Ongoing meteor work

Spanish Meteor Network: 2006 continuous monitoring results

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Initial results from the first year of continuous CCD low-scan-rate all-sky and video monitoring by the SPanish Meteor Network (SPMN) are presented. Under extraordinary weather conditions, the SPMN recorded almost 40 bright (over $m = -6$) fireballs, some of which were observed simultaneously from several stations. Daily observations of meteor activity have helped to increase our knowledge on cometary and asteroidal-origin meteoroid streams. The focus herein will be on the overall description of the fireballs recorded, first estimations of the measured spatial fluxes of selected streams, and information on unexpected activity from poorly-known meteoroid streams.

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1 Introduction

We previously reported on the first steps in the development of the SPanish Meteor Network (SPMN) by using innovative low-scan-rate all-sky CCD cameras that achieve +2/+3 meteor limiting magnitude (Trigo-Rodríguez et al., 2004). The year 2006 was extraordinary for the SPMN network, especially due to the excellent weather conditions during autumn and winter that guaranteed almost a continuous record of meteor activity from the different SPMN stations. During 2006 new progress has been made by having set up two additional all-sky CCD stations in Catalonia and three video stations in Andalusia with the main goal to increase our atmospheric coverage of meteor and fireball activity (Trigo-Rodríguez et al., 2006b). Since the two already active cores of the network (Andalusia and Catalonia) are separated by 1000 km, it minimizes the chance that adverse weather affects both sites and that meteor activity is recorded almost every night. During 2006, the SPMN built their first cameras with an internal rotating shutter to obtain measurements of meteor velocities (Figure 2). The shutter is located nearby the focal plane, between the lens and the chip, and more details will be given during the next Meteoroids 2007 meeting. First results are consistent with a velocity uncertainty of the order of 0.2–0.3 km/s, similar to photographic or video systems (Trigo-Rodríguez et al., 2007b). Additionally, for those all-sky CCD cameras still operating without rotating shutters we have performed common field monitoring with video cameras to provide meteor velocities. The different stations and imaging systems are listed in Table 1 (Figure 1). As a consequence of all this effort, reliable trajectory and orbital data of both meteors and fireballs are being obtained.

Figure 1 – Location of the SPMN all-sky stations. For image simplicity, only the names of the main stations are shown. The circles around the operative all-sky stations are the optimal range for bright fireball detection (350–400 km) although from some of the stations larger detection distances have been achieved (see e.g. Trigo-Rodríguez et al., 2003).

2 General overview of bright bolides recorded

Since the number of recorded fireball events were quite high, this section was restricted to placing special emphasis in the description of the brightest fireballs (over −6 absolute magnitude), and especially to those meteorite-dropping events that we are currently studying in more detail. Table 4 provides a preliminary list of such events giving clues on their origin. Due to the incomplete development status of the network, we are still not covering certain areas completely, and thus many

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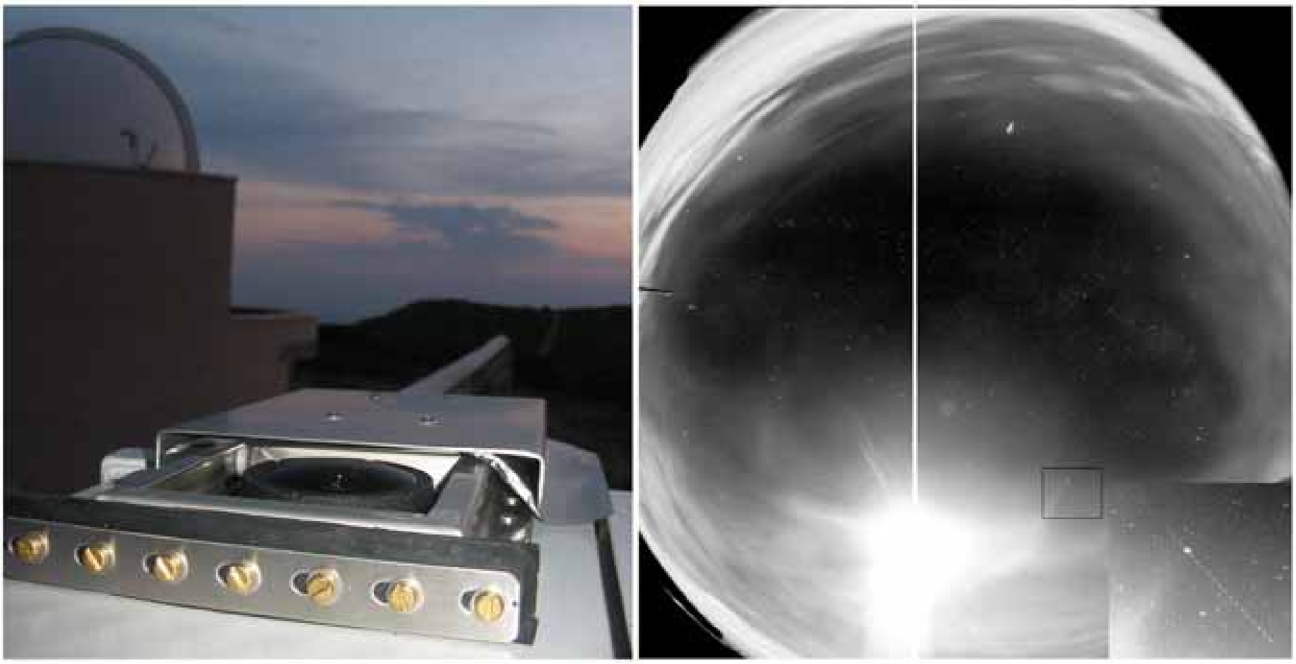

Figure 2 – An example of the excellent camera performance even under unfavourable conditions (partially cloudy skies with disturbing Moon). a) All-sky CCD camera of Montsec (SPMN station #3, OAdM). b) All sky-image taken by the camera shown in a). The black square nearby the full Moon includes an $m = -2$ Perseid imaged on 2006 August 12.

Table 1 – Current list of CCD all-sky and video stations in operation by the SPMN. Under the column labeled "imaging system" the meaning for the different acronyms are: AS (low-scan-rate CCD all-sky camera), WF (low-scan-rate wide-field CCD camera), WFV (Wide field video cameras) and MS (low-scan rate CCD wide field camera). The location of the currently operative all-sky stations are shown in Figure 1.

