Investigation

Developed by HOU Leader, Janet Ward

22 Kaliope Light Curve

22 Kalliope Facts:

1. Discovered in 1852, Main Belt Minor Planet with small orbiting moon Linus
2. M-type spectrum but its low density and very low albedo doesn't fit it well in this model
3. possible self-gravitating rubble pile
4. Dimensions 215×180×150 km and estimated 6 to 8 E18 kg
5. Rotational period 4.148 h
6. Temperature 161K

1. Binary Asteroids and Rubble Piles:

The image below is the 25143 Itokawa asteroid imaged by the Japanese spacecraft Hayabusa. Examine its features and compare them to other feature you have observed on our moon and images of other asteroids. Is there anything unusual about its features in comparison? [Prepare a worksheet to write this question with its answer, as well as other later questions.]

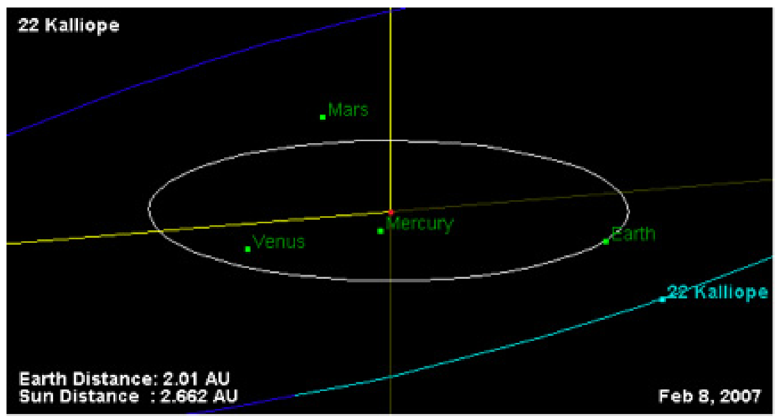
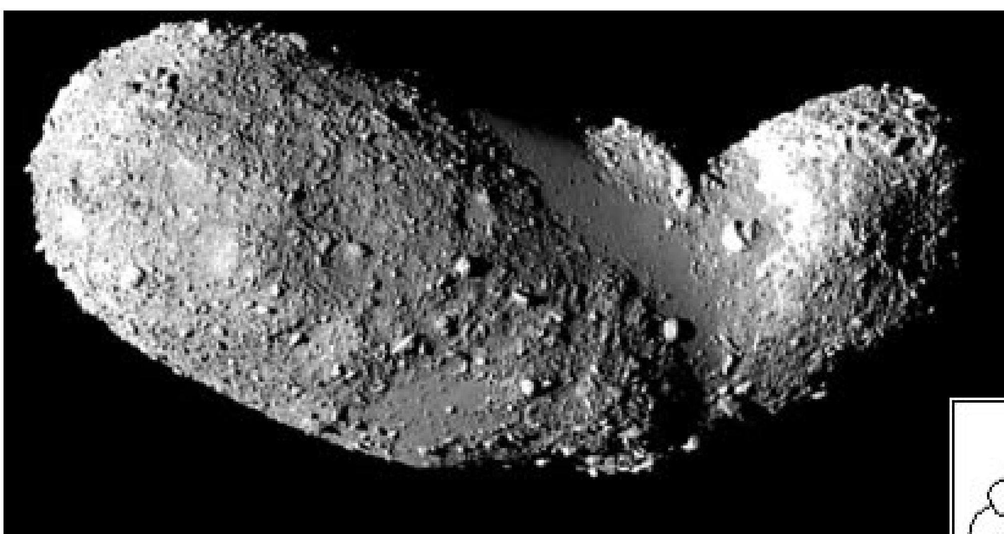


