GOcEcl: A new deep feed for larger apertures

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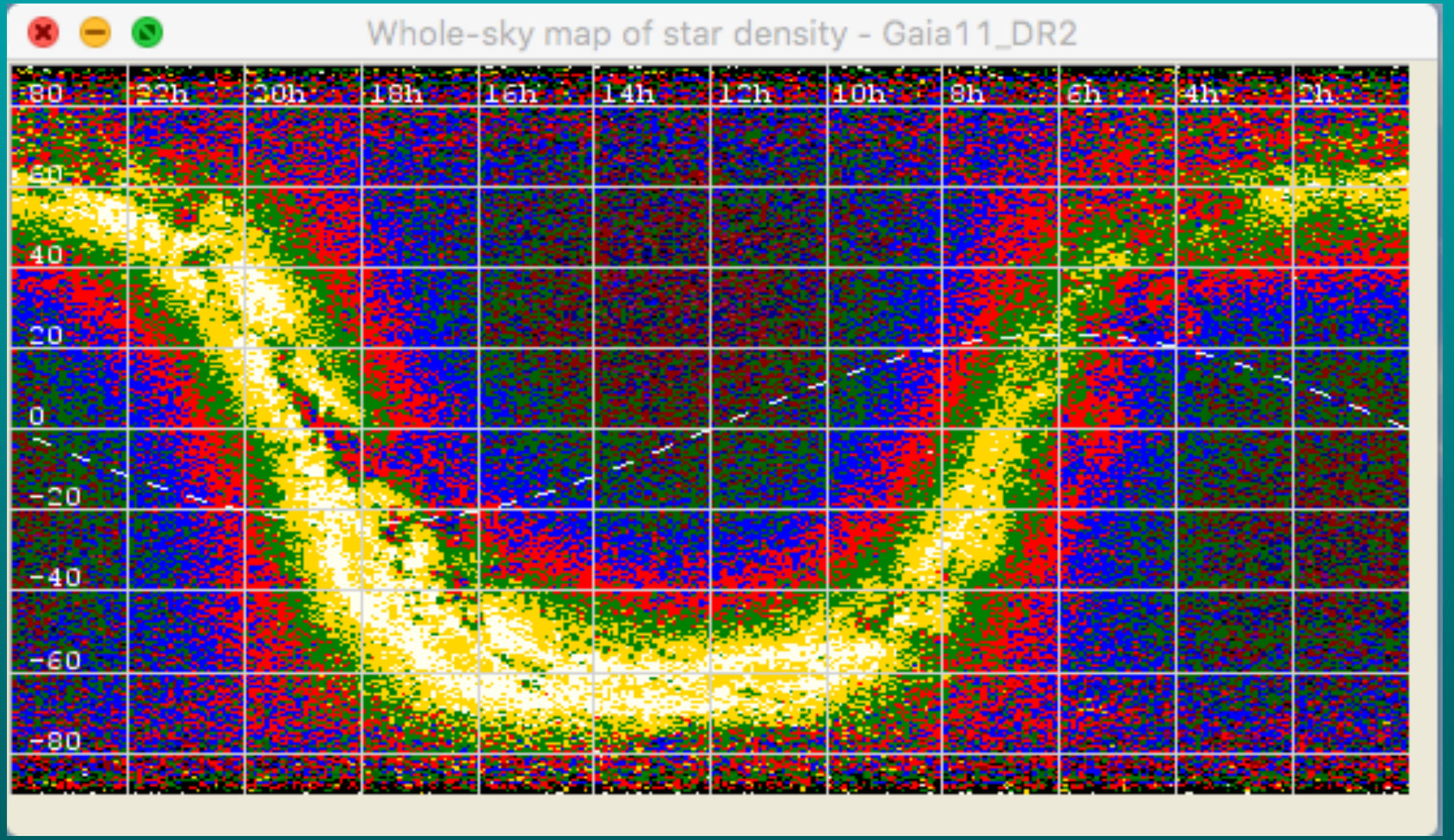
Introduction

- General comments & motivation
- Star catalog
- Asteroids used
- Limitations and unique properties
- Statistics
- Sample predictions

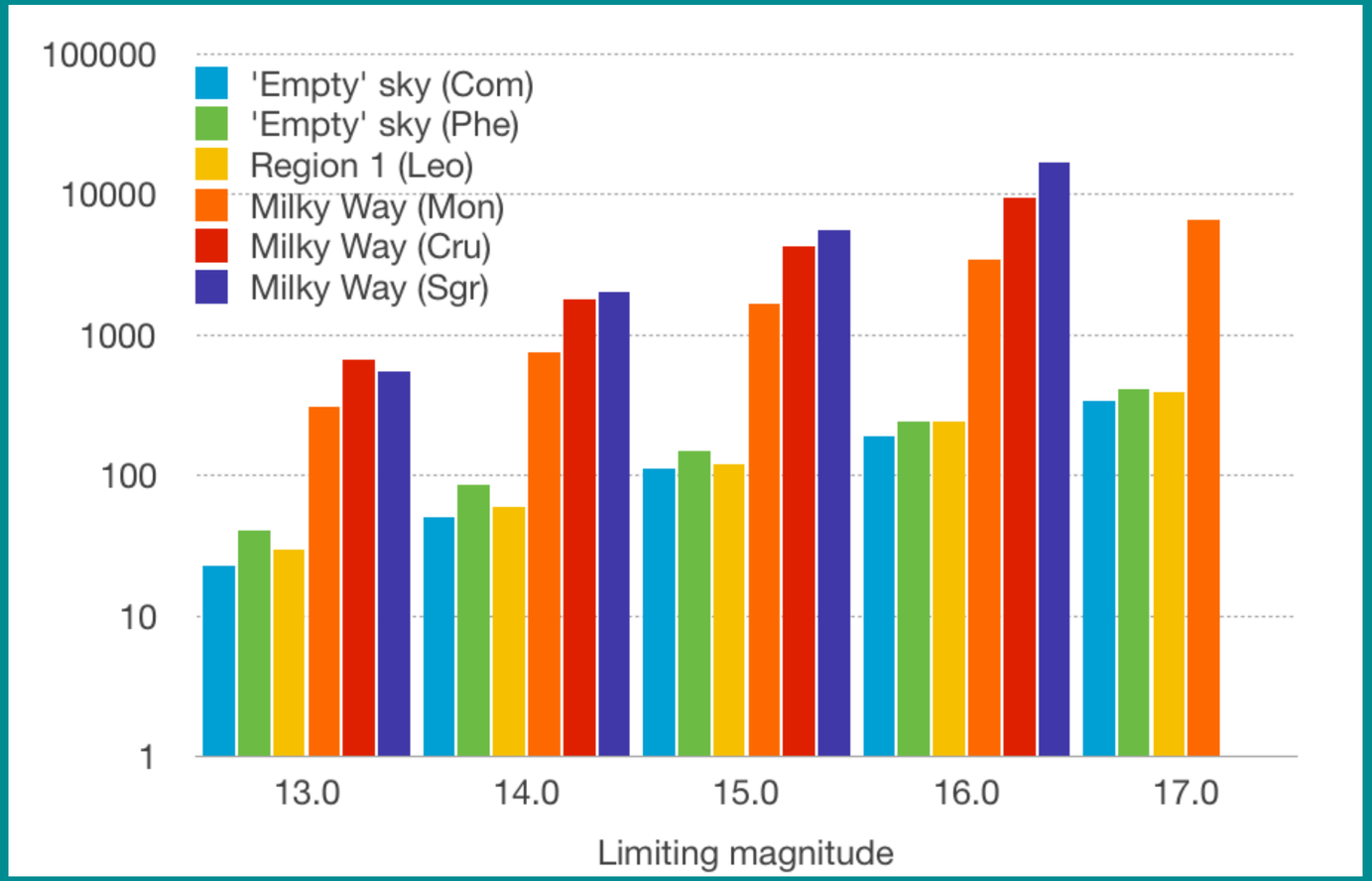
Star catalog

- DR2 is a VERY big catalog - using the whole thing is not practical
- Few amateurs have the capability to observe the faintest stars in the catalog, so a magnitude limit of 17 is used
- Asteroids are not evenly distributed over the sky- most are in the main belt, near the ecliptic
- To avoid overlapping with other prediction feeds, a bright star limit of 14 is used.


