Daytime Arietids and Marsden Sunskirters (ARI, IAU #171)

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During routine low-light level video observations with CAMS (Cameras for All-sky Meteor Surveillance) in June of 2011, four Daytime Arietid meteors were triangulated during the hour before dawn. The measured orbital elements are in good agreement with the linked orbit of the Marsden Sunskirter group comet C/1999 J6 = C/2004 V9 = P/2010 H3. Unlike results from past radar observations of this daytime shower, and prior less accurate multi-station video observations, there is no longer a discrepancy in semi-major axis. This result firmly establishes the association of the Daytime Arietids with the Marsden Sunskirter group of comets.

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1 Introduction

The Daytime Arietids (ARI, IAU#171) are a daytime shower with a radiant only ~ 30° from the Sun. Nevertheless, a visual observer can observe the shower in the early morning in the first three weeks of June, in the hour before dawn, with rates of 1 − 2 per hour at best. Because of that, the shower can also be targeted in video observations (Fujiwara et al., 2004).

The Daytime Arietids have been associated with the Marsden group of "sunskirter" comets (Seargent, 2002; Sekanina & Chodas, 2005; Jenniskens, 2006), currently with ~ 38 known comet members. These have orbits that come as close as 0.025 AU from Earth orbit. Most of these small, tens of meter sized comets are only seen when they are very close to the Sun and cross the field of view of the SOHO and STEREO satellites. However, some apparitions have been linked, by predicting the return of the comet successfully. It is now known, that ~ 35 meter sized Marsden group comet C/1999 J6 broke into C/2004 V9 and C/2004 V10 (Marsden, 2004), and that the brighter C/2004 V9 re-appeared as C/2010 H3 (Marsden, 2010b; Marsden, 2010a). From that we know that the orbital period of this comet is 5.5 years (semi-major axis 3.117 AU).

The proposed association had, until now, a glaring problem: radar observations of the Daytime Arietids claimed a much shorter orbit for the meteoroids than is measured for the comet fragments. The Harvard Radar Project measured a mean semi-major axis of 1.750 AU (Sekanina, 1973) and 1.376 AU (Sekanina, 1976) based on 55 and 48 meteors, respectively. More recently, CMOR radar observations (Campbell-Brown, 2004) measured a semi-major axis decreasing from $a = 2.2$ AU at 70° solar longitude to 1.6 AU at 86°.

If the meteoroids were formed at the same time that the Marsden sungrazer parent comet broke into the family of objects now observed by SOHO and STEREO, then the meteoroids should have a semi-major axis similar to those of the comet fragments (Ohtsuka et al., 2003). Jupiter perturbs the orbit near aphelion, but does not easily change the semi-major axis. If the meteoroids originated from an earlier fragmentation event that left comet 96P/Machholz, then the meteoroid orbits might be more dispersed from planetary perturbations over time, but should still have a semi-major axis not much different than those of the remaining comet fragments.

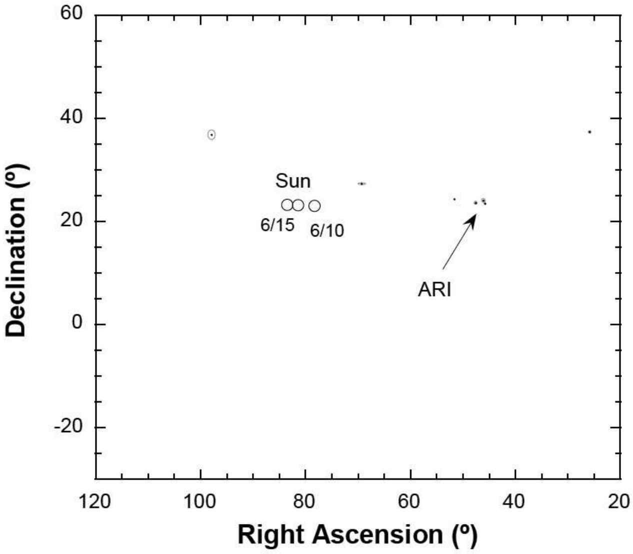

Figure 1 – Radiant position of CAMS meteors in the daytime sky during 2011 June 2–15. Arrow marks the Daytime Arietids.

