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Meteor Showers Identified from a Million Video Meteors

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Agenda

- History
- Procedure
- Tools
- Statistics
- Results
- Conclusions

History

- Searching the IMO database for meteor showers is not new ...

IMC 2006	188,068 meteors (01/1993-07/2006)	Base procedure • based on Bayes' decision rule • two-step detection (radiant and shower search) • iterative radiant search • Gaussian distribution
IMC 2008	359,957 meteors (01/1993-07/2008)	Improvements • observability function and activity profiles • corrected meteor counts • improved meteor altitude formula / velocity estimates • Laplace distribution
WGN 37:4 2009	451,282 meteors (01/1993-04/2009)	Improvements: • Based on MDC meteor shower list • manual refinement of results
WGN 38:5 2010	168,830 meteors only SL 250-315° (01/1993-12/2009)	Specific analysis of PER/AUR region in September/October
IMC 2013	1,063,057 meteors (01/1993-12/2011)	Improvements: see next slides

Base Procedure

- Cut the data into sol long slices of 2° length, 1° shift.
- Compute for each meteor M in each slice and all possible radiants R (α / δ / v_{inf}) the conditional probability P (M | R).
- Determine the radiants iteratively:
  - → Start: Accumulate P (M | R) over all possible R
    - → Loop: Select the radiant R` with largest probability P (M | R`)
    - → Determine all meteors M` belonging to R`
    - → Accumulate P (M‘ | R) over all possible R and subtract it from the original distribution
  - → End: Reassign the meteors to the radiants and recompute the shower parameters
- Connect radiants with similar position/velocity in consecutive solar longitude intervals.
- Compute shower parameters: Radiant position, drift, velocity.
- Compare the showers against the MDC list.

Enhancements 2012/13

- More than a million single station meteors available.
- Introduction of radiant rank, i.e. at which position a radiant is located in the sorted radiant list of that sol long interval.
- Forward/backward radiant search during shower detection.
- Early publishing of unprocessed radiant and meteor shower list in the web.
- Intermediate results presented in monthly video network reports.
- In preparation of IMC 2013, bi-directional match between IMO video network meteor shower list and latest MDC list including all showers.

Analysis Steps

- Phase 1: Automatic detection of showers in the video meteor database (minimum duration: 5° sol long), identification according to MDC list, manual refinement/rejection of showers → 101 showers.
- Phase 2: Detailed manual check for missing „established“ MDC showers → 6 additional showers.
- Phase 3: Manual check for all MDC „workling list“ showers, completion of list with short duration and weak showers, disambiguation → 22 additional showers.
- Phase 4: Identification showers that belong to the Antihelion source.

Tools

- To match the IMO video network list with the MDC list, a little „Excel tool“ (available to everyone) was created.
- Functions:
  - → Find the best matching MDC list shower given a radiant found in the IMO video network radiant list.
  - → Find the best matching radiant in the IMO video network radiant list given a MDC meteor shower.
  - → Find the best matching MDC list shower and IMO video network radiant given arbitrary sl/α/δ/v_{geo} values.

SL	Alpha	Delta	Vinf	Rank	dSL	dPos	dVgeo	MATCH
127	306,2	-9,5	24	3	0	1,36	-0,96	*2,32*
128	307,3	-9	24	3	1	1,06	-0,96	*3,02*
126	305,6	-10	24	3	-1	2,05	-0,96	*4,02*
125	305,6	-10	24	3	-2	2,05	-0,96	*5,02*
129	307,3	-9	23	3	2	1,06	-2,10	*5,16*
130	307,8	-9	23	3	3	1,43	-2,10	*6,53*
124	304,6	-10,5	24	3	-3	3,03	-0,96	*6,99*
123	304,1	-10,5	24	2	-4	3,37	-0,96	*8,34*
131	308,8	-9	23	3	4	2,32	-2,10	*8,42*
122	303,6	-11	25	2	-5	4,07	0,16	*9,23*
132	309,5	-8	23	3	5	2,88	-2,10	*9,98*
121	303,1	-10,5	25	1	-6	4,15	0,16	*10,31*
133	309,5	-8	23	3	6	2,88	-2,10	*10,98*
126	312,3	-11,5	28	11	-1	6,51	3,47	*10,98*
126	296,9	-4,5	25	19	-1	10,32	0,16	*11,49*
134	309,9	-8,5	23	3	7	3,28	-2,10	*12,38*
120	302	-11	25	1	-7	5,33	0,16	*12,49*
123	310,9	-14,5	26	28	-4	7,58	1,27	*12,85*
125	312,3	-14	28	12	-2	8,06	3,47	*13,53*
119	302,1	-11,5	25	1	-8	5,53	0,16	*13,69*
128	298,4	-3	22	14	1	9,67	-3,25	*13,93*
125	297,5	-10	22	13	-2	9,16	-3,25	*14,42*
132	303,2	-4	21	28	5	5,39	-4,42	*14,81*
129	298,1	-13	22	16	2	9,63	-3,25	*14,89*
135	310,3	-9	22	3	8	3,74	-3,25	*15,00*
118	302,6	-11,5	26	1	-9	5,14	1,27	*15,41*

Input	MDC #	IMO	Entry Num	# Entries
MDC List	1		1	4
or	SL	Alpha	Delta	Vgeo
Radiant Pos	123	160	9	29

	sSL	dPos	dVgeo
Weights	1,0	1,0	1,0

Color MATCH	0	20	100

	SL	Alpha	Delta	Vgeo	MDC #	IMO
Search Params	*127*	*306,6*	*-8,2*	*22,2*	*1*	*CAP*

Enter MDC # AND Entry Num **OR**
IMO 3-Letter-Code AND Entry Num **OR**
SL/Alpha/Delta/Vgeo
Sort = Ctrl-o

Statistics (I)

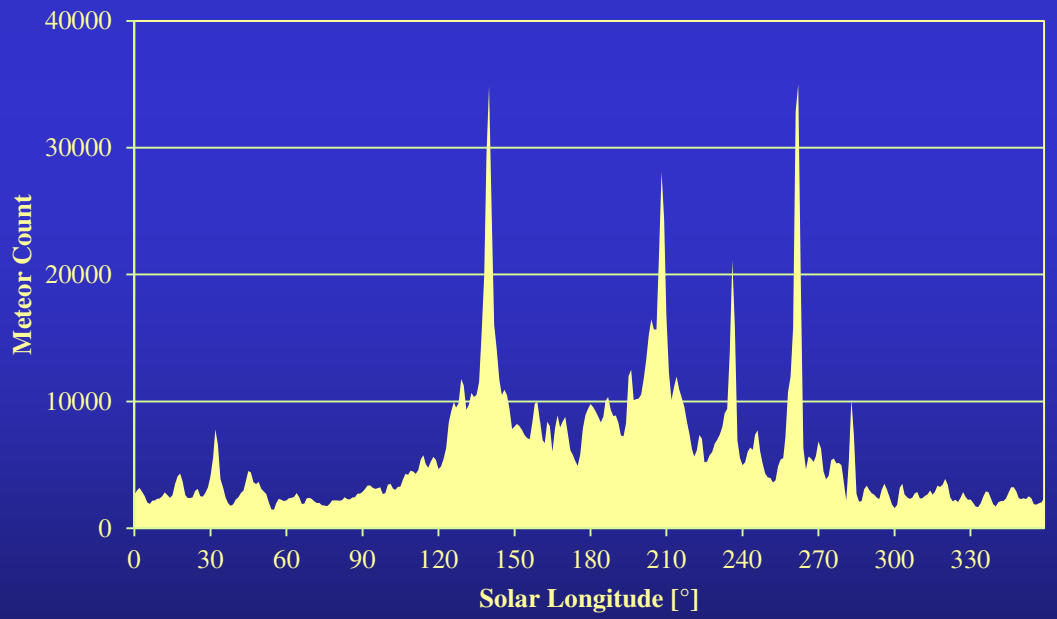
- Observers contributing >1,000 meteors.

