3000000 light curves in the EDMOND database

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The EDMOND database already contains around 3 million records of meteors. However, these are only used for triangulation, for orbit determination (EDMOND) and for statistics of meteor streams (Molau, 1999). In addition to the geometric measurements, the data also includes information about meteor brightness.

1 Introduction

EDMOND contains data for about **3060250** meteors (up to 31 December 2014). Processing of this data has yielded **210887** meteor orbits (after reduction by means of qualitative criteria). The source data from MetRec and UFO Tools do not only contain astrometric information. In that data we can also find information about meteor brightnesses. But, this brightness data (other than the absolute magnitude) is not used. This means that there are 3 million meteor lightcurves hidden in our database!

2 How to extract these light curves?

Since MetRec and UFO Tools have a different format of data storage, we need two conversion utilities to obtain the brightness data.

1. We need to identify an optimal data storage format that will enable further processing.
2. We need to create utilities that will combine multistation meteor lightcurves.
3. We need to create tools that will combine light curves with atmospheric trajectory data.
4. We need to create a graphical interface for the new database to welcome the user.

Format of MetRec data

The MetRec data consists of two files:

- ***.ref file** contains data about the observing site and data about the reference stars *(Figure 1)*;
- ***.inf file** contains data about the *.ref file and data about the captured object: time, magnitude, RA and DEC (*Figure 2*).

Format of UFO data

UFO data is a single XML file. It contains detailed information about the station, the camera and the captured object. The captured object is measured frame by frame to provide information about the frame number, the sum of luminosity, the magnitude, the azimuth and the elevation, as well as the RA and DEC.

```
SiteCode 14270
Longitude 11.191670
Latitude 46.144199
Altitude 680
OperationMode unguided
ReferenceDate 2012 4 8
ReferenceTime 19 30 0
NoiseLevel 6
MaxStarDiameter 5.9
MinStarDiameter 1.0
VideoBrightness 240
VideoContrast 255
CenterOfPlate  192  144
OrderOfPlateConstants 3
NumOfRefStars 134
RefStar1  1.8  1.1   363  11.0620  61.7510 128.75  24.50
RefStar2  1.8  0.0   259  12.9000  55.9600  46.50  72.00
RefStar3  3.0  1.6   149  10.3720  41.4990 212.00 123.75
RefStar4  2.3  0.0   215  11.0310  56.3820 140.25  54.50
RefStar5  2.6  0.2   194  11.2350  20.5240 195.50 267.00
RefStar6  3.1  1.5   243   9.3510  34.3930 297.75 123.75
RefStar7  2.4  0.0   217  11.8970  53.6950  99.50  82.00
RefStar8  3.0  1.1   203  11.1610  44.4980 155.50 126.00
RefStar9  3.5  1.4   136  11.3080  33.0940 166.50 196.50
RefStar10  2.9 -0.1   ---  12.9340  38.3180  42.50 182.00
RefStar11  3.4  0.3    95  10.2780  23.4170 266.25 220.50
RefStar12  3.1  0.2   132   8.9870  48.0420 265.50  41.75
RefStar13  3.9  1.2   105   9.8790  26.0070 288.75 190.25
RefStar14  3.8  1.0    65  10.8890  34.2160 195.00 180.00
RefStar15  3.3  0.1   160  12.2570  57.0330  78.75  64.25
```

