ASTEROIDS 1 CERES AND 4 VESTA: WHAT WE KNOW ABOUT THEM BEFORE DAWN MISSION. D. F. Lupishko[1], R. A. Mohamed[2], [1]Institute of Astronomy of Karazin Kharkiv National University, Ukraine, lupishko@astron.kharkov.ua, [2]University of Garyounis, Benghazi, Libya, rafzg@yahoo.com

Introduction: Dawn space mission to Ceres and Vesta was selected as a NASA's Discovery Program mission as far back as in Dec. 2001. It was successfully launched in Sept. 2007 and now is on its way to reach Vesta in 2011 and Ceres in 2015. Both of these main-belt bodies were witness to much of our Solar system's history and their detailed study is necessary for understanding of earliest stages of the Solar system forming including main asteroid belt origin. Dawn spacecraft will work during about 5-7 months in the orbits around each asteroid, investigating these quite different protoplanets and supplying us with a lot of new information concerning the bodies' compositions, thermal history and interior structure, shapes and sizes, possible presence of water ice in Ceres' mantle, masses and gravity fields, optical properties, etc. In order to interpret the obtained data qualitatively it is necessary to summa-rize what we know about these asteroids now from ground-based and Hubble Space Telescope observations.

Sizes, masses and densities. Table below contains these parameters obtained as the weighted average values of the most recent and accurate their determinations. Ceres and Vesta are the two most

Asteroid	D, *km*	$M\cdot10^{-23}$, *g*	ρ, g/cm^3
1 Ceres	947±8	9.49±0.06	2.06±0.05
4 Vesta	529±10	2.70±0.02	3.5±0.2

massive objects in asteroid belt and contain about 35% of its total mass. Their sizes and masses are measured most precisely as compared with other asteroids, therefore their bulk densities are also determined well and for both asteroids they are slightly smaller than for corresponding meteorite analogues. It means that Ceres and Vesta are essentially solid (coherent) objects without essential macroporosity.

Shape and axis rotation. Ceres' shape has been determined to be an oblate spheroid with a ratio of equatorial to polar axis $a:c$ = 1.07 which corresponds to a gravitationally relaxed body [10]. The shape of Vesta was investigated also with HST-ima-

Aster	P_{rot}, *hr*	Axis ratio	Pole coordinates
1 Ceres	9.075	1.07:1.07:1	λ_0=315°, β_0=74°
4 Vesta	5.342	1.26:1.22:1	λ_0=336°, β_0=57°

ging which revealed a huge impact crater 460 km in diameter near the south pole. The 13-km-deep crater occupies the bigger part of Vesta's south hemisphere and to a great extent affects its shape. Ceres and Vesta have different shapes and rotation rates but rather similar orientations of rotation axes. Vesta is the most fast rotator among largest asteroids and very likely that the impact event, originated the huge crater, also influenced much the asteroid rotation.

Taxonomy and mineralogy. Ceres is classified as low-albedo G-type asteroid. Its spectrum shows strong UV (<0.4 μm) and IR (3.0 μm) bands and is flat in the visible and near-IR region. In general Ceres' spectrum is consistent well with carbonaceous chondrites, though a consensus as to the exact surface composition of Ceres remains elusive, and no meteorites have been linked to it. Microwave observations have been interpreted as Ceres is covered with a material like clay minerals (phyllosilicates), which would indicate that water played a role in Ceres' history. Further support for this conclusion came from the detection of a possible signature at 3 μm of hydrated minerals. Detection of OH escaping from the northern limb [1] fits with a model in which a winter polar cap is replenished by subsurface percolation which dissipates in the summer. Subsurface water ice could be preserved within Ceres for the age of the Solar system and the most acceptable composition of Ceres' surface is thought to consist of metamorphosed and/or aqueously altered clay minerals and about 25% of water inside.

Vesta's reflectance spectrum provides clear identification of the surface minerals: they are low-calcium pyroxene and plagioclase. This composition is directly comparable to the HED basaltic achondrites (howardites, eucrites, diogenites). Indeed, vis-near-IR spectra of Vesta and this class of meteorites are almost indistinguishable. Thus, unlike other large asteroids Vesta has a basaltic surface that retains a record of ancient volcanic activity. Color measurements in the 13-km-deep crater are consistent with excavation deep into a high-calcium pyroxene-rich crust or olivine upper mantle. The excavated matter is sufficient to account for the family of small Vesta-like asteroids that extends to dynamical source region for meteorites. Thus, Vesta's crater may be a source of basaltic achondrite meteorites [9].

Thermal properties and internal structure. Using HST measurements Thomas et al. [10] revealed that Ceres' shape is significantly less flattened than that expected for a homogeneous object. This fact together with a recent thermodynamic modeling of Ceres' evolution [7] is consistent with some central mass concentration supporting the hypothesis that Ceres is differentiated and may have a subsurface ocean (see also [6]). According to the model, the ice would have melted and separated from the silicate rock. This process quickly produced a silicate core and a liquid mantle, at the same time presserving a thin frozen surface crust. Due to the high water content the silicates in Ceres cannot be melted even if short-lived radioactive nuclides (^{26}Al) are considered, because the large latent heat of the water absorbs energy and the convection in the water removes heat. This model predicts a hydrostatic shape for the spinning Ceres (P=9.075 hr) with differences in polar and equatorial exes of 32 km, what was well confirmed by HST-data (spheroid 487×455 km).