Station number	Station location (Province)	Longitude	Latitude (N)	Alt. (m)	Imaging system
1	El Arenosillo, BOOTES-1 (Huelva)	06°43′58″ W	37°06′16″	40	AS+WFV
2	La Mayora, BOOTES-2 (Málaga)	04°02′40″ W	36°45′35″	60	AS
3	Montsec, OAdM (Lleida)	00°43′46″ E	42°03′05″	1570	AS
4	Montseny (Girona)	02°31′14″ E	41°43′17″	300	AS
5	Sevilla (Sevilla)	05°58′50″ W	37°20′46″	28	WFV
6	Cerro Negro (Sevilla)	06°19′35″ W	37°40′19″	470	WFV
7	Torremolinos (Málaga)	04°31′11″ W	36°36′34″	10	MS
8	Folgueroles (Barcelona)	02°19′33″ E	41°56′31″	580	MS
9	Aras de los Olmos, UVAO (Valencia)	01°06′01″ W	39°56′46″	1300	AS

Table 2 – Averaged orbital elements of two ν Aurigids imaged by SPMN video cameras. All elements given for Equinox (2000.00). For comparison the averaged orbital elements of ν Aurigids (stream #229, Table 7, (Jenniskens, 2006) are shown. Full trajectory details and individual orbits are given in (Trigo-Rodríguez et al., 2007b).

Reference	q	a	e	i	ω	Ω
This work average (N=2)	0.225	1.97	0.886	123.°9	310.°6	—
#229	0.267	1.298	—	134.°3	311.°0	208.°0

fireball records are from only a single station. In such a case, the meteoroid source (given in Table 4 between parentheses) was deduced by taking into account the criteria of the meteor's path intersection with the radiant, apparent trajectory length and apparent angular velocity. Of course, fireball association is unequivocal only in those cases when two or more stations recorded the fireball, and when consequently the geocentric radiant is accurately determined. The planned future deployment of additional SPMN stations will allow an increase in the number of double or multiple-station fireballs. Another important aspect we are currently working on is the fireball's timing. Our idea is to develop additional video stations surrounding the all-sky network "cores". This is already achieved in western Andalusia where three video stations with 3–4 cameras each are covering common fields with all-sky CCD cameras. However, we don't have a complete coverage at this point all around the network, being the reason of time uncertainties of several seconds (given in first column of Table 4). This is an important aspect to solve in the future with simultaneous video observations.

By examining Table 4, it can be deduced that the most important sources of fireballs encountering the Earth during 2006, were the meteoroid streams associated with comets 1P/Halley, 4P/Tempel, 8P/Tuttle, 7D/Pons-Winnecke, 45P/Honda-Mrkos-Pajdusáková, 55P/Tempel-Tuttle, and 109P/Swift-Tuttle. It deserves to be mentioned that less fireballs were recorded from the Taurid complex (associated with 2P/Encke) compared to the level exhibited and recorded by our cameras in 2005. In the opposite way, particularly remarkable was the completely unexpected fireball activity associated with 1P/Halley, and 7D/Pons-Winnecke. Fireball rates for the streams associated with these comets are usually low. Consequently both detections are a significant success for the network and were possible mainly because of its continuous monitoring efforts.

3 Continuous follow up of annual streams: the unexpected Orionid outburst

We focus here on an overall description of the recorded activity of cometary meteor showers. From precise velocity determinations, we obtained orbital data from both major meteor showers, and also from poorly-known meteoroid streams. Several low-velocity cometary showers were active during 2006. For example, between June 27 and July 1 we imaged four June Bootid fireballs associated with comet 7 P/Pons-Winnecke. With an unexpected outburst observed in 1998, this stream with a geocentric velocity of only 14.1 km/s, is a likely source of Interplanetary Dust Particles (IDPs). Despite that, the June Bootids exhibited in 2006 a low level of visual activity but with a background of bright fireballs that was remarkable. During July and August our cameras also recorded several α Capricornid fireballs that are typically associated with 45P/Honda-Mrkos-Pajdusáková, although other cometary sources have been suggested. The brightest one occurred on 2006 July 20 at $22^h24^m41\overset{s}{.}5 \pm 0.1^s$ UTC over Doñana Natural Park, reaching absolute magnitude -12 ± 2. This interesting event is one of the brightest members of this stream ever recorded, with an estimated photometric mass of 500±200 kg. Fortunately, it was imaged from one all-sky CCD camera and one video camera that were monitoring the sky from La Mayora (Málaga) and Sevilla (Figure 5). From the astrometric reduction of the double station images of the bolide, we have estimated a geocentric radiant of RA $= 300.95 \pm 0.14°$ and Dec $= -14.44 \pm 0.12°$ and a V_∞=27.0±0.3km/s. The computed orbital elements confirm its association with the α Capricornid stream (Table 3 from (Trigo-Rodríguez et al., 2007a).

Table 3 – Orbital elements of the Doñana bolide.

a (AU)	2.62	±0.09
e	0.798	±0.007
q(AU)	0.5273	±0.0026
ω	$274\overset{\circ}{.}77$	$\pm 0\overset{\circ}{.}28$
Ω	$117\overset{\circ}{.}97678$	$\pm 0\overset{\circ}{.}00021$
i	$4\overset{\circ}{.}96$	$\pm 0\overset{\circ}{.}12$

A good example of the excellent performance of our all-sky cameras to record visual meteors was the detection of an unexpected outburst in the Orionid activity during 2006. As the limiting magnitude of the meteors recorded by the all-sky CCDs is +3 for this meteor shower (Trigo-Rodríguez et al., 2004) we recorded an important part of the display, rich in bright meteors and fireballs. Despite very bad weather in Andalusia, two stations in Catalonia (#4 and 8) recorded the outburst on Oct. 21 under excellent conditions, and several orbits were obtained (Trigo-Rodríguez et al., 2007a). While the typical Zenithal Hourly Rate (ZHR) of this meteor shower is 20 meteors/hour, the activity imaged during October 20/21 was three times higher (Trigo-Rodríguez et al., 2006a). This was confirmed by using the count rates obtained from the all-sky systems that had been corrected through a high fidelity meteor simulation. The simulation provides a means to account for sensor sensitivity characteristics, geometric loss terms, radiant position changes, and the meteor stream's particle distribution, as well as convert to a ZHR measure using a standard human observer's perception. The corrected SPMN counts were found to be 2.8 times stronger during the outburst than four hours later when the Orionid activity returned to normal yearly levels. Note also that a background of unusually bright Orionid fireballs was detected from Oct. 15–25 supporting the idea that meteoroids trapped in a resonance played a role in the unusual display. In fact, since the parent body (1P/ Halley) was far away when the activity increase occurred, the outburst meteoroids may have been trapped in a Jovian resonance (Trigo-Rodríguez et al., 2007b) to produce such a display. In the literature we found only one previous reported case, the 1993 Orionid outburst observed from Holland by the Dutch Meteor Society (Jenniskens, 2006). It is important to note that the

