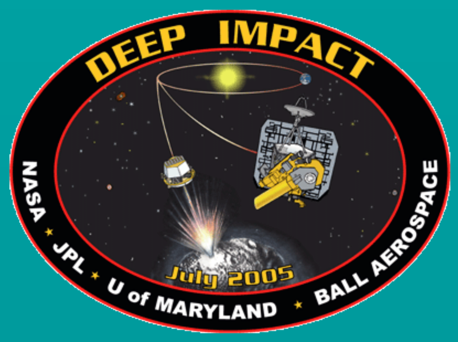

Recreating the Deep Impact Ejecta Cloud: Estimating Optical Depth, Albedo, and Composition using SPICE and the Shape Model

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Introduction

I am currently a senior at the University of Maryland, College Park and am an employed student researcher with the PDS Small Bodies Node. I have been working for the last year with SBN regarding the Deep Impact mission and comet 9P/ Tempel 1. The goals for the project are clearly stated in the abstract below, however analysis of the data has only just begun. Qualitative results along with descriptions of how I will go about analyzing the data is presented here in this poster.

Abstract

On July 4, 2005, Deep Impact struck the surface of Comet 9P/ Tempel 1, excavating a large cloud of material from deep inside the nucleus of the comet. King et al. (2007) and A'Hearn et al. (2008) have studied the properties of ejected material that crossed the limb of the comet. As a follow-up, we observe the shadow on the surface of the nucleus to analyze the material before it crosses the limb.

In this study, we attempt to create a three-dimensional model of the cloud of ejecta to estimate the optical depth and albedo of particles within the layers of Tempel 1's nucleus. This will allow us to constrain the composition of these particles. We use images taken by the Medium Resolution Instrument (MRI) along with SPICE data and the Shape model to determine how light naturally falls onto the surface near the impact site. From this information, we measure the brightness around the impact site as a function of time due to the shadow created by the ever-changing cloud of ejecta. Next, we will create a three-dimensional model of the cloud to determine which parts of the cloud are creating the corresponding areas of the shadow. This allows for an estimation of the optical depth of the cloud. This study has implications for understanding the layering present within short-period comets, for it may tell us something about the materials that were around during the evolution of the Solar System.

A'Hearn, M. F., *et al.*. Optical Depth and Albedo of the Deep Impact Ejecta in the First Minutes. *ACM*, 2008.

King, A., M, *et al*, The Properties of Comet Tempel 1 as Determined Through the Cometary Ejecta. *BAAS* **38**, 449 (*DPS 2007*).

Deep Impact Mission Overview

The Deep Impact Mission is an ongoing mission that began on January 12, 2005. The original goals were:

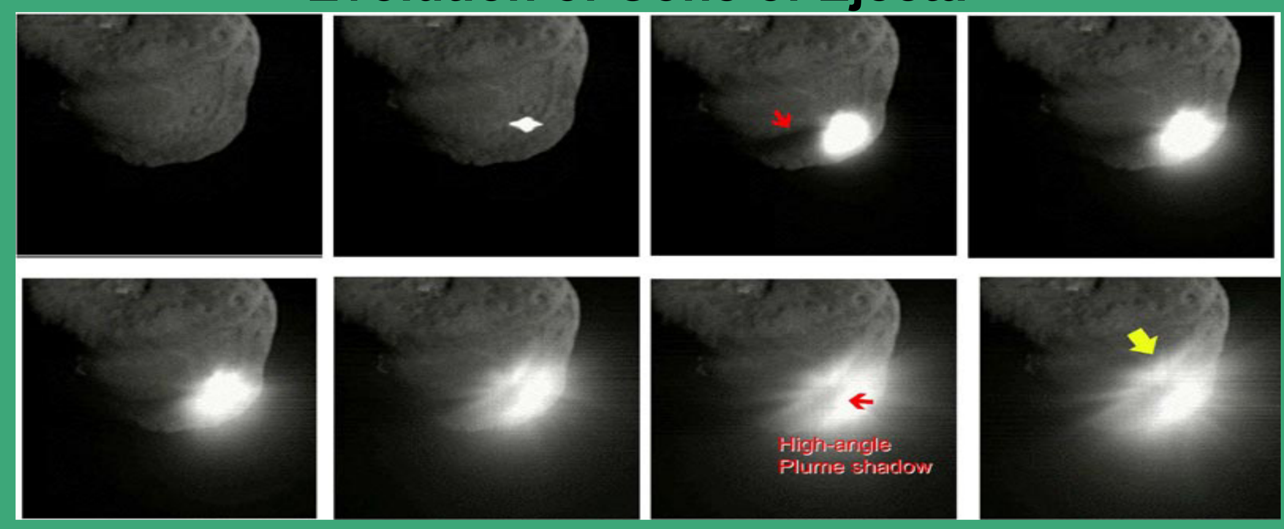
1) Gain information about the nucleus of 9P/Tempel 1