Figure 1 – MetRec *.ref file.

```
AppearanceDate 01.01.2013
AppearanceTime 17:13:53
ReferenceStars 20120408.ref
FrameCount 20
#   time  bright   x      y       alpha    delta   c_x    c_y    c_alpha  c_delta  use
01  53.447 ----  0.246  0.735    3.3154   54.752  -----  -----  --------  -------  no
02  53.487 ----  0.247  0.717    3.3228   53.935  -----  -----  --------  -------  no
03  53.527 ----  0.247  0.700    3.3306   53.119  -----  -----  --------  -------  no
04  53.567  2.6  0.248  0.682    3.3384   52.304  -----  -----    3.3364   52.328  yes
05  53.607  1.8  0.249  0.665    3.3462   51.490  -----  -----    3.3455   51.453  yes
06  53.647  2.2  0.249  0.645    3.3535   50.567  -----  -----    3.3544   50.576  yes
07  53.687  2.0  0.250  0.627    3.3599   49.729  -----  -----    3.3629   49.699  yes
08  53.727  1.9  0.250  0.607    3.3726   48.813  -----  -----    3.3711   48.820  yes
09  53.767  2.0  0.251  0.588    3.3774   47.909  -----  -----    3.3791   47.940  yes
10  53.807  2.1  0.252  0.569    3.3872   47.042  -----  -----    3.3868   47.059  yes
11  53.847  1.8  0.252  0.550    3.3970   46.159  -----  -----    3.3943   46.176  yes
12  53.887  2.0  0.253  0.532    3.4019   45.321  -----  -----    3.4015   45.292  yes
13  53.927  2.1  0.254  0.513    3.4082   44.434  -----  -----    3.4085   44.407  yes
14  53.967  2.2  0.256  0.493    3.4126   43.493  -----  -----    3.4153   43.531  yes
15  54.007  2.2  0.256  0.475    3.4204   42.643  -----  -----    3.4219   42.644  yes
16  54.047  2.2  0.257  0.457    3.4287   41.817  -----  -----    3.4284   41.755  yes
17  54.087  2.3  0.258  0.435    3.4370   40.824  -----  -----    3.4347   40.865  yes
18  54.127 ----  0.259  0.414    3.4453   39.832  -----  -----  --------  -------  no
19  54.167 ----  0.260  0.392    3.4536   38.839  -----  -----  --------  -------  no
20  54.207 ----  0.261  0.371    3.4619   37.845  -----  -----  --------  -------  no
```

Figure 2 – MetRec *.inf file.

MetRec brightness determination

As the first step in the detection, a mean background image is subtracted from the digitized frame. The mean image is derived from the previous frames. Negative pixel values in the difference image are set to zero, so that only pixels with an increased brightness are investigated further.

