The Minor Planet Center Data Processing System

Matthew J. Holman
Harvard-Smithsonian Center for Astrophysics

OUTLINE

Brief Minor Planet Center History
Motivation
Minor Planet Center Roles and Responsibilities
Minor Planet Center Operations
Current Focus Areas

Brief Minor Planet Center History

After WWII, the IAU established
the Minor Planet Center
at the Cincinnati
Observatory in 1947.

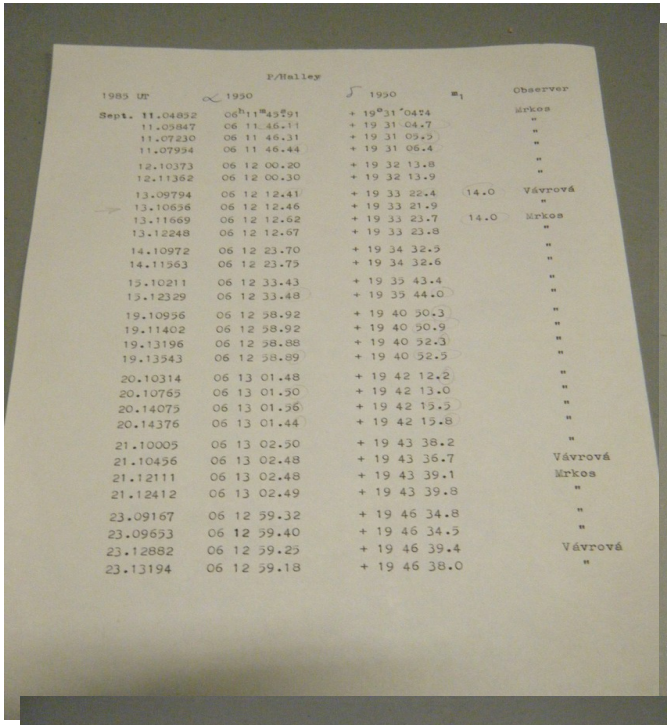
Initial task:
Recovering all the lost minor planets

Of 1564 numbered objects (i.e. with good orbits),
30% were lost.

The MPC moved to the Smithsonian Astrophysical Observatory (SAO) in 1978.

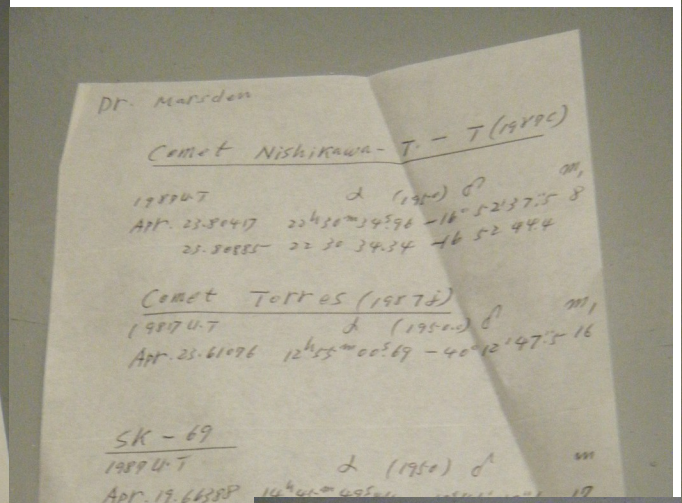
The last two lost numbered asteroids
(878) Mildred, discovered in 1916 and rediscovered in 1991; and
(719) Albert, discovered in 1911 and rediscovered in 2000,
were identified by Gareth Williams (MPC).

Ancient MPC Data Processing System



P/Halley

1985 UT	α 1950	δ 1950	m1	Observer
Sept. 11.04832	06h11m43s91	+ 19°31'04"4		Mrkos
11.05847	06 11 46.11	+ 19 31 04.7		"
11.07230	06 11 46.31	+ 19 31 05.5		"
11.07994	06 11 46.44	+ 19 31 06.4		"
12.10373	06 12 00.20	+ 19 32 13.8		"
12.11362	06 12 00.30	+ 19 32 13.9		"
13.09794	06 12 12.41	+ 19 33 22.4	14.0	Vávrová
13.10636	06 12 12.46	+ 19 33 21.9		"
13.11669	06 12 12.62	+ 19 33 23.7	14.0	Mrkos
13.12248	06 12 12.67	+ 19 33 23.8		"
14.10972	06 12 23.70	+ 19 34 32.5		"
14.11563	06 12 23.75	+ 19 34 32.6		"
15.10211	06 12 33.43	+ 19 35 43.4		"
15.12329	06 12 33.48	+ 19 35 44.0		"
19.10956	06 12 38.92	+ 19 40 30.3		"
19.11402	06 12 38.92	+ 19 40 30.9		"
19.13196	06 12 38.88	+ 19 40 32.3		"
19.13543	06 12 38.89	+ 19 40 32.5		"
20.10314	06 13 01.48	+ 19 42 12.2		"
20.10765	06 13 01.50	+ 19 42 13.0		"
20.14075	06 13 01.56	+ 19 42 15.5		"
20.14376	06 13 01.44	+ 19 42 15.8		"
21.10005	06 13 02.50	+ 19 43 38.2		"
21.10456	06 13 02.48	+ 19 43 36.7		Vávrová
21.12111	06 13 02.48	+ 19 43 39.1		Mrkos
21.12412	06 13 02.49	+ 19 43 39.8		"
23.09167	06 12 59.32	+ 19 46 34.8		"
23.09653	06 12 59.40	+ 19 46 34.5		"
23.12882	06 12 59.25	+ 19 46 39.4		Vávrová
23.13194	06 12 59.18	+ 19 46 38.0		"



Dr. Marsden

Comet Nishikawa-T.-T (1990c)

1990 U.T. α (1950) δ m1

Apr. 23.80417 22h50m34s96 −16°52'37".5 8

23.80885 22 50 34.34 −16 52 44.4

Comet Torres (1987f)

1987 U.T. α (1950.0) δ m1

Apr. 23.61096 12h55m00s69 −40°12'47".5 16

SK-69

1989 U.T. α (1950) δ m

Apr. 19.66388

19.67431

SK-70

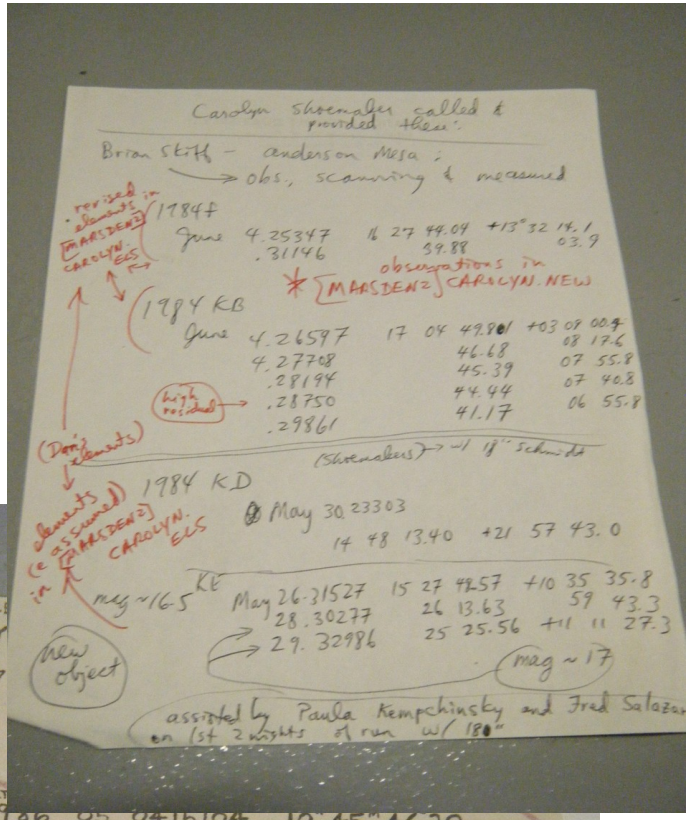
Apr. 23.67396

23.68476

24.66181

24.67222

T. Spahr



Carolyn Shoemaker called & provided these:

Brian Skiff – anderson Mesa; → obs., scanning & measured

revised elements [MARSDEN] CAROLYN ELS

1984 KB

June 4.25347 16 27 49.09 +13° 32 14.1

.31146 39.88 03.9

observations in [MARSDEN] CAROLYN. NEWS

1984 KB

June 4.26597 17 04 49.801 +03 07 00.9

4.27708 46.68 08 17.6

.28194 45.39 07 55.8

high residual → .28750 44.44 07 40.8

.29861 41.17 06 55.8

(Don's elements) (Shoemakers) → 1 16" Schmidt

(elements (e assumed) in [MARSDEN] CAROLYN ELS

1984 KD

May 30.23303

14 48 13.40 +21 57 43.0

mag ~16.5 KE

May 26.31527 15 27 42.57 +10 35 35.8

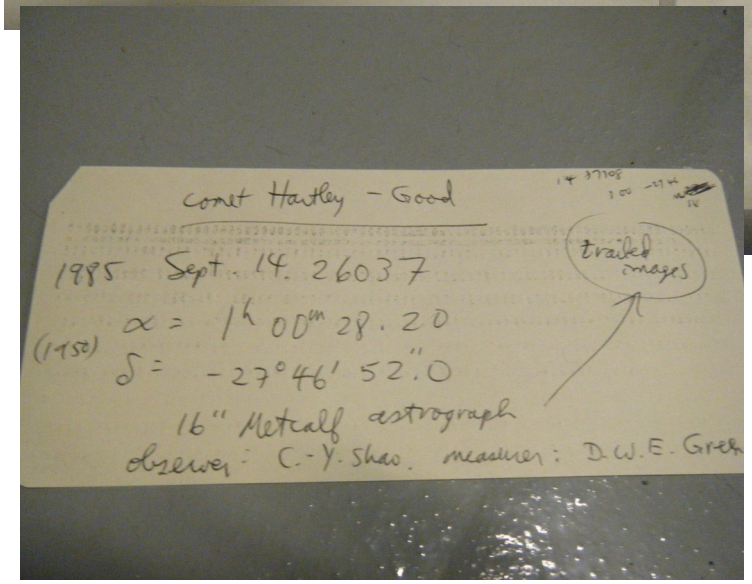
28.30277 26 13.63 59 43.3

29.32986 25 25.56 +11 11 27.3

new object

mag ~17

assisted by Paula Kempchinsky and Fred Salazar on 1st 2 nights of run w/ 180"



Comet Hartley – Good

1985 Sept. 14.26037

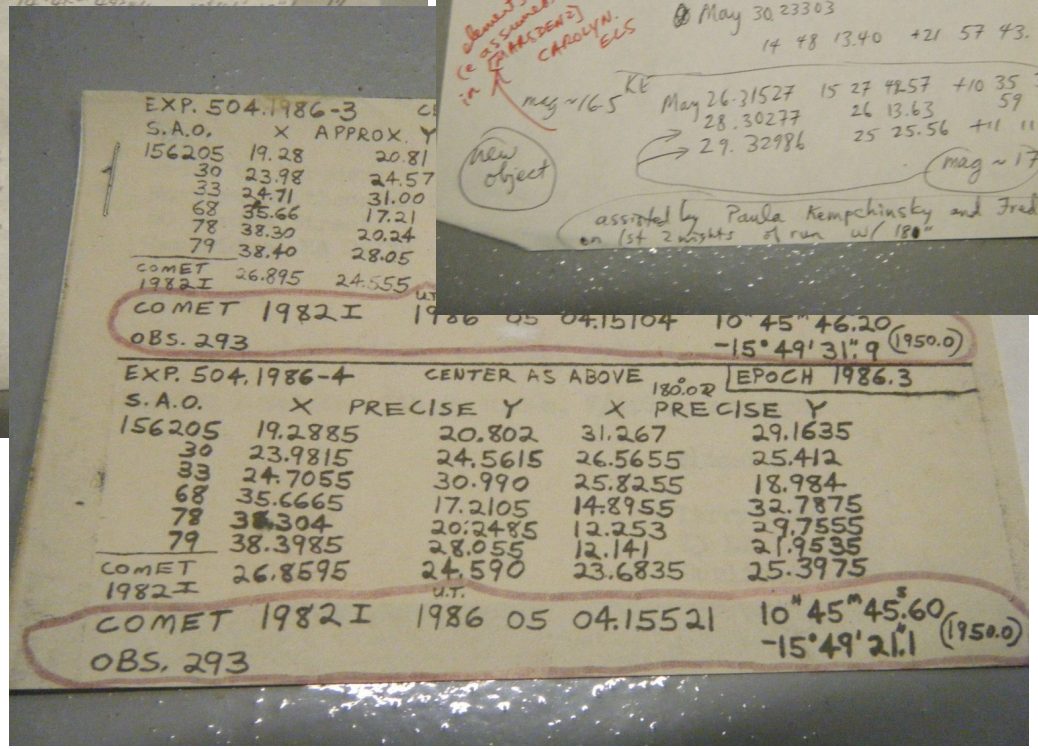
(1950) α = 1h 00m 28.20

δ = −27°46' 52".0

trailed images

16" Metcalf astrograph

observer: C.-Y. Shao. measurer: D.W.E. Green



EXP. 504.1986-3			
S.A.O.	X	APPROX. Y	
156205	19.28	20.81	
30	23.98	24.57	
33	24.71	31.00	
68	35.66	17.21	
78	38.30	20.24	
79	38.40	28.05	
COMET 1982I	26.895	24.555	

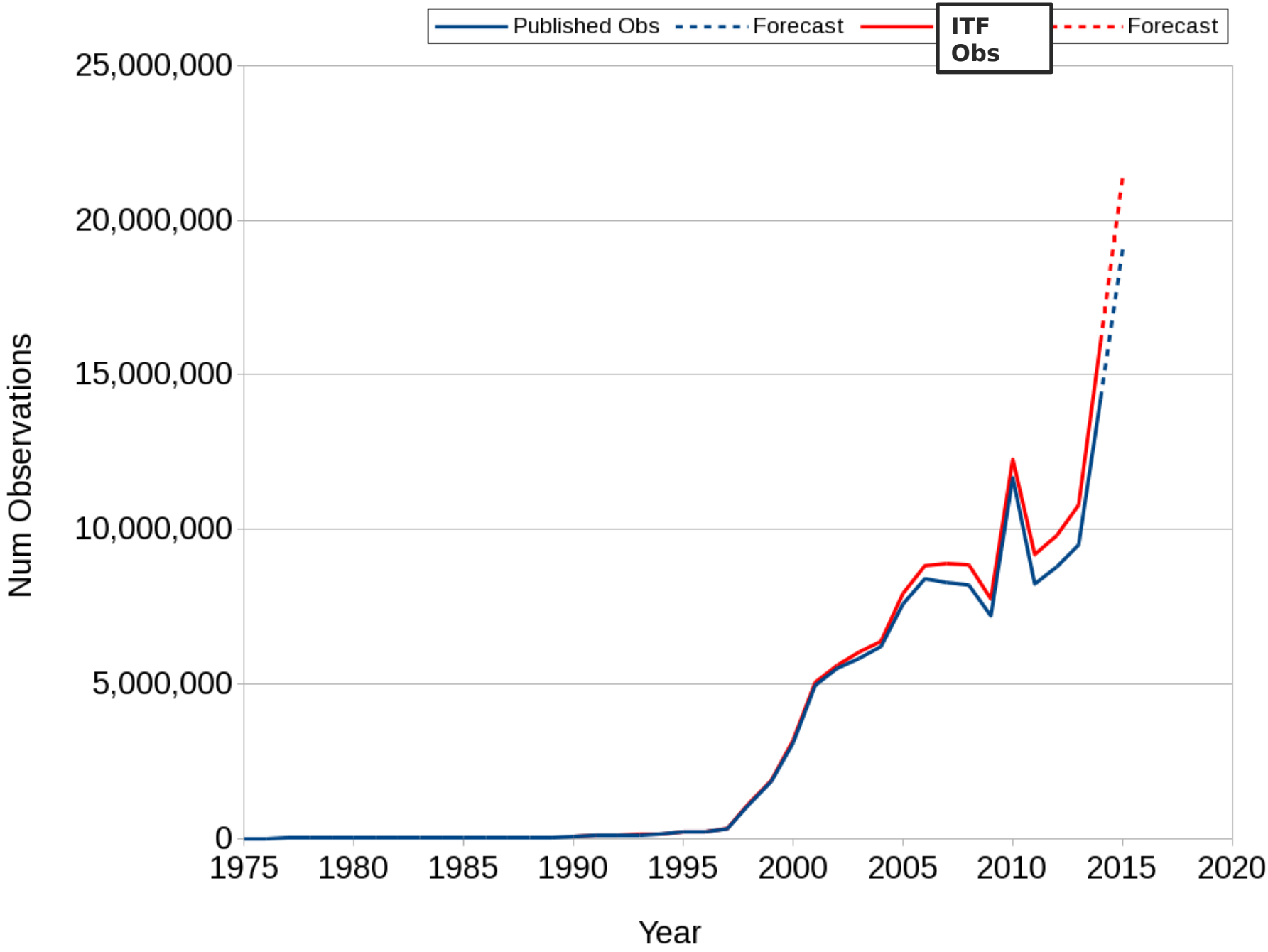
COMET 1982I 1986 05 04.15164 10h45m46.20 −15°49'31".9 (1950.0)

