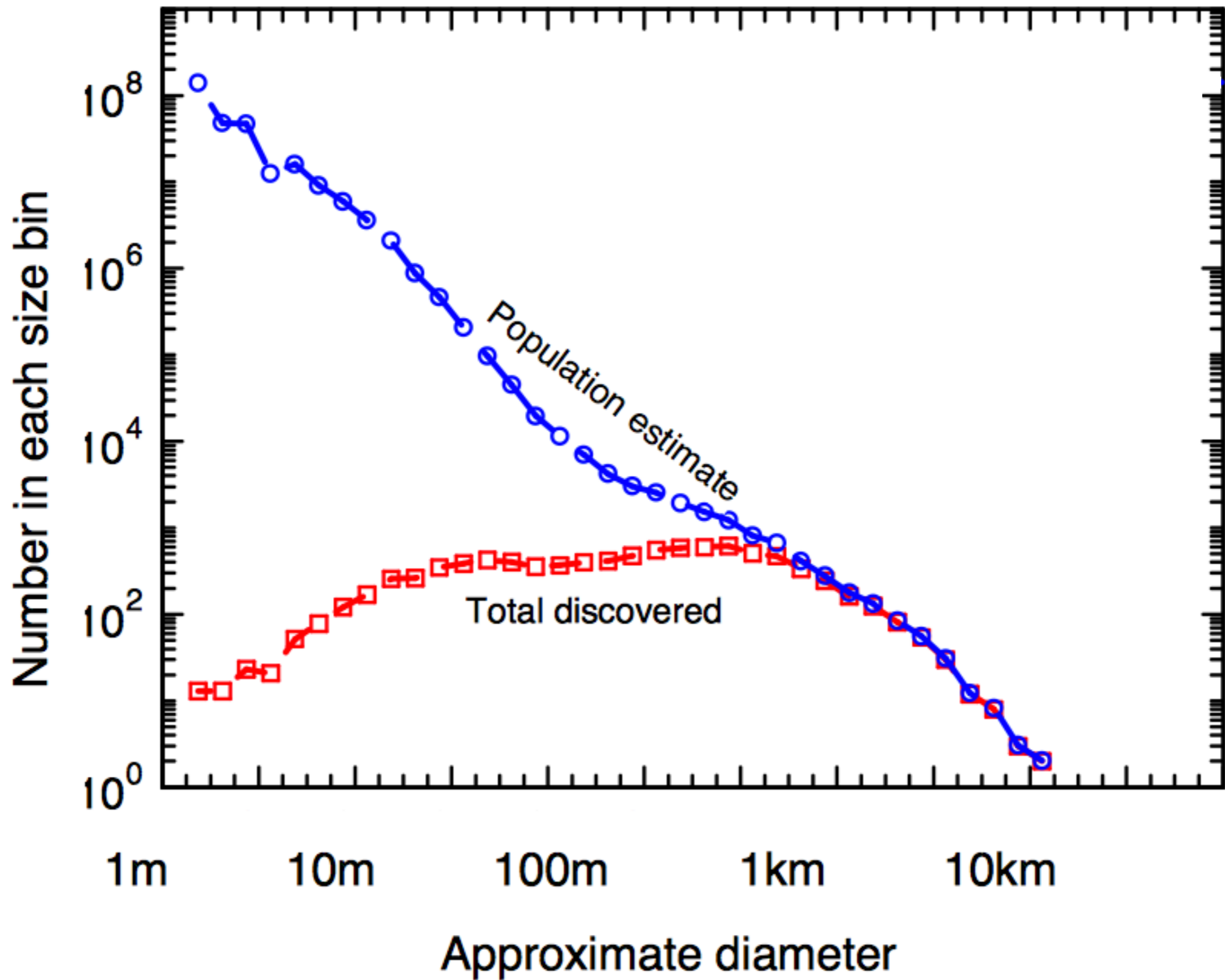


Rapid Response Characterization of Near-Earth Objects

Nick Moskovitz

(Lowell Observatory)

