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Multi-station Video Orbits of Minor Meteor Showers

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Abstract During 2006 the SPanish Meteor Network (SPMN) set up three automated video stations in Andalusia for increasing the atmospheric coverage of the already existing low-scan-rate all-sky CCD systems. Despite their initially thought complementary nature, sensitive video cameras have been employed to setup an automatic meteor detection system that provides valuable real-time information on unusual meteor activity, and remarkable fireball events. In fact, during 2006 SPMN video stations participated in the detection of two unexpected meteor outbursts: Orionids and Comae Berenicids. The three new SPMN stations guarantee almost a continuous monitoring of meteor and fireball activity in Andalusia (Spain) and also increase the chance of future meteorite recoveries. A description of the main characteristics of these new observing video stations and some examples of the trajectory, radiant and orbital data obtained so far are presented here.

Keywords Meteors · Meteor showers

1 Introduction

High-sensitivity video devices have been commonly used for the study of the activity of meteor streams. These provide useful data for the determination, for instance, of radiant, orbital and photometric parameters (Koten 1999; Koten et al. 2003, 2007; Molau et al. 1997; Molau 2004; de Lignie and Jobse 1996). With this aim, multiple-station video observations of major and minor meteor showers have been systematically performed since

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June 2006 within the framework of the SPanish Meteor Network (SPMN). For this purpose, three new automated video stations supported by Universidad de Huelva have been set up in Andalusia. These are endowed with high sensitivity wide-field video cameras that achieve a meteor limiting magnitude of about +3. The new stations have increased the coverage performed by the low-scan all-sky CCD systems operated by the SPMN. Wide field video systems achieve a time accuracy of about 0.01 s for determining the appearance of meteor and fireball events. This work provides an overall description of the activity of several meteor showers observed during the first year of operation of the SPMN video stations. Particularly, our present efforts are specially dedicated to obtaining accurate heliocentric orbits to link these meteoroid streams with their progenitor bodies. Our research program is particularly focused in the coverage of scarcely known minor meteoroid streams, and the study of bright meteorite-dropping bolides. A new software package is being developed by the SPMN in order to help with the analysis of the huge amount of data recorded so far.

2 Description of the Observing Stations and Procedures

The three new SPMN video stations (Table 1) are endowed with different models of Watec and Mintron cameras. These are high-sensitivity devices that employ a black and white 1/2″ Sony interline transfer CCD image sensor. Fast aspherical lenses (f0.8–f1.2) are attached to the video cameras in order to maximize image quality and detect meteors as faint as magnitude +2/+3. Their focal length ranges from 3.8 to 12 mm. Dew removers are also attached to the optics when the systems must operate below dew point and, in order to increase the signal to noise ratio, thermoelectrical coolers (Peltier systems) are also attached to the cameras when operation temperature is high (above 25°C). The whole system was designed to be fully portable in order to setup mobile stations when necessary. In fact, the Cerro Negro video station (Table 1) is a mobile station.

The observing stations are automatically switched on and off at sunset and sunrise, respectively. The images taken by the cameras at 25 fps and with a resolution of 720 × 576 pixels are continuously sent either to a set of videocassette recorders (VCR) or to PC computers through a video capture card. Every VCR stores the whole observing session on VHS tapes that are processed later on in order to extract from them the video sequences containing meteor trails. However, the computers run a software (UFOCapture, by SonotaCo, Japan) that automatically registers meteor trails and stores the corresponding video frames on hard disk. In any event, before the signal from the cameras reaches the computers or the VCRs, a video time inserter that employs a GPS device (KIWI-OSD, by PFD Systems) inserts time information on every video frame. This allows us to measure time in a precise way (about 0.01 s) along the whole meteor path. In addition, some of the cameras have also a diffraction grating attached to the optics in order to record meteor

Table 1 Geographical location of the fixed and mobile video stations located in Andalusia and operated by the SPMN

SPMN station #	Station (Province)	Longitude	Latitude	Altitude (m)
1	Seville (Seville)	05°58′50″ W	37°20′46″ N	28
2	Cerro Negro (Seville)	06°19′35″ W	37°40′19″ N	470
3	El Arenosillo (Huelva)	07°00′00″ W	36°55′00″ N	30

spectra and perform the chemical characterisation of corresponding meteoroids. Astrometric reduction was made by hand, comparing the *X*, *Y* positions of stars and meteors in every frame of the sequences with meteors. Note that we don't use any software for automatic astrometry of the images. This crucial step was made via direct measurements of the pixel position, as in all our previous work (see e.g. Trigo-Rodríguez et al. 2002, 2004, 2006b). The *Network* software also allows us to predict the position of every meteor from each station by assuming the typical values of ablation height (Trigo-Rodríguez et al. 2002, 2004b). A search through the database of meteors that appeared during the same observing interval and in the proper position allowed the unequivocal identification of common double-station meteors. Once identified, the software estimates the atmospheric trajectory and radiant for each meteor. From the astrometric measurements of the shutter breaks and the trajectory length, the velocity of the meteoroid was derived. The average value of observed velocities for each shutter-break was obtained, and the preatmospheric velocity V_∞ was taken from the velocity measured in the earliest frames of the video sequences. In the last step, we determine the orbital elements from our trajectory and radiant data by using the *MORB* program Ceplecha et al. (2000). As a consequence of the observational data reduction effort, reliable trajectory and orbital data was obtained and is presented in Sect. 3.

