Minor Planet Center: Status and Plans

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Agenda

- MPC background
- Previous challenges
- MPC developments
- MPC and LSST

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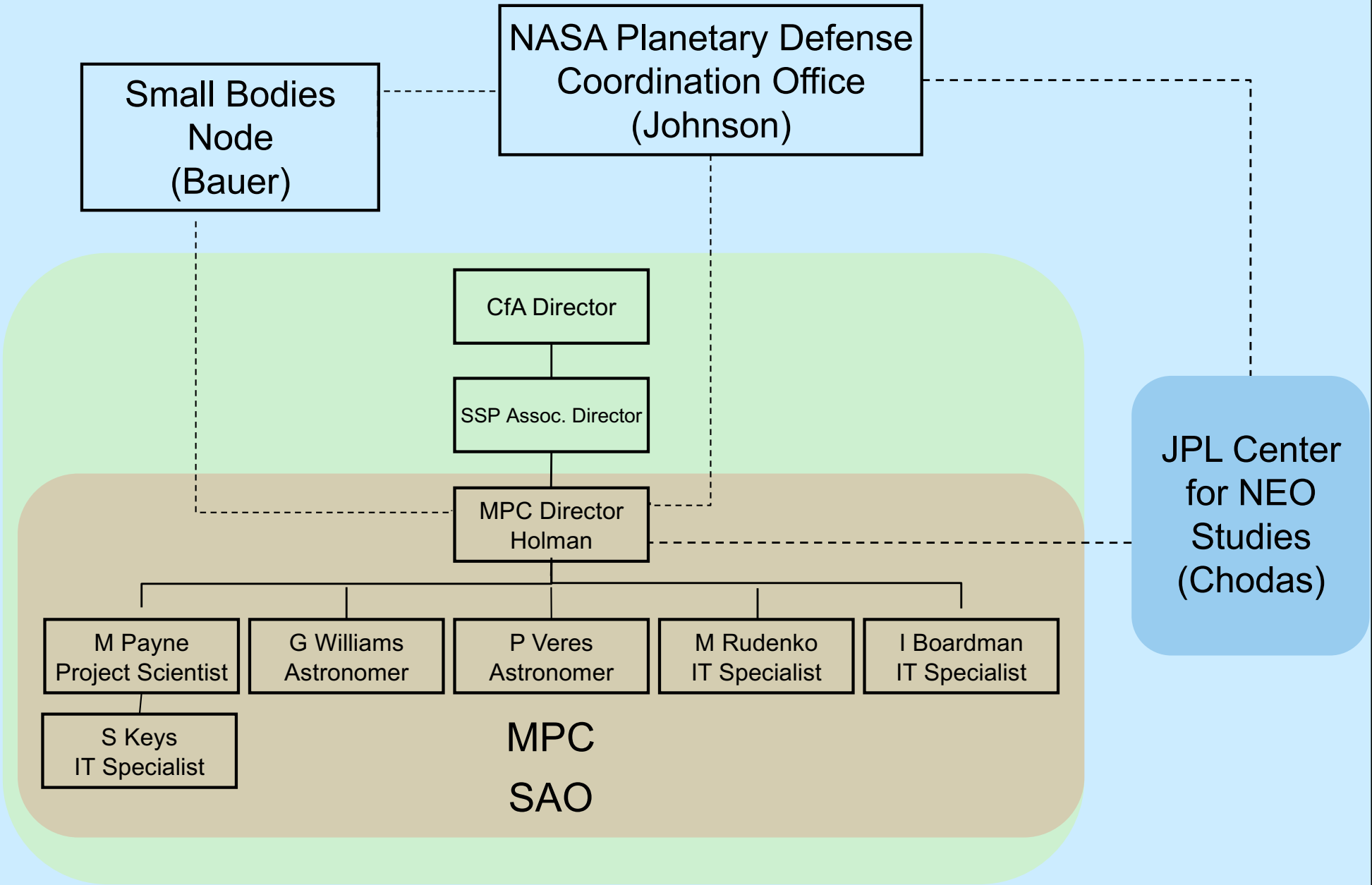
Minor Planet Center Organization

- Hosted by the Smithsonian Astrophysical Observatory (SAO) at the Harvard-Smithsonian Center for Astrophysics (CfA).
- Granted authority for operation by the International Astronomical Union (IAU).
- Has become a functional sub-node of the Small Bodies Node (SBN) of the NASA Planetary Data System.
- Funded 100% by NASA's Near Earth Object Observations (NEOO) program since 2008, through early 2017. Now funded through a Cooperative Agreement via a sub-award from U Maryland. SBN is responsible for oversight of the sub-award.
- Funded to grow to 10 FTEs + equipment + travel.

