Identification of two new meteor showers: #797 EGR and #798 ACD

Lauriston de Sousa TRINDADE[1,2], Marcelo ZURITA[2,3], Alfredo DAL'AVA JR.[2,4], Gabriel Gonçalves SILVA[2,5], Carlos Augusto Bella DI PIETRO[2]

[1] **Universidade Estadual do Ceará / UAB Pólo Maracanaú , BRAZIL**
lauristontrindade@yahoo.com.br

[2] **Brazililian Meteor Observation Network - BRAMON, Nhandeara, BRAZIL**
bramon@bramonmeteor.org

[3] **Associação Paraibana de Astronomia - APA, João Pessoa, BRAZIL**
marcelozurita@gmail.com

[4] **Pontifícia Universidade Católica de Minas Gerais, Poços de Caldas, BRAZIL**
alfredojr@dalava.com.br

[5] **Instituto de Química, Universidade de São Paulo, São Paulo, BRAZIL**
gabrielg@iq.usp.br

The Brazilian Meteor Observation Network - BRAMON - reports the discovery of two new meteor showers, initially observed after a search in its own database. For the meteor shower # 797 EGR, it is listed one meteor in 2014, eight meteors in 2015 and three meteors in 2016 (two are in the BRAMON database and one in the EDMOND database), occurring between solar longitudes of 77º and 89º. The average radiant position is in right ascension of 342.3º and declination of -51.39º. For the meteor shower # 798 ACD, it is listed two meteors in 2014 (one meteor in the BRAMON database and one meteor in the EDMOND database), eleven meteors in 2015 (ten meteors in the BRAMON database and one meteor in the base of EDMOND data), six meteors in 2016 and four meteors in 2017, occurring between solar longitudes of 120.7º and 139.7º. The average radiant position is in right ascension of 68.82º and declination of -38.15º.

1 Introduction

BRAMON is a meteor-monitoring network that was created in 2014 to record and study meteors over Brazil, which is in a privileged position in the southern hemisphere (Amaral et al., *in press*), as well as to provide more detailed information about high-luminosity bolides and other meteorites (Zurita et al., 2019). The result of this effort resulted in the production of a database made available together with the EDMOND database (Amaral et al., 2018; EDMOND, 2018).

2 New showers

A video showing the evolution of the radiants of the meteors paired by BRAMON between the years 2014 and 2015 was created as a first analysis approach. It was observed, in both years, an unexpected concentration of meteors in the direction of the Grus constellation, always in mid-June. During the video analysis process, it was also noticed a meteor grouping that happened in the Caelum constellation repeating at the beginning of August. The calculations were performed following the methodology proposed by Drummond (1981), showing the existence of two small outbursts to be called epsilon Gruids (EGR) e August Caelids (ACD).

3 Methodology

For the identification of a new shower, it was adopted that a meteor cluster must have at least six members whose orbits have the criterion of similarity smaller than 0.105 in relation to the group average orbit. The similarity criterion was initially defined by Southworth & Hawkins (1963) in which the similarity between two orbits is defined as the distance between two points in a five-dimensional space, described by their conventional orbital parameters: q (perihelion distance), e (eccentricity), i (inclination), ω (perihelion argument) and Ω (longitude of the ascending node), as shown in Equation 1.

$$[D_{sh}]^2 = (e_2 - e_1)^2 + (q_2 - q_1)^2 + \left(2sin\left(\frac{I_{21}}{2}\right)\right)^2 + \left(\frac{e_2 - e_1}{2}\right)^2 \left(2sin\left(\frac{\Pi_{21}}{2}\right)\right) \quad (1)$$

where, suffix 1 and 2 refer to the two orbits to be compared, I_{21} is the angle between the planes of the two orbits, and Π_{21} is the angle between their respective perihelion points. These angles are defined in Equations 2 and 3, and Γ is defined in Equation 4.

