# A search for stream and associations in meteor database. Method of indices

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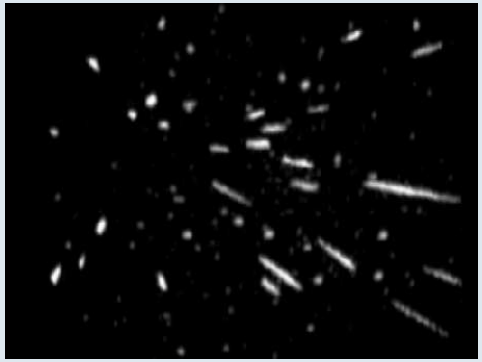
- A search for minor streams and associations and a study of sporadic background necessitate a reliable separation of major meteoroid streams from the database

- Meteors in a database are often assigned to a shower by applying one of D-criterions



- J. Svoreň, L. Neslušan, V. Porubčan, 2006, *A search for stream and associations in meteor database. Method of indices*, Planet. Space Sci. 48, 933

# Dissimilarity criterion

Given a known meteoroid stream orbit ($M$), the parent body orbit ($N$) would be associated if the dissimilarity function

$$D(M, N) \leq D_m$$

where $D_m$ is an appropriate cut-off value.

# Dissimilarity criterion

## Dissimilar criteria based on orbit shape and size

- Southworth & Hawkins (1963)

$$D_{SH}^2 = [e_B - e_A]^2 + [q_B - q_A]^2 + \left[2 \cdot \sin \frac{I_{BA}}{2}\right]^2 + \left[\frac{e_B + e_A}{2}\right]^2 \left[2 \cdot \sin \frac{\pi_{BA}}{2}\right]^2$$

- Drummond (1981)

$$D_D^2 = \left[\frac{e_B - e_A}{e_B + e_A}\right]^2 + \left[\frac{q_B - q_A}{q_B + q_A}\right]^2 + \left[\frac{I_{BA}}{180^\circ}\right]^2 + \left[\frac{e_B + e_A}{2}\right]^2 \left[\frac{\theta_{BA}}{180^\circ}\right]^2$$

- Jopek (1993) $= D_{SH} + D_D$

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# Dissimilarity criterion

## A dissimilarity criterion based on orbital dynamics

- Valsecchi *et al.* (1999)

$$D_N^2 = [U_B - U_A]^2 + w_1 \, [\cos\theta_B - \cos\theta_A]^2 + \Delta\xi$$

- Jopek *et al.* (2006)

$$\begin{aligned} D_V^2 \quad = \quad & w_{h1}(h_{i1} - h_{j1})^2 + w_{h2}(h_{i2} - h_{j2})^2 + 1.5\, w_{h3}(h_{i3} - h_{j3})^2 \\ & + w_{e1}(e_{i1} - e_{j1})^2 + w_{e2}(e_{i2} - e_{j2})^2 + w_{e3}(e_{i3} - e_{j3})^2 \\ & + 2\, w_E (E_i + E_j)^2 \end{aligned}$$

# Cluster analysis

- having the distance function and the similarity threshold a meteoroid stream can be detected by a suitable cluster analysis algorithm
- cluster analysis algorithm defines a meteor stream
  - single neighbour linking technique (Sekanina, Welch)
  - wavelet transform technique (Galligan, Brown *et al.*)
  - method of indices (Svoreň *et al.*)

A search for stream and associations in meteor database.

