Draconids 2011: outburst observations by the Croatian Meteor Network

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The predicted Draconid meteor shower outburst during October 2011 was observed by a portion of the Croatian Meteor Network, whose stations encountered clear weather. A total of 88 Dracond orbits have been calculated from 16 contributing stations. We present results for 53 orbits obtained from the fully automatic observation and processing pipeline. Two methods of trajectory estimation were applied, showing better fit results using a linearly changing velocity model versus a constant velocity model. The estimated mean radiant position has been found to be at $\alpha = 262\overset{\circ}{.}6$ and $\delta = +56\overset{\circ}{.}6$, and the estimated geocentric velocity $V_{\mathrm{g}} = 20.9$ km/s.

1 Introduction

The Draconid meteor shower outburst that occurred on October 8, 2011, had been predicted by various authors and described in several papers (Vaubaillon et al., 2011; Maslov, 2011; Asher and Steel, 2012). All the Draconid outburst predictions were fairly similar with respect to the predicted meteor flux, but varied significantly on the level of activity that could be observed. While Vaubaillon et al. (2011) predicted two outbursts of up to ZHR = 500, more conservative predictions by Maslov (2011) set the ZHR at only 50. Given the timing of the peak, Europe was the favored longitude for observation, which conveniently fell within the Croatian Meteor Network's (CMN) area of multi-station coverage.

The CMN cameras have continously monitored the sky over Croatia and its neighboring countries since 2007 (Andreić and vSegon, 2010). Images are captured by 1004X video cameras equipped with 4 mm, $f/1.2$ lenses using the SkyPatrol software. The resultant files are then post-processed by both the MTP_Detector and CMN software packages. The camera fields of view and the astrometry techniques applied result in meteor detection position errors of about $0\overset{\circ}{.}06$ or less (depending on capture resolution, the number of reference stars, and their spread across the focal plane). The standard CMN data processing pipeline ends with data products formatted for import into the software package UFOOrbit. This permits the orbital information generated to be compatible with existing data from the SonotaCo Network. Catalogues of orbits from CMN data have been compiled for the years 2007 to 2010; see, e.g., Korlević et al. (2013) for the years 2008 and 2009.

During the night of October 8, 2011, weather conditions over Croatia were quite variable. A low-pressure system that generated heavy storms and showers (not meteor in nature) had moved rapidly across Croatia. Its quick passage had opened up clear skies first for the northwestern part of the CMN, and only later on for other stations in the network. The intensity of storms had been such that 5 multi-station observations of sprites were made during that night. Despite the thunderstorms, skies cleared sufficiently, so a total of 448 Dracondis were recorded, of which 88 Draconid orbits have been calculated from multi-station data. In this paper are presented the data from a fully automatic process of capture, detection, and astrometry, followed by the trajectory and orbit calculations made using the multiparameter fit software developed recently (Gural, 2012).

2 Draconids as observed from the Croatian Meteor Network

A total of 88 Draconid meteors were captured by at least two CMN cameras. These meteors have been further filtered by constraining the convergence angle (Q_a) between intersecting observation planes, discarding meteors with $Q_a < 15°$ and leaving a set of 53 meteors captured by two or more stations: 28 from two stations, 18 from three, 6 from four, and 1 from five stations. Simulations run with the multi-parameter fit method showed that 15° is the angle below which observations have reduced reliability due to larger errors in estimation of the fit parameters. Two different models for velocity propagation were used in the trajectory estimation: a non-decelerating model (constant velocity marked as V_0) and a constant decelerating model (linear change in velocity marked as V_1).

