Ancient comet-like activities of Jupiter Trojans after being captured. E. Cho[1,2] and Y. J. Choi[1,2], [1]Korea Astronomy and Space Science Institute, 776 Daedeok-daero Yuseong-gu, Daejeon, Republic of Korea (jonjin4368@kasi.re.kr), [2]University of Science and Technology, 776 Daedeok-daero Yuseong-gu, Daejeon, Republic of Korea.

Introduction: It is believed that Jupiter Trojans (JTs) originated from the primordial trans-Neptunian disk [1,2], which is a source of dynamically hot Kuiper Belt Objects (hot KBOs) [3]. Similar H-distribution of JTs and hot KBOs reveals their common origin [4]. Centaurs are a transient population that orbits between Jupiter and Neptune and are dynamically related to the primordial disk [5]. Some Centaurs behave like comets by releasing gas and dust. The comet-like activities of the active Centaurs might be triggered from thermal energy increased by solar radiation [6].

Since JTs, hot KBOs, and Centaurs share a common origin, the primordial trans-Neptunian disk, their initial components had been possibly similar. Although high solar radiation at 5.2 AU would have already altered the components of JTs, there is a possibility that JTs had behaved like active Centaurs after being captured within the current location until their initial composition was exhausted enough to stop the activities. In this study, we explore the early evolutionary process of JTs after being captured by using a numerical model.

Model: Changes in external energy can alter the composition and structure of the object. As we assume a spherically symmetric object, the chemical and physical alteration causes a stratified distribution. Solar radiation and latent heat of sublimation and crystallization control the energy within each layer. At each layer, the energy flux variation can change the composition and structure. Ices can alter their phase or vaporize, and gases can refreeze according to temperature and pressure. The gases released from amorphous ice or sublimated from crystalline ice drag dust grains smaller than pore size and change the structure. These stratified changes affect energy distribution again. In this model, the mechanisms are solved with energy and mass conservation simultaneously at each layer and time step [7].

The energy conservation law is

$$\frac{\partial(\rho u)}{\partial t} + \nabla \cdot \left(\vec{F} + \sum_{\alpha} u_{g,\alpha} \vec{J}_{\alpha}\right) = \lambda \rho_{\alpha} H_{ac} - \sum_{\alpha} q_{\alpha} H_{\alpha}$$

The mass conservation laws of water ice/vapor are

$$\frac{\partial \rho_{\alpha}}{\partial t} = -\lambda \rho_{\alpha}$$

$$\frac{\partial \rho_{c}}{\partial t} = (1-f)\lambda \rho_{\alpha} - q_{v}$$

$$\frac{\partial \rho_{v}}{\partial t} + \nabla \cdot \vec{J}_{v} = q_{v}$$

More descriptions of this model can be found in Prialnik et al. (2004) [7].

Input parameters: Since JTs came from the primordial trans-Neptunian disk, we assume JTs as icy bodies with an initial temperature of 50 K. We set an initial bulk density to 1 g/cm^3 [8,9] and take a low albedo value of 0.04 [10].

Distribution of composition and structure affects the energy and mass evolution of the objects. To examine the early evolution of JTs with various initial conditions, we conduct a case study by changing input parameters as listed in Table 1. The mass fractions of trapped gases in amorphous water ice are put by Hillman and Prialnik (2012), which modeled Jupiter-family comets [11].

Table 1: Input parameters in this case study

Case	D/I[1]	Mass fraction of trapped gas ($CO/CO_2/NH_3$)	K_d[2]	Radius (km)	Initial water ice[3]
A	1	1.50/0.20/0.05	0.2	50	Am.
B	3	1.50/0.20/0.05	0.2	50	Am.
C	1	0.75/0.10/0.025	0.2	50	Am.
D	1	1.50/0.20/0.05	1.0	50	Am.
E	1	1.50/0.20/0.05	0.2	25	Am.
F	1	-	0.2	50	Cr.

[1] Dust to ice ratio; [2] Dust thermal conductivity (W/m/K)
[3] Am.: Amorphous; Cr.: Crystalline

Results and Discussion: When JTs moved from the primordial disk into the current location, the increasing solar radiation caused thermal and mechanical alteration within the bodies. The stratified alteration was affected by initial conditions, and some factors caused activities like those observed in active Centaurs.

Alteration by crystallization. Phase transition of water ice is a function of temperature. When the temperature increases, amorphous water ice can become a crystalline structure. Figure 1 is a result of alteration by the crystallization process. The crystallization front proceeds inward with increasing temperature (Figures 1a and 1b). During crystallization, gases trapped in amorphous water ice are released and flow up and down. Since the initial temperature is 50 K, downward gas flows refreeze below the crystallization front, except for CO, which has a low sublimation temperature (Figure 1c).

