolution of the nucleus
- Unlike the planets, comets did not form with molten interiors
  - No gravitational differentiation
  - Comets simply grow via accretion of whatever materials are around its path
  - If I can determine composition of the cloud, it can tell us much information about the composition of the Solar System as the planets were forming

# Methods to be Used

- Linux operating system with Interactive Data Language program (IDL)
- Using images from both before and after the collision from the MRI
- Calculating Optical Depth
  - Amount of light removed from a beam by scattering or absorption during its path through a medium
  - Average many before images to reduce noise
  - Compare intensity values of the shadowed region after the collision to the same region before the collision
  - Gives an approximation of optical depth of the cone as a function of time

# Shadow Images



# Methods to be Used, cont'd

- Geometric Model of the Cone
  - Information used from SPICE dataset
    - Altitudes, azimuths, etc.
  - If altitude and azimuth of the Sun in each part of the shadow are known, then an imaginary ray can be drawn from that point on the nucleus towards the Sun
    - The ray should intersect with the area of the cone that is creating the shadowed region from which the ray started
  - This is a work in progress, but will be invaluable to the discovery of the albedo and chemical make-up of cone

# Example of the Geometric Model

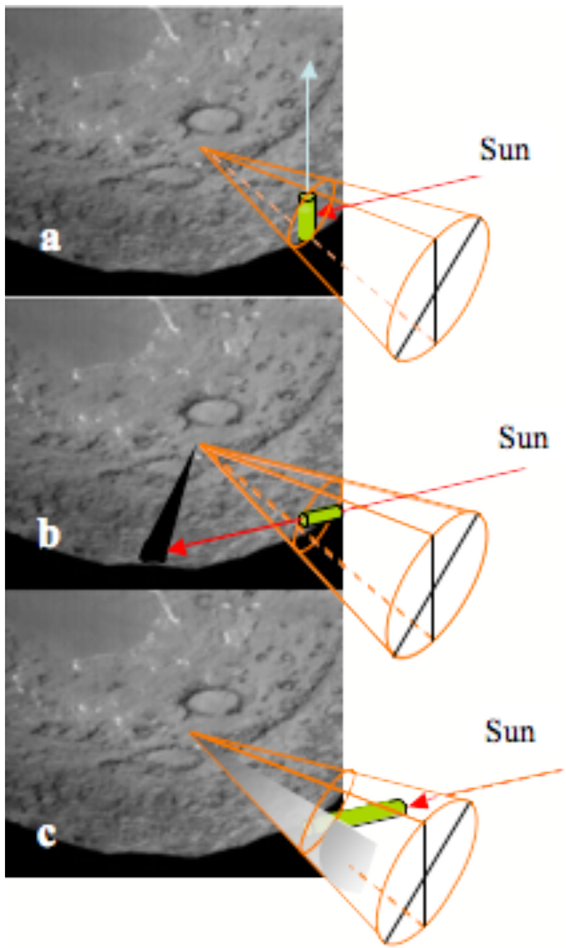



Figure 5

Figure 5. The geometry of the light scattering for the three cases considered in the project. The cone represents the ejecta cloud; the red line shows the sunlight direction. The green cylinder shows one of the fibers in the cloud that we consider.

(a)Limb obscuration case. The studied part of the cloud, green cylinder, is along the direction to the observer (shown by blue line), which supposedly goes perpendicular to the plane of the page. The particles located inside the green cylinder produce scattering and absorption that result in attenuation of the limb.

(b) Case of the shadow on the nucleus. The shadow is the point on the surface, where the light reaches the nucleus, is cast by the light scattering in the part of the cloud shown by the green cylinder. The figure models the case shown in Fig.3a

(c) Obscuration of the rear part of the cloud by its front part. The green cylinder shows the part of the cloud that produces obscuration (attenuation) of the lower part of the cloud (shown grey) that makes it darker than the front part of the cloud. See Fig. 3b.

# Comet 9P/Tempel 1

This is a movie file taken by the HRI imager as the collision was occurring. As you can see, the cone of ejecta rises up quite quickly and there is an incredible increase in brightness as well

# Methods to be Used, cont'd

- Absolute Brightness and Albedo
  - Ratio of the light scattered by the particle to the light scattered and absorbed (extinction of the light)
  - Once optical depth is known along with the absolute brightness, an estimation for the albedo of the particles can be made
    - Brightness of the ejecta cone will show how much light was scattered, and the optical depth will show how much light was absorbed
  - This leads to conclusions about the composition of the grains in the cone of ejecta
  - If the albedo is very nearly 1, the particles are almost assuredly ices, etc.

# Conclusion

- Overall, my research is somewhat similar to Ashley King’s in nature
  - Looking at shadowed region as opposed to limb
  - Likely will lead to the discovery of more ices in the nucleus
- Ultimately, the goal of my research is to use the optical depth and albedo of the particles in the cone to make educated conclusions about the chemical/mineralogical make-up and the physical state of the cometary nucleus