SUBLIMATION ACTIVITY OF (145) ADEONA, (704) INTERAMNIA, (779) NINA, AND (1474) BEIRA AND SOME CONFIRMATIONS. V. V. Busarev[1, 2], S. I. Barabanov[2], M. P. Scherbina[1], and V. B. Puzin[2], [1]Lomonosov Moscow State University, Sternberg Astronomical Institute (SAI MSU), University Av., 13, 119992 Moscow, Russia, e-mail address: busarev@sai.msu.ru, [2]Institute of Astronomy of the Russian Academy of Science (IA RAS), Pyatnitskaya St. 48, 109017 Moscow, Russia.

Introduction: Discovering spectral signs of sublimation activity in September 2012 on four main-belt primitive asteroids (145) Adeona, (704) Interamnia, (779) Nina, and (1474) Beira at their perihelion distances [1, 2] raised questions about the probable mass nature of this phenomenon on main-belt bodies that could contain free water ice. As is known, the mineralogy of solid rock bodies is sensitive to conditions of their origin. However, the orbital ellipticity of a small planet makes it possible to test the volatility of the body's material depending on heliocentric distance and accompanying surface temperature changes. Now we are able to confirm this periodic process on Nina as it approached perihelion in September 2016.

Observational Data and Discussion: Spectra of the main-belt asteroids (145) Adeona, (704) Interamnia, (779) Nina, and (1474) Beira were obtained in September 2012 using a 2-m telescope with a low-resolution (R ≈ 100) CCD spectrophotometer in the 0.35-0.90 μm wavelength range at Terskol Observatory (Mt. Terskol, 3150 m above sea level, Russia) operated by IA RAS. To calculate reflectance spectra of the asteroids, a standard reduction procedure was employed (flat-field correction, bias and dark subtraction, etc.), and HD9986, HD10307, and HD 173071 were used as solar analog stars. The corresponding averaged and normalized reflectance spectra of the asteroids obtained in September 2012 are shown in Figs 1-4.

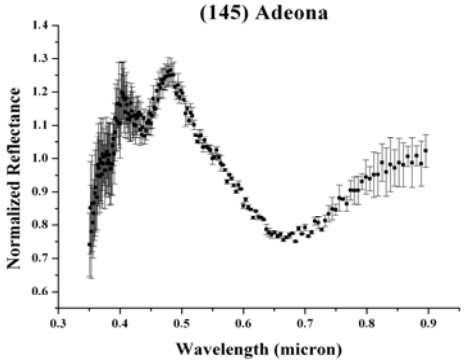

Fig. 1. Averaged and normalized (R = 1 at 0.55 μm) reflectance spectrum of (145) Adeona on 19 September 2012. The spectrum is obtained as an average of two spectra (error bars represent the standard deviation).

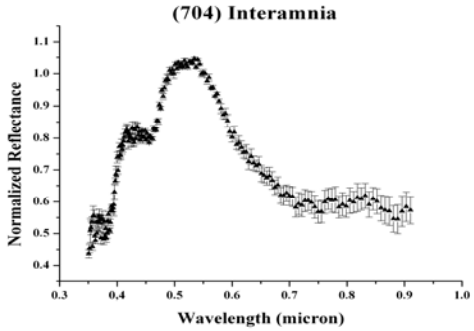

Fig. 2. Averaged and normalized reflectance spectrum of (704) Interamnia on 13 September 2012. The spectrum is obtained as an average of five spectra.

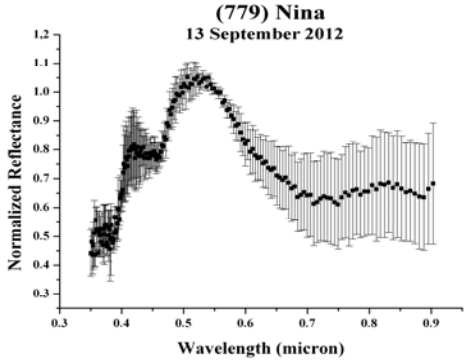

Fig. 3. Averaged and normalized reflectance spectrum of (779) Nina on 13 September 2012. The spectrum is obtained as an average of twelve spectra.

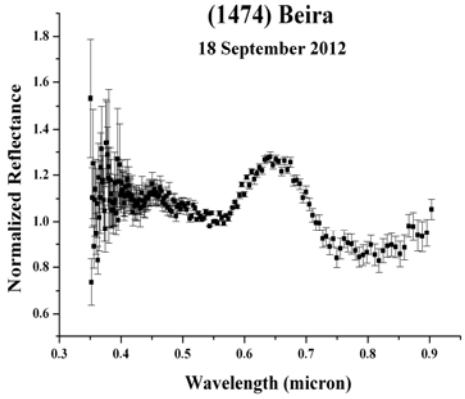

Fig. 4a. Averaged and normalized reflectance spectrum of (1474) Beira on 18 September 2012. The spectrum is obtained as an average of five spectra.

