The Minor Planet Center Status Report

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Smithsonian Astrophysical Observatory
Harvard-Smithsonian Center for Astrophysics

8 November 2015

MPC Organization

- MPC is hosted by the Smithsonian Astrophysical Observatory (SAO).
- MPC Director reports to SAO's Associate Director for Solar, Stellar, and Planetary Sciences (SSP) division (Andrew Szentgyorgyi).
- Granted authority for operation by the International Astronomical Union (IAU).
- Funded 100% by NASA's Near Earth Object Observations (NEOO) program since 2008, through early 2017.
- Funded via a grant rather than a contract.
- Funded for 6 FTEs + 1 graduate student + equipment + travel.

Minor Planet Center
Roles and Responsibilities

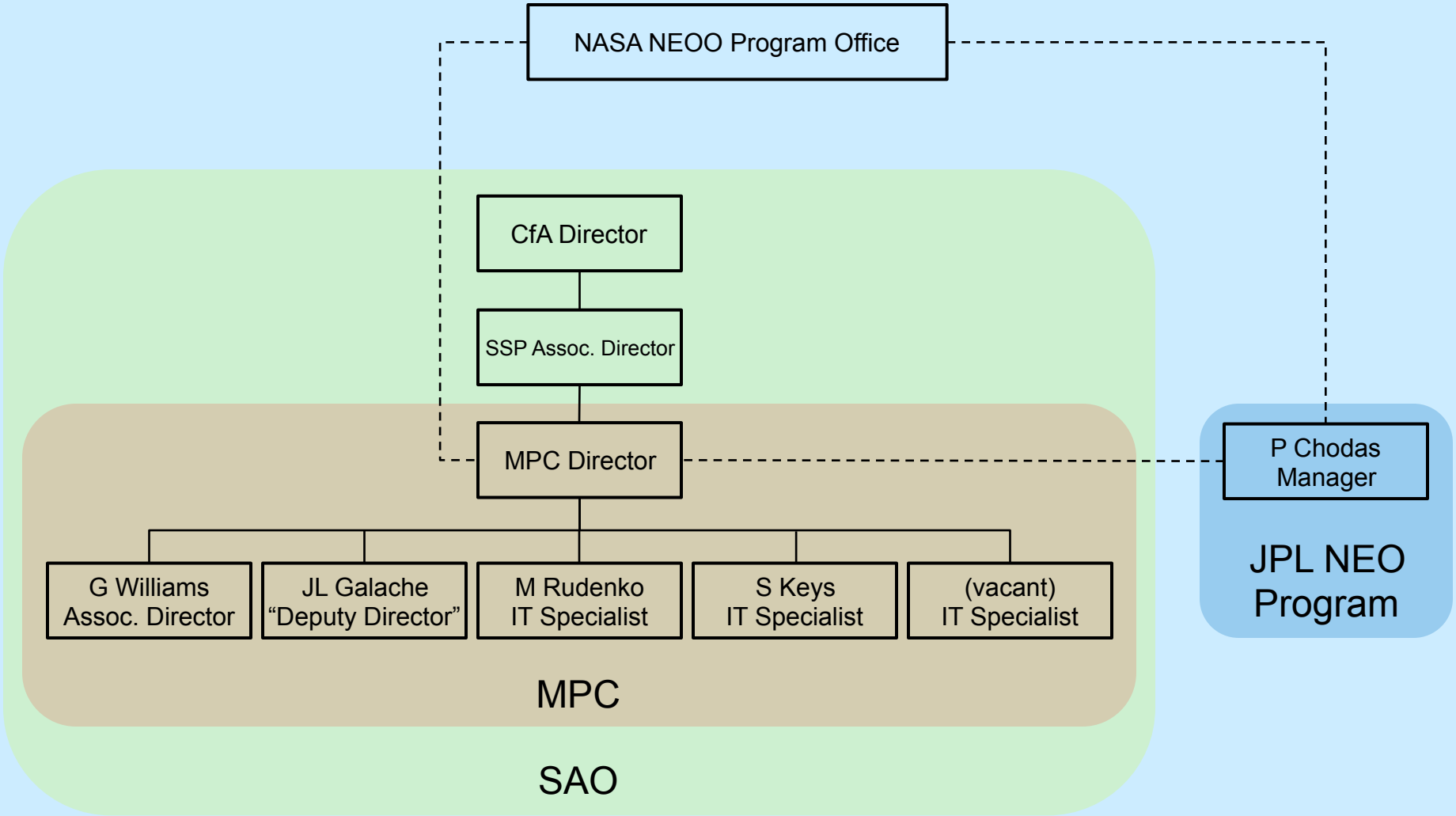
• The MPC is the world's nerve center for minor planet and comet observations.

• The MPC collects, processes, distributes all positional measurements, orbits, and discovery information for all minor planets and comets (and some natural satellites too).

• We alert the world of impending impacts for newly discovered NEOs.

• We help coordinate worldwide observers.

MPC Team


NASA NEOO Program Office
CfA Director
SSP Assoc. Director
MPC Director
P Chodas
Manager
JPL NEO
Program
G Williams
Assoc. Director
JL Galache
“Deputy Director”
M Rudenko
IT Specialist
S Keys
IT Specialist
(vacant)
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 ~130 million observations.
- Maintain and provide access to database of almost 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 (82,000 designations assigned in 2014, ~150,000 expected by end of 2015).

Roles and Responsibilities

- Prepare for increased data flow expected from Large Synoptic Survey Telescope (LSST) and future space-based surveys (NEOCAM) that are on the way.
- Interact with our user base of astronomers through online and phone communications, conferences, workshops, etc.
- Interact with the public through interviews (TV, radio) and other outreach channels.
- Exploit modern media outlets for communication and EPO.

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.

Time-Consuming Tasks

- Although the vast majority (>99%) of observations reported to the MPC are processed automatically, the fraction that is not handled automatically can be time-consuming. This includes:
  - ➢ Erroneous observations that have been incorporated into orbits and the databases must be extracted when they are identified.
  - ➢ Certain NEOs, TNOs, and satellites that need manual attention.
  - ➢ Some aspects of upkeep of the NEOCP, including interaction with the surveys.
- Hardware, software, and database installation and maintenance is also time-consuming.

NASA Review of MPC

Undertaken as a result of the resignation of Tim Spahr in January, 2015.

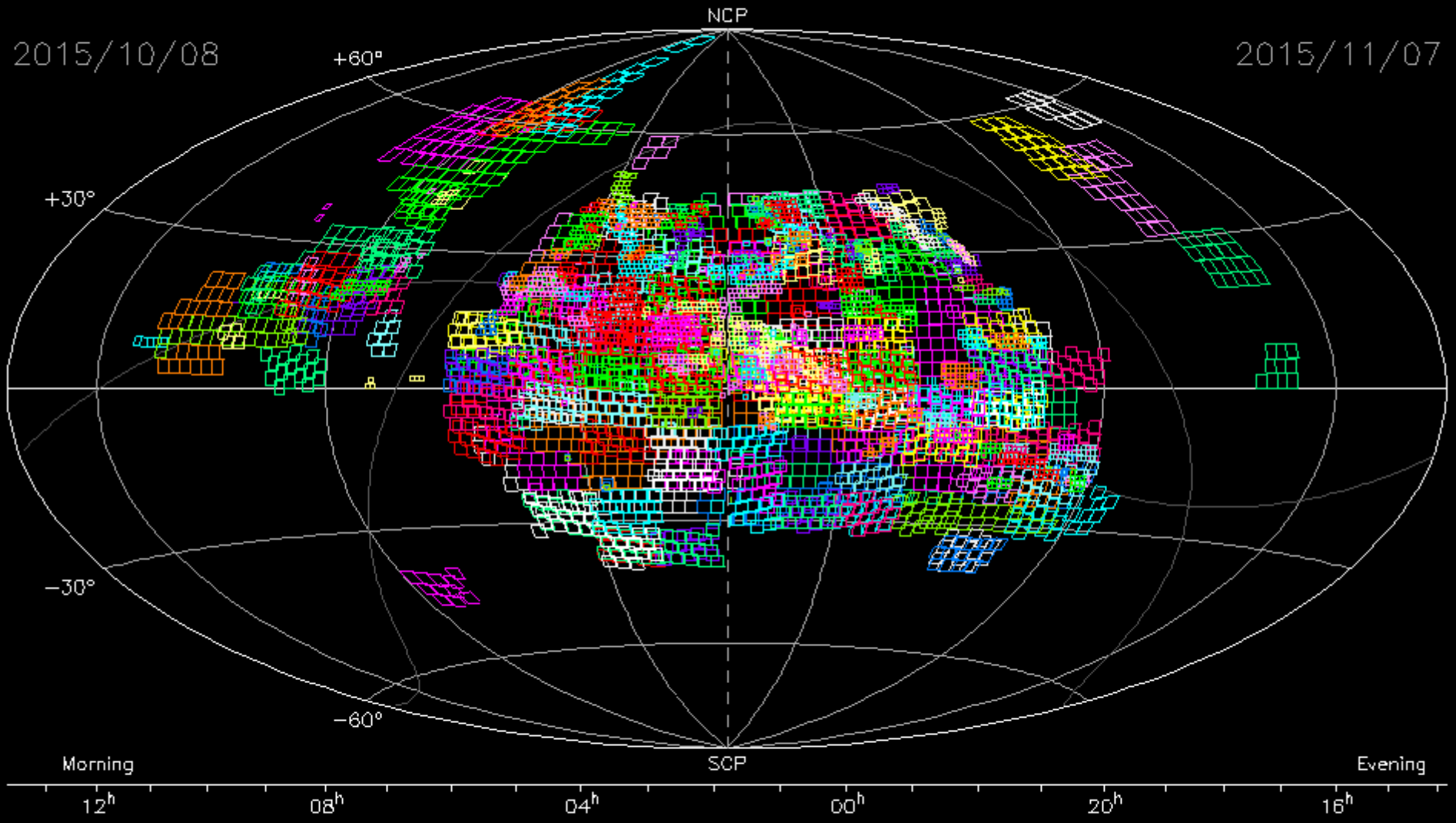
NASA convened a panel in May, 2015, to study SAO's handling of the MPC.

