THE NEW EUROPEAN PROJECT FOR THE EXPLORATION OF ASTEROIDS: AGORA.

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INTRODUCTION. Asteroids, together with comets, constitute the most "primitive" objects in the solar system. They constitute an extremely diverse family, with 4 major classes and up to 87 subclasses. It is now generally considered that they represent an intermediate stage in the formation of a terrestrial planet, accretion having been inhibited in the belt by the proximity of Jupiter. They can thus yield information on differentiation and collision associated processes active among planetoids early in the history of the solar system (fragmentation, cratering, formation of a regolith). Furthermore, asteroids are the parent bodies of most meteorites, the major source of extraterrestrial material. Documentation of these samples by linking asteroid and meteorite classes would greatly enhance their scientific interest. Therefore, a first exploration mission towards the asteroids now ranks among the highest priorities of both the european and american planetary science communities. A new proposal, AGORA (Asteroid Gravity, Optical and Radar Analysis) has been selected for an assessment study by the European Space Agency. In the following, we will discuss the optimum scientific payload and technical constraints of such a mission.

SCIENTIFIC GOALS. An imaging camera is clearly required, to observe the morphology of the asteroid. In particular, it should be able to measure the thickness of a plausible regolith (origin of gas-rich meteorites; possible buffering role during accretion). The minimum thickness which can be measured by observing flat-bottomed craters (1) is of the order of the spatial resolution. As regolith evolution models predict thicknesses of a few km (2) down to several hundred meters (3), a resolution of 50 to 100 m is a reasonable choice, which allows complete coverage with a small number of frames.

Near-infrared spectrometry is also mandatory, as it yields the mineralogical (and thus chemical) composition of the surface. The study of gas-rich meteorites shows that asteroidal regoliths should be essentially free of glass, which would modify their spectra. The abundances of the major classes of silicates, opaque and hydrated minerals can thus be determined if the signal/noise ratio and the spectral resolution are $\gtrsim$ 50 (4). Lateral transport should spread mineralogical boundaries on a scale of at least a few km, which fixes the relevant spatial resolution.

We also need a radar altimeter, to determine the geometry of the encounter (minimum approach distance, time of passage at closest approach), as well as to provide additional information on the shape of craters and other morphological features. An accuracy on the distance of $\sim$ 100 m is adequate for this altimetry task. Analysis of the echo also yields informations on the roughness of the surface on a scale of a few cm.

We next consider that an accurate determination of the mass, and thus the density of the asteroid is one of the major scientific goals of such a mission: a bulk density exceeding that of the surface layers would indicate that the body is differentiated (plausible existence of a dense core). Differentiation of small bodies (less than 200 km in size) requires heating by short-lived radioactive nuclides (e.g. ^{26}Al), and would have made possible cycles of accretion, differentiation, and fragmentation early in the history of the solar system. A metallic core representing 10 % of the total mass can be reliably detected if the accuracy on the density is $\sim$ 5 %.

γ-ray and X-ray spectroscopy provide additional results on the chemical composition. X-ray Mg/Si and Al/Si mappings are closely related to infrared results on silicate families. γ-ray spectroscopy is more complementary, yielding U, Th, and K abundances and thus the volatile/refractory ratio in the body. Other important elements such as H and Fe can also be measured. These methods have relatively low spatial resolution (tens of km at 100 km distance). They require long exposure times, and can only be implemented during a rendez-vous mission.

MULTIPLE FLY-BY OR RENDEZ-VOUS. Due to the variety of asteroids in classes (5) and sizes, a first exploration mission should visit several of these bodies. Ariane IV is able to launch a probe flying by 3 or more asteroids 20 to 100 km in size at a distance of 500 km, and a relative speed of 5 to 10 km/s. The allowed payload varies from 100 to more than 200 kg, depending on the trajectory. We have shown that imagery (with a 6° field camera), infrared spectrometry (with a filter-wheel spectrometer) and altimetry (using a pulse-compression radar) can be performed at the required level of performance during such a fast fly-by with a three-axis stabilized probe. A good accuracy on the determination of the mass can also be achieved, as will be discussed hereafter. A multiple rendez-vous would have several advantages: γ-ray and X-ray spectroscopy can be implemented, the whole surface is observed (as compared to one half with the fly-by), the infrared signal/noise ratio is improved, and the mass can easily be determined from the orbital period of the probe. However, such a mission requires a solar sail or an ionic thruster. A test of the latter (project AMSAT) is scheduled in 1985. A decision will then be made between the two options.

DETERMINATION OF THE MASS OF THE ASTEROID DURING A FAST FLY-BY. Perturbations induced by a small asteroid on the trajectory of the probe amount to ~ 0.2 arcsec, far too small to be directly measured by earth-based or on-board tracking. Conventional gradiometry imposes strong constraints on asteroid tracking by the platform, and is limited to asteroids more than 60 km in size. The most promising method consists in launching a small reflector a few days before the encounter, which travels closer to the asteroid than the probe, and is thus more perturbed. The differential perturbation can be measured either as a distance increment, with a high accuracy radar-altimeter, or a change in the relative direction, with a high accuracy camera (Figure 1). Either method should provide the required 5 % accuracy on a 30 km asteroid. At this level of accuracy, all other perturbations (solar pressure, keplerian differential motion between the probe and the reflector) must be evaluated.

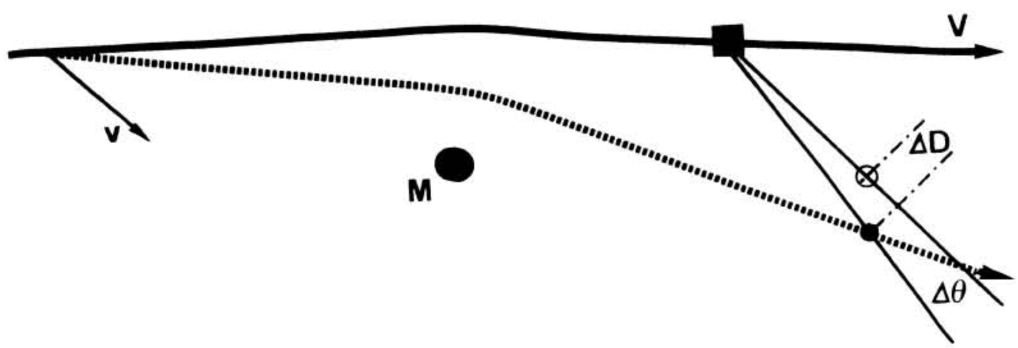

Figure 1: Determination of the mass by tracking of a small reflector

References: 1. Quaide and Oberbeck, JGR 73, 5247 (1968); 2. Housen et al., 601; 3. Langevin and Maurette, LPI XI, 602 (1980); 4. Gaffey and McCord, 688; 5. Chapman and Gaffey, 655; 2, 4 and 5 in "Asteroids", Gehrels, (1979).