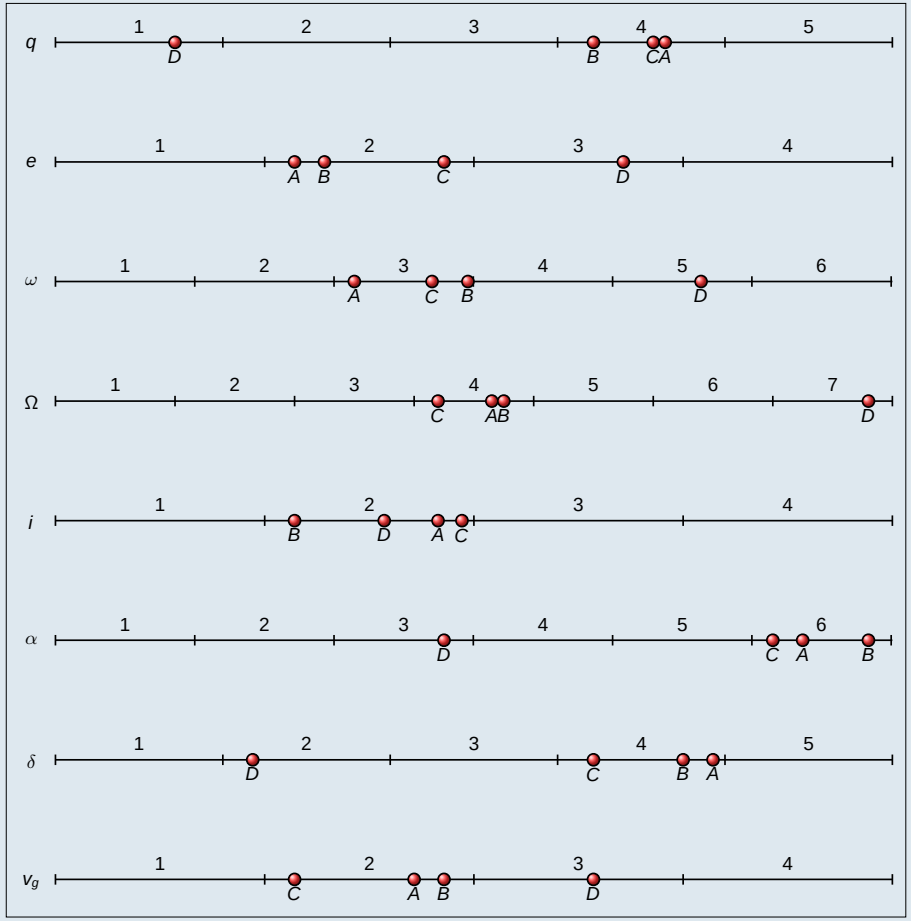
**Method of indices**

# Material used and the philosophy of the procedure

## The basic idea of the procedure

- division of the observed ranges of parameters into a certain number of equidistant intervals
- an assignment of indices to each meteor according to the intervals pertinent to its parameters

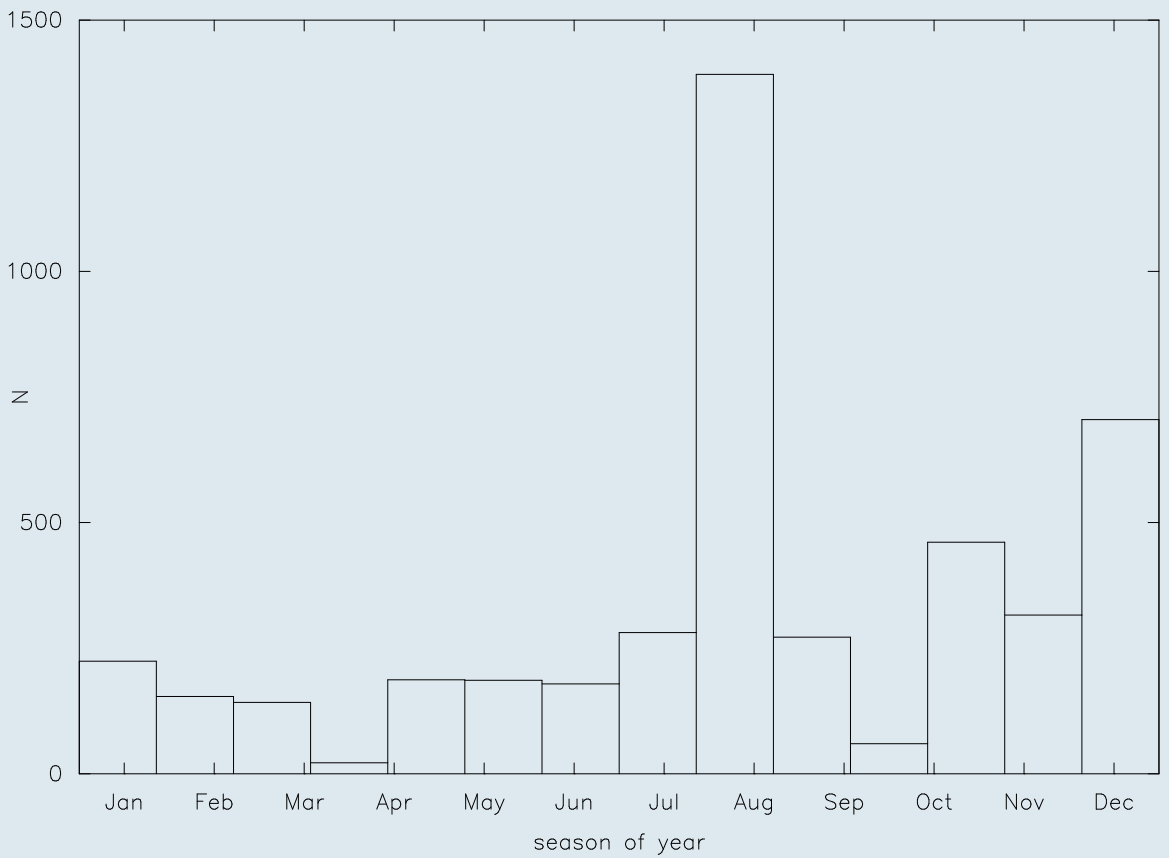
| meteor | combination of indices |
|---|---|
| A: | 42342642 |
| B: | 42342642 |
| C: | 42342642 |
| D: | 13572323 |



