Identification of Optical Component of North Toroidal Source of Sporadic Meteors and its Origin

T. Hashimoto • J. Watanabe • M. Sato • M. Ishiguro

Abstract We succeeded to identify the North Toroidal source by optical observations performed by the SonotaCo Network, which is a TV observation network coordinated by Japanese amateurs. This source has been known only for radar observations until now. The orbits of the optical meteors in the North Toroidal source are relatively large eccentricity and semi-major axis, compared with those of the radar meteors. In this paper, we report the characteristics of this North Toroidal source detected by optical observations, and discuss the possible origin and evolution of this source.

Keywords sporadic source · North Toroidal · optical method

1 Introduction

The major six sources of sporadic meteors were discovered mainly by radar observations: Helio (H) and Antihelio (HA), South and North Apex components (SA/NA), and South and North Toroidal (ST/NT). Due to the high efficiencies realized in modern radar technologies, high resolution and sensitive observations have been carried out on these sporadic sources (Campbell-Brown 2008). On the other hand, optical data has not been enough to study these sources until now. Especially, Toroidal sources have never been identified by optical method. In this paper, we report the first identification of the North Toroidal sources among the data obtained by the TV observation network coordinated by Japanese amateurs. We also report the characteristics of the orbits of meteors belonging to the NT source, and discuss the possible origin and evolution of this source.

2 Observational Material

We analyzed data collected by SonotaCo network, which is the coordinated monitoring observation network of automated detection for bright meteors or fireballs among amateur astronomers (SonotaCo 2009). We selected the meteors by using analysis software, UFOOrbit ver. 2.11 for securing well-determined orbits with the following conditions: length of the trail ≥ 1.5 degrees, the angle of the intersection of two apparent passes of trails' extension ≥ 10 degrees. The total number of the selected samples is 13,275. Among them, 5,341 meteors are judged to belong to 20 major meteor showers using

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the analysis software UFOAnalyzer Ver. 2. The rest of 7,934 meteors are thought to be sporadic meteors. The radiants of these 7,934 meteors are plotted in Figure 1.

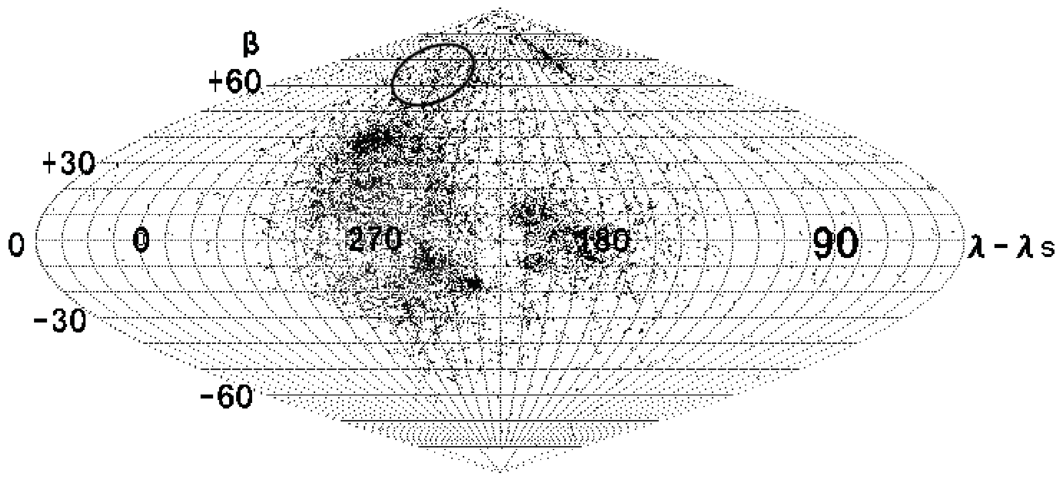

Figure 1. Distribution of radiant points of 7,934 sporadic meteors.