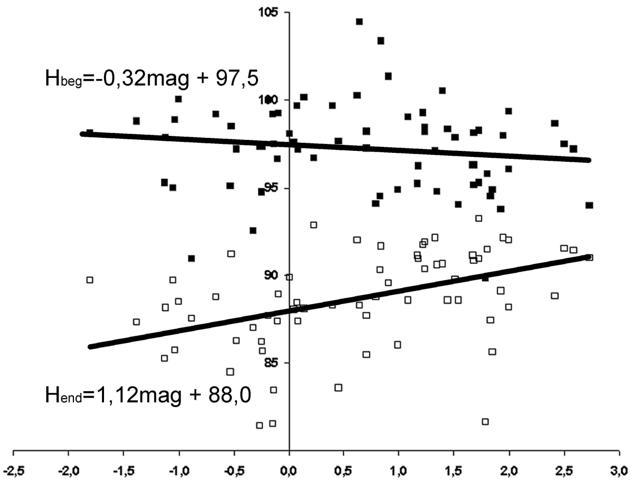

Figure 1 – Magnitude-height dependence for the 2011 Draconids fainter than magnitude −2.5.

Based on the V_0 results, the calculated average beginning and end heights for all Draconid meteors fainter than magnitude −2.5 were found to be $h_{\text{beg}} = 98$ km and $h_{\text{end}} = 88$ km, respectively. The resulting dependance of height parameters on estimated magnitude is presented in Figure 1.

It can be seen that beginning heights increase about 0.3 km per magnitude step, while the end heights have a dispersion that is much larger such that, for each magnitude brighter, a meteor penetrates 1.1 km deeper into the atmosphere. The average duration of the 2011 Draconids as seen by the CMN video cameras was found to be 0.66 seconds.

Average results (including mean orbital elements) on 53 meteors with $Q_a > 15°$ processed by the non-decelerating model are found to be as follows (error estimations being presented as one standard deviation value):

$\alpha = 261\overset{\circ}{.}8 \pm 2\overset{\circ}{.}7$, $\delta = +55\overset{\circ}{.}4 \pm 1\overset{\circ}{.}2$,
$V_{\text{geo}} = (19.97 \pm 0.55)$ km/s,
$1/a = (0.339 \pm 0.041)$ AU^{-1}, $q = (0.995 \pm 0.002)$ AU,
$e = 0.663 \pm 0.041$,
$i = 30\overset{\circ}{.}6 \pm 0\overset{\circ}{.}7$, $\omega = 172\overset{\circ}{.}4 \pm 2\overset{\circ}{.}2$, $\Omega = 195\overset{\circ}{.}0 \pm 0\overset{\circ}{.}1$.

A graph showing single-meteor radiant positions calculated by employing a non-decelerating meteor propagation model of the multi-parameter fit solution is presented in Figure 2.

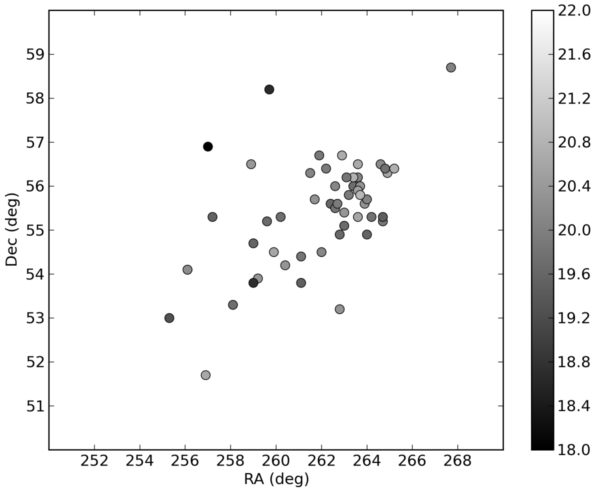

Figure 2 – Radiant positions calculated by the non-decelerating model, grayscale-coded V_{geo}.

Average results (including mean orbital elements) on 53 meteors with $Q_a > 15°$ processed by the constant decelerating model are found to be as follows (error estimations being presented as one standard deviation value):

$\alpha = 262\overset{\circ}{.}6 \pm 2\overset{\circ}{.}2$, $\delta = +55\overset{\circ}{.}6 \pm 1\overset{\circ}{.}0$,
$V_{\text{geo}} = (20.91 \pm 0.81)$ km/s,
$1/a = (0.285 \pm 0.048)$ AU^{-1}, $q = (0.996 \pm 0.002)$ AU,
$e = 0.716 \pm 0.048$,
$i = 31\overset{\circ}{.}7 \pm 1\overset{\circ}{.}0$, $\omega = 173\overset{\circ}{.}1 \pm 1\overset{\circ}{.}7$, $\Omega = 195\overset{\circ}{.}0 \pm 0\overset{\circ}{.}1$.