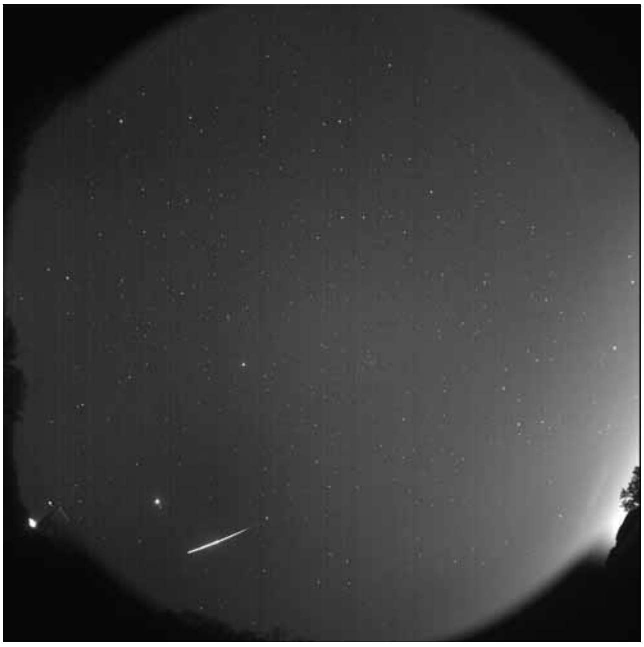

Figure 3 – A likely σ Leonid fireball of magnitude -9 ± 1 recorded on April 20, 2006 at $23^{h}40^{m}15^{s} \pm 15^{s}$ from the all-sky CCD camera located in La Mayora (BOOTES-2, Málaga).

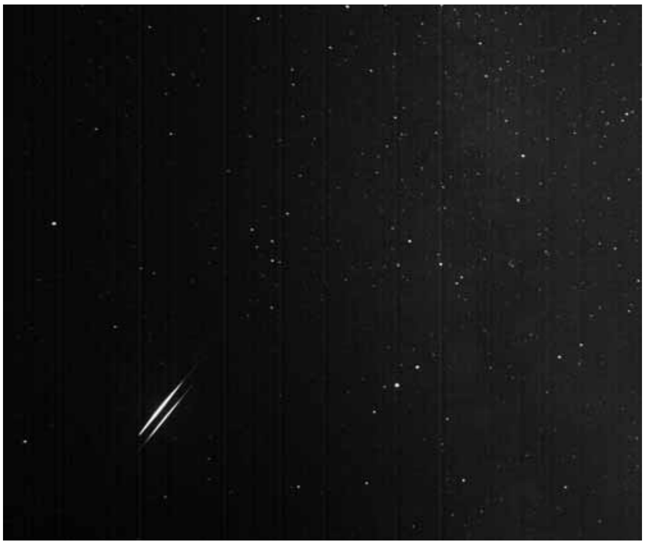

Figure 4 – Unusual twin of fireballs appeared on 2006 June 6 in the interval $03^{h}08^{m}15^{s} \pm 15^{s}$ UTC. Part of an all-sky image obtained from La Mayora (BOOTES-2) all-sky station. Unfortunately, no velocity measurements were made, but a possible link with the τ Herculids (comet 73P/Schwassmann-Wachmann 3) can be inferred from the paths length and alignment.