For a long time Vesta was the only known differentiated asteroid with an intact internal structure, consisting of a metal core, an ultramafic mantle and a basaltic crust. Extensive mineralogical, petrological, isotopic and chronological data suggest that heating, melting and formation of a metal core, a mantle and a basaltic crust took place in the first few million years of Solar system history. It is likely that many more Vesta-like asteroids formed at that period but were destroyed by impacts [3]. Thus, Vesta is really one of the most fascinating asteroids, which in its structure and composition can be viewed as the smallest terrestrial planet.

It is known that alteration processes due to energetic cosmic rays, solar wind ions and micrometeorites change the spectral properties of silicate-rich objects (Moon, asteroids), inducing progressive darkening and reddening of their surfaces. The authors of [11] performed an ion irradiation experiment on a eucrite meteorite Bereba, which characterizes the surface of Vesta well, in order to simulate the solar wind irradiation on this asteroid. Their result is: if solar wind ions do reach the surface of Vesta, its reflectance spectrum should be much redder and its albedo lower. Thus, solar wind particles can not reach the asteroid surface and this strongly suggests the presence of a magnetic field shielding the surface from solar wind ions. The authors of that paper are sure that they have obtained the first remote detection of the magnetic field of an asteroid.

Optical and structural properties. Ceres and Vesta are quite different in their albedos, colors, magnitude-phase and polarization-phase dependences (see Table below), what is a consequence of their different surface mineralogy. The high resolution HST imaging of Ceres gave lightcurve with the amplitude of 0.04 mag which cannot be matched by Ceres' rotationally symmetric shape, and is modeled by albedo variations [2]. The geometric albedo at V-band was estimated to be 0.090±0.003. The first

Asteroid	Albedo p_v	U-V	P_{min}, %	Slope h
1 Ceres	0.07-0.10	1.15	1.70	0.257
4 Vesta	0.26-0.42	1.30	0.61	0.065

spatially resolved surface albedo and color maps of Ceres have been constructed from HST observations and 11 surface albedo features were identified, ranging in scale 40–350 km. Overall the range of these albedos and color variations is found to be small compared to other asteroids and some icy satellites [2], that is Ceres' surface is photometrically homogeneous. The uniformity of albedo, together with the large water content as indicated by its mean density [10], suggest that Ceres could have been resurfaced, probably by melted ice, during the heavy bombardment phase of Solar system formation. Radar data found the Ceres' surface to be very rough at the scales between 10 km to meters. At the same time at centimeter and decimeter scales the surface of Ceres is smoother and that one of Vesta is rougher than the lunar one, which can be presumably because of differences in material strength. Since weak carbonaceous material is more readily comminuted than is basaltic material, Ceres would be expected to have a finer-grained regolith. Both asteroids are thought to be covered by at least tens of meters of regolith, which is generated and modified by impacts [8].

The Vesta's lightcurves show an amplitude of 0.12 mag which is mostly due to albedo variations over the surface but not due to asteroid shape.

Both asteroids Ceres and Vesta are polarimetrically unique bodies. According to our UBVRI-observations in 1986 [4], Ceres shows a monotonic increase of position angle of polarization plane with wavelength as large as 2 deg within 0.37-0.83 μm, which is several times greater the accuracy of measurement. Similar increase takes place in UBV measurements of Ceres by Zellner and Gradie in 1974 and in some observations by other authors after 1986. However in some Ceres' apparitions this effect is not observable. One of the possible explanation of it can be the influence of crystals of water hoar-frost near the one of asteroid poles (polar cap).

Our observations of Vesta in 1990 and 1996 [5] revealed (for the first time for asteroids in general) variations in the polarization-plane position angle with axis rotation (that is, over the surface) as much as 8º in U-band and 2.5º in I-band. The comparing of amplitude and character of variations with Vesta's topography agrees well with the hypothesis that they are the result of presence of orderly oriented linear features on asteroid surface (grooves, slopes) related to the forming of huge (460 km) crater on Vesta.

Summary. Dawn is the first mission to orbit the main-belt asteroids. Its objective is to obtain data on two most massive and complementary bodies Ceres and Vesta which suffered the different evolutionary histories. In spite of the fact that these two protoplanets were formed and evolved so close to each other, they are quite different: Vesta is believed to be melted and differentiated, and Ceres is believed to contain the subsurface water ice. We do not know any other asteroid with such properties. Being the largest and the most massive objects in asteroid belt they have survived largely intact through the collisional history of our planet system and therefore they can be considered in a certain sense as the transition objects between the rocky bodies of the inner Solar system and the icy bodies of the outer one. Ceres and Vesta have preserved retrievable records of the physical and chemical conditions during the early planet-forming epoch, therefore their study can give an understanding of many problems concerning the Solar system origin and evolution.

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