$$I_{21} = \arccos[cos(i_1)\cos(i_2) + \sin(i_1)\sin(i_2)\cos(\Omega_2 - \Omega_1)] \quad (2)$$

$$\Pi_{21} = \omega_2 - \omega_1 + 2\Gamma arcsin\left(cos\left(\frac{i_2+i_1}{2}\right) sin\left(\frac{\Omega_2-\Omega_1}{2}\right) sec\frac{i_{21}}{2}\right) \quad (3)$$

$$\Gamma = \begin{cases} +1, & |\Omega_2 - \Omega_1| \le 180° \\ -1, & |\Omega_2 - \Omega_1| > 180° \end{cases} \quad (4)$$

Drummond (1981), proposed some modifications in the dissimilarity criterion of Southworth & Hawkins (1963), resulting in D-Drummond Criterion (DD), whose definition is shown in Equation 5.

$$[D_D]^2 = \left(\frac{e_2-e_1}{e_2+e_1}\right)^2 + \left(\frac{q_2-q_1}{q_2+q_1}\right)^2 + \left(\frac{I_{21}}{180°}\right)^2 + \left(\frac{e_2+e_1}{2}\right)^2\left(\frac{\theta_{21}}{180°}\right)^2 \quad (5)$$

where, I_{21} is the angle between the two orbital planes defined in Equation 2, and θ_{21} is the angle between the perihelion points of each orbit, defined in Equation 6.

$$\theta_{21} = \arccos[\sin(\beta_1)\sin(\beta_2) + \cos(\beta_1)\cos(\beta_2)\cos(\lambda_2 - \lambda_1)] \quad (6)$$

where, λ and β are respectively the longitude and ecliptic latitude of the perihelion defined in Equations 7 and 8.

$$\lambda = \Omega + \arctan(\cos(i)\tan(\omega)) \quad (7)$$

$$\beta = \arcsin(\sin(i)\sin(\omega)) \quad (8)$$

Subsequently, other definitions were proposed by Jopek (1993) and by Valsecchi, Jopek & Froeschlé (1999). However, for the validation of these showers it was used the criterion defined by Drummond (1981).

3.1 *Identification of clusters*

The identification of the meteors was done using a visual approach. The epsilon Gruid meteors were initially identified in a visual analysis of an animation showing the radiant position of the recorded meteors identified during the first two years of BRAMON operation. The animation was composed of 731 frames, one for each night between 01/01/2014 and 12/31/2015. Each frame was generated using the UFOOrbit software (Sonotaco, 2009) and shows a celestial map with the radiant of all the meteors recorded in the previous 15 nights, in addition to the position of each meteor shower officially known that is active at the time. Observing the resulting animation, a concentration of supposedly "sporadic" meteors was observed between June 7 and 19, next to the Grus Constellation. Using the UFOOrbit software (Sonotaco, 2009), the orbital parameters of these meteors were extracted. They were numbered 19, with seven in the year 2014 and twelve in the year 2015. The August Caelids meteors were perceived during the use of the UFORadiant software (Sonotaco, 2009) while analyzing the BRAMON database in search of new meteors candidates for the epsilon Gruids shower. The orbital parameters of eight meteors were extracted, seven of them occurred in 2015 and one in 2016.

3.2 *Dissimilarity test*

At first, it was obtained the average orbit of the meteors in initial cluster. Then, the dissimilarity between this average orbit and each meteor in the cluster was calculated using the D Criterium (Drummond, 1981). All meteors of the cluster with D Criterium smaller than 0.105 were maintained while the others were discarded. A new average orbit was calculated for the remaining meteors and dissimilarity was calculated again for each member of the new cluster. The process was repeated until the number of members of the cluster stabilized. As a minimum limit of six meteors in two distinct years to was achieved, the cluster can be reported as a potential annual meteor shower. Lastly, the dissimilarity test was used in a search for a parental body of the proposed showers. The dissimilarity between the average orbit of these showers and the objects of the Comet and near-Earth asteroid databases was calculated as done by Šegon et al., 2013.