Whole-sky map of star density - Gaia11_DR2
80
22h
20h
18h
16h
14h
12h
10h
8h
6h
4h
2h
60
40
20
0
-20
-40
-60
-80

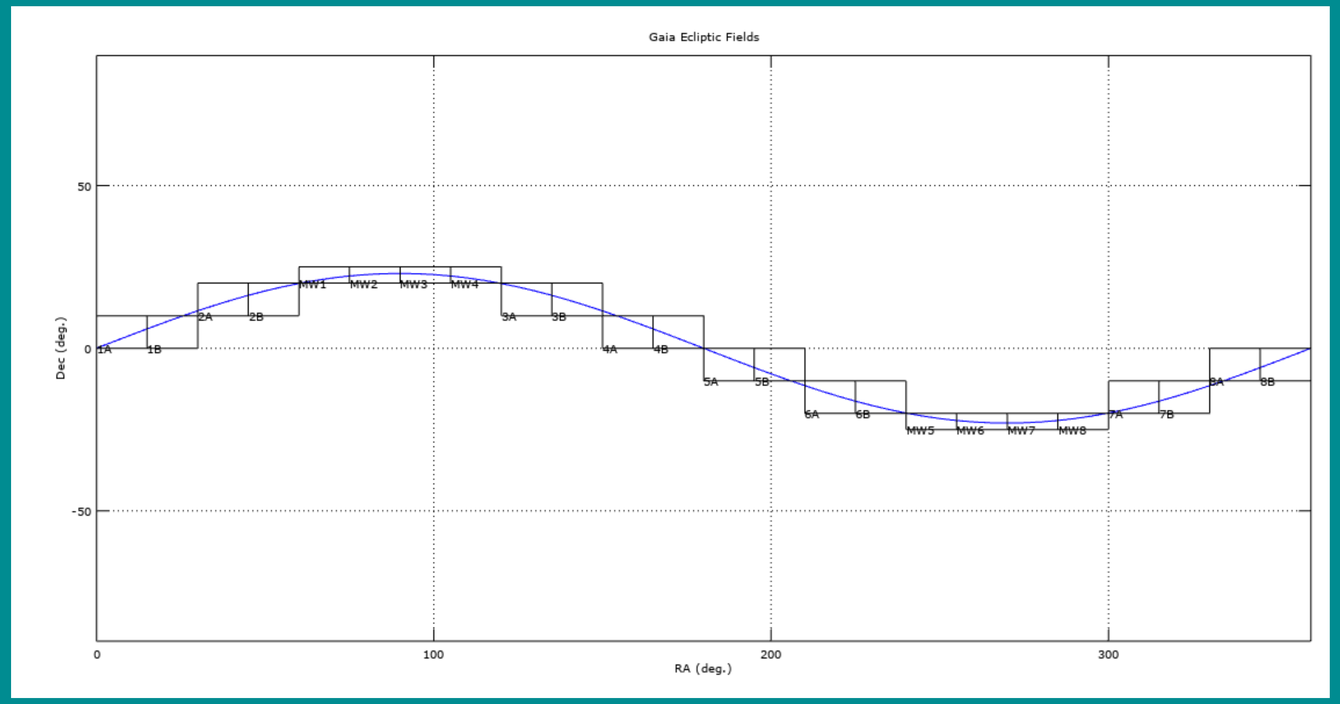
Star density

- Small areas of DR2 downloaded with ViZier
- This gives an idea of the variation in star density around the sky
- For prediction catalog, separate fields are used



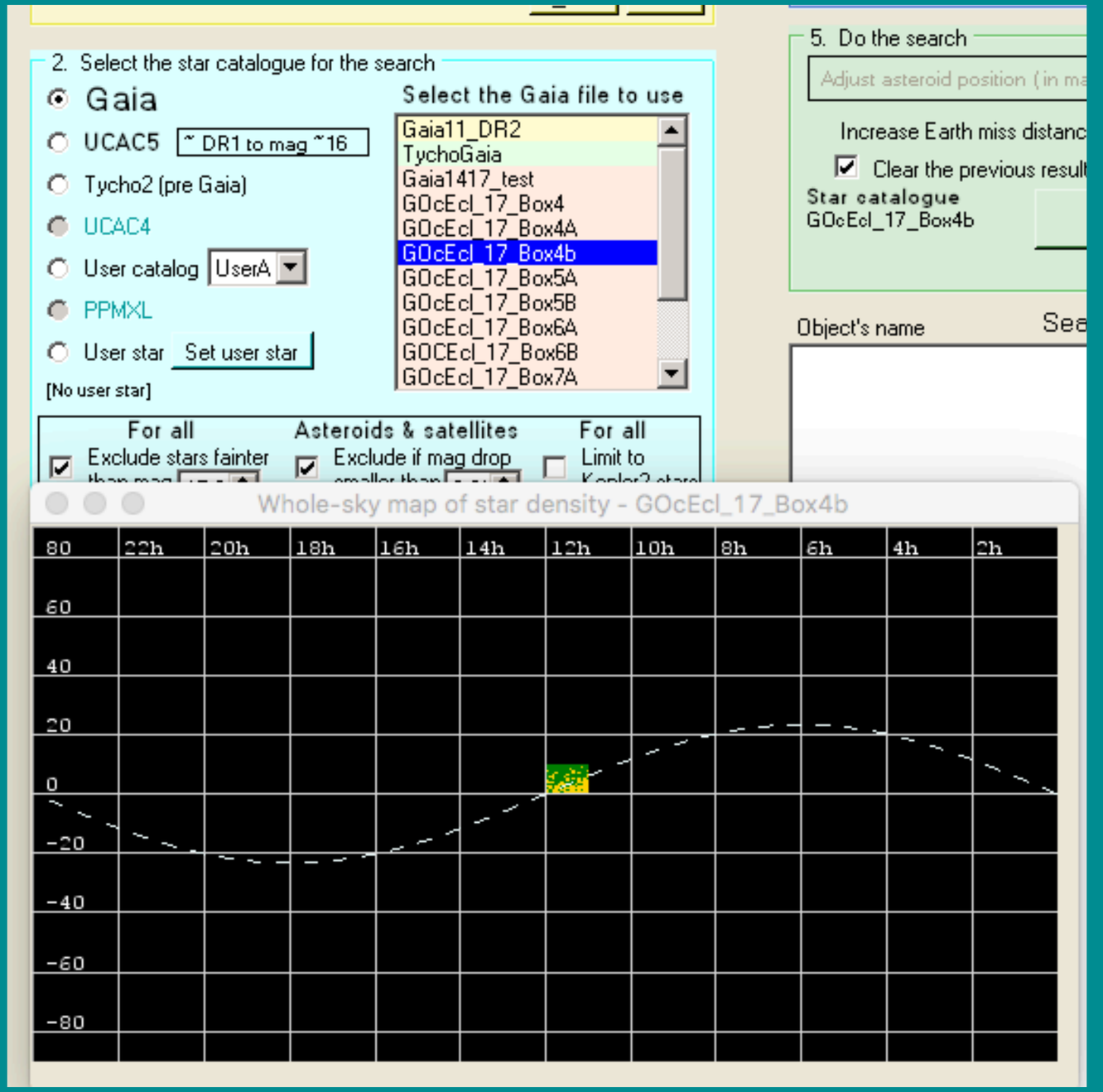
Star search fields

- ‘GOcEcl’ = “Gaia Occultations on the Ecliptic”
- Areas are 1h R.A. x 10 deg Dec
- Only stars from G mag. 14 - 17
- Total stars in all fields (not Milky Way): roughly 3 million



