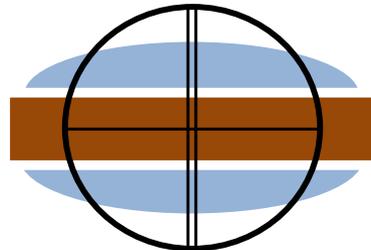


High resolution orbits with high speed shutters

Felix Bettonvil

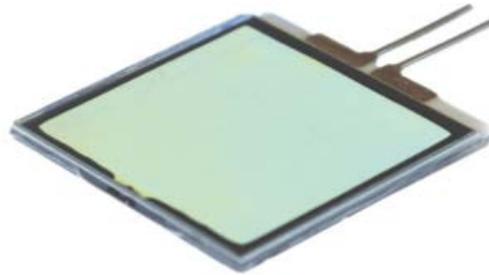
U Leiden, NOVA



Content

- Introduction / history
- Aim/goal
- Instrument design
- Results
- Reduction process
- Analysis – first impressions
- Outlook

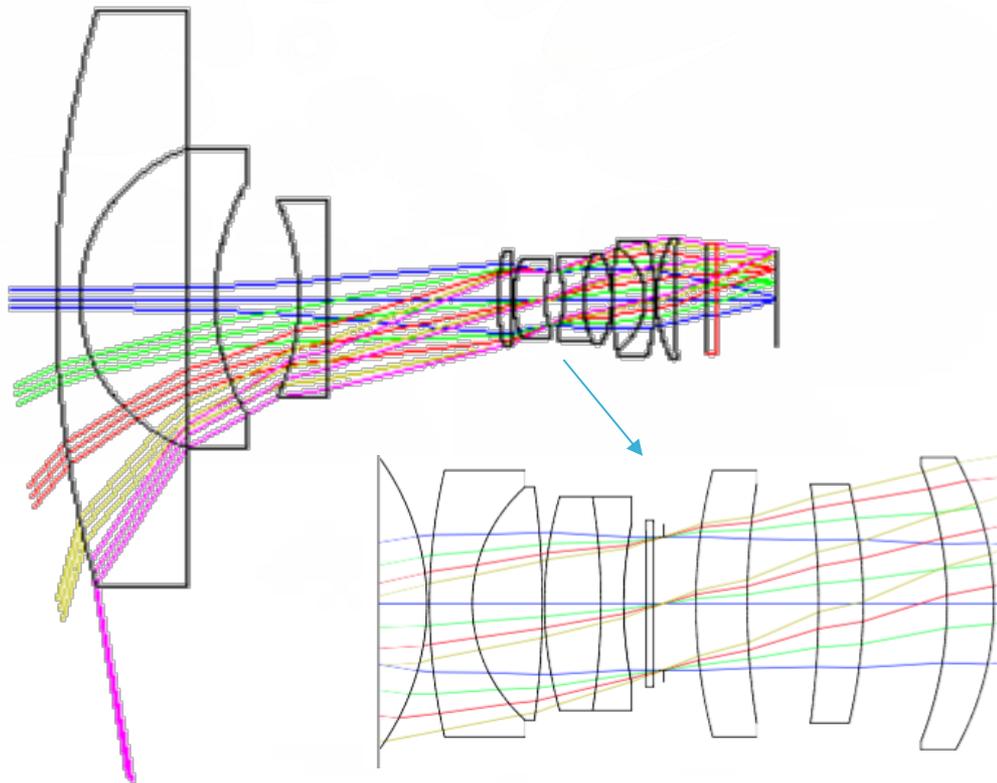
Introduction



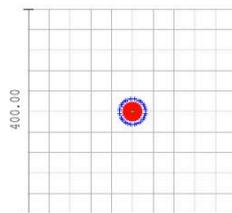
<i>Size</i>	<i>Outer dimensions</i>	<i>Clear aperture</i>	<i>Thickness</i>
7x8	7.0mm x 8.2mm	5.0mm x 5.0mm	Model dependent, ranging from 1.3mm to 5.3mm
13x15	13.0mm x 15.0mm	9.8mm x 9.8mm	
1x1	25.4mm x 25.4mm	22.2mm x 20.2mm	
2x2	50.8mm x 50.8mm	47.6mm x 45.6mm	
D1 (circular)	25.4mm diameter	22.2mm diameter	
D2 (circular)	50.8mm diameter	47.0mm diameter	