While it is clear that there are concentrations corresponding to HA, and SA/NA, there is also a weak concentration at around $\lambda - \lambda_{sun}$ = 230 ~ 290 degrees, and β = +50 ~ +80 degrees. This area corresponds to the NT source determined by radar observations. There are 410 meteors with radiants are located in this area.

3 Characteristics of Optical NT Meteors

Assuming these meteors belong to the NT source, we analyzed the characteristics of these meteors in order to compare to radar NT meteors. Due to the optical monitor, these meteors are relatively bright, including the fireball-class. Figure 2 shows the absolute magnitudes of detected optical NT meteors. This means that the original size of the optical NT meteoroids is larger than that of radar NT meteoroids.

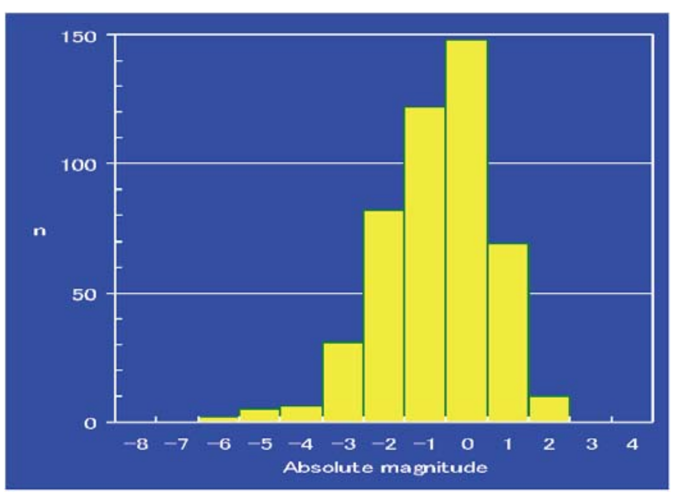

Figure 2. Absolute magnitude of optical NT meteors.

The orbital elements of the optical NT meteors are also different from radar NT meteors. Figures 3 and 4 indicate the distribution of their eccentricities and semi-major axes, respectively. Each figure contains the value of the radar NT meteors studied by Jones and Brown (1993) for comparison.

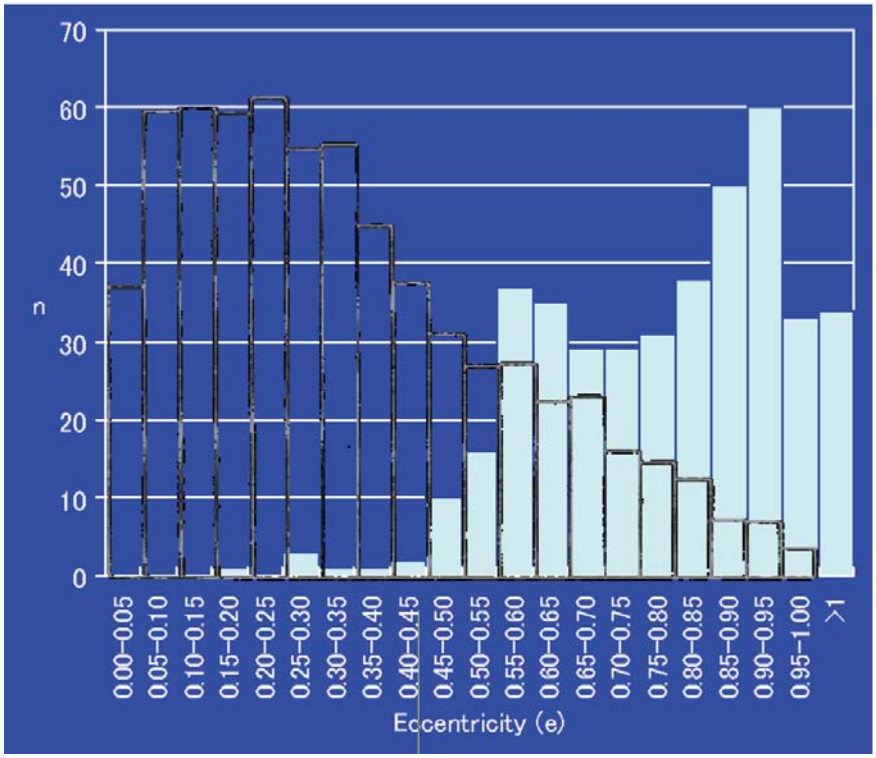

Figure 3. Distribution of eccentricity of optical NT meteors.

