



# Prospecting Asteroid Resources

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# What is the Resource?

# Where is the Resource?

- **Water:**

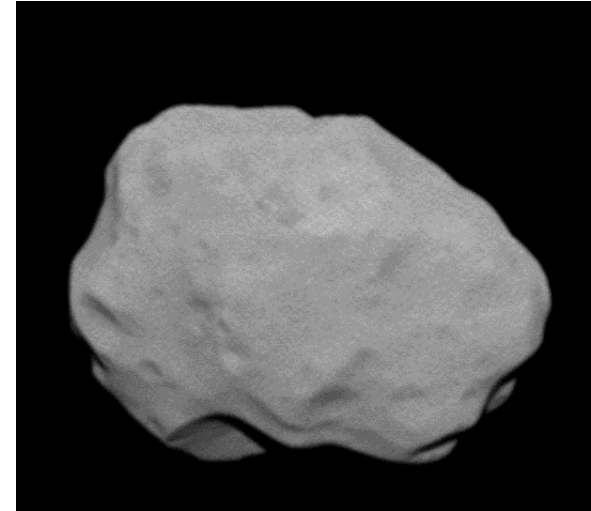
- There are 4 meteorite types that have useful amounts of water.....forget the rest.
- CI, CM, CR, C2 (and some ungrouped) carbonaceous chondrites.
- We know the mineralogy ~ 900 meteorite samples.

- **Iron:**

- Fragments of the cores of asteroids that melted and differentiated in the first ~million years after accretion.
- We know the mineralogy - 1242 meteorites

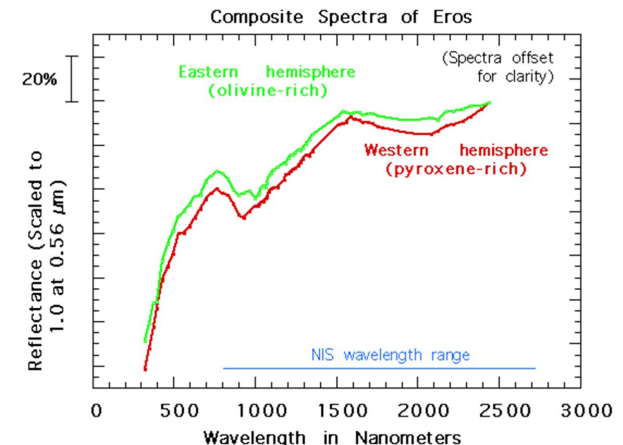
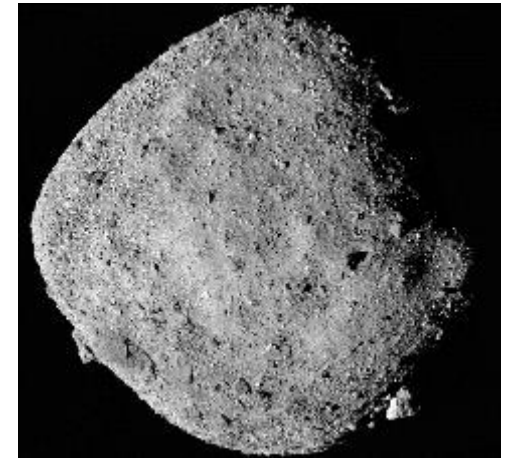
- **Location:**

- These asteroids are all over the asteroid belt and near-Earth space.
- The critical issue is that the resource needs be accessible in terms of energy and cruise time.



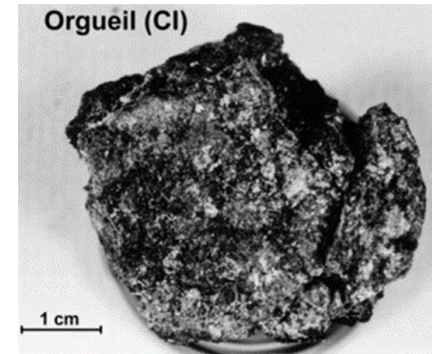
# Small Asteroids are Typically a Single Mineral Assemblage