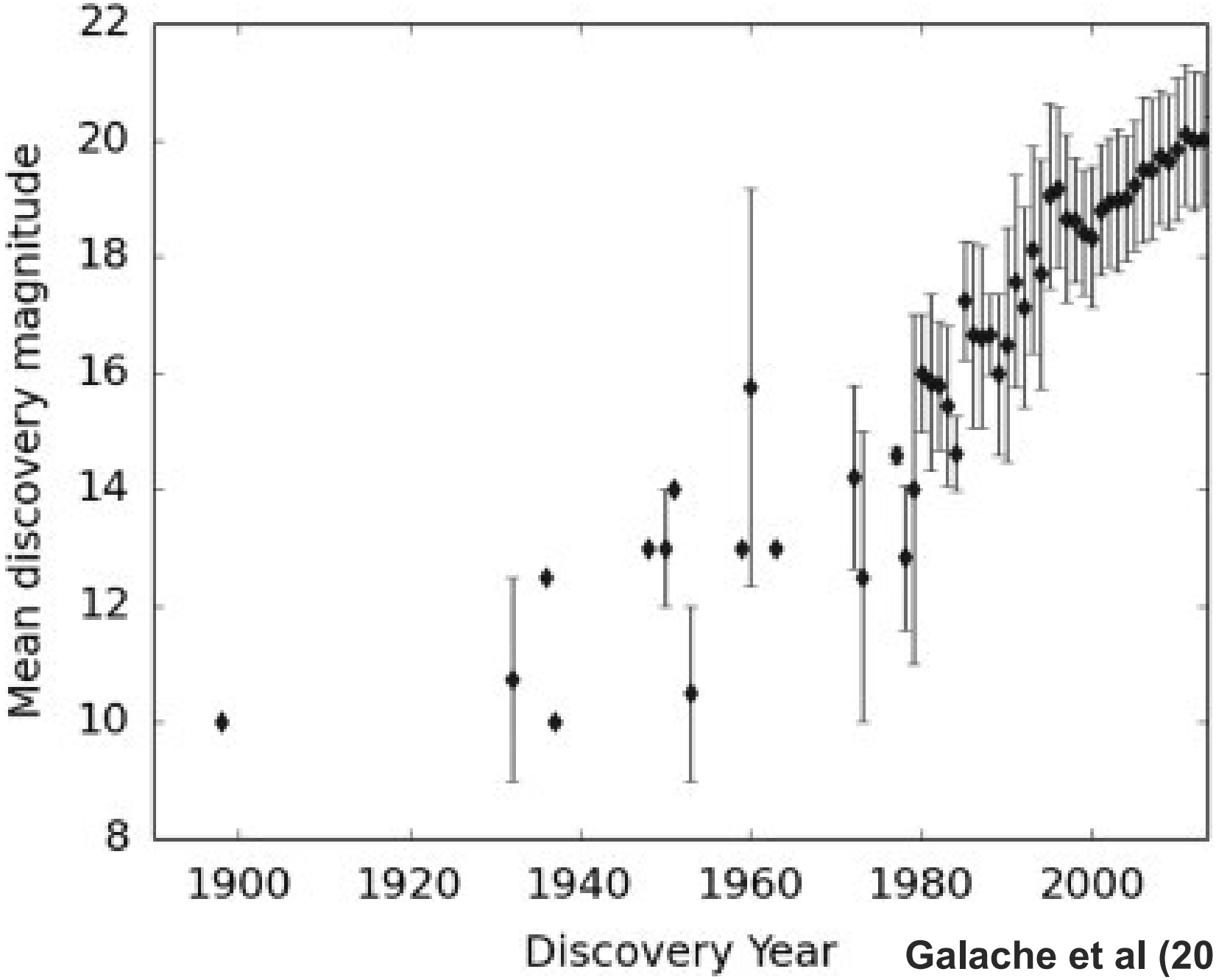
OBS. 293

EXP. 504.1986-4	CENTER AS ABOVE		180.0"	EPOCH 1986.3	
S.A.O.	X PRECISE	Y	X PRECISE	Y	
156205	19.2885	20.802	31.267	29.1635	
30	23.9815	24.5615	26.5655	25.412	
33	24.7055	30.990	25.8255	18.984	
68	35.6665	17.2105	14.8955	32.7875	
78	38.304	20.2485	12.253	29.7555	
79	38.3985	28.055	12.141	21.9535	
COMET 1982I	26.8595	24.590	23.6835	25.3975	

COMET 1982I 1986 05 04.15521 U.T. 10h45m45s.60 −15°49'21".1 (1950.0)

OBS. 293


Published Obs
Forecast
ITF Obs
Forecast
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Num Observations
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year



Galache et al (2015)

MOTIVATION

Congressional Mandates Regarding
Potentially Hazardous Asteroids (PHAs)

1998: Find 90% of PHAs with D > 1km. (Achieved in 2010.)

2006: Find 90% of PHAs with D > 140m by the end of 2020.

Budget to support NEO surveys is growing

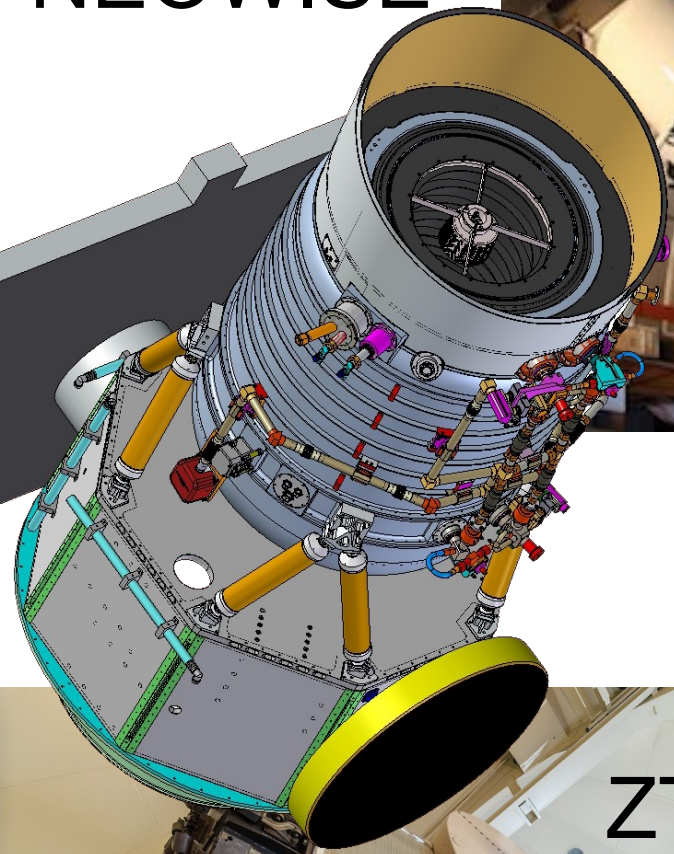
$4 M in 2010
$20 M in 2012
$40 M in 2014
$50 M in 2016

PHA Criteria:

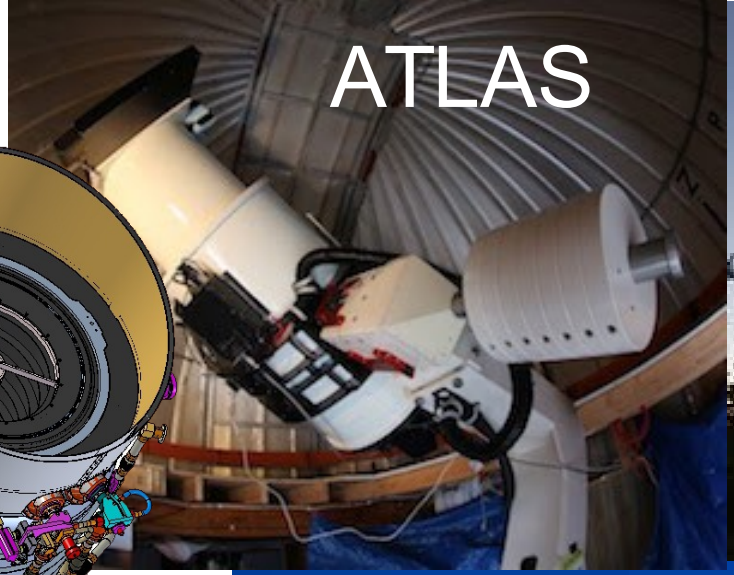
- q < 1.3 au
- MOID < 0.05 au
- H < 22 (D > 140m for 0.14 albedo)

Chelyabinsk, 15 February 2013
By Alex Alishevskikh - Flickr: Meteor trace, CC BY-SA 2.0,
https://commons.wikimedia.org/w/index.php?curid=24726667