2) Learn more about the composition of the sub-surface layers of the comet

3) Put the the pieces back together and learn about the history and evolution of the nucleus.

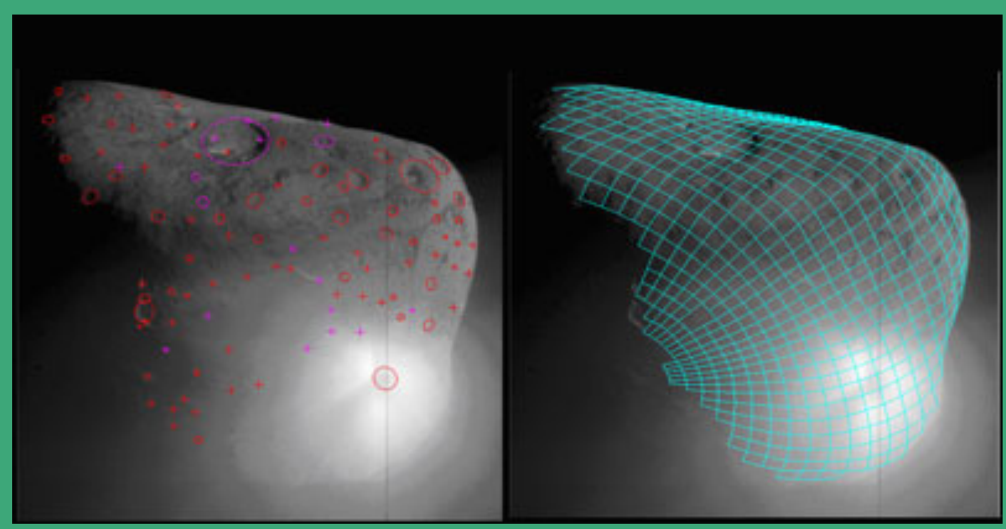
After successfully colliding with Tempel 1, astronomers were able to have access to numerical data never seen before regarding cometary interiors. The satellite had 3 cameras on board, including the High Resolution Imager (HRI), the Medium Resolution Imager (MRI), and the Impactor Targeting System (ITS). As the satellite originally flew towards Tempel 1, images were taken only every four hours, but during the last two months of approach the frequency of imaging increased to the point where it was almost continuous

Evolution of Cone of Ejecta



The above eight images exhibit how the ejecta plume caused by the Deep Impact impactor developed as a function of time. The collision occurred at 5:52 UTC on July 4, 2005. As one can see, the arrows highlight the shadowed regions on or caused by the cone of ejecta, which are imperative to my research. Each image displayed above was taken with the High Resolution Instrument (HRI) imager on board the satellite. Exactly 0.84 seconds elapsed between each image seen above. Check out http://www.nasa.gov/mov/121520main_HRI-Movie.mov to watch a video format of the ejecta plume forming.

Shape Model



Measured Quantities

Mean Radius: 3.0±0.1 km

RA: 293.8°

Declination: 772.6°

Largest Dimension: 7.5 km

Shortest Dimension: 5.0 km

•As one can see, only about 25% of the surface was actually imaged because the mission was a fly-by