Name	IMO Code	Nights	Teff	Meteors
Sirko Molau	MOLSI	3,138	31,410.0	185,158
Enrico Stomeo	STOEN	1,121	15,001.5	93,548
Javor Kac	KACJA	1,794	18,791.5	73,296
Jörg Strunk	STRJO	2,247	17,642.7	63,337
Stefano Crivello	CRIST	984	9,848.1	53,594
Rui Goncalves	GONRU	971	11,257.2	48,301
Flavio Castellani	CASFL	1,476	11,953.8	38,735
Robert Lunsford	LUNRO	803	5,102.1	33,229
Antal Igaz	IGAAN	684	6,748.3	28,765
Ilkka Yrjölä	YRJIL	1,299	7,050.5	26,356
Steve Kerr	KERST	426	3,161.6	25,183
Detlef Koschny	KOSDE	924	5,441.0	23,952
Bernd Brinkmann	BRIBE	1,235	6,144.8	23,627
Wolfgang Hinz	HINWO	779	4,447.8	22,605
Rosta Štork	STORO	139	1,356.4	21,368
Klaas Jobse	JOBKL	251	1,801.9	20,090
Maurizio Eltri	ELTMA	646	4,322.2	19,987
Carl Hergenrother	HERCA	1,102	7,432.3	19,440
Jürgen Rendtel	RENJU	647	3,823.4	17,223
Erno Berkó	BERER	321	4,195.6	16,574
Stane Slavec	SLAST	1,278	5,948.8	16,448
Mihaela Triglav	TRIMI	944	4,246.4	14,735
Orlando Benitez-Sanchez	BENOR	1,018	5,227.4	13,899
Mitja Govedic	GOVMI	618	3,121.5	13,718
Zsolt Perkó	PERSZ	378	2,042.0	13,243

Name	IMO Code	Nights	Teff	Meteors
Istvan Tepliczky	TEPIS	414	2,342.4	11,964
Stephen Evans	EVAST	457	2,807.3	11,411
Eckehard Rothenberg	ROTEC	637	2,841.8	10,476
Steve Quirk	QUIST	341	3,041.8	10,109
Mike Otte	OTTMI	424	1,987.8	8,451
Hans Schremmer	SCHHA	576	2,018.5	7,415
Carlos Saraiva	SARAN	168	2,031.8	6,584
Paolo Ochner	OCHPA	408	2,058.4	6,239
other	OTHER	14	91.4	6,037
Mirko Nitschke	NITMI	213	942.5	5,425
Biondani Roberto	ROBBI	294	1,583.4	5,320
Rob McNaught	MCNRO	52	401.2	5,285
József Morvai	MORJO	357	1,704.4	5,156
Maciej Maciejewski	MACMA	132	2,022.7	4,890
Ulrich Sperberg	SPEUL	159	1,021.6	4,339
Karoly Jonas	JONKA	235	1,127.1	4,210
Leo Scarpa	SCALE	118	916.9	3,896
Szilárd Csizmadia	CSISZ	271	1,005.5	3,591
Martin Breukers	BREMA	86	720.4	2,696
Malcolm Currie	CURMA	123	533.9	2,133
Grigoris Maravelias	MARGR	36	225.0	1,783
Stefan Ueberschaer	UEBST	173	882.3	1,684
Zoltán Zelko	ZELZO	74	585.2	1,578
Gregor Kladnik	KLAGR	59	316.4	1,469
Milos Weber	WEBMI	29	49.4	1,050

Statistics (II)

- Each meteor contributes to two consecutive intervals.
- Between 1,458 meteors (sol long 55°) and 35,000 (sol long 262°) meteors per interval.

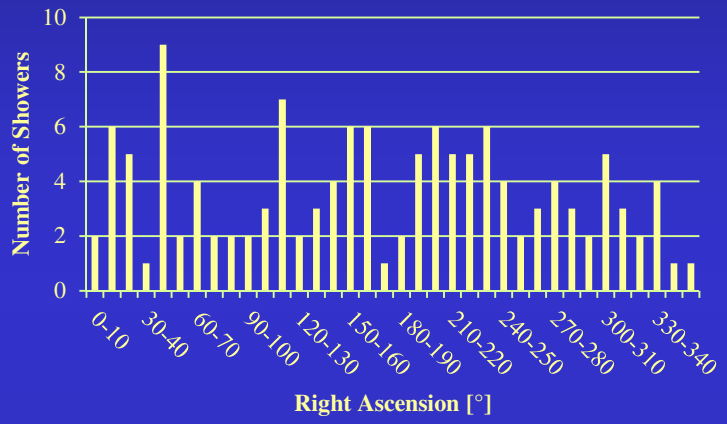


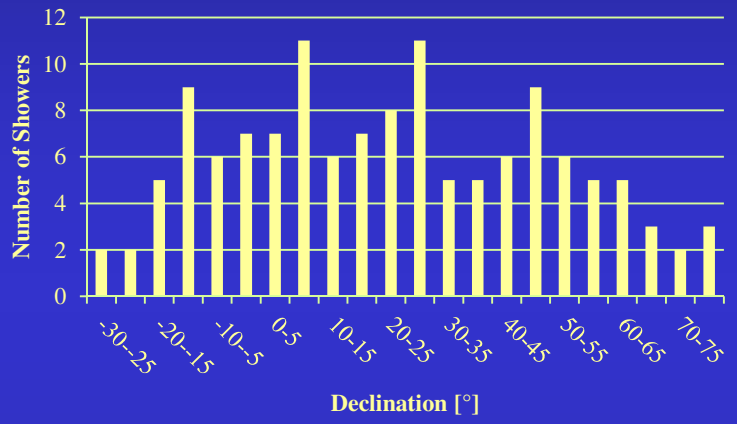
Statistics (III)

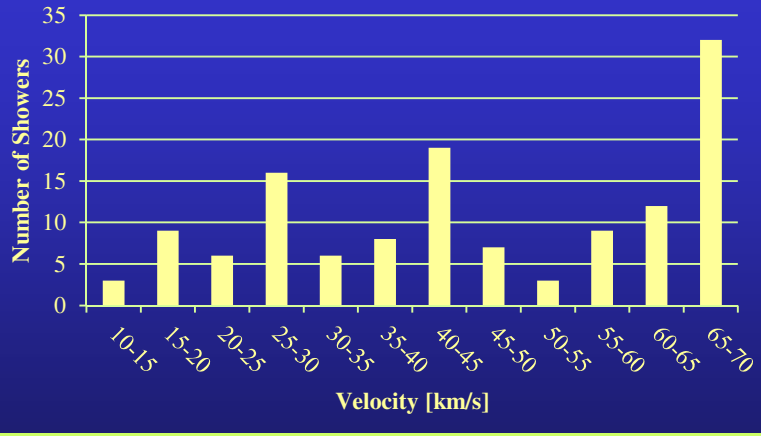
- 365,000 (35%) of all meteors were assigned to showers.
- 106 meteor showers detected (without Antihelion), corresponding to 39 „established“ and 77 „working list“ MDC showers.
- 23 segments of the Antihelion source detected, corresponding to 2 „established“ (NTA/STA),18 „working list“ MDC showers and 6 „unknown“ showers.
- 14 additional meteor shower candidates (too weak to be reported immediately to MDC, maybe linked to sporadic sources, worthwhile to be checked and confirmed or rejected).

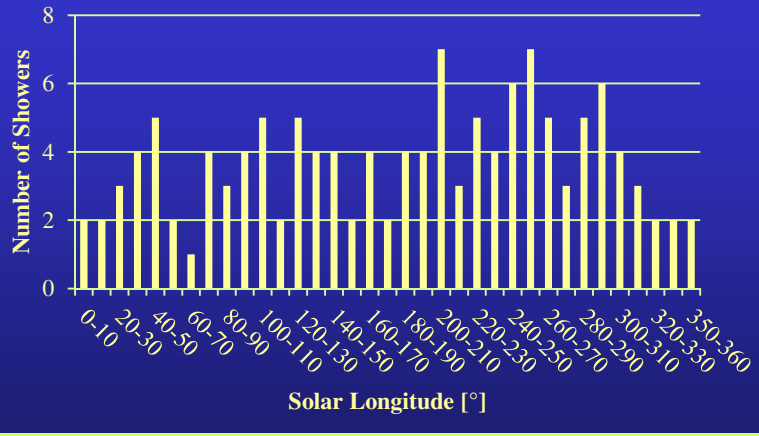
Statistics (IV)

- Meteor shower distribution over SL / α / δ / v_{geo}.









Results (I)

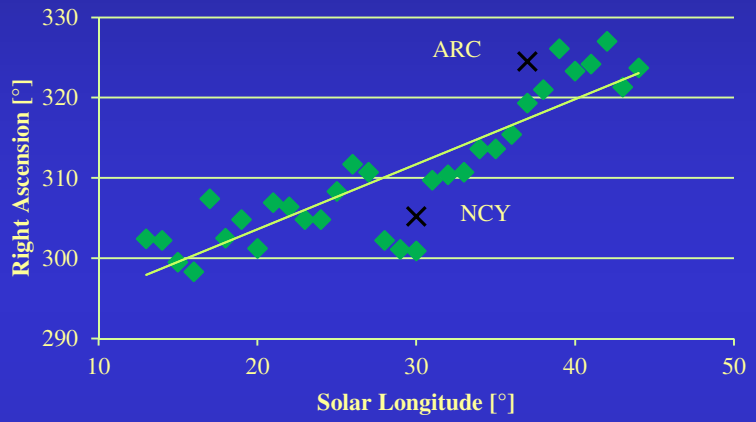
- The full list of meteor shower is presented as a poster.
- 38 „established“ MDC showers were not found:
  - → 13 daytime showers: 100 XSA, 128 MKA, 144 APS, 152 NOC, 153 OCE, 156 SMA, 172 ZPE, 173 BTA, 188 XRI, 202 ZCA, 212 KLE, 221 DSX, 325 DLT.
  - → 12 showers detected by radar: 110 AAN, 151 EAU, 165 SZC, 242 XRD, 320 OSE, 321 TCB, 324 EPR, 326 EPG, 327 BEQ, 328 ALA, 329 SSE, 390 THA.
  - → 4 southern hemisphere showers: 102 ACE (δ=-60), 137 PPU (δ=-45), 185 BHY (δ=-75), 254 PHO (δ=-45).
  - → 6 showers which should checked if they are indeed annual and „established“.