MPC Team


NASA Planetary Defense Coordination Office (Johnson)
Small Bodies Node (Bauer)
CfA Director
SSP Assoc. Director
MPC Director Holman
JPL Center for NEO Studies (Chodas)
M Payne Project Scientist
G Williams Astronomer
P Veres Astronomer
M Rudenko IT Specialist
I Boardman IT Specialist
S Keys IT Specialist
MPC
SAO

Roles and Responsibilities

- Keep up with NEO discoveries and orbits *in real time*, as required by NASA.
- Maintain the NEO Confirmation Page to facilitate coordination of NEO follow-up observations. (50-100 unique objects posted each night)
- Warn of NEOs coming within 6 Earth Radii within 6 months. For the MPC, the time horizon is more like 6 days because of discovery circumstances.
- Identify NEOs from observations of mostly Main Belt Asteroids (which account for >99% of incoming observations) because NEOs can have MBA-like motions. (An "observation" means a single astrometric measurement.)
- Process ~2 million new observations reported each month. MPC database currently holds ~170 million observations.
- Maintain and provide access to database of more than 700,000 objects with known orbits (~500,000 are numbered, i.e., have highest quality orbits).
- Process observations from any and all sources (~200 active observatory codes/year from ground-based optical and radar, and space-based IR data). The bulk of observations come from just a few large surveys: Catalina Sky Survey + Mt. Lemmon Survey, Pan-STARRS, and NEOWISE (space-based).
- Designate new asteroid discoveries.

Roles and Responsibilities

- Archive all of our data with the Planetary Data System.
- Maintain digest2 tracklet classification code.
- Mirror databases
- Prepare for increased data flow expected from the Large Synoptic Survey Telescope (LSST) and possible future space-based surveys.
- Interact with our user base of astronomers through online and phone communications, conferences, workshops, etc.
- Interact with the public through interviews (TV, radio, webcast) and other outreach and communication channels.