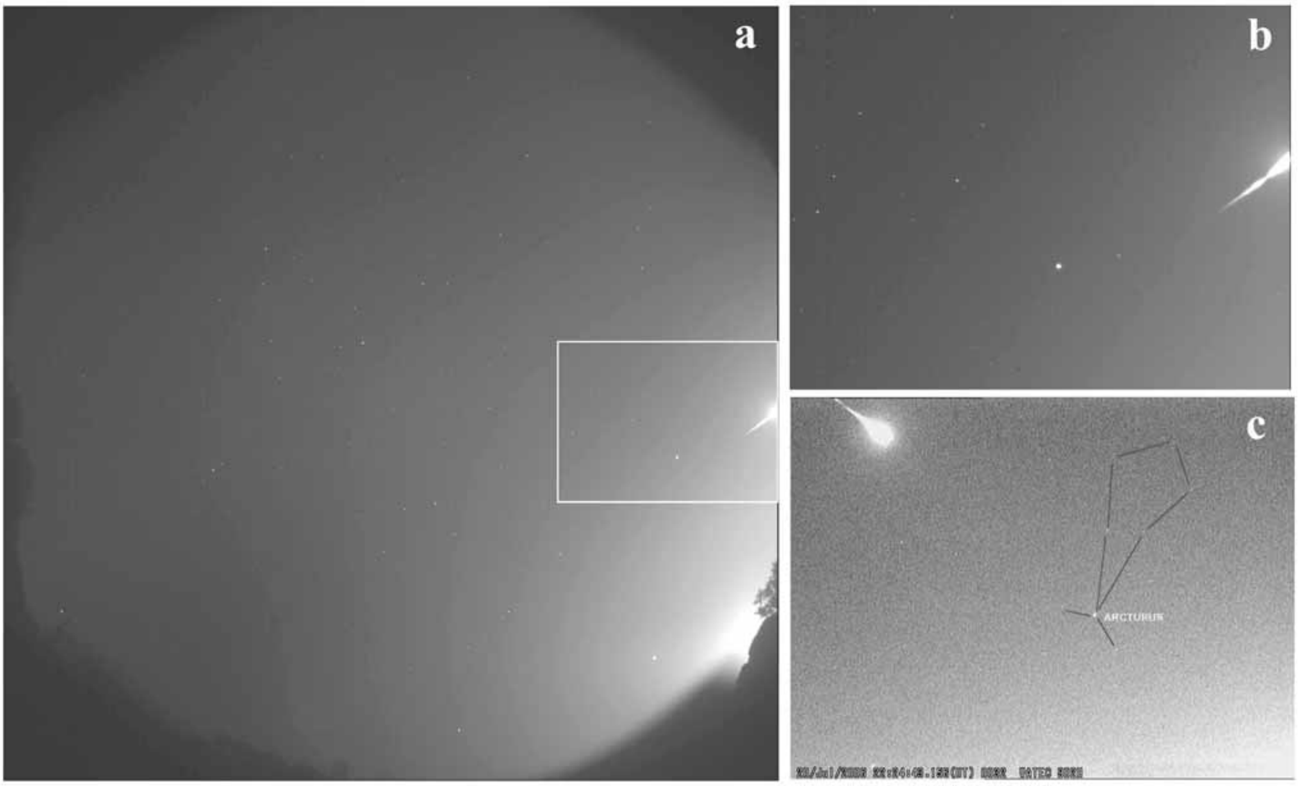

Figure 5 – The SPMN010706 (Doñana) bolide imaged from La Mayora (Málaga) and Sevilla. a) Full all-sky image showing the ending flares illuminating the western horizon. b) Magnified apparent trajectory from La Mayora. c) Last frame recorded by the video system from Sevilla.

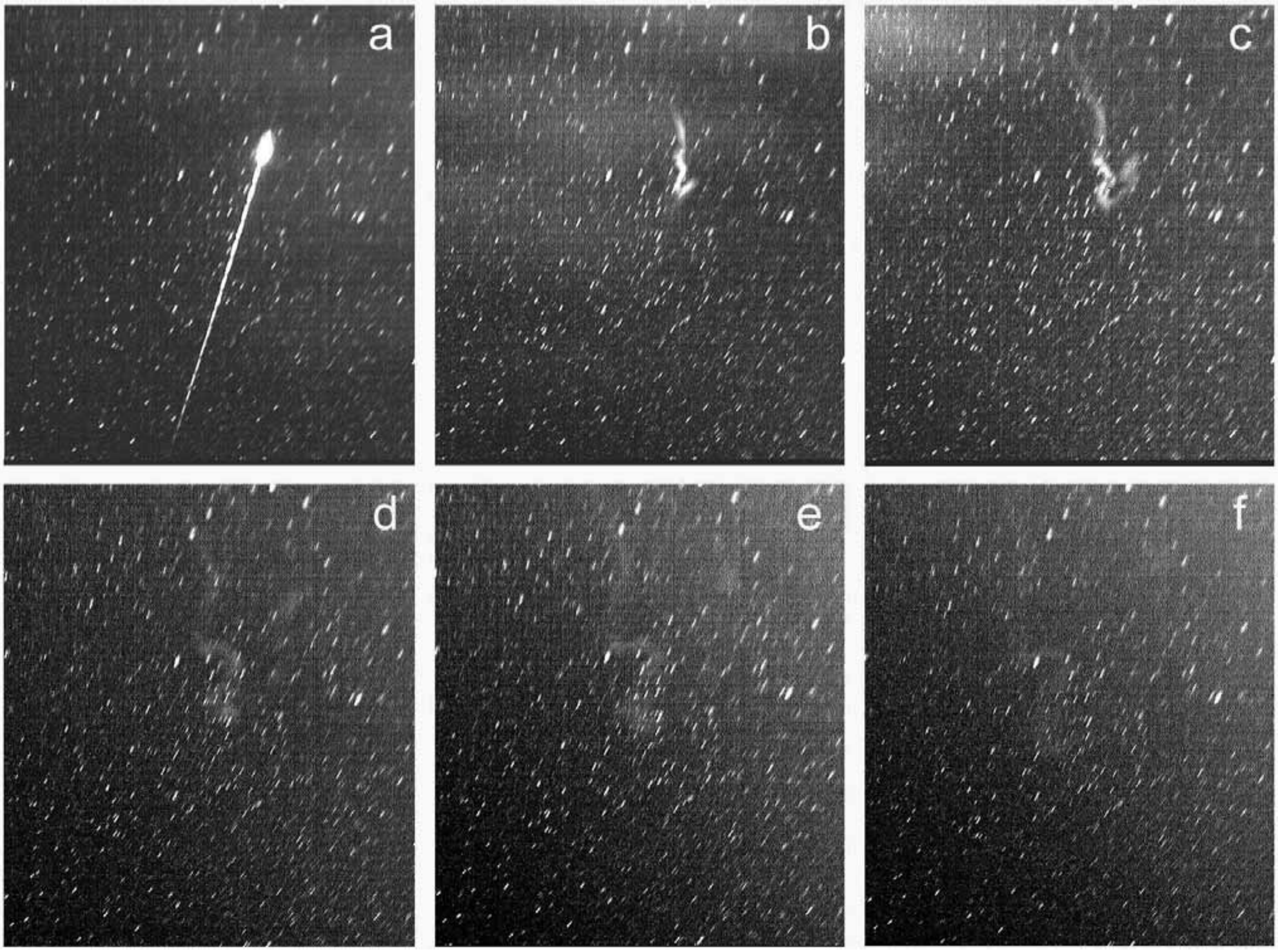

Figure 6 – a) An $m = -9$ Leonid appeared on 2006 Nov. 18 at $05^h33^m12^s \pm 45^s$ UTC. Part of an all-sky CCD image taken from Montseny (Girona). b) to f) Evolution of the persistent train in consecutive images taken every 90 seconds (for 10 minutes after the fireball's appearance). The train was visible for a total of 15 minutes.

activity was not restricted to the night of 20/21 Oct. since a background of bright fireballs persisted for several days around that date. Reduction of the images and magnitude data has provided information on these unusually large 1P/Halley meteoroids, and the origin of the outburst.

The Earth marginally crossed the two-revolution dust trail of 55P/Tempel-Tuttle on the morning of 2006 Nov. 19. Our video cameras noticed an increase in the number of +1 to +3 meteors at $04^h45^m \pm 10^m$ UTC, just as theoretically predicted (McNaught & Asher, 1999). Several impressive fireballs producing long-lasting (5–15 min.) trains were also imaged by SPMN all-sky cameras from Nov. 15–25 (see e.g. Figure 6).