A draft report from the panel was presented to SAO Director and to NASA.

SAO has sent its response to the report to NASA HQ.

SKY COVERAGE

Plot prepared 2015/11/08.492 by the Minor Planet Center

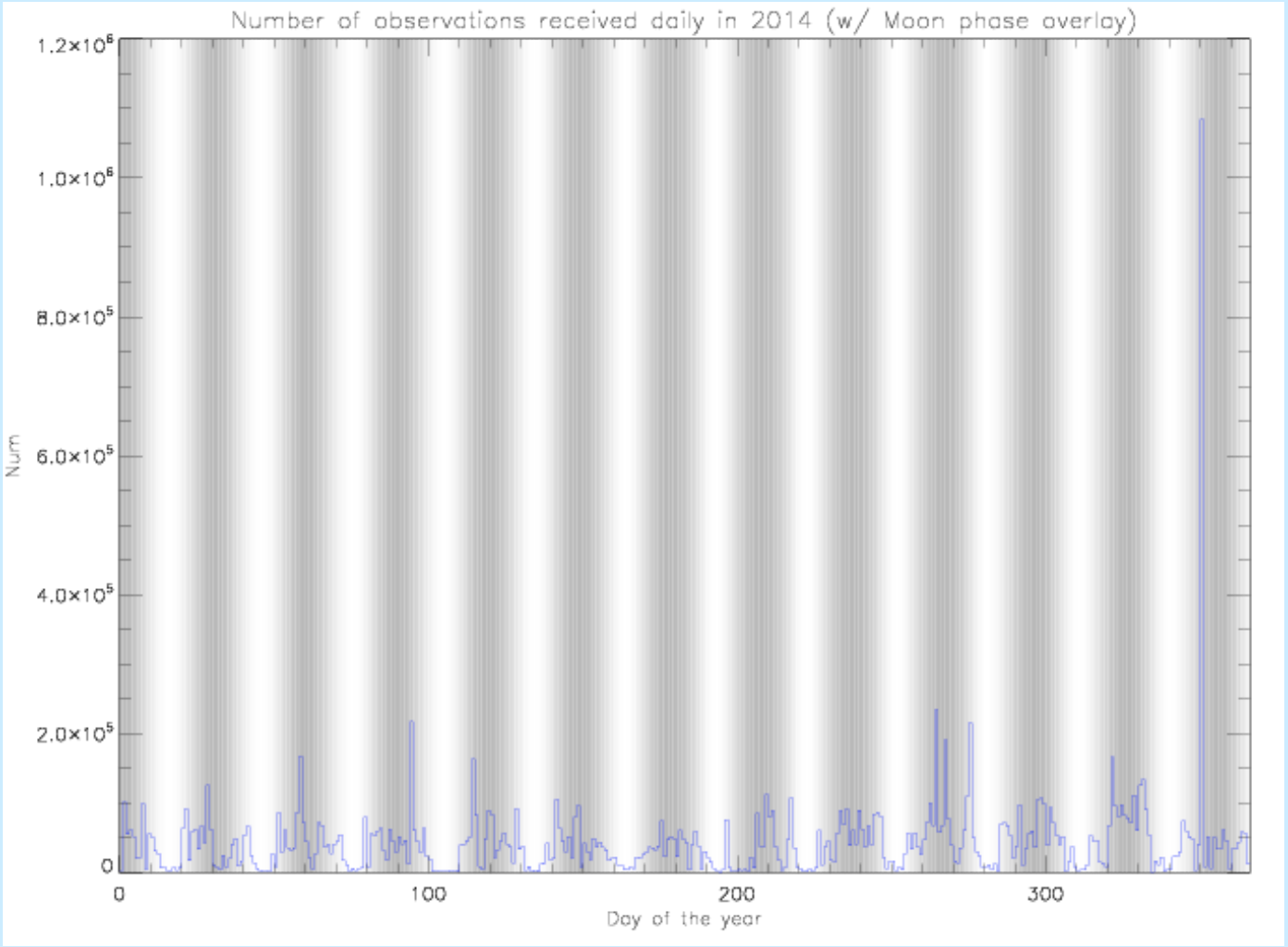


Opposition Point = 01 48.0,+11 08. Fields reaching fainter than V = 18.0.

2015/11/07 (2015 311)	2015/11/06 (2015 310)	2015/11/05 (2015 309)	2015/11/04 (2015 308)	2015/11/03 (2015 307)
2015/11/02 (2015 306)	2015/11/01 (2015 305)	2015/10/31 (2015 304)	2015/10/30 (2015 303)	2015/10/29 (2015 302)
2015/10/28 (2015 301)	2015/10/27 (2015 300)	2015/10/26 (2015 299)	2015/10/25 (2015 298)	2015/10/24 (2015 297)
2015/10/23 (2015 296)	2015/10/22 (2015 295)	2015/10/21 (2015 294)	2015/10/20 (2015 293)	2015/10/19 (2015 292)
2015/10/18 (2015 291)	2015/10/17 (2015 290)	2015/10/16 (2015 289)	2015/10/15 (2015 288)	2015/10/14 (2015 287)
2015/10/13 (2015 286)	2015/10/12 (2015 285)	2015/10/11 (2015 284)	2015/10/10 (2015 283)	2015/10/09 (2015 282)