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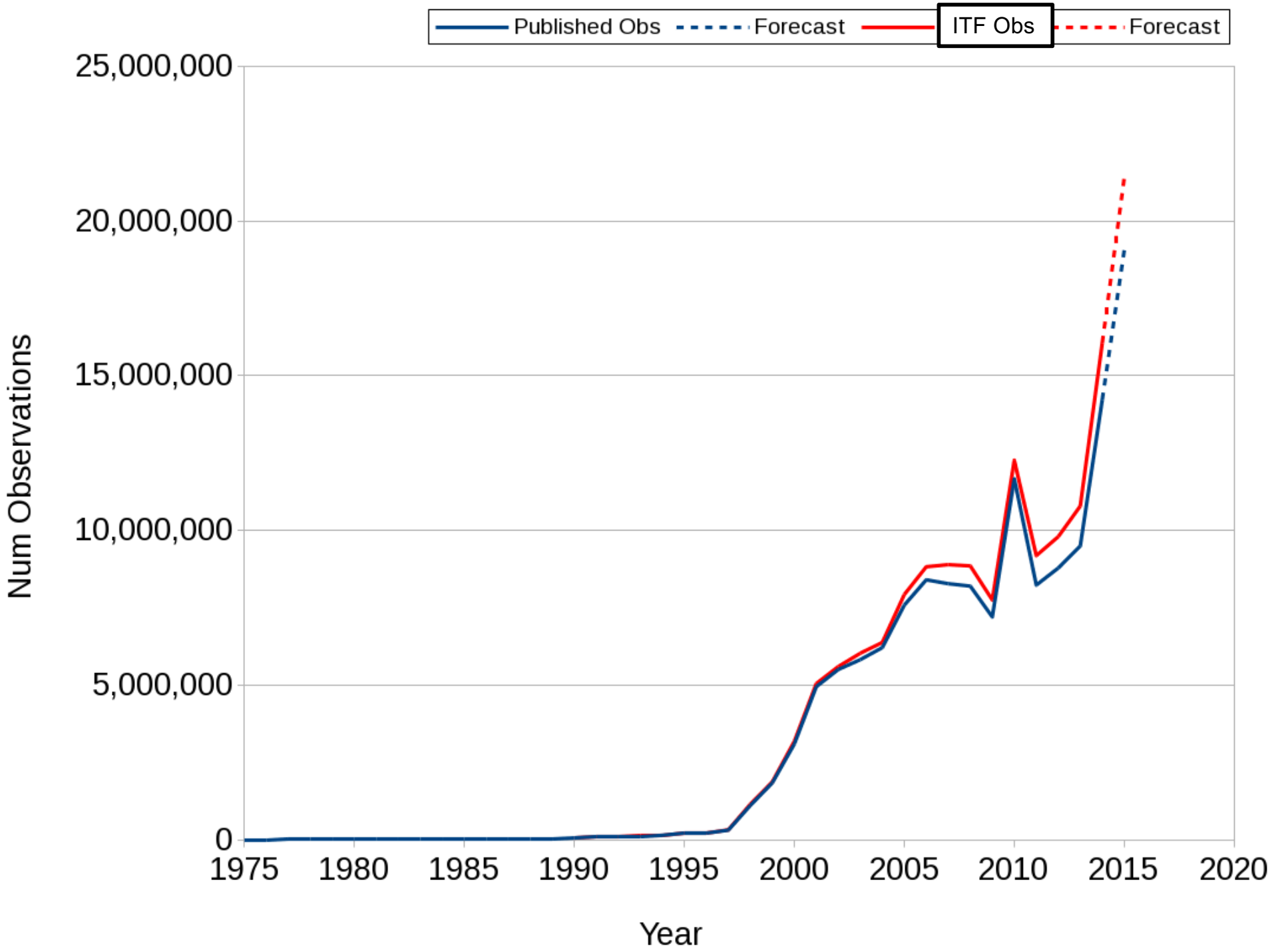