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<ufoanalyzer_record version ="200"
   clip_name="M20120131_221606_DunLa_10s_CE" o="1" y="2012" mo="1"
   d="31" h="22" m="16" s="6.880000"
   tz="0" tme="1.000000" lid="DunLa_10s" sid="CE"
   lng="17.270500" lat="48.082699" alt="125.000000" cx="720"
   cy="576" fps="25.000000" interlaced="1" bbf="0"
   frames="71" head="25" tail="25" drop="-1"
   dlev="27" dsize="2" sipos="3" sisize="9"
   trig="1" observer="Roman_Piffl" cam="Watec_902H" lens="Goyo_0.95"
   cap="" u2="221" ua="228" memo=""
   az="8.034631" ev="45.723446" rot="357.713257" vx="79.922417"
   yx="0.966861" dx="-24.058992" dy="5.110302" k4="-0.000612"
   k3="-0.027677" k2="-0.011801" atc="58.299999" BVF="-0.300000"
   maxLev="255" maxMag="1.486300" minLev="25" mimMag="4.000000"
   dl="32" leap="50" pixs="44" rstar="110"
   ddega="0.033164" ddegm="0.082146" errm="0.363821" Lmrgn="5"
   Rmrgn="5" Dmrgn="5" Umrgn="5">
  <ua2_objects>
<ua2_object
   fs="48" fe="88" fN="41" sN="15"
   sec="0.800000" av="4.877322" pix="31" bmax="75"
   bN="0" Lmax="221.739136" mag="1.638045" cdeg="0.015166"
   cdegmax="0.033879" io="3" raP="352.863861" dcP="-9.014144"
   av1="4.958315" x1="317.848053" y1="117.213600" x2="339.450806"
   y2="84.878815" az1="6.649399" ev1="26.623760" az2="9.405540"
   ev2="23.147804" azm="8.190636" evm="24.710350" ra1="285.862976"
   dc1="67.902039" ra2="281.802765" dc2="63.951656" ram="283.466858"
   dcm="65.733444" class="Iw_JNO" m="0" dr="1.019535"
   dv="6.269828" Vo="17.428900" lng1="17.544207" lat1="49.604111"
   h1="88.947037" dist1="193.056763" gd1="170.232208" azL1="48.778595"
   evL1="33.974815" lng2="17.679779" lat2="49.680882" h2="80.654999"
   dist2="197.310410" gd2="180.078674" len="15.383389" GV="19.229235"
   rao="83.860466" dco="-6.256966" Voo="19.900000" rat="80.024834"
   dct="-12.037234" memo="">
  <ua2_objpath>
<ua2_fdata2 fno=" 48" b=" 57" bm="000" Lsum="   134.3" mag="+2.18" az="   6.6660063" ev="  26.6565424" ra=" 285.8065933" dec=" +67.9311187"></ua2_fdata2>
<ua2_fdata2 fno=" 50" b=" 50" bm="000" Lsum="   125.5" mag="+2.26" az="   6.7857677" ev="  26.4491647" ra=" 285.6411454" dec=" +67.7062173"></ua2_fdata2>
<ua2_fdata2 fno=" 55" b=" 61" bm="000" Lsum="   174.5" mag="+1.90" az="   7.0848572" ev="  26.0707392" ra=" 285.1613713" dec=" +67.2802796"></ua2_fdata2>
<ua2_fdata2 fno=" 62" b=" 62" bm="000" Lsum="   150.9" mag="+2.06" az="   7.5757514" ev="  25.5047346" ra=" 284.3694922" dec=" +66.6324615"></ua2_fdata2>
<ua2_fdata2 fno=" 63" b=" 51" bm="000" Lsum="   111.7" mag="+2.38" az="   7.6538340" ev="  25.4433848" ra=" 284.2304020" dec=" +66.5570946"></ua2_fdata2>
<ua2_fdata2 fno=" 66" b=" 71" bm="000" Lsum="   177.8" mag="+1.88" az="   7.8280007" ev="  25.1514348" ra=" 284.0089007" dec=" +66.2374626"></ua2_fdata2>
<ua2_fdata2 fno=" 68" b=" 60" bm="000" Lsum="   180.5" mag="+1.86" az="   7.9660560" ev="  24.9883563" ra=" 283.7980499" dec=" +66.0504868"></ua2_fdata2>
<ua2_fdata2 fno=" 72" b=" 75" bm="000" Lsum="   199.7" mag="+1.75" az="   8.2160931" ev="  24.6903968" ra=" 283.4232339" dec=" +65.7087180"></ua2_fdata2>
<ua2_fdata2 fno=" 73" b=" 64" bm="000" Lsum="   195.3" mag="+1.78" az="   8.2302146" ev="  24.6111327" ra=" 283.4370376" dec=" +65.6286232"></ua2_fdata2>
<ua2_fdata2 fno=" 74" b=" 62" bm="000" Lsum="   168.2" mag="+1.94" az="   8.3310792" ev="  24.5072841" ra=" 283.2789541" dec=" +65.5064541"></ua2_fdata2>
<ua2_fdata2 fno=" 79" b=" 67" bm="000" Lsum="   221.7" mag="+1.64" az="   8.6542723" ev="  24.1528122" ra=" 282.7918299" dec=" +65.0930027"></ua2_fdata2>
<ua2_fdata2 fno=" 80" b=" 71" bm="000" Lsum="   185.9" mag="+1.83" az="   8.7556653" ev="  24.0191475" ra=" 282.6538721" dec=" +64.9412145"></ua2_fdata2>
<ua2_fdata2 fno=" 81" b=" 57" bm="000" Lsum="   173.6" mag="+1.90" az="   8.7743676" ev="  23.9371206" ra=" 282.6606632" dec=" +64.8574761"></ua2_fdata2>