3.3 *Nomenclature*

Based on a proposal from Jenniskens (2008), a meteor shower name is defined by the constellation that has the star closest to its radiant, using the possessive form of Latin followed by the suffix *id* or *ids*. If greater precision is required, the name should include the Greek letter from the name of the brightest star closest to the radiant. One can opt to add the name of the month of the shower peak to its name to distinguish it from other showers in the same constellation. Following these criteria, the names defined for the showers were epsilon Gruids, for its radiant being next to the epsilon Gruid star, and August Caelids, for their radiant being in the Caelum constellation and its maximum occurring in the month of August. The acronyms must be unique, containing three letters and approaching the spelling of the name of the shower. For epsilon Gruids, the acronym EGR was defined and the 797 number was designated by the Meteor Data Center. For the August Caelids, ACD along with the 798 number.

4 Results

4.1 *EGR - epsilon Gruids*

After the initial report to the IAU, new meteors linked to the shower were registered by BRAMON, maintaining the orbital dissimilarity criterion. The records were distributed as follows: 2014 - one meteor; 2015 - eight meteors; 2016 - three meteors. The meteors of the Grus constellation cluster occurred from June 7 to 19 with an average solar longitude of 81.37° (J2000.0). The mean radiant position of shower # 797 EGR was determined to be under the point with R.A. = 342.28° and Dec = -51.39°. The average geocentric velocity of the meteors is 52.86km / s, the mean daily motion of the radian was estimated as ΔR.A. = 1.1º/day and ΔDec = 0.0º/day. No parental body candidates were found using the dissimilarity test between the average orbit of the shower # 797 EGR and the objects in the Comet and near-Earth asteroid databases. Details of the shower orbital parameters can be seen in Table 1 and the distribution of the meteors around the radiant is shown in Figure 1.

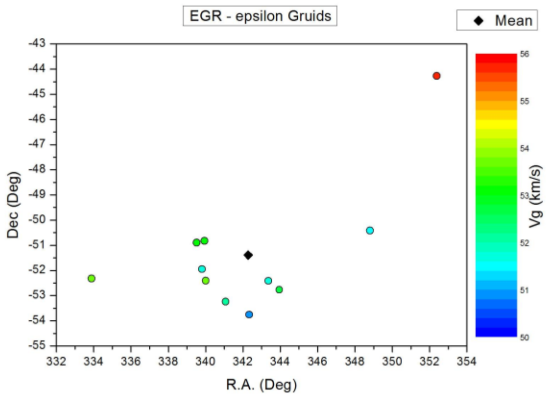

Figure 1. Distribution of meteors (with geocentric velocities) around the mean position of the epsilon Gruids radiant.

4.2 ACD - August Caelids

Again, after the initial report to the IAU, new meteors registered by BRAMON were added to the shower, maintaining the criterion of orbital dissimilarity. The records were distributed as follows: 2014 - one meteor; 2015 – eleven meteors; 2016 - six meteors; 2017 - four meteors. The meteors of the Caelum constellation cluster occurred from July 23 to August 12, with average solar longitude of 131.38° (J2000.0). The average radiant position of shower # 798 ACD was determined to be under the point with R.A. = 68.82° and Dec = -38.15°. The average geocentric velocity of the meteors is 44.87km / s, the mean daily motion of the radian was estimated as ΔR.A. = 0.54º/day and ΔDec = 0.13/day. Again, no parental body candidates were found using the dissimilarity test between the average orbit of the shower # 798 ACD and the objects in the Comet and near-Earth asteroid databases. Details of the orbital parameters can be seen in Table 2 and the distribution of the meteors around the radiant is shown in Figure 2.

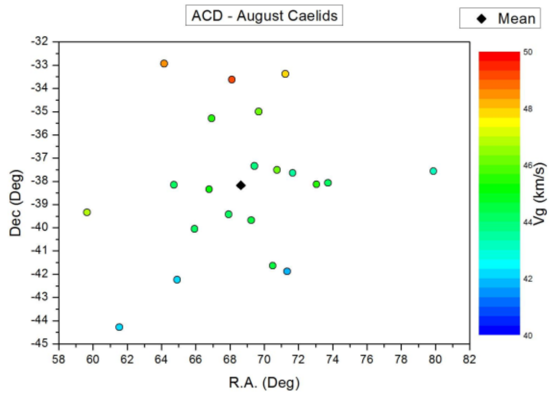

Figure 2. Distribution of meteors (with geocentric velocities) around the mean position of the August Caelids radiant.