NEOWISE

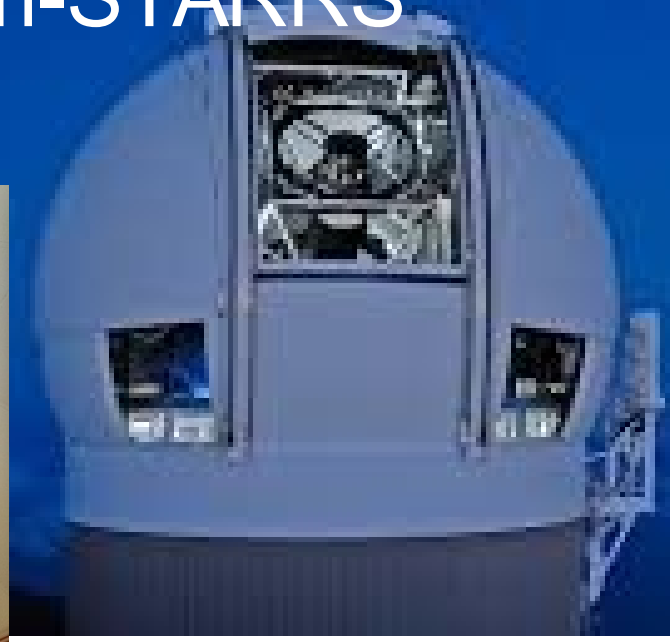


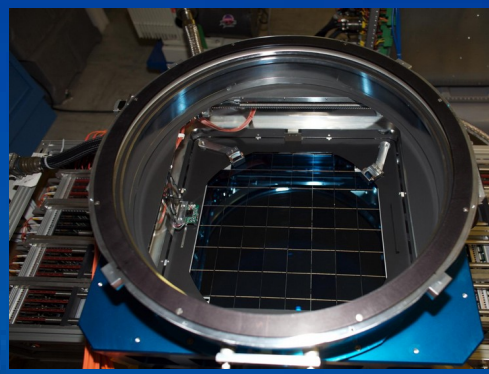
ATLAS



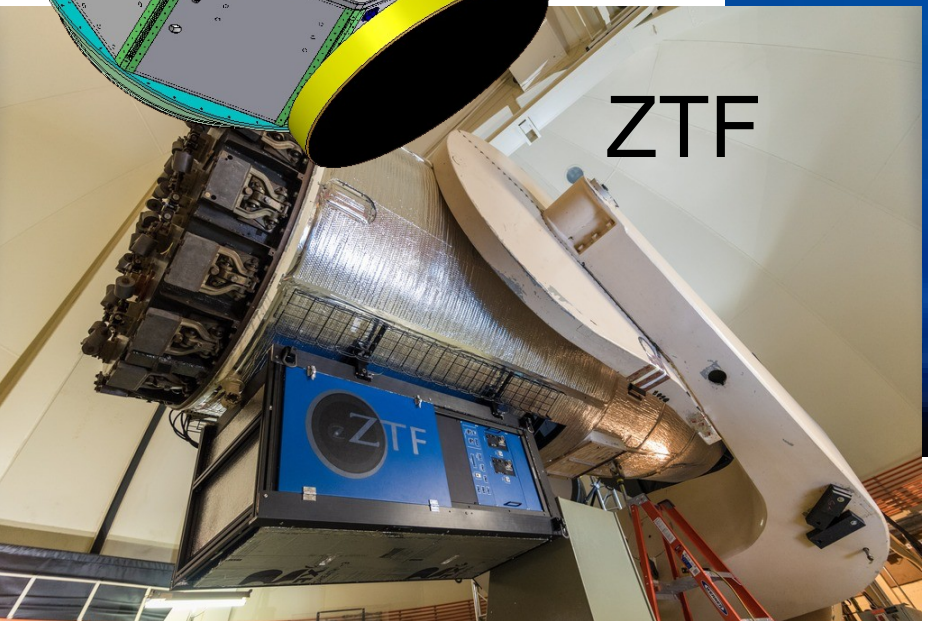
Catalina Sky Survey

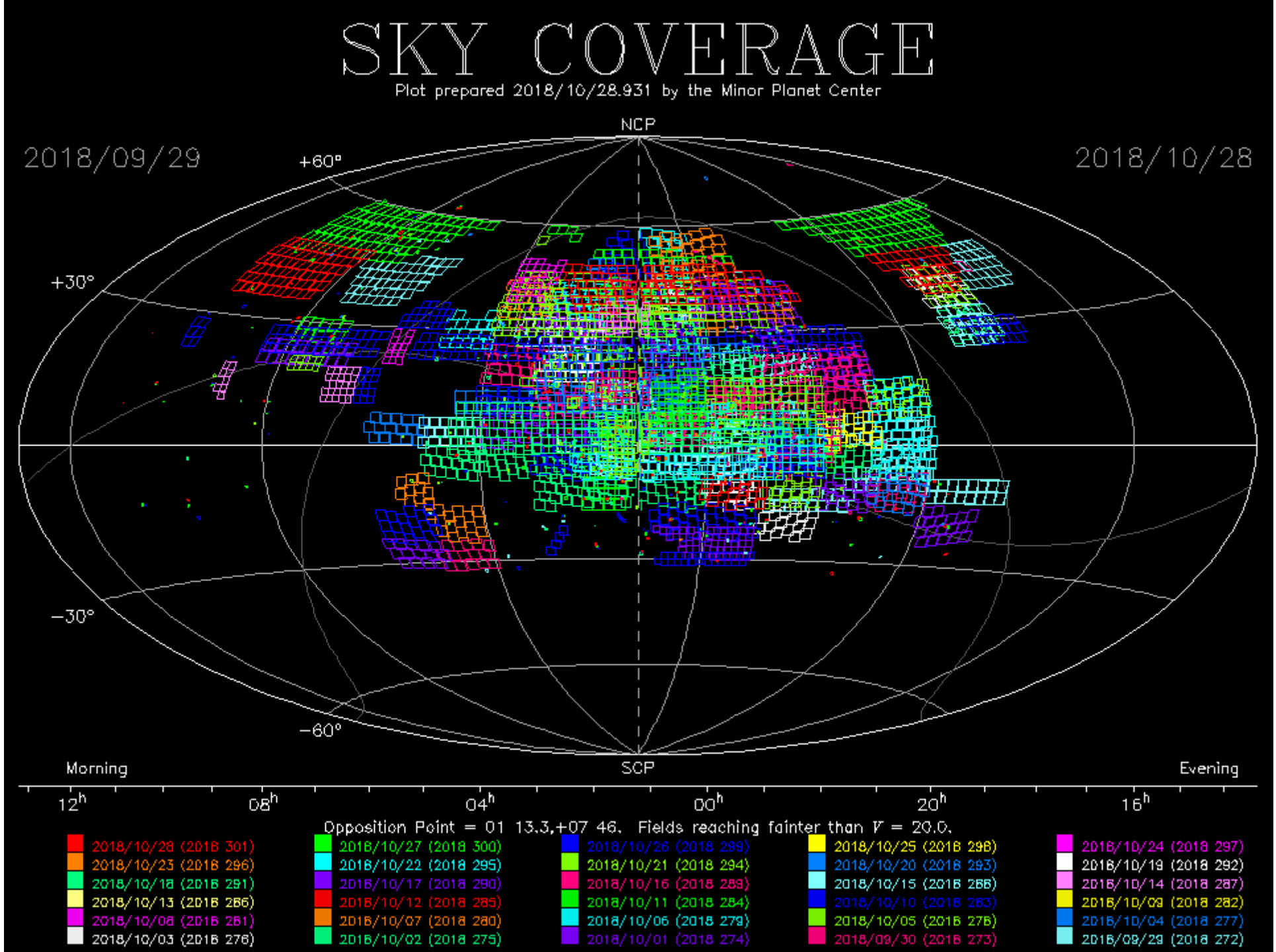
Pan-STARRS

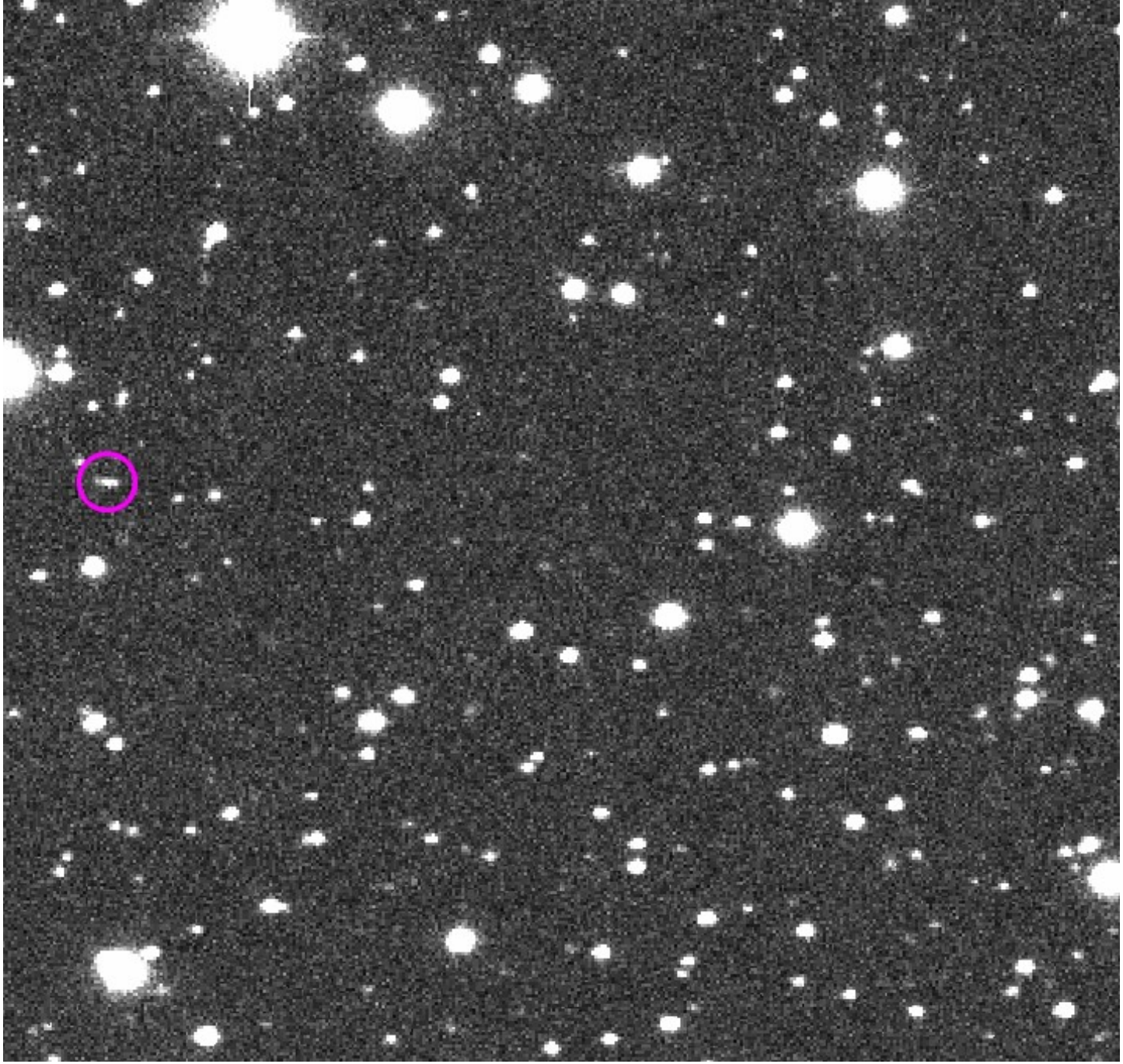




ZTF



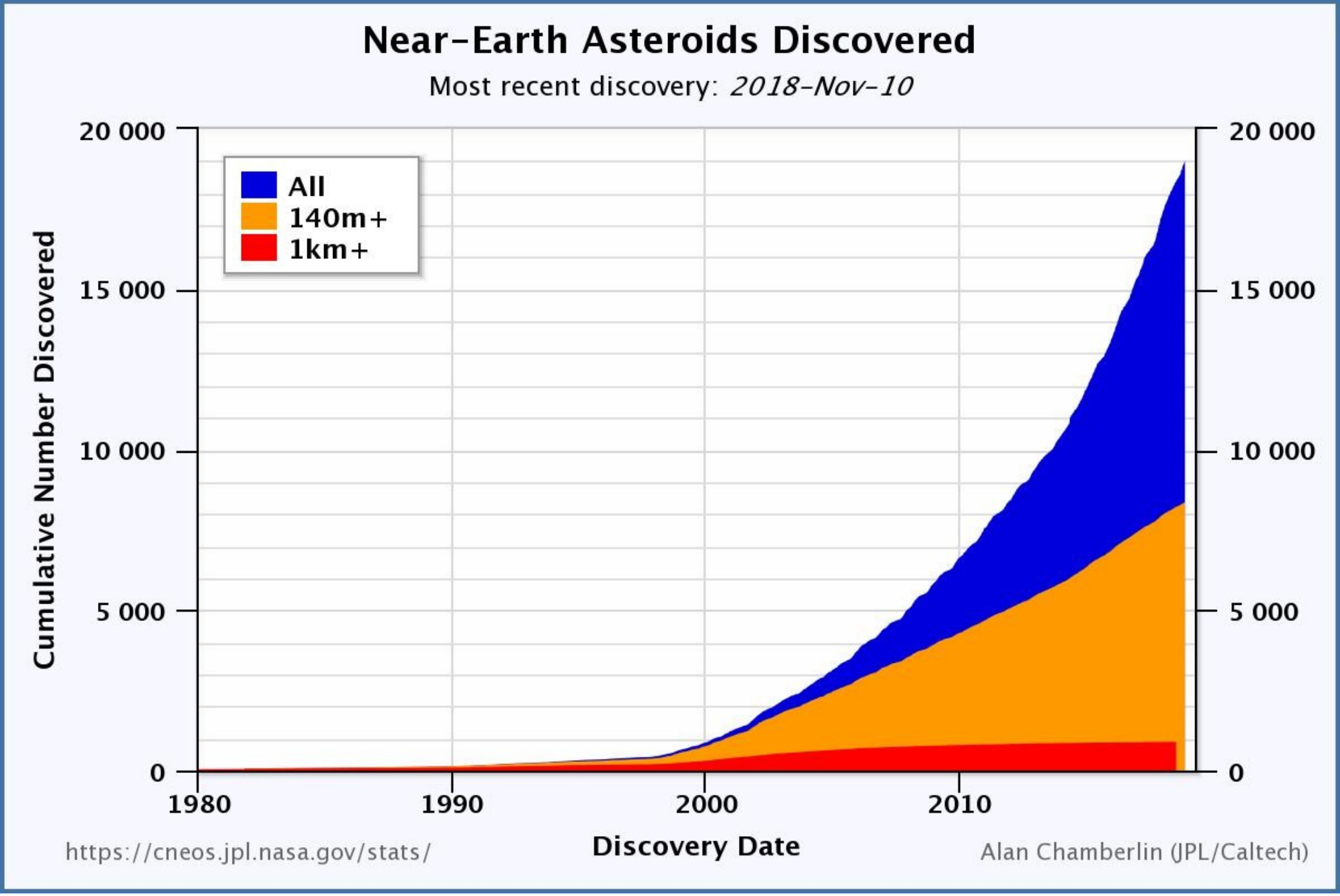

SKY COVERAGE
Plot prepared 2018/10/28.931 by the Minor Planet Center
NCP
2018/09/29
2018/10/28
+60°
+30°
−30°
−60°
Morning
Evening
SCP
12h
08h
04h
00h
20h
16h
Opposition Point = 01 13.3,+07 46. Fields reaching fainter than V = 20.0.
2018/10/28 (2018 301)
2018/10/27 (2018 300)
2018/10/26 (2018 299)
2018/10/25 (2018 298)
2018/10/24 (2018 297)
2018/10/23 (2018 296)
2018/10/22 (2018 295)
2018/10/21 (2018 294)
2018/10/20 (2018 293)
2018/10/19 (2018 292)
2018/10/18 (2018 291)
2018/10/17 (2018 290)
2018/10/16 (2018 289)
2018/10/15 (2018 288)
2018/10/14 (2018 287)
2018/10/13 (2018 286)
2018/10/12 (2018 285)
2018/10/11 (2018 284)
2018/10/10 (2018 283)
2018/10/09 (2018 282)
2018/10/08 (2018 281)
2018/10/07 (2018 280)
2018/10/06 (2018 279)
2018/10/05 (2018 278)
2018/10/04 (2018 277)
2018/10/03 (2018 276)
2018/10/02 (2018 275)
2018/10/01 (2018 274)
2018/09/30 (2018 273)
2018/09/29 (2018 272)

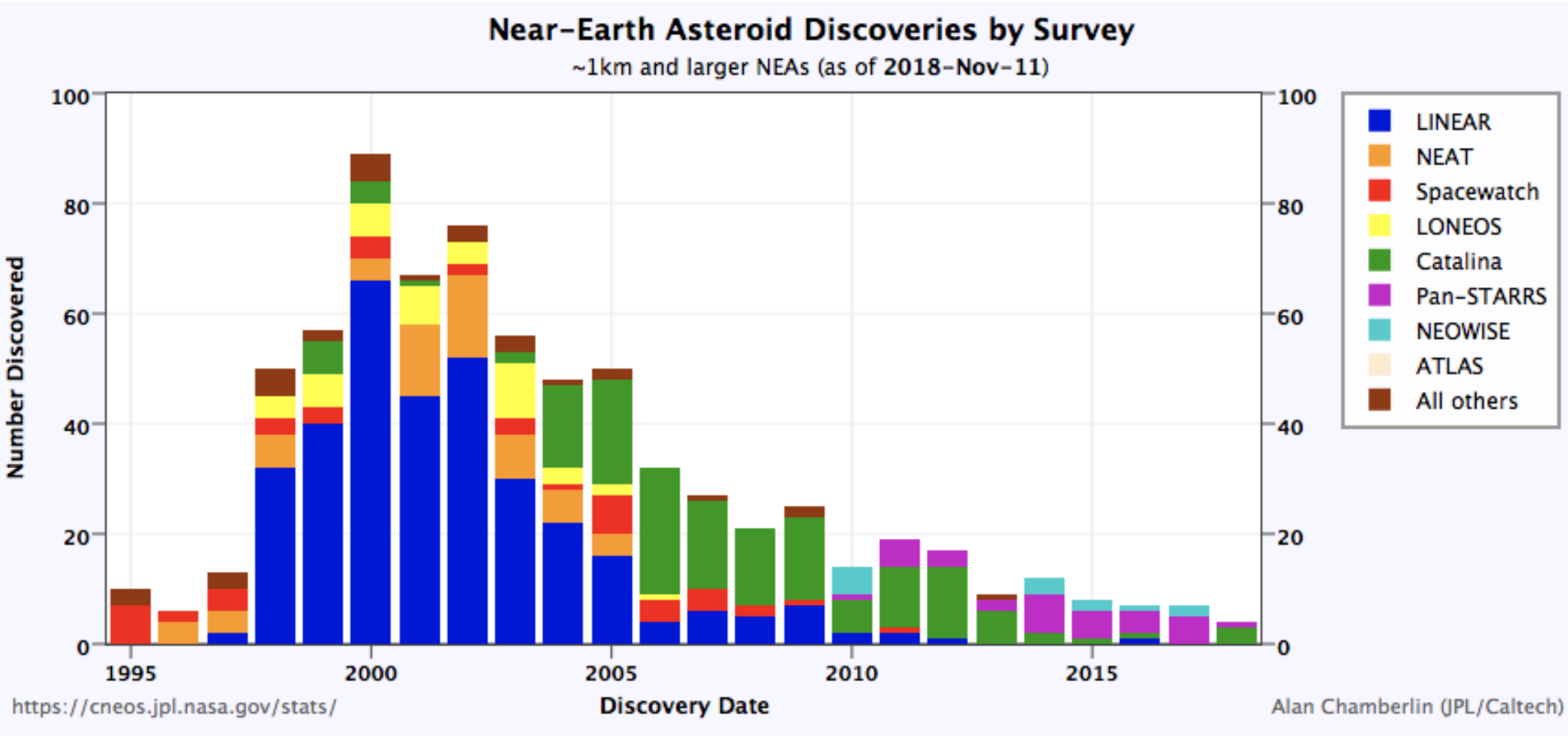


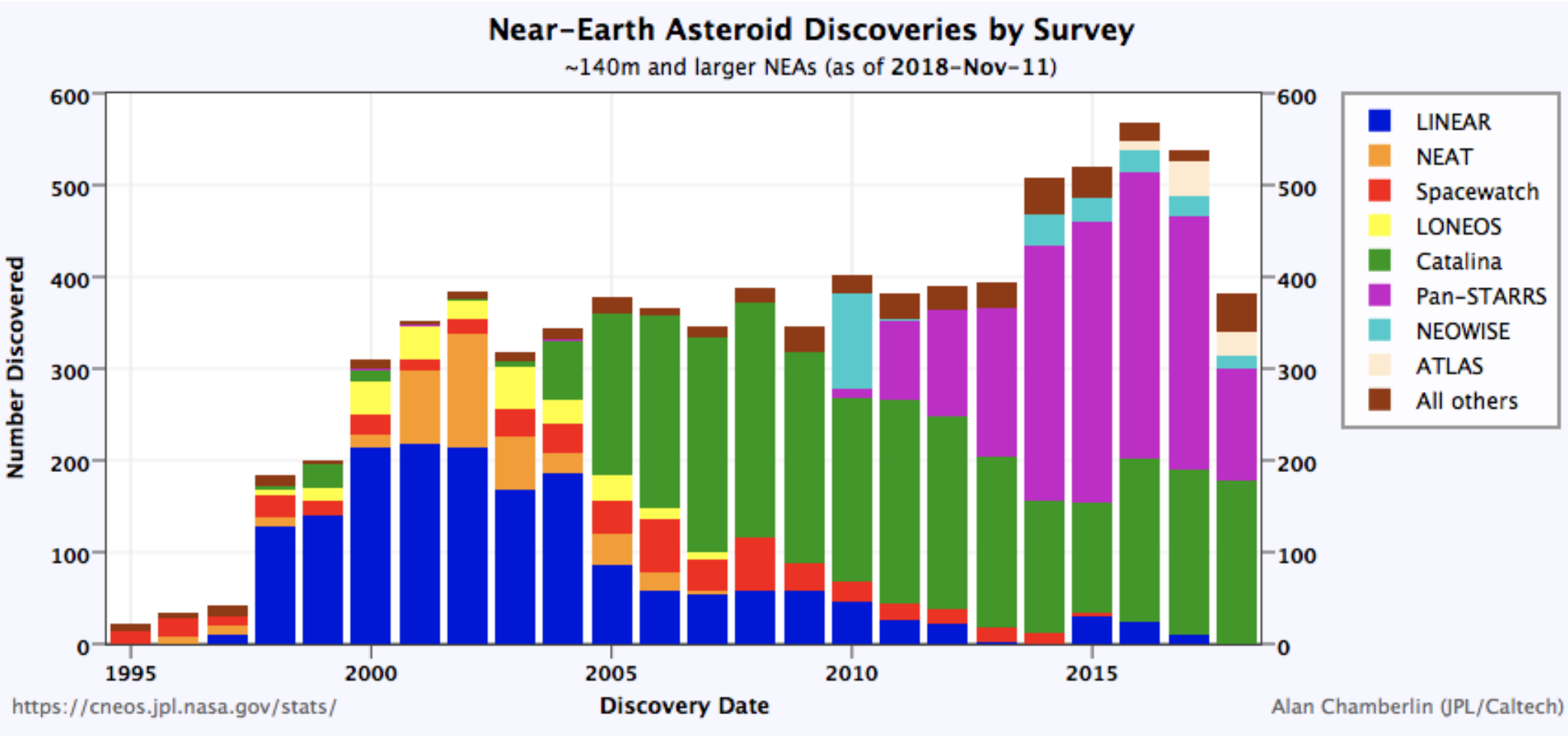
NASA/JPL-Caltech/CSS-Univ. of Arizona

2014 AA

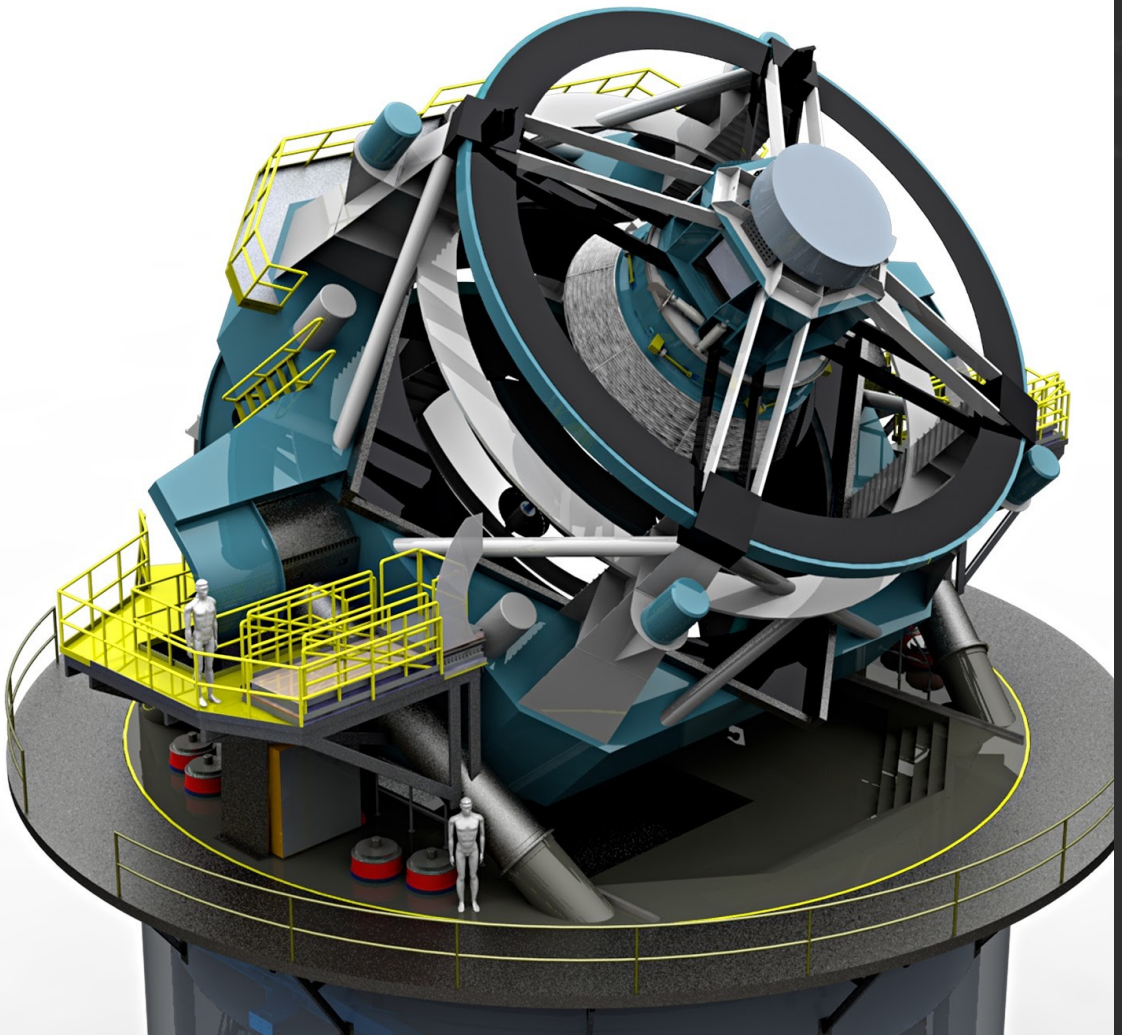
Discovered 1 Jan 2014
by Catalina Sky Survey