A graph showing single-meteor radiant positions calculated by employing the constant deceleration model of the multi-parameter fit solution is presented in Figure 3.

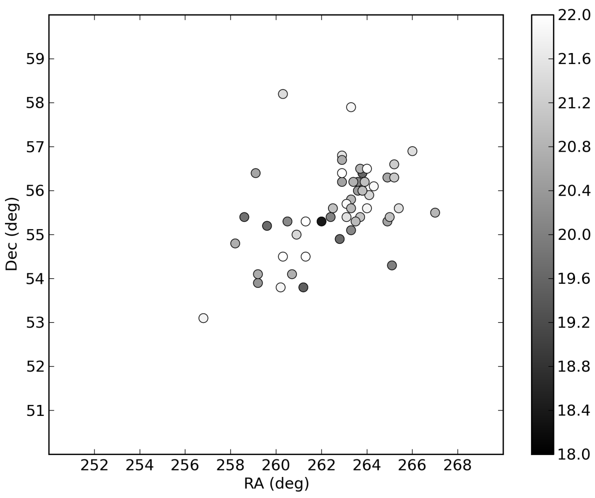

Figure 3 – Radiant positions calculated by the constant deceleration model, grayscale-coded V_{geo}.

Side-by-side orbit plots for V_0 and V_1 models are shown in Figure 4.

