Confirmation of the July Gamma Draconids (GDR, IAU #184)

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During routine low-light level video observations with CAMS (Cameras for All-sky Meteor Surveillance) made in the month of July 2011, we detected the July Gamma Draconids (GDR), a meteor stream discovered by P. Babadzhanov in 1963, and observed by the SonotaCo Network in 2007–2008. The stream is included in the IAU Working List of Meteor Showers as shower #184, awaiting verification. We detected this shower beginning on July 24, through its peak on July 28, and to the shower's end on August 1. Our mean orbital elements are $q = 0.978 \pm 0.001$ AU, $1/a = 0.022 \pm 0.005$ AU^{-1}, $i = 40\overset{\circ}{.}24 \pm 0\overset{\circ}{.}20$, $\omega = 202\overset{\circ}{.}31 \pm 0\overset{\circ}{.}22$, and $\Omega = 124\overset{\circ}{.}66 \pm 0\overset{\circ}{.}37$ ($N = 25$). The GDR meteors move in an intermediate long-period comet orbit with orbital period between 270 and 600 years. The parent body remains undiscovered.

Received 2011 December 1

1 Introduction

The IAU Working List of Meteor Showers contains more than 300 unconfirmed minor showers that need verification. A new network of low-light level video cameras has been established in Northern California with the goal to confirm these showers existence. Each verified minor shower can be used to identify a parent body among the recent Near Earth Object discoveries and trace its origins and three dimensional dust distribution back in time (Jenniskens et al., 2011).

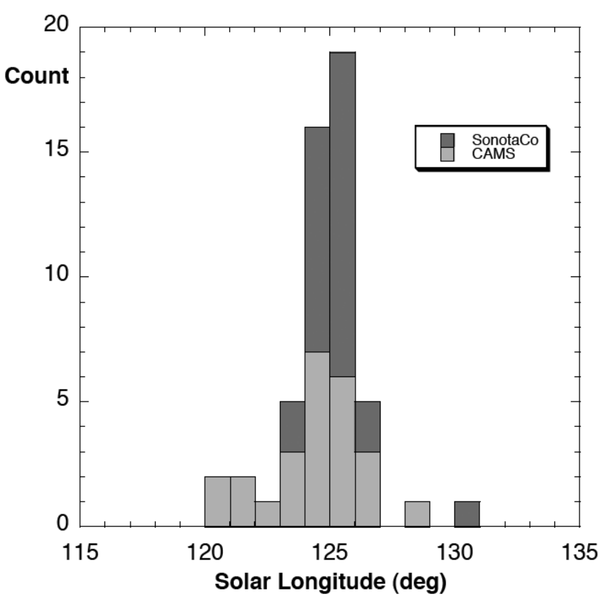

Figure 1 – Activity curve of July Gamma Draconids from SonotaCo and CAMS data.

Here, we report on observations made during the month of 2011 July, which confirm the July Gamma Draconids shower. This shower was first recognized by Pulat Babadzhanov (Babadzhanov, 1963), based on only three photographed meteors with anomalous radiant, speed, and orbital elements. Based on the provided B1950 coordinates, it was included in the working list of Jenniskens (2006) with geocentric radiant (J2000) of $\alpha = 278\overset{\circ}{.}8$, $\delta = +48\overset{\circ}{.}8$, and $V_g = 25.1$ km/s. It was also noticed by the SonotaCo meteor video survey of 2007–2008 made in Japan (SonotaCo, 2009), initially designated as IAU #344 (JUG), before it was recognized to be the same shower as #184. Shower #344 was subsequently dropped from the IAU Working List.

Based on 22 orbits from the solar longitude period $\lambda_\odot = 121\overset{\circ}{.}8$–$125\overset{\circ}{.}3$, SonotaCo put the radiant on July 28 at $\alpha_\mathrm{p} = 280\overset{\circ}{.}1$ (drifting by $+1\overset{\circ}{.}17$/day), $\delta_\mathrm{p} = +51\overset{\circ}{.}1$ (drifting by $+1\overset{\circ}{.}45$/day), and speed $V_g = 27.4$ km/s using a 4° diameter circle for shower association. The 2007–2009 database contains 27 meteors associated with this shower (labeled "J5_jug"), shown in Figure 1. This shower is noticeably absent from the Canadian Meteor Orbit Radar (CMOR) observations made from 2001 to 2008 (Brown et al., 2009). The shower was also not (yet) detected in single-station video observations in the IMO Video Meteor Network, part of which overlapped the SonotaCo observing time interval (Molau and Rendtel, 2009).