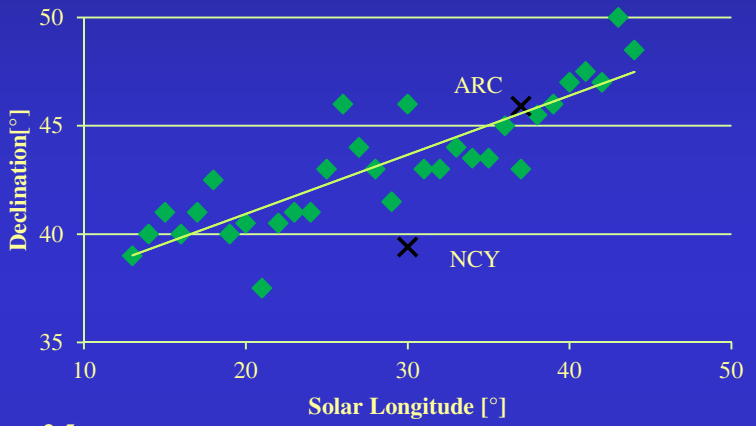
Results (II)

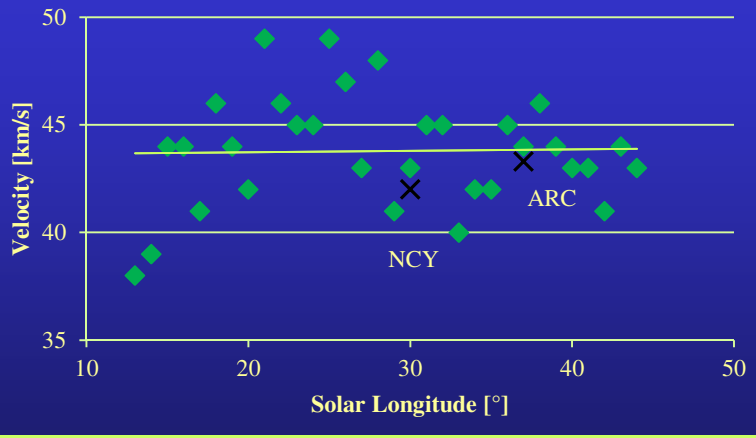
- 6 cases in question:
  - → 27 KSE (kappa Serpentids): Listed by Cook (1973) , few photographic orbits, confirmed by CAMS: *very* weak shower?
  - → 61 TAH (tau Herculids): Listed by Lindblad (1971), few photographic orbits, period & invisible these days?
  - → 63 COR (Corvids): Observed by Hoffmeister, dormant shower?
  - → 183 PAU (Pisces Austrinids): Listed by Kashcheev (1967), active in August instead of July?
  - → 233 OCC (October Capricornids): IMO as reference, based on visual observations, dormant shower?
  - → 252 ALY (April Lyncids): Single telescopic observation in 1971.

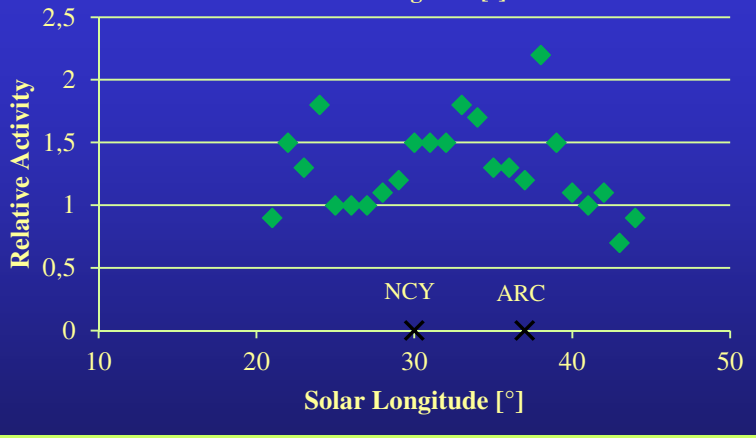
Results (III)

- 348 ARC and 409 NCY are probably the same shower.



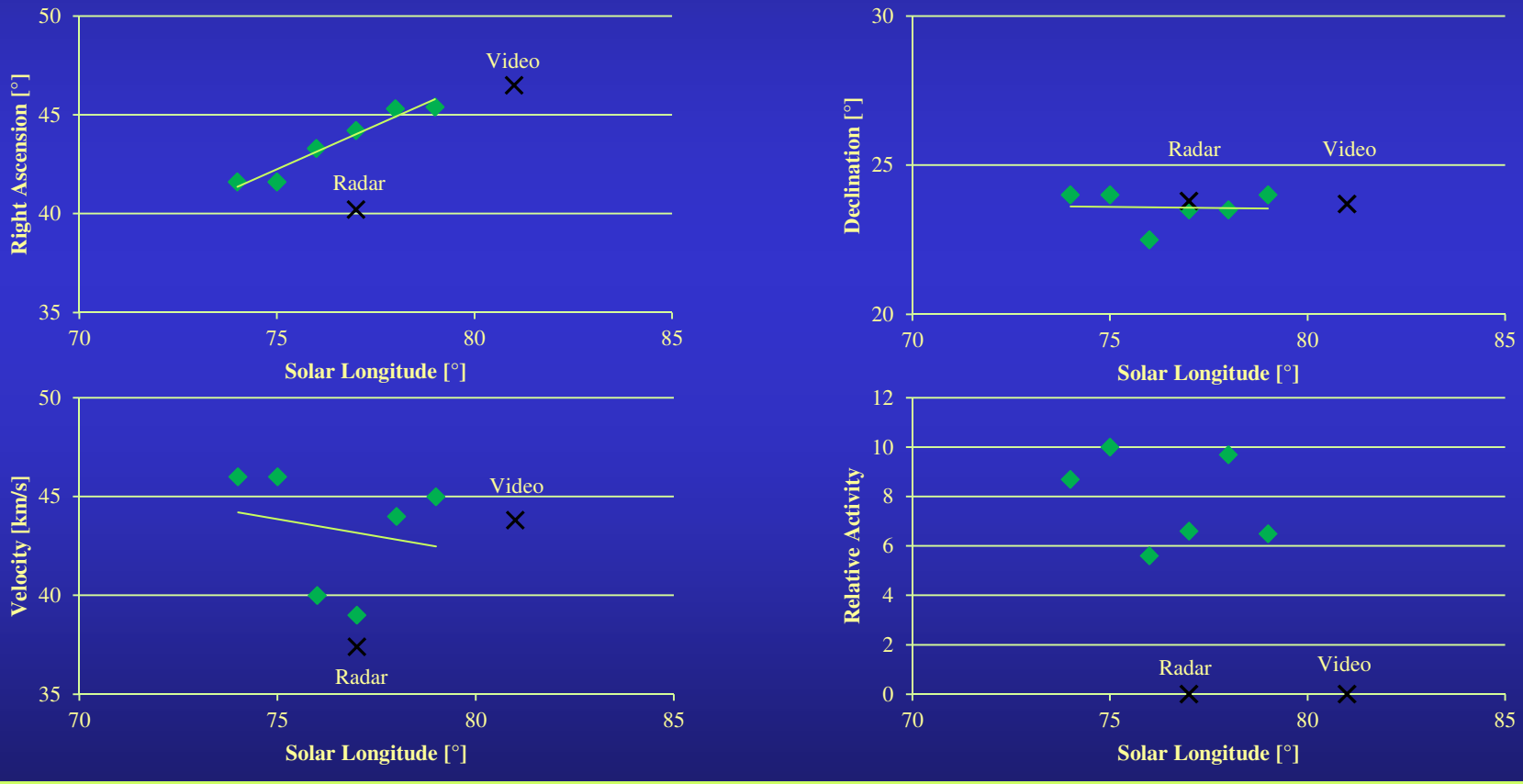






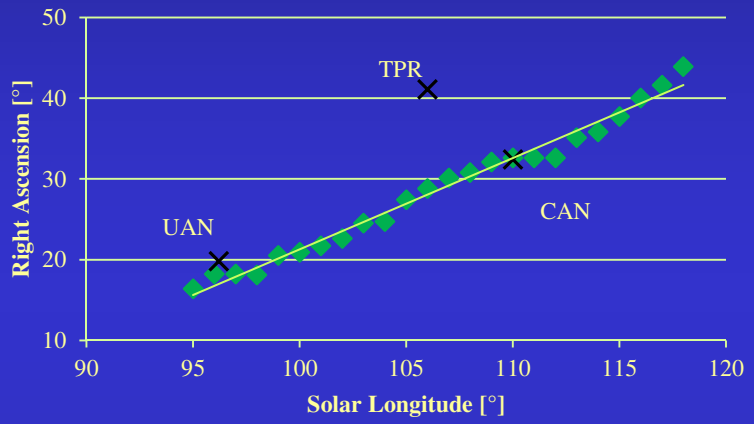
Results (IV)

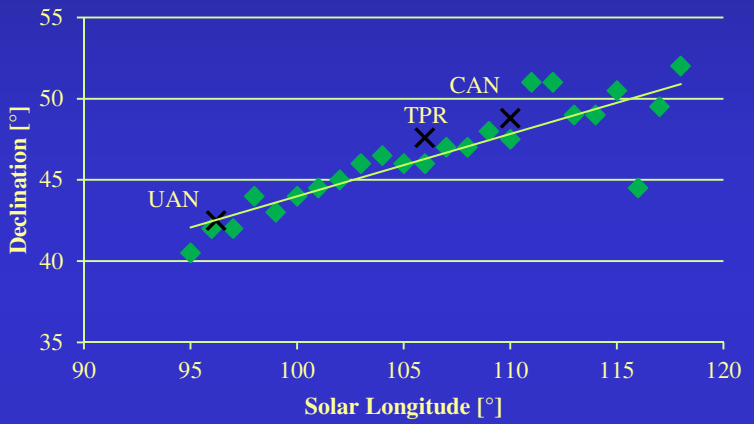
- 171 ARI – a daytime shower observed by video!