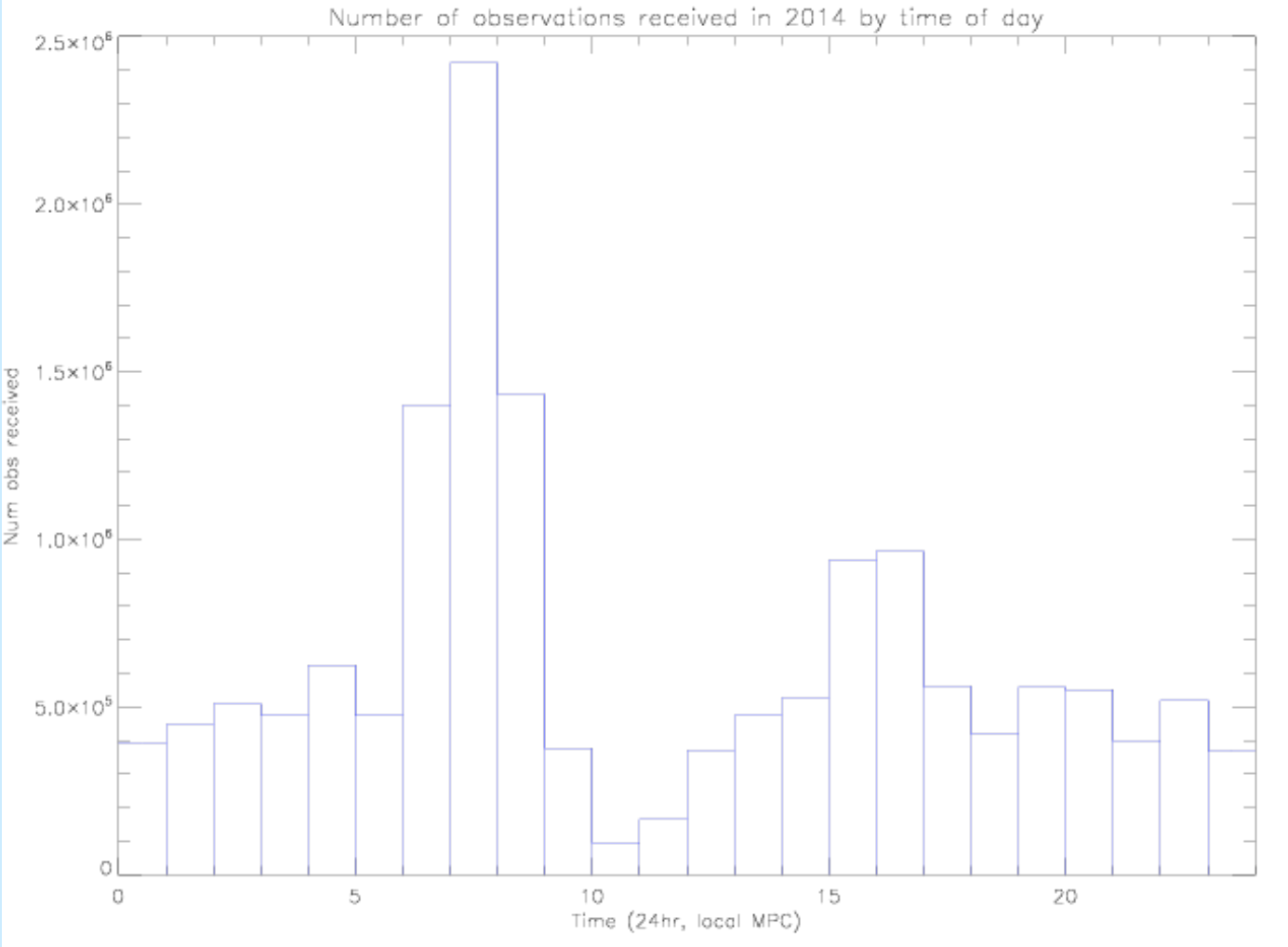
Data Influx

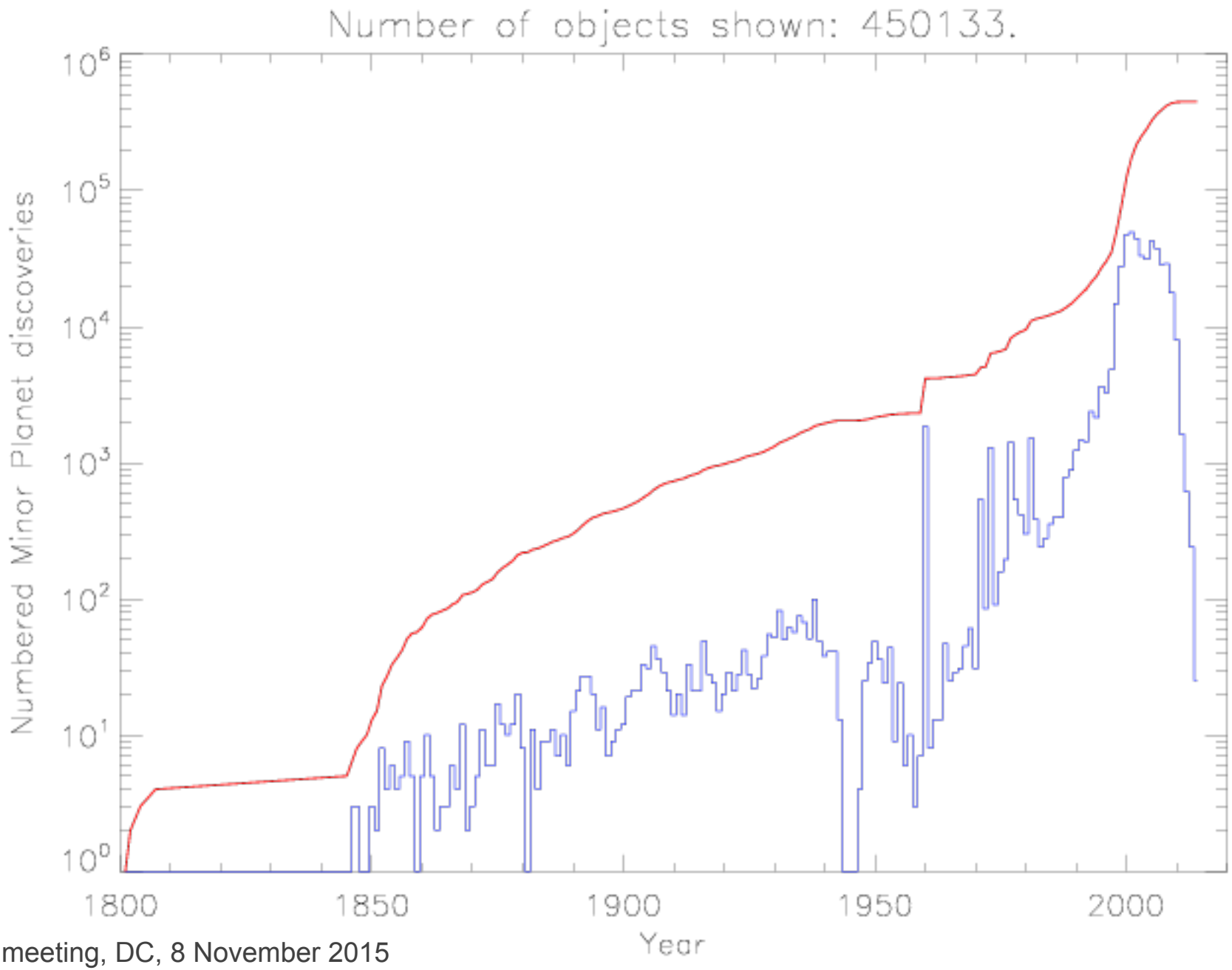
Constant data flow; observations come in everyday…