2 CAMS: Cameras for All-sky Meteor Surveillance

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

3 Confirmation of the July Gamma Draconids

On a graph of the July 2011 results plotted in right ascension and declination (Figure 2), one shower stood out immediately at high ca. +50° declination. Checking against the IAU Working List of Meteor Showers, the radiant location, duration and peak solar longitudes, and geocentric velocity corresponded to the July Gamma Draconids (GDR, IAU #184), awaiting confirmation.

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IMO bibcode WGN-401-holman-gdr
NASA-ADS bibcode 2012JIMO...40...36H

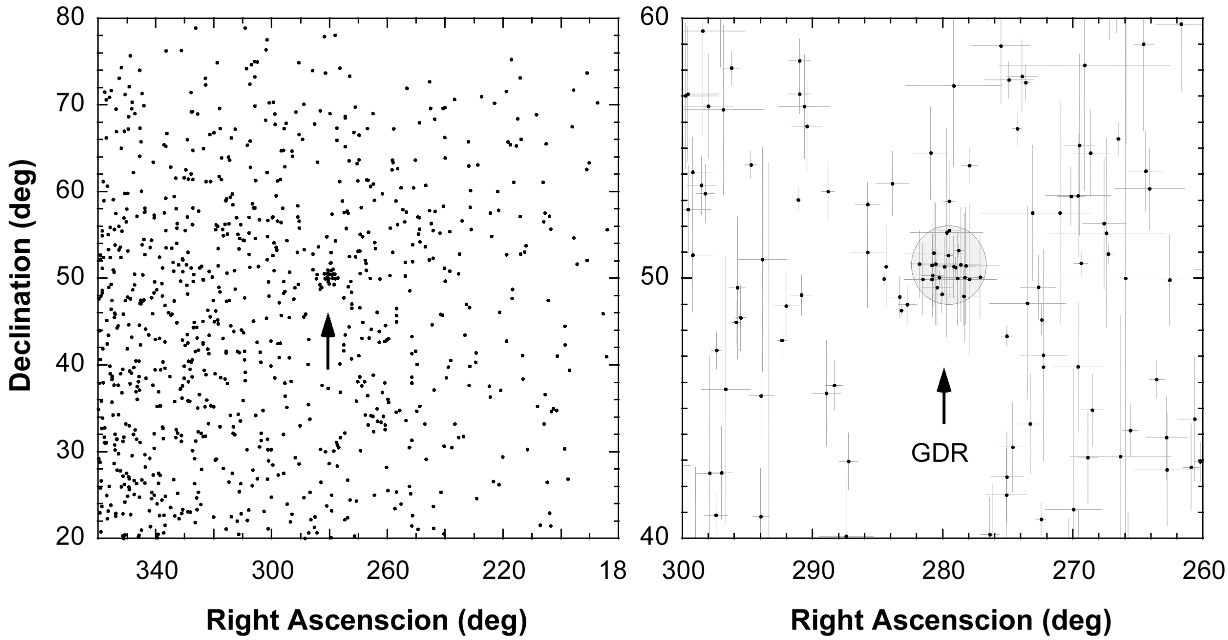

Figure 2 – The cluster of GDR orbits stands out clearly against the sporadic background of orbits recorded during July 2011 (*left*). A close-up of the GDR cluster is shown (*right*).

Table 1 – Orbital elements of July gamma Draconids ($D_{SH} < 0.1$).