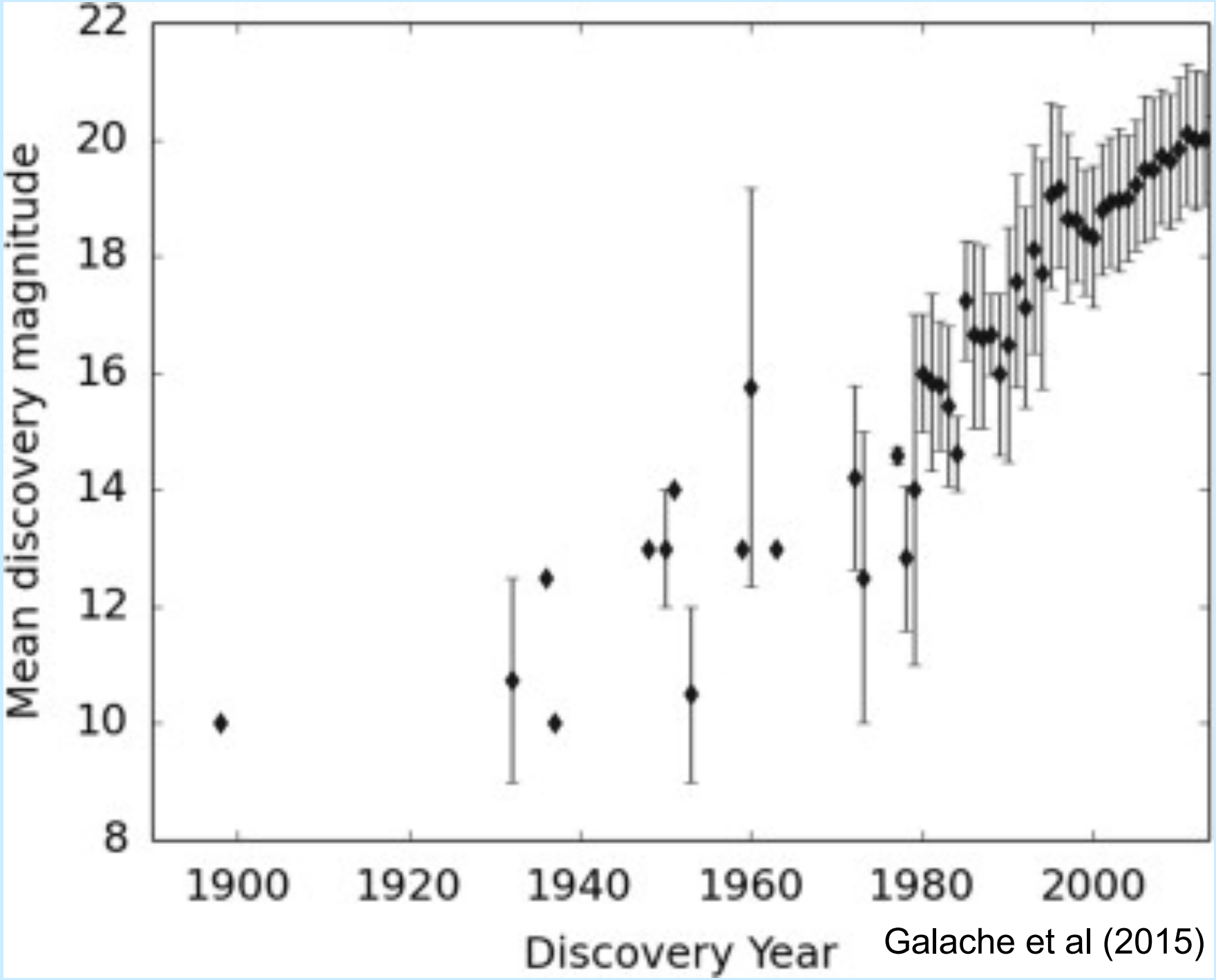
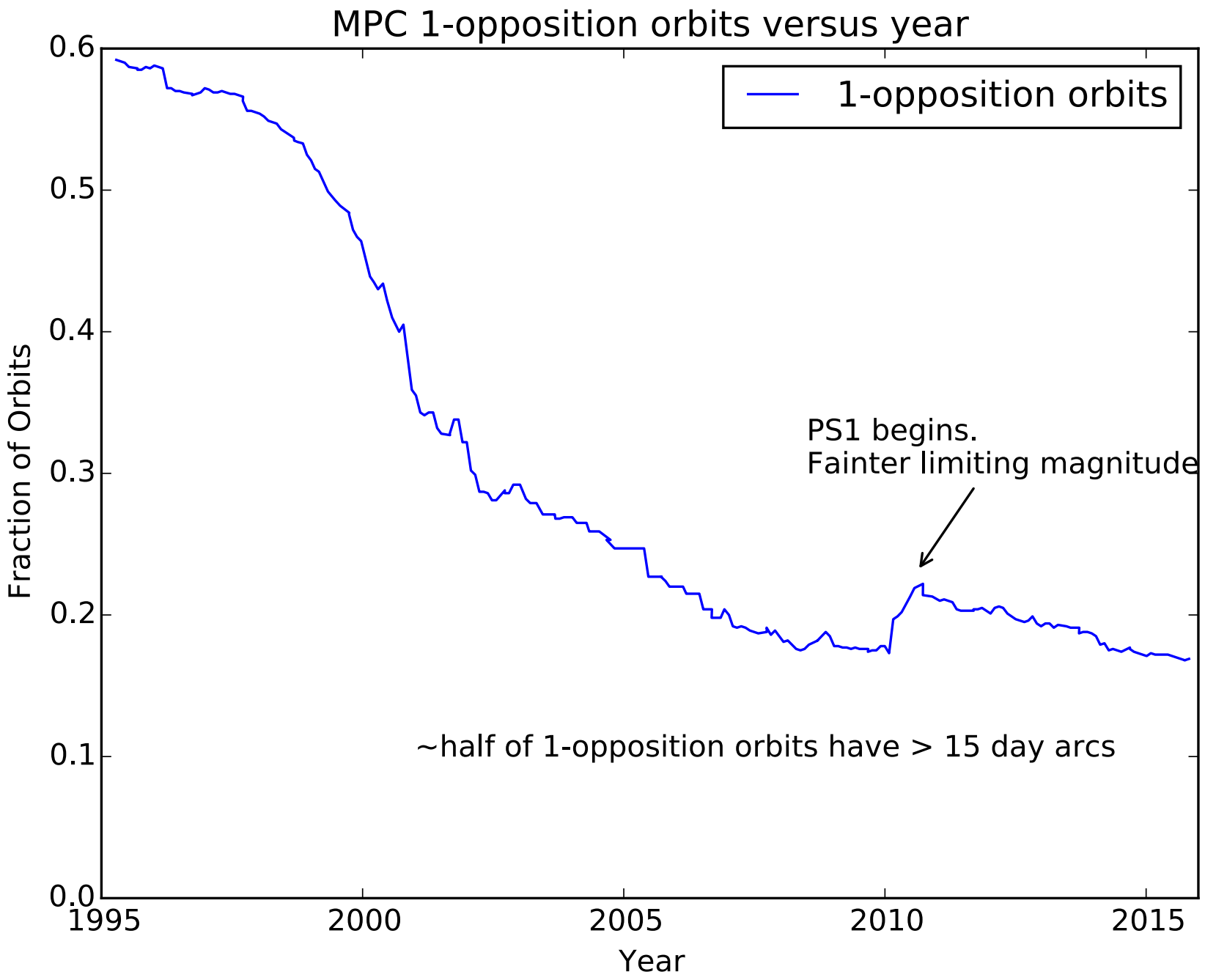