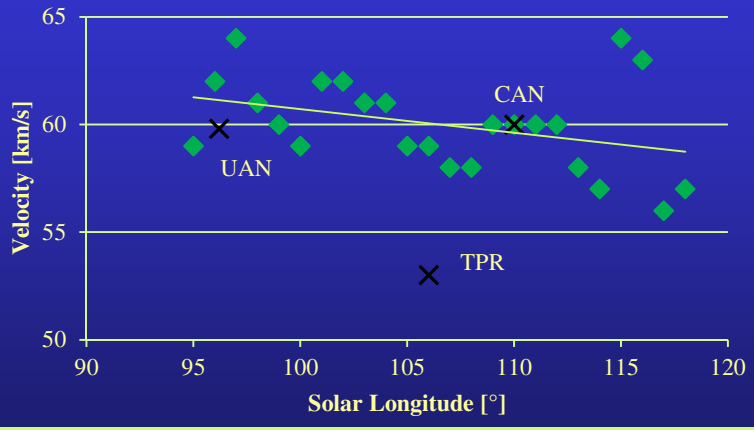


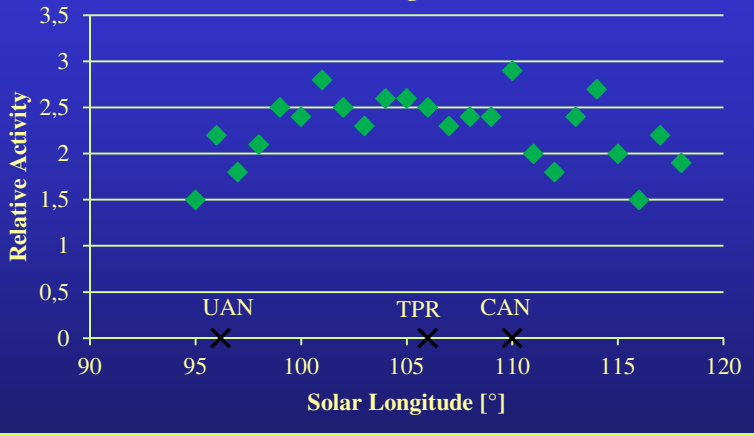
Results (V)

- 507 UAN is an early part of 411 CAN, 373 TPR is similar.



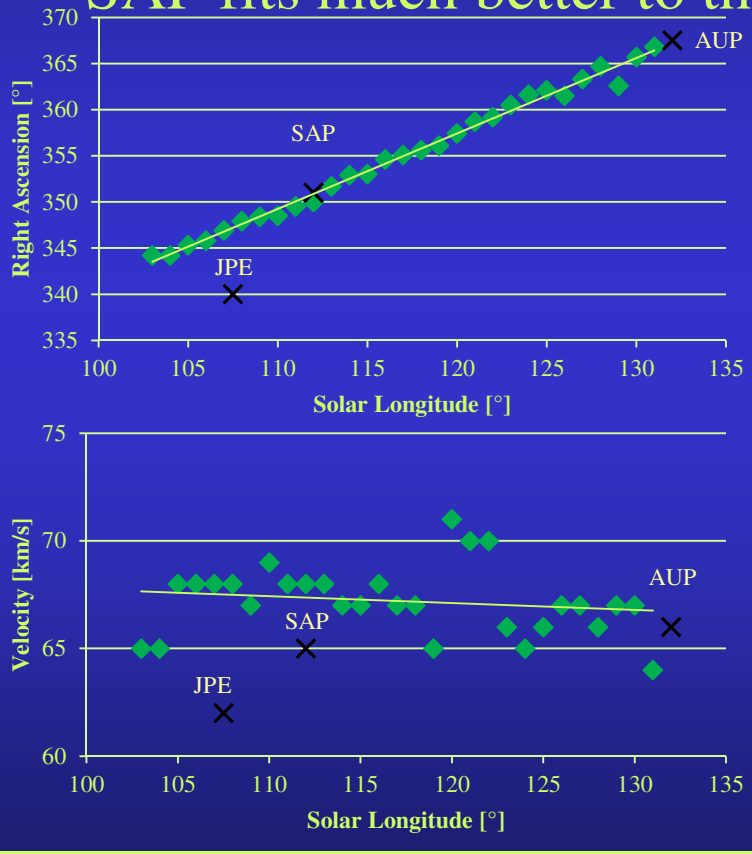


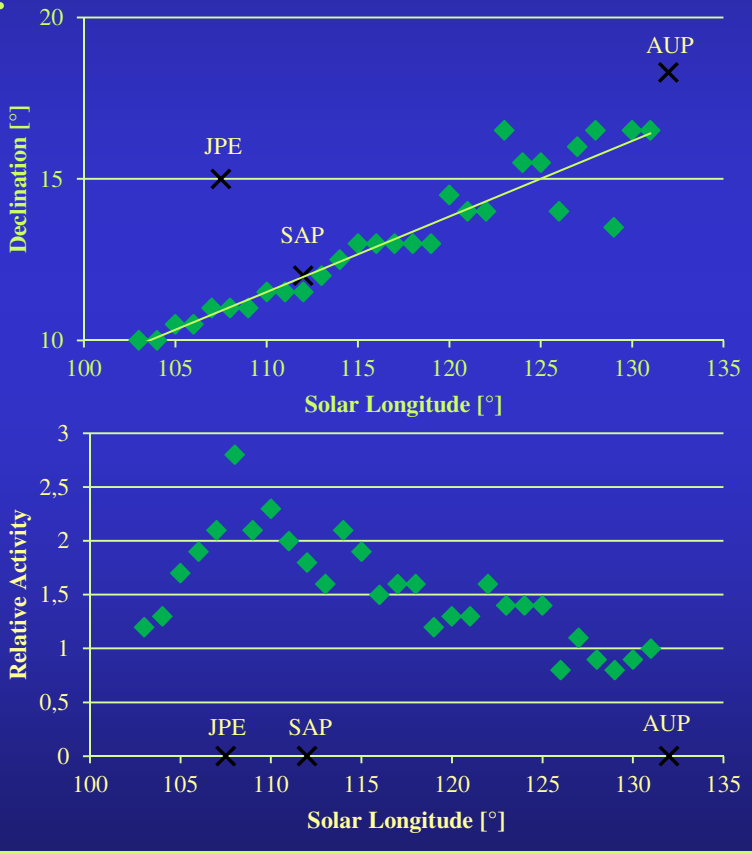




Results (VI)

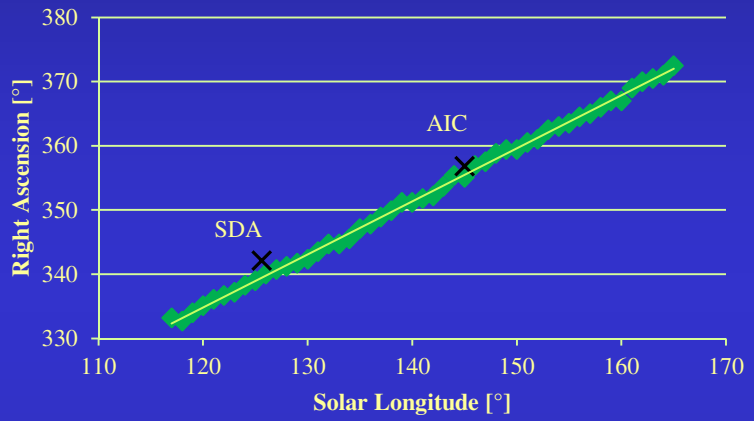
- 175 JPE is „established, but „working list“ 415 AUP and 522 SAP fits much better to the data.