Finally, in December 2006 we recorded the display of the Geminid shower associated with 3200 Phaethon, see for instance Figure 9. Tens of multiple-station Geminid meteors have been obtained. After the first year of continuous SPMN operation, the volume of data generated by both CCD and video cameras is overwhelming. In any case, data reduction is in progress and we have started to develop a software package called *Amalthea* to help with the astrometric and photometric tasks (see e.g. the photometric curve shown in Figure 8). At the end of the month, during twilight on Dec. 21/22 we observed a nice display of fireballs and bright meteors from the Ursids. However, the activity decreased in a couple of hours down to normal rates. The activity was probably produced by a dust trail of 8P/Temple (Lyytinen & Nissinen, 2006).

4 CCD and video recorded activity from minor showers

We have recently been motivated to follow the activity of minor showers on the basis of the newly available instrumentation of the SPMN (Trigo-Rodríguez et al., 2006b). The goal is not only to better define the flux of cometary meteoroids that are reaching the Earth from a variety of comets, but to also identify new cometary streams. Particularly useful to achieve such a goal are the video observations that the SPMN has been performing continuously since 2006 June. In order to study poorly-known meteor streams we developed an observing plan for orientation of our cameras dependant on the position of the most interesting radiants. However, in Meteor Science when you are trying to study a minor shower during a badly-covered observing period, you cannot rule out the chance of finding new unexpected sources of meteor streams. Here we briefly describe some interesting results, giving a few examples

Table 4 – 2006 bright (over absolute magnitude −6) fireballs imaged by SPMN stations.

Date	Time (UTC)		Max. Absolute magnitude	Imaging system	Station number(s)	Source (IMO code), Notes
2006 Jan. 11	03^h20^m	$\pm5^m$	-12±3	Only visual reports		SPO [1]
2006 Jan. 23	$22^h13^m40^s$	$\pm30^s$	-7±1	AS	4	SPO
2006 Apr. 15	$20^h54^m15^s$	$\pm15^s$	-9±1	AS	2	[2]
2006 Apr. 20	$23^h40^m15^s$	$\pm15^s$	-9±1	AS	2	SLE
2006 Jun. 3	$03^h08^m15^s$	$\pm15^s$	-6±1	AS	2	SAG
2006 Jun. 6	$03^h08^m15^s$	$\pm15^s$	-7±1 / -5±1	AS	2	THE? [3]
2006 Jun. 11	03^h52^m	$\pm1^m$	-10±3	Only visual reports		SPO
2006 Jun. 27	$03^h22^m15^s$	$\pm30^s$	-10±1	AS	2	JBO
2006 Jun. 28	$02^h58^m15^s$	$\pm30^s$	-6±1	AS	2	JBO
2006 Jun. 29	$02^h19^m29^s$	$\pm30^s$	-7±1	AS	4	JBO
2006 Jun. 29	$02^h52^m15^s$	$\pm30^s$	-9±1	AS	2	JBO
2006 Jul. 1	$23^h46^m20^s$	$\pm1^s$	-8±1	Only visual reports		JBO
2006 Jul. 20	$22^h24^m41.5^s$	$\pm0.5^s$	-12±2	AS+WFV	2, 5	CAP
2006 Jul. 21	$21^h00^m58^s$	$\pm30^s$	-7±1	AS+WFV	4	CAP
2006 Jul. 24	$04^h15^m15^s$	$\pm15^s$	-10±2	AS	2	SPO
2006 Aug. 10			-7±1	AS	4	PER
2006 Aug. 20	$18^h48^m57.1^s$	$\pm0.1^s$	-7±1	WFV	1	DAQ
2006 Aug. 21	$18^h48^m57.1^s$	$\pm0.1^s$	-7±1	WFV	1	PER?
2006 Aug. 31	$01^h44^m41.8^s$	$\pm0.1^s$	-9±1	WFV	1	SPO?
2006 Sep. 29	$00^h07^m20.5^s$	$\pm0.1^s$	-6±1	WFV	5	SPO?
2006 Oct. 16	$03^h16^m28^s$	$\pm45^s$	-6±1	AS	4	ORI
2006 Oct. 21	$03^h01^m59^s$	$\pm45^s$	-6±1	AS	4	ORI
2006 Oct. 21	$03^h25^m48^s$	$\pm45^s$	-5±1	AS+WF	4,8	ORI
2006 Oct. 21	$03^h41^m41^s$	$\pm45^s$	-8±1	AS	4	ORI
2006 Oct. 22	$03^h19^m34^s$	$\pm45^s$	-9±1	AS	4	ORI
2006 Nov. 17	$03^h15^m40.5^s$	$\pm0.1^s$	-9±2	WFV	5	TAU
2006 Nov. 18	$05^h33^m12^s$	$\pm45^s$	-9±1	AS	4	LEO [4]
2006 Nov. 19	$00^h41^m22.9^s$	$\pm0.1^s$	-8±2	WFV	5	TAU
2006 Nov. 19	$03^h52^m47^s$	$\pm45^s$	-5±1	AS	3	STA
2006 Nov. 19	$04^h53^m52^s$	$\pm45^s$	-6±1	AS	4	LEO
2006 Nov. 20	$06^h14^m38.3^s$	$\pm0.1^s$	-9±2	WFV	5	LEO
2006 Nov. 21	$00^h29^m28.6^s$	$\pm0.1^s$	-6±1	WFV	1	LEO
2006 Nov. 21	$05^h36^m44^s$	$\pm45^s$	-6±1	AS	4	LEO
2006 Dec. 1	$18^h48^m57.1^s$	$\pm0.1^s$	-7±1	WFV	1	SPO?
2006 Dec. 13	$18^h23^m50^s$	$\pm45^s$	-6±1	AS	4	SPO
2006 Dec. 14	$04^h36^m25^s$	$\pm15^s$	-10±1	AS+WF	4,8	GEM [5]
2006 Dec. 15	$04^h30^m03.4^s$	$\pm0.1^s$	-7±1	WFV	1	MON
2006 Dec. 21	$01^h09^m31^s$	$\pm45^s$	-6±1	AS	4	SPO
2006 Dec. 22	$18^h10^m16.0^s$	$\pm0.1^s$	-10±2	WFV	5	URS [6]

Notes:
1: Reported sound.
2: Artificial bolide: Seech-1 reentry.
3: Fireball twin (see Figure 4).
4: 15 minute persistent train (see Figure 6).
5: See Figure 9.
6: See Figure 8.

