Discovery of the Upsilon Andromedids (UAN, IAU #507)

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During routine low-light level video observations with CAMS (Cameras for Allsky Meteor Surveillance) made from 2011 June 2 to August 7, a weak shower with a radiant near Upsilon Andromedae was discovered. In that same section of the sky, the Phi Piscids (PPS) were detected, listed as #372 in the IAU Working List of Meteor Showers. The Alpha Triangulids (ATR, IAU #414) and August Piscids (AUP, IAU #415) are activity from the same stream and should be removed from the list. Radiant and speed of the July Pegasids (JPE, IAU #175) match the Great Comet of 1771 (C/1771 A1) as well as earlier identified comet C/1979 Y1 Bradfield.

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1 Introduction

The IAU Working List of Meteor Showers contains more than 300 unconfirmed showers that need verification. The Cameras for Allsky Meteor Surveillance (CAMS) project was established to do so. CAMS is a three-station 60-camera meteor surveillance system using Watec Wat902 H2 cameras equipped with 12-mm focal length lenses. CAMS is based in northern California and was operated during the summer of 2011 from Fremont Peak Observatory, Lick Observatory, and a winery in Lodi (Jenniskens et al., 2011).

Here we report on observations of the Northern Apex region from June 2 through August 7, 2011 (Figure 1). The Canadian Meteor Orbit Radar (CMOR) identified the Phi Piscids (PPS, IAU#372) in this region (Brown et al., 2010). Single-station video observations collected in the IMO Video Meteor Network (VMN) suggested activity from showers labeled numbers 26 (PPS, IAU #372), 31 (JPE, IAU #175), 39 (ATR, IAU #414), 41, and 46 (AUP, IAU #415) (Molau, 2010; Molau & Rendtel, 2009). Nearby are the c-Andromedids (CAN) and Northern June Aquilids (NZC), which are not discussed here.

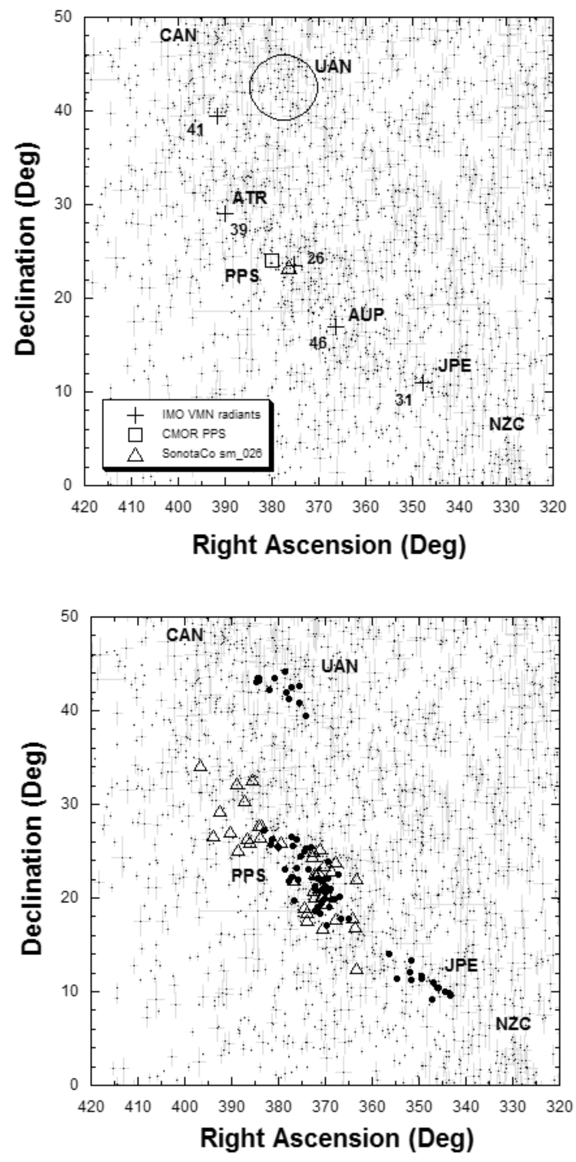

Figure 1 – CAMS geocentric radiants detected in the Northern Apex region between 2011 June 2 and August 7. Top: meteor showers identified in previous orbit surveys (see text). Bottom: members of the Phi Piscids (PPS, IAU #372), the July Pegasids (JPE, IAU #175), and the new Upsilon Andromedids (UAN, IAU #507). CAN are the c-Andromedids. NZC is the subject of another paper.