Near-Earth Asteroids Discovered
Most recent discovery: 2018-Nov-10
All
140m+
1km+
20 000
15 000
10 000
5 000
0
Cumulative Number Discovered
1980
1990
2000
2010
Discovery Date
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)

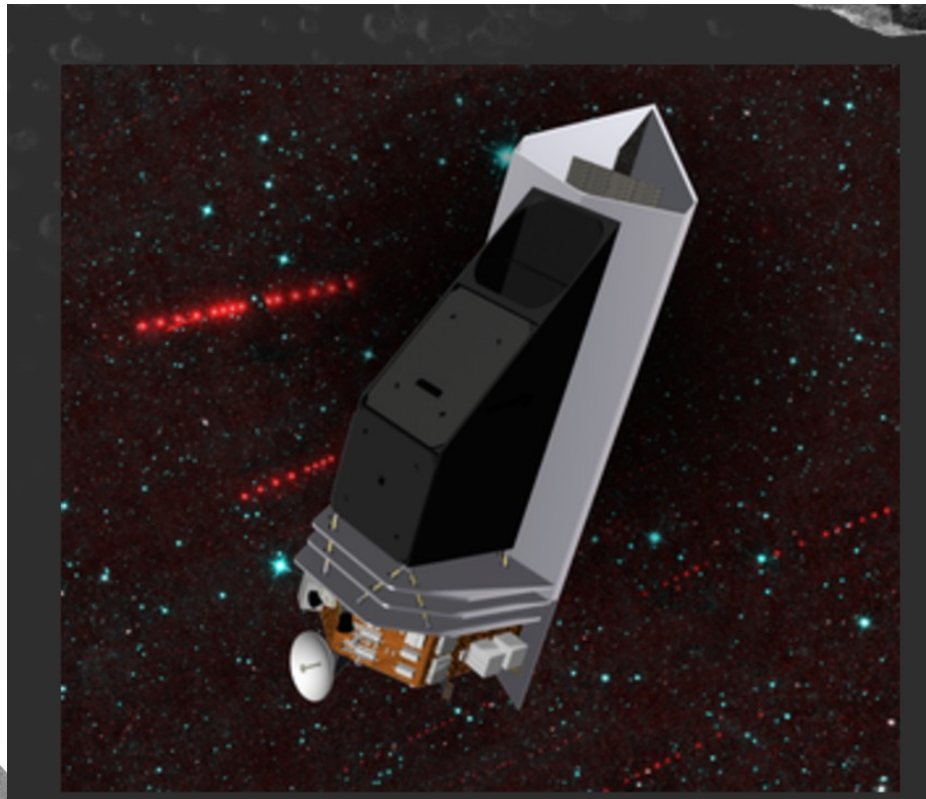

Near-Earth Asteroid Discoveries by Survey
~1km and larger NEAs (as of 2018-Nov-11)
Number Discovered
Discovery Date
0
20
40
60
80
100
1995
2000
2005
2010
2015
LINEAR
NEAT
Spacewatch
LONEOS
Catalina
Pan-STARRS
NEOWISE
ATLAS
All others
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)


Near-Earth Asteroid Discoveries by Survey
~140m and larger NEAs (as of 2018-Nov-11)
Number Discovered
Discovery Date
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)
LINEAR
NEAT
Spacewatch
LONEOS
Catalina
Pan-STARRS
NEOWISE
ATLAS
All others
0
100
200
300
400
500
600
1995
2000
2005
2010
2015

Large Synoptic Survey Telescope



NEOCam



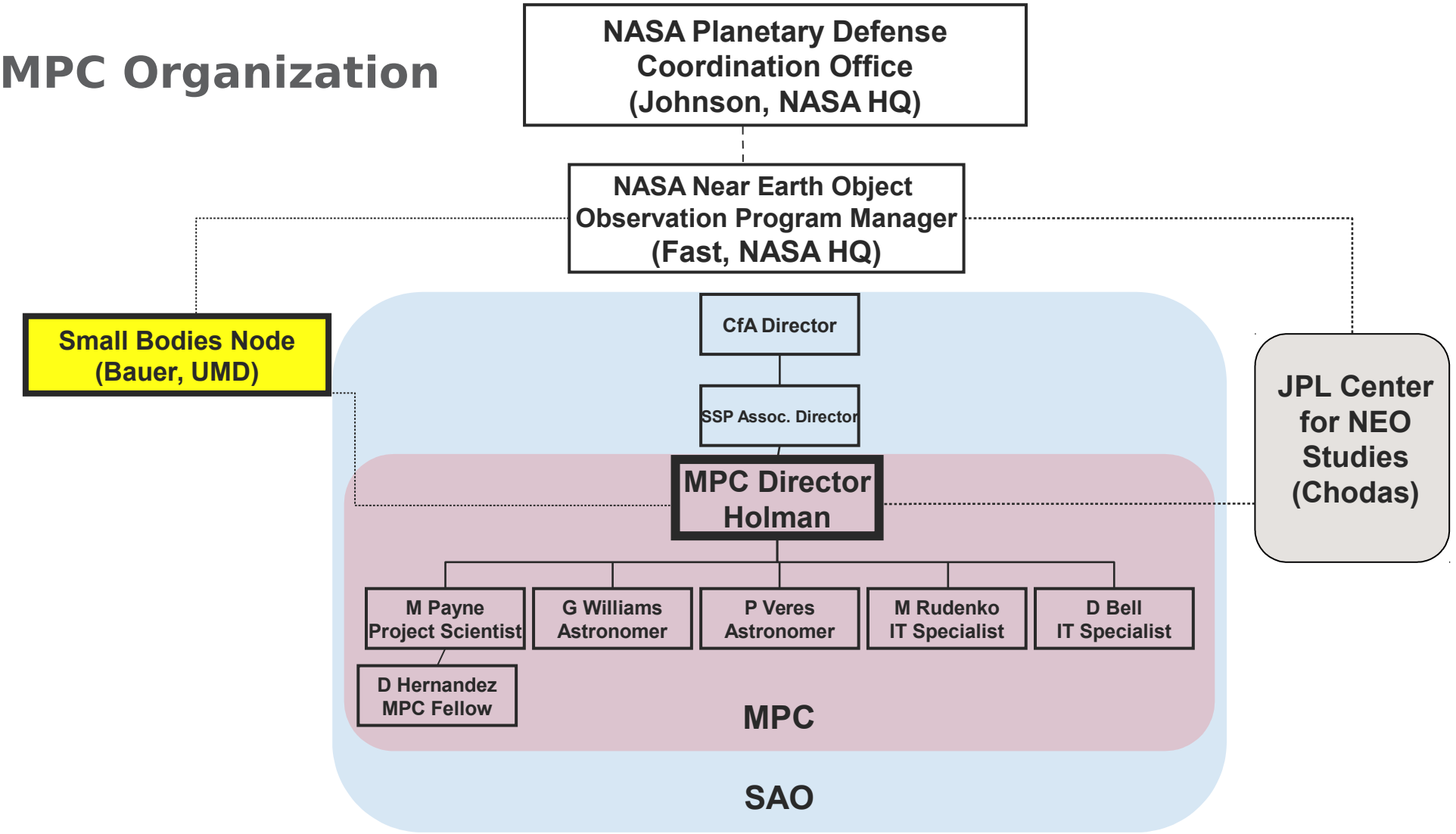
NEOCam - The NEOCam space telescope will survey the regions of space closest to the Earth's orbit, where potentially hazardous asteroids are most likely to be found. NEOCam will use infrared light to characterize their physical properties such as their diameters. (Image credit: NASA/JPL-Caltech)

MPC Overview

- Hosted by the Smithsonian Astrophysical Observatory (SAO) at the Harvard-Smithsonian Center for Astrophysics (CfA).
- Granted authority by the International Astronomical Union (IAU).
- Functional sub-node of the Small Bodies Node of the NASA Planetary Data System.

- Funded 100% by NASA since 2008, via grants through 2017, now through a Cooperative Agreement via a sub-award from University of Maryland (PI Gerbs Bauer). SBN is responsible for oversight of the award.
- Growing to 10 FTEs + Equipment + Travel.

MPC Organization



The MPC is hiring:
https://www.cfa.harvard.edu/hr/postings/18-62.html

MPC Roles and Responsibilities

- Process ~2 millions new observations per month. The current MPC database holds ~175 million observations.
- Identify candidate NEOs in real time, from a stream of observations composed mostly of Main Belt Asteroids.
- Maintain the NEO Confirmation Page (NEOCP) to facilitate coordination of NEO follow-up observations.
- Warn of NEOs coming within 6 Earth-radii within next 6 months.
- Provide access to a database of ~800,000 objects with known orbits.
- Archive data with the Small Bodies Node of the NASA Planetary Data System.

MPC Operations:

How does the MPC do what it does?

The Minor Planet Center (MPC) is the single worldwide location for receipt and distribution of positional measurements of minor planets, comets and outer irregular natural satellites of the major planets. The MPC is responsible for the identification, designation and orbit computation for all of these objects. This involves maintaining the master files of observations and orbits, keeping track of the discoverer of each object, and announcing discoveries to the rest of the world via electronic circulars and an extensive website. The MPC operates at the Smithsonian Astrophysical Observatory, under the auspices of Division F of the International Astronomical Union (IAU).

All of the MPC's operating funds come from a NASA's Near-Earth Object Observations program grant. Much of the computer equipment that the MPC uses was provided by the Tamkin Foundation.

Running Tallies

Near-Earth Objects Discovered

THIS MONTH:	16
THIS YEAR:	1343
ALL TIME:	16846

Minor Planets Discovered

THIS MONTH:	46
THIS YEAR:	20441
ALL TIME:	739476

Comets Discovered

THIS MONTH:	0
THIS YEAR:	39
ALL TIME:	3986

Observations

THIS MONTH:	422753
THIS YEAR:	13.0 million
ALL TIME:	174.4 million

Typical Sequence of Events

1. **Receive astrometry, carry out sanity checks, and archive the data.**

2. If the observations correspond to a known object, natural or artificial, process later in background.

3. If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.

4. Otherwise, into the Isolated Tracklet File (ITF).

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).

Receive Astrometry, Carry out Sanity Checks, and Archive Data

- Processing (Info)

MPC Submission Information

For those wishing to submit astrometric observations for publication in the *Minor Planet Circulars* information is available on the format of astrometric observations. Observations, formatted as described therein, should be sent to obs@cfa.harvard.edu. Reports for new comets should also (following the redistribution of tasks at the 2015 IAU GA) be reported to the MPC. Note that visual reports of comet discoveries should be reported to mpc@cfa.harvard.edu.

Further technical information on Minor Planet Center submissions is available:

- Information on the pending introduction of the ADES format is available here.
- Observation format
- Indication of observational details
- Orbit format (export)
  - The HTML pages describing the new format for import of orbital elements will be available here at some future date.
- Orbit format (import) Orbits submitted for publication in the *MPCs* need to be in a special format.
  - The document describing the new format for import of orbital elements will be available here at some future date.

MPC1992 format

Data reported in ‘tracklets’ of 2+ astrometric observations

Each 80-character line represents an astrometric observation

Header includes observer details

Subject line can indicate possible NEOs

```
                                     2014 AA

Observations:
     K14A00A* C2014 01 01.26257 05 32 35.55 +13 59 45.0          19.1 VqEA002G96
     K14A00A  C2014 01 01.26896 05 32 28.89 +13 59 36.7          18.8 VqEA002G96
     K14A00A  C2014 01 01.28176 05 32 15.27 +13 59 16.4          18.9 VqEA002G96
     K14A00A  C2014 01 01.30701 05 31 47.92 +13 58 21.1          19.0 VqEA002G96
     K14A00A  C2014 01 01.30828 05 31 46.54 +13 58 17.9          19.0 VqEA002G96
     K14A00A  C2014 01 01.30955 05 31 45.15 +13 58 14.6          19.1 VqEA002G96
     K14A00A  C2014 01 01.31081 05 31 43.79 +13 58 11.1          18.9 VqEA002G96
```

Astrometry Data Exchange Standard (ADES) format

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  <obsBlock>
    <obsContext>
      <observatory>
       <mpcCode>658</mpcCode>
        <name>Dominion Astrophysical Observatory</name>
      </observatory>
      <submitter>
        <name>D. D. Balam</name>
        <institution>Dominion Astrophysical Observatory</institution>
      </submitter>
      <telescope>
        <aperture>1.82</aperture>
        <design>Reflector</design>
        <detector>CCD</detector>
      </telescope>
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      <comment>
        <line>This is a comment</line>
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    </obsContext>
    <obsData>
     <optical>
        <trkSub>ZVA7520</trkSub>
        <mode>CCD</mode>
        <stn>658</stn>
        <obsTime>2018-11-08T08:41:11Z</obsTime>
        <ra>73.433625</ra>
        <dec>37.236972</dec>
        <rmsRA>0.15</rmsRA>
        <rmsDec>0.15</rmsDec>
        <astCat>2MASS</astCat>
      </optical>
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        <stn>658</stn>
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        <dec>37.241306</dec>
        <rmsRA>0.15</rmsRA>
        <rmsDec>0.15</rmsDec>
        <astCat>2MASS</astCat>
      </optical>
    </obsData>
  </obsBlock>
</ades>
```

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3. **If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.**

4. Otherwise, into the Isolated Tracklet File (ITF).

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).

Candidate NEO?
DIGEST2

- Digest2 is a tracklet classifier that outputs a score that tracks the likelihood that the tracklet represents an NEO.
- Tracklet classification is an essential capability for the NEOCP, on the critical path for the MPC's primary funded task.
- The MPC applies digest2 to all submitted candidates for the NEOCP and posts all objects scoring above a threshold.
- The algorithm is a statistical ranging algorithm.
- Source code is publicly available.

- Processing (Info)

The NEO Confirmation Page

Please ensure you are familiar with the notes at the bottom of this page.

Page last updated on Oct. 28.934 UTC.

Problems? Comments?

Get ephemerides | Reset form

Select object(s) from the current list of objects needing confirmation (NEO desirability score, discovery date, rough current position and magnitude given, as well as number of observations, arc, nominal *H* and number of days since it was last observed):

All objects with *V* = -30 to 30, with Decl. between -90 ° and +90 °, with an NEO desirability score of 0 % to 100 %

or just the objects selected below: Deselect All | Select All

Temp Desig	Score	Discovery	R.A.	Decl.	V	Updated	Note	NObs	Arc	H	Not Seen/dys
ZU8D95A	51	2018 10 28.4	08 59.9	+38 30	21.4	Updated Oct. 28.52 UT		7	0.08	18.3	0.426
ZU8D833	78	2018 10 28.3	01 50.7	+45 42	20.9	Updated Oct. 28.47 UT		10	0.12	20.4	0.487
ZU8D7C0	88	2018 10 28.3	02 08.1	+40 40	19.7	Updated Oct. 28.91 UT		15	0.59	24.8	0.032
ZU8D74B	100	2018 10 28.2	01 20.2	+39 10	20.8	Updated Oct. 28.89 UT		14	0.58	25.4	0.060
ZU20606	100	2018 10 28.2	00 06.9	+32 33	19.8	Updated Oct. 28.84 UT		12	0.56	23.7	0.107
ZU8D6E9	93	2018 10 28.2	01 11.9	+37 56	19.8	Updated Oct. 28.85 UT		15	0.57	25.5	0.092
ZU8D6E2	46	2018 10 28.2	00 48.0	+43 29	21.3	Updated Oct. 28.53 UT		11	0.16	18.7	0.507
ZU8D6E1	69	2018 10 28.2	00 49.2	+43 08	21.0	Updated Oct. 28.44 UT		8	0.16	19.7	0.506
ZU8D6D0	63	2018 10 28.2	00 29.2	+43 10	21.1	Updated Oct. 28.53 UT		11	0.18	18.5	0.500
ZU8D6D2	79	2018 10 28.2	00 28.2	+42 23	21.3	Updated Oct. 28.45 UT		11	0.18	21.4	0.500
ZU8D66C	55	2018 10 28.2	23 44.7	+39 21	20.7	Updated Oct. 28.37 UT		12	0.15	19.7	0.580
ZU8D62C	25	2018 10 27.4	09 00.0	+51 08	21.3	Updated Oct. 28.59 UT		16	1.05	17.9	0.452
ZU8D610	83	2018 10 27.3	07 41.7	+52 36	21.2	Updated Oct. 28.47 UT		20	1.09	19.3	0.475
ZU8D586	59	2018 10 27.1	19 15.4	+52 11	20.4	Updated Oct. 28.83 UT		24	1.63	10.2	0.120
P20JSkh	40	2018 10 26.4	01 27.6	+42 47	20.5	Updated Oct. 28.55 UT		20	1.82	18.2	0.626
A109uG7	90	2018 10 26.5	04 07.5	-11 10	17.7	Updated Oct. 28.46 UT		28	1.89	21.8	0.489
A109uG6	88	2018 10 26.5	04 22.5	-23 55	17.3	Updated Oct. 28.38 UT		22	1.79	20.1	0.571
ZU8CCC6	38	2018 10 21.4	03 03.0	+44 19	20.9	Updated Oct. 28.36 UT		22	6.89	17.8	0.607
ZU8A2EB	10	2018 10 20.4	02 11.8	+17 10	19.8	Updated Oct. 28.20 UT		29	7.75	19.4	0.753
ZU88CE6	10	2018 10 20.3	01 41.8	+20 09	20.7	Updated Oct. 28.20 UT		26	7.79	19.6	0.752

The information in the table (including any PCCP objects) is available in a text file. The layout of this file matches the table layout exactly, except that the R.A. is converted to decimal hours and the Decl. to decimal degrees.

Typical Sequence of Events

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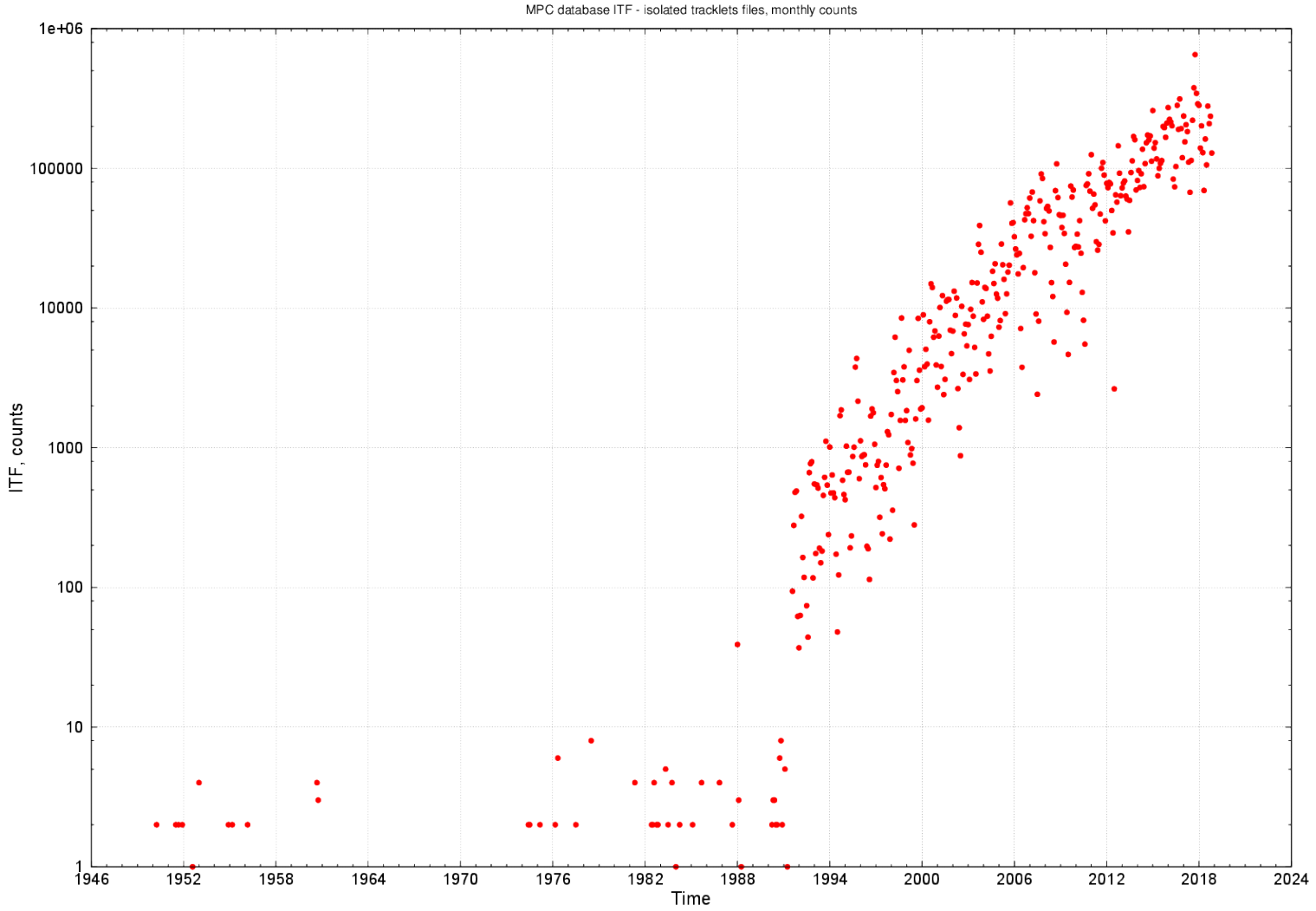
Isolated Tracklet File (ITF)



Monthly additions of tracklets to the ITF.

Courtesy of A. Mamoutkine/T. Spahr (SBN)

Typical Sequence of Events

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Minor Planet Electronic Circular (MPEC)

M.P.E.C. 2018-U19 Issued 2018 Oct. 19, 14:42 UT

The Minor Planet Electronic Circulars contain information on unusual minor planets and routine data on comets. They are published on behalf of Division F of the International Astronomical Union by the Minor Planet Center, Smithsonian Astrophysical Observatory, Cambridge, MA 02138, U.S.A.

Prepared using the Tamkin Foundation Computer Network

MPC@CFA.HARVARD.EDU
URL https://www.minorplanetcenter.net/ ISSN 1523-6714

2018 UA

Observations:

```
     K18U00A* C2018 10 19.16634 23 45 19.04 +17 27 05.0          18.9 GVEU019703
     K18U00A  C2018 10 19.17684 23 45 21.32 +17 26 30.2               VEU019703
     K18U00A  C2018 10 19.18209 23 45 22.30 +17 26 10.4          18.6 GVEU019703
     K18U00A  C2018 10 19.21348 23 45 28.52 +17 23 47.3          18.5 GVEU019703
     K18U00A  C2018 10 19.21674 23 45 29.11 +17 23 29.3               VEU019703
     K18U00A  C2018 10 19.22127 23 45 30.02 +17 23 03.4          18.2 GVEU019703
     K18U00A HC2018 10 19.34492 23 46 29.72 +17 00 20.8          17.4 RoEU019691
     K18U00A HC2018 10 19.34602 23 46 30.81 +17 00 00.2          17.3 RoEU019691
     K18U00A HC2018 10 19.34711 23 46 31.90 +16 59 39.4          17.3 RoEU019691
     K18U00A KC2018 10 19.35216 23 46 37.26 +16 58 00.0          17.2 RoEU019291
     K18U00A KC2018 10 19.35336 23 46 38.59 +16 57 35.8          17.2 RoEU019291
     K18U00A KC2018 10 19.35459 23 46 39.96 +16 57 10.8          17.1 RoEU019291
     K18U00A HC2018 10 19.37528 23 47 07.44 +16 49 23.4          17.0 RoEU019691
     K18U00A HC2018 10 19.37628 23 47 09.00 +16 48 58.1          17.3 RoEU019691
     K18U00A HC2018 10 19.37728 23 47 10.58 +16 48 33.1          17.2 RoEU019691
     K18U00A [C2018 10 19.44188723 59 47.84 +18 31 50.9          16.3 GVEU019Q62
     K18U00A [C2018 10 19.44340323 59 56.39 +18 32 11.9          16.3 GVEU019Q62
     K18U00A [C2018 10 19.44630800 00 13.18 +18 32 53.3          16.3 GVEU019Q62
```

Observer details:

291 LPL/Spacewatch II. Observer R. S. McMillan. 1.8-m f/2.7 reflector + CCD.

691 Steward Observatory, Kitt Peak. Observer R. S. McMillan. 0.9-m f/3 reflector + CCD.

703 Catalina Sky Survey. Observer G. J. Leonard. Measurers B. M. Africano, E. J. Christensen, G. A. Farneth, D. C. Fuls, A. R. Gibbs, A. D. Grauer, H. Groeller, J. A. Johnson, R. A. Kowalski, S. M. Larson, G. J. Leonard, R. L. Seaman, F. C. Shelly. 0.68-m Schmidt + 10K CCD.

Q62 iTelescope Observatory, Siding Spring. Observer M. Suzuki. 0.5-m reflector + CCD.

Orbital elements:

```
2018 UA                                                  Earth MOID = 0.0002 AU
Epoch 2019 Apr. 27.0 TT = JDT 2458600.5                  MPC
M  83.04914          (2000.0)            P               Q
n   0.60148789      Peri.  255.20147     -0.18840520     -0.98188781
a   1.3899039       Node   205.68429     +0.91786417     -0.16880527
e   0.4473326       Incl.    2.64429     +0.34932628     -0.08602975
P   1.64            H     30.2           G   0.15        U   5
Residuals in seconds of arc
181019 703  0.2-  0.2-    181019 691  0.0   0.2-    181019 691  0.3-  0.3+
181019 703  0.7+  0.1-    181019 691  0.0   0.1-    181019 691  0.2-  0.1-
181019 703  0.5-  0.6-    181019 691  0.2-  0.1-    181019 691  0.1-  0.1+
181019 703  0.5+  0.2+    181019 291  0.0   0.1-    181019 Q62  0.5+  0.1+
181019 703  0.4-  0.2+    181019 291  0.0   0.1-    181019 Q62  0.0   0.2-
181019 703  0.4-  0.5+    181019 291  0.2-  0.0     181019 Q62  0.7-  0.2-
```

Ephemeris:

```
2018 UA                  a,e,i = 1.39, 0.45, 3                  q = 0.7682
Date     TT    R. A. (2000) Decl.    Delta      r      Elong.  Phase    V
2018 09 19    23 43 10.5 +16 42 48   0.2249  1.2202   161.6    15.1    28.2
...
2018 10 04    23 39 25.5 +17 44 54   0.1093  1.1039   160.1    17.9    26.5
...
2018 10 12    23 37 35.5 +17 57 43   0.05266 1.0464   155.5    23.3    25.0
...
2018 10 18    23 38 32.7 +17 55 18   0.01119 1.0063   151.7    28.0    21.7
2018 10 19    23 42 11.0 +17 45 36   0.0042960.9999   151.8    28.1    19.6
2018 10 20    12 46 44.8 -14 11 15   0.0027020.9932    13.1   166.9    31.7
...
2018 10 26    12 55 35.6 -13 35 28   0.04420 0.9518    15.8   163.5
...
2018 11 03    12 57 52.6 -13 34 19   0.1011  0.8997    22.7   154.8    34.5
...
2018 11 18    13 08 42.9 -13 56 21   0.2177  0.8189    34.7   136.7    32.9
```

A. U. Tomatic (C) Copyright 2018 MPC M.P.E.C. 2018-U19

Close approach of Earth

‘Oumuamua

Rob Weryk
Pan-STARRS

M.P.E.C. 2017-U181 Issued 2017 Oct. 25, 03:53 UT

The Minor Planet Electronic Circulars contain information on unusual minor planets and routine data on comets. They are published on behalf of Division F of the International Astronomical Union by the Minor Planet Center, Smithsonian Astrophysical Observatory, Cambridge, MA 02138, U.S.A.

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COMET C/2017 U1 (PANSTARRS)

Further observations of this object are very much desired. Unless there are serious problems with much of the astrometry listed below, strongly hyperbolic orbits are the only viable solutions. Although it is probably not too sensible to compute meaningful original and future barycentric orbits, given the very short arc of observations, the orbit below has e ~ 1.2 for both values. If further observations confirm the unusual nature of this orbit, this object may be the first clear case of an interstellar comet.

Observations:

```
     CK17U010  C2017 10 18.47298 01 59 57.442+02 06 04.30          19.8 TLEU181F51
     CK17U010  C2017 10 18.49990 01 59 08.910+02 07 20.19               LEU181F51
     CK17U010  C2017 10 19.39715 01 34 55.362+02 45 03.20          19.9 TLEU181F51
     CK17U010  C2017 10 19.40837 01 34 38.745+02 45 28.24          19.9 TLEU181F51
     CK17U010  C2017 10 19.41968 01 34 21.948+02 45 53.55          20.1 TLEU181F51
     CK17U010  C2017 10 19.43106 01 34 05.174+02 46 18.89          20.1 TLEU181F51
     CK17U010 KC2017 10 19.86072 01 24 07.89 +03 01 07.5           19.6 TUEU181104
     CK17U010 KC2017 10 19.86492 01 24 02.21 +03 01 16.3           19.8 TUEU181104
     CK17U010 KC2017 10 19.86905 01 23 56.69 +03 01 24.7           20.3 TUEU181104
     CK17U010 KC2017 10 19.94093401 22 22.288+03 03 53.76          20.3 TUEU181J04
     CK17U010 KC2017 10 19.94390101 22 18.372+03 03 59.57          20.1 TUEU181J04
     CK17U010  C2017 10 20.17250 01 17 27.47 +03 11 07.8           19.9 TUEU181I52
     CK17U010  C2017 10 20.17348 01 17 26.22 +03 11 09.6           20.2 TUEU181I52
     CK17U010  C2017 10 20.17448 01 17 24.96 +03 11 11.3           20.2 TUEU181I52
     CK17U010  C2017 10 20.17546 01 17 23.73 +03 11 13.0           20.6 TUEU181I52
     CK17U010 KC2017 10 21.22371 00 57 56.30 +03 39 16.9           20.2 ToEU181291
     CK17U010 KC2017 10 21.22623 00 57 53.76 +03 39 20.5           19.5 ToEU181291
     CK17U010 KC2017 10 21.22877 00 57 51.19 +03 39 24.2           19.6 ToEU181291
     CK17U010  C2017 10 21.37476 00 55 26.71 +03 42 45.0           20.4 ToEU181926
     CK17U010  C2017 10 21.37804 00 55 23.53 +03 42 49.8           20.1 ToEU181926
     CK17U010  C2017 10 21.38132 00 55 20.35 +03 42 53.7           20.4 ToEU181926
     CK17U010 |C2017 10 22.29708 00 41 56.27 +04 01 25.0                vEU181H06
     CK17U010 |C2017 10 22.30118 00 41 52.93 +04 01 29.3                vEU181H06
     CK17U010 |C2017 10 22.30512 00 41 49.76 +04 01 33.5           20.7 TvEU181H06
     CK17U010 1C2017 10 22.46548 00 39 44.84 +04 04 55.4                EU181Q62
     CK17U010 1C2017 10 22.47027 00 39 41.16 +04 04 59.9                EU181Q62
     CK17U010 1C2017 10 22.47506 00 39 37.39 +04 05 04.8           19.9 T EU181Q62
     CK17U010 KC2017 10 23.18830 00 31 01.55 +04 16 02.6           20.4 TqEU181734
     CK17U010 KC2017 10 23.19547 00 30 56.65 +04 16 08.7           20.1 TqEU181734
     CK17U010 KC2017 10 23.20264 00 30 51.76 +04 16 14.6           20.4 TqEU181734
     CK17U010  C2017 10 24.23395 00 20 19.64 +04 30 08.4           20.9 TUEU181G96
     CK17U010  C2017 10 24.23917 00 20 16.75 +04 30 12.3                UEU181G96
     CK17U010  C2017 10 24.24438 00 20 13.82 +04 30 15.6           21.0 TUEU181G96
     CK17U010  C2017 10 24.24957 00 20 10.85 +04 30 19.7           20.7 TUEU181G96
```

Observer details:

104 San Marcello Pistoiese. Observers P. Bacci, M. Maestripieri. Measurers P. Bacci, L. Tesi, G. Fagioli. 0.60-m f/4 reflector + CCD.

291 LPL/Spacewatch II. Observer R. A. Mastaler. 1.8-m f/2.7 reflector + CCD.

734 Farpoint Observatory. Observer G. Hug. 0.69-m reflector + CCD.

926 Tenagra II Observatory. Observers M. Schwartz, P. R. Holvorcem. Measurer M. Schwartz. 0.81-m f/7 Ritchey-Chretien + CCD.

F51 Pan-STARRS 1, Haleakala. Observers J. Bulger, T. Lowe, A. Schultz, M. Willman. Measurers K. Chambers, S. Chastel, L. Denneau, H. Flewelling, M. Huber, E. Lilly, E. Magnier, R. Wainscoat, C. Waters, R. Weryk. 1.8-m Ritchey-Chretien + CCD.