<i>Model</i>	<i>Open state transmittance</i>	<i>Contrast</i>	<i>Closing time (T₁₀₀-T₁₀)</i>	<i>Opening time (T₀-T₉₀)</i>	<i>V_D</i>
FOS	≥39.5%	≥1,000:1 ≥1,800:1	≤6ms ≤150μs	≤30ms ≤35ms	@ 4V @ 24V
FOS-ETR	≥32.5%	≥850:1 ≥1,200:1	≤6ms ≤500μs	≤35ms ≤40ms	@ 5V @ 18V
FOS-NIR(1100)	≥37.0%	≥250:1 ≥350:1	≤5ms ≤120μs	≤15ms ≤20ms	@ 5V @ 24V
X-FOS(G2)	≥37.5%	≥1,800:1	≤50μs	≤1.8ms	@ 18V
X-FOS(G2)-CE	≥30.0%	≥120,000:1	≤50μs	≤1.8ms	@ 18V
PolarSpeed®-S	≥37.5%	≥300:1	≤30μs	≤30μs	@ 24V
PolarView®-ND(212)	≥25%	≥1,000:1	≤10ms	≤15ms	@ 4.5V
PolarView®-ND(14)	≥50%	≥10:1	≤50ms	≤250ms	@ 9V
FSD	≥83%	Light scattering	≤7ms	≤9ms	@ 110V

16mm F/2.8 Zeiss Distagon fisheye

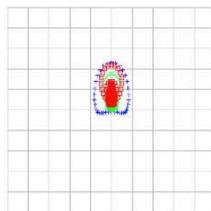


OBJ: 0.00 (deg)



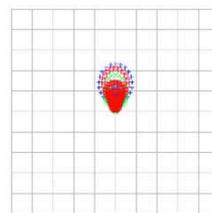
IMA: 0.000 mm

OBJ: 60.00 (deg)



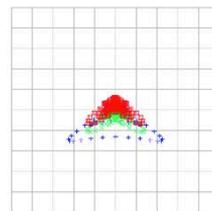
IMA: 17.767 mm

OBJ: 30.00 (deg)

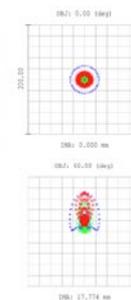


IMA: 9.764 mm

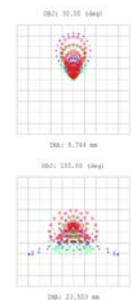
OBJ: 105.00 (deg)



IMA: 23.480 mm



IMA: 0.000 mm



IMA: 9.764 mm

OBJ: 60.00 (deg) IMA: 17.767 mm

OBJ: 105.00 (deg) IMA: 23.480 mm

Spot Diagram

Spot Diagram



BINGO!

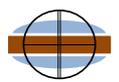
All sky camera Dwingeloo
2015:10:11 - 22:43:48 UT - ISO1600 - 20 cycl/sec - 87"

Idea

- A LC shutter can also chop fast, up to **1 kHz**
- This allows for **precise** velocity determination
- And consequently a accurate orbits
 - thus better semi major axis, stream origin
- GOAL:
 - Determination of fine detail in distribution of orbits.
 - Focus on large streams: PER, GEM, QUA

Sensitivity

Parameter	Accuracy	D_{SH}	
		Perseid	Geminid
velocity [km/s]	0.040	0.0018	
	0.036		0.0019
Time (sec)	30	0.0001	
	30		0.0002
Astrometry RA [deg]			
	0.002		0.0003
Astrometry Decl [deg]			
	0.003		0.0002
Longitude station [deg]			
	0.17		0.0001
Latitude station [deg]			
	0.17		0,0001