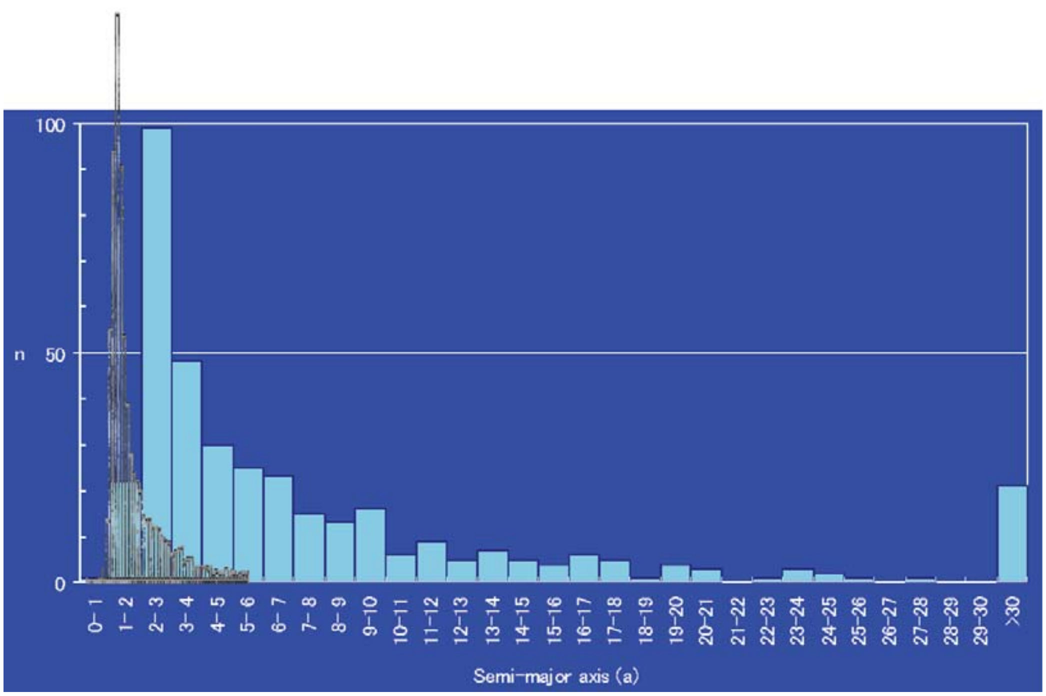

Figure 4. Distribution of semi-major axis of optical NT meteors.

The optical NT meteors have a more eccentric orbit with larger semi-major axis than the radar NT meteors. On the other hand, the inclination is not so different from radar NT meteors, as shown in Figure 5.