Date	α	δ	V_g	q	e	i	ω	Ω	D	D_{SH}
2011-07-24	279°.69	+51°.76	28.37	0.981	0.981	41°.97	201°.50	120°.93	0.037	0.099
2011-07-24	280°.45	+49°.65	27.79	0.972	0.956	40°.92	204°.37	120°.97	0.028	0.060
2011-07-25	281°.79	+50°.55	28.68	0.973	0.986	42°.28	203°.83	121°.90	0.044	0.060
2011-07-25	280°.06	+49°.36	28.16	0.972	0.999	40°.96	204°.00	121°.91	0.030	0.050
2011-07-26	281°.53	+49°.97	27.65	0.972	0.941	40°.87	204°.42	122°.92	0.040	0.045
2011-07-27	279°.50	+51°.84	27.79	0.983	0.971	41°.03	200°.97	123°.79	0.022	0.048
2011-07-27	279°.88	+50°.45	28.58	0.977	1.035	41°.40	202°.29	123°.85	0.027	0.034
2011-07-27	280°.82	+49°.97	28.07	0.974	0.990	40°.98	203°.55	123°.86	0.024	0.027
2011-07-28	280°.83	+50°.52	28.03	0.976	0.988	41°.02	202°.87	124°.68	–	–
2011-07-28	277°.94	+49°.96	27.59	0.980	1.020	39°.74	201°.54	124°.72	–	–
2011-07-28	277°.13	+50°.05	26.62	0.982	0.968	38°.66	201°.21	124°.74	–	–
2011-07-28	280°.78	+50°.12	28.12	0.975	1.001	40°.95	203°.17	124°.75	–	–
2011-07-28	278°.39	+49°.31	27.14	0.977	0.991	39°.17	202°.55	124°.82	–	–
2011-07-28	280°.29	+50°.03	27.81	0.975	0.992	40°.48	202°.99	124°.87	–	–
2011-07-28	278°.87	+50°.00	26.61	0.978	0.940	38°.99	202°.43	124°.91	–	–
2011-07-29	279°.03	+50°.42	27.17	0.980	0.974	39°.63	201°.80	125°.65	0.005	0.012
2011-07-29	278°.31	+50°.03	26.69	0.980	0.961	38°.87	201°.80	125°.66	0.023	0.025
2011-07-29	280°.53	+50°.56	26.67	0.977	0.915	39°.50	202°.90	125°.68	0.061	0.066
2011-07-29	278°.22	+50°.49	26.97	0.981	0.975	39°.27	201°.22	125°.73	0.011	0.016
2011-07-29	278°.78	+51°.07	27.13	0.982	0.968	39°.73	201°.03	125°.79	0.009	0.016
2011-07-29	279°.17	+50°.44	27.42	0.979	0.990	39°.88	201°.74	125°.86	0.014	0.020
2011-07-30	278°.63	+50°.53	26.95	0.981	0.973	39°.24	201°.28	126°.63	0.012	0.027
2011-07-30	280°.67	+50°.98	27.75	0.979	0.985	40°.61	202°.01	126°.66	0.016	0.037
2011-07-30	279°.57	+50°.89	27.72	0.980	1.040	40°.31	201°.34	126°.69	0.010	0.028
2011-08-01	279°.58	+51°.21	27.02	0.982	0.967	39°.54	200°.92	128°.45	0.011	0.056
Average	279°.62	+50°.41	27.54	0.978	0.972	40°.24	202°.31	124°.66	0.024	0.040
±	0°.23	0°.13	0.12	0.001	0.005	0°.20	0°.22	0°.37	–	–
σ	1°.17	0°.63	0.62	0.003	0.025	0°.99	1°.10	1°.84	0.015	0.023

Our data show good agreement with the mean radiant position and speed and the shower duration reported by SonotaCo (2009). Our mean radiant position is at $\alpha = 279\overset{\circ}{.}62 \pm 0\overset{\circ}{.}23$ and $\delta = 50\overset{\circ}{.}41 \pm 0\overset{\circ}{.}13$, which fits well inside of the radiant distribution circle presented in the above reference. Twenty-four radiant points fit inside a circle sized 3° (encircled gray area in Figure 2). All have entry speeds of $V_g = 27.54 \pm 0.62$ km/s. One more possible GDR was identified in data from August 1 after inspecting the August 1–7 period using the D-criterion against the mean orbital elements derived from the July data. This brings the total to 25 shower candidates in the period July 24 through August 1 (Table 1).

Figure 3 shows those 25 radiant coordinates plotted against solar longitude. The solid lines show the drift rates given by SonotaCo (2009). The dashed line is a least-squares fit to our data, showing a much lower declination drift, and a negative right ascension drift, contrary to what has been reported by SonotaCo. Using the slopes of the regression lines, we measure these drift rates to be $-0\overset{\circ}{.}24$/day in right ascension, and $+0\overset{\circ}{.}07$/day in declination. However, the correlation coefficients for these regression lines are very low at $R = 0.37$ in right ascension and $R = 0.20$ in declination.