Star search fields

- ‘GOcEcl’ = “Gaia Occultations on the Ecliptic”
- Areas are 1h R.A. x 10 deg Dec
- Only stars from G mag. 14 - 17
- Total stars in field shown (‘4B’) = 97 773



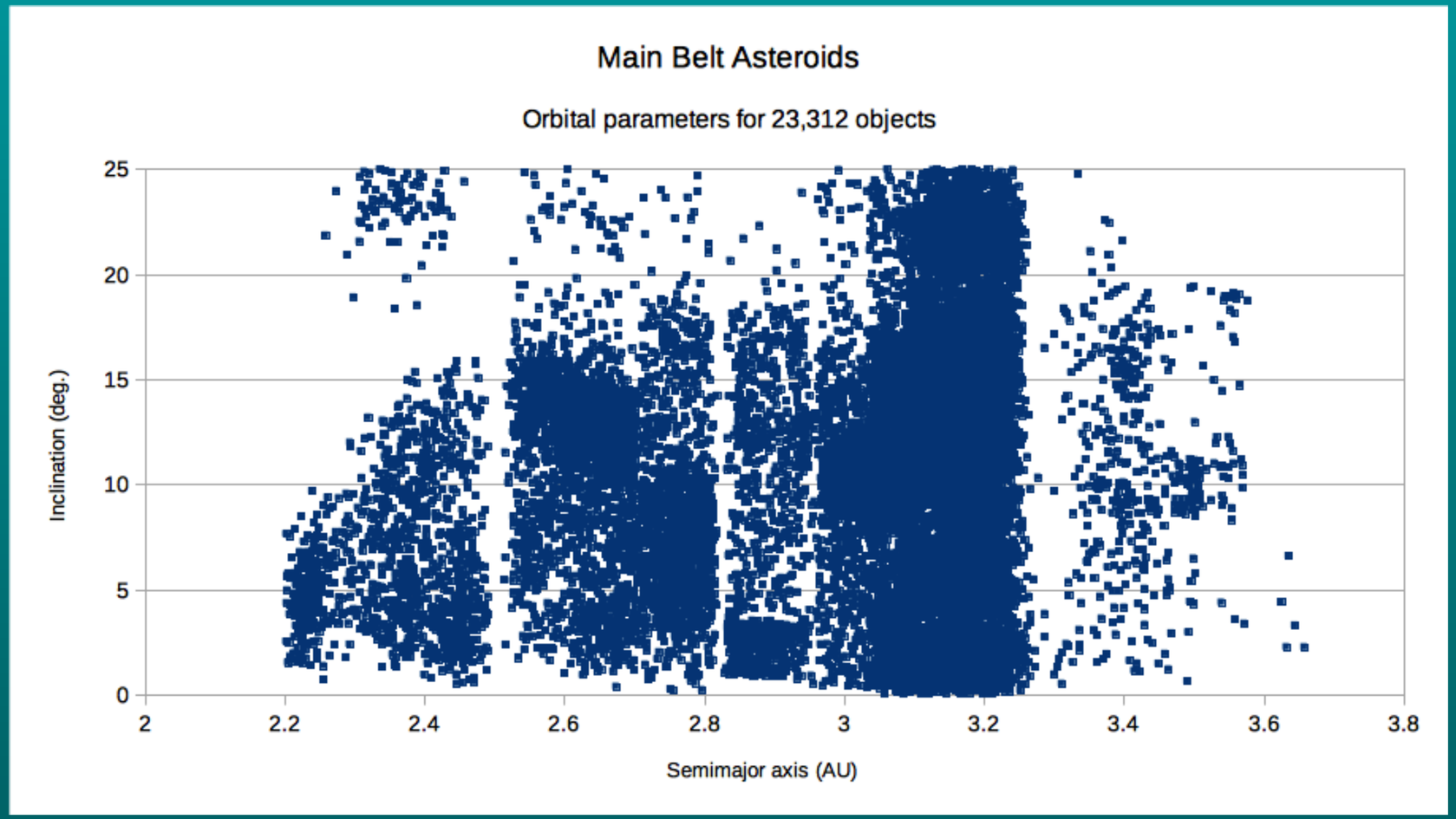
Asteroids

- Asteroids in the main belt are mostly near the ecliptic
- They are easily selected by their orbital parameters, in particular semi major axis, eccentricity and inclination
- Near Earth objects, TNOs and other objects are not included
- Trojans and Hildas are a special case and could also be included if there is enough interest

Main Belt Orbits

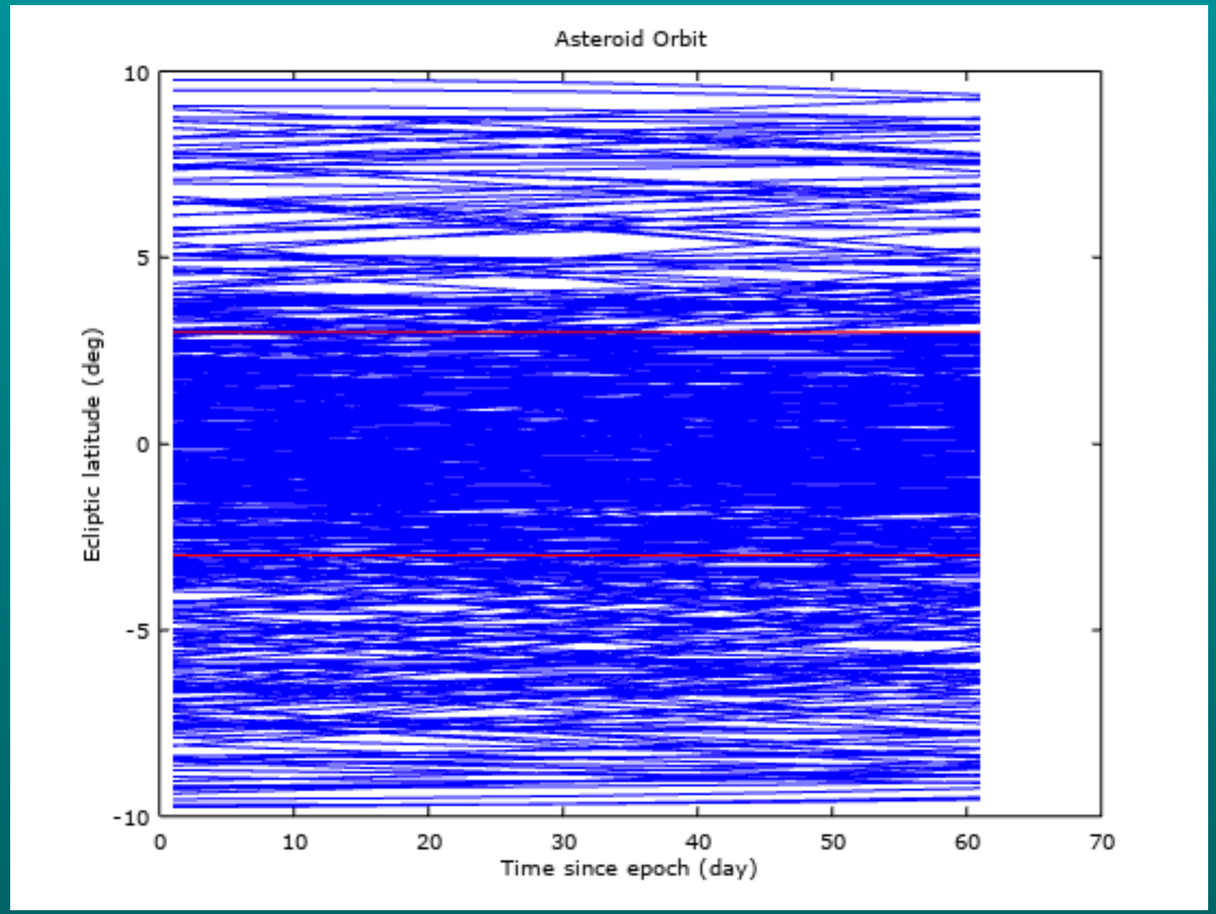
Data set used:

- Limits on orbit diameter. (2.2 AU< *a* < 3.8 AU)
- Low inclination (*i* < 25˚)
- *Eccentricity limit also applied (e < 0.3)*
- Kirkwood gaps and asteroid families visible

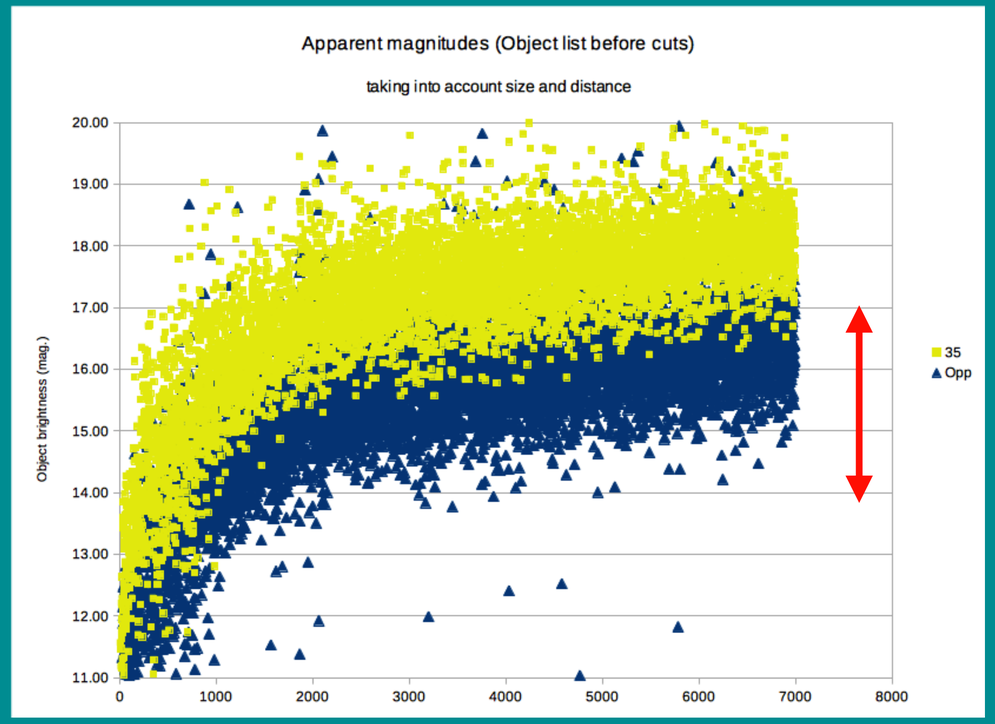


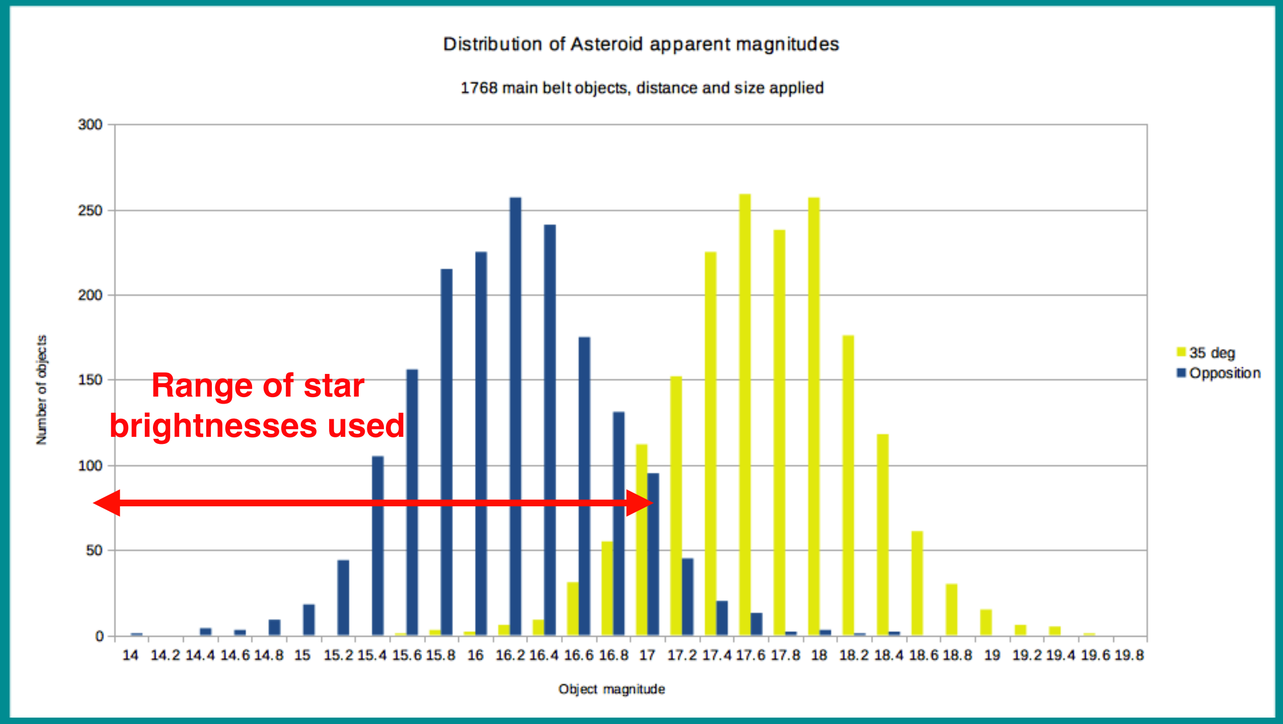
Orbit geometry

- ‘Band of sky’ near ecliptic will limit the inclinations used
- Many MB objects have low inclinations (below 10 deg) - main concentration below 5 degrees.
- Perspective from Earth also has an effect