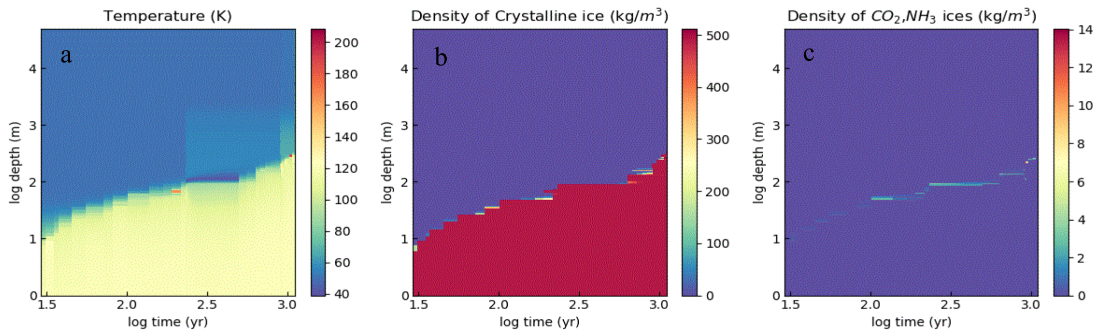

Figure 1: Alteration of (a) the temperature and densities of (b) crystalline water ice and (c) volatile ices.

Outbursts. The refrozen ices below the crystallization front disrupt the front movement by absorbing energy for ices sublimation. After the volatile ices below the front almost disappear, the crystallization is triggered. The crystallization process is exothermic, so the temperature nearby the front increases. The enhanced temperature causes a runaway of the crystallization front, resulting in massive gas flows. The upward gas flows accompany the dust flow by dragging dust grains from the interior. The sporadic massive flows appear at the surface as outbursts (Figures 2a-e). The outbursts would have stopped after the amorphous ice was almost exhausted within the objects. If the internal dust grains are less red because of unirradiated environments [12], the past dust outbursts might have changed JTs' color to be less red by recovering the surface. If some JTs had crystalline water ice initially instead of amorphous ice due to their formation sites, they would not have got any outbursts (Figure 2f). The absence of dust outbursts might have allowed their surface color to keep red.

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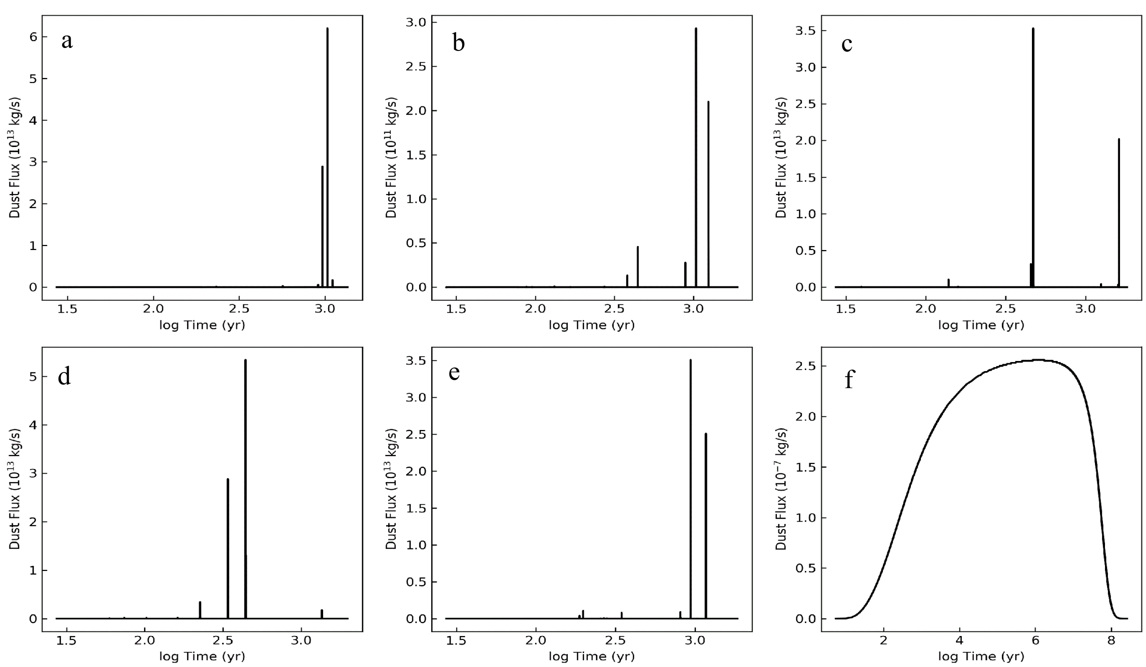

Figure 2: Dust flux profiles of (a) case A, (b) case B, (c) case C, (d) case D, (e) case E, and (f) case F.