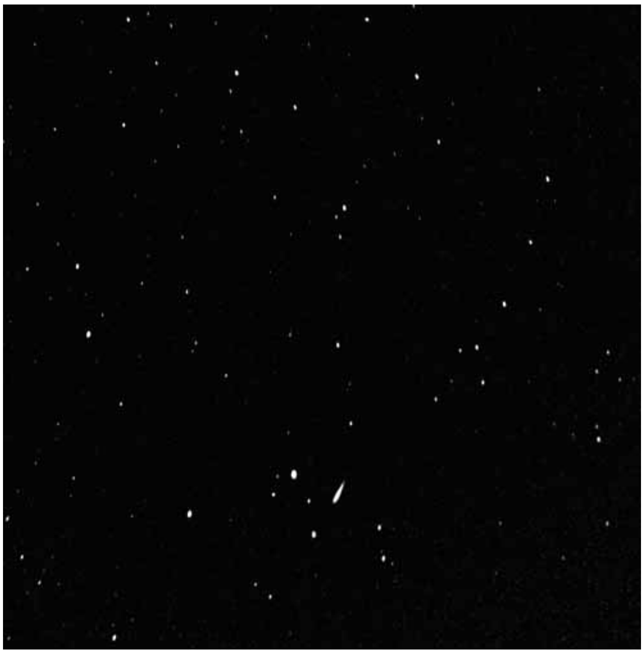

Figure 7 – An $m = -3$ almost stationary Lyrid appeared on 2006 Apr. 21 at $01^{\rm h}44^{\rm m}03^{\rm s} \pm 30^{\rm s}$ UTC. Part of an all-sky CCD image taken from Montseny (Girona).

of the orbital data.

No meteor showers were producing bright visual meteors until April. Some bright meteors of the Lyrids were imaged (see e.g. Figure 7) from April 20 to 24, but the activity was quite low (ZHR<10). A few members of the η Aquarids were detected in May, but the radiant was too low to generate good rates.

In June we imaged some bright meteors of τ Herculids, but the activity was normal during its activity period (ZHR<3). The June Boötids presented a background of fireballs, but no fainter meteors were imaged. In July the activity of bright meteors increased, but the α Capricornid stream was the only source of bright fireballs (see section 3).

Despite moonlight interfered with the Perseids in August, we recorded activity of some interesting minor showers. For example, during the second half of August the video cameras imaged five double-station meteors of π Eridanids (ERI), four of them brighter than $m = 0$. Two double-station κ Cygnid meteors were also obtained. The video systems recorded also π Eridanid activity in early September. Additional orbital data of other minor showers like e.g. δ Aurigids, σ Orionids and Taurids were obtained in the second part of September.

October was marked by the activity of several minor showers of scientific interest. Only a few (single station) October Camelopardalids were imaged by SPMN all-sky and video cameras, but the activity level from Europe seems to confirm its annual nature (Lyytinen, 2007). In mid October our video cameras detected some members of the δ Aurigids, but also two members of the ν Aurigids have been (at this point) identified by double-station work on Oct. 13 and 14. The derived trajectory and radiant data (Trigo-Rodríguez et al., 2007b) together with the averaged orbital elements (Table 2, page 14) are very similar to those ob-

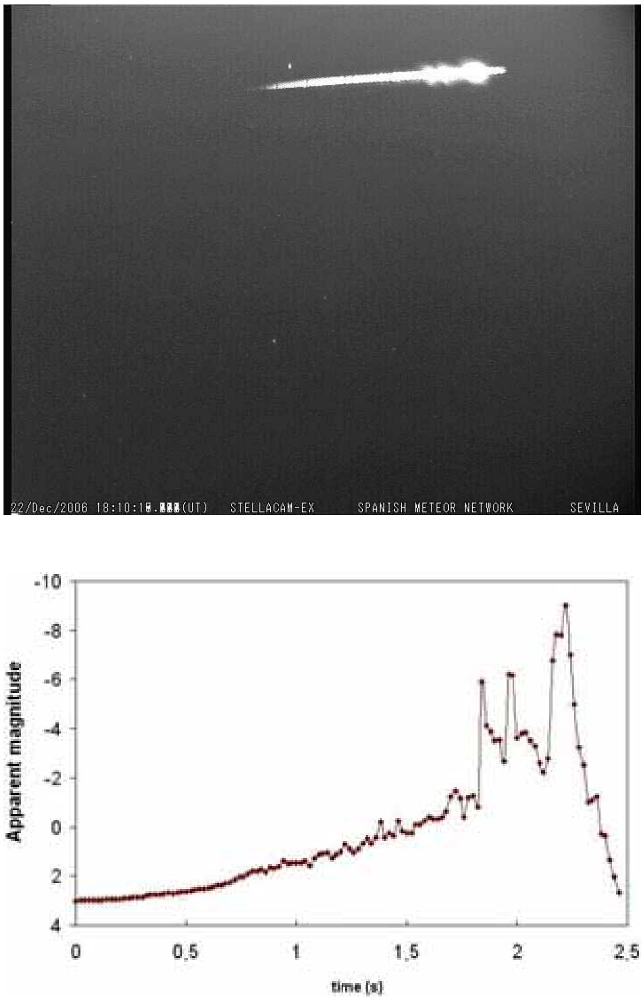

Figure 8 – Top: an $m = -10$ Ursid fireball recorded on 2006 Dec. 22 at $18^{\rm h}10^{\rm m}16^{\rm s}$ UTC from Sevilla SPMN video station. The summer triangle stars visible in the image can be used for comparison of the fireball's luminosity (though they may be hard to see in the printed version). Bottom: the light curve obtained by Amalthea software.

tained by (Sekanina, 1976) marked as shower #229 in Table 7 of (Jenniskens, 2006). We note that the activity of October Ursa Majorids reported by Uehara et al. (2006) was not detected by either the all-sky cameras or the video cameras. On the other hand, during October and November several multiple-station Taurids were recorded, although the activity of fireballs was remarkably lower than that exhibited by the two branches of the stream in 2005.