Asteroid brightness

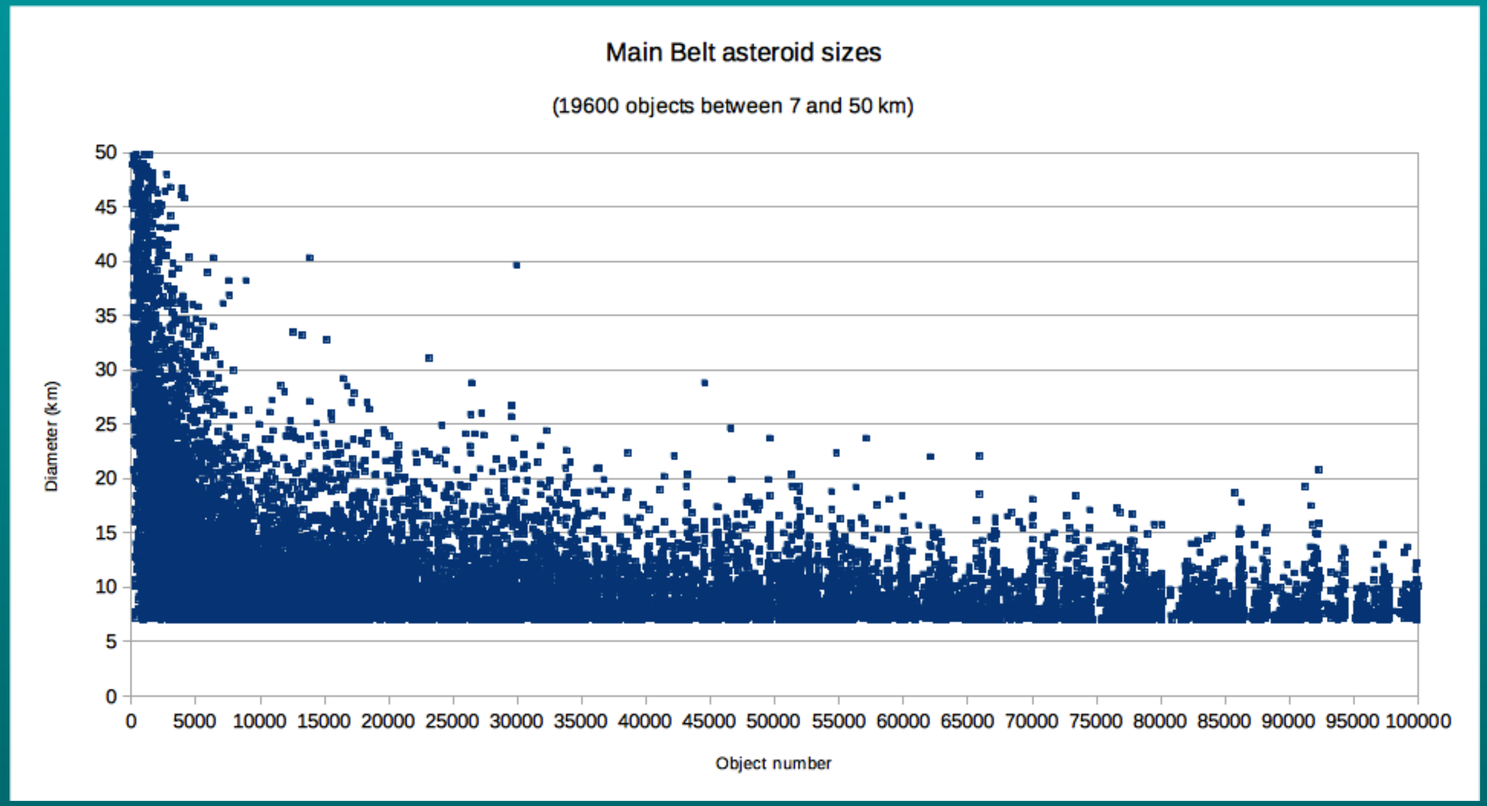




- Sufficient brightness difference needed between star and asteroid
- Object number is a rough indicator of brightness
- Objects at opposition are 1 - 2 magnitudes brighter than 35 deg elong-> avoid this area

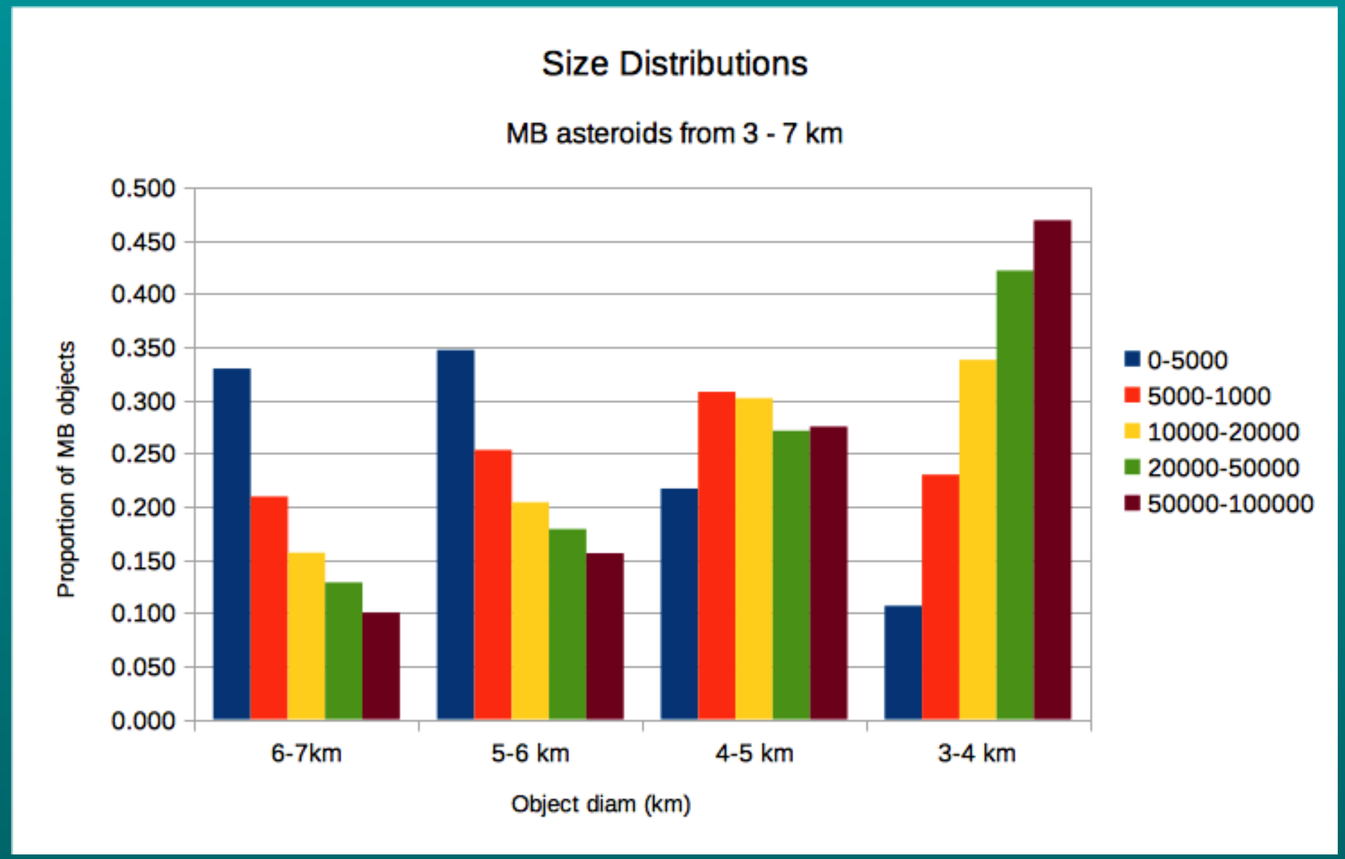
Asteroid sizes - selected set

- Object numbers are also a proxy for size (more small objects are discovered today)
- If interested in objects with diameter > 5km, high object numbers are not needed
- (This is Main Belt: TNOs not included)



Asteroid sizes - small objects

- Object numbers are also a proxy for size (more small objects discovered today)
- If intested in objects > 5km, high object numbers not needed
- (This is Main Belt: TNOs not included)



GOcEcl unique properties

- GOcEcl uses RA distributed catalog fields (‘boxes’)
- Allows prediction generation for different parts of the sky and month
- Can also predict for particular objects (e.g. Trojans) or parts of the sky (stationary points, star clusters)
- Milky Way fields not yet implemented : will use smaller fields