Table 1 – List of the Meteors (#797 EGR)

Meteor	λ⊙	R.A	DE	Vg	a	e	q	Peri	Node	i	DD
20140613_081309	82.06	341.08	-53.24	52.20	9.40	0.92	0.72	66.62	262.06	95.90	0.037
20150607_064431	76.02	339.52	-50.90	53.10	3.62	0.79	0.75	65.60	256.00	103.10	0.069
20150609_051055	77.87	340.01	-52.41	53.74	7.99	0.91	0.76	62.40	257.90	100.60	0.041
20150610_020603	78.70	333.89	-52.32	53.70	15.90	0.96	0.67	71.76	258.70	99.35	0.070
20150612_034607	80.68	342.34	-53.76	50.90	4.51	0.84	0.74	66.20	260.70	95.00	0.038
20150613_023001	81.59	348.81	-50.42	51.60	3.39	0.77	0.78	62.80	261.60	98.90	0.075
20150614_051655	82.65	343.37	-52.42	51.80	5.67	0.87	0.73	66.61	262.60	96.44	0.025
20150614_054050	82.34	343.95	-52.77	52.80	11.36	0.93	0.75	62.40	263.58	97.00	0.044
20150615_044227	83.58	339.94	-50.83	53.11	10.21	0.93	0.68	71.84	261.39	98.54	0.056
20160612_035508	81.40	339.81	-51.95	51.65	4.94	0.86	0.71	69.98	261.39	96.78	0.032
20160613_054413*	-	-	-	51.20	4.75	0.85	0.70	70.80	261.5	105.00	0.051
20160619_081923	88.26	352.39	-44.27	55.62	6.36	0.88	0.76	61.86	268.53	107.48	0.073
Means	81.37	342.28	-51.39	52.86	7.36	0.88	0.73	66.60	261.43	99.50	0.05

** Meteor from the EDMOND database*

Table 2 – List of the Meteors (#798 ACD)

Meteor	λ⊙	R.A	DE	Vg	a	e	q	Peri	Node	i	DD
20140801_082848*	-	-	-	44.44	4.65	0.78	1.000	347.6	308.8	78.87	0.037
20140804_072928	131.67	70.74	-37.51	46.26	13.66	0.928	0.982	339.0	311.7	80.07	0.068
20150803_080134	130.47	66.78	-38.34	45.10	4.61	0.780	0.100	343.6	310.5	80.30	0.024