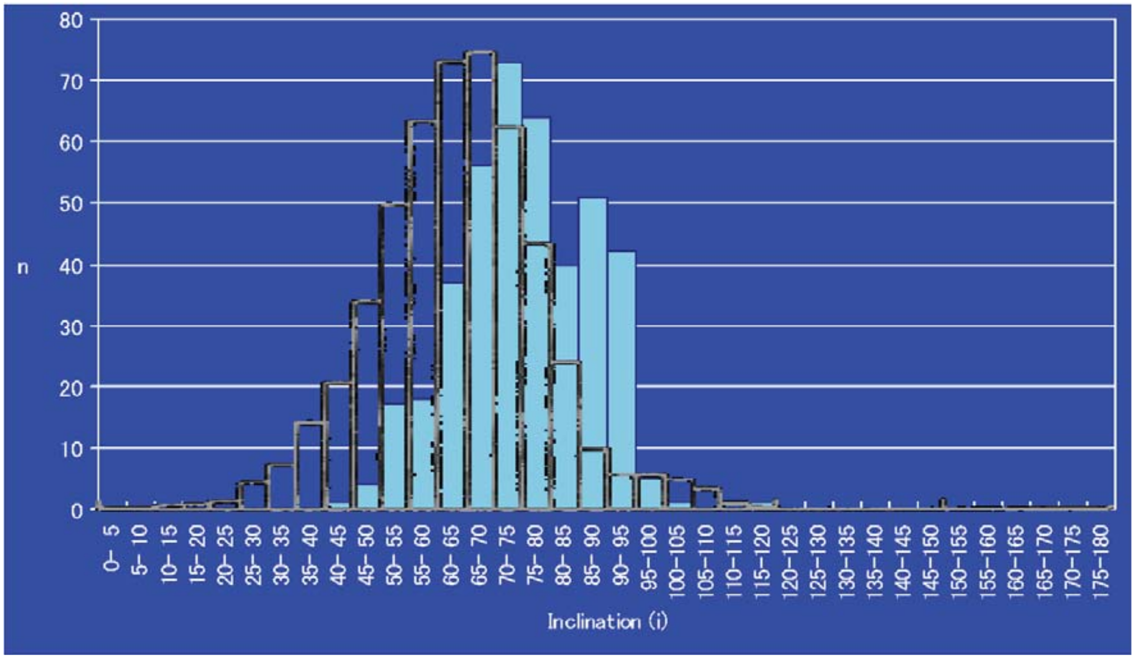

Figure 5. Distribution of inclination of optical NT meteors.

4 Origin of the NT

It is clear that the orbits of the NT meteors depend on their size such that larger eccentricity and semi-major axis with larger meteoroids, while the inclination is similar. This situation gives us a strong implication regarding the orbital evolution of the NT meteoroids. Because of the P.R. effect, the smaller meteoroids change their orbits faster than the larger ones. Even if the orbits of all the meteoroids of different size are the same initially as large eccentricity and semi-major axis, the orbits of smaller meteoroids shrink into smaller and circular orbits more rapidly than larger meteoroids. The NT meteoroids are thought to be a stage on the way of such orbital evolution. If so, we speculate that the parent object or objects should have been close to the orbit of larger-size meteoroids, namely large eccentricity and relatively large semi-major axis of more than a few A.U.

The theoretical evolutional tracks of the orbits of the NT meteoroids can be plotted in the *a*-*e* diagram. Within this diagram, the evolutional track depends strongly on the initial orbit, and not on the size of meteoroids. Smaller meteoroids evolve along the track into the smaller and circular orbits faster than larger meteoroids. Therefore, the observed distribution of the orbits of optical and radar NT meteoroids should be located in the one evolutional track if the origin is the same. It is important to find out any appropriate evolutional track which passes through the both observed components of the NT. Our preliminary trials show that two possible groups of evolutional tracks are plausible. One is a group of large-*e* & small-*a* orbits, and the other is that of large-*e* & large-*a* orbits. Figures 6 and 7 show the *a*-*e* diagrams with evolutional tracks of the two groups, respectively.

