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All-sky Meteor Orbit System AMOS and preliminary analysis of three unusual meteor showers

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ABSTRACT

All-sky Meteor Orbit System (AMOS) is a semi-autonomous video observatory for detection of transient events on the sky, mostly the meteors. Its hardware and software development and permanent placement on several locations in Slovakia allowed the establishment of Slovak Video Meteor Network (SVMN) monitoring meteor activity above the Central Europe. The data reduction, orbital determination and additional results from AMOS cameras – the SVMN database – as well as from observational expeditions on Canary Islands and in Canada provided dynamical and physical data for better understanding of mutual connections between parent bodies of asteroids and comets and their meteoroid streams. We present preliminary results on exceptional and rare meteor streams such as September ϵ Perseids (SPE) originated from unknown long periodic comet on a retrograde orbit, suspected asteroidal meteor stream of April α Comae Berenicids (ACO) in the orbit of meteorites Příbram and Neuschwanstein and newly observed meteor stream Camelopardalids (CAM) originated from Jupiter family comet 209P/Linear.

1. Introduction

Research of the population of meteoroids directly interacting with the Earth enhances our knowledge on the origin and structure of the Solar System and could help us to predict future collisions of larger bodies. This demands systematic monitoring of all components of interplanetary matter. Nowadays, the meteor catalog of the International Astronomical Union (IAU MDC) contains 95 well defined and periodic meteor showers, and more than 460 meteor showers which are insufficiently well defined are included in the working list. The parent bodies of meteor streams are only known for 10% of them. Meteor particles come from comets as they are released during the sublimation of its ices. Some meteors could come from asteroids, originating by different processes, such as the tidal disruption, thermal stress, fast rotation and erosion by cosmic rays. Based on the rotation of asteroids (Harris, 1996), it is suggested that almost all of the Near Earth Asteroids (NEA) larger than 200 m are remnants of mutual collisions and are gravitationally bound aggregates. If such an asteroid flies within the Roche limit of a planet, it tends to break up under the influence of the tidal forces. It has been shown (Kornoš et al., 2009) that a meteoroid stream could originate in a tidal disruption of the asteroid and the rotation of an asteroid effectively increases the Roche limit further out from the Earth and, therefore, the frequency of the tidal disruption is higher than previously anticipated (Tóth et al., 2011a). A systematic monitoring of the night sky by dedicated surveys (Catalina, Pan-Starrs, LINEAR, LONEOS, Spacewatch, etc.), identifying potentially hazardous bodies, brought an increase in discoveries of NEAs. This increased the number of objects with orbits similar to meteor streams, especially those near the ecliptic plane, for instance Porubčan et al. (2004) found 9 new associations between weak showers and asteroids.

However, connecting large (asteroidal) and small (meteoroidal) populations, their origin and size–frequency distributions is not trivial as pointed out by Ceplecha (1992). Personal communication with Minor Planet Center Manager (Tim Spahr, 2012) suggests that Pan-Starrs1 is finding more highly eccentric small NEA. Brown et al. (2013) found that there are significantly more 10–50 m NEA than expected. Systematic monitoring of meteor activity based on video techniques (Molau et al., 1999; Koten et al., 2003, 2011; Trigo-Rodriguez et al., 2008; Tóth et al., 2008, 2011b; SonotaCo,

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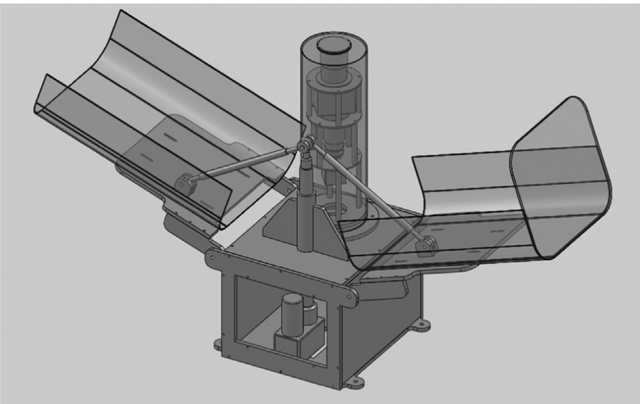

Fig. 1. AMOS camera with opened outer housing.

2009; Brown et al., 2010; Jenniskens et al., 2011; Cooke and Moser, 2012; Kornoš et al., 2014a) gives information about smaller particles, but with possible larger ones in the same streams originated in cometary or asteroidal breakup processes.

The aim of AMOS is not just to gather as much as meteor data and orbits as possible but also identify unknown streams, individual meteors coming from asteroids, systematic monitor known showers, observe unexpected shower outbursts and bright bolides with potential meteorite falls, all with the focus on orbital accuracy better than most all-sky video system due to the about two times higher pixel resolution.