2 Stream search

We use three D-criteria distance functions in our analysis: $D_{SH}/2$, D_D, and $D_H/2$, each normalized according to (Jopek & Froeschlé, 1997). We found similar results from each using a threshold of $D_c = 0.054$, scaled to $D_{SH}/2$ and the other distance functions for 99% reliability at $M \geq 10$ (Jopek & Froeschlé, 1997), where M is the number of linked stream members found using a given D_c value. Our search algorithm was to take each orbit in the sample set and use it as the comparison orbit for all other orbits in the same sample set. The number of orbits in the sample set that matched the comparison orbit was tabulated. We found that graphing these counts as a function of various orbital elements revealed sharp spikes, each identified with a meteoroid stream. One such graph is shown in Figure 2. Each symbol is the count for one of 1311 orbits.

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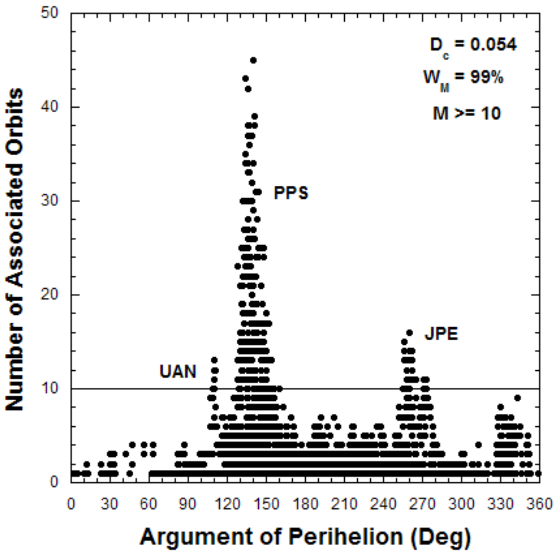

Figure 2 – Number of associated orbits as a function of the argument of perihelion of the orbit.

3 Confirmation of the Phi Piscids

The central radiant in Figure 1 is the Phi Piscids (PPS), first included in the IAU list as number 372 from observations by the CMOR system (Brown et al., 2010) using radar data from 2001 to 2008. CMOR detected this shower, with a peak at 106° solar longitude, during only three days. Using the CMOR mean PPS orbit as a comparison, only 2 matches to the CAMS data were found.

SonotaCo (2010) also identified a stream at this location, designated as sm_026 (abbreviated for Sirko Molau (2010), shower 26) in their 2007–2009 on-line databases, but active over a longer period of time. The CMOR geocentric velocity (and correspondingly the orbital elements a and e) are lower than those found by SonotaCo. The SonotaCo sm_026 mean orbit produced 43 matched CAMS orbits. The resulting average radiant, velocities and orbital elements (Table 1) agree well between the two datasets.

The radiant and peak activity for shower 26 from VMN data (Molau, 2010) also agree well, but the velocity is higher (Table 1). These PPS orbits are shown in Figures 1 and 3. In both figures, SonotaCo's orbits for sm_026 are shown with open triangles.

The Phi Piscids have a wide and asymmetrical activity curve with a peak on June 26 at $\lambda_\odot = 94°$ (Figure 4), which agrees well with the peak at 95° observed by SonotaCo. The change of argument of perihelion as a function of solar longitude ($0.39°/1°\lambda_\odot$) suggests this shower's long duration is due to precession of the orbit, similar to the July-tail of the Perseid shower (Jenniskens, 2006).