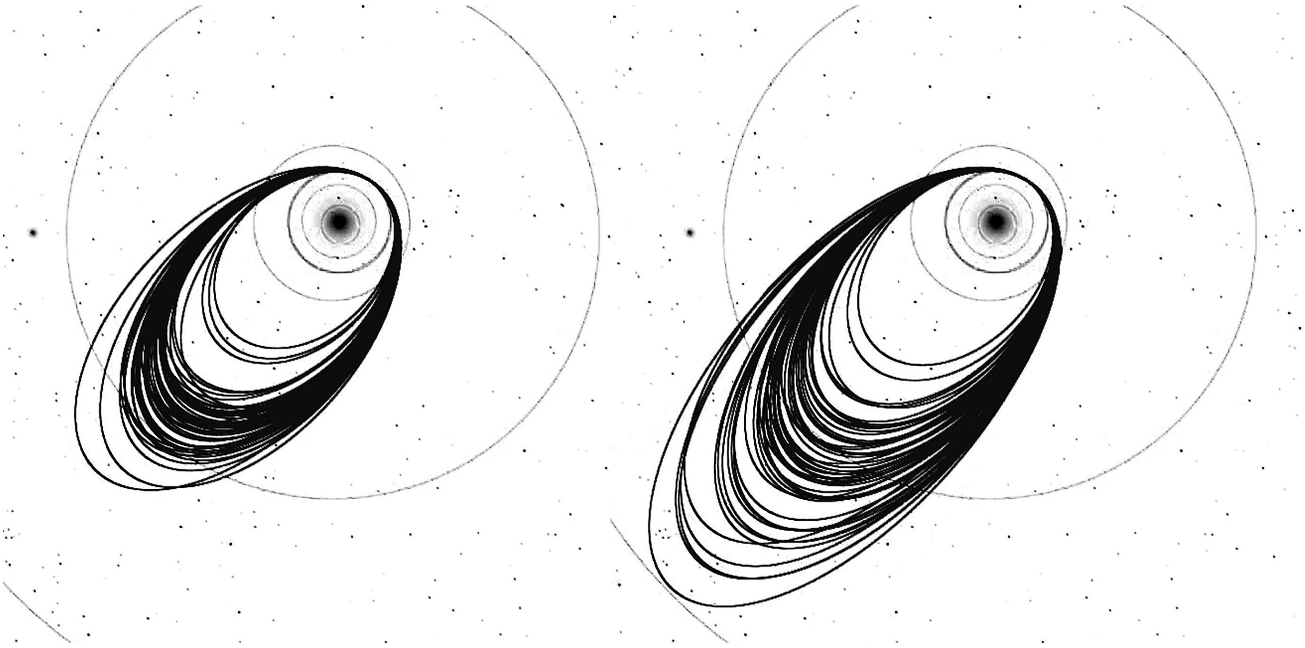

Figure 4 – Side-by-side orbit plots for V_0 (*left*) and V_1 (*right*) models.

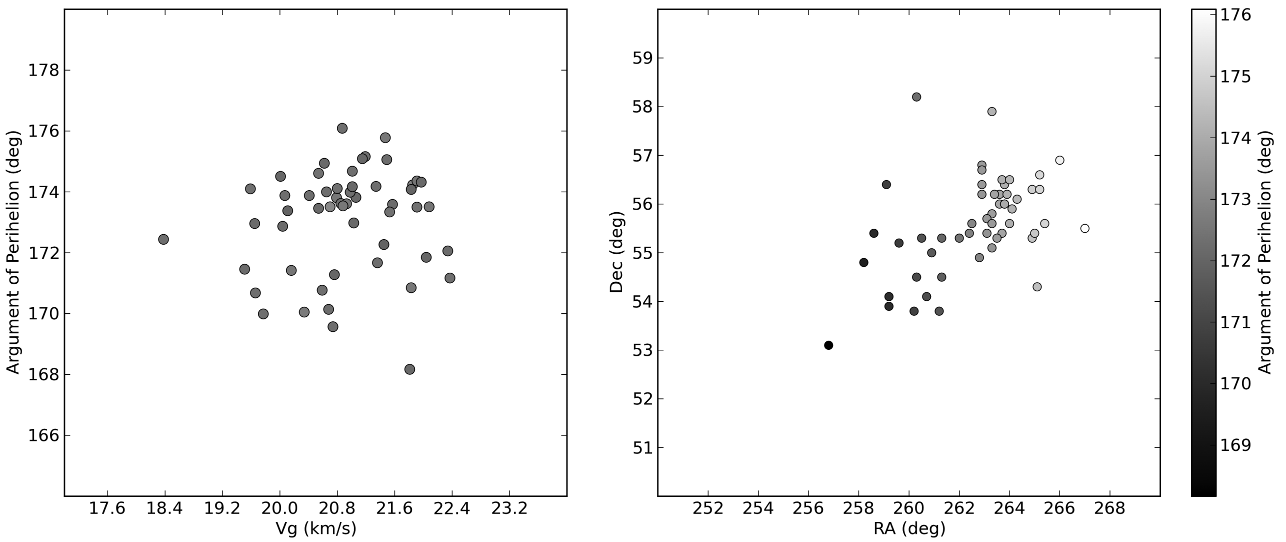

Figure 5 – Geocentric velocity (*left*) and radiant position (*right*) versus argument of perihelion plots for the 2011 Draconids.

3 Discussion

As can be seen from the presented radiant and orbit plots, there is a significant difference in radiant positions as well as resulting orbits between the V_0 and V_1 models.

The radiant spread is smaller for the constant deceleration model, which is also evident from the smaller standard deviations seen in right ascension and declination. Moreover, the resulting mean aphelion distance of 4.9 AU for meteors calculated by using the non-decelerating model puts meteoroids at orbits inside Jupiter's orbit—not in agreement with previous, more precise observations of the Draconid meteors.

Results for the linearly changing velocity (or constant deceleration) model, by contrast, puts the mean aphelion distance at 6.0 AU, which is the very same value as reported for the main body of the Draconids' parent body: Comet 21P/Giacobini-Zinner.

Thus, we may come to the conclusion that the constant deceleration model better describes the observed meteor trajectories than the more orthodox non-deceleration model approach. Also, in the case of the CMN Draconid observations, they are of sufficient accuracy for each meteor's deceleration to be detected.