‘Humpty Dumpty’ events - example

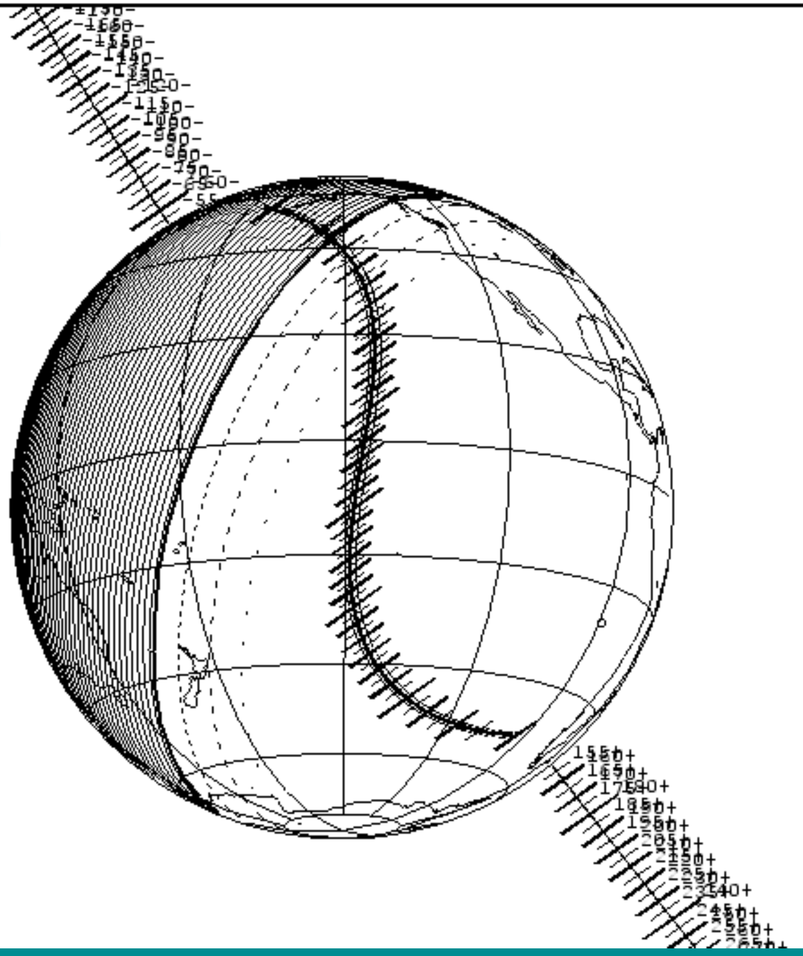
17627 Humptydumpty occults G140741.6-114237 on 2020 Jun 25 from 3h 18m to 8h 40m UT

Star:
Mag V = 16.6; B = 17.9; R = 15.8
RA = 14 7 41.5894 (astrometric)
Dec = -11 42 36.950 ...
[of Date: 14 8 47, -11 48 22]
Prediction of 2020 Jun 21.0

Max Duration = 23.6 secs
Mag Drop = 2.4 (2.7r)
Sun : Dist = 120°
Moon: Dist = 70°
: illum = 18 %
E 0.034"x 0.034" in PA 90

Asteroid:
Mag = 18.9
Dia = 16km, 0.008
Parallax = 3.098"
Hourly dRA = 0.046s
dDec = -0.95"

- June 25, 2020
- Faint star (mv=16.6)
- Long duration event (up to 23 sec)
- Object diam 16 km
- Possible real-time updates?



Occult 4.10.4.0, MPCorb2020Mar19 Errors: Star+PeakEphemUncert

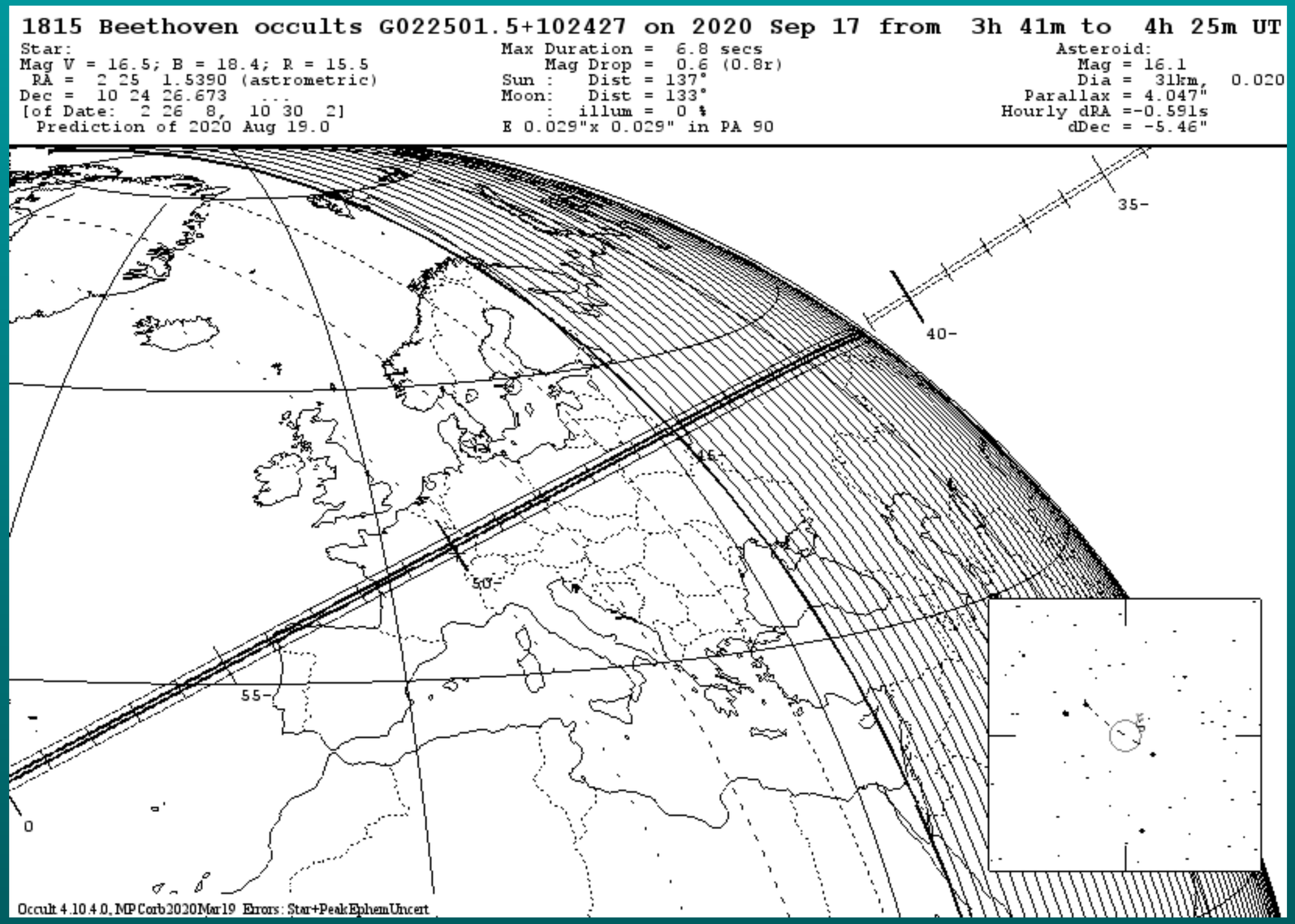
Musical interlude

- Beethoven wrote a nice piece of piano music about the moon…
- Moon dates and twilight avoidance is necessary for faint stars
- Search whole sky during new moon
- Search evening fields during waning moon (last quarter), morning during waxing moon (first quarter)
- Avoid Full moon +/- 2 days altogether

- (PS: This year is the 200th anniversary of Beethoven’s death)

More Beethoven

- Sept 17, 2020 (am)
- Faint star (mv=16.5)
- Long duration event (up to nearly 7 sec)
- Object diam 16 km
- NO MOON



RESULTS!