Image: Minor Planet 25143 Itokawa



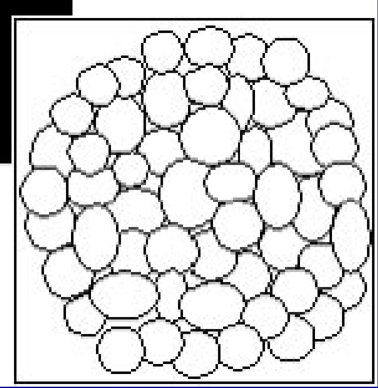


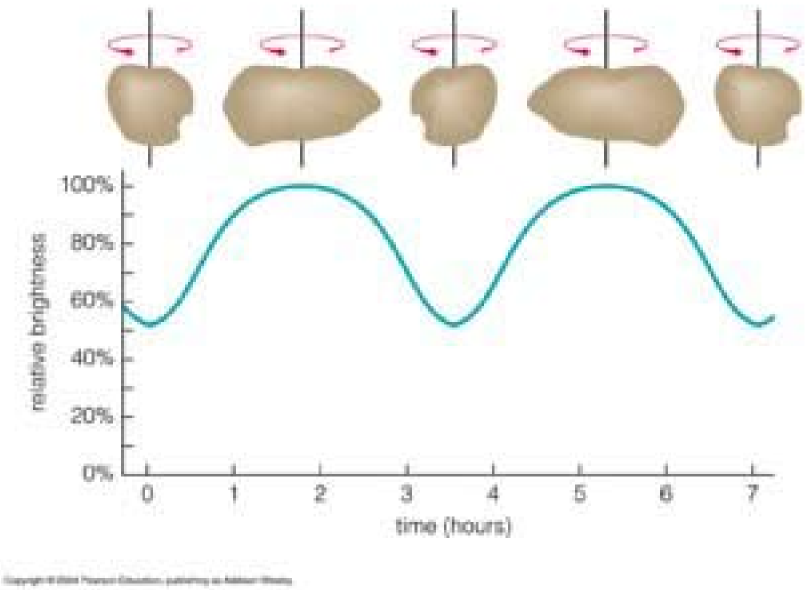
Image: Structure of a self- gravitational rubble pile

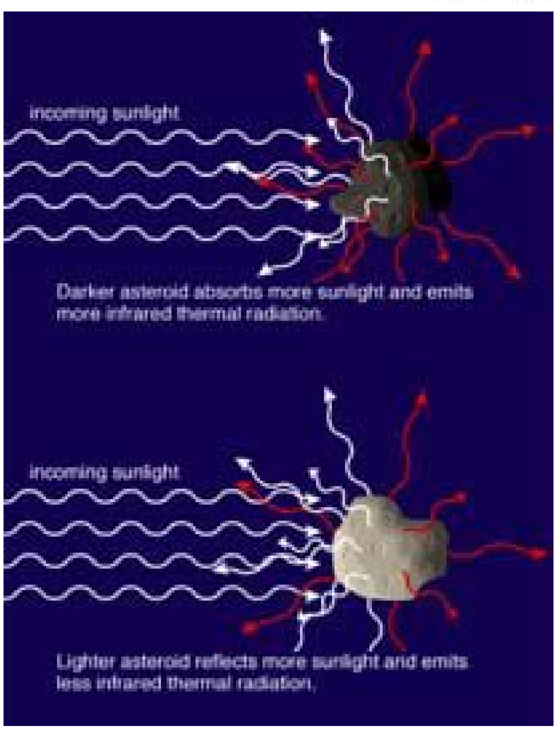
22 Kalliope has been designated as an M-class Minor Planet by its spectrum, which should imply that it's composed of metal. However, it's not as shiny and reflective of sunlight like a typical metallic asteroid and the computations of density confirm that it can't be metallic.

The most likely explanation at this time is that its composition is similar to Itokawa, shown above, and may be a "rubble pile" asteroid. Rubble piles are formed when an asteroid smashes apart after collision or tidal disruptions and then the bits fall back on each other over days and weeks in a loose self-gravitating conglomerate. So craters are not part of the surface features. Noting its oddly bent shape, Itokawa is also probably composed of two asteroids that collided with each other.

2. Light Curves: Shape and Composition

SHAPE EFFECTS: Asteroid light curves have two minimum and maximum due to their usual elongated potato shape and its rotations