# Search for stream and associations

## Used data

The method was tested on the IAU Meteor Data Center Lund catalogue
`http://www.astro.sk/~ne/IAUMDC/Ph2003/database.html`



# Search for stream and associations

## Used data

| No. | Name | Amount |
|---|---|---|
| 1. | $\alpha$ Capricornids | 52 |
| 2. | S. Taurids | 89 |
| 3. | S. $\iota$ Aquarids | 13 |
| 4. | Geminids | 352 |
| 5. | S. $\delta$ Aquarids | 29 |
| 6. | Lyrids | 17 |
| 7. | Perseids | 804 |
| 8. | Orionids | 58 |
| 9. | Draconids | 8 |
| 10. | Quadrantids | 45 |
| 11. | Virginids | 10 |
| 12. | $\kappa$ Cygnids | 33 |
| 13. | Leonids | 36 |
| 14. | $\chi$ Orionids | 18 |
| 15. | Ursids | 3 |
| 16. | $\sigma$ Hydrids | 10 |
| 17. | N. Taurids | 40 |
| 19. | Monocerotids | 10 |
| 26. | N. $\delta$ Aquarids | 11 |
| 28. | N. Andromedids | 14 |
| 31. | $\eta$ Aquarids | 15 |
| 33. | N. $\iota$ Aquarids | 6 |
| 34. | All sporadic | 2850 |
| | | 4581 |

The following streams classification is used in the analysis

- *Major streams*: Quadrantids, Lyrids, $\eta$-Aquarids, $\alpha$-Capricornids, $\delta$-Aquarids, Perseids, Orionids, Taurids, Leonids and Geminids
- *Minor streams*: all the other streams from Cook's working list 1973
- *Associations*: other groups consisting of, at least, 3 similar orbits.

# Search for stream and associations

- Step 1: determination of the ranges of parameters

| | |
|---|---|
| $q$ | 0.0 – 1.1 AU |
| $e$ | 0.0 – 1.6 |
| $\omega$, $\Omega$, $\alpha$ | 0 – 360° |
| $i$ | 0 – 180° |
| $\delta$ | -60° – +90° |
| $v_g$ | 0 – 74 km/s |
| Final set of meteors: | 4535. |