Published Obs
Forecast
ITF Obs
Forecast
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Num Observations
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year



Galache et al (2015)


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

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MPC Developments

• Developing new data processing pipeline to cope with expected increase in data flow over the next ~10 years, with improved automation and robustness.

Drawbacks of Current Pipeline

- Limited staff knowledge and involvement.
- Documented mostly with the code itself.
- Only accepts MPC1992 format observations.
- Unlikely to cope with an addition 100x increase in observation volume.

New MPC Pipeline Rationale

- Modernize to use current operating systems and programming languages.
- Broaden the personnel base capable of using, maintaining, and improving the code amongst MPC staff.
- Cope with expected data flow increase over the next ~10 years with improved automation and robustness.
- Incorporate new formats for observations and orbits.
- Incorporate unit and regression testing.
- Provide full documentation.
- Provide more functionality to the community.

New Pipeline Features

- Target platform: Linux, Python/Fortran/C(++), Postgres.
- Very modular, highly documented.
- Multi-programmer project.
- Source code stored on BitBucket.
- Will accept new observations submission format(s).

MPC Developments

- New computing infrastructure:
  - Deployed computing cluster to the Smithsonian's Herndon Data Center in Virginia.
  - Deploying similar hardware to SAO Cambridge Discovery Park site.
  - Exploring cloud computing, starting with serving static files via AWS.
  - Exploring using Harvard's Odyssey Research Computing Facility.

MPC Developments

- New ADES observation format:
  - Developed from a meeting at SAO in May 2015, led by Steve Chesley.
  - Includes many more fields than the present MPC data format.
  - XML and PSV versions.
  - The MPC is ready to accept ADES-format submissions. Export of ADES
  - Converting MPC archive to ADES.
  - Assigning submissionIDs and observationIDs.
  - Still accepting 80-char format.

www.minorplanetcenter.net/iau/info/ADES.html

MPC Developments

MPC is hiring:

Hired a Software Developer (Ian Boardman).
Hired a Project Scientist (Matt Payne).
Hired an Astronomer (Peter Veres).

Advertising for:

Web Developer
MPC Fellow -- 2 year postdoc position from astronomy, CS, data science, etc

Plan to hire Data System Specialist

MPC Developments

- Collecting exposure information:
  - Report a planned sequence of exposures (time, RA/Dec, camera, orientation, filter, etc.
  - Or report exposure information throughout the night, automatically.
  - Information can be incorporated into the NEOCP to allow other groups to see what regions of sky are being observed.
  - Allows the MPC to trigger calculations in advance of the observations being reported.

MPC Developments

MPChecker:

- Supply an RA/Dec, obsCode, date/time, and search radius, get back a list of the RA/Dec, mag, motion vector of all minor planets in that region.

- Making MPChecker faster and portable:
  - Pre-calculate where all the minor planets will be on a nightly basis, to support spatial indexing
  - Use Chebyshev interpolation tables to significantly speed up frequent calculations of minor planet positions.
  - Make the code available, and make the supporting tables available and updatable.

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MPC and LSST

- Processing 10^5 observations/night, nearly all real.
- 10^2 -10^3 exposures/night.
- 170 x 10^6 observations in database.
- 700 x 10^3 orbits.
- ~10^7 observations in the Isolated Tracklet File (ITF).

- Will receive 10^6 -10^7 observations/night, many false.
- 10^2 -10^3 exposures/night.
- Number of observations in database will grow rapidly.
- Number of orbits in database will grow rapidly.
- The size of the ITF will grow rapidly, and it will be mostly false tracklets.

MPC and LSST

- The MPC would like LSST to function like any other survey.
  - LSST reports observations, in tracklets, as soon possible (nightly).
  - MPC processes the data and makes it available to the community, as soon as possible (near real time).
  - MPC assigns submissionIDs, observationIDs, and designations.
  - MPC identifies known objects and makes its best effort to link with previous observations.
  - MPC facilitates linking by LSST and other groups.

MPC and LSST

- LSST will not be the only survey.
  - All the current NEO surveys are continuing and expanding.
  - Surveys with DECam, HyperSuprimeCam, and CFHT/MegaPrime are comparably deep and wide, and they are happening NOW.
  - New ground-based surveys like ZTF are being developed.
  - Space-based surveys are being developed.
- It is much more effective to bring all the data together, as soon as possible.
- There will still be an NEOCP in the LSST-era, because there will be other relevant surveys and follow-up.

MPC and LSST

- Computation speed for nearly all MPC calculations is not a bottleneck. (Linking can be computational intensive.)
- Staff time is the limited, so we need to focus on automating as many tasks as possible.
- We intend to work with LSST, as we do with any survey or individual MPC user, to test and smooth the observation submission and processing procedures.

Questions?