2 CAMS: Cameras for All-sky Meteor Surveillance

CAMS is a three-station 60-camera meteor surveillance using Watec Wat902 H2 Ultimate cameras with f1.2/12-mm focal length lenses. During June 2011, the CAMS network stations were located at Fremont Peak Observatory, at Lick Observatory, and at a rural location near Lodi, California. The CAMS methods have been described in detail in previous work (Jenniskens et al., 2011), and more information about the CAMS network can be found on the web-site `http://cams.seti.org`.

3 Detection of the Daytime Arietids

Here, we report on the detection of four Daytime Arietids during routine observations on June 10, 13 and 15, 2011. The meteors were captured in the hour before dawn. Weather permitted observations in that time

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Table 1 – Daytime Arietid radiant (α, δ), speed (V_g), deceleration parameters (a_1, a_2), beginning and end height (H_b, H_e), peak absolute visual magnitude (m_V), and lightcurve asymmetry parameter (F).

Time (UT)	Date m/d/y	α (°)	δ (°)	V_g (km/s)	a_1 (km/s^2)	a_2 (/s)	H_b (km)	H_e (km)	m_V (magn.)	F
$11^h34^m42^s$	6/10/11	45.85 ±0.22	+23.50 ±0.24	42.06 ±0.03	0.000 ±0.03	0.174 ±0.034	103.6 ±0.09	95.8 ±0.16	+0.8	0.49
$11^h51^m32^s$	6/10/11	46.12 ±0.39	+24.09 ±0.38	41.49 ±0.18	0.000 ±0.01	0.034 ±0.089	98.4 ±0.06	95.7 ±0.07	+3.4	0.17
$12^h03^m42^s$	6/13/11	47.60 ±0.33	+23.63 ±0.30	43.73 ±0.33	0.201 ±0.12	3.068 ±0.68	97.1 ±0.22	87.4 ±0.21	+1.1	0.41
$11^h34^m06^s$	6/15/11	51.68 ±0.07	+24.33 ±0.07	40.91 ±0.04	0.001 ±0.000	5.156 ±0.26	101.6 ±0.03	90.1 ±0.05	+0.2	0.46

Table 2 – Orbital elements of Daytime Arietids ($J2000$).

Time (UT)	$\lambda_\odot$ (°)	a (AU)	q (AU)	e (°)	i (°)	ω (°)	Ω (°)	Π (°)
$11^h34^m42^s$	79.114	2.992	0.0588 ±0.0017	0.980 0.001	25.950 0.94	25.43 0.43	79.120 0.000	104.55 0.43
$11^h51^m32^s$	79.125	2.835	0.0664 ±0.0040	0.977 0.001	26.11 1.08	26.92 0.93	79.132 0.000	106.06 0.93
$12^h03^m42^s$	82.000	3.513	0.0422 ±0.0034	0.988 0.001	30.57 0.97	21.77 0.92	82.005 0.001	103.78 0.82
$11^h34^m06^s$	83.891	2.608	0.0663 ±0.0007	0.975 0.001	21.19 0.12	26.62 0.15	83.898 0.000	110.52 0.15
CAMS $\sigma(N=4)$	81.0 (±4)	3.0	0.0584 ±0.0114	0.980 ±0.003	26.0 ±3.8	25.1 ±2.3	81.0 ±2.3	106.2 ±3.0
CMOR: σ	78.5 (±3)	1.6 ±0.4	0.088 ±0.003	0.94 ±0.03	29 ±6	27 ±4	78.5 ±3	105.5 ±4
SonotaCo: $\sigma(N=8)$	82.2 ±3.5	2.1 ±0.6	0.064 ±0.013	0.967 ±0.014	31.1 ±7.6	24.9 ±2.5	82.2 ±3.5	107.1 ±1.6
Fujiwara: $\sigma(N=3)$	77.8 ±2.2	2.6 ±0.8	0.073 ±0.006	0.97 ±0.01	32.0 ±3.3	27.0 ±0.2	77.8 ±2.2	104.9 ±2.1
Marsden group comet: C/1999 J6	78.4	3.117	0.0478	0.9847	23.964	25.019	78.359	103.378

interval also on June 9 and 14, but without further detections.