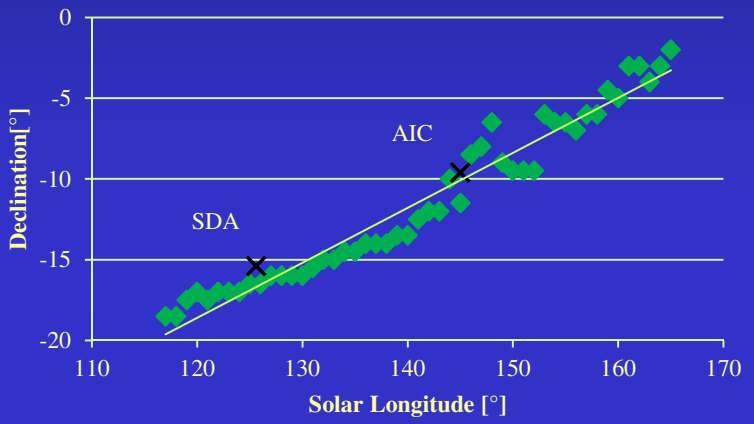


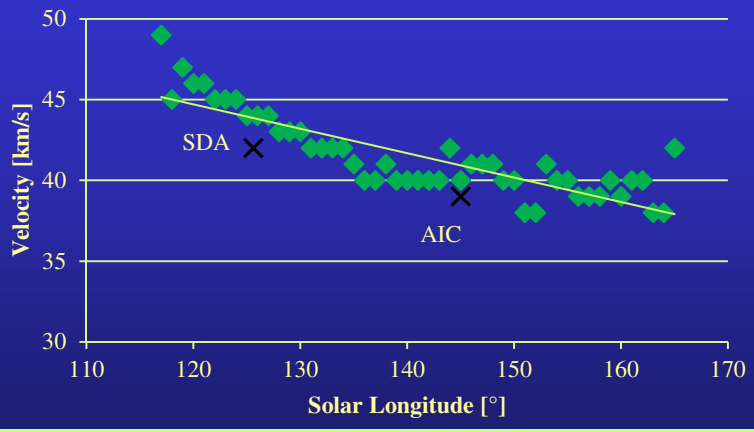


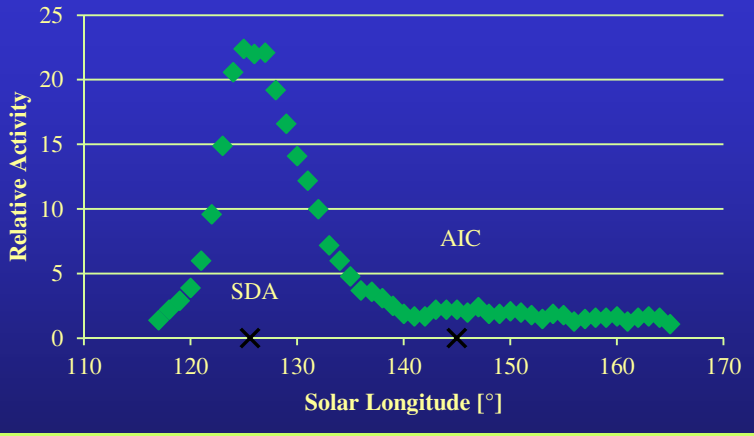
Results (VII)

- 505 AIC are a late part of 5 SDA.



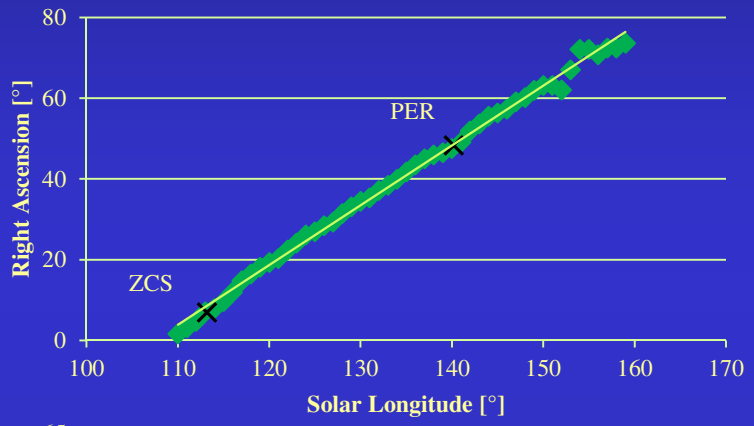


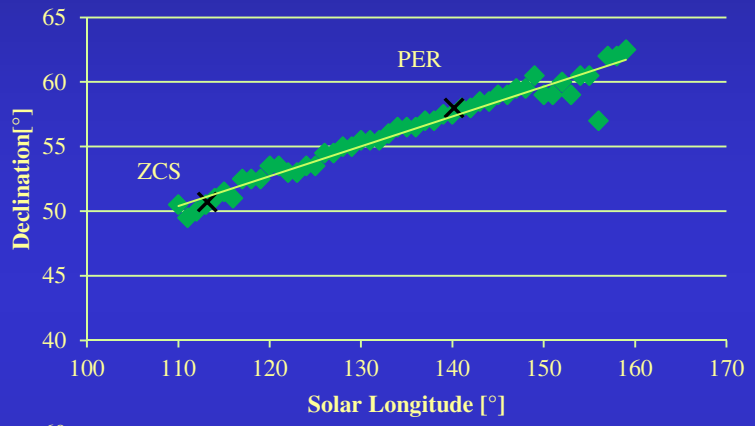


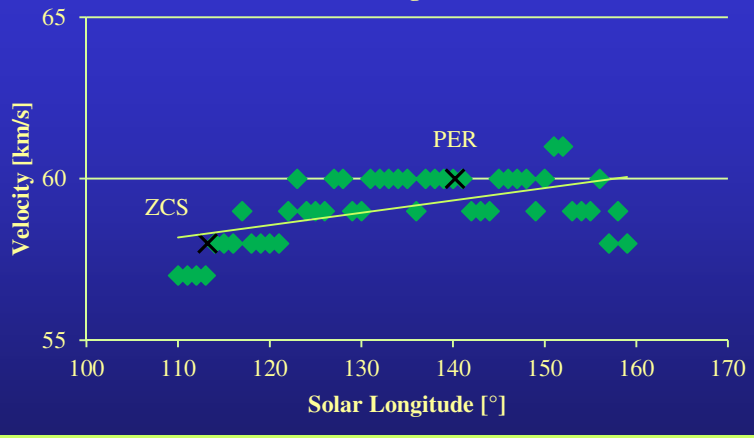


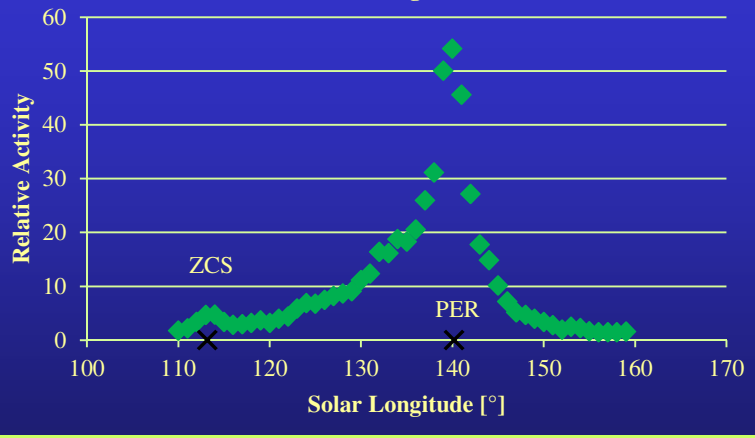
Results (VIII)

- 444 ZCS are an early part of 7 PER (?)