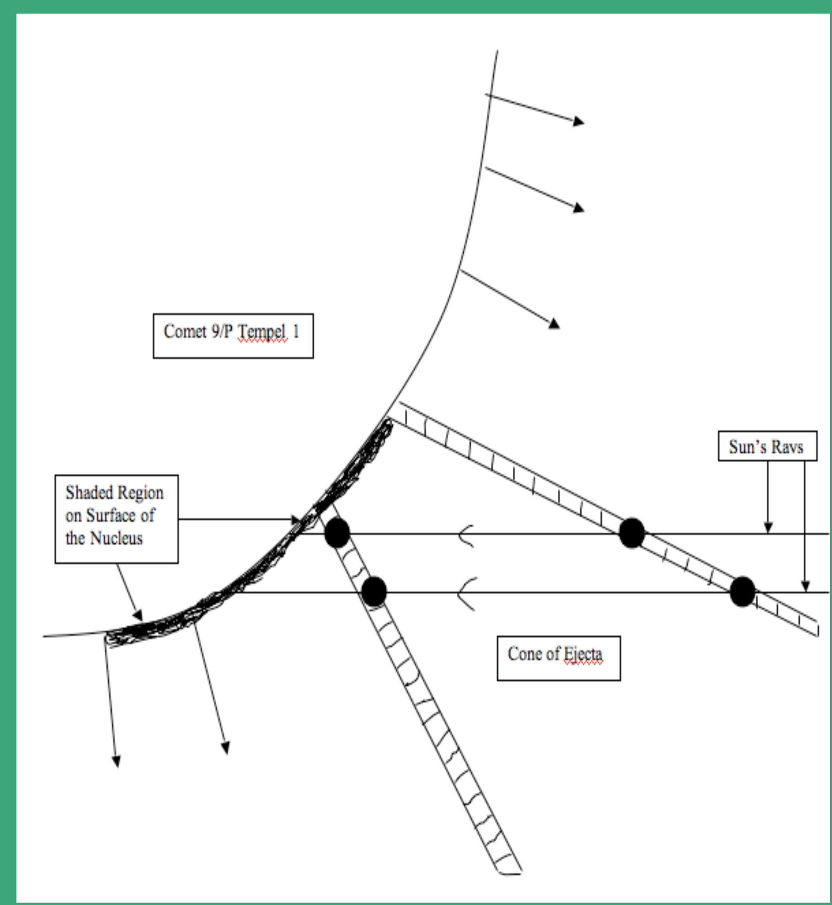
•The red circles on the left indicate control points which were clearly visible regions in all or most of the images taken (189 points in total).

• Entering these control points into a grid-making routine results in the shape model that maps the surface (right image)

• The shape model consists of plates that are connected from the control points and ultimately allows for the geometry of the surface to be defined

•It allows for a many angles (solar clock angle, celestial clock angle, etc.) and surface normals to be calculated, which are imperative for me to use to determine how the light naturally falls on the surface

How Light Falls on the Surface



•The image to the left is a sketch of the cross-section of the cone of ejecta along with some surface normals

•As one can see, the Sun's rays come from the left side of the image and intersect the cone in two separate spots before reaching the nucleus(black circles)

•Thus, the light will be partially blocked upon intersecting with the first circle, then the remaining percentage of the original light will be partially blocked again upon passing through the second circle

•Each of these occultations will cause the light that eventually hits the surface to be only a fraction of its original intensity

•As a result, after determining how the light naturally falls onto the surface before the collision, we can monitor the brightness in the shadowed region on the nucleus as a function of a time in order to learn about the optical depth of the particles in the cone ($I=I_o e^{-\tau}$)

•Then once optical depth and brightness values are collected, albedo can then be measured as well, which allows us to constrain the composition of the particles

Further Information:

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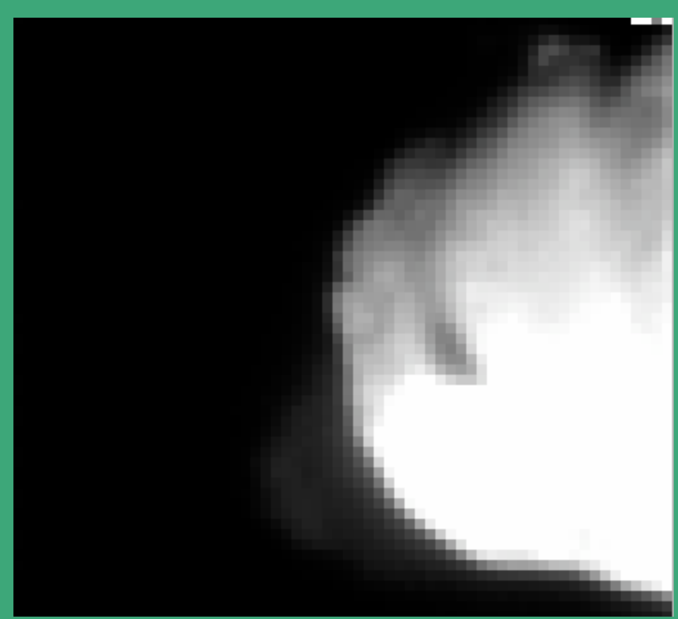
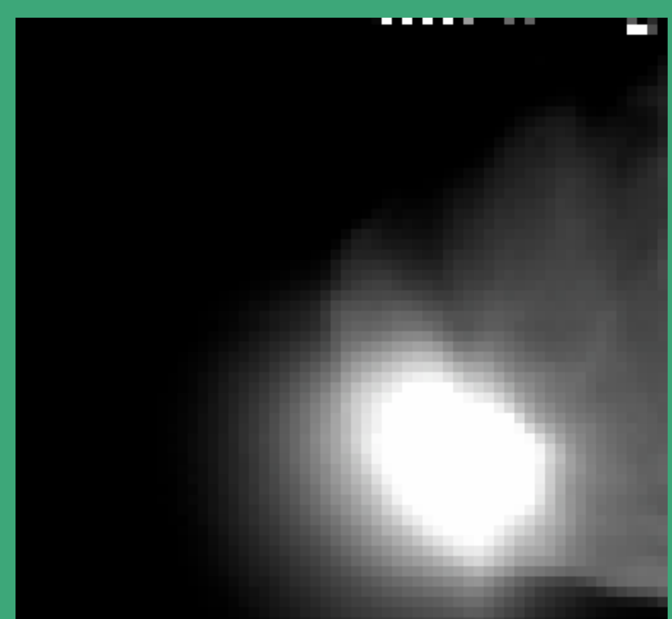
• All data and information used for the research in this project can be found at http://pdssbn.astro.umd.edu/

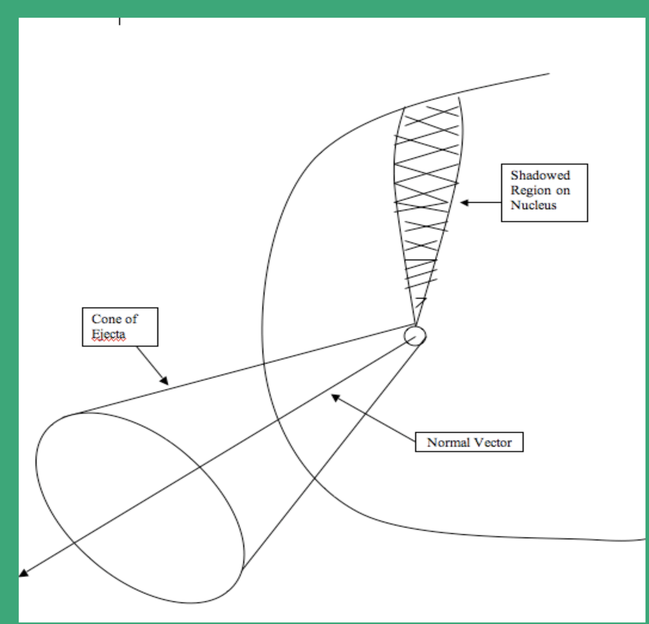
•Additional images and movies gathered during the Deep Impact mission of Tempel 1 can be found at http://deepimpact.umd.edu/

•This research was made possible by the NASA PDS Small Bodies Node and the College Student Investigators.

Modeling the Cone of Ejecta







•The first image is taken by the MRI and shows the beginning formation of the shadow and the cone of ejecta. The ejecta is still very near the surface here and as a result the shadow is fainter.

•The second image is also taken by MRI and shows the ejecta formed into a much larger, conical shape. The shadow is clearly visible above and to the left.

•The third image is a sketch showing effectively what type of geometry we are dealing with in this project. The sunlight intersects with the 3D cone of ejecta and thus is scattered, causing the shadow to form on the surface of the nucleus. Using the shape model and how the light naturally falls onto the surface, it will be possible to trace rays backwards from points in the shaded region of the nucleus back to the Sun. These rays will pass through the cone of ejecta on their path to the Sun, in turn showing which parts of the cloud are creating the corresponding areas of the shadow. Thus, we will create a 3-dimensional representation of the cone that will look like the third image above. This will allow us to pinpoint where the values for optical depth and albedo that we measure from the shadow are located on the cone, which in turn shows where within the nucleus the particles originated.