- We have rendezvous with four small asteroids. All are a single mineral assemblage.
  - Expect exogenous materials at the few percent level from impacts.
- Three additional lines of independent evidence for single assemblage asteroids.
  1. Rotational spectroscopy
  2. Meteorites and meteorite showers
  3. Spectroscopy of asteroid dynamical families



# Prospecting for Asteroids

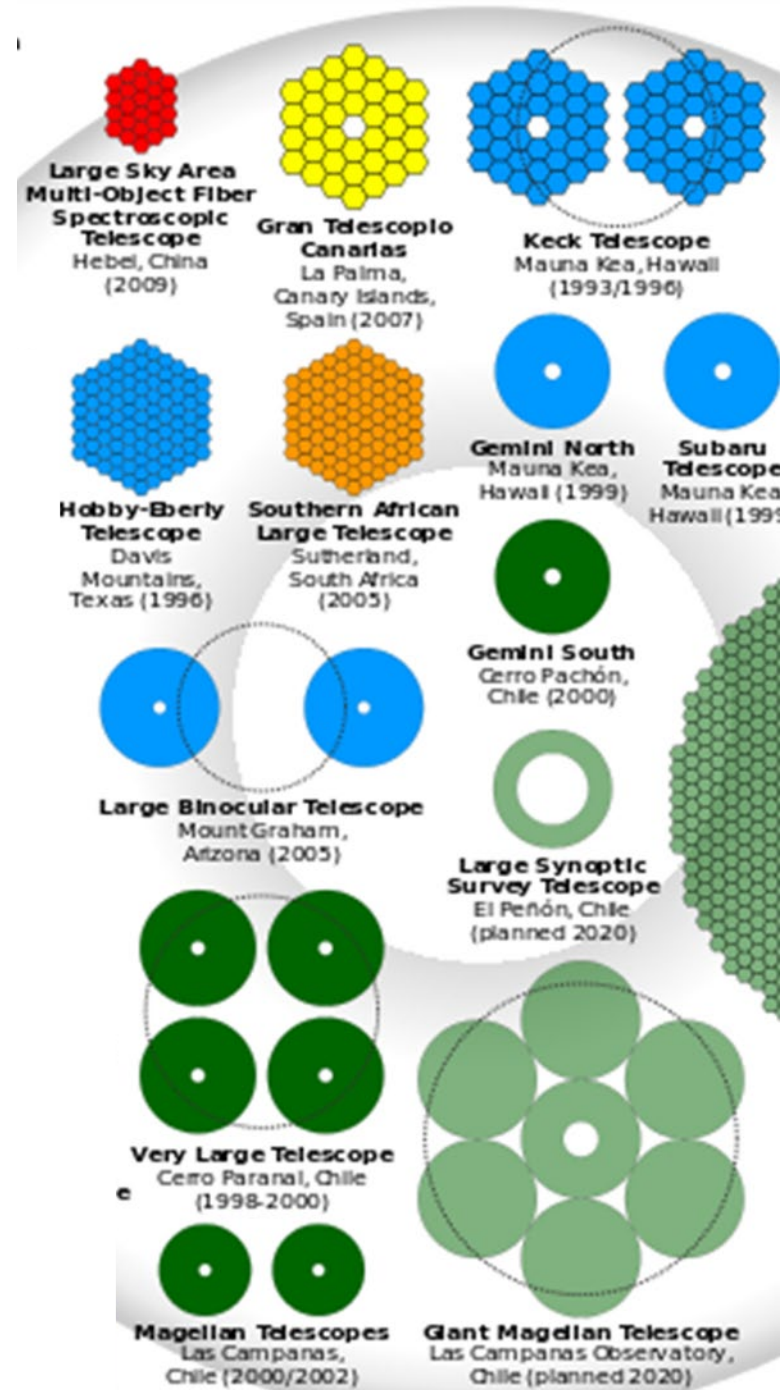
- Telescopic remote sensing actually works very well for prospecting asteroids.
- What can be learned at a telescope:
  - Rotation rate: lightcurve
  - Shape: lightcurve inversion/occultation
  - Cohesion: rotation rate/lightcurve
  - **Albedo:** flux at thermal wavelengths
  - Comae/activity: optical imaging
  - Surface texture: polarization and phase curve
  - Mineralogy: reflectance/emission spectra
  - Volatiles: reflectance spectra
  - Space weathering: reflectance spectra
  - Mineralogical variation: rotational reflectance spectra
  - **Dielectric:** radar return
  - **Surface porosity:** radar return
  - Grain size/surface texture: thermal emission spectra
- Doing prospecting by spacecraft is hugely expensive, slow, and wasteful.
- Do your prospecting at the telescope!!! Big telescopes are not cheap, but orders of magnitude cheaper than spacecraft!





