# Orbital evolution of Geminids and Quadrantids by middle and upper atmosphere radar observations

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A meteor head echo is caused by radio waves scattering from the intense region of the plasma surrounding and co-moving with a meteoroid during atmospheric entry at about 70–130 km altitude. Meteor head echo observations were carried out using the high-power large-aperture (HPLA) Kyoto university Shigaraki middle and upper atmosphere (MU) radar in Japan (34.85° N, 136.10° E). The 46.5 MHz MU radar consisting of 475 crossed Yagi antennas has a nominal transmitter peak power of 1 MW and comprises a circular, phased-array antenna with a diameter of 103 m. The MU radar beam was pointed in the zenith direction with the field of view of $\sim 15°$. Since 2009 the atmospheric trajectories and interplanetary orbital elements have been derived using the MU radar meteor head echoes (e.g. [1–3]). More than 140,000 sets of orbital elements of meteors were obtained until January 2014. Typical errors for velocity and perihelion distance are 0.25 km/s and 0.003 au, respectively. Such a huge number of meteoroid orbits with precise orbital accuracies has not been observed before. Here we report population of 2009–2013 Geminid and 2014 Quadrantid meteoroids. The orbits of Geminids' meteoroids, whose parent body is a comet-asteroid transition object (3200) Phaethon [4], were observed in 2009 ($n = 163$), 2010 ($n = 310$) and 2013 ($n = 513$) whereas Quadrantids ($n = 223$), whose parent body is 2003 $EH_1$ [5], were obtained in 2014. Figure shows radiant distributions (RA & DEC) and orbital elements (perihelion distance - eccentricity) of Geminids as a function of the Radar Cross Section (RCS) which is approximately a linear function of the log of electron line densities of a meteor trail corresponding to a meteoroid mass. The meteoroid orbital evolution of Geminids and Quadrantds considering Poynting-Robertson drag will be discussed compared with their parent bodies.

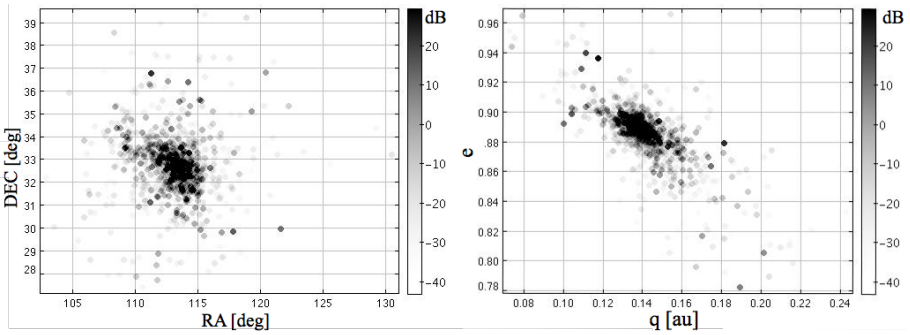


**Figure:** Radiants and orbital elements of 2009–2013 Geminids as a function of RCS (Radar Cross Section).

**References:** [1] Kero J. et al., (2011): First results from the 2009–2010 MU radar head echo observation programme for sporadic and shower meteors: the Orionids 2009, MNRAS 416, 2550–2559. [2] Kero J. et al., (2012): The 2009–2010 MU radar head echo observation programme for sporadic and shower meteors: radiants and diurnal rates, MNRAS 425, 135–146. [3] Kero J., Szasz C., Nakamura T., (2013): MU head echo observations of the 2010 Geminids: radiant, orbit, and meteor flux observing biases, Ann. Geophys. 31, 439–449. [4] Jewitt D., et al. (2012): The Dust Trail of Asteroid (3200) Phaethon [5] Jenniskens, P. (2004) :2003 EH1 Is the Quadrantid Shower Parent Comet, AJ 127, 3018–3022.