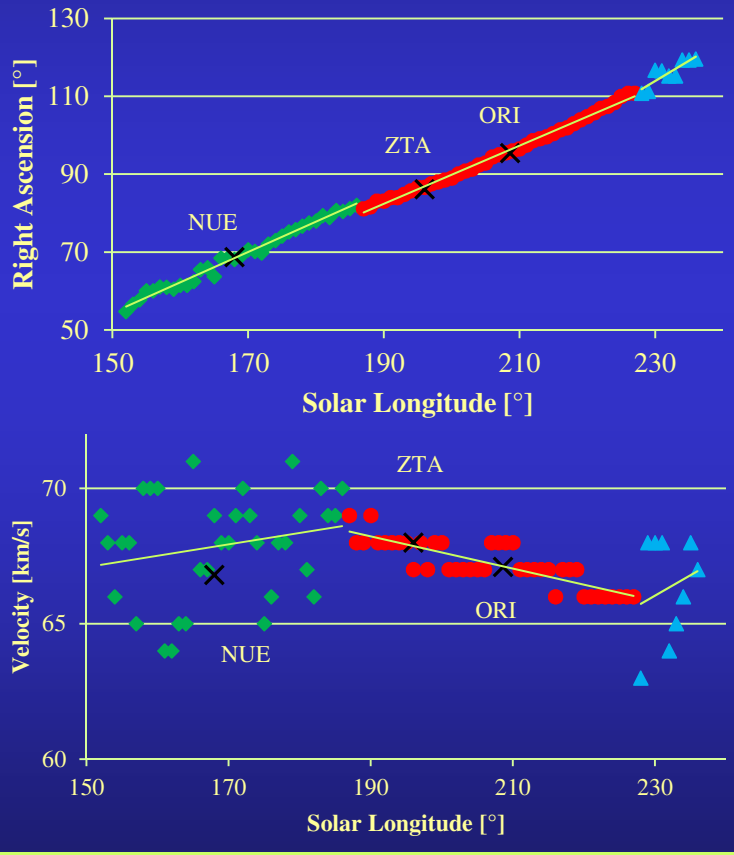


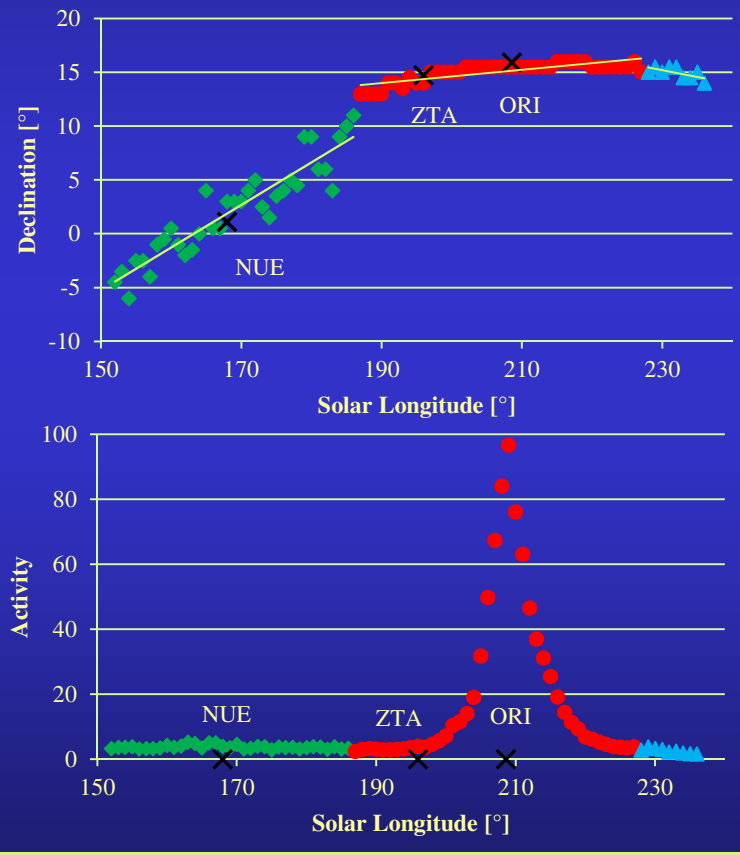




Results (IX)

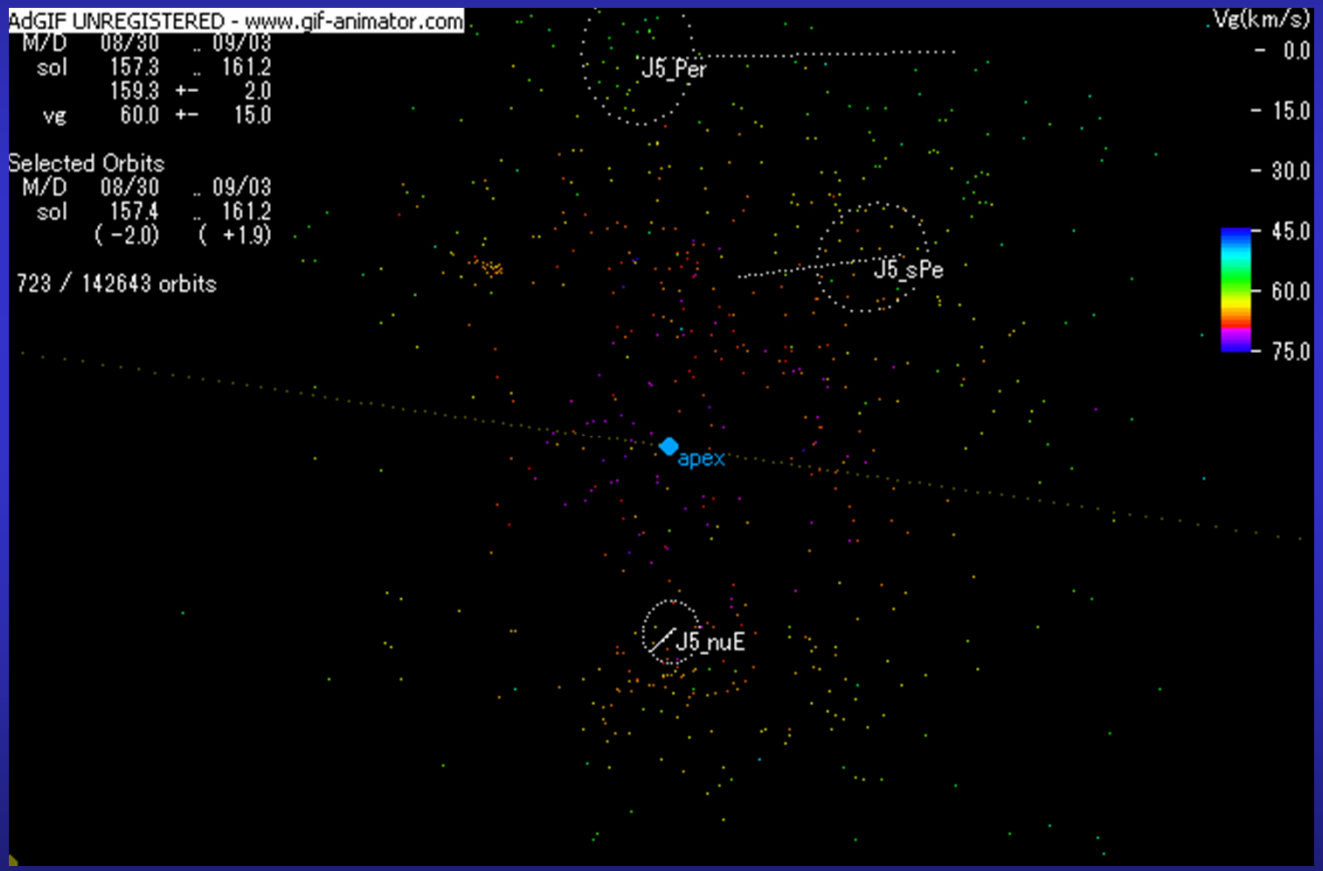
- 337 NUE (?) and 226 ZTA are early parts of 8 ORI.





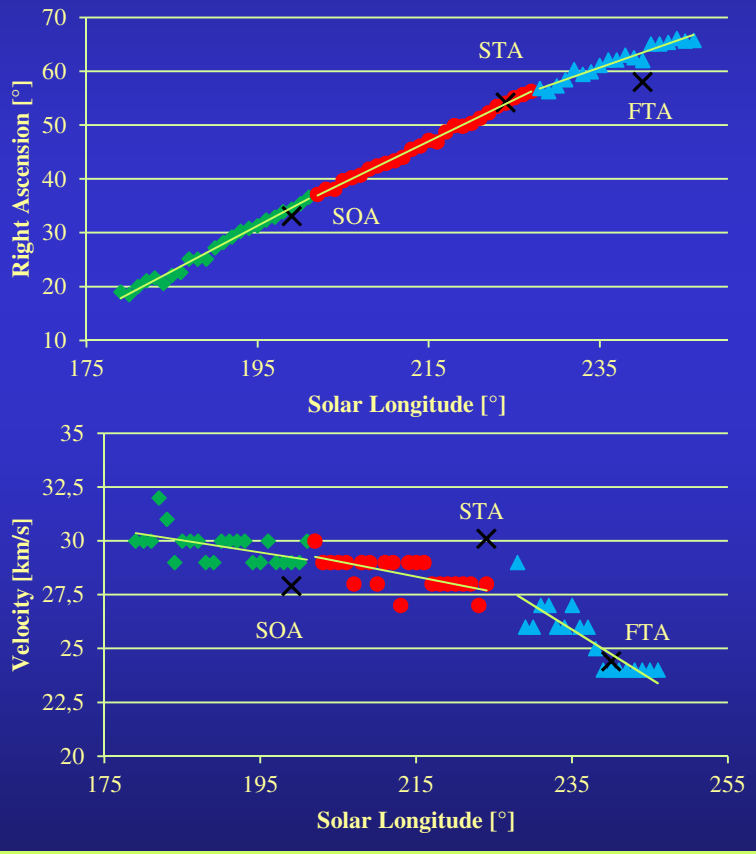
Results (X)

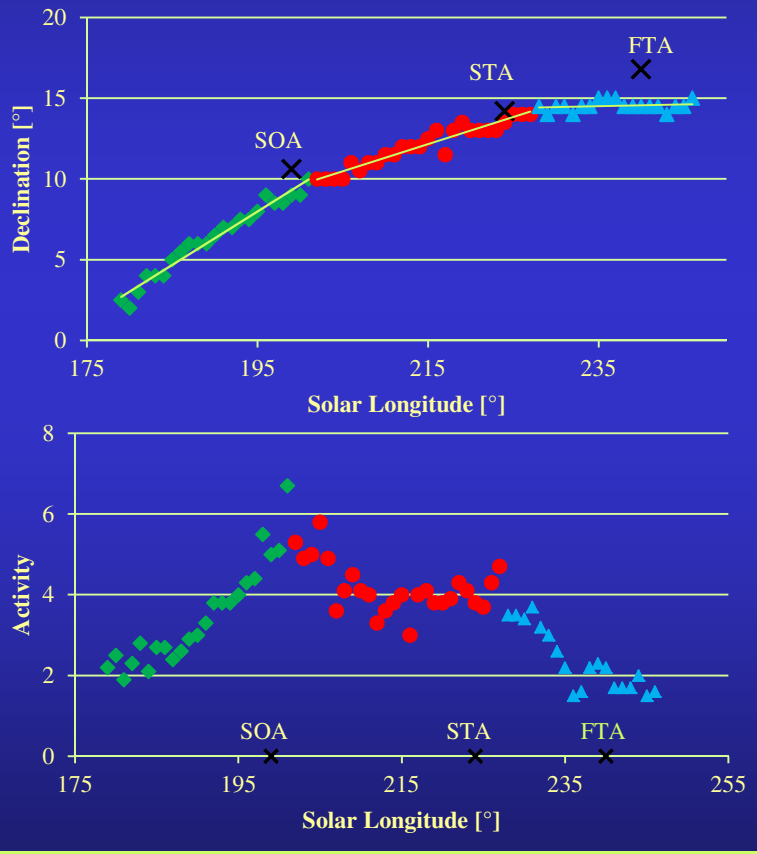
- Orbits between 160 and 200° sol long from 6 years of SonotaCo network data.
- Each image represents 4° in sol long with 1° shift.