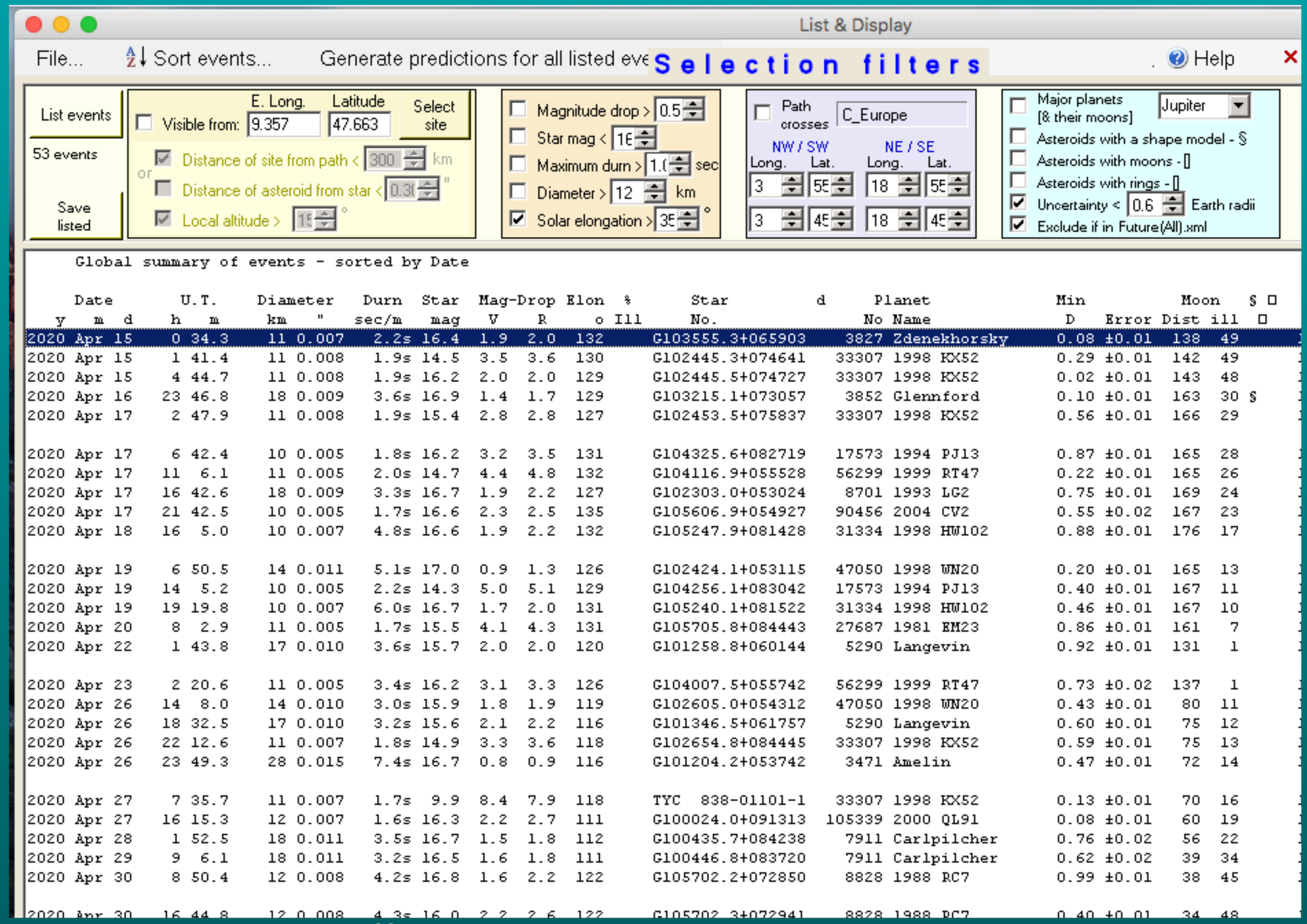
- Subset of main belt asteroids used (9000 - 27000 objects), up to 50 km diameter
- Predictions generated for a 15 degree wide band, 1 month period
- Predictions over water or complete misses are removed by hand
- OCCULT filter function can be used to sort by geographical region
- For particular areas and regions this could be optimised with smaller filter areas

Typical result statistics

- Time period: 30 days
- 9211 objects
- 1 field 10 x 15 deg at quadrature
- 53 events
- Paths checked manually
- At least half are faint stars or small objects

Example results

- Mostly Gaia stars
- >9000 main belt Asteroids used, 53 events all < 20 km
- Faint stars dominate (one TYC star mag 9.9)
- Long duration event (up to nearly 7 sec)
- Multiple events for same object
- None in Steve Preston's list



Global summary of events - sorted by Date

Date y m d	U.T. h m	Diameter km	"	Durn sec/m	Star mag	Mag-Drop V	R	Elon o	% Ill	Star No.	d	Planet No	Name	Min D	Error	Moon Dist	ill	§	□
2020 Apr 15	0 34.3	11	0.007	2.2s	16.4	1.9	2.0	132		G103555.3+065903	3827	Zdenekhorsky		0.08	±0.01	138	49		
2020 Apr 15	1 41.4	11	0.008	1.9s	14.5	3.5	3.6	130		G102445.3+074641	33307	1998	KX52	0.29	±0.01	142	49		
2020 Apr 15	4 44.7	11	0.008	1.9s	16.2	2.0	2.0	129		G102445.5+074727	33307	1998	KX52	0.02	±0.01	143	48		
2020 Apr 16	23 46.8	18	0.009	3.6s	16.9	1.4	1.7	129		G103215.1+073057	3852	Glennford		0.10	±0.01	163	30	§	
2020 Apr 17	2 47.9	11	0.008	1.9s	15.4	2.8	2.8	127		G102453.5+075837	33307	1998	KX52	0.56	±0.01	166	29		
2020 Apr 17	6 42.4	10	0.005	1.8s	16.2	3.2	3.5	131		G104325.6+082719	17573	1994	PJ13	0.87	±0.01	165	28		
2020 Apr 17	11 6.1	11	0.005	2.0s	14.7	4.4	4.8	132		G104116.9+055528	56299	1999	RT47	0.22	±0.01	165	26		
2020 Apr 17	16 42.6	18	0.009	3.3s	16.7	1.9	2.2	127		G102303.0+053024	8701	1993	LG2	0.75	±0.01	169	24		
2020 Apr 17	21 42.5	10	0.005	1.7s	16.6	2.3	2.5	135		G105606.9+054927	90456	2004	CV2	0.55	±0.02	167	23		
2020 Apr 18	16 5.0	10	0.007	4.8s	16.6	1.9	2.2	132		G105247.9+081428	31334	1998	HW102	0.88	±0.01	176	17		
2020 Apr 19	6 50.5	14	0.011	5.1s	17.0	0.9	1.3	126		G102424.1+053115	47050	1998	WN20	0.20	±0.01	165	13		
2020 Apr 19	14 5.2	10	0.005	2.2s	14.3	5.0	5.1	129		G104256.1+083042	17573	1994	PJ13	0.40	±0.01	167	11		
2020 Apr 19	19 19.8	10	0.007	6.0s	16.7	1.7	2.0	131		G105240.1+081522	31334	1998	HW102	0.46	±0.01	167	10		
2020 Apr 20	8 2.9	11	0.005	1.7s	15.5	4.1	4.3	131		G105705.8+084443	27687	1981	EM23	0.86	±0.01	161	7		
2020 Apr 22	1 43.8	17	0.010	3.6s	15.7	2.0	2.0	120		G101258.8+060144	5290	Langevin		0.92	±0.01	131	1		
2020 Apr 23	2 20.6	11	0.005	3.4s	16.2	3.1	3.3	126		G104007.5+055742	56299	1999	RT47	0.73	±0.02	137	1		
2020 Apr 26	14 8.0	14	0.010	3.0s	15.9	1.8	1.9	119		G102605.0+054312	47050	1998	WN20	0.43	±0.01	80	11		
2020 Apr 26	18 32.5	17	0.010	3.2s	15.6	2.1	2.2	116		G101346.5+061757	5290	Langevin		0.60	±0.01	75	12		
2020 Apr 26	22 12.6	11	0.007	1.8s	14.9	3.3	3.6	118		G102654.8+084445	33307	1998	KX52	0.59	±0.01	75	13		
2020 Apr 26	23 49.3	28	0.015	7.4s	16.7	0.8	0.9	116		G101204.2+053742	3471	Amelin		0.47	±0.01	72	14		
2020 Apr 27	7 35.7	11	0.007	1.7s	9.9	8.4	7.9	118		TYC 838-01101-1	33307	1998	KX52	0.13	±0.01	70	16		
2020 Apr 27	16 15.3	12	0.007	1.6s	16.3	2.2	2.7	111		G100024.0+091313	105339	2000	QL91	0.08	±0.01	60	19		
2020 Apr 28	1 52.5	18	0.011	3.5s	16.7	1.5	1.8	112		G100435.7+084238	7911	Carlpilcher		0.76	±0.02	56	22		
2020 Apr 29	9 6.1	18	0.011	3.2s	16.5	1.6	1.8	111		G100446.8+083720	7911	Carlpilcher		0.62	±0.02	39	34		
2020 Apr 30	8 50.4	12	0.008	4.2s	16.8	1.6	2.2	122		G105702.2+072850	8828	1988	RC7	0.99	±0.01	38	45		
2020 Apr 30	16 44.8	12	0.008	4.3s	16.0	2.2	2.6	122		G105702.3+072941	8828	1988	RC7	0.40	±0.01	34	48		

How to observe?