# Prospecting at Asteroids

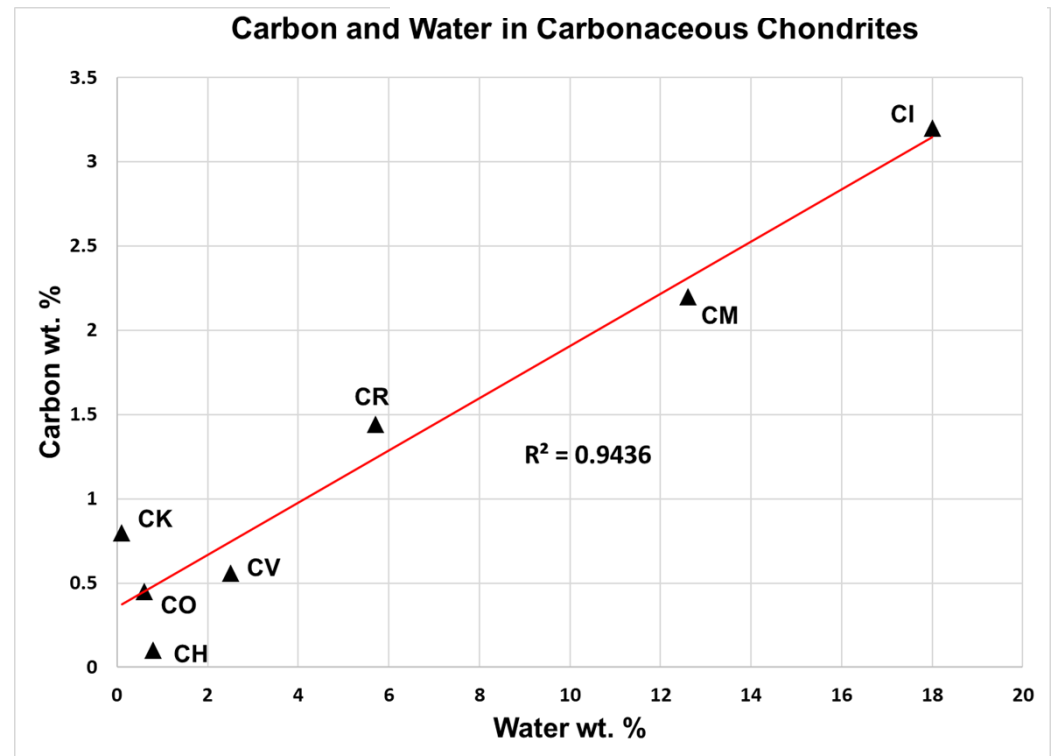
- You don't need to prospect at a small asteroid.
  - Ores are not concentrated on small asteroids....there are no concentration processes.
  - You don't get significant mineralogical variation in a small asteroid. The whole asteroid is the ore body.
  - “High-grading” is a useless concept for asteroids since there are no local concentration mechanisms.
- The mineralogical information is in the meteorite collection.
- Asteroid reconnaissance is done via telescope.



# Albedo and Water

- For water-rich asteroids, albedo is a key measurement.
- They are very dark because of higher carbon, organic, and opaque contents.
- Carbon and organics are strongly correlated with water.
- Darker = More water

Type	Albedo
S	0.07-0.23
C	0.02-0.06
M	0.07-0.2
E	0.2+up
R	0.16+up
P	0.02-0.07
D	0.02-0.07
U	Various



# Determining Asteroid Sizes

## Albedo

High Albedo  
"Chalk"