G96 Mt. Lemmon Survey. Observer G. J. Leonard. Measurers E. J. Christensen, D. C. Fuls, A. R. Gibbs, A. D. Grauer, J. A. Johnson, R. A. Kowalski, S. M. Larson, G. J. Leonard, R. G. Matheny, R. L. Seaman, F. C. Shelly. 1.5-m reflector + 10K CCD.

Current MPC Focus Areas

- Legacy System Migration
- New MPC Data Format
- New Algorithms and Services

Legacy System Migration

Legacy System Migration

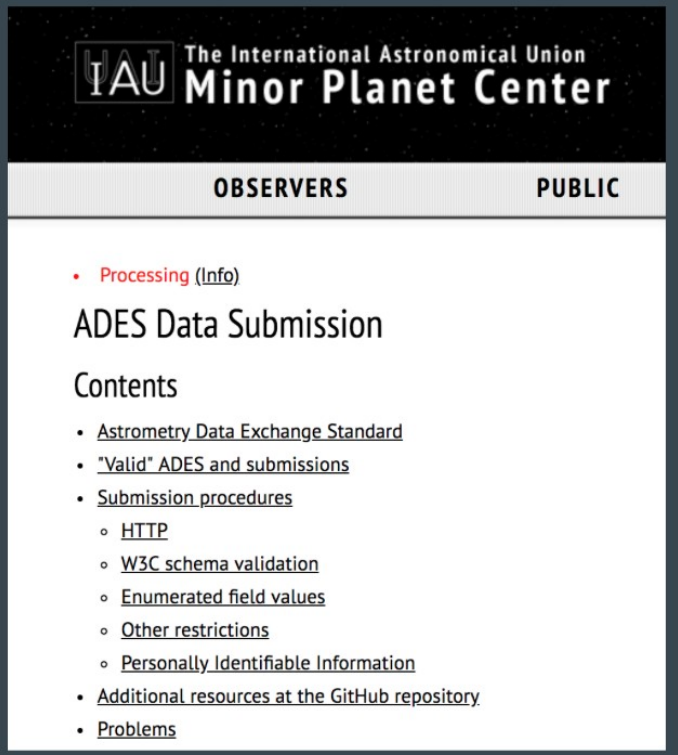
- We currently have a hybrid VMS-Linux system
- We are in the midst of a major legacy migration project, moving the remaining VMS processes to Linux machines.

Drivers, Features, and Goals of New System

- Full MPC staff capable of operating, maintaining, and developing the system
- Modern code base: Linux, Python, Fortran/C(++), Git, PostgreSQL
- Performance and scaling to support a 10-100x data flow increase in the coming decade.
- Support Astrometry Data Exchange Standard (ADES) format to handle better data (GAIA, etc.)
- Provide full documentation.

ADES

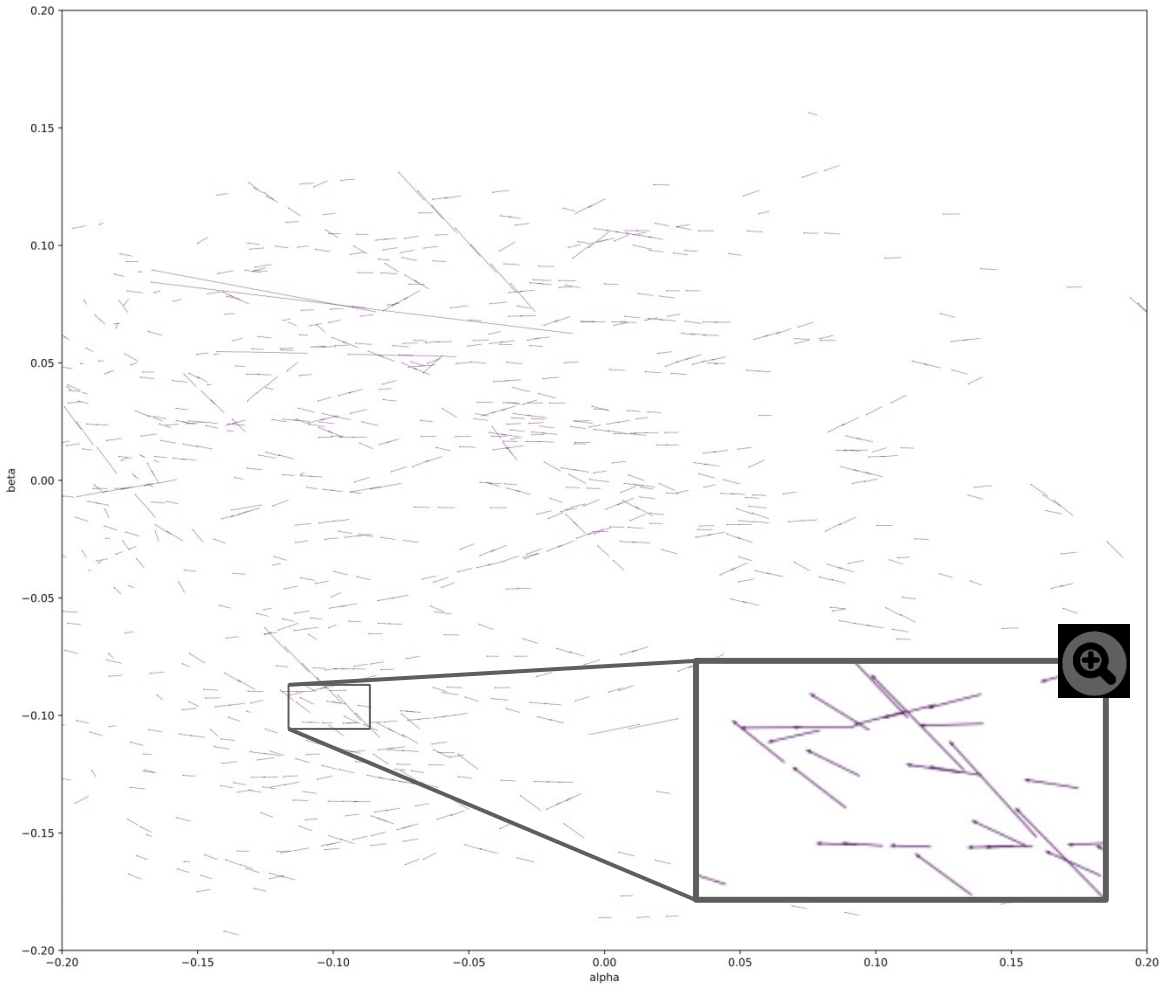
- Developed from 2015 meeting at SAO, led by Steve Chesley
- Many more fields possible than current obs80 format
- XML & PSV versions
- MPC is accepting ADES-format submission
  - https://minorplanetcenter.net/iau/info/ADES.html
  - Test functionality available
- Assigning submissionsIDs & observationIDs
- Still accepting obs80 format



New Algorithms: Linkin

- Observed from Earth, asteroid trajectories are highly nonlinear
- This, with the high density of asteroids makes naïve linking difficult
- Unknown parameters (asteroid radial distance and velocity).
- Sparse observations can be separated by weeks, months, or years
- Brute force is impractical with 14m observations

Asteroid tracklets (from Earth's perspective)



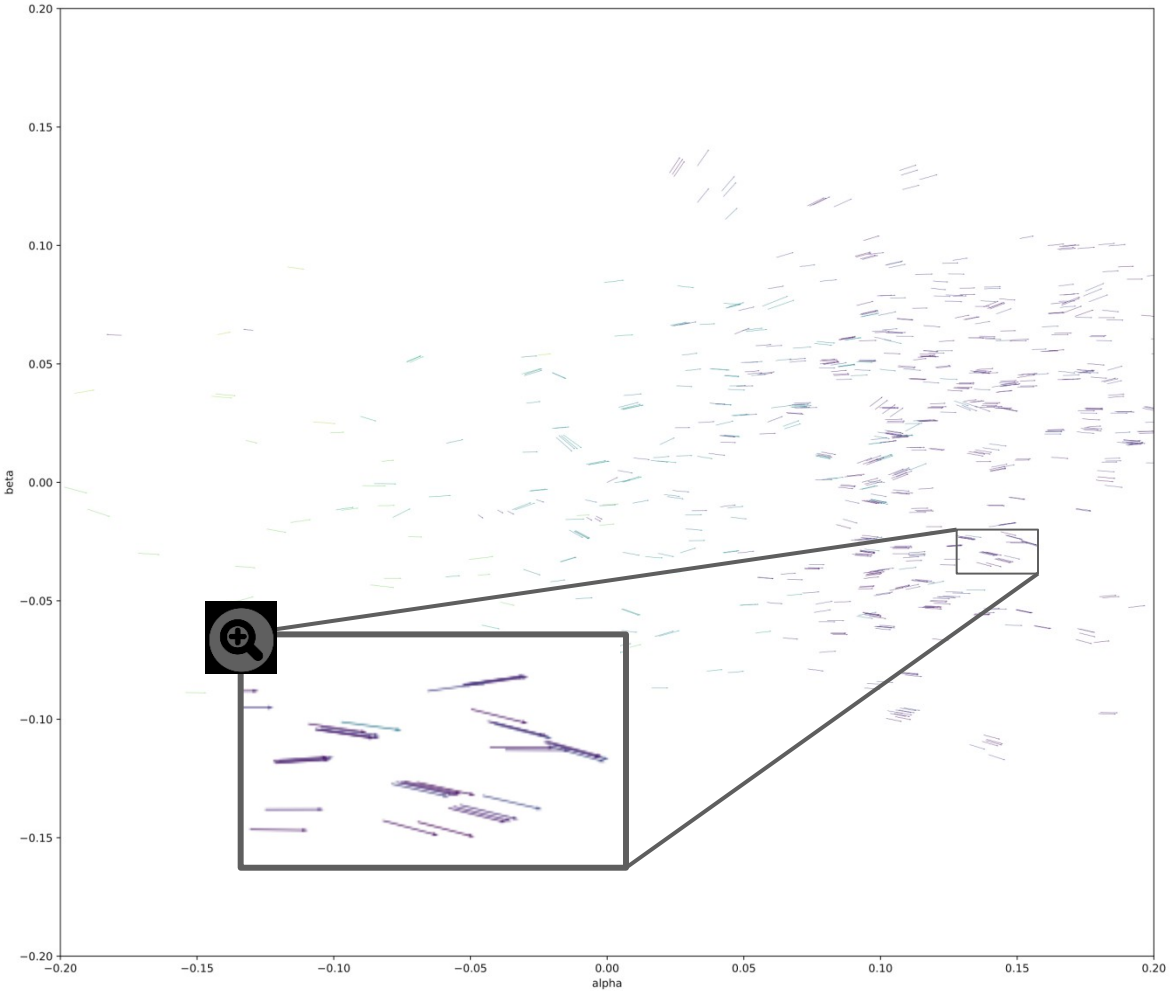
New Algorithms: Linkin

- Iterate over parameters (heliocentric distances and radial velocities)
- Apply a heliocentric transformation to a common reference time.
- Search for clusters.
- New solution is O(n log n)!

Heliocentric Linking and Clustering (HelioLinC), based on Bernstein & Khushalani (2000) formalism.

Holman et al (2018).

Asteroid tracklets (from the Sun's perspective)



New Algorithms:
Faster MPChecker

MPChecker allows the user to query for nearby minor planets.

Given observatory code, date/time, RA/Dec, and search radius→ list of asteroids

This is used heavily by a variety of communities.

Current external version is brute force and takes a few seconds.

New approach is ~80x faster, and there is room for improvement.

- Precompute the geocentric RA/Decs of all MPs on daily intervals
- Organize the MPs by date/time and sky region (HEALPix)
- A query to MPChecker quickly figures out which sky regions are involved and which MPs might be in the neighborhood.
- Computes accurate positions of just those MPs from the designated observatory.
- Generates statistically robust uncertainty regions.

Summary

The Minor Planet Center is playing a key role in the search for NEOs.

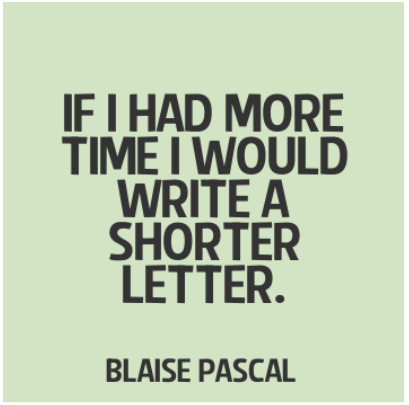
It's a challenging task, but we are keeping up.

We are in the midst of a major legacy migration project.

We are developing new algorithmic approaches.

We are planning for a massive increase in data volume.

Thank You


IF I HAD MORE TIME I WOULD WRITE A SHORTER LETTER.
BLAISE PASCAL
QuotePixel.com

The MPC is hiring

- Ramp up to ~10 FTE
  - Matt Holman: Director
  - Matt Payne: Project Scientist
  - Gareth Williams: Assoc. Director
  - Mike Rudenko: Sys Admin
  - Peter Veres: Astronomer-Operator