3 Results

Because of extraordinary weather conditions in Spain during 2006, it was possible to obtain a huge amount of data related to the activity of minor and major streams. The number of nights studied by the video network was 150, corresponding to about 1,400 h of effective time, and about 3,000 meteors/month. Consequently, it is easy to understand that most of the results obtained so far still need to be reduced. In order to help with this, we are developing a software package called Amalthea which can perform in shorter time different tasks related to astrometry and photometry. We focus here on data obtained from several major streams, but especially on poorly studied meteoroid streams.

Since June 2006, the new SPMN video stations have registered an important number of bright fireballs belonging to different meteor showers (see e.g. Trigo-Rodríguez et al. 2007a) and also participated in the confirmation of the Orionid outburst in October 2006 (Trigo-Rodríguez et al. 2006, 2007b). SPMN video cameras also followed the activity of 2006 Leonids (Jenniskens 2006b).

As many of the meteor trails have been registered simultaneously by several of these observing stations, it has been possible to obtain the orbital elements of the corresponding meteoroids. Some of the results obtained so far are shown in Tables 2 and 3. Thus, for instance, in August 2006 we could observe several members of the π Eridanids (ERI). The data show a radiant position close to the estimated for the proposed parent body (see Table 7 of Jenniskens 2006a).

Jenniskens (2006a) proposes an activity period for September ε Perseids (SPE) in mid-September (Table 7, radiant#208), past observations suggest extended activity much earlier (Trigo-Rodríguez 1989). A clear example would be the video meteor SPMN070806 (Tables 2 and 3) that seems to be associated with this diffuse stream. Its radiant position has a small difference in declination that would be produced either by high dispersion or radiant drift. In any case, it is clear that the first week of September requires additional coverage of the activity of minor showers radiating from Auriga and Perseus.

Table 2 Trajectory and radiant data of 2006 SPMN video meteors. Equinox (2000.0)

SPMN code	Stream	M_v	H_b (km)	H_{max} (km)	H_e (km)	α_g (°)	δ_g (°)	V_∞ (km/s)	V_g (km/s)	V_h (km/s)
050806	ERI	−3	105.8	–	84.0	53.4 ± 0.3	−14.5 ± 0.3	59.9 ± 0.3	58.5	39.9
070806	SPE	−1	113.6	–	94.0	53.3 ± 0.3	30.4 ± 0.3	63.8 ± 0.3	62.6	36.0
101006	NTA	+1	106.5	102.7	86.5	31.0 ± 0.2	17.7 ± 0.2	23.5 ± 0.2	21.1	34.8
011106	LEO	+1	97.3	–	84.3	154.8 ± 0.3	25.3 ± 0.7	72.0 ± 0.2	70.8	42.1
061106	LEO	−3	99.0	96.8	87.4	155.0 ± 0.3	25.0 ± 0.7	72.2 ± 0.3	71.0	42.3
071106	LEO	−1	107.2	–	95.1	156.3 ± 0.3	21.5 ± 0.3	72.1 ± 0.2	70.9	42.2
031206	ALY	−1	98.2	–	88.6	135.33 ± 0.19	38.93 ± 0.10	56.3 ± 0.2	55.1	47.5
071206	COM	−1	99.8	–	92.7	180.2 ± 0.3	27.6 ± 0.3	63.8 ± 0.3	62.8	39.9
081206	HYD	−2	111.6	–	94.8	135.4 ± 0.3	−2.5 ± 0.3	58.9 ± 0.3	58.1	45.0

Stream association is given using IMO standard labels (Mv: visual magnitude; H_b, Hmax, He: height corresponding to the beginning point, maximum brightness point, and ending point, respectively; α_g, δ_g: right ascension and declination of the geocentric radiant; $V\infty$: pre-atmospheric meteor velocity; V_g: geocentric meteor velocity; V_h: heliocentric meteor velocity)

Table 3 Orbital elements of imaged meteors. Equinox (2000.00)