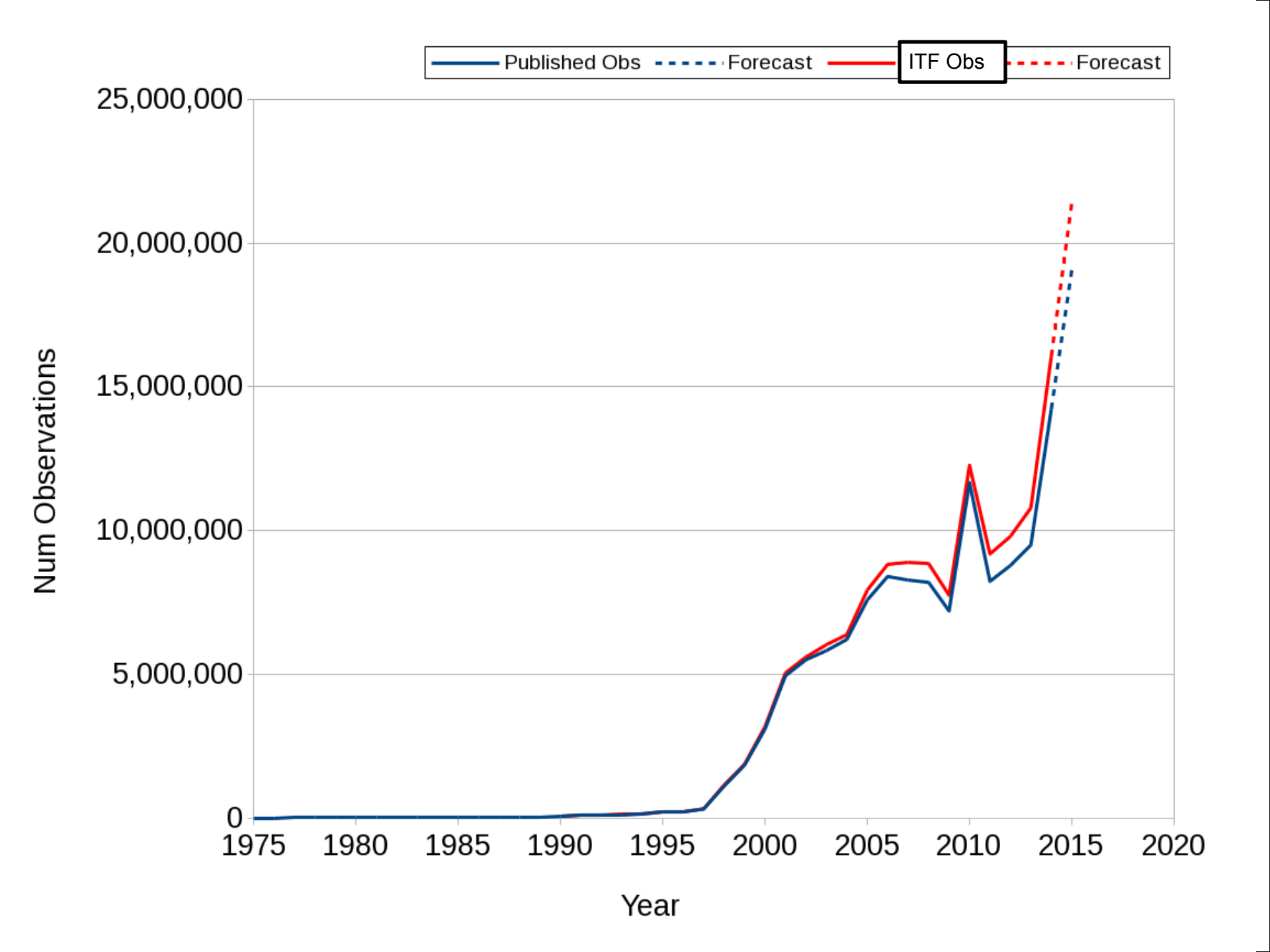


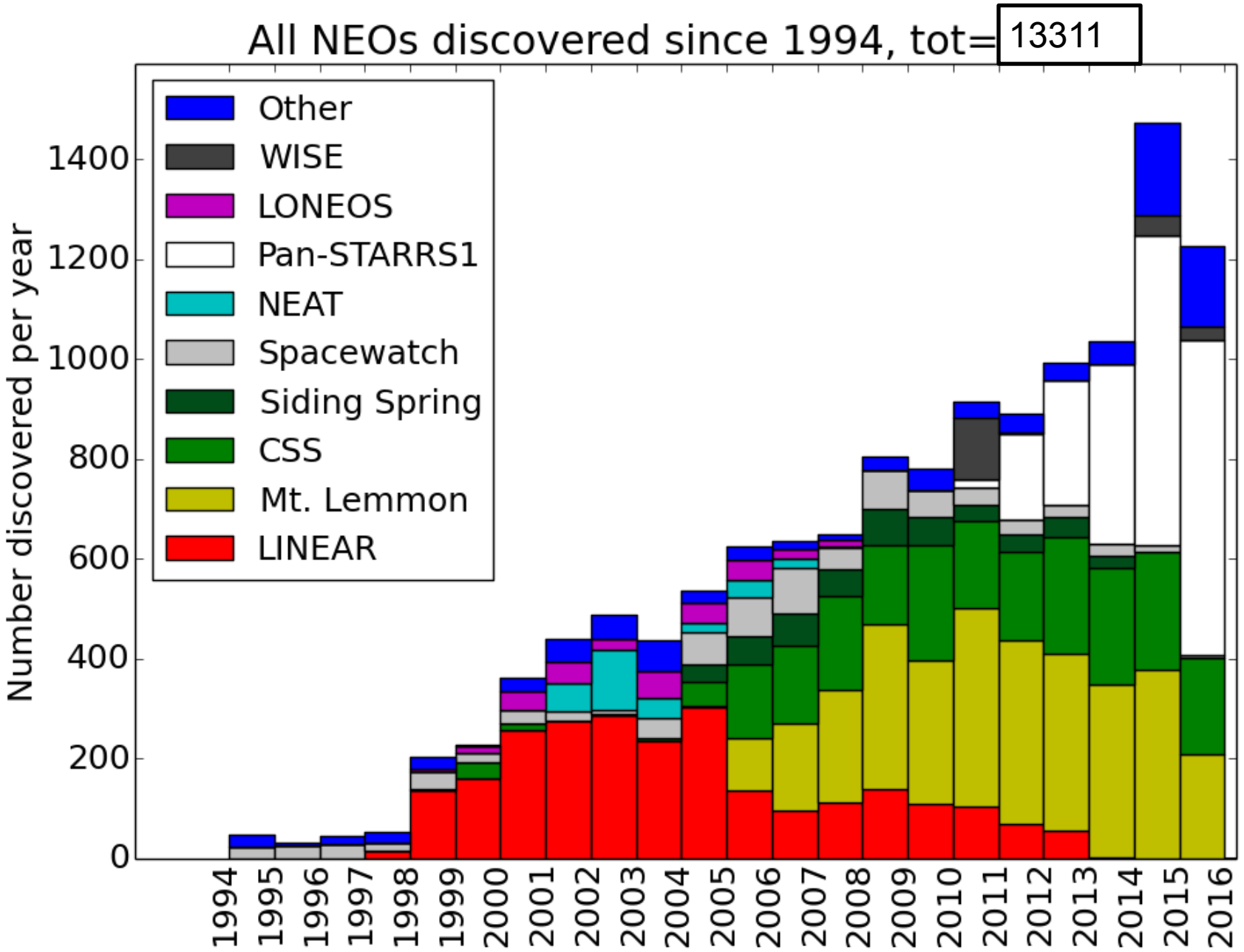
Data Influx

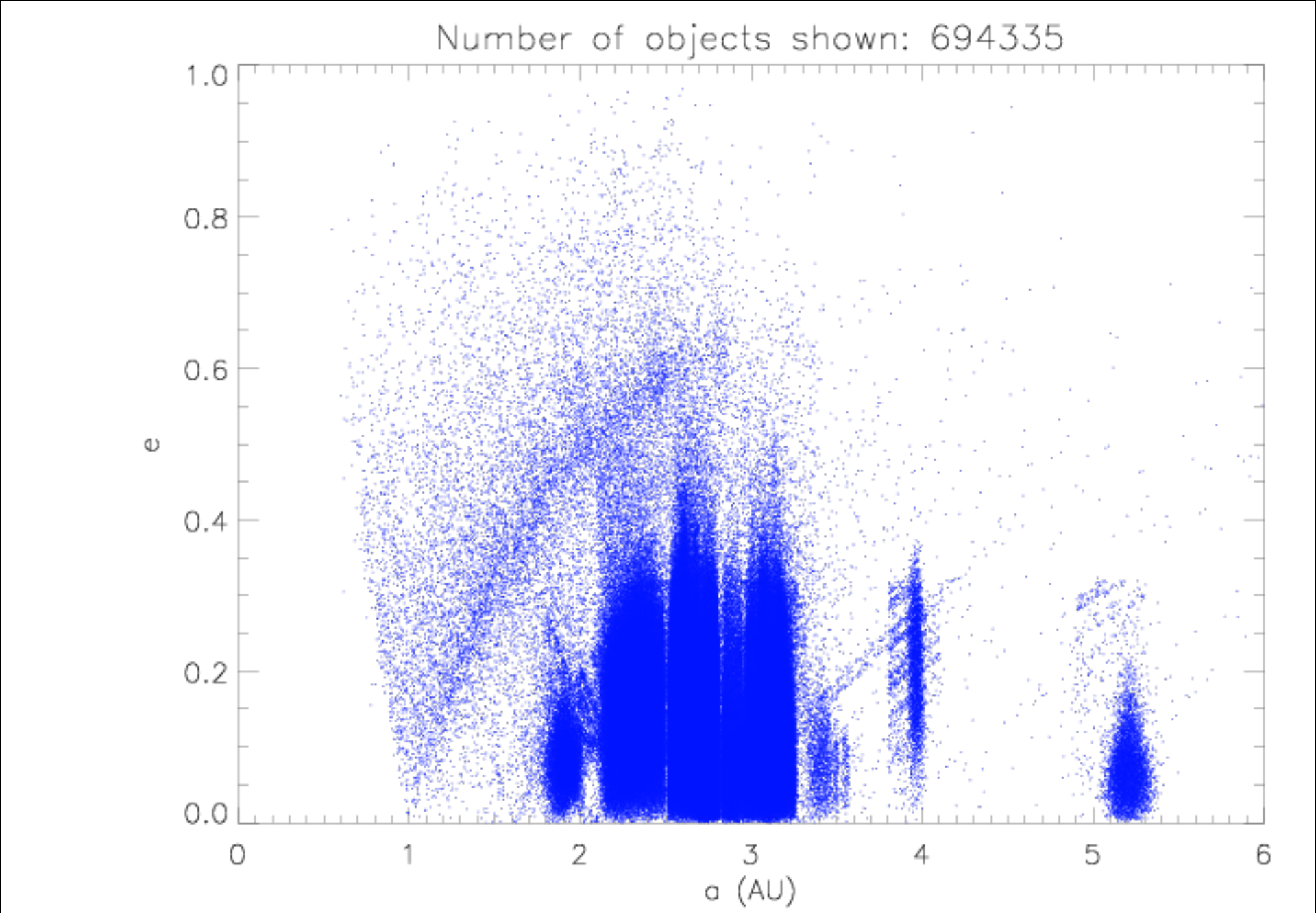
…all day.