20150803_082609	130.49	66.92	-35.29	45.47	3.46	0.715	0.984	338.1	310.5	82.62	0.068
20150803_082609*	-	-	-	46.20	4.16	0.760	0.980	338.4	310.5	83.40	0.043
20150804_080655	131.43	67.92	-39.42	44.30	4.73	0.790	1.000	344.5	311.4	78.50	0.021
20150805_060514	132.31	71.66	-37.64	43.59	4.37	0.778	0.972	334.8	312.3	76.97	0.039
20150807_081437	134.31	73.72	-38.07	44.30	5.83	0.830	0.980	337.3	314.3	77.50	0.030
20150808_064000	135.21	69.67	-35.00	46.30	4.15	0.760	0.990	339.8	315.2	83.40	0.051
20150808_074553	135.25	71.33	-41.88	41.80	4.02	0.750	1.000	346.6	315.3	73.50	0.063
20150808_084713	135.29	69.42	-37.34	43.68	3.18	0.686	0.997	343.4	315.3	78.99	0.089
20150811_055544	138.05	70.49	-41.63	44.50	14.19	0.929	1.007	350.3	318.1	76.23	0.098
20150723_083249	120.69	59.64	-39.34	46.75	7.86	0.873	1.000	345.0	300.7	82.48	0.082
20160725_043910	122.44	61.53	-44.28	42.18	4.74	0.788	1.005	347.6	302.4	73.85	0.075
20160726_081137	123.54	64.15	-32.93	48.40	5.94	0.839	0.956	330.6	303.5	87.05	0.085
20160805_062223	133.03	68.11	-33.62	49.02	10.9	0.910	0.981	338.7	313.1	86.82	0.075
20160805_074642	133.09	73.04	-38.13	45.44	13.7	0.928	0.980	338.3	313.1	78.18	0.070
20160806_081216	134.06	69.24	-39.67	44.59	6.38	0.843	1.002	346.9	314.1	78.01	0.040
20160812_055149	139.72	71.23	-33.38	47.94	6.11	0.838	0.990	341.6	319.7	85.70	0.076
20170724_061921	121.31	65.92	-40.05	44.08	6.77	0.856	0.975	335.9	301.3	76.48	0.085
20170730_071856	127.09	64.91	-42.24	42.06	3.79	0.735	1.004	347.0	307.1	74.50	0.068
20170806_073702	133.80	64.72	-38.15	44.30	3.21	0.686	1.009	350.6	313.8	80.44	0.096
20170807_060147	134.69	79.88	-37.56	43.18	9.13	0.897	0.939	327.6	314.7	73.46	0.092
Means	131.33	68.62	-38.17	44.94	6.5	0.81	0.99	341.4	311.1	79.45	0.065

** Meteor from the EDMOND database*

5 Conclusion

The discovery of two meteor showers in such a short time of operation of such a new meteor monitoring network demonstrates the potential of showers yet to be unveiled on the southern hemisphere. This potential can be exploited by BRAMON due to the privileged position of its stations distributed throughout Brazil and to the large number of operators integrating the network. In addition, the association of BRAMON with other initiatives such as the SONEAR Observatory can help on the search for parental bodies associated with the newly confirmed showers and future finds.

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References

Amaral L. S., Trindade, L. S., Bella C. A. P. B., Zurita M. L. P. V., Poltronieri R. C., Silva G. G., Faria C. J. L., Jung C. F., and Koukal J. A. (*in press*). "Brazilian Meteor Observation Network: History of creation and first developments". *Proceedings of the IMC, Petnica, 2017.*

Amaral, L. S, Bella C. A. P. B, Trindade, L. S., Zurita, M. L. P. V., Silva G. G., Domingues M. W. S., Poltronieri R. C, Faria C. J. L. and Jung C. F. (2018). "A Search Method for Meteor Radiants". *WGN, the Journal of the IMO*, **46:6**, 191-197.

Drummond J. D. (1981). "A test of comet and meteor shower associations". *Icarus*, **45**, 545–553.

EDMOND (2018). "EDMOND Database". http://www.daa.fmph.uniba.sk/edmond .

Jenniskens P. (2008). "The IAU Meteor Shower Nomenclature Rules". *Earth Moon Planet*, **102**, 5–9.

Jopek T. J. (1993). "Remarks on the Meteor Orbit Similarity D-Criterion". *Icarus*, **106**, 603-607.

Šegon D., Andreić Ž., Korlević K., Novoselnik F., Vida D. and Skokić I. (2013). "8 new showers from Croatian Meteor Network data". *WGN, the Journal of the IMO*, **41:3**, 70-74.

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

Southworth R. B. and Hawkins G. S. (1963). "Statistics of meteor streams". *Smithsonian Contributions to Astrophysics*, **7**, 261.

Valsecchi G. B., Jopek T. J. and Froeschlé C. (1999). “Meteoroid stream identification: a new approach – I. Theory”. *Mon. Not. R. Astron. Soc.*, **304**, 743-750.

Zurita M., Damiglê R., Di Pietro C., Trindade L., Silva G. G., Lima A., Mota A., Arthur R. and Betzler A. S. (2019). “A bright fireball over the coast of the state of Bahia”. *Boletim da Sociedade Astronômica Brasileira*, **31:1**, 14-16.