SPMN code	q (AU)	$1/a$ (AU^{-1})	e	i (°)	ω (°)	Ω (°)
050806	0.816 ± 0.007	0.19 ± 0.03	0.848 ± 0.022	117.2 ± 0.5	54.49 ± 1.23	336.46192 ± 0.00001
070806	0.813 ± 0.011	0.52 ± 0.03	0.580 ± 0.022	153.4 ± 0.8	242 ± 2	156.52746 ± 0.00002
101006	0.507 ± 0.007	0.636 ± 0.016	0.677 ± 0.007	4.26 ± 0.19	282.54 ± 1.12	201.46599 ± 0.00023
011106	0.9880 ± 0.0005	0.023 ± 0.022	0.977 ± 0.021	156.3 ± 0.9	177.8 ± 1.5	236.46875 ± 0.00008
061106	0.9878 ± 0.0007	0.008 ± 0.032	0.99 ± 0.03	156.8 ± 1.1	177.3 ± 1.9	236.46878 ± 0.00010
071106	0.9865 ± 0.0018	0.016 ± 0.022	0.985 ± 0.022	156.9 ± 0.8	185.1 ± 2.3	236.50565 ± 0.00007
031206	0.2052 ± 0.0020	−0.508 ± 0.019	1.104 ± 0.005	84.1 ± 0.5	300.5 ± 0.4	273.06619 ± 0.00001
071206	0.688 ± 0.014	0.24 ± 0.03	0.832 ± 0.019	134.3 ± 0.6	250.2 ± 1.9	273.18564 ± 0.00002
081206	0.228 ± 0.006	−0.25 ± 0.03	1.057 ± 0.007	110.2 ± 0.8	119.6 ± 1.0	93.18892 ± 0.00001

In October 2006 we detected several members of the Andromedids (AND), the Northern Taurids (NTA) and the ν Aurigids (NAU) minor meteor showers. The results calculated for the ν Aurigids (Trigo-Rodríguez et al. 2007b, MNRAS) show orbital similitude with the orbital elements obtained by Sekanina (1976). It was completely unexpected to find members of this meteoroid stream so early in the month because the previously reported activity period is October 20–22 (Jenniskens 2006a). However, other single station meteors recorded by the SPMN video cameras were also well associated by alignment and angular velocity with this radiant. The SPMN video stations were also able to record in November the activity of 2006 Leonids (Jenniskens 2006b). Three orbits obtained during the outburst are shown in Table 3.

On December 24–25, 2006 SPMN video cameras recorded a high activity of the Comae Berenicids (COM). Four video cameras operated from two stations in Seville province (Spain) recorded the event. In particular, two Watec video cameras operated under dark skies with fields of view 88° × 56° and 57° × 43° and limiting meteor magnitudes of +3 recorded 12 Comae Berenicids meteors between 3 h 30 m and 4 h 30 UTC. 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 $N = 25$) provided a maximum COM meteoroid flux of 4×10^{-3} ($m_{6.5}/km^2/h$) with corresponds to an equivalent (human) ZHR = 60 ± 25, about 10 times the activity expected for this minor shower in such date. Accurate single-station astrometry reveals that this activity comes from an apparent radiant located in RA: 181 ± 2° and DEC: +26 ± 2°. SPMN 071206 exhibit a similar radiant to the derived from single-station data. This activity is in agreement with additional forward scatter meteor observations performed by the SPMN from Cerro Negro (Seville) 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. However, these data could not be contrasted with other sources. Alastair McBeath (Society for Popular Astronomy, England) pointed out that a possible confirmation of this data is an anomalous peak observed in the 3–4 h UTC interval by Gaspard de Wilde from Belgium (Mc Beath, pers. comm.). Although a clear confirmation of this high activity has not been obtained we think it deserves to be mentioned. During the December monitoring we also recorded a detectable activity from the α Lyncids (ALY) and the σ Hydrids (HYD) radiants, and at least one orbit has been obtained for these (SPMN031206 and SPMN081206, respectively). About 80% of the December multiple-station data remains to be reduced.

4 Conclusions

The SPMN has increased its atmospheric coverage in the south of Spain by means of three new video stations. These allow achieving a spatial resolution of about 1 arc min, a time resolution of about 0.01 s and a meteor velocity accuracy that ranges between 0.2 and 0.4 km/s. Besides, the distance separating the two main cores of the network (Catalonia and Andalusia) guarantee almost a continuous monitoring of meteor and fireball activity, which has provided a huge amount of data during the last year (in total, eight observing stations are in operation). We have also given a few examples of how the SPMN multiple-station observations can provide valuable orbital information on minor meteoroid streams. Many of the data obtained so far still need to be reduced, although a new software package is being developed by our network to help with this task. On the other hand, the SPMN video systems are currently under expansion in order to improve the devices used to register meteor spectra and also to include daytime monitoring cameras.

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