There is also another interesting thing we can see from the V_1 model reults. If one looks at a graph plotting geocentric velocity $V_{\rm geo}$ versus the argument of perihelion ω, as shown in Figure 5 on the left panel, one can see that it seems that we have two virtually distinct groups of radiants. If we take a look at Figure 5 on the right panel, where the axes plotted are right ascension versus declination with the argument of perihelion indicated as color-coded symbols, there is an obvious trend for the argument of perihelion, increasing in value from bottom-left to the top-right portion of the plotted Draconid radiant points.

The resulting orbital data for those two groups of radiants, separated at an arbitrary argument of perihelion of $\omega = 172\overset{\circ}{.}5$ are as follows, starting with $\omega < 172\overset{\circ}{.}5$ orbits:

$\alpha = 259\overset{\circ}{.}9 \pm 1\overset{\circ}{.}2$, $\delta = +54\overset{\circ}{.}8 \pm 1\overset{\circ}{.}2$,
$V_{\text{geo}} = (20.96 \pm 0.92)$ km/s,
$1/a = (0.280 \pm 0.061)$ AU^{-1}, $q = (0.994 \pm 0.001)$ AU,
$e = 0.722 \pm 0.061$,
$i = 31\overset{\circ}{.}6 \pm 1\overset{\circ}{.}1$, $\omega = 170\overset{\circ}{.}8 \pm 1\overset{\circ}{.}1$, $\Omega = 195\overset{\circ}{.}0 \pm 0\overset{\circ}{.}1$.

For $\omega > 172\overset{\circ}{.}5$ orbits, we have the following:

$\alpha = 263\overset{\circ}{.}9 \pm 1\overset{\circ}{.}1$, $\delta = +55\overset{\circ}{.}9 \pm 0\overset{\circ}{.}6$,
$V_{\text{geo}} = (20.89 \pm 0.76)$ km/s,
$1/a = (0.287 \pm 0.041)$ AU^{-1}, $q = (0.997 \pm 0.001)$ AU,
$e = 0.714 \pm 0.041$,
$i = 31\overset{\circ}{.}7 \pm 1\overset{\circ}{.}0$, $\omega = 174\overset{\circ}{.}0 \pm 0\overset{\circ}{.}8$, $\Omega = 195\overset{\circ}{.}0 \pm 0\overset{\circ}{.}1$.

The two mean hypothetical radiant positions differ by more than 3°, but there is no obvious difference in mean orbital elements, with the exception of the argument of perihelion ω which differ by about 3° as well. One should also note that radiants with $\omega < 172\overset{\circ}{.}5$ show higher dispersion, having a higher σ value than the $\omega > 172\overset{\circ}{.}5$ set.

Possible explanations for what is seen here is that two different trails were observed, ejected during different main body perihelion passages. The first group, according to the smaller dispersion, is conjectured to be younger with $\omega > 172\overset{\circ}{.}5$, and the second grouping is older with $\omega < 172\overset{\circ}{.}5$. However, since the estimated margins of error for this dataset are higher than the mean errors by one order of magnitude, the authors cannot claim this is the only reason for the dispersion in the radiants measured. Deeper analysis that will be made on manually checked observations should reveal if this explanation is in fact plausible. Also, adding observations from other neighboring meteor networks can fill in data on meteors having $Q < 15°$ and provide a better picture of this Draconid outburst.

4 Summary

On October 8, 2011, the Draconid meteor outburst was observed with video cameras in the Croatian Meteor Network and the processing results have been presented. The resulting mean radiant position from fully automatic data processing is in agreement with the predicted positions for the 1900 trail, differing by $0\overset{\circ}{.}6$ in right ascension and $0\overset{\circ}{.}2$ in declination.

More detailed analysis will be done on manually rechecked observations, as well as filling in the dataset with observations from neighboring meteor networks. Detailed data on each meteor will be provided in a future paper once this analysis has been completed.

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