Results (XI)

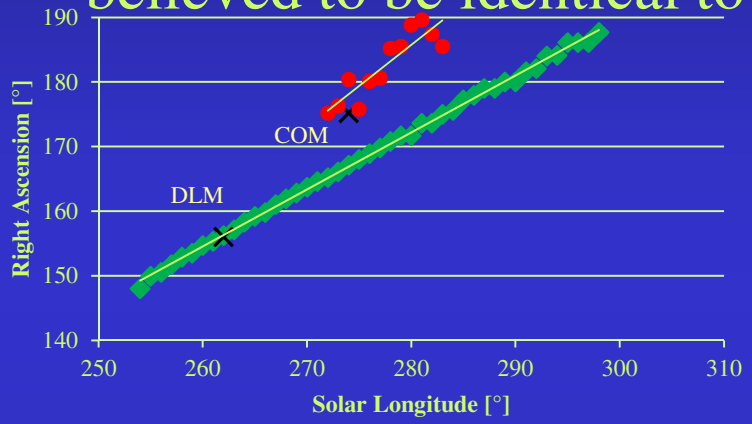
- 28 SOA is an early, 286 FTA a late part of 2 STA.

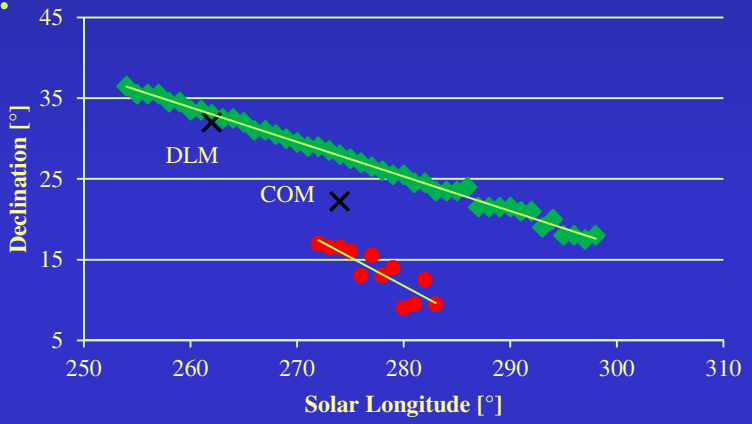


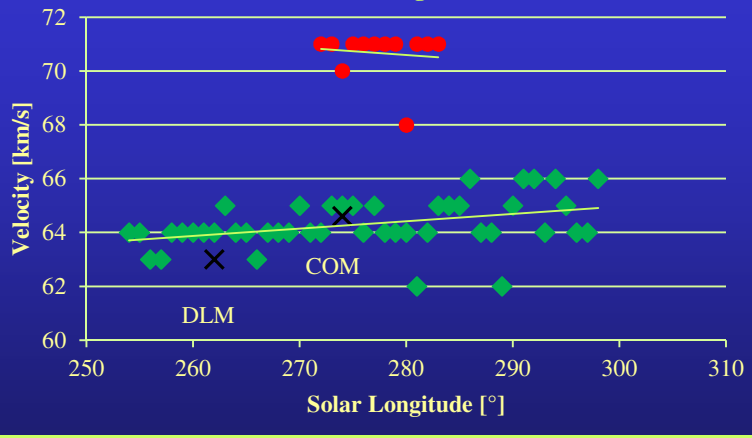


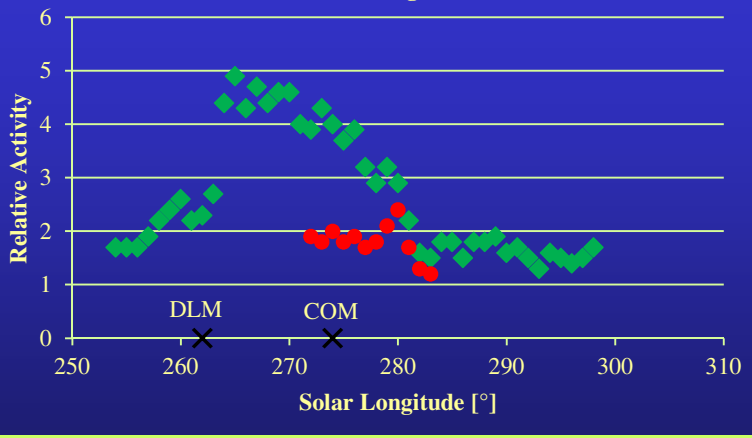
Results (XII)

- 20 DLM were deleted from the MDC list, because they were believed to be identical to COM.



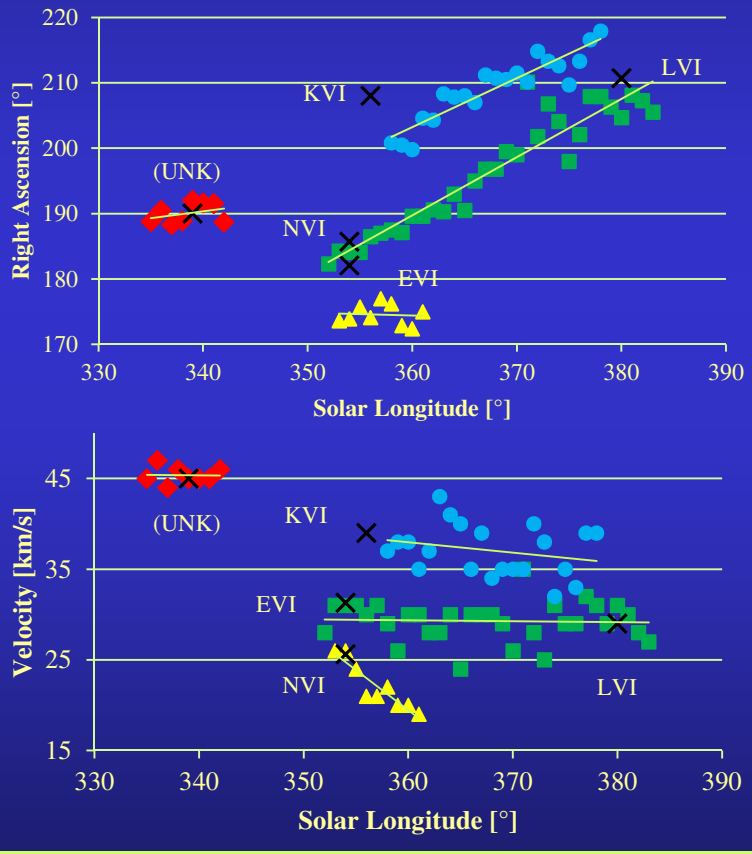


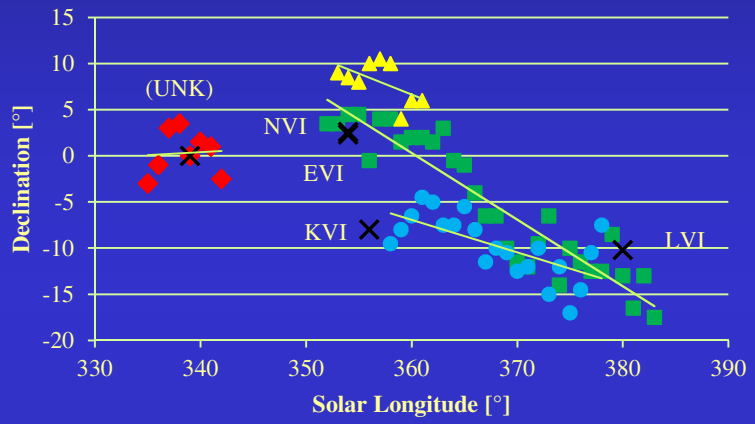


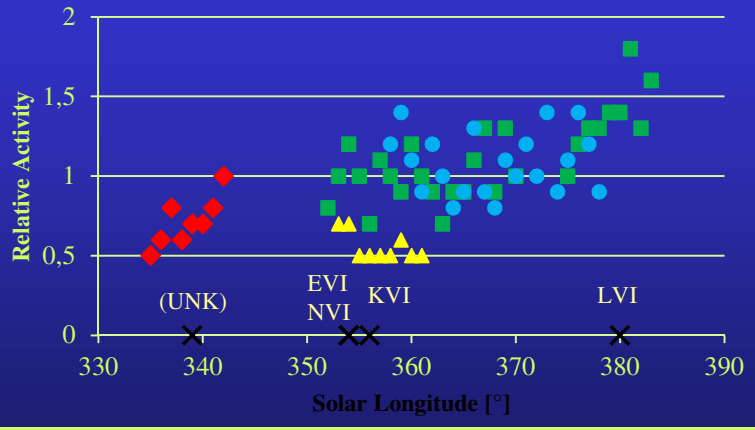


Results (XIII)

- 11 EVI and 49 LVI are two identical showers.