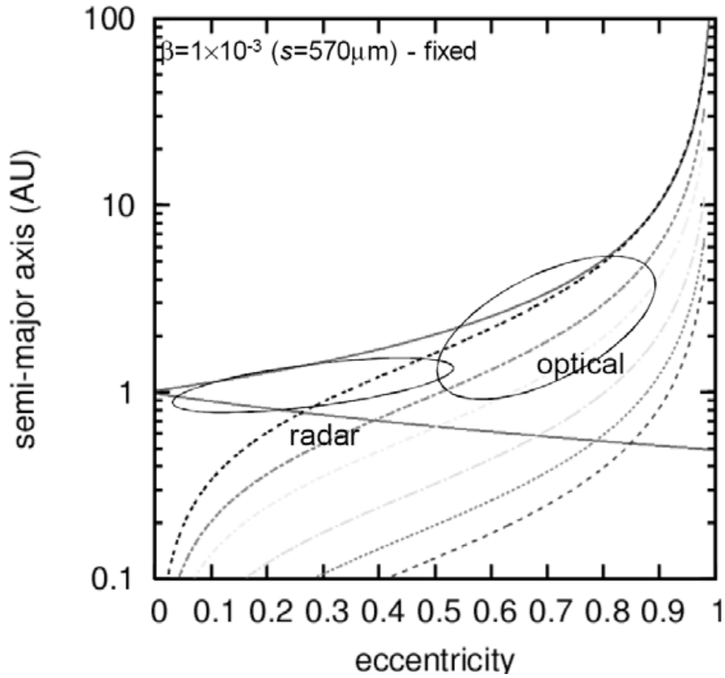

Figure 6. *a*-*e* diagram of the possible evolutional track of the meteoroids from large-*e* and large-*a* orbits.

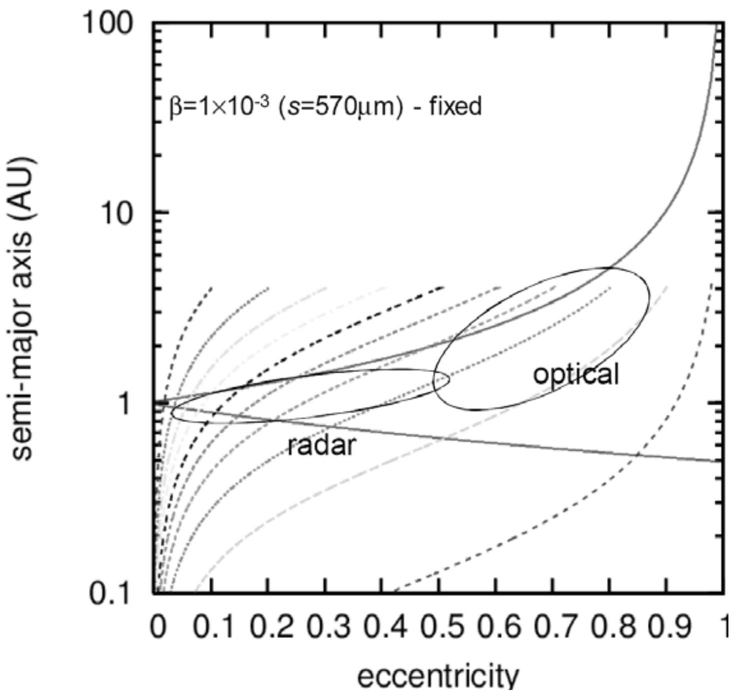

Figure 7. Same as Figure 6, but from large-*e* and small-*a* orbits.

The former group is suggesting high-inclined short-period comets, which was already suggested by Wiegert (2008). Although Wiegert et al. (2009) also tried to simulate the NT from the near-Earth asteroids, it seems to be impossible to explain the origin of the large-*a* meteoroids detected in optical NT, if we assume the origin of the NT is only one object.

However, it should be noted that there is an annual variation of the NT source. In our sample, the number of the optical NT increased in autumn and winter. Recent detailed study of the radar NT meteors by Campbell-Brown & Wiegert (2009) clearly shows that the NT has several components of different orbital characteristics. This suggests that the NT source has been originated from several different parent objects. Anyway, no definite candidate has been identified yet. Further studies should be needed to clarify the origin of the NT source.

5 Conclusion

We identified the optical component of the North Toroidal source that the size of the meteoroids is larger than that detected by the radar method. These larger NT meteoroids have different orbital characteristics; larger eccentricity and semi-major axis than those of the radar NT meteoroids. This strongly suggests the orbital evolution of the meteoroids in the NT source by the P.R. effect. One of the possible parent(s) of the NT source should have larger eccentricity and semi-major axis of a few or much larger values.

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