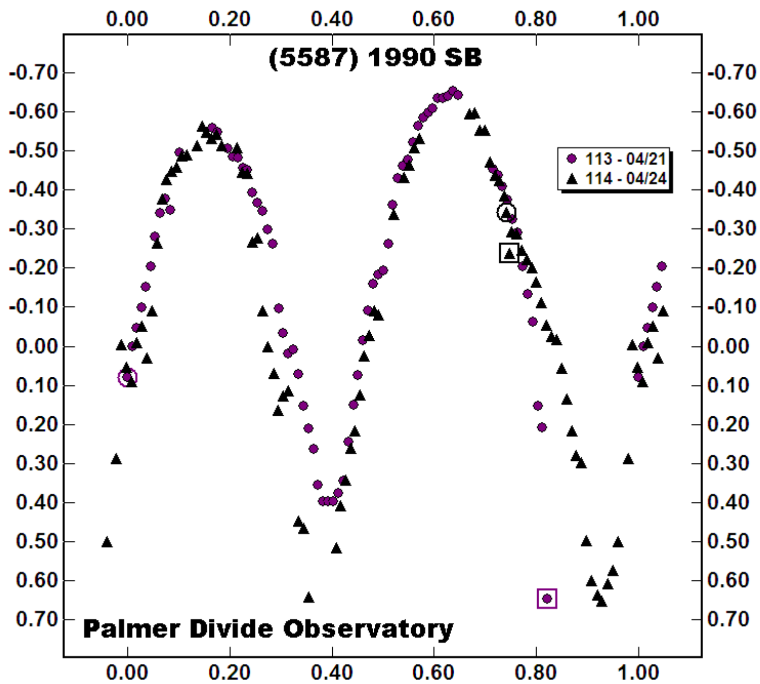




MATERIAL EFFECTS: Composition directs the best way to measure the brightness of an asteroid. Darker asteroids can be detected using infrared techniques.

3. How Big Is It, How Hot Is It, How Fast Does It Spin?

The average main belt asteroid looks something like a potato so during each rotational period, it presents two elongated sides, and two shortened ends. During those times, the light curve will show two bright peaks, and two dim troughs. On the average, it rotates at least once in an eight-hour period, allowing collection of the entire curve with one night's data. Others can be much more difficult and take several days or even months to rotate just once. So data must be collected over a long time to build the light curve.

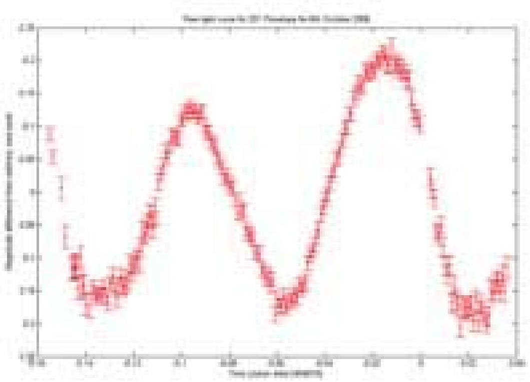


Light curve courtesy Minor Planet Observer/Palmer Divide Observatory
http://www.minorplanetobserver.com/pdolc/5587_1990sb.htm

4. Light Curve of 22 Kalliope

Using intensity or the brightness of the object you will determine:

- rotation rate
- temperature
- brightness



Example: Light curve of asteroid 201 Penelope showing one full rotation of 3.7474 hours. Courtesy Las Cumbres Observatory Global Telescope

A. PLOT LIGHT CURVE: (Intensity vs. Time)
Using light curve photometry for 22 Kalliope collected from derived published literature to plot a light curve on graph paper, and carefully sketch a best-fit curve. Measure the length of the period of one cycle.

Elapsed Time (h)	Change in Magnitude
0.4	0.23
0.150	0.25
0.301	0.23
0.440	0.18
0.590	0.14
0.790	0.03
1.050	-0.06
1.280	-0.14
1.325	-0.12
1.550	0.00
1.645	0.03
1.710	0.06
1.855	0.10
2.190	0.21
2.380	0.22
2.700	0.14
3.000	0.03
3.325	-0.13
3.550	-0.23
3.620	-0.25
3.780	-0.17
3.950	-0.06
4.030	-0.02
4.100	0.03
4.160	0.06
4.530	0.20
4.855	0.25

B. Compute Rotation Rate From Light Curve:

$$\omega = (2\pi/\text{rotation period})$$

The accepted value for the rotation period of 22 Kalliope is 4.148 h. What is the percentage error of your estimate from this value?

This was a rough technique to extract the rotation period. What factor accounted for the greatest error in your value and how could that be resolved better using an alternate technique?