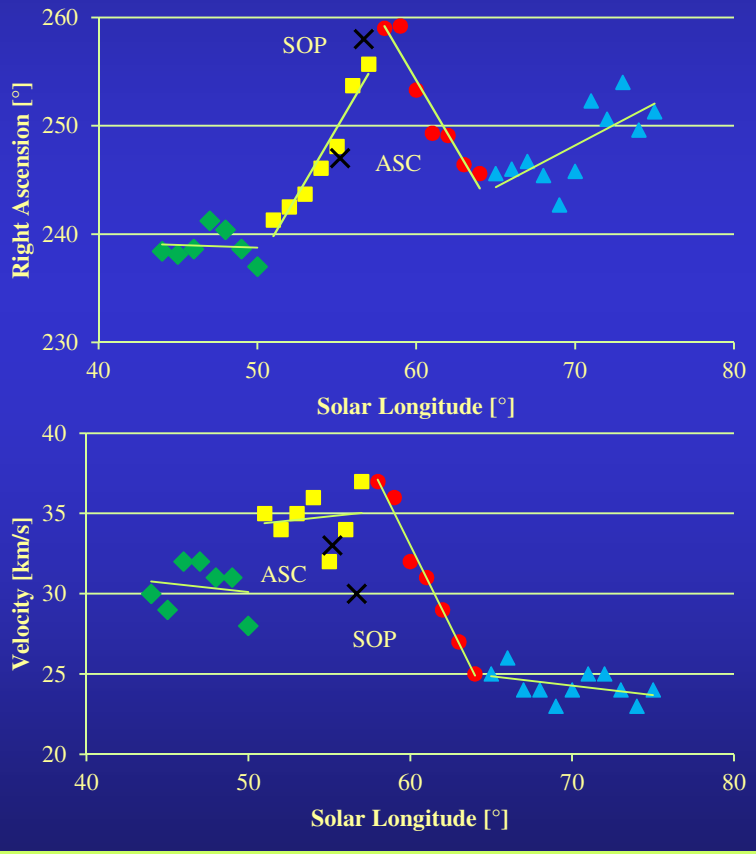


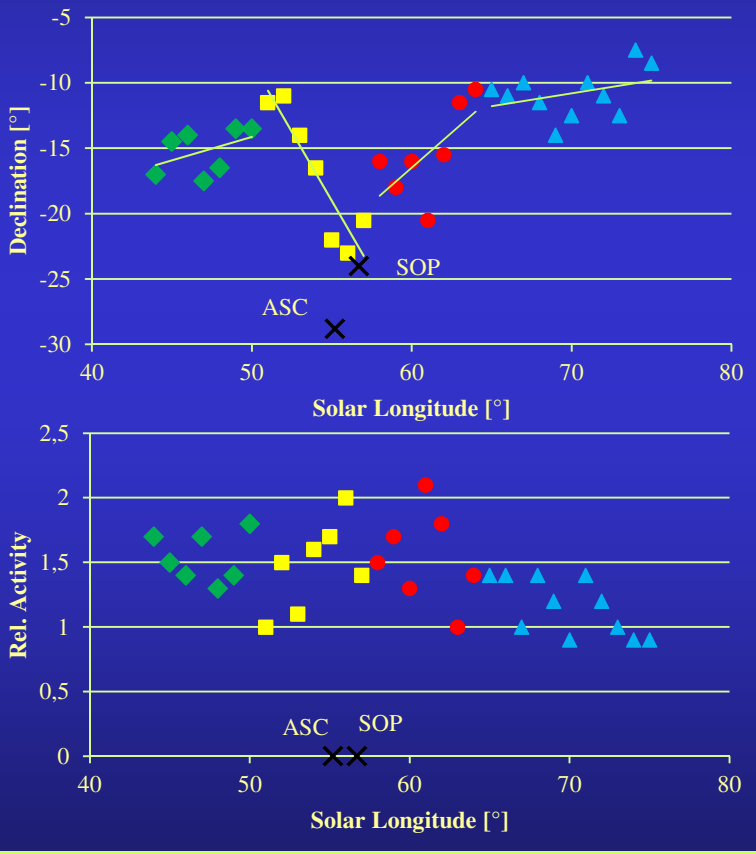




Results (XIV)

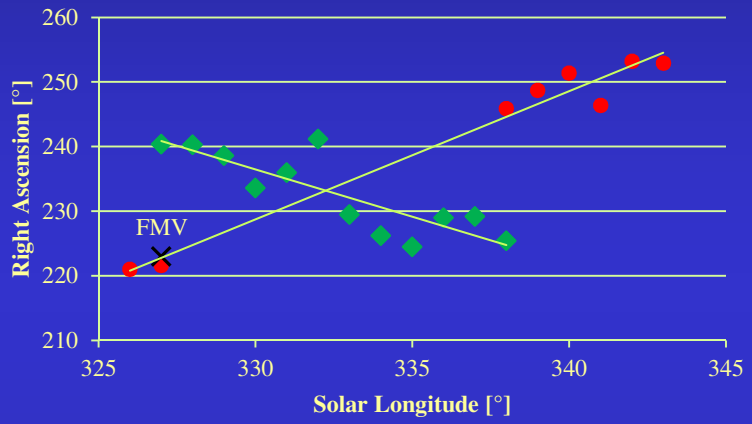
- 55 ASC and 150 SOP are two identical showers.

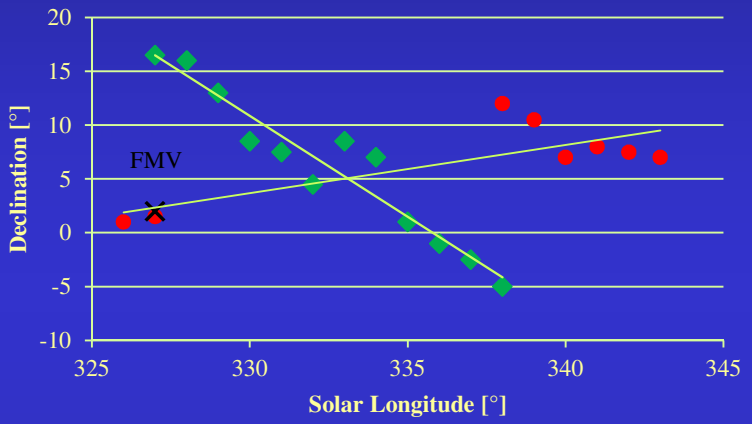


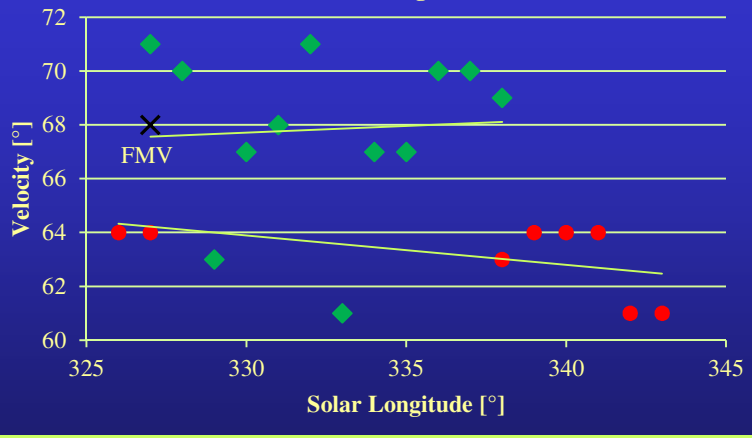


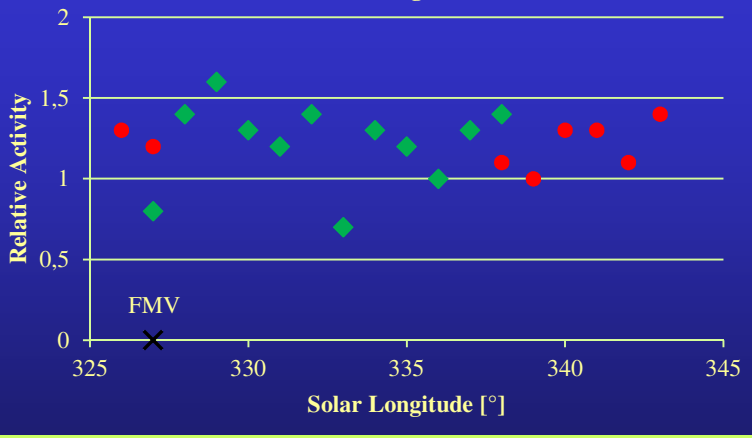
Results (XV)

- Do 516 FMV intersect with the N Apex source?









Conclusions

- The MDC list has certain weaknesses which may results in double registration of meteor showers:
  - → Only the peak sol long is given, but not the activity interval.
  - → Certain long-lasting meteor showers cannot be well described with a single set of parameters (e.g. variable or radiant drift).
- It should be decided whether complex sources like Antihelion are treated as one, or as a set of individual meteor showers.
  - → In the latter case we find half a dozen new showers.
- Dormant showers should be clearly marked as such.
- An (online) tool may help to identify meteor showers and prevent double registration of showers.

Thanks for your Attention

Questions?