In November, our station #4 detected a likely increase in the α Monocerotids (AMO) on Nov. 18, between $03^{\rm h}15^{\rm m}$ and $03^{\rm h}45^{\rm m}$ UTC. This included three bright members (magnitudes -4, -2 and 0) with duration of about 0.5 second. Some other AMO members were detected during other nights, but the number of meteors is too low to be representative. Video cameras located in stations #5 and #6 also imaged meteors from this stream and several double-station trails were recorded between Nov. 17 and Nov. 20.

In the first half of December the activity of minor streams was mostly dominated by the σ Hydrids. A few

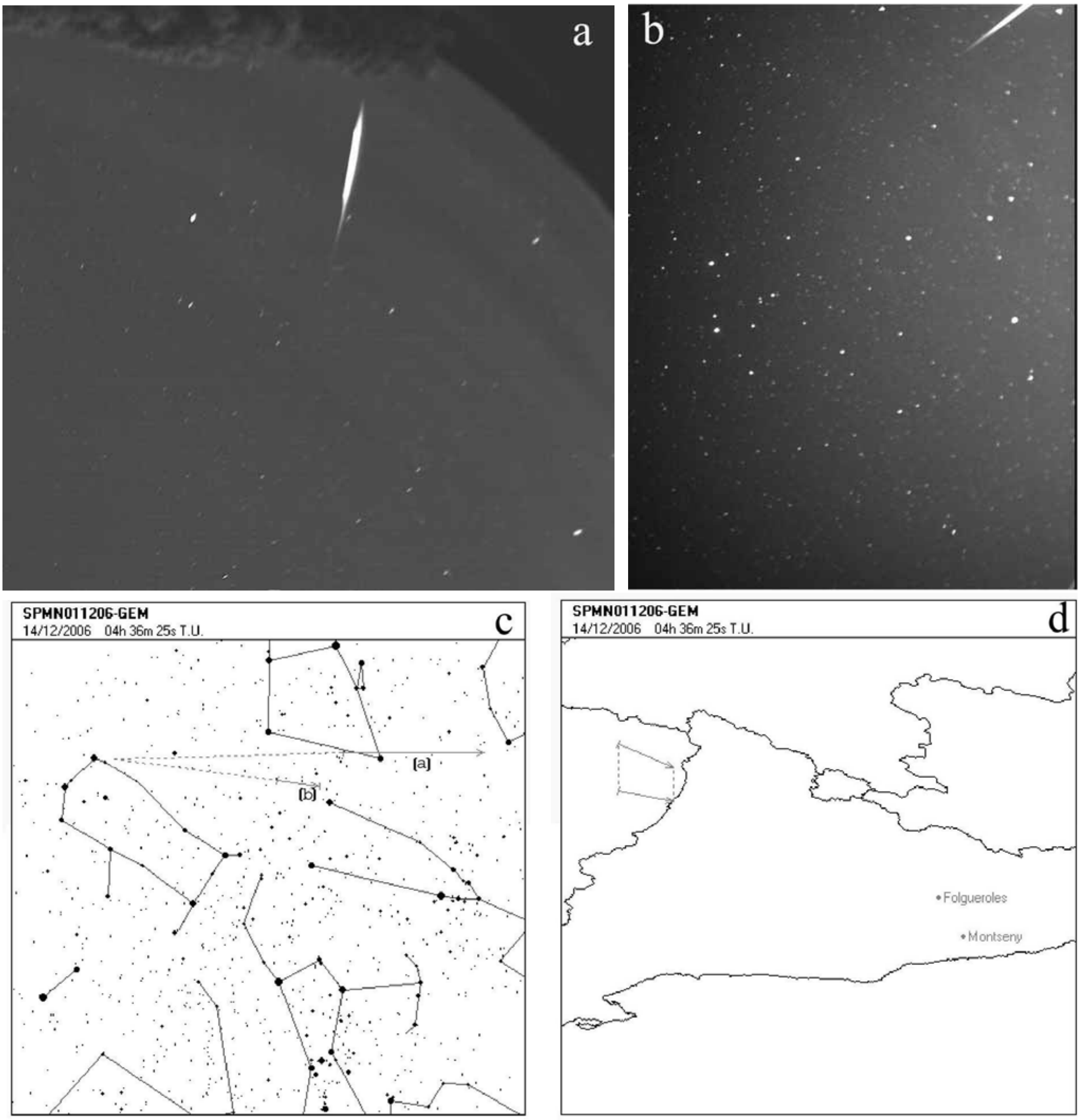

Figure 9 – The extraordinary Ribagorza bolide. This −10 magnitude Geminid (SPMN011206) was imaged on 2006 Dec. 14 at $04^{\mathrm{h}}36^{\mathrm{m}}25^{\mathrm{s}} \pm 15^{\mathrm{s}}$ UT from a) Montseny, and b) Folgueroles. c) Apparent trajectory of the meteor from both stations. d) Atmospheric trajectory and its projection on the ground. e) The heliocentric orbit of the meteoroid projected on the ecliptic plane, where the orbits of Earth (E) and Mars (M) are shown for comparison.