C. Determine Temperature from a best fit curve of brightness vs. wavelength for four observations:

$$T_A^4 = L_S (1 - A) / (16\pi\ \varepsilon\sigma_{SB}\ r_{SA}^2)$$

Parameter	Describes	Value	How to Find Measured Values	Measured Value
L_S	solar luminosity	3.827×10^{26} Watts		
A	asteroid albedo, amount of sunlight reflected	measured, a default value for an unknown is 0.1	JPL small-body database "Physical Parameter" table for specific asteroid	
ε	emissivity	0.9		
σ_{SB}	Stefan-Boltzmann constant	5.6704×10^{-8} W/m²K⁴		
r_{SA}	Sun-asteroid distance	measured	JPL small- body database "Orbit Diagram" on observation date	

TEMPERATURE PARAMETER TABLE

a. Open the JPL Small-Body Database browser: http://ssd.jpl.nasa.gov/sbdb.cgi and enter "22 Kalliope" in **SEARCH**.

b. Scroll down to the **PHYSICAL PARAMETER** table and look for the **Geometric Albedo** value and record it in the **Temperature Parameter Table** above.

c. Click on the **Orbit Diagram** Tab and shape the orbit using the date arrows for the observation date **February 8, 2007**.

[write the following on worksheet]

The Sun distance is ___________ AU

Convert the value to meters using the conversion factor 1 AU = 1.4958 E11 meters

The Sun to 22 Kalliope distance on Feb 8, 2007 was _________________m. Record this value in the table above.

d. Compute the estimated temperature by taking the fourth root of the quotient. The unit will be in degrees Kelvin:

$$T_A^4 = L_S (1 - A) / (16\pi\ \varepsilon\sigma_{SB}\ r_{SA}^2)$$

[write on worksheet:]

The estimated temperature value, T_A, for 22 Kalliope on the observation night was ___________ K or _____________ °C.

Is this a hot or cold asteroid by definition using your estimated value? ____________________

NASA states that the average surface temperature of an asteroid is -100°C. How does your computed value compare? What was your percentage deviation from NASA's average value?

D. Derive Asteroid Albedo From Light Curve: _______________

$$A = L_v/(L_{th} + L_v)$$

$$L_v = \pi R_A^2\ L_S/4\pi r_{SA}^2\ A/4\pi r_{EA}^2$$

$$L_{th} = P_{in} = \pi R_A^2 L_S (1 - A)/4\pi r_{SA}^2$$

ALBEDO PARAMETER TABLE

Parameter	Describes	Value	How to Find Measured Values	Measured Value
A	albedo- brightness of reflected sunlight	derive		
L_v	visible light observation	derive		
L_{th}	thermal infrared brightness	derive		
R_A	radius of asteroid	measured	JPL small- body database “Physical Parameter” table for specific asteroid	
L_S	Solar luminosity	3.827×10^{26} Watts		
r_{SA}	Sun-asteroid distance	measured	JPL small- body database “Orbit Diagram” on observation date	
r_{EA}	Earth- asteroid distance	measured	JPL small- body database “Orbit Diagram” on observation date	

a. Open the JPL Small-Body Database browser http://ssd.jpl.nasa.gov/sbdb.cgi: and enter “22 Kalliope” in SEARCH.

b. Scroll down to the **PHYSICAL PARAMETER** table and look for the **Diameter** value, which is in kilometers. Convert to radius in meters and record it in the **Albedo Parameter Table** above.

c. Click on the **Orbit Diagram** Tab and shape the orbit using the date arrows for the observation date **February 8, 2007**. [write on worksheet:]

The Sun distance is ___________ AU

The Earth distance is __________ AU

Convert the value to meters using the conversion factor 1 AU = 1.4958 E11 meters

The Sun to 22 Kalliope distance on Feb 8, 2007 was ________________m. Record this value in the table above.

The Earth to 22 Kalliope distance on Feb 8, 2007 was ________________m. Record this value in the table above.

d. Compute the Visible Light parameter and place in the Albedo Table.

$$L_v = \pi R_A^2\ L_S/4\pi r_{SA}^2\ A/4\pi r_{EA}^2$$

e. Compute the Thermal Infrared Brightness parameter and place in the Albedo Table.

$$L_{th} = P_{in} = \pi R_A^2 L_S (1 - A)/4\pi r_{SA}^2$$

f. Compute the Albedo of 22 Kalliope:

$$A = L_v/(L_{th} + L_v)$$

Exit Ticket

Design an illustration of the following terms by creating a diagram of Earth, the Sun and planets, the Asteroid Belt, and the Kuiper Belt.

asteroid comet meteroid meteor meteorite

- Note the general placement of orbits of the objects about the Sun and with respect to the 8 planets.
- Create a "callout " for planet Earth to explain terms as they apply to atmospheric effects and impacts
- Note when each is properly in use.