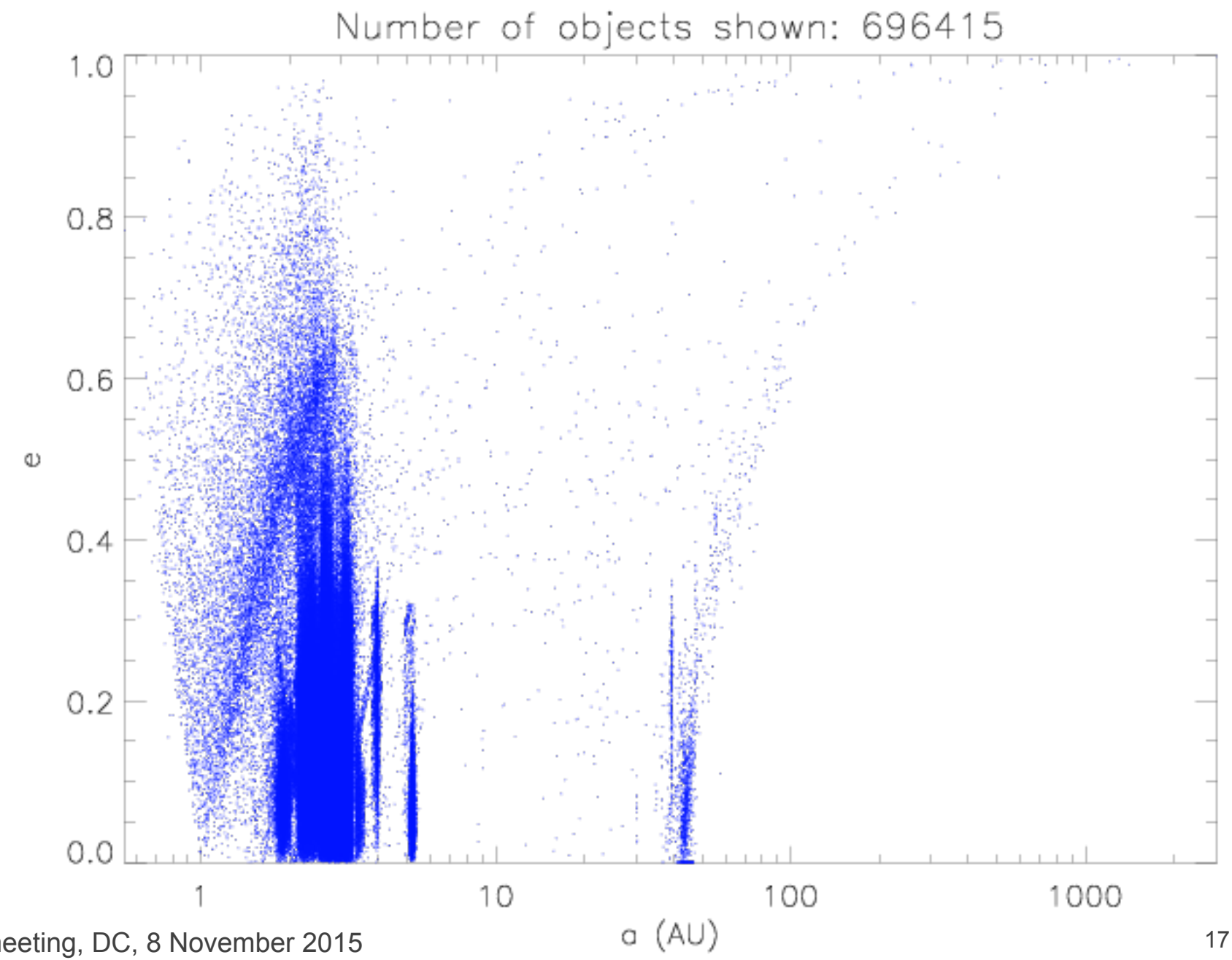


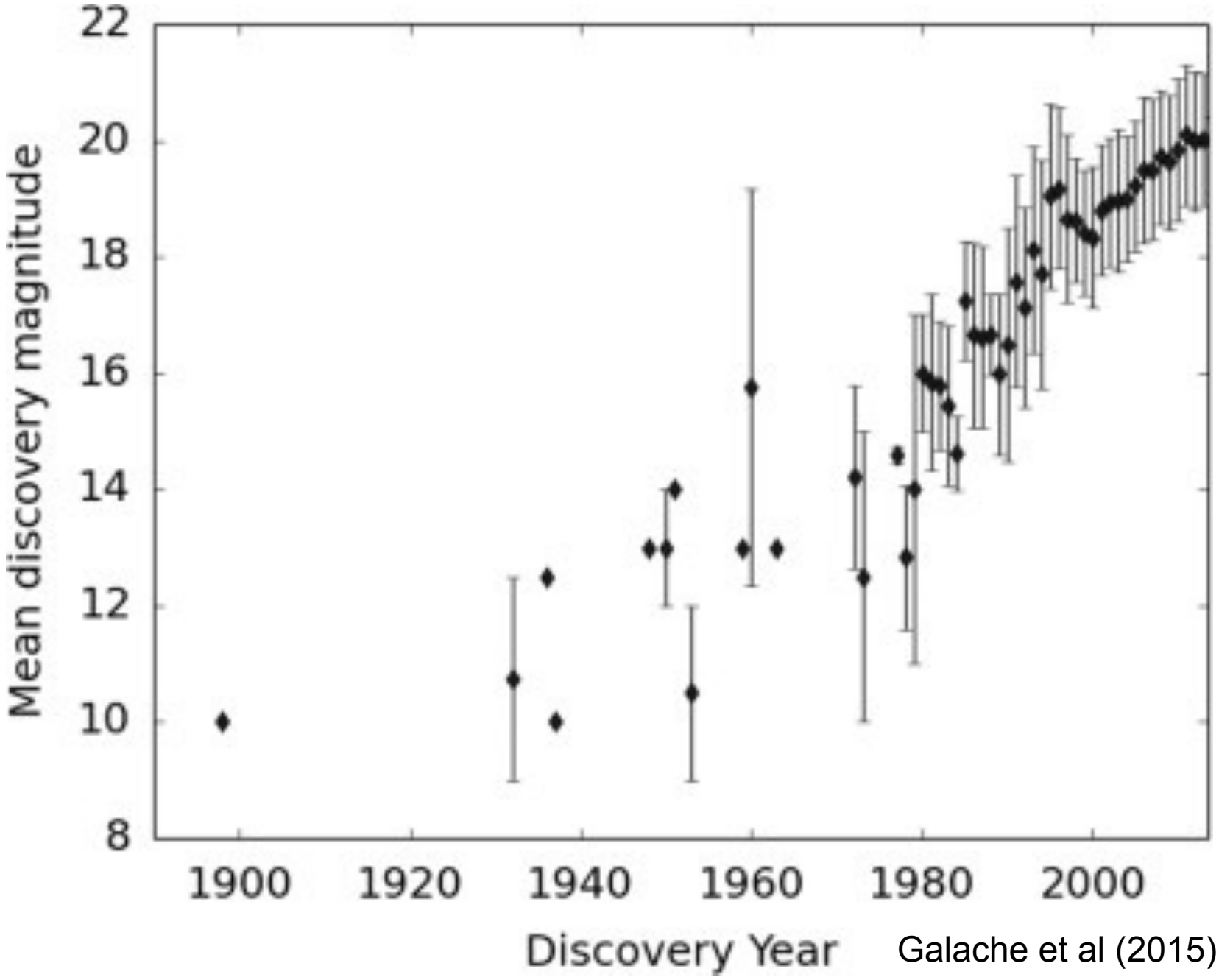

Number of objects shown: 450133.
Numbered Minor Planet discoveries
10^6
10^5
10^4
10^3
10^2
10^1
10^0
1800
1850
1900
1950
2000
Year


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

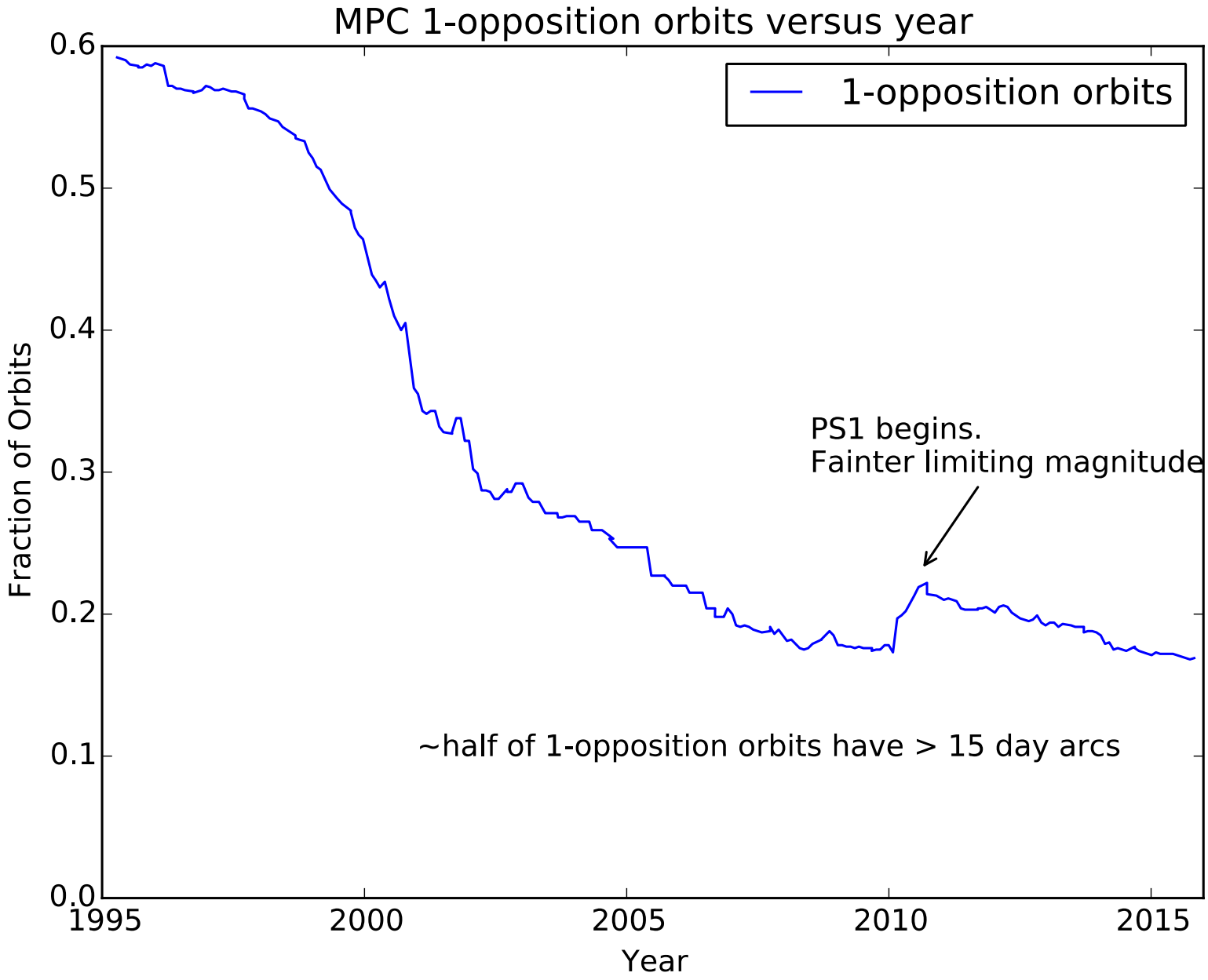

All NEOs discovered since 1994, tot= 13311
Other
WISE
LONEOS
Pan-STARRS1
NEAT
Spacewatch
Siding Spring
CSS
Mt. Lemmon
LINEAR
Number discovered per year
0
200
400
600
800
1000
1200
1400
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


Number of objects shown: 694335
1.0
0.8
0.6
0.4
0.2
0.0
e
0
1
2
3
4
5
6
a (AU)


Number of objects shown: 696415
1.0
0.8
0.6
0.4
0.2
0.0
e
1
10
100
1000
a (AU)



Galache et al (2015)


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

The Future of MPC Processing

New MPC Observation Processing Pipeline

Drawbacks of Current Pipeline

- Limited staff knowledge and involvement.
- Documented only in routines.
- Only accepts MPC1992 format observations.
- Unlikely to cope with further 2 order of mag. increase in observation volume.

New MPC Processing 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 source code openly to the community.

New Pipeline

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

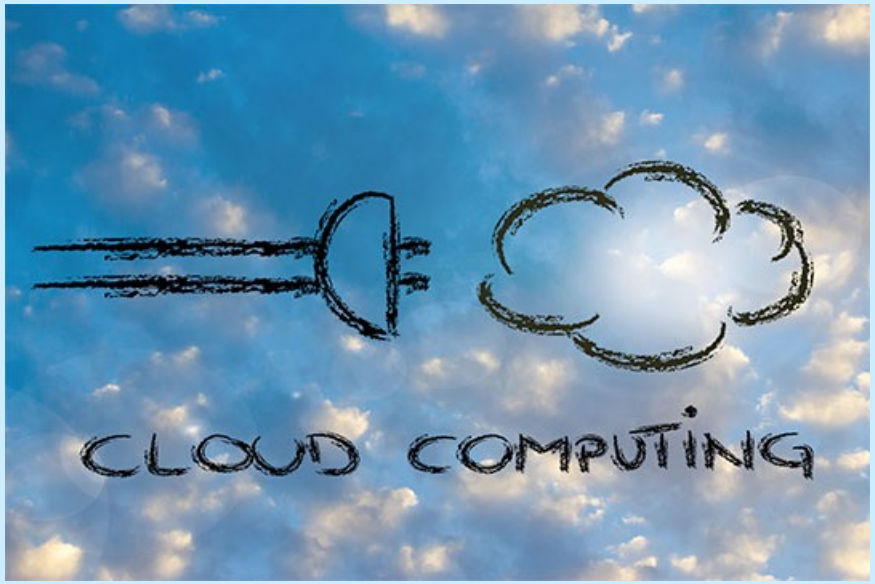
New Observation Format

- Developed from a meeting at SAO in May, 2015, led by Steve Chesley. Presented at the IAU GA.
- Will be primary format for submitting observations to MPC.
- XML and PSV
- Vastly greater number of designations.
- Accommodate more observing sites.
- Will include positional and timing uncertainties.
- Can accept microarcsecond precision (GAIA).
- UOIs (Unique Observation Identifier).

Future of MPC Operations

Short Term:
Move MPC machines to Smithsonian's computing facility in Herndon, VA.

Medium Term:



Thanks

MPC Team

Matthew Holman, Interim Director:

- Coordinates the team.
- Leads semi-weekly progress meetings.
- Oversees the budget, grant proposal.
- Responsible for personnel evaluations.
- Interacts with NASA NEOO Program Manager, as well as with JPL counterparts.

Holman has relevant experience through solar system dynamics background, previous work on ground-based and space-based searches for TNOs and irregular satellites. Holman leads the PS1 Outer Solar System key project and its pipeline development. Holman was the Associate Director of the CfA's Theoretical Astrophysics Division for over a decade.

MPC Team

Gareth Williams, Associate Director:

- Design and maintenance of observations processing pipeline.
- Design and programming for new observations processing pipeline.
- Point of contact for observation submission problems. Preparation of MPC publications and data within.
- Processing of imminent impactors.
- Represent MPC on various IAU committees.
- Interact with media.

MPC Team

J.L. Galache:

- Support the MPC Director in his duties and advise on MPC strategy.
- Interact with the asteroid community to identify areas of improvement in MPC services.
- Design new tools/services and oversee development.
- Institutional relations with mission-aligned organizations.
- Represent MPC at the International Asteroid Warning Network (IAWN).
- Manage MPC communications (public+social media) interacting with journalists and the public.
- Supervise research students and MPC volunteers.