Instrument

Canon 1100D + 50mm/F2 (2.8)
20x30° FoV

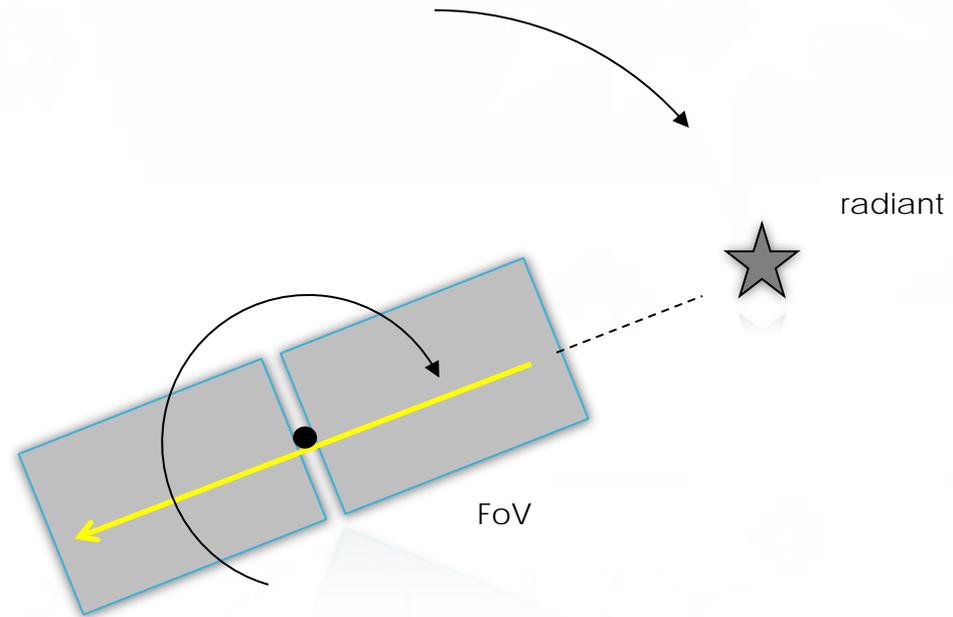
LC-TEC chopper

TC80N3 exposure
controller

Chopper controller
10-6 stab; 10-6 acc







Results

Shower	Location	Lens	Cycl/s	Resolution	2 nd cam	# trails	# double station
Perseids 2014	Bosnia	50/F2.8	50 – 200 Hz	21"	none	5	none
Geminids 2014	Netherlands	2x50/F2.8	200 Hz	21" + 17"	video	17	13
Perseids 2015	Croatia	2x50/F2.8	200 – 300 Hz	17" + 17"	12M + video	13	10
Geminids 2015	France	2x50/F2.8	200 Hz	17" + 17"	CABERNET*	31	?

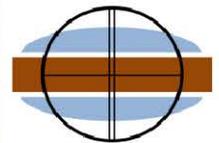
Sensitivity ~3x relative old photographic work

200 Hz



CHIPOIAtA

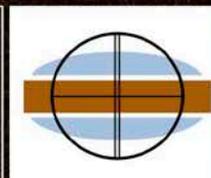
December '13, '2014, '23.40.25' UT: 'Geminid' +1' near 'Hyades' in 'Tau'
Canon '550D' + 'Nikkor' 50mm/F2.8, '200' cycl/sec, 'ISO6400, 'T=15s'
Twisk, 'The' Netherlands'