There is also a drift in speed, at −0.20 km/s per degree of solar longitude, with a more significant regression coefficient of $R = 0.60$. In fact, the 27 meteors identified as July Gamma Draconids in the most recent SonotaCo database have a radiant drift of $-0\overset{\circ}{.}20$/day in right ascension and $+0\overset{\circ}{.}28$/day in declination, in good agreement. Three have slightly higher velocity. Combined data, minus the higher velocity candidates ($N = 49$), have a radiant drift of $-0\overset{\circ}{.}23$/day in right ascension and $+0\overset{\circ}{.}14$/day in declination, and a drift in speed of −0.18 km/s per day.

The duration of the shower given by SonotaCo is $7\overset{\circ}{.}0$ in solar longitude, ranging from $\lambda_\odot = 121\overset{\circ}{.}8$ to $\lambda_\odot = 128\overset{\circ}{.}8$, with a mid-point at $\lambda_\odot = 125\overset{\circ}{.}3$, which is also the value given for the peak. Our data show a duration of $7\overset{\circ}{.}52$ degrees in solar longitude, starting at $\lambda_\odot = 120\overset{\circ}{.}93$ and ending at $\lambda_\odot = 128\overset{\circ}{.}45$, with the midpoint between our two best nights occurring at $\lambda_\odot = 125\overset{\circ}{.}3$, in good agreement. SonotaCo reports a geocentric velocity of 27.4 km/s, with an allowable error of ±3.0 km/s for their shower associations. Our results show a mean geocentric velocity of 27.54 ± 0.12 km/s for our GDR candidates, in good agreement. Here, the error is that of mean value, not the standard deviation of individual orbits. Both are listed in Table 1.

4 Orbital elements

The GDR candidates also stand out when graphed in terms of their orbital elements, inclination and longitude of perihelion (Figure 4). Note that the distribution of the GDR orbits, while dispersed, does not appear to be Gaussian in either Figures 2, *right*, and 4, *right*.

The GDR meteor candidates have mean heliocentric velocities of 41.57 km/s that are very close to the parabolic limit of 42.13 km/s, and four candidates have eccentricities just above 1 and negative values for $1/a$ due to inaccuracies in the calculation of their semi-major axes (Table 1). We used the orbital elements from our best night, July 28, as a comparison to check the validity of all other GDR candidate orbital elements. The D-criteria procedure is described in detail by Jenniskens and Gural (2011) and Jenniskens (2008). Here, two different types of D-criteria were examined: D and D_{SH}. The mean eccentricity of the other candidates is substituted for the four candidates with $e > 1.0$. These D-criterion test values are shown in Table 1. All of the resulting D_{SH} values are below the often adopted cut-off level of $D_{SH} \leq 0.15$ (see the above-mentioned references), and the similarly low values for D indicate that these orbits are related, so these meteors are verified as GDR shower members.

The magnitude range of the GDR meteors is +0.2 to +4.0, with a mean absolute magnitude (at 100 km distance) of $M_v = +2.3$. The magnitude distribution index averages $\chi = 1.8 \pm 0.3$ for three magnitude intervals. The light curve F-values range from 0.19 to 0.91, with a mean value of $F = 0.61$. Nineteen GDR meteors have F-values above 0.5, and six have lower values, from 0.19 to 0.48, suggesting most peak late during entry, typical for somewhat more cohesive materials. The GDR meteors tend to have a beginning height from the middle to the top range of other observed meteors with similar entry speeds (93–104 km), with one GDR at the lowest end of the range (86 km). These penetration depths are consistent with a cometary origin.

5 Discussion

The Earth intercepts the GDR steam at its descending node, just before the stream reaches perihelion (Figure 5, perihelion position marked "GDR"). Locations and distribution of ascending node points are shown in Figure 6. Most tend to pass just behind the orbit of Uranus. These ascending nodes scatter around $r_\Omega = 19.7$ AU, somewhat beyond the orbit of Uranus at 19.1 AU. The clustering of orbits behind the orbit of Uranus might suggest that this comet was captured by Uranus in a previous orbit.