The magnitude range of all detected PPS meteors is -0.8 to $+3.0$. The magnitude distribution index averages $\chi = 3.17$ for the interval from -1 to $+2$ magnitude ($N = 43$). The PPS radiant does not rise at Fremont Peak Observatory (our standard observer) until 07^h37^m UT, so we use the interval from 07^h37^m to 12^h18^m UT (the beginning of civil twilight), or 4.68 hours as our t_{eff} value, and the values $N = 9$, $h_r = 15.79$, $\chi = 1.75$, $\gamma = 1.26$, and $L_m = 5.4$. With this, the peak ZHR for the PPS stream on June 26 is ZHR is 8.4 ± 2.8, using the formula by (Jenniskens, 1994). The radiant passes closest to the zenith during the daytime, around 7 hours local time, and sets around 14 hours local time.

The mean heliocentric distance to the point of ascension for the PPS meteoroids is 5.30 AU, with a one sigma dispersion of 0.97 AU, so many PPS meteoroids have a node at the orbit of Jupiter. Their mean orbital period, with 4 long-period outliers removed, is 49.0 ± 5.6 years, which is 4.1 times the mean period for Jupiter. The mean period suggests that the potential parent body is a Halley-type comet, possibly with meteoroids in a 1:4 mean-motion resonance. Such accumulation of dust in resonances can lead to meteor outbursts such as, for example, seen with the Orionids of comet 1P/Halley. There is no likely parent body candidate among known comets.

4 Confirmation of the July Pegasids (JPE)

The July Pegasids are distinct from the PPS stream, even though they share the same inclination. There are 14 JPE orbits similar to the mean orbit by Ueda (2012), identified in Figures 1 and 3. The radiant, geocentric velocity, and orbital element drifts all agree with the results by (Ueda, 2012). Rates never exceeded 3 per degree of solar longitude.

Among the JPL/NASA (JPL/NASA, 2012) list of 3158 comet orbits, the July Pegasids are a good match with comet C/1979 Y1 (Bradfield), as identified by Ueda (2012). D_H shows the lowest distance function match at 0.054. However, we also find that comet C/1771 A1 (Great Comet) matches our data at 0.032 for D_H, which is a slightly better fit (Table 1). Both could perhaps be the same comet or, perhaps, they originated from one parent body at the time of the formation of the July Pegasid shower.

The JPE stream ascends near the Earth's orbit, but outside of it by 0.4 AU. The mean orbital period, with 4 long period outliers removed, is 45.4 ± 9.6 years, which also suggests that the potential parent body is a Halley-type comet. Comet C/1979 Y1 (Bradfield) has an orbital period just over 300 years, which makes this a long-period comet similar to comet Thatcher, parent of the Lyrid shower.

5 The August Piscids and Alpha Triangulids

VMN radiant 46, listed as the August Piscids (IAU #415), lies between the PPS and JPE radiants (Figure 1), and shares a similar velocity to PPS. We used a radiant/velocity distance function to find orbital elements for the VMN radiant data in our data. A very