MPC Team

Mike Rudenko, IT:

- Lead system+database administrator.
- Webmaster (including maintenance and new web tool development).
- Spec, maintenance and upgrade of MPC computer cluster.
- Design and maintenance of website and tools for the IAU's Committee for Small Body Nomenclature.
- Programming for new observations processing pipeline.
- Orbit computation and object identification.

MPC Team

Sonia Keys, IT:

- Maintenance of DIGEST2 code.
- Setup and maintenance of MPC source code repository.
- Monitor and update the NEO Confirmation Page.
- Provide technical assistance to observers.
- Programming for new observations processing pipeline.
- Orbit computation and object identification.

Interactions with Amateur Community
(and professionals behaving like amateurs)

- Used to waste a significant amount of time dealing with problematic data (several hours a week for two MPC staff).
- Previous MPC Director, Tim Spahr, implemented corrective measures ~2 years ago:
  - ➢ No more hand-holding for problematic observers. Incorrectly formatted observations are automatically sent back with error report.
  - ➢ Observers who continue to send bad observations may get their MPC ObsCode revoked.

Current Pipeline

- Developed over last 20+ years.
- Incremental increases in capabilities over time.
- Coped with 2+ order of magnitude increase in observations.
- Target platform: OpenVMS, DCL/Fortran, batch execution.
- Modular.
- ~6,000 lines of code, with calls to other non-pipeline-specific routines.

Cloud-Based MPC Web Services and Computations

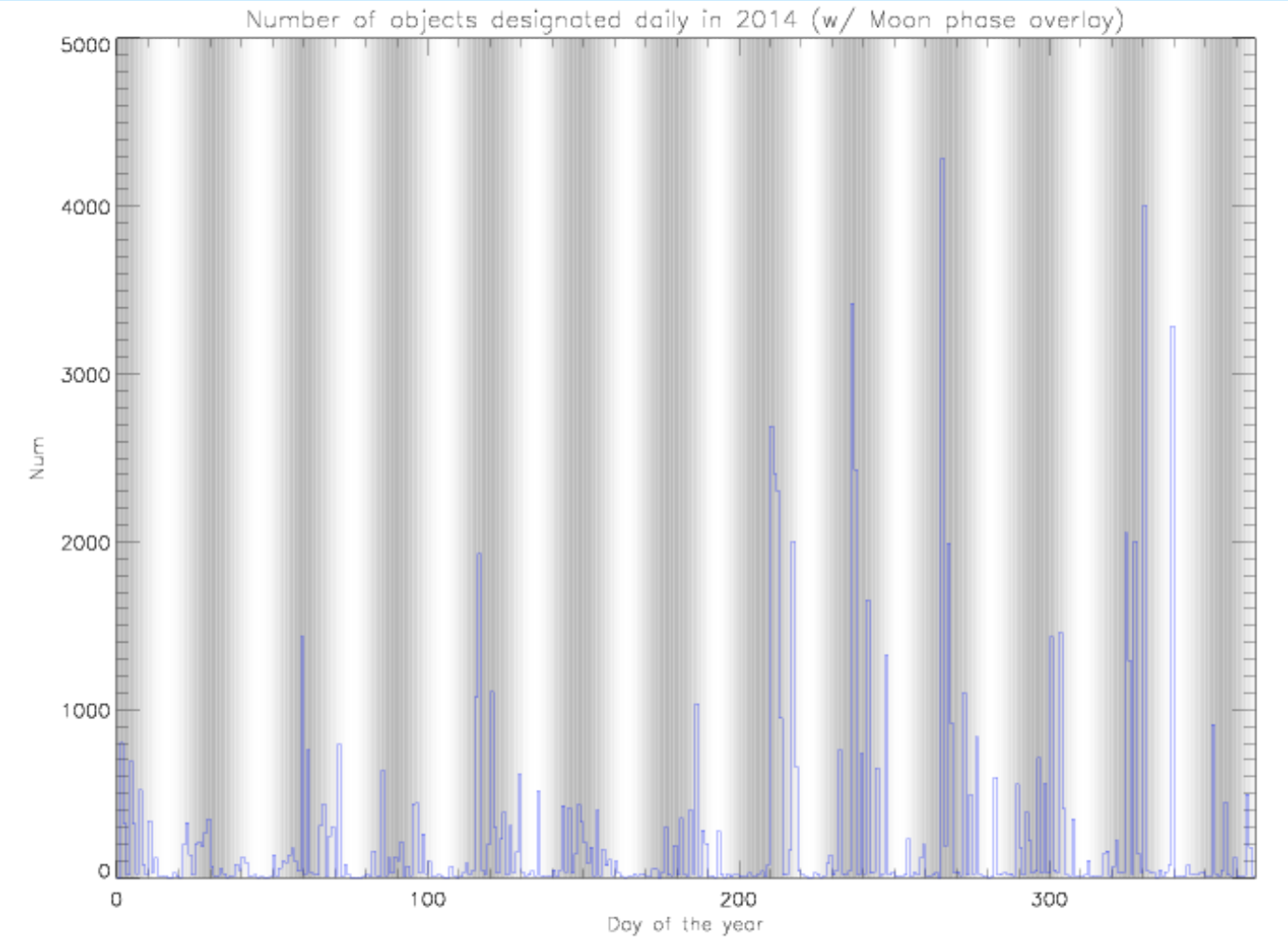
- Can elastically increase the scale of our operations with increased demand.
- Increased up time.
- Worry-free real-time database and system backups.
- No hardware hassles.
- Initial plan: Surveys and approved users to access MPC services on the Cloud; others will access our local machines.
- We are in conversation with Amazon Web Services about an education grant (free usage for a limited period of time) for testing.
- We do not yet have a cost model.

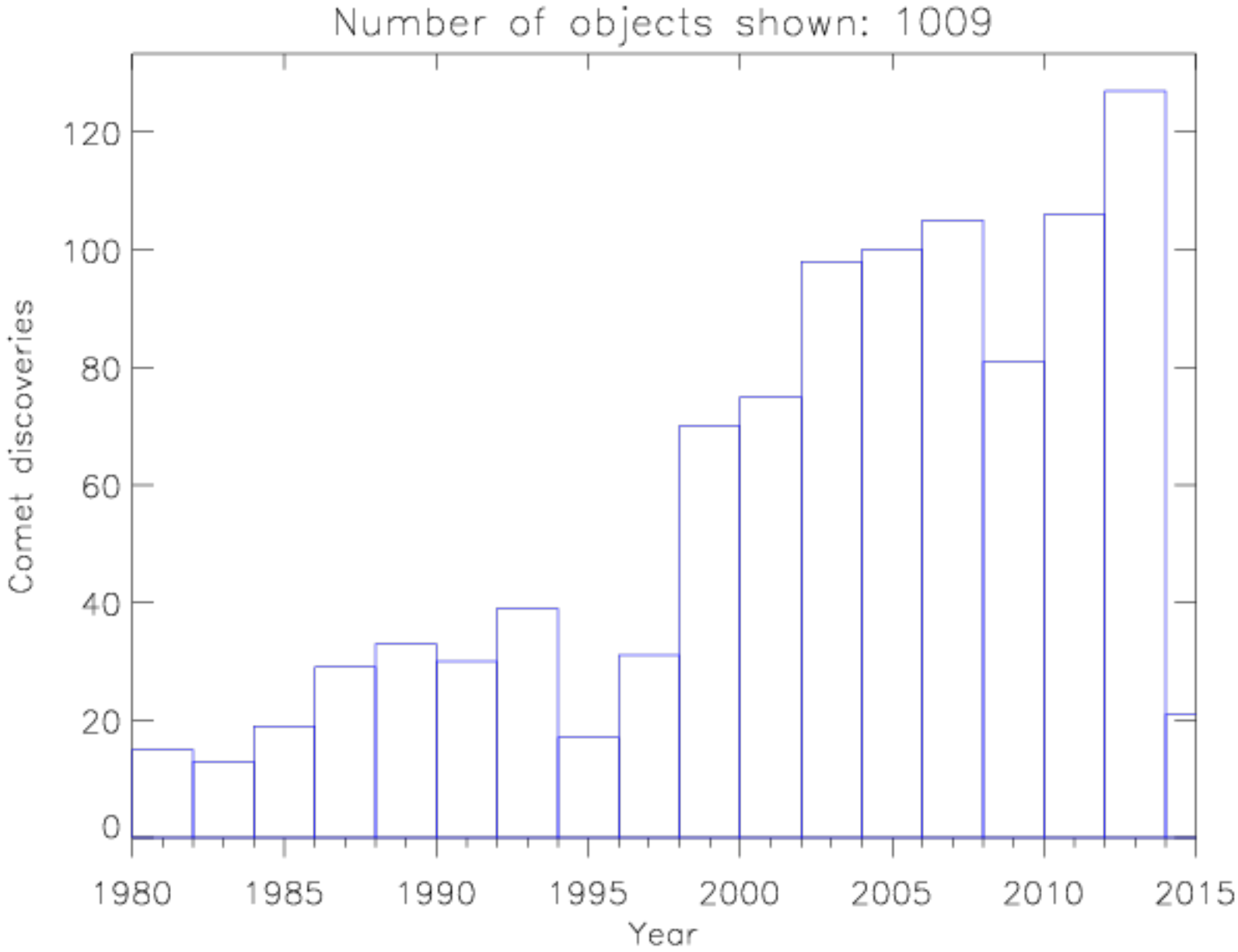
Robust Computing Processes and Reliable Web Presence

- Currently have an automatic failover system running at Harvard Earth and Planetary Science Department (EPS).
- All MPC databases also backed up at Harvard EPS.
- Exploring replacing that fail-over system with one running at SI's computing facility in Herndon, VA.
- Studying the possibility of moving web services and possibly processing operations to the Cloud.
- Also studying moving computers to local server farm (high uptime reliability, backup diesel generators, physical security and 24h access to machines).