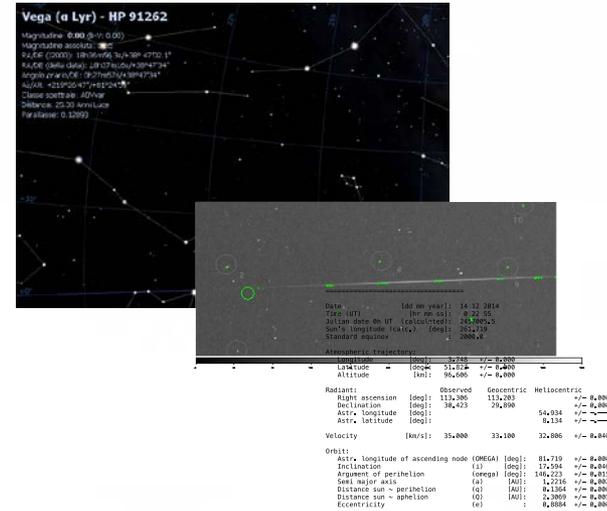
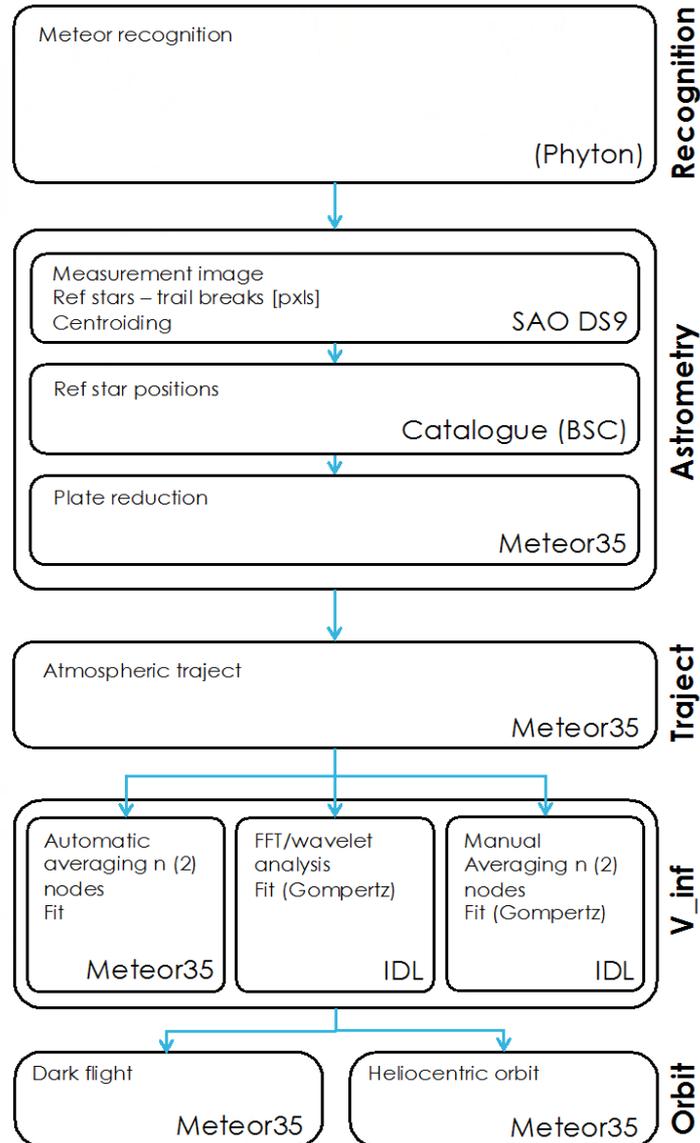
300 Hz

CHIPOLAtA

August 14, 2015, 02.14.26 UT: Perseid -1 in Aries, $12^{\circ} \times 12^{\circ}$
Canon 550D + Nikkor 50mm/F2.8, 300 cycl/sec, ISO6400, T=14s
Hvar, Croatia



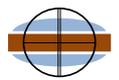
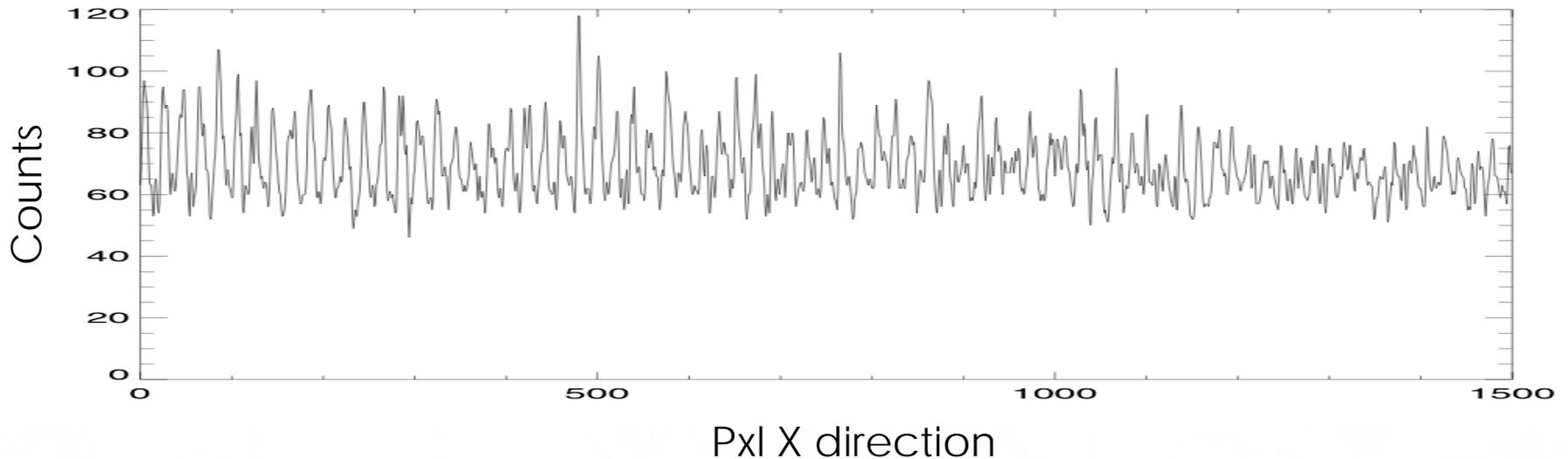
Reduction