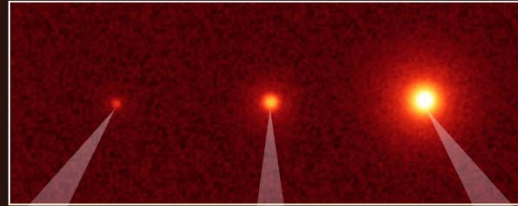
Low Albedo  
"Charcoal"

Visible Light



Brightness alone does not correspond to size

Infrared Light



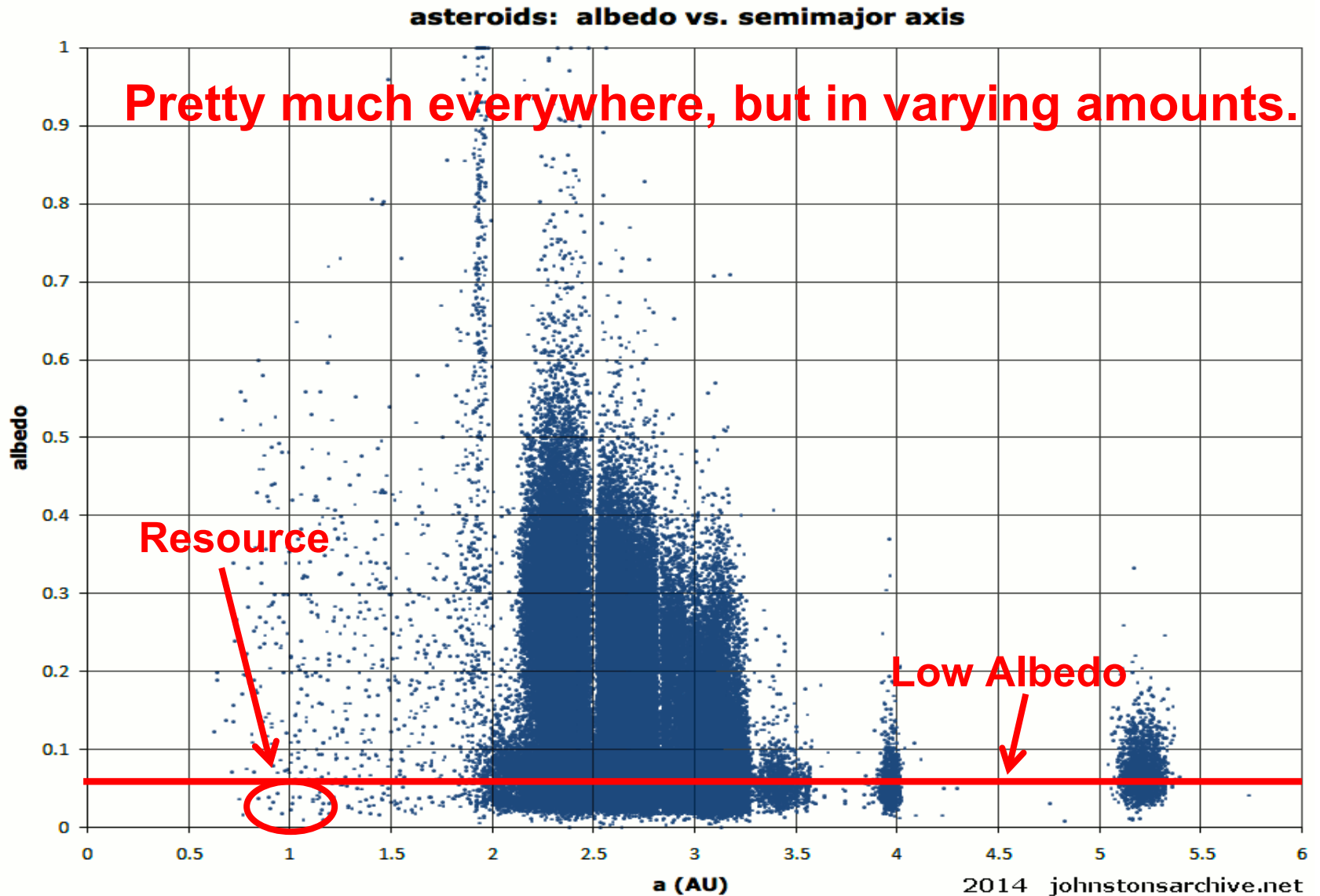
Brightness corresponds to size

High Albedo  
"Chalk"