Data Influx

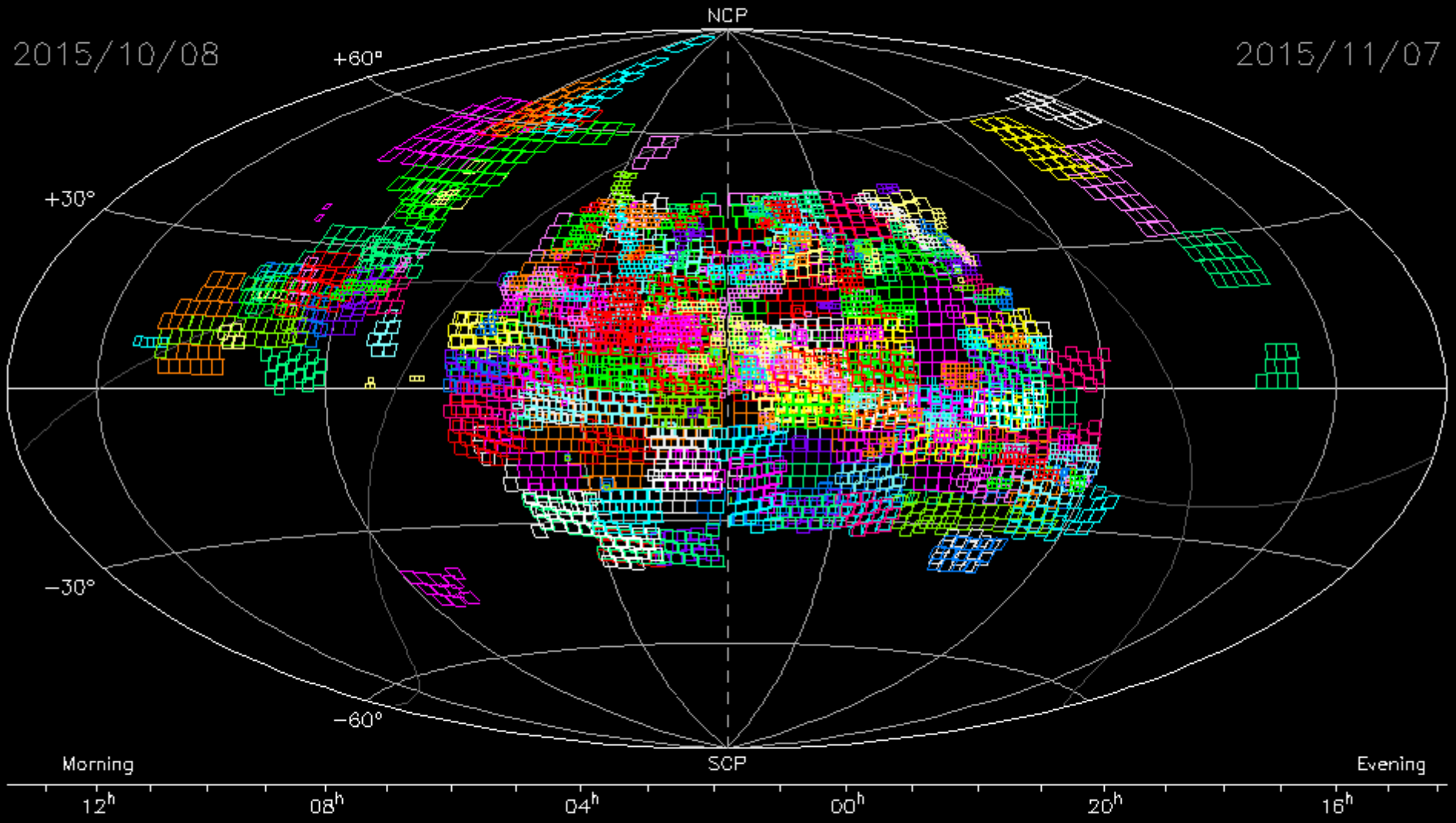
And new objects get designated.




Number of objects shown: 1009
Comet discoveries
0
20
40
60
80
100
120
1980
1985
1990
1995
2000
2005
2010
2015
Year

SKY COVERAGE

Plot prepared 2015/11/08.492 by the Minor Planet Center



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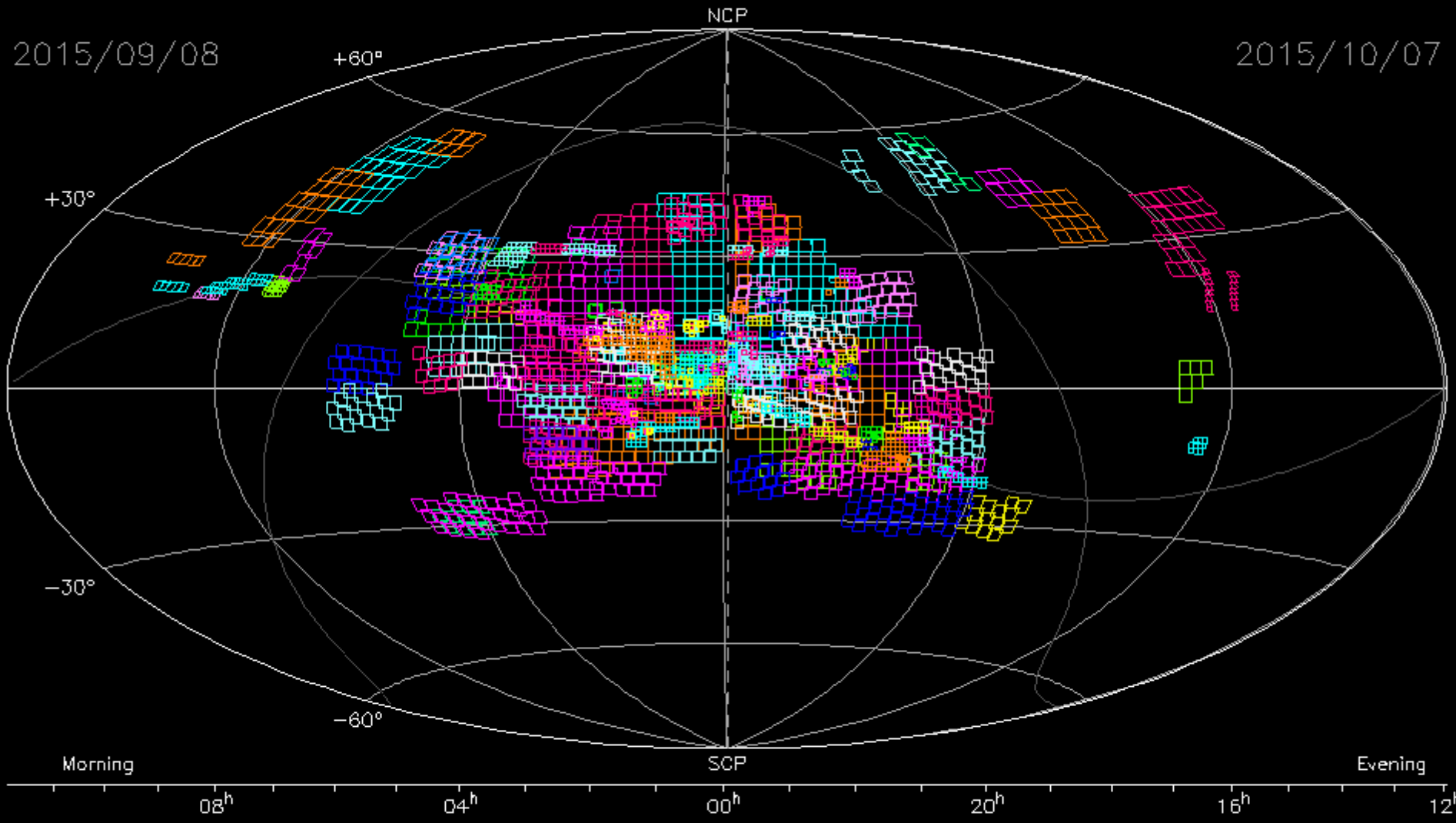
2015/11/02 (2015 306)	2015/11/01 (2015 305)	2015/10/31 (2015 304)	2015/10/30 (2015 303)	2015/10/29 (2015 302)
2015/10/28 (2015 301)	2015/10/27 (2015 300)	2015/10/26 (2015 299)	2015/10/25 (2015 298)	2015/10/24 (2015 297)
2015/10/23 (2015 296)	2015/10/22 (2015 295)	2015/10/21 (2015 294)	2015/10/20 (2015 293)	2015/10/19 (2015 292)
2015/10/18 (2015 291)	2015/10/17 (2015 290)	2015/10/16 (2015 289)	2015/10/15 (2015 288)	2015/10/14 (2015 287)
2015/10/13 (2015 286)	2015/10/12 (2015 285)	2015/10/11 (2015 284)	2015/10/10 (2015 283)	2015/10/09 (2015 282)