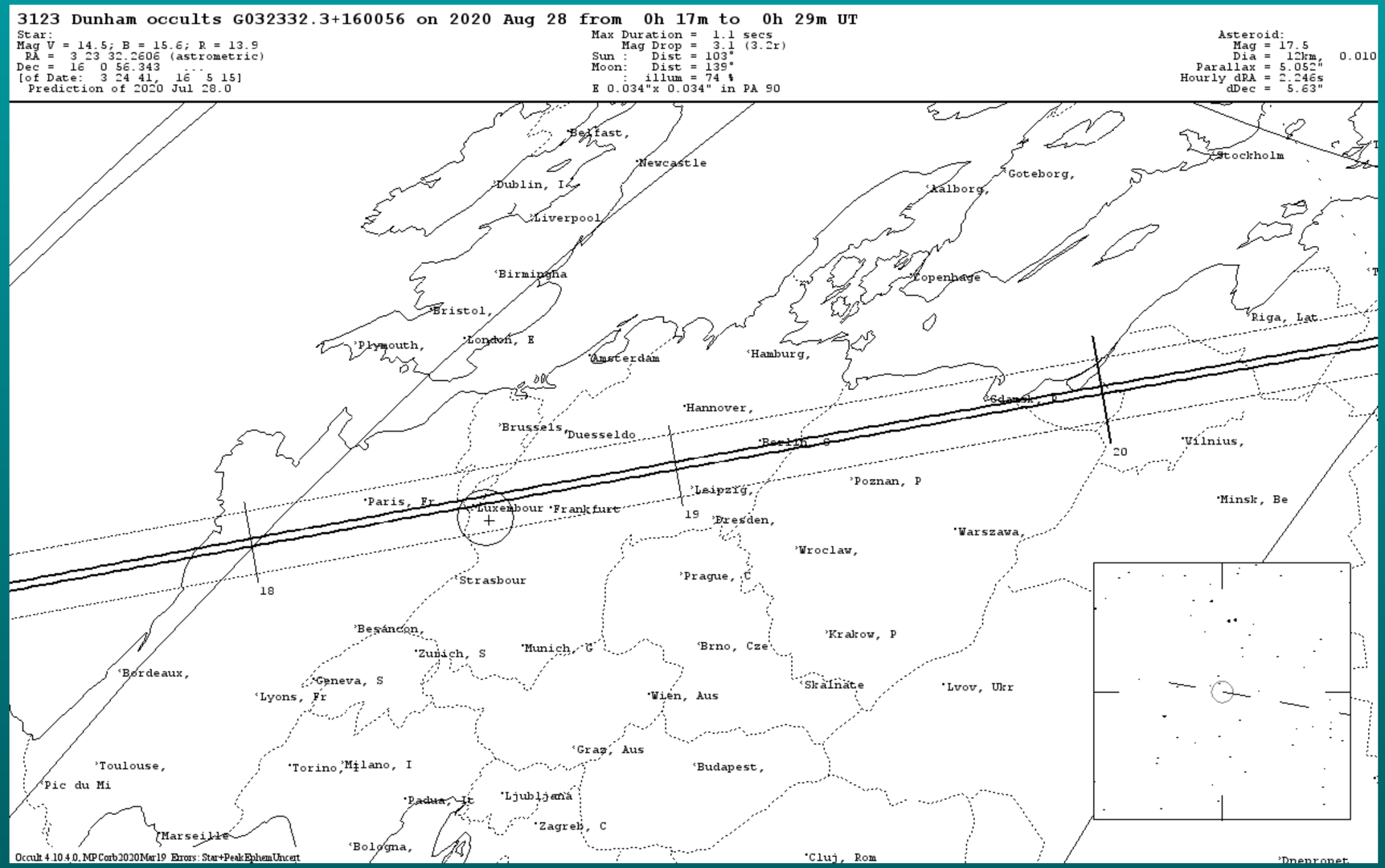
- A ‘deep’ feed can produce many predictions - probably too many for Occultwatcher
- Target audience: Semi-professional facilities with 0.5 m class telescopes
- Mobile observations will be difficult for mag > 15.0
- With small objects and faint stars, unlikely to have multiple chords - aim is set bounds on object size, not profiles
- Stationary point events could allow longer integration times
- How to observe fast events? (< 1 second?)

Conclusions

- A ‘deep’ feed can produce many predictions - probably too many for Occultwatcher
- Target audience: Semi-professional facilities with 0.5 m class telescopes
- The star catalog and asteroid list must be carefully chosen, results have to be carefully filtered
- Directed searches for Trojan/Hilda events could also be interesting
- Some advantages to using a R.A. limited star catalog - can be fine tuned to specific requirements
- At least half the events found are faint stars or small objects

Thanks for your attention!

More recent results



More recent results

Num Asteroids	Star field	Total events	Notes	Events/day
	(Mag. 14-17 unless indicated)			
9211	Gaia1417(Test)	53 events	MB only,15 – 50 km size → expect 10 000 / yr?	
9211	4B (Leo/Vir)	151 events	10km min size, Dur. Max 1.5 s, Mag drop > 0.3m; roughly 1/3 over noninhabited areas	
9211	6A (Vir/Lib)	>821 events in 2 month period	10km min size, Dtmax 1.5 s, Mag drop > 0.5m;	13.68
3867	6A (Vir/Lib)	82 events in 1 month period	7km min size, Dtmax 1.5 s, Mag drop > 0.5m;	2.73
3867	6A (Vir/Lib)	128 events in 1 month period	7km min size, Dtmax 1.0 s, Mag drop > 0.2m;	4.27
16583	6A (Vir/Lib)	287 events in 1 month period (60 events moonlit)	10km min size, Dtmax 1.0 s, Mag drop > 0.2m; Most events < 2 sec long	9.57
16583	4B (Leo/Vir)	110 events in 1 month period (roughly 60 are brighter than mag 16)	7km min size, Dtmax 1.0 s, Mag drop > 0.5m;	3.67
16583	8A (Aqr) – am	321 events in 12 day period	7km min size, Dtmax 1.0 s, Mag drop > 0.5m;	26.75
16583	8B (Psc) – am	299 events in 12 days	7km min size, Dtmax 1.0 s, Mag drop > 0.4m;	24.92
16583	7B (Cap) – am	463 events in 12 days	7km min size, Dtmax 1.0 s, Mag drop > 0.4m;	38.58
16583	5A (Vir) – pm	124 events in 15 days	as above	8.27
16583	5B (Vir) – pm	253 events in 15 days	as above	16.87
16583	6B (Vir) – pm	1341 events in 15 days	as above	89.40
16583	7A (Vir) – pm	1073 events in 15 days	as above	71.53
127346	6A (Vir/Lib) = STATIONARY PT	2219 in 30 days (676 events brighter than 16m, longest event 24 s)	objects above 3 km , Duration > 1 sec, mag drop 0.5 m	73.97
3000	6A (Vir/Lib) = pm STATIONARY PT	591 events in 30 days (longest event 70 s, 67 objects; probably only ca 100 usable)	larger obj only , Duration > 1 sec, mag drop 0.5 m	19.70
3000	7B (Cap) – am STATIONARY PT	491 events in 30 days (roughly 128 usable)	larger obj only , Duration > 1 sec, mag drop 0.5 m	16.37

Thank You

Robert Purvinskis, ESOP-39, August 2020