2. Overview of the system

The system AMOS consists of four major display components: a fish-eye lens, image intensifier, projector lens and a digital video camera. The resulting field of view of AMOS is $180^\circ \times 140^\circ$ with the image resolution of 1280×960 pixels with video frame rate of 15/s (DMK 23U274). Upcoming version of AMOS is going to use digital cameras with the resolution of 1600×1200 pixels and frame rate of 20/s (DMK 41AU02). Limiting magnitude for stars is about +5 mag. for a single frame, the efficiency is lower for moving objects approx. +4 mag. due to the trailing lost.

The operation of cameras is semi-automatic and a remote control is available through internet connection. The entire system is protected by outer and inner enclosures and is secured by environmental detectors for temperature, rain and illumination of the sky (Fig. 1). AMOS is able to work even during full Moon which does not saturate most of the field of view and only rises the level of sky background and lowers the limiting magnitude. AMOS itself needs DC current of its operation with the voltage of 24 V (Zigo et al., 2013).

Although the system was primarily designed for meteor observation, it could be used for meteorological, geophysical, aviation or satellite observations as well. The inner part of the camera is portable and fully operational by itself, weighting only 6.5 kg and with the height of 50 cm and base width of 25 cm. Portable configuration is ideal of man-assisted operation and ground or on-board operations. The outer enclosure was tested for extreme weather conditions in a wind tunnel up to the wind speed of 52 m/s in a closed configuration. The test proved that the system is able to operate and be aerodynamically stable up to 32 m/s (Tesár et al., 2014).

3. Database of precise video orbits – Slovak Video Meteor Network

The first prototype of AMOS has been working at the AGO Modra Observatory since 2007. Nowadays, four AMOS cameras create a Slovak Video Meteor Network (SVMN) at locations of AGO Modra (AGO), Arborétum Tesárske Mlyňany (ARBO), Kysucké Nové Mesto Observatory (KNM) and Važec. The direct distance between individual stations ranges from 80 to 150 km and are operated remotely. These four station form a Slovak Video Meteor Network (SVMN) which is governed by the Comenius University in Bratislava. Additional stations in Central and Eastern Slovakia will enlarge the network in the near future. The current performance of an individual AMOS camera (Fig. 3) within SVMN is equal to detection of approximately 10,000 single-station meteors per year (about 20% of them are double or multi-station) and about 50 transient luminous events like sprites or elves.

SVMN yields to a standard astrometric error of 0.03–0.05° that translates to the accuracy of several tens or hundreds of meters for a meteor atmospheric trajectory, when the detailed all-sky reduction described in Ceplecha (1987) and Borovicka et al. (1995) is used. Also we are developing our own trajectory software MT v.085 and detection AMOS software. Currently, we use UFOCapture software for meteor detection and UFOAnalyzer for astrometric data reduction, where each meteor is individually measured.

Data from SVMN are being continuously reduced and published on freely accessible web site (http://daa.fmph.uniba.sk/meteor_network). The current version of orbital dataset of video meteors recorded by SVMN from 2009 to 2014 contains 2779 relatively accurate video orbits (Fig. 2). AMOS was also tested at locations with better observing conditions. For instance, the observational expedition on Tenerife and La Palma at Canary Islands in 2014 showed that AMOS has 4 times as higher efficiency there as in the conditions of Central Europe, mostly due to dark sky background and atmospheric conditions. The installation of two AMOS cameras on Canary Islands observatories of IAC is in preparation phase. Future plans include installation of two AMOS cameras in Chile to cover southern hemisphere sky .

AMOS cameras took a place on the first European airborne meteor mission Draconids 2011 (Vaubaillon et al., 2015) and well as ground based observational expedition Draconids 2011 (Toth et al., 2013). Even though the Košice meteorite, that fell in Slovakia, was instrumentally observed by non-dedicated video cameras (Borovička et al., 2013), our team was successful in meteorites' recovery (Tóth et al., 2015). Recently, AMOS cameras of SVMN observed fireball dropping meteorite over Czech Republic on December 9, 2014 (Spurný and Borovička, personal communication), which was actually recovered. Similarly, AMOS cameras observed a very bright fireball with possible meteorite fall above Romania on January 7, 2015 from a distance of more than 600 km.

4. Observations of unusual meteor streams

4.1. Outburst of September ϵ Perseids (SPE) in 2013

An unexpected high activity – an outburst – of the meteor shower of September ϵ Perseids (SPE) was observed on September 9/10, 2013. The SPE shower is established meteor shower in IAU Meteor Data Center, but with the unknown parent body. We analyzed SPE meteors observed by the European stations network (EDMONd) and collected in the video meteor orbits database EDMOND (Kornoš et al., 2014b). We also compared two AMOS all-sky video datasets of SPE meteors, gathered from AGO and ARBO stations of SVMN. We obtained (Gajdoš et al., 2014) activity profiles of the 2013 SPE outburst during 4 h around its maximum and