The trajectory data of these four meteors are listed in (Table 1). The time and date of each meteor is given, as well as the geocentric radiant position and speed (equinox J2000), the deceleration parameters a_1 and a_2, where deceleration as a function of time equals $a = a_1 \exp(a_2 t)$, the beginning and end height, the absolute visual magnitude of the peak of the light curve and the light curve asymmetry parameter F. For definitions, see (Jenniskens et al., 2011).

In total, 512 meteors were triangulated between June 1 and 15. The four Daytime Arietids stand out well as a tight cluster of three radiants in the daytime sky and one slightly to higher right ascension Figure 1. The cluster of three CAMS Daytime Arietids has a mean radiant of $\alpha = 46.5 \pm 0.^\circ 9$, $\delta = +23.7 \pm 0.3$, and $V_g = 42.4 \pm 1.2$ km/s. All of the other 508 radiant positions fall outside of Figure 1.

The orbital elements calculated from the radiant and speed are given in (Table 2). Based on the calculated error bars, there is significant dispersion in perihelion distance (q), eccentricity (e), inclination (i), argument of perihelion (ω), and longitude of perihelion (Π).

4 Discussion and conclusion

Table 1 compares our results to the mean of the three Daytime Arietid orbits measured with intensified video cameras published by Fujiwara et al. (Fujiwara et al., 2004) and orbits reported by the SonotaCo network (SonotaCo, 2009) with mostly wider field low-light level cameras. Eight meteors in the SonotaCo database (2007 – 2009) are marked "Arietids". Another meteor marked "sporadic" is likely also an Arietid. One of these, however, has a 10° lower longitude of perihelion and may not be a member of the stream. With the exception of this meteor, the radiant position and speed are in general agreement with our data, but more widely scattered. Unlike our data, the geocentric speed correlates only weakly with semi-major axis, for unknown reason. The speeds are not corrected for deceleration.

Our new orbits have semi-major axis in the range $a = 2.6 - 3.5$ AU, higher than previously reported. When taking all low-light-level video orbits together, and after excluding three outlayers with low declination and speed, the mean geocentric speed is still higher than the 35.7 km/s quoted in the IAU database, higher even than the 39.4 km/s derived from the CMOR results after correction for deceleration. The radiant drift is $+0.87°$ per degree solar longitude (instead of $+0.70°$) in R.A. and $+0.07°$ (instead of $+0.60°$) in Declination. The velocity does not significantly change with solar longitude. During the peak of the shower at 78.5° solar longitude (Campbell-Brown, 2004), the CAMS measured radiant would be at $\alpha = 44.3°$, $\delta = +23.5°$, $V_g = 42.4$ km/s.

It is unclear why the radar observations show a much smaller semi-major axis on average than our optical observations. It is possible that the deceleration of the meteoroids was not accurately taken into account. The deceleration correction in the radar observations is based on a mean behavior for other showers with known speed (Campbell-Brown, 2004).

On the other hand, the decelerations measured for the four CAMS Daytime Arietids are not unusual, perhaps even on the low side (Table 1). For comparison, all 512 meteors detected by CAMS in this time period had a mean $a_1 = 0.17 \pm 0.85$ km/s^2, and $a_2 = 2.1 \pm 5.3$ /s (1 sigma variation).

All optical observations together show q decreasing with -0.0026 AU/° and ω decreasing with -0.59 °/° (between solar longitude 76° and 86°). Other parameters do not vary significantly. Some of that variation may be related to particle density, as the beginning height of the meteors also decreases with -0.56 km/°, while the mean magnitude stays constant. CMOR results (Campbell-Brown, 2004) also showed a decrease of perihelion distance (-0.001 AU/°) and decrease of argument of perihelion with solar longitude (-0.6 °/°), the most striking variations.

In Table 2, the CAMS results are compared to the linked orbit of Marsden group comet C/1999 J6 = 2004 V9 = 2010 H3 (for Epoch 2010), calculated by Syuichi Nakano (Nakano, 2008). There is good agreement between the CAMS orbital data and the linked Marsden group comet within the error bars calculated from the measurement uncertainty. This establishes the proposed association of the Daytime Arietids with the Marsden Sungrazer group. It is now possible that the meteoroids are debris from the breakup that created the Marsden group family of comets, or derived from an earlier fragmentation that left 96P/Machholz.

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