The GDR orbit semi-major axes, a, ranges from 11.5 to 771.7 AU ($N = 21$), not including the four orbits with longer (> 1000 AU) but unspecified values of a. The aphelion distances are larger than 22 AU and the orbital periods longer than 39 years. The mean value of $1/a$ is $+0.019 \pm 0.005$ AU, corresponding to $a = 53 \pm 20$ AU. Such an orbit would have an orbital period of about 380 years, at the border of intermediate long-period comets ($P > 200$ years) and the shorter Halley-type comet orbits, both originating from the Oort cloud.

The observed radiant and velocity drift translate into a significant daily drift of the longitude of perihelion of $+0\overset{\circ}{.}56$ per degree of solar longitude ($N = 49$, $R = 0.80$), and a decreasing inclination of $-0\overset{\circ}{.}31$ per degree of solar longitude ($R = 0.66$). Such variations are expected only if the comet or meteoroid orbits had significant precession over time.

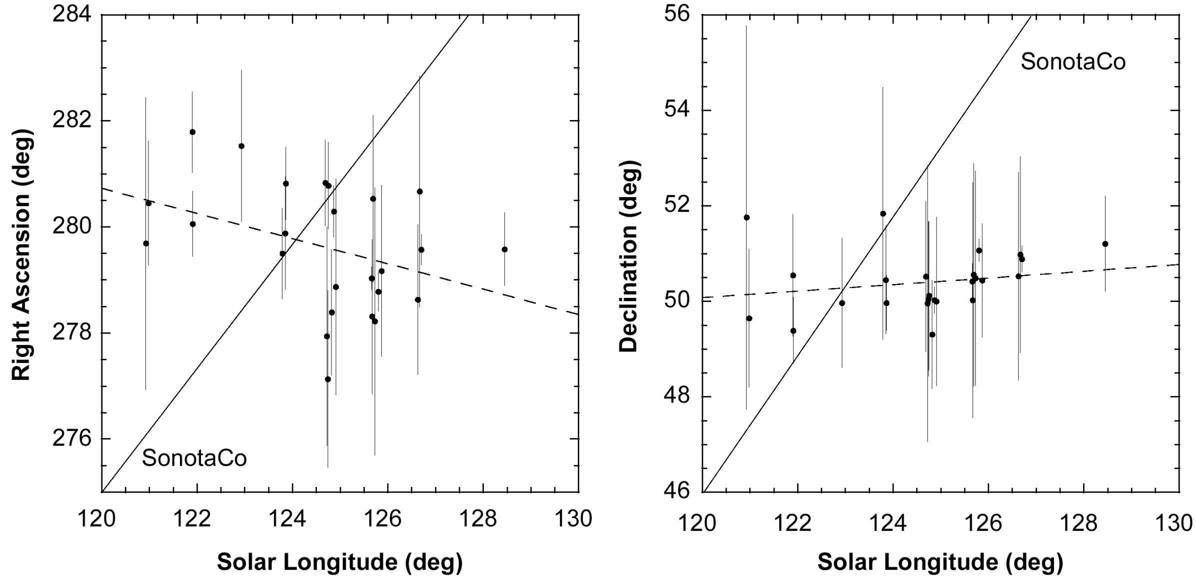

Figure 3 – Radiant drift is shown for right ascension and declination for the GDR meteors. The solid lines show the rates of drift reported by SonotaCo (2009). The dashed lines are fitted regression lines to our data that show the rates of GDR drift observed in July 2011.