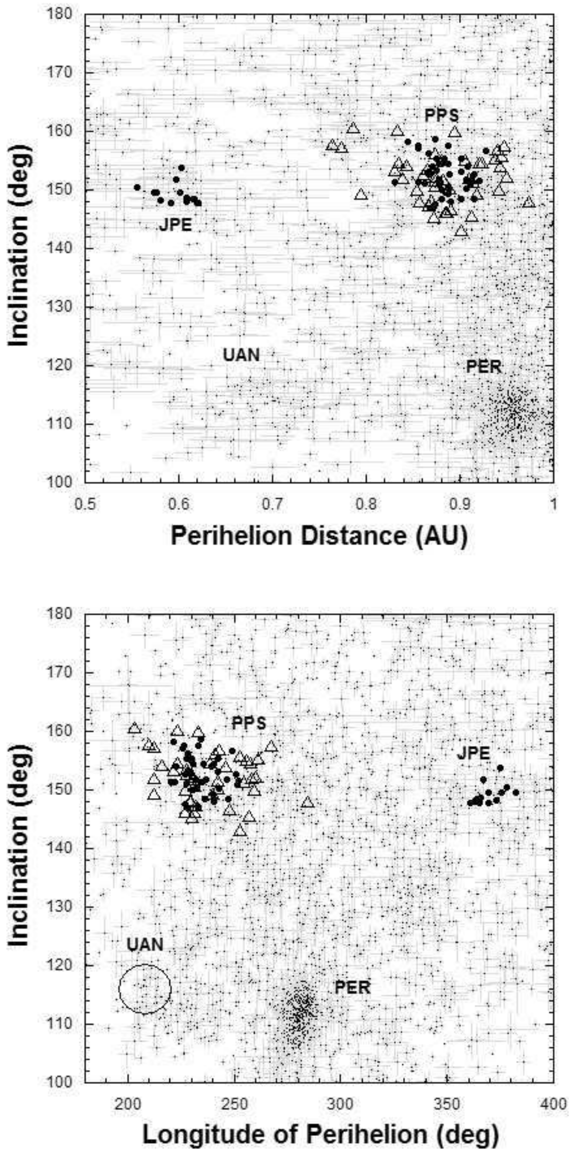

Figure 3 – Showers in meteoroid orbital element space.

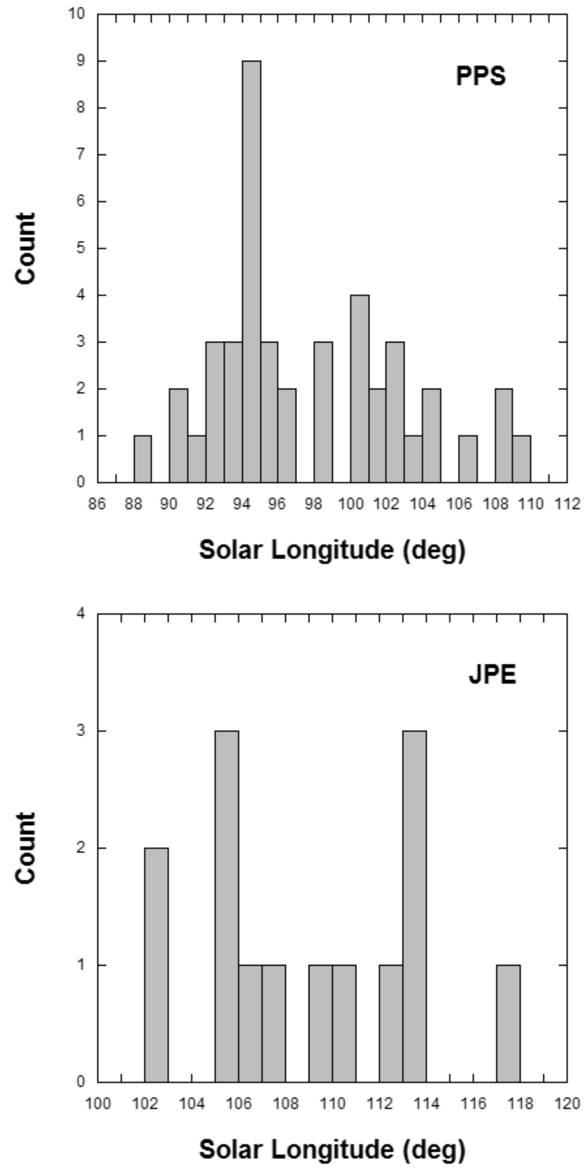

Figure 4 – Activity curves of the PPS and JPE showers.

high D_c value of 0.18 was needed for any detection to occur using the established distance functions, and those orbital elements are sufficiently similar to the PPS that a separate shower is not recognized.

Similarly, the radiant for VMN shower 39, listed as the Alpha Triangulids (IAU #414), lies on the other side of the PPS radiant from VMN shower 46 (Figure 1), and also shares a similar velocity to PPS. We also found that ATR orbits matching with cut-off value $D_c = 0.13$ tended to overlap those found for PPS at the same cut-off level.