FFT method

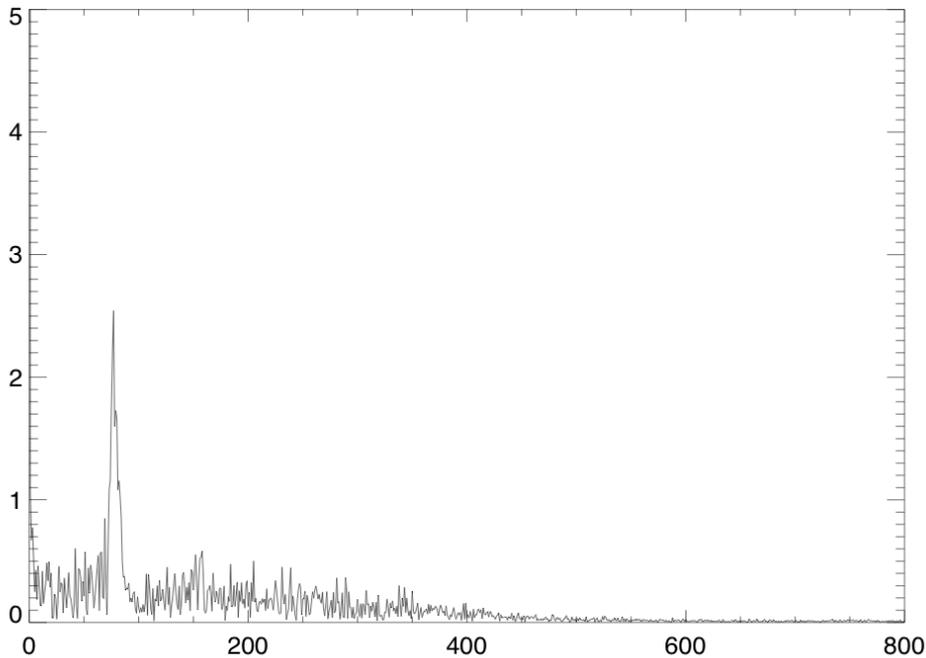
- Compute dominant frequency

Intensity profile



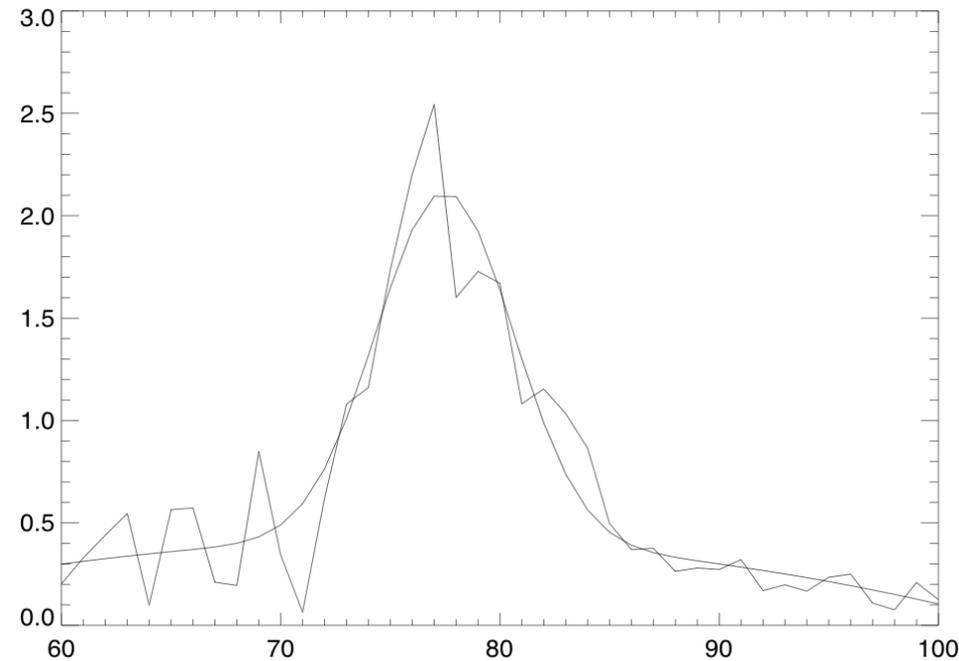
FFT method

Frequency spectrum

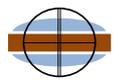


Frequency

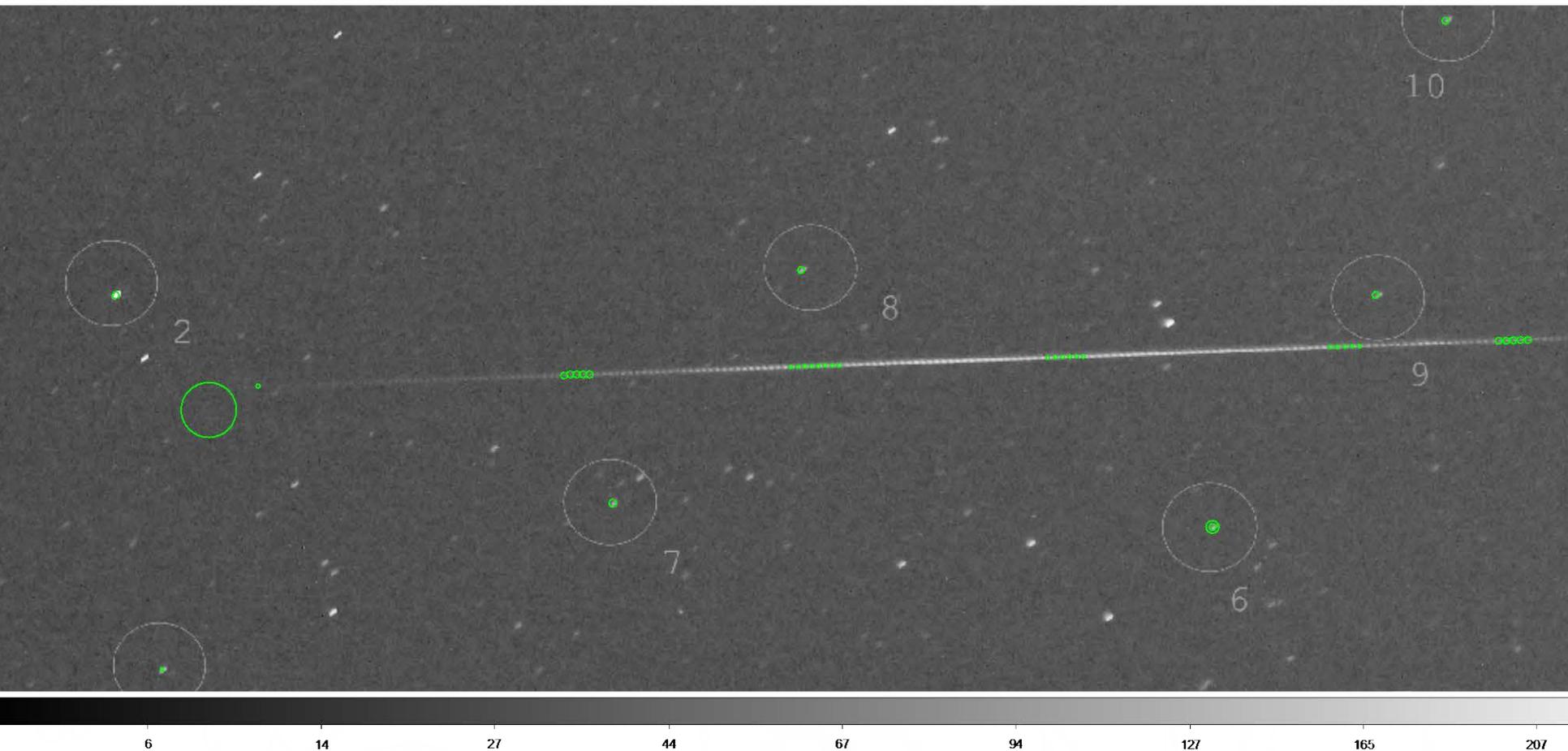