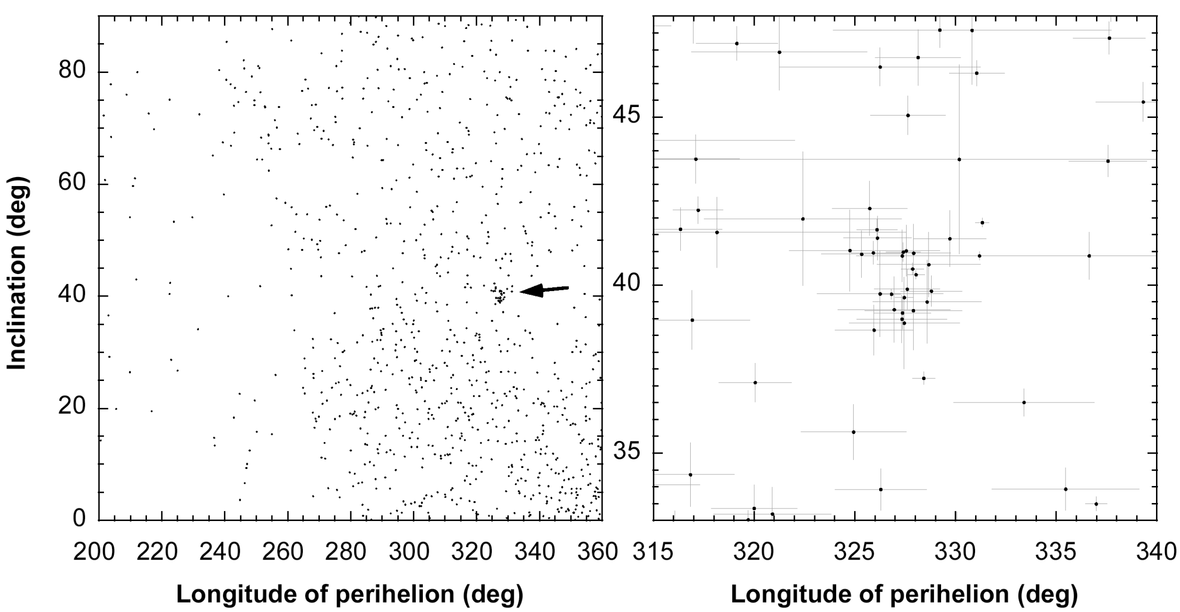

Figure 4 – GDR candidates shown by inclination versus longitude of perihelion.

New long period comets tend to have intermittent compact debris streams lasting just a few hours. Hence, the ca. 8-day duration of this shower also indicates that the detected GDR meteors belong to an older stream with multiple returns to the inner solar system.

Notice that the shower was not detected by CMOR (Brown et al., 2009). In that sense, the GDR are different from the recently confirmed ARC shower (Phillips et al., 2011), which was discovered by CMOR and had video activity levels similar to the GDR. The relatively low magnitude distribution index for the GDR may be responsible, the CMOR radar being sensitive for fainter meteors of magnitude +6 to +8.

6 Conclusions

We confirm the existence of the July Gamma Draconids shower, previously detected in a photographic survey by Babadzhanov (1963) and in a video survey by the SonotaCo Network in 2007–2009. We confirm the time of the shower peak (July 28) and the activity period (July 24–August 1), but find a different radiant drift than reported before.

While there is no known parent body at the present time, the GDR stream of meteoroids likely originated from an intermediate long-period comet, with a small possibility that the source was in a Halley-type orbit.