- Step 2: the ranges of parameters are divided into intervals

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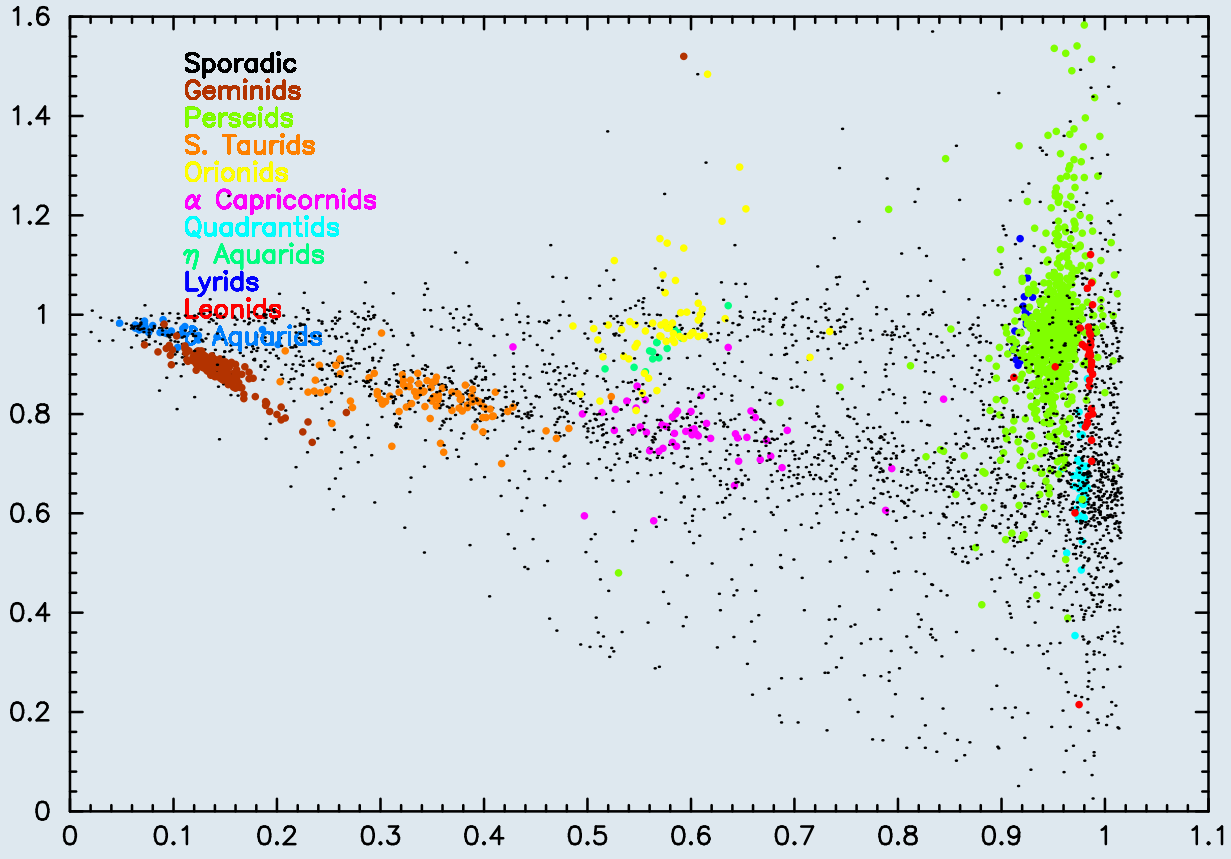
# Search for stream and associations

The dependence of the eccentricity on the perihelion distance for the meteors of the IAU MDC catalogue.



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- Step 2: the ranges of parameters are divided into intervals.

| Parameter | $q$ | $e$ | $\omega$ | $\Omega$ | $i$ | $\alpha$ | $\delta$ | $v_g$ |
|---|---|---|---|---|---|---|---|---|
| Mean error | 0.021 | 0.045 | 3.8 | 3.1 | 1.8 | 2.8 | 1.2 | 1.3 |
| Range | 1.1 | 1.6 | 360 | 360 | 180 | 360 | 150 | 74 |
| Range/(mean error) | 52.38 | 35.56 | 94.74 | 116.13 | 100.00 | 128.57 | 125.00 | 56.92 |
| Range/(mean error)/17.78 | 2.95 | 2.00 | 5.33 | 6.53 | 5.62 | 7.23 | 7.03 | 3.20 |
| Intervals | 3 | 2 | 5 | 7 | 6 | 7 | 7 | 3 |

Basic division of parameters

# Search for stream and associations

## Results

- Almost all major streams (except of the northern branch of $\delta$-Aquarids) were identified - confirming the effectiveness of the procedure
- The method was able to identify very widely spread Taurids and some minor streams
- The method enables a study of the fine structure of the streams and their filaments (Svoreň, J., Porubčan, V., & Neslušan, L. 2001, Meteoroids 2001 Conference, 495, 105)

| No. | Name | % |
|---|---|---|
| 1. | $\alpha$ Capricornids | 34 / 28 |
| 2. | S. Taurids | 29 / 21 |
| 4. | Geminids | 93 |
| 5. | S. $\delta$ Aquarids | 34 |
| 6. | Lyrids | 82 |
| 7. | Perseids | 79 |
| 8. | Orionids | 87 |
| 10. | Quadrantids | 91 |
| 13. | Leonids | 55 |
| 17. | N. Taurids | 30 |
| 26. | N. $\delta$ Aquarids | - |
| 31. | $\eta$ Aquarids | 93 |

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