Low Albedo  
"Charcoal"

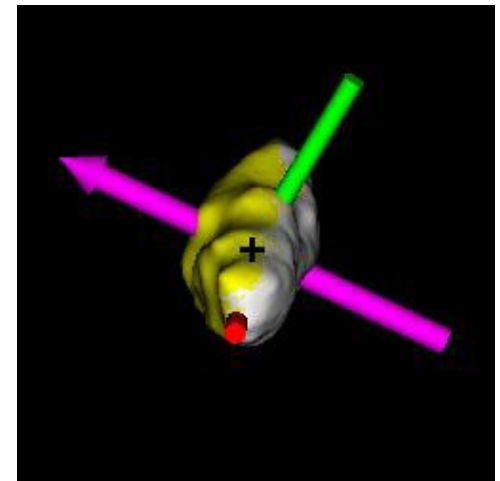
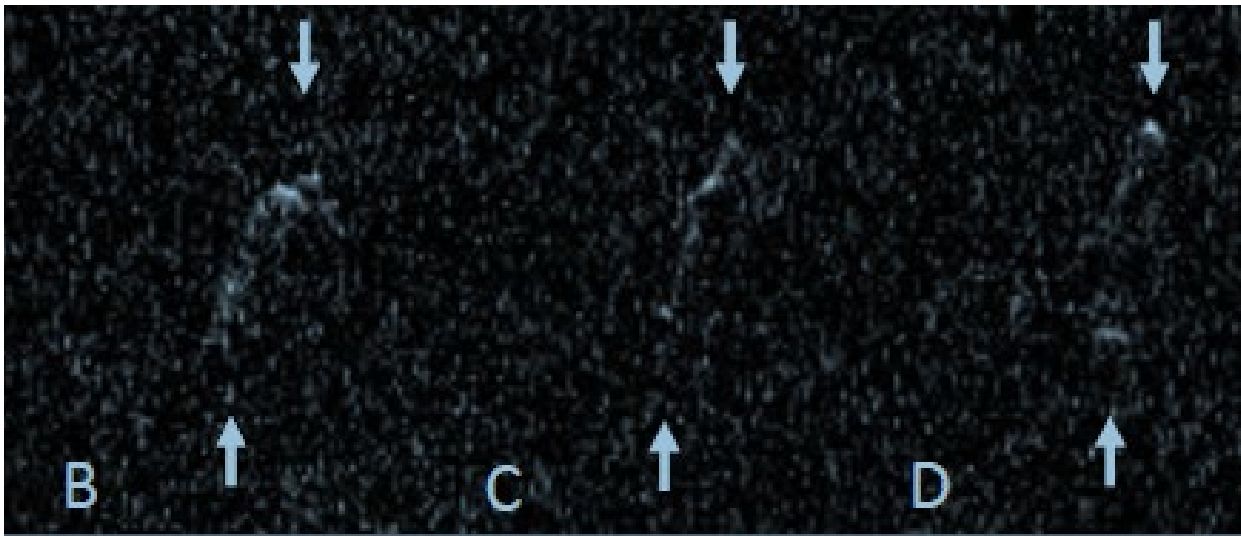
# Where are the Low-Albedo Asteroids?