bright χ Orionids and some meteors of the δ Arietids and the Monocerotids were also recorded. As mentioned in section 3, on Dec. 21–22 we recorded an outburst of the Ursids. This meteoroid stream is associated with 8P/Tuttle (Jenniskens, 2006). Some bright meteors and fireballs were imaged (Figure 6) and five double-station meteors were obtained. In the second half of December an unexpected Coma Berenicid (COM) outburst occurred on the night of Dec. 24–25. Four video cameras of the SPanish Meteor Network (SPMN) operated from two stations in Sevilla province (Spain) recorded this activity increase. In particular, two Watec video cameras operated under dark skies with fields of view $88° \times 56°$ and $57° \times 43°$ and limiting meteor magnitudes of +3 recorded 12 Coma Berenicids meteors between $03^{h}30^{m}$ and $04^{h}30^{m}$ UTC. Accurate single-station astrometry reveals that this activity comes from an apparent radiant located at RA $= 181° \pm 2°$ and DEC $= +25° \pm 1°$. This radiant is also consistent with a couple of bright Coma Berenicid double-station meteors. From this data Peter Gural (Science Applications International Corp., USA) performed a simulation taking into account sensor sensitivity, geometric loss, radiant altitude and position, as well as particle distribution ($r = 2.0 \pm 0.4$, for $N = 25$) in order to get a maximum meteoroid flux of 4×10^{-3} ($m_{6.5}$/km^2/hr) with corresponds to an equivalent (human) ZHR of 60 ± 25, about ten times the activity expected for this minor shower in such date. Additional forward scatter meteor observations performed by the SPMN from Cerro Negro (Sevilla) using a computer-controlled ICOM IC-PCR1500 radio scanner attached to a 1/2-wave vertical antenna and a Hamtronic LNK-50 preamplifier. This system was tuned to 55.249 MHz, and the whole observing session was recorded on hard disk. During the peak about 5 echoes/minute (mostly short-duration, less than 1^{s}) were recorded in sharp contrast with the sporadic background obtained on other December nights. Alastair McBeath (Society for Popular Astronomy, England) points out that a possible confirmation of this data is an anomalous peak observed in the 03^{h}–04^{h} UTC interval by Gaspard de Wilde from Belgium (McBeath, pers. com.). Data reduction has involved astrometric measurements to exclude contamination from other sources. In particular, the α Lyncids (ALY), ϵ Viriginids (EVR), and an unexpected possible radiant at RA $= 188°$ and DEC $= +33°$ were also active. On other nights COM activity exhibited ZHR < 10, although some bright COM members were imaged by all-sky CCD stations (see e.g. Figure 10).

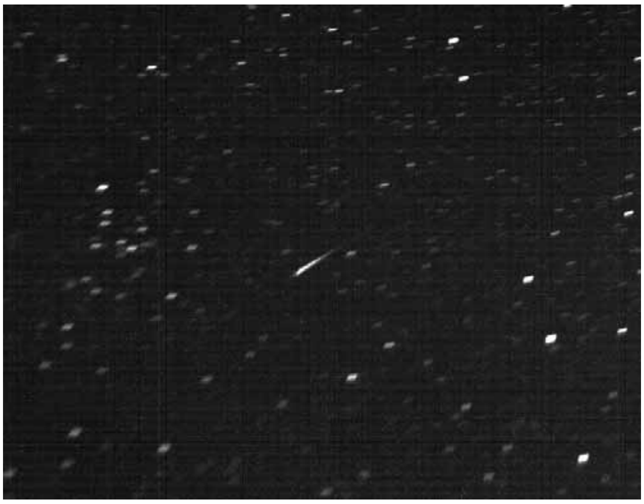

Figure 10 – An $m = -2$ Coma Berenicid meteor appeared on 2006 Dec. 21 at $03^{h}56^{m}23^{s} \pm 45^{s}$ UTC. Part of an all-sky CCD image taken from Montseny (Girona).

5 Conclusions

CCD and video cameras can be used to obtain information on the meteor activity level anytime of the year. The only problem is to post-process the large amount of data that is collected. We have given a few examples of how the SPMN multiple-station observations can provide valuable orbital information on minor meteoroid streams. The year 2006 has been one for firm establishment of the SPMN project, but many of the data still need to be reduced. However, the good results obtained up until now are encouraging the participants to continue the data reduction work and a program called *Amalthea* is in the process of being developed by the SPMN to help with video and CCD data reduction. Finally, although our network is still in a preliminary stage, significant progress is expected for the next future. A good example is the recent grant received from the *Junta de Andalucía* that will allow us to set up other 2–3 additional stations in Andalusia during 2007–2008.

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References

Jenniskens P. (2006). *Meteor showers and their parent comets.* Cambridge University Press, Cambridge, UK.

Lyytinen E. (2007). Personal communication.

Lyytinen E. and Nissinen M. (2006). "Ursid meteors

2006". Central Bureau Astronomical Telegrams 773, IAU.

McNaught R. H. and Asher D. J. (1999). "Leonid dust trails and meteor storms". *WGN*, **27:2**, 85–102.

Sekanina Z. (1976). "Statistical model of meteor streams IV. A study of radio streams from the synoptic year". *Icarus*, **27**, 265–321.

Trigo-Rodríguez J., Madiedo J. M., A.J. C.-T., and A. S. (2006a). "Orionid meteors 2006". Central Bureau Astronomical Telegrams 698, IAU.

Trigo-Rodríguez J. M., A. C.-T., Llorca J., Ugarte Postigo A., Mateo Sanguino T., and F. G. (2003). "A superbolide recorded by the Spanish Fireball Network". *WGN*, **31:2**, 49–52.

Trigo-Rodríguez J. M., Castro-Tirado A., Llorca J., Fabregat J., Martínez V. J., Reglero V., Jelínek M., Kubánek P., Mateo, T., and de Ugarte Postigo A. (2004). "The development of the Spanish Fireball Network using a new all-sky CCD system". *Earth, Moon Planets*, **95**, 553–567.

Trigo-Rodríguez J. M., Llorca J., Castro-Tirado A. J., Ortiz J. L., Docobo J. A., and Fabregat J. (2006b). "The Spanish Fireball Network". *Astronomy & Geophysics*, **47:6**, 26–28.

Trigo-Rodríguez J. M., Madiedo J. M., Castro-Tirado A. J., Ortiz J. L., Gural P. S., Llorca J., Fabregat F., Vítek S., Pujols P., and Troughton B. (2007a). "Spanish Meteor Network: 2006 all-sky and video monitoring results". In *Lunar Planet. Sci. 38*. Lunar and Planetary Institute, Houston. Abstract #1584.

Trigo-Rodríguez J. M., Madiedo J. M., Vaubaillon J., Llorca J., Gural P. S., Pujols P., and T. T. (2007b). "The origin of the 2006 Orionid outburst: 1P/Halley meteoroids trapped in a Jovian resonance". *MNRAS*. submitted.

Uehara S., SonotaCo, Fujiwara Y., Furukawa T., Inoue H., Kageyama K., Maeda K., Muroishi H., Okamoto S., Masuzawa T., Sekiguchi T., Shimizu M., and Yamakawa H. (2006). "Detection of October Ursa Majorids in 2006". *WGN*, **34:6**, 157–162.