The meteors reported by VMN for the shower 41 radiant also share a similar velocity to PPS. All of this suggests that activity observed from these three radiants is actually an extension of PPS activity.

6 The Upsilon Andromedids

Figure 2 shows a spike indicating an active stream with $\omega \approx 110°$ that is above our chosen reliability level. We found the same spike for other orbit elements and were able to identify 13 members of this stream listed in Table 2. Based on the IAU Shower List, this stream appears to be previously undetected, and we use the name Upsilon Andromedids.

This stream has orbital elements (Table 2) that are distinct from the mean for PPS, JPE, and VMN showers 46 (AUP), 39 (ATR), and 41. While the rates are low, the orbits form a compact cluster in Figures 1 and 3. We detect radiant drifts of $1.18°/1°\lambda_\odot$ and $+0.35°/1°\lambda_\odot$ in right ascension and declination, respectively. The activity profile is symmetrical, and runs from $\lambda_\odot = 93°$ to $\lambda_\odot = 101°$ (June 25 – July 4) never exceeding a count of 3 per night. The shower is rich in bright meteors. The magnitude distribution is flat from 0 to +3 with 3

Table 1 – The radiant at the peak of the shower and median orbital elements. Error bars are standard errors. Dispersions are in terms of standard deviation of the distribution. Possible parent body elements are also shown.

Survey	α_g [°]	δ_g [°]	v_g [km/s]	q [AU]	$1/a$ [AU^{-1}]	i [°]	ω [°]	Ω [°]
PPS (IAU #372):								
CAMS	12.9 ± 0.7	22.0 ± 0.4	67.1 ± 0.1	0.883 ± 0.003	0.09 ± 0.01	152.6 ± 0.5	136.7 ± 0.6	97.7 ± 0.8
Disp.	4.4	2.7	0.6	0.021	0.04	3.14	3.7	5.40
SonatoCo	16.3 ± 1.4	23.4 ± 0.7	66.6 ± 0.3	0.882 ± 0.008	0.20 ± 0.02	152.2 ± 0.7	136.2 ± 1.4	101.6 ± 1.7
Disp.	9.1	4.7	1.8	0.049	0.13	4.31	9.3	11.0
CMOR	20.1	24.1	62.9	0.856	0.48	152.6	125.02	106.0
VMN	15.3	23.5	69.1	-.-	-.-	-.-	-.-	-.-
JPE (IAU #175):								
CAMS	348.8 ± 1.1	11.1 ± 0.4	64.5 ± 0.2	0.598 ± 0.005	0.07 ± 0.02	149.3 ± 0.5	260.5 ± 0.7	109.1 ± 1.2
Disp.	4.1	1.4	0.6	0.020	0.05	1.7	2.7	4.4
Ueda	351.7	11.8	63.4	0.531	0.09	148.8	268.7	114.00
VMN	347.9	11.0	66	-.-	-.-	-.-	-.-	-.-
C/1979 Y1 (Bradfield)				0.565	0.02	146.4	264.0	108.6
C/1771 A1 (Great Comet)				0.528	(0.00)	148.6	260.4	111.9

meteors in each bin (plus one -1.8 meteor), resulting in $\chi = 1.0$. The F-skew values range from 0.26 to 1.00, with a mean value of 0.62 ± 0.07, indicating that these meteoroids are somewhat durable.

The UAN stream ascends just beyond 2 AU, well beyond the orbit of Mars. The mean orbital period, with 2 long period outliers removed, is 107.4 ± 31.2 years, which again suggests that the potential parent body is a Halley-type comet. The parent body of such showers can have evolved well beyond an orbit intersecting Earth's orbit.

7 Conclusions

We confirm the existence of the PPS and JPE streams, and find that JPE may be related to comet C/1771 A1

Table 2 – The geocentric radiant, speed, and orbit for the 13 Upsilon Andromedids in June/July 2011.