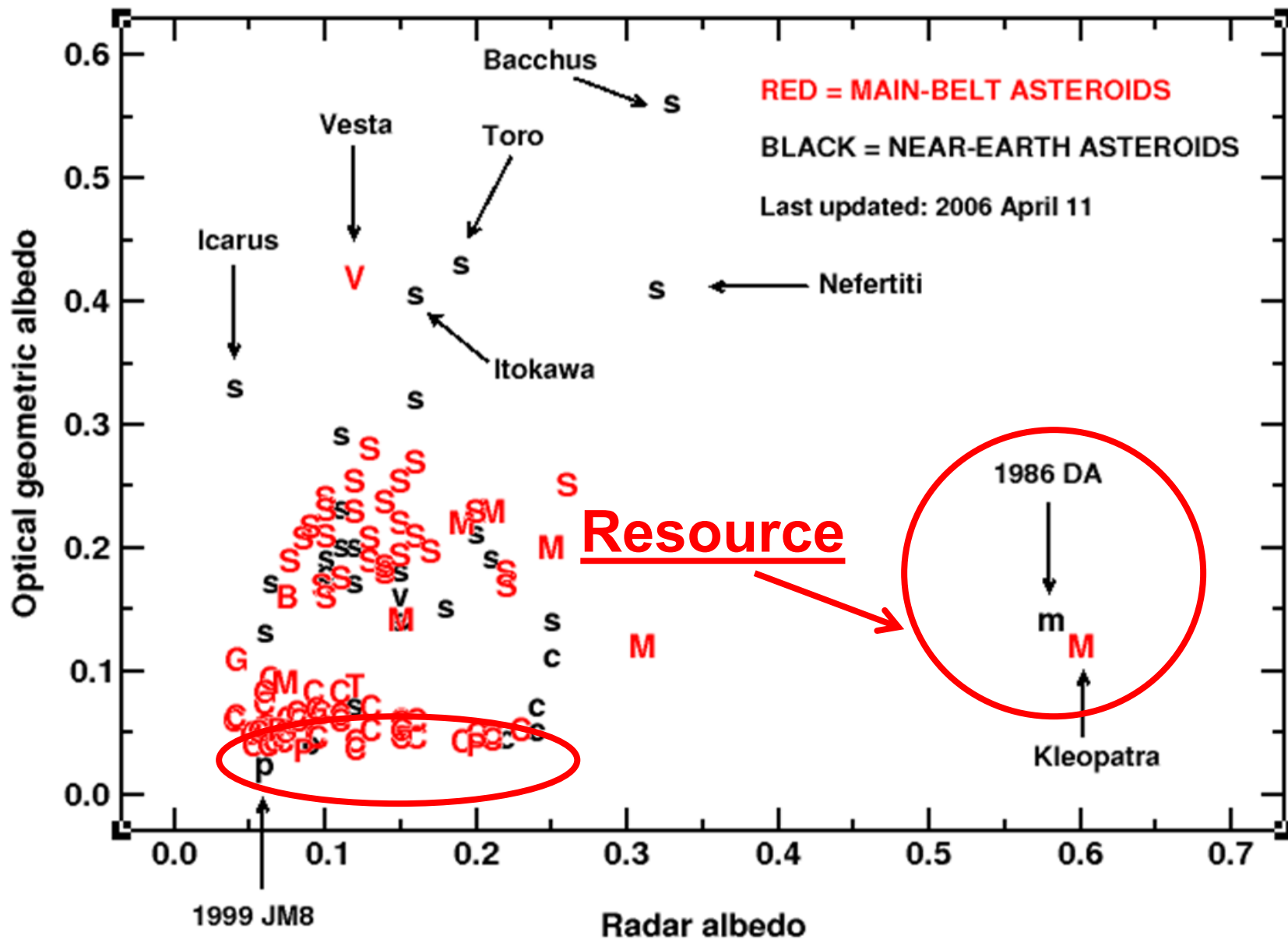


# Radar

- **Great for:**
  - Determining asteroid shape
  - Ranging and orbit determination
  - Surface dielectric...i.e. metal
- **Problems**
  - Limited range, return falls off by  $1/r^4$
  - For a 100-meter diameter asteroid, maximum effective radar range is about 0.1 AU (15 million Km).
  - Radar images are not pictures.



# Asteroid Radar and Optical Albedos





**Asteroid radar requires lots  
of power and a big dish**

**If you want radar  
time on Arecibo,  
talk to me....**







# To Wrap Up



- Useful asteroids contain volatiles or metal. The rest are rocks.
- Prospecting for “ore” asteroids should be done remotely at a telescope. Orders of magnitude cheaper and more effective than a reconnaissance mission.
- Small asteroids are overwhelmingly a single mineral assemblage.
- Once at an asteroid, prospecting and “high-grading” are a waste of time. There are NO concentration mechanisms.
- Ore geology on the asteroids is different from Terrestrial ore geology, but very understandable given knowledge of the geologic context.
- The next talk will discuss where and how to search for asteroid resources.