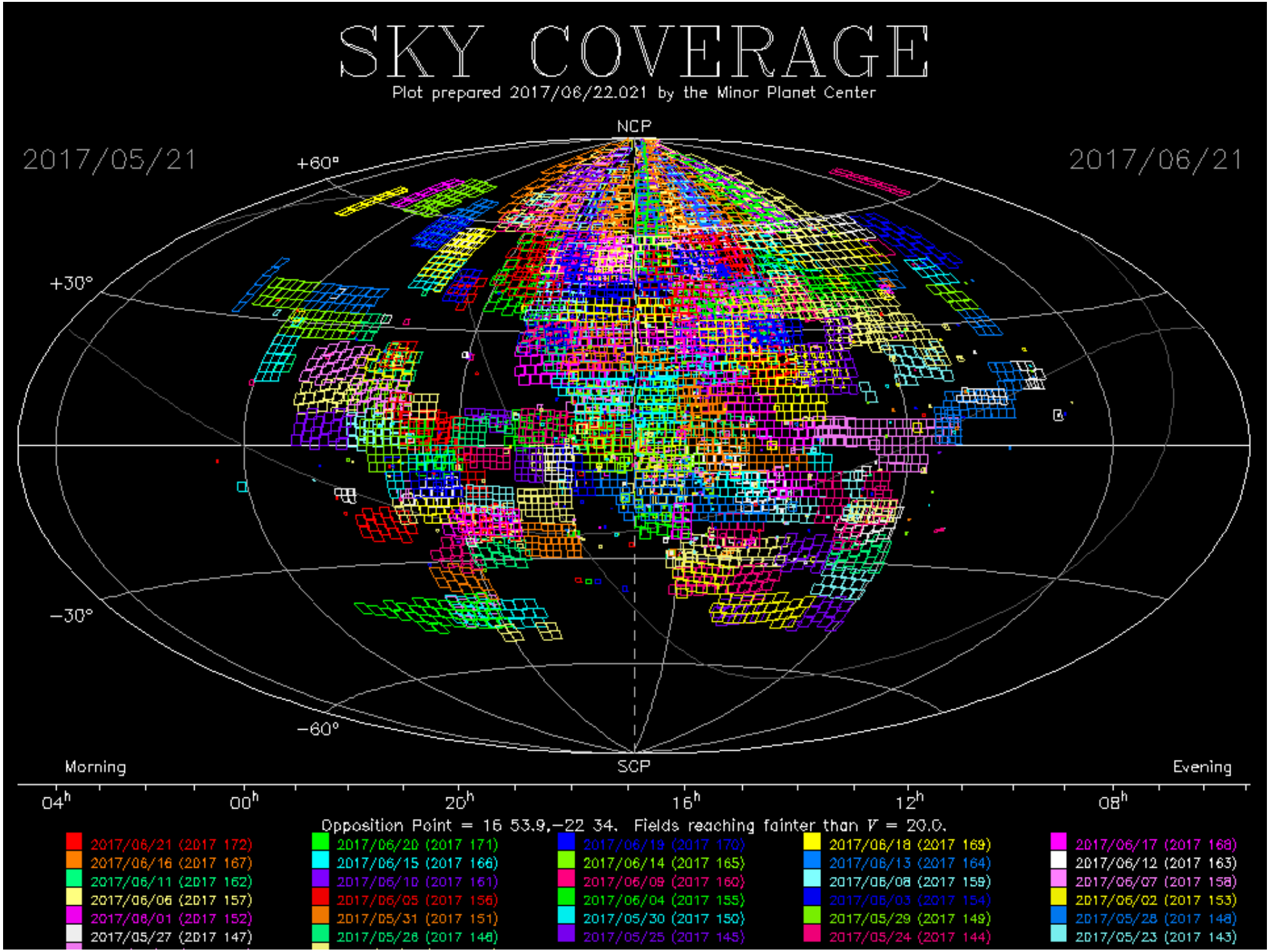
TNO designation requirements:

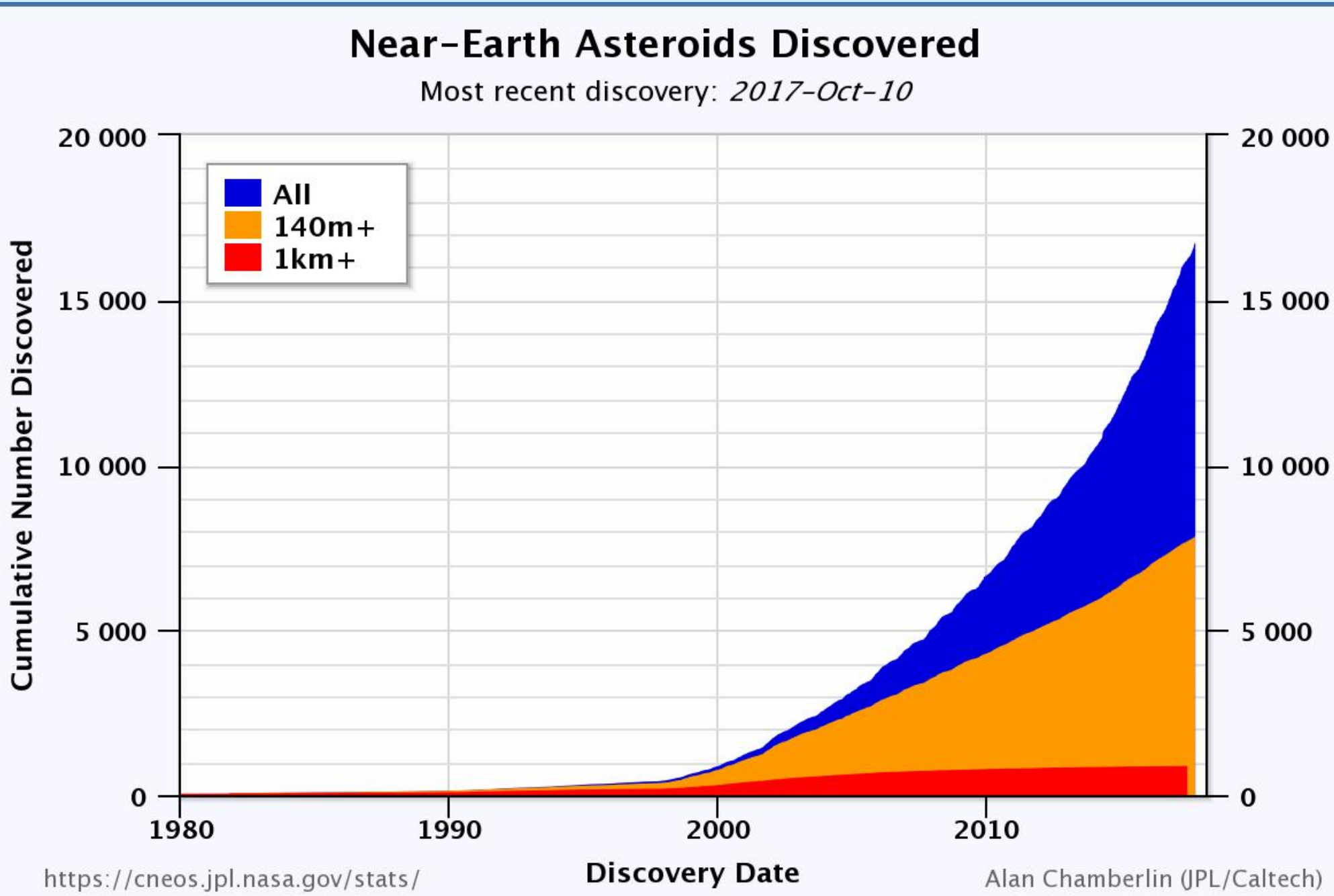
- Observations on at least 2 separate nights, near opposition
- At least 2 observations on those 2 nights
- Reported together in a single submission

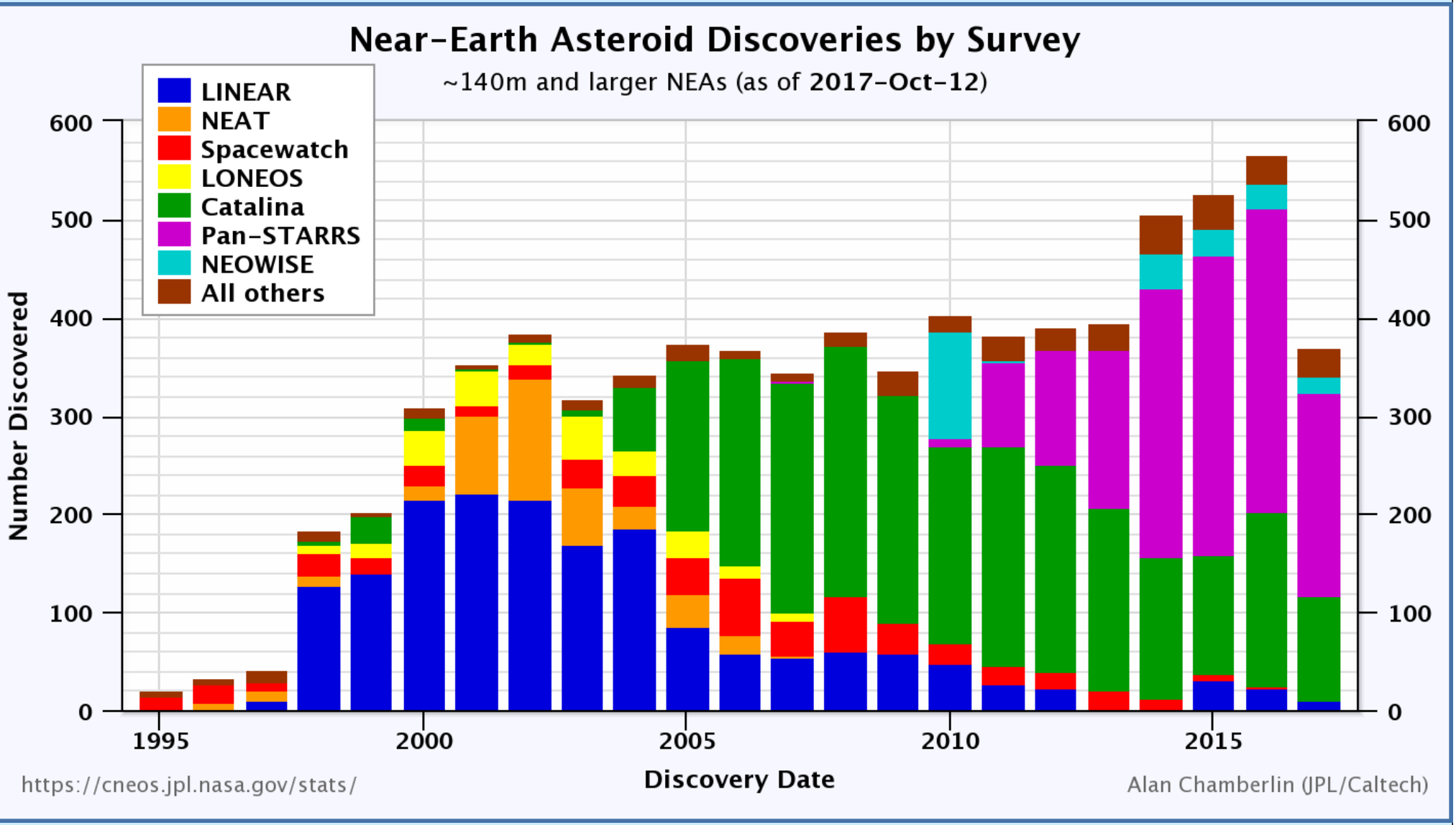
Orbital uncertainties and uncertainty maps