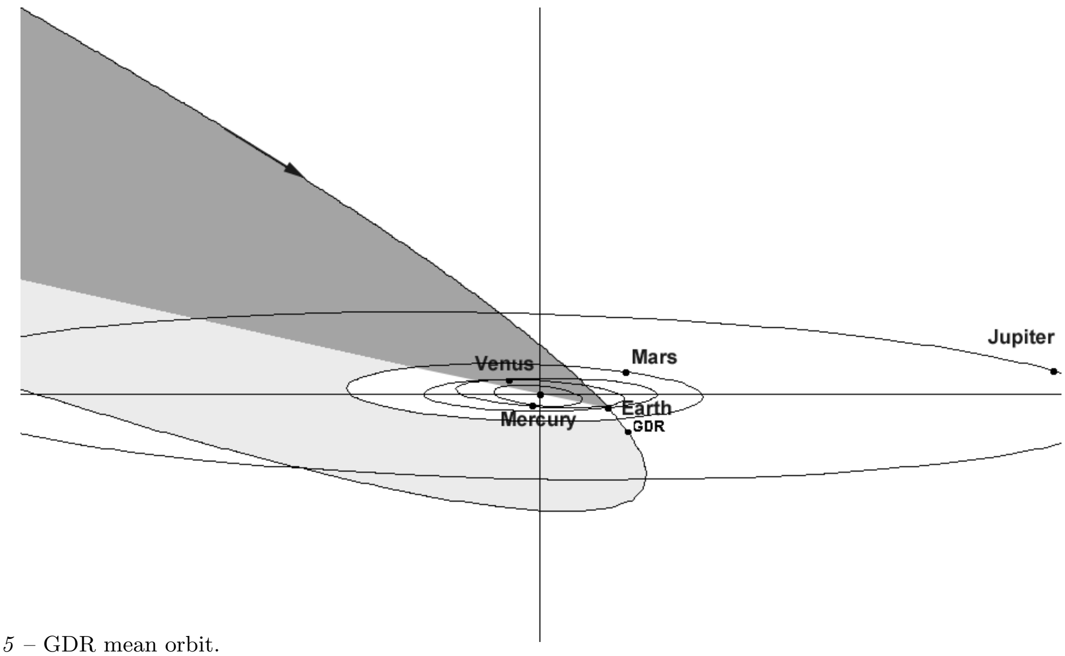

Figure 5 – GDR mean orbit.

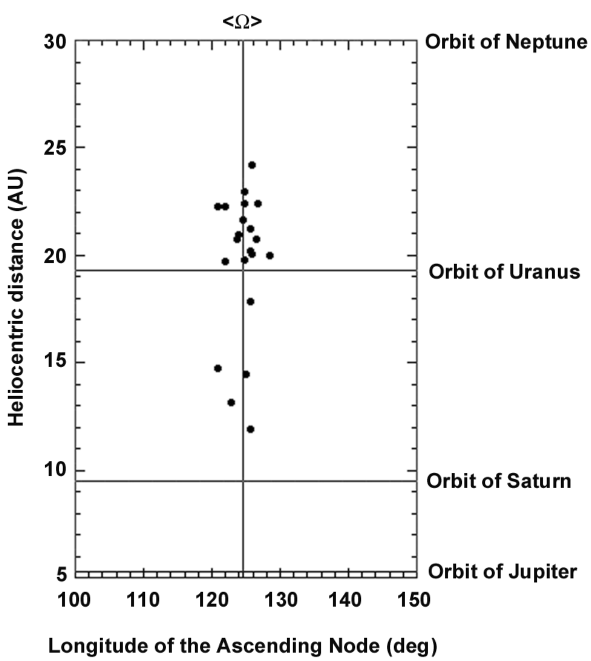

Figure 6 – The heliocentric distances to each orbits ascending node are shown. A clustering just beyond the orbit of Uranus is evident.

Acknowledgements

We thank Peter Gural for developing the software algorithms used in this investigation.

We also thank the Fremont Peak Observatory Association and the Lick Observatory staff for their assistance in maintaining two of the CAMS stations, specifically FPOA director Rick Morales and board member Mark Levine. And, finally, we also thank Tom and Carmela Hoffman of Heritage Oaks Winery in Lodi, California for graciously hosting the third CAMS station. CAMS is supported by the NASA Planetary Astronomy program.

References

Babadzhanov P. (1963). "Orbital elements of photographic meteors". *Smithsonian Contrib. Astrophys.*, **7**, 287–291.

Brown P., Wong D. K., Weryk R. J., and Weigert P. (2009). "A meteoroid stream survey using the Canadian Meteor Orbit Radar. II: Identification of minor showers using a 3D wavelet transform". *Icarus*, **207**, 66–81.

Jenniskens P. (2006). *Meteor Showers and their Parent Comets*. Cambridge University Press.

Jenniskens P. (2008). "Meteoroid steams that trace to candidate dormant comets". *Icarus*, **194**, 13–22.

Jenniskens P. and Gural P. S. (2011). "Discovery of the February Eta Draconids (FED, IAU #427): the dust trail of a potentially hazardous long-period comet". *WGN, Journal of the IMO*, **39**, 93–97.

Jenniskens P., Gural P. S., Dynneson L., Grigsby B., Newman K. E., Borden M., Koop M., and Holman D. (2011). "CAMS: Cameras for Allsky Meteor Surveillance to validate minor meteor showers". *Icarus*, **216**, 40–61.

Molau S. and Rendtel J. (2009). "A comprehensive list of meteor showers obtained from 10 years of observations with the IMO video meteor network". *WGN, Journal of the IMO*, **37**, 98–121.

Phillips M., Jenniskens P., and Grigsby B. (2011). "Confirmation of the April Rho Cygnids (ARC, IAU #348)". *WGN, Journal of the IMO*, **39**, 131–136.

SonotaCo (2009). "A meteor shower catalog based on video observations in 2007–2008". *WGN, Journal of the IMO*, **37**, 55–62.

Handling Editor: Marc Gyssens