<ua2_fdata2 fno=" 82" b=" 66" bm="000" Lsum="   174.4" mag="+1.90" az="   8.8531683" ev="  23.8622798" ra=" 282.5381055" dec=" +64.7676372"></ua2_fdata2>
<ua2_fdata2 fno=" 88" b=" 61" bm="000" Lsum="   142.6" mag="+2.12" az="   9.2234098" ev="  23.4123288" ra=" 282.0256566" dec=" +64.2491191"></ua2_fdata2>
  </ua2_objpath>
</ua2_object>
  </ua2_objects>
```


Figure 3 – UFO Analyser *.XML file.

UFO brightness determination

The magnitude of one field is computed from the light accumulated for the pixels of the object in one field. The accumulated light is the sum of the increased light of the pixels of the object.

The increased light is the brightness of the pixel at the instance minus the brightness of the pixel before the appearance of the object.

The background brightness is taken to be the mean value from the 10 preceding frames.

3 Database

After the conversion, we can create a database with the following format:

1) Station (latitude, longitude, altitude)
2) Camera (FOV, sensor, resolution etc.)
3) Information about each frame:
   a) Date and time
   b) Light sum (only from UFO data)
   c) Magnitude
   d) Azimuth and elevation
   e) RA and DEC
4) Image of the meteor (only from UFO data)

Problems with the extracted data

We have no information about the original reduction – we need to use the data "as it is". Hence we cannot apply any further detection to allow for following effects:

1) distance
2) speed
3) vignetting and field distortion
4) meteor parts (shock waves, body, foot)
5) in the frames of video , some data is often missing due to it being impossible to detect the peak
6) background noise
7) saturation (above level 255)
8) spectral sensitivity
9) extinction, refraction, the effect of the height above the horizon on the signal level (increased background etc.)
10) light pollution

Benefits of that database

We can extract data for statistical analyses. In combination with the EDMOND database we could try to determine typical light curves for more than 300 regular showers and determine typical light curves for outbursts. The comparison of light curves year by year and filament by filament for major showers would also be interesting. We could also investigate the preheating phase for high altitude meteors and investigate fragmentation and physical parameters for different types of meteoroid bodies.

Current status

1) Data is being collected for additional data mining.
2) Procedures are being created to populate the database (for UFO data this has already been completed).
3) A GUI is being created that will enhance database usability.
4) The mapping of normalized light curves is being tested (using data from the DRA and SPE outbursts).
5) We are attempting to identify a suitable name for the light curve database (the working name is METaLICA – *MET*eor *LI*ght *C*urve d*A*tabase).

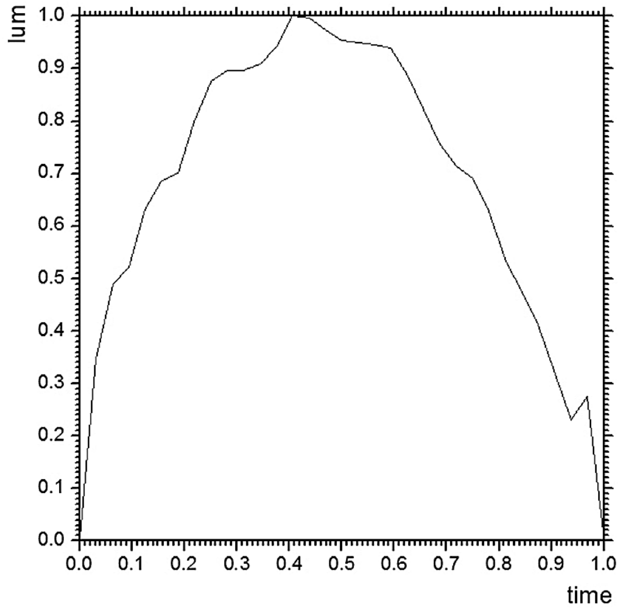

Figure 4 – Normalized lightcurve of a Draconid meteor.

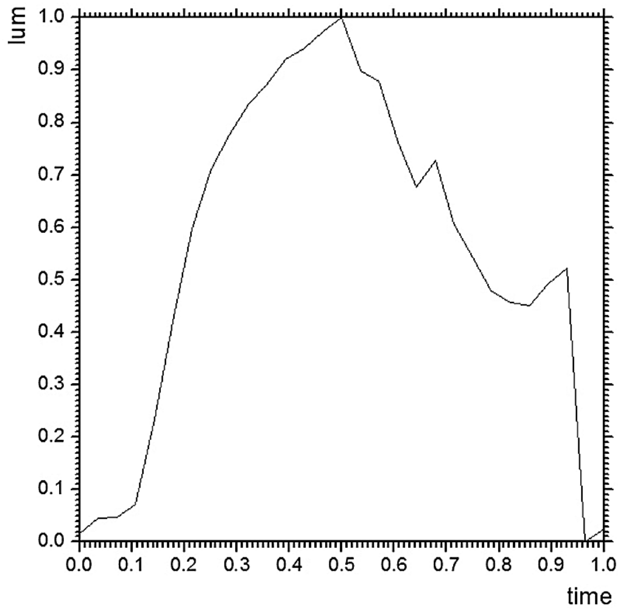

Figure 5 – Normalized lightcurve of a Draconid meteor containing a flare.

Timetable

1) End of 2015 – conversion procedures will be completed.
2) Spring 2016 – database in testing mode.
3) IMC 2016 – presentation of the database.

4 Conclusion

Although the data in the new database will contain some errors and difficult to standardize, statistical methods should be useful in such a large file to determine some physical characteristics (brightness distribution, tensile strength, brightness vs. altitude, density of parent particles, etc.).

References

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Molau S. (1999). “The meteor detection software Met-Rec”. In Arlt R. and Knöfel A., editors, *Proceedings of the International Meteor Conference*, Stará Lesná, Slovakia, 20–23 August 1998. IMO, pages 9–16.

SonotaCo (2009). “A meteor shower catalog based on video observations in 2007–2008”. *WGN, Journal of the IMO*, **37**, 55–62.

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