DIGEST2

- Digest2 is a tracklet classifier that outputs a likelihood the tracklet corresponds to an orbit classification of interest, e.g., a NEO. (~2,000 lines of code for C version.)
- 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.
- This automatic process replaces some, but not all, manual processes. The fixed threshold avoids oversights and misjudgments.
- The algorithm is a statistical ranging algorithm.
- Source code is publicly available.
- Sonia Keys is leading a paper on digest2.


SKY COVERAGE
Plot prepared 2017/06/22.021 by the Minor Planet Center
NCP
2017/05/21
2017/06/21
+60°
+30°
−30°
−60°
Morning
SCP
Evening
04h
00h
20h
16h
12h
08h
Opposition Point = 16 53.9,−22 34. Fields reaching fainter than V = 20.0.
2017/06/21 (2017 172)
2017/06/20 (2017 171)
2017/06/19 (2017 170)
2017/06/18 (2017 169)
2017/06/17 (2017 168)
2017/06/16 (2017 167)
2017/06/15 (2017 166)
2017/06/14 (2017 165)
2017/06/13 (2017 164)
2017/06/12 (2017 163)
2017/06/11 (2017 162)
2017/06/10 (2017 161)
2017/06/09 (2017 160)
2017/06/08 (2017 159)
2017/06/07 (2017 158)
2017/06/06 (2017 157)
2017/06/05 (2017 156)
2017/06/04 (2017 155)
2017/06/03 (2017 154)
2017/06/02 (2017 153)
2017/06/01 (2017 152)
2017/05/31 (2017 151)
2017/05/30 (2017 150)
2017/05/29 (2017 149)
2017/05/28 (2017 148)
2017/05/27 (2017 147)
2017/05/26 (2017 146)
2017/05/25 (2017 145)
2017/05/24 (2017 144)
2017/05/23 (2017 143)


Near-Earth Asteroids Discovered
Most recent discovery: 2017-Oct-10
All
140m+
1km+
Cumulative Number Discovered
20 000
15 000
10 000
5 000
0
1980
1990
2000
2010
Discovery Date
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)


Near-Earth Asteroid Discoveries by Survey
~140m and larger NEAs (as of 2017-Oct-12)
LINEAR
NEAT
Spacewatch
LONEOS
Catalina
Pan-STARRS
NEOWISE
All others
Number Discovered
0
100
200
300
400
500
600
1995
2000
2005
2010
2015
Discovery Date
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)

Community Questions/Suggestions

Uncertainty maps: there needs to be much work here.

Linking: what is being done to improve this?

We really need to be able to link over the 10-12 days of bright time, but some objects will fade anyway.

Isolated Tracklet File needs attention

Need a Users' group and a significantly bigger staff in order to be able prepare for the data of the next data.

Need to start training that staff now.

Need to address potential single point personnel failure

Community Questions/Suggestions

Develop a dictionary of IDs of minor planets

Documentation needed for absolute magnitudes.