Day/UT	α_g [°]	δ_g [°]	v_g [km/s]	q [AU]	$1/a$ [AU^{-1}]	i [°]	ω [°]	Ω [°]
25 09:24:59	14.2 ± 1.3	39.5 ± 1.2	60.2 ± 0.7	0.712 ± 0.024	-0.03 ± 0.08	119.3 ± 2.0	113.9 ± 3.3	93.34 ± 0.0
25 09:49:48	15.6 ± 0.6	40.9 ± 0.6	59.8 ± 0.3	0.691 ± 0.010	-0.06 ± 0.03	116.9 ± 0.9	111.9 ± 1.4	93.36 ± 0.0
27 09:02:34	15.5 ± 0.5	42.7 ± 0.5	57.8 ± 0.1	0.707 ± 0.008	0.08 ± 0.02	113.8 ± 0.7	111.9 ± 1.2	95.24 ± 0.0
28 08:54:39	17.9 ± 0.8	41.3 ± 0.9	59.5 ± 1.5	0.694 ± 0.023	0.00 ± 0.14	117.6 ± 1.7	111.4 ± 4.3	96.18 ± 0.0
28 09:26:05	18.3 ± 0.4	41.9 ± 0.4	58.9 ± 0.5	0.684 ± 0.008	0.02 ± 0.04	116.2 ± 0.7	109.9 ± 1.4	96.21 ± 0.0
28 10:29:49	17.3 ± 0.2	42.6 ± 0.2	58.1 ± 0.1	0.695 ± 0.003	0.07 ± 0.01	114.7 ± 0.3	110.5 ± 0.4	96.25 ± 0.0
1 08:40:12	21.9 ± 0.4	42.3 ± 0.3	59.4 ± 0.4	0.675 ± 0.008	0.01 ± 0.03	117.6 ± 0.6	109.0 ± 1.2	99.04 ± 0.0
1 11:57:49	20.9 ± 0.1	43.4 ± 0.4	58.3 ± 0.5	0.688 ± 0.007	0.06 ± 0.05	115.2 ± 0.8	109.8 ± 1.5	99.17 ± 0.0
2 07:24:54	18.7 ± 0.3	44.2 ± 0.2	58.3 ± 0.2	0.738 ± 0.005	0.07 ± 0.02	114.6 ± 0.4	115.8 ± 0.8	99.95 ± 0.0
3 08:38:45	24.5 ± 0.3	43.4 ± 0.3	58.3 ± 0.3	0.660 ± 0.006	0.04 ± 0.03	116.4 ± 0.5	106.8 ± 1.0	100.94 ± 0.0
3 09:14:57	24.1 ± 1.3	43.5 ± 1.5	58.6 ± 0.4	0.667 ± 0.025	0.05 ± 0.07	116.4 ± 2.3	107.5 ± 3.5	100.97 ± 0.0
3 12:02:30	24.3 ± 0.3	43.2 ± 0.4	58.5 ± 0.3	0.662 ± 0.007	0.07 ± 0.03	116.7 ± 0.6	106.6 ± 1.1	101.08 ± 0.0
4 08:43:43	24.6 ± 0.8	43.1 ± 0.7	59.2 ± 0.9	0.676 ± 0.017	0.04 ± 0.08	117.9 ± 1.3	108.8 ± 2.9	101.90 ± 0.0
mean	19.8 ± 1.0	42.5 ± 0.4	58.8 ± 0.2	0.688 ± 0.006	0.03 ± 0.01	116.4 ± 0.4	110.3 ± 0.8	97.97 ± 0.8
Disp.	3.8	1.3	0.7	0.022	0.041	1.5	2.7	3.0

(Great Comet) as well as comet C/1979 Y1 (Bradfield). We show that activity from AUP and ATR is related to PPS, and should be removed from the IAU MDC list. Finally, we show the existence of a new weak stream, the Upsilon Andromedids (UAN, IAU#507).

8 Acknowledgements

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