Fit

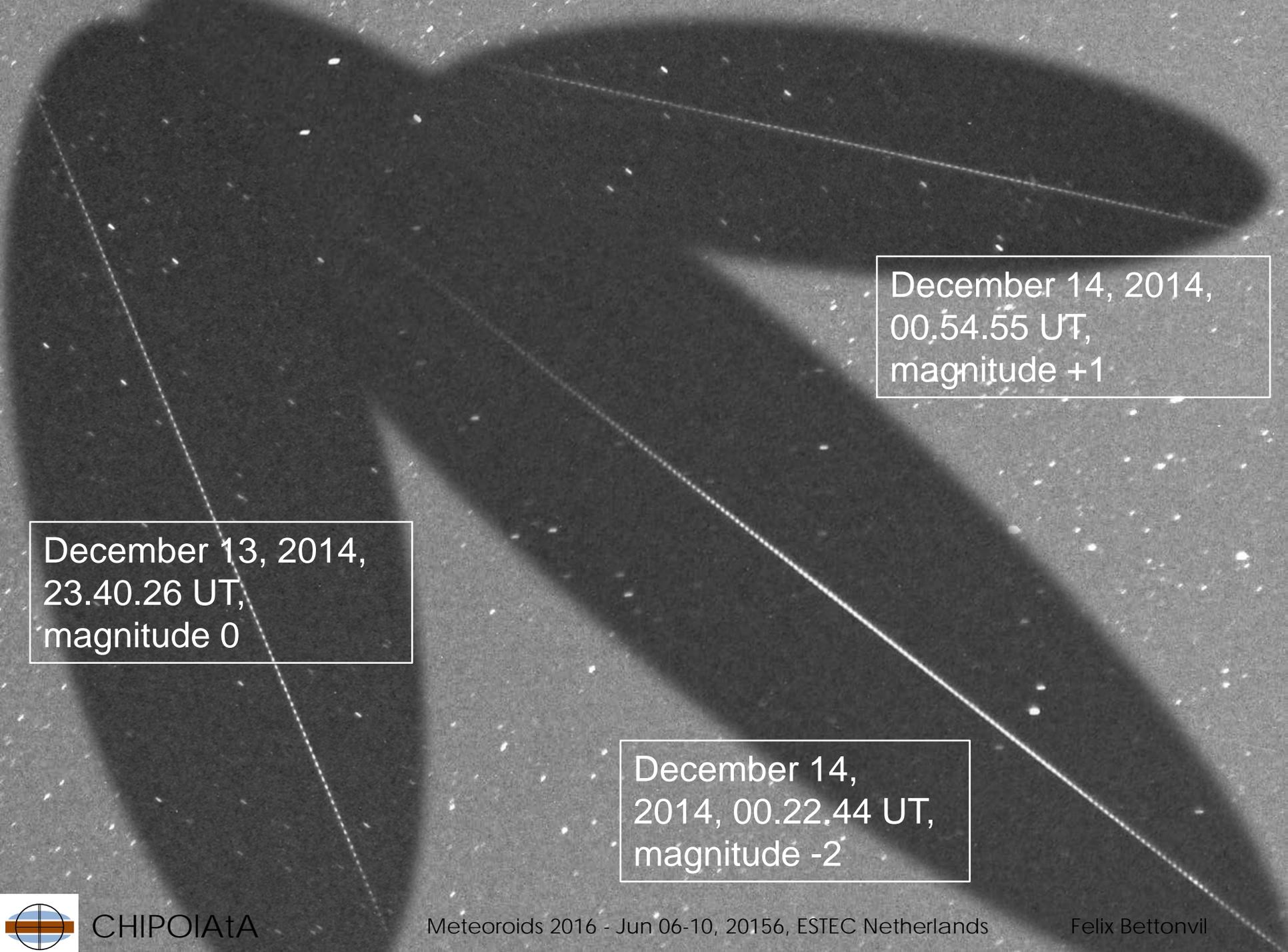


Frequency



Classical measurement

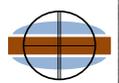




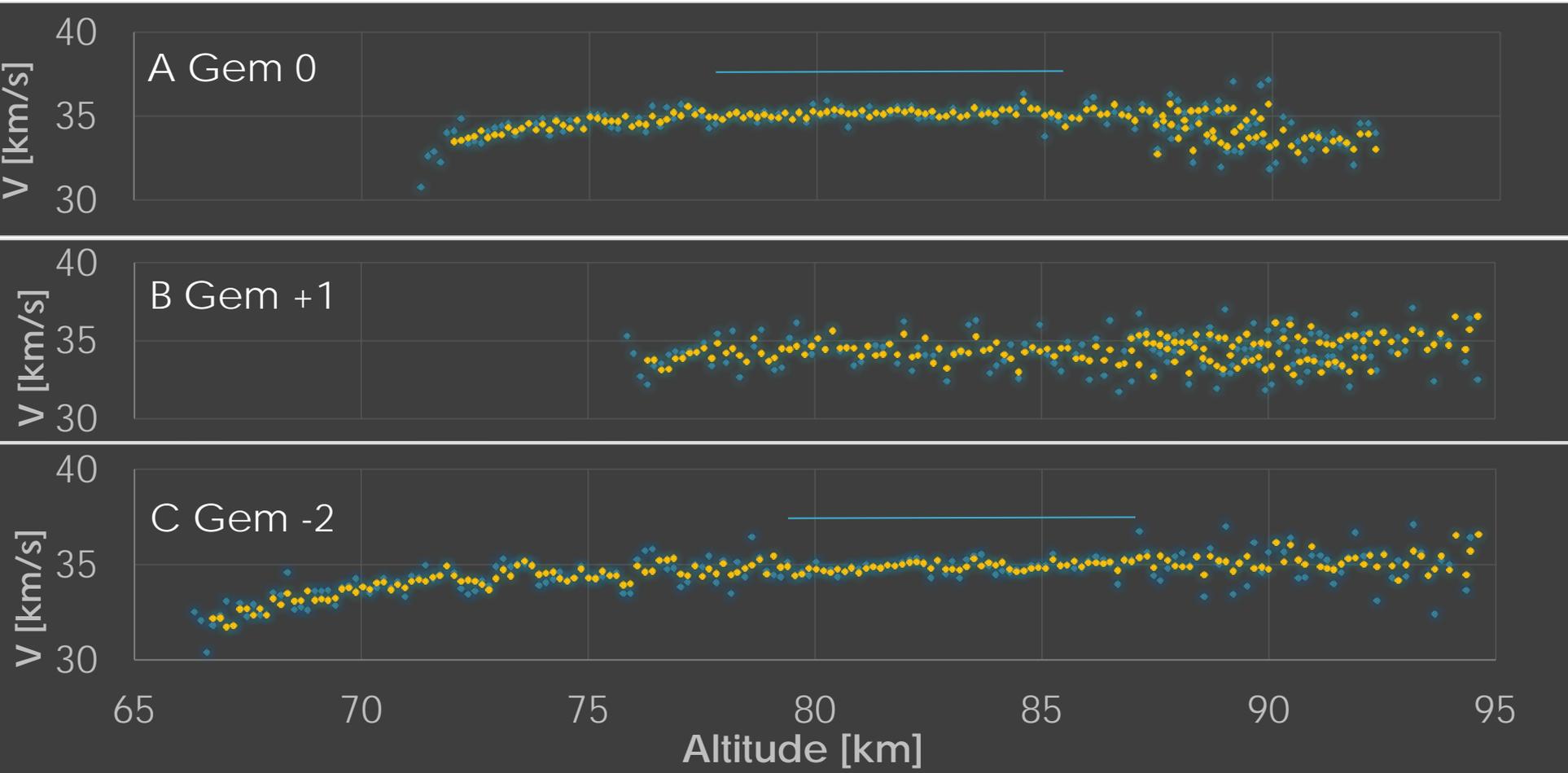
December 13, 2014,
23.40.26 UT,
magnitude 0

December 14, 2014,
00.54.55 UT,
magnitude +1

December 14,
2014, 00.22.44 UT,
magnitude -2



Results

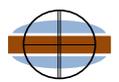


Results

	A	B	C
average V [km/s]	35,18	34,01	35,05
σ^* [km/s]	0,32	0,63	0,41
Error [km/s]	0,005	0,008	0,004
Accuracy** [km/s]	0.05	-	0.08

* 6p moving average

** estimated V_{inf}



Open questions

- What is the distribution of velocities?
- What is the relation between velocities and brightness?

Conclusions & next steps

- Geminids: velocity is not constant as function of height
- Wish for improve of sensitivity, lower noise
 - Upgrade cams