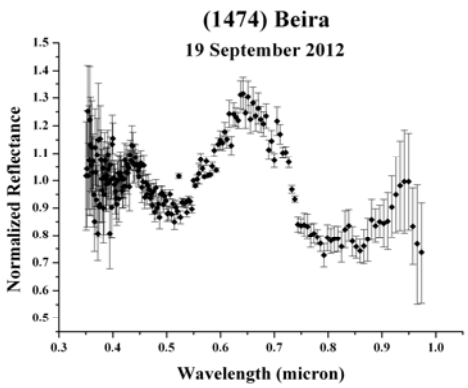

Fig. 4b. Averaged and normalized reflectance spectrum of (1474) Beira on 19 September 2012. The spectrum is obtained as an average of nine spectra.

According to taxonomic classification [3], Adeona is of Ch type, Interamnia – of B, Nina – of X, and Beira – of B. Values of geometric V-band albedo of Adeona, Interamnia, and Nina are 0.06, 0.08, and 0.16, respectively [4]. It should be emphasized that such type asteroids are expected to be primitive containing low-temperature compounds (hydrated silicates, oxides and hydro-oxides, organics, etc.) (e. g., [5]). Despite the previously assumed high-temperature mineralogy of Nina, radar observations showed that the asteroid is also primitive but has a heterogeneous composition [6]. This is confirmed by elevated standard deviations on Nina's averaged reflectance spectrum obtained from 12 separate reflectance spectra over about a half of its rotational period (Fig. 3).

We found [1, 2] unusual overall shapes of the reflectance spectra of Adeona, Interamnia, Nina (in the range ~0.4-0.6 μm), and Beira (in the range ~0.55-0.75 μm) at the times of these observations, appearing as a considerable growth of reflectivity in the short-wavelength range (up to ~30-40%) (Figs 1-4). Such maxima were absent in reflectance spectra of other asteroids observed by us at the Terskol observatory with the same facilities and nearly concurrently. At the time of our observations, Interamnia, Nina, and Beira were near their perihelion distances, when temperature on the surface reached a maximum near the subsolar point. At the same time, Adeona approaching to the Sun was close to its middle heliocentric distance. We proposed that the unusual visible-range increase in asteroid reflectivity could be a result of sublimation activity of the surface matter including water ice [1, 2].

Later, on 26 and 28 September 2016, we acquired spectral confirmation of sublimation activity on (779) Nina just before perihelion passage (Fig. 5). Nina's reflectance spectra obtained at gradually decreasing heliocentric distances demonstrate a dramatic change of the spectral slope from positive to neutral (nearly at the same rotational phases), produced likely by a growth of coma of sublimed water ice particles scattered reflected from the asteroid light in the short-wavelength range (Fig. 5, curves 2 and 3).

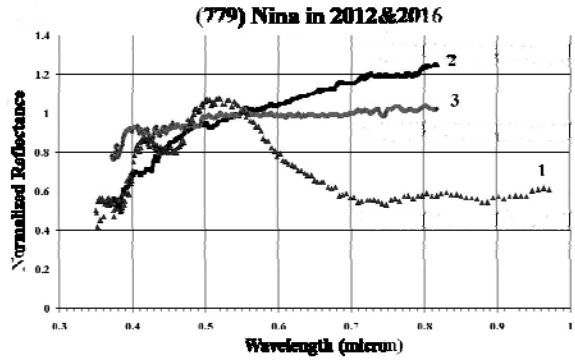

Fig. 5. Comparison of averaged and normalized reflectance spectra of (779) Nina (perihelion distance q = 2.0589 AU) obtained on 13 September 2012 (1, heliocentric distance r = 2.149 AU, after perihelion) and on 26 September 2016 (2, heliocentric distance r = 2.060 AU, before perihelion) and 28 September 2016 (3, r = 2.060 AU, before perihelion). Spectra on 26 and 28 September 2016 were acquired nearly at the same rotational phases of Nina and correspond to its successively decreasing heliocentric distance near perihelion.

Coclusions: Previous findings of cometary-like bodies among main-belt asteroids were interpreted in most cases as random events connected with "dynamical" contamination of the asteroid family with atypical icy objects (for instance, extinct comet nucleus), which become active only due to sporadic collisions or impacts (e. g., [7-8]). Another point of view is that free water ice is widespread in the subsurface interiors of primitive main-belt asteroids themselves (e. g., [9, 10]).

Our discovery of simultaneous sublimation activity on several main-belt primitive asteroids at shortest heliocentric distances supports the last opinion and points likely to the same or similar physical and chemical conditions of origin of the bodies corresponding to the outer edge of the main-belt and beyond.

References: [1] Busarev V. V. et al. (2015) *Icarus, 262,* 44–57. [2] Busarev V. V. et al. (2016) *Solar Sys. Res. 50,* 281–293. [3] Bus S. J. and Binzel R. P. (2002). *Icarus, 158,* 146–177. [4] Masiero J. R. et al. (2014) *Astrophys. J.*, *791*, 121–131. [5] Gaffey M. J. et al. (2002). In: Asteroids III (W. F. Bottke et al. eds.), Univ. of Arizona Press, 183–204. [6] Shepard M. K. et al. (2010). *Icarus, 208,* 221–237. [7] Hsieh H. H., Jewitt D. (2006) *Science 312*, 561–563. [8] Hsieh H. H. et al. (2011) *Aph J. 736*, L18–L23. [9] Schorghofer N. (2008) *Aph J. 682*, 697-705. [10] Rivkin A. S., Emery J. P. (2010) *Nature 464*, 1322–1323.