  - David Bell: DBA & Web Developer
  - David Hernandez: (MPC Fellow): Precision N-Body Development
  - Michael Lackner: Database & Software Development
- Future hires
  - Web Developer (Paresh Prema)
  - Astronomer-Operator
  - 2nd MPC Fellow, or another Astronomer-Operator

See the SAO employment opportunities page:
https://www.cfa.harvard.edu/hr/postings/18-62.html

MPC Users Group

Role

- Guide improvements of the MPC and its processes and services for the current era,focusing primarily on the surveys and NEO follow-up operations.
- Help the MPC community get the most out of its collective resources, while meeting its main objectives.
- Best position the MPC and members of its community to cope with the increasing volume and velocity of data that will come from the expansion of current surveys.

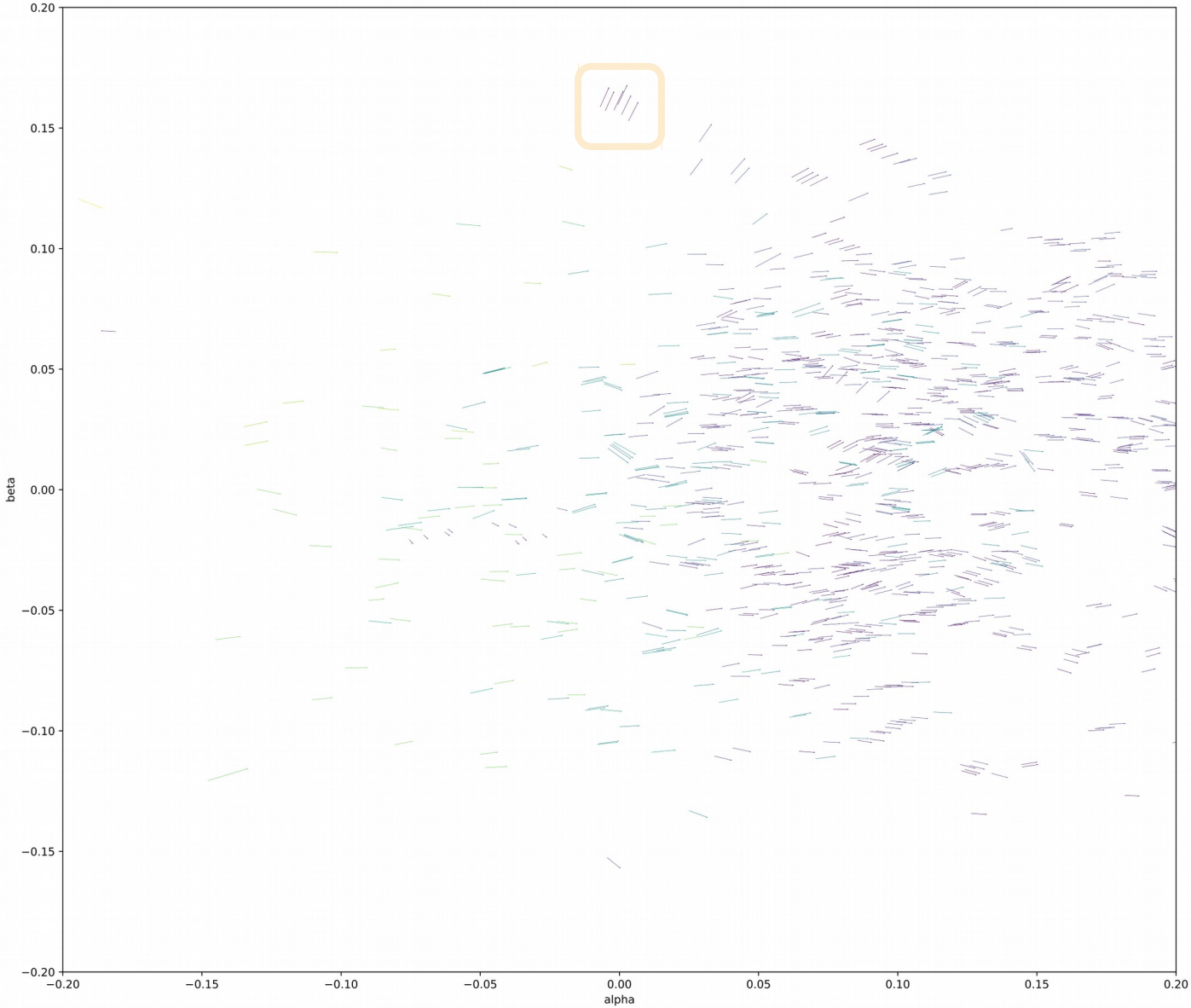
Members

- Steve Chesley (JPL: Chair)
- Rob Seaman (Catalina)
- Marc Buie (SWRI)
- Richard Wainscoat (UH)
- Dave Tholen (UH)
- Carrie Nugent (Olin)

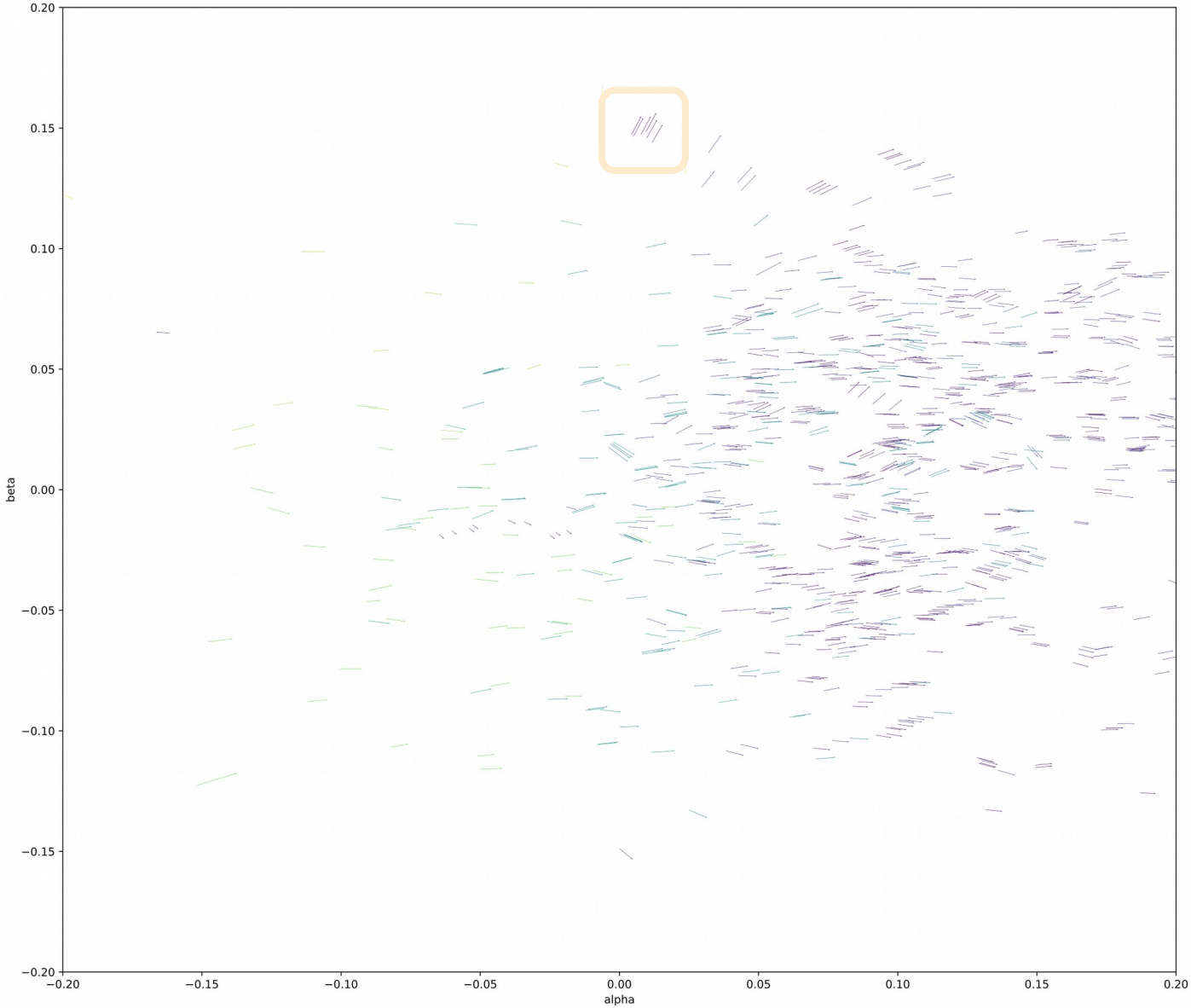
Alternates

- Melissa Brucker
- Tyler Linder
- Larry Denneau (UH)
- Davide Farnocchia (JPL)

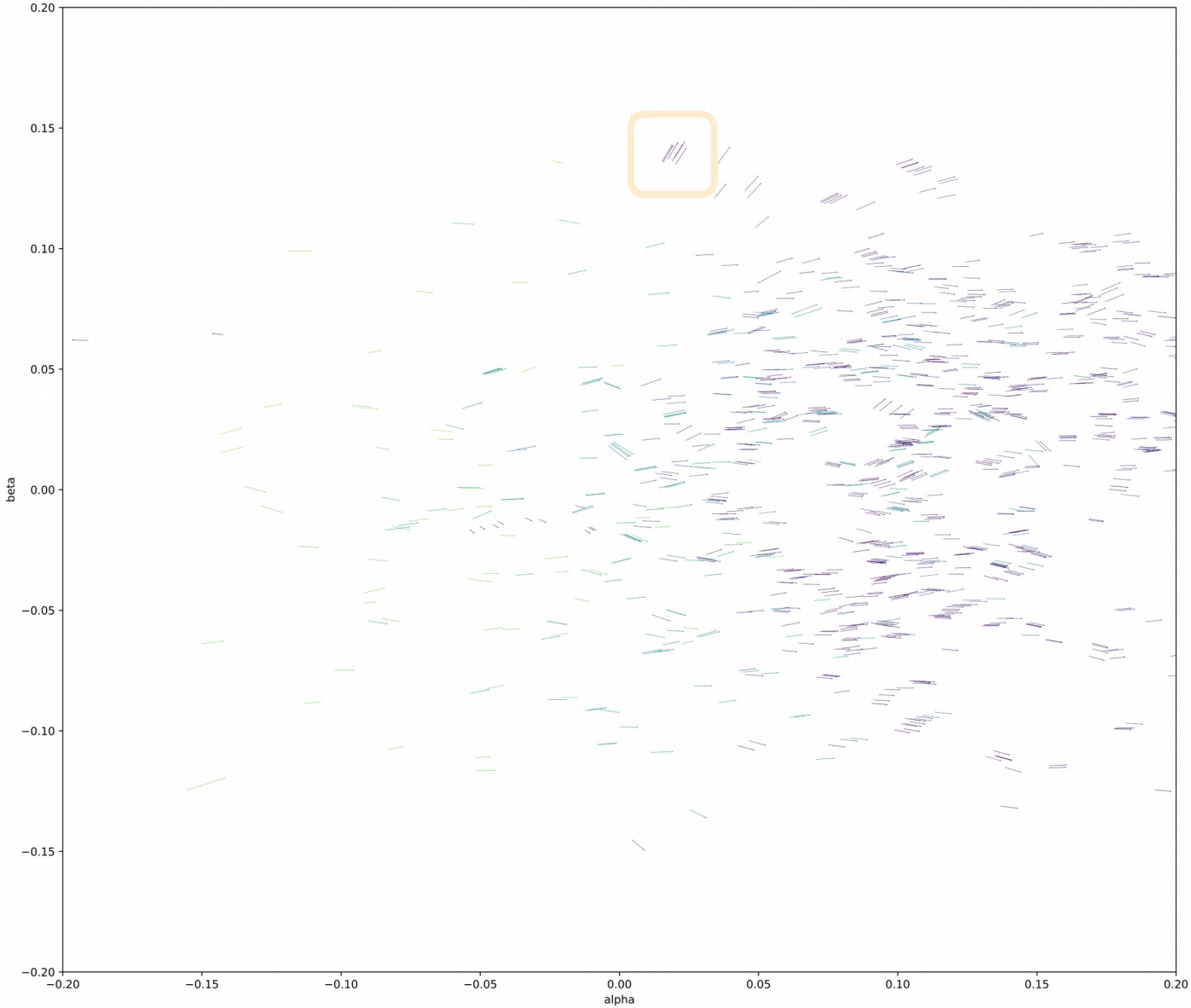
THE VIEW FROM THE SUN



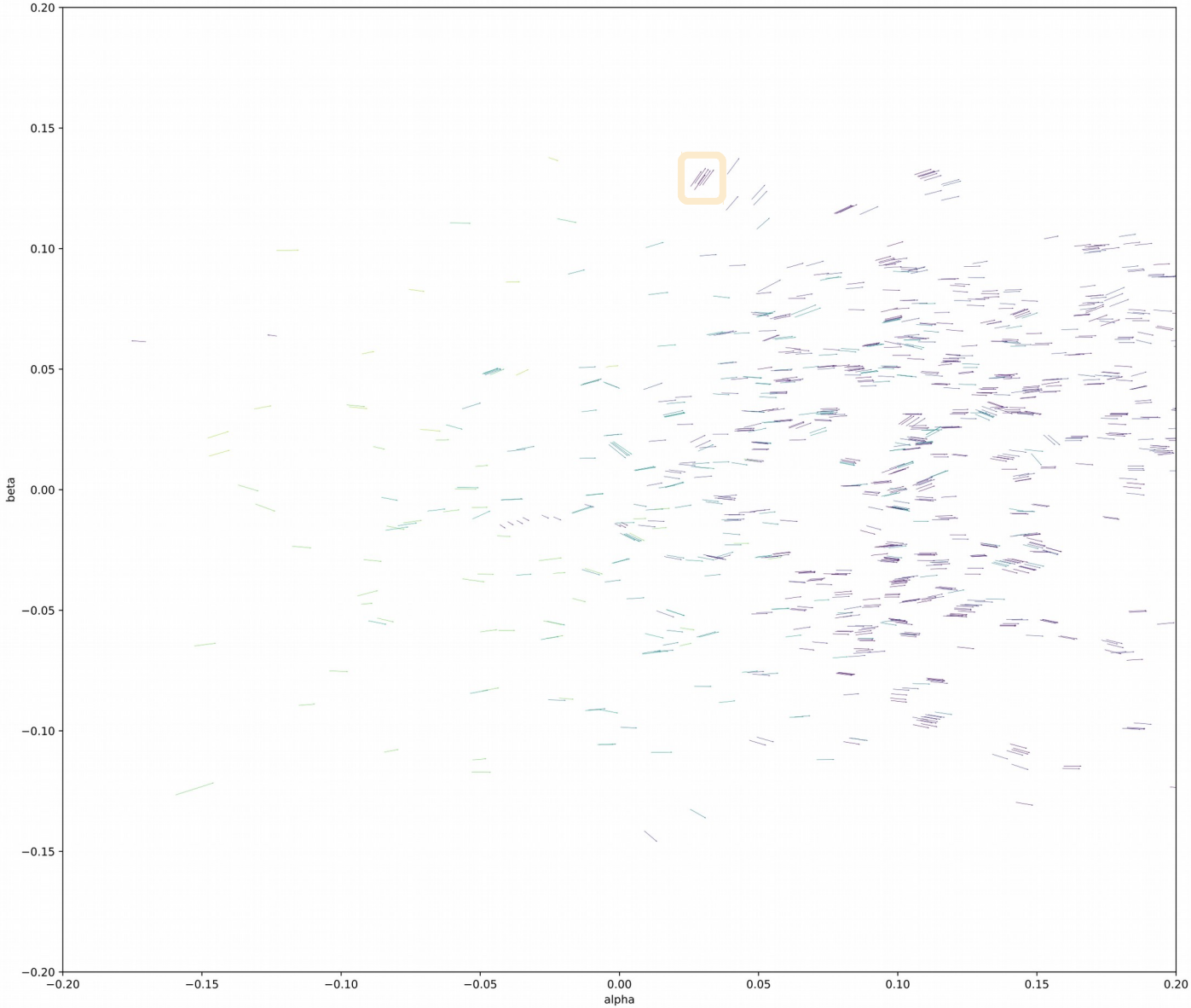
THE VIEW FROM THE SUN



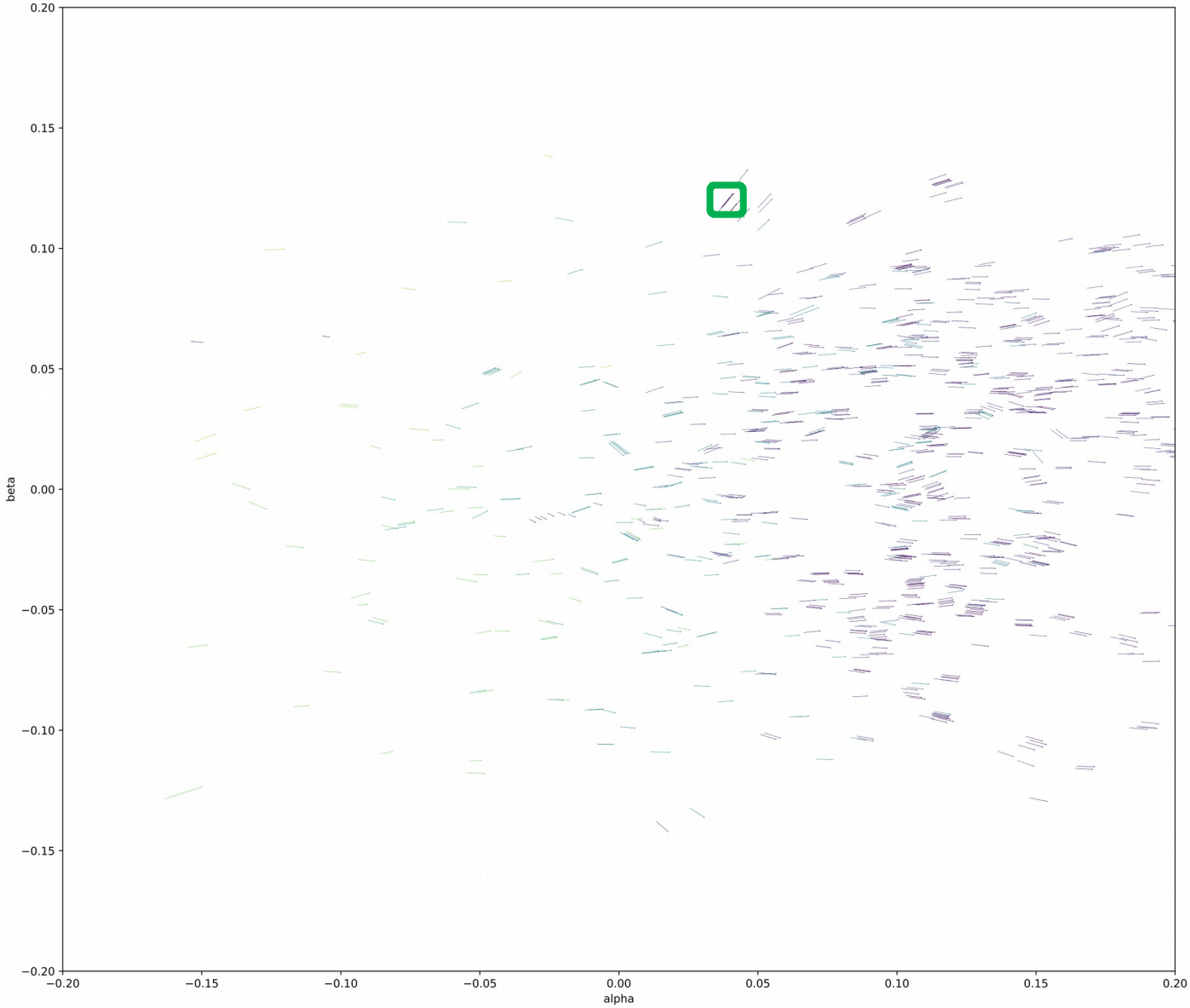
THE VIEW FROM THE SUN



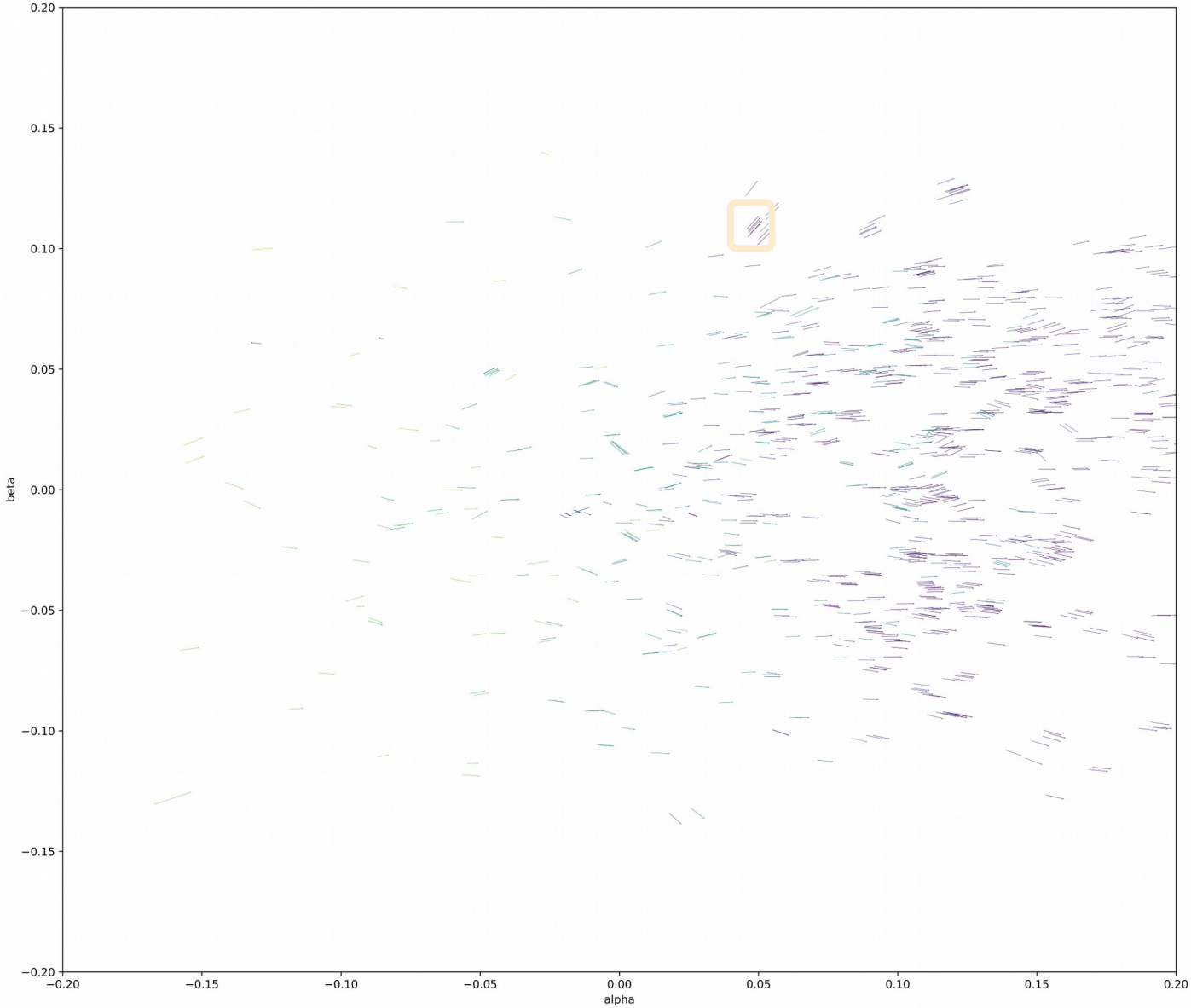
THE VIEW FROM THE SUN



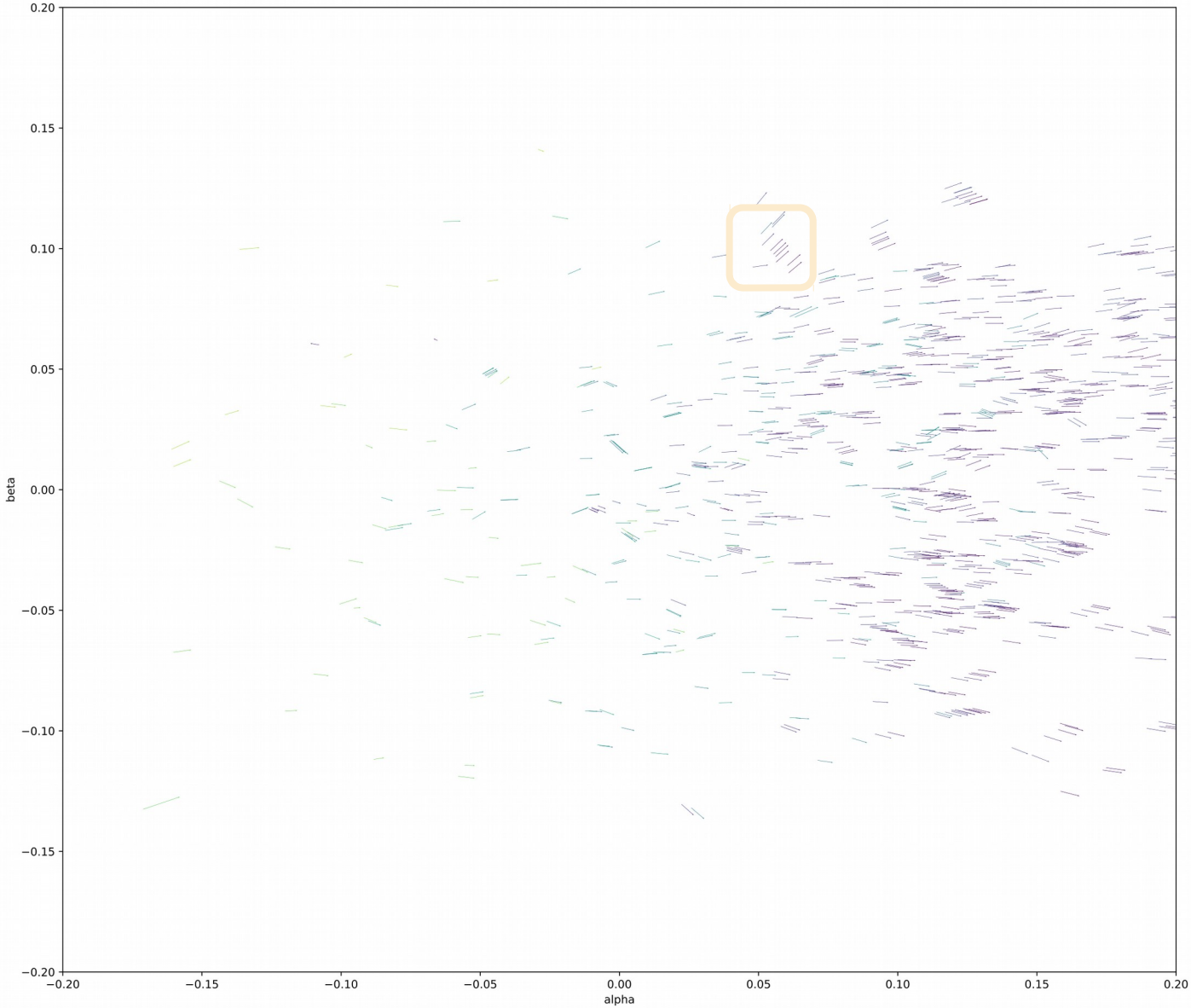
THE VIEW FROM THE SUN



THE VIEW FROM THE SUN



THE VIEW FROM THE SUN



Faster n-body integrators

Symplectic n-body map:

A modified version of the Wisdom & Holman (1991) approach.

Uses canonical heliocentric coordinates.
Interleaves advances along Keplerian arcs with interactions terms.

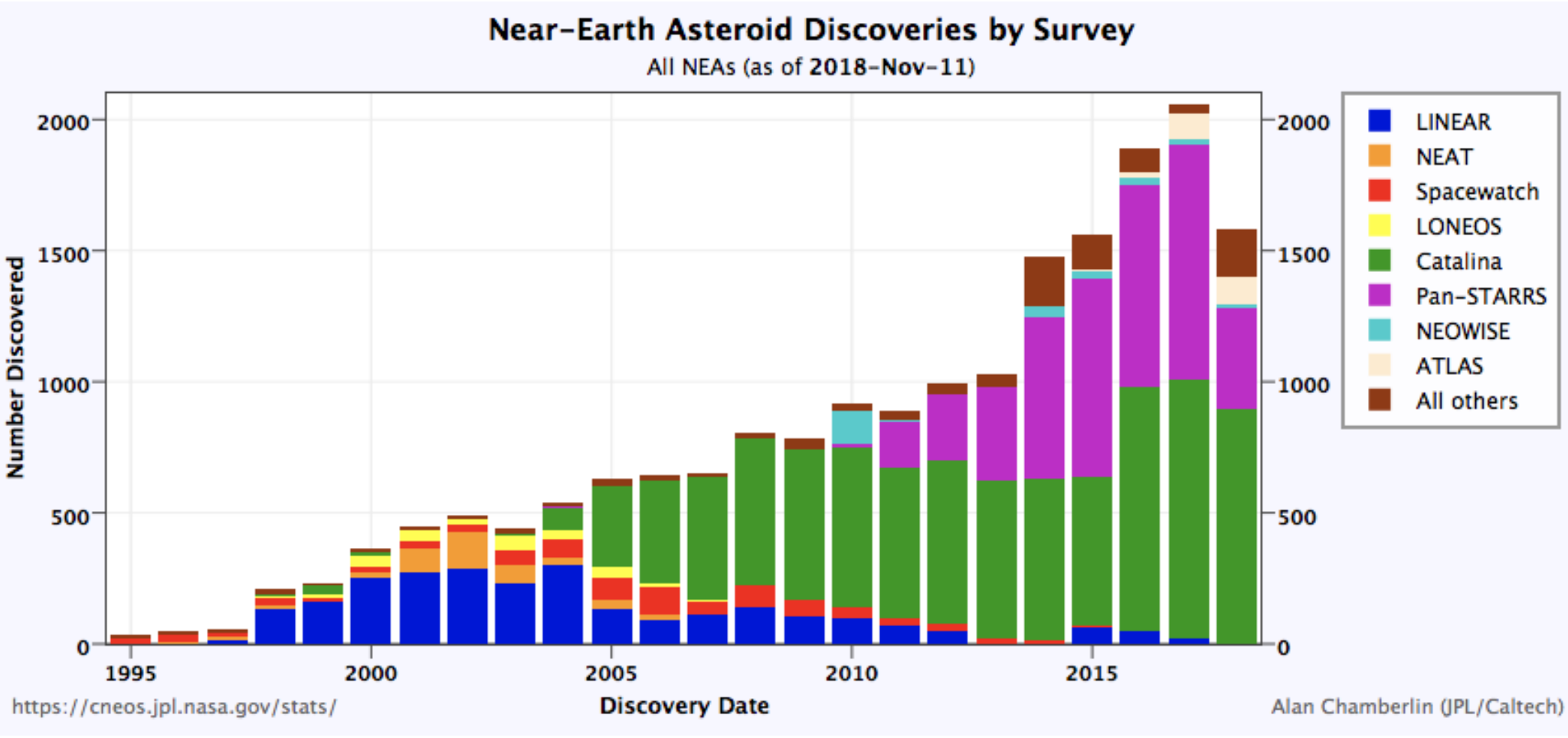
Should be 10x faster for same accuracy.

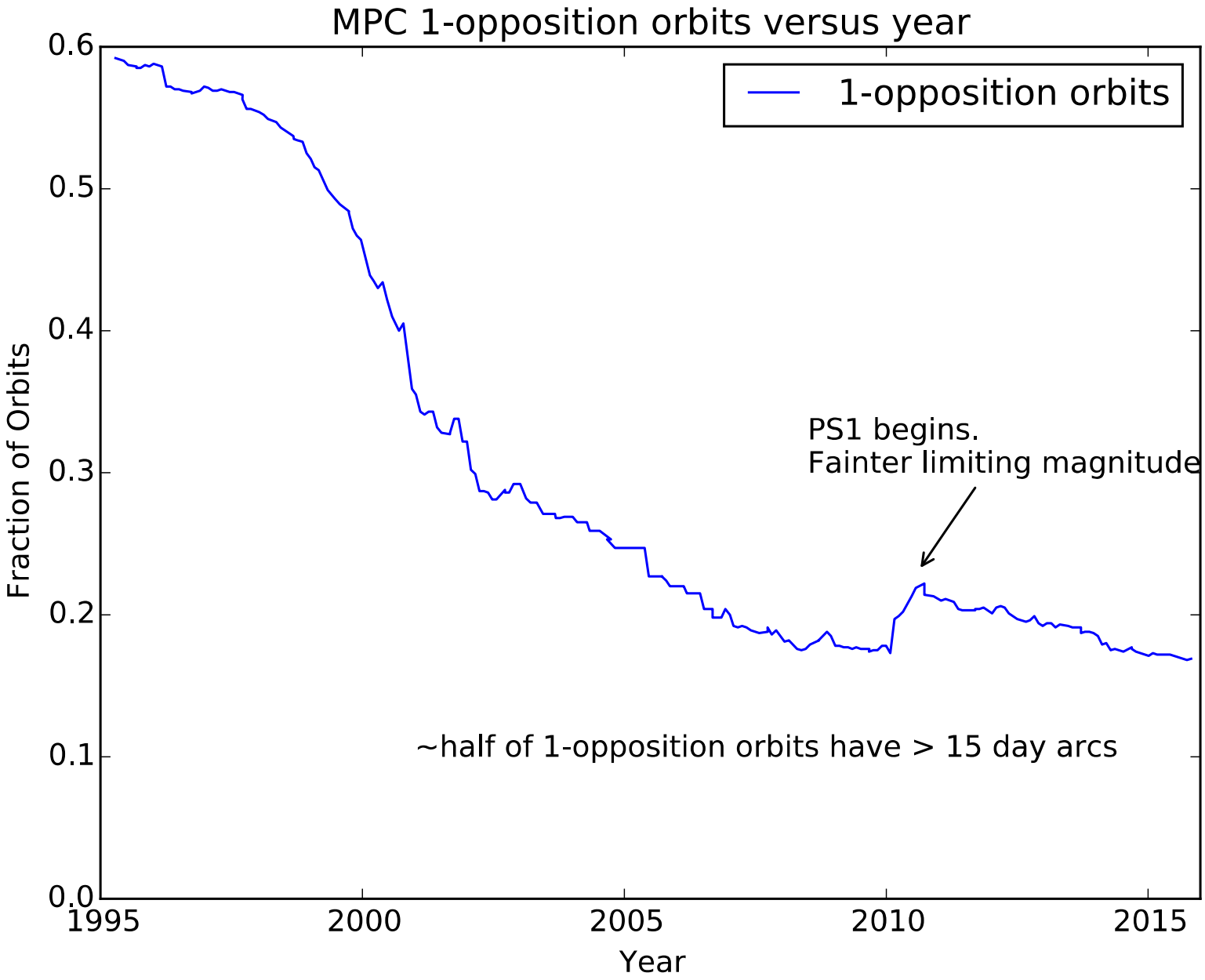
The positions of the sun, large planets, and moon come from JPL's DE430 ephemeris but are stored in memory.

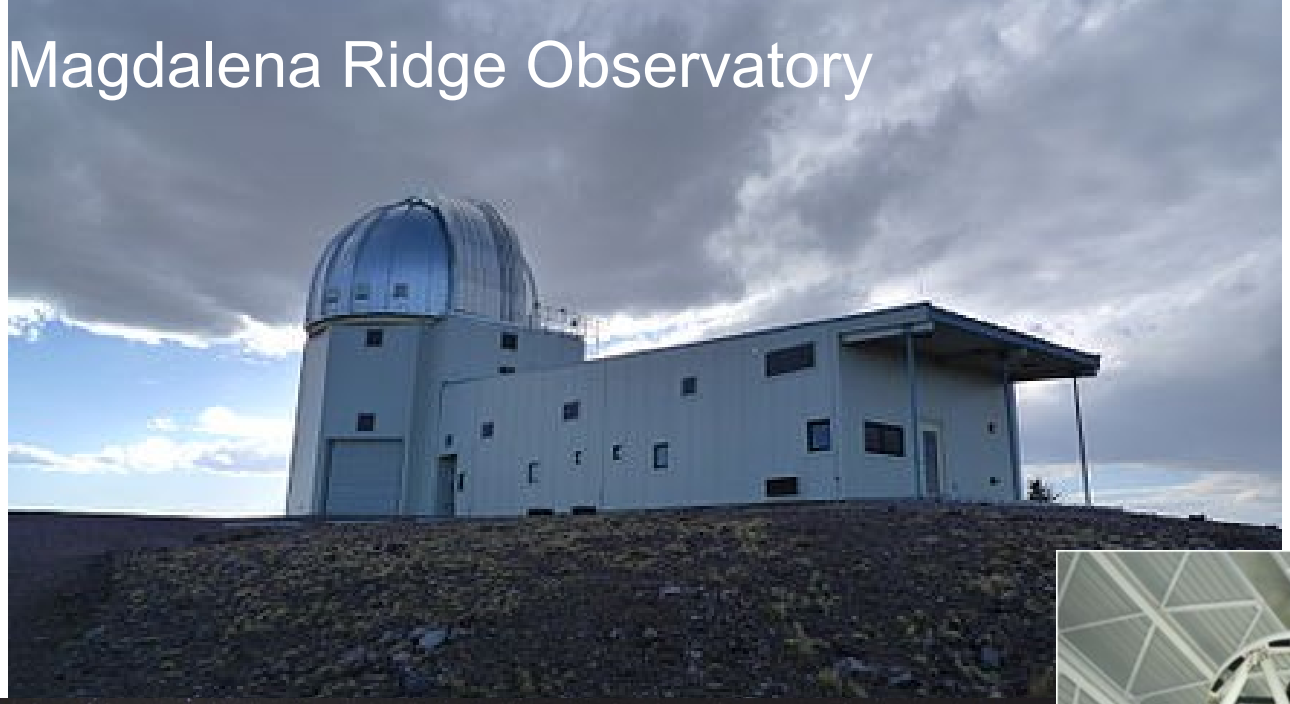
Integrates the orbits of the large asteroids in the field of themselves and the sun and large planets.

Integrates the orbits of the small asteroids in the field of the sun, large planets, and large asteroids.

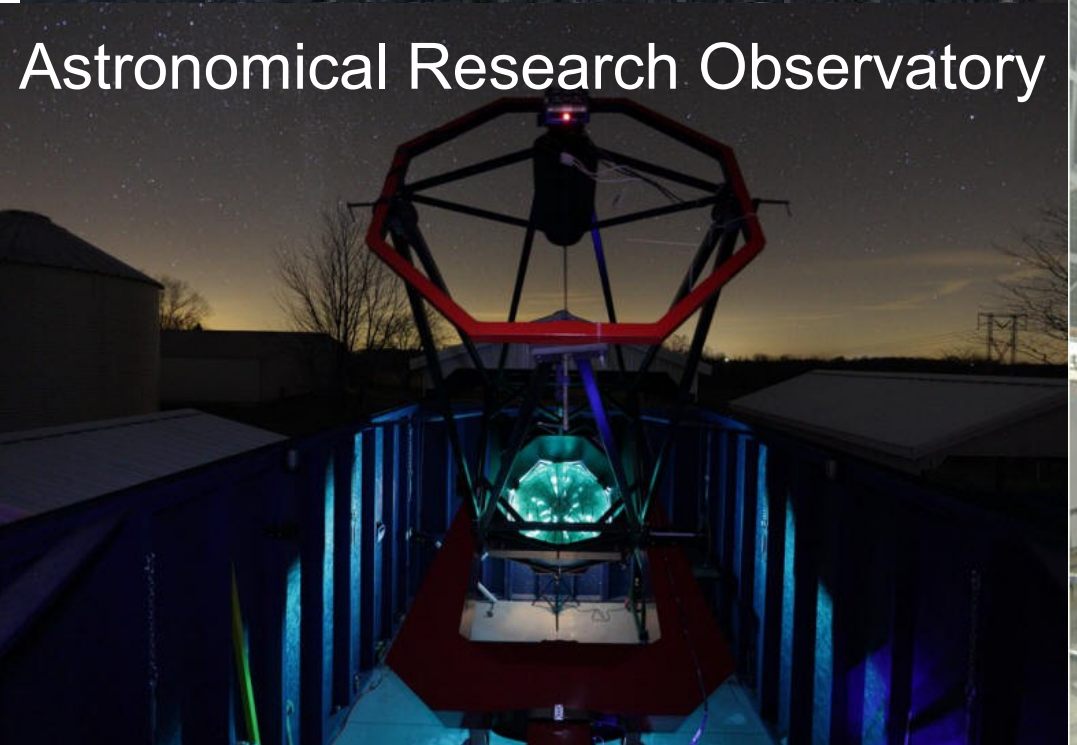
Adding functionality for best handling close approaches.
Adding in gravitational harmonics where needed.
Adding in GR terms where needed.


Near-Earth Asteroid Discoveries by Survey
All NEAs (as of 2018-Nov-11)
Number Discovered
2000
1500
1000
500
0
1995
2000
2005
2010
2015
Discovery Date
LINEAR
NEAT
Spacewatch
LONEOS
Catalina
Pan-STARRS
NEOWISE
ATLAS
All others
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)


MPC 1-opposition orbits versus year
1-opposition orbits
Fraction of Orbits
Year
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1995
2000
2005
2010
2015
PS1 begins.
Fainter limiting magnitude
~half of 1-opposition orbits have > 15 day arcs



Spacewatch



LCOGT

Exposure Information

What

- Report “pointings” as exposures taken, or a planned sequence
- Community buy-in: PS, ATLAS, Catalina:
- All are welcome!!

Why

- Coordination of NEO follow-up activities
- Internal MPC data pre-processing
- Pre-covery.

How

- Automated submission of JSON file
- https://www.minorplanetcenter.net/pointings/

WIP

- Current: Testing live submissions
- Nov 1st, 2018: Announcement & Query API
- Mid-Nov 2018: Integrate into NEOCP

E.g.

- For square equatorially-aligned field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