SKY COVERAGE

Plot prepared 2015/11/08.497 by the Minor Planet Center

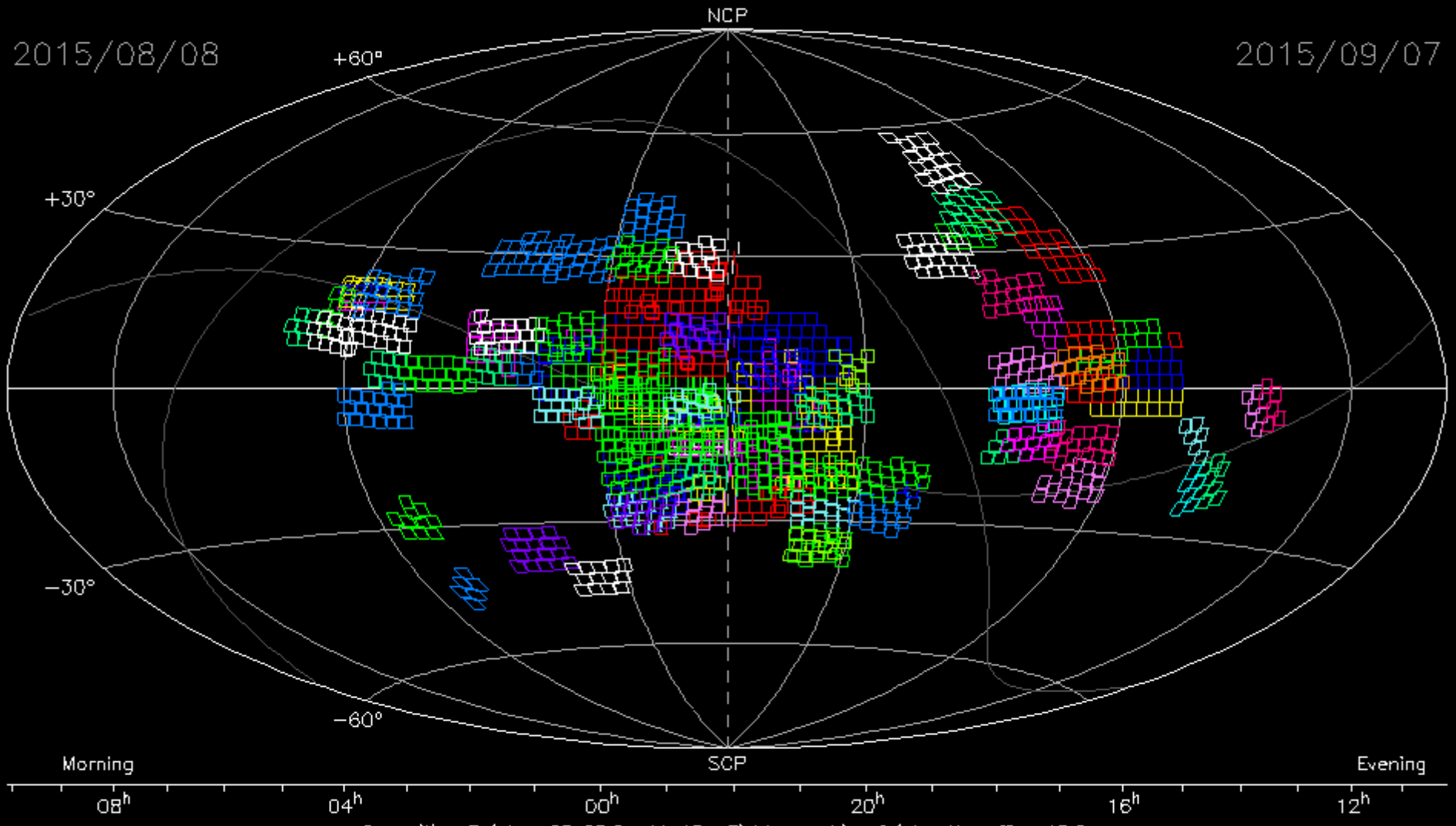


Opposition Point = 23 56.2,−00 25. Fields reaching fainter than V = 18.0.

2015/10/07 (2015 280)	2015/10/06 (2015 279)	2015/10/05 (2015 278)	2015/10/04 (2015 277)	2015/10/03 (2015 276)
2015/10/02 (2015 275)	2015/10/01 (2015 274)	2015/09/30 (2015 273)	2015/09/29 (2015 272)	2015/09/28 (2015 271)
2015/09/27 (2015 270)	2015/09/26 (2015 269)	2015/09/25 (2015 268)	2015/09/24 (2015 267)	2015/09/23 (2015 266)
2015/09/22 (2015 265)	2015/09/21 (2015 264)	2015/09/20 (2015 263)	2015/09/19 (2015 262)	2015/09/18 (2015 261)
2015/09/17 (2015 260)	2015/09/16 (2015 259)	2015/09/15 (2015 258)	2015/09/14 (2015 257)	2015/09/13 (2015 256)
2015/09/12 (2015 255)	2015/09/11 (2015 254)	2015/09/10 (2015 253)	2015/09/09 (2015 252)	2015/09/08 (2015 251)

SKY COVERAGE

Plot prepared 2015/11/08.495 by the Minor Planet Center

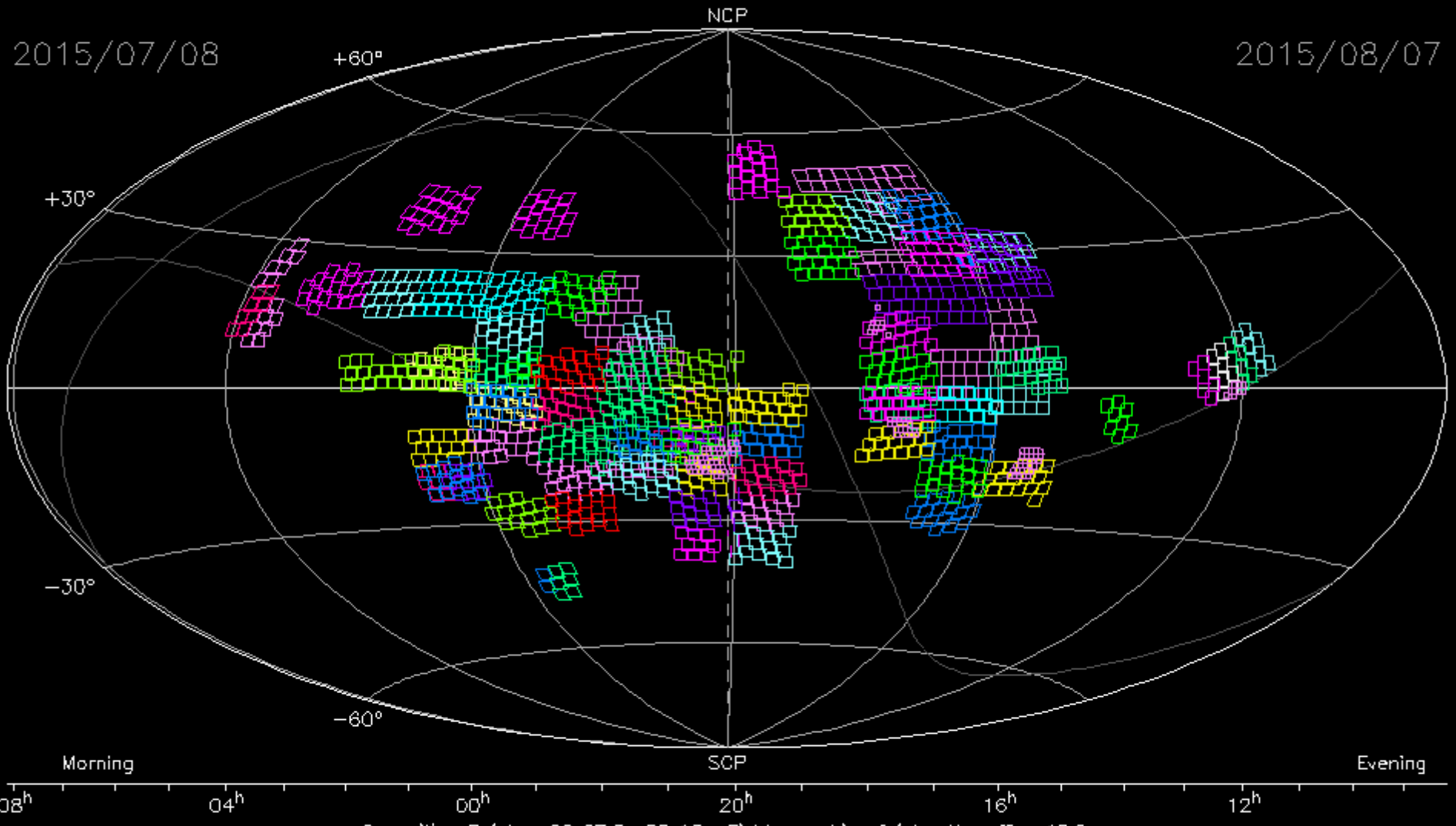


Opposition Point = 22 05.9,−11 42. Fields reaching fainter than V = 18.0.

2015/09/07 (2015 250)	2015/09/06 (2015 249)	2015/09/05 (2015 248)	2015/09/04 (2015 247)	2015/09/03 (2015 246)
2015/09/02 (2015 245)	2015/09/01 (2015 244)	2015/08/31 (2015 243)	2015/08/30 (2015 242)	2015/08/29 (2015 241)
2015/08/28 (2015 240)	2015/08/27 (2015 239)	2015/08/26 (2015 238)	2015/08/25 (2015 237)	2015/08/24 (2015 236)
2015/08/23 (2015 235)	2015/08/22 (2015 234)	2015/08/21 (2015 233)	2015/08/20 (2015 232)	2015/08/19 (2015 231)
2015/08/18 (2015 230)	2015/08/17 (2015 229)	2015/08/16 (2015 228)	2015/08/15 (2015 227)	2015/08/14 (2015 226)
2015/08/13 (2015 225)	2015/08/12 (2015 224)	2015/08/11 (2015 223)	2015/08/10 (2015 222)	2015/08/09 (2015 221)

SKY COVERAGE

Plot prepared 2015/11/08.497 by the Minor Planet Center



Opposition Point = 20 07.3,−20 13. Fields reaching fainter than V = 18.0.

2015/08/07 (2015 219)	2015/08/06 (2015 218)	2015/08/05 (2015 217)	2015/08/04 (2015 216)	2015/08/03 (2015 215)
2015/08/02 (2015 214)	2015/08/01 (2015 213)	2015/07/31 (2015 212)	2015/07/30 (2015 211)	2015/07/29 (2015 210)
2015/07/28 (2015 209)	2015/07/27 (2015 208)	2015/07/26 (2015 207)	2015/07/25 (2015 206)	2015/07/24 (2015 205)
2015/07/23 (2015 204)	2015/07/22 (2015 203)	2015/07/21 (2015 202)	2015/07/20 (2015 201)	2015/07/19 (2015 200)
2015/07/18 (2015 199)	2015/07/17 (2015 198)	2015/07/16 (2015 197)	2015/07/15 (2015 196)	2015/07/14 (2015 195)
2015/07/13 (2015 194)	2015/07/12 (2015 193)	2015/07/11 (2015 192)	2015/07/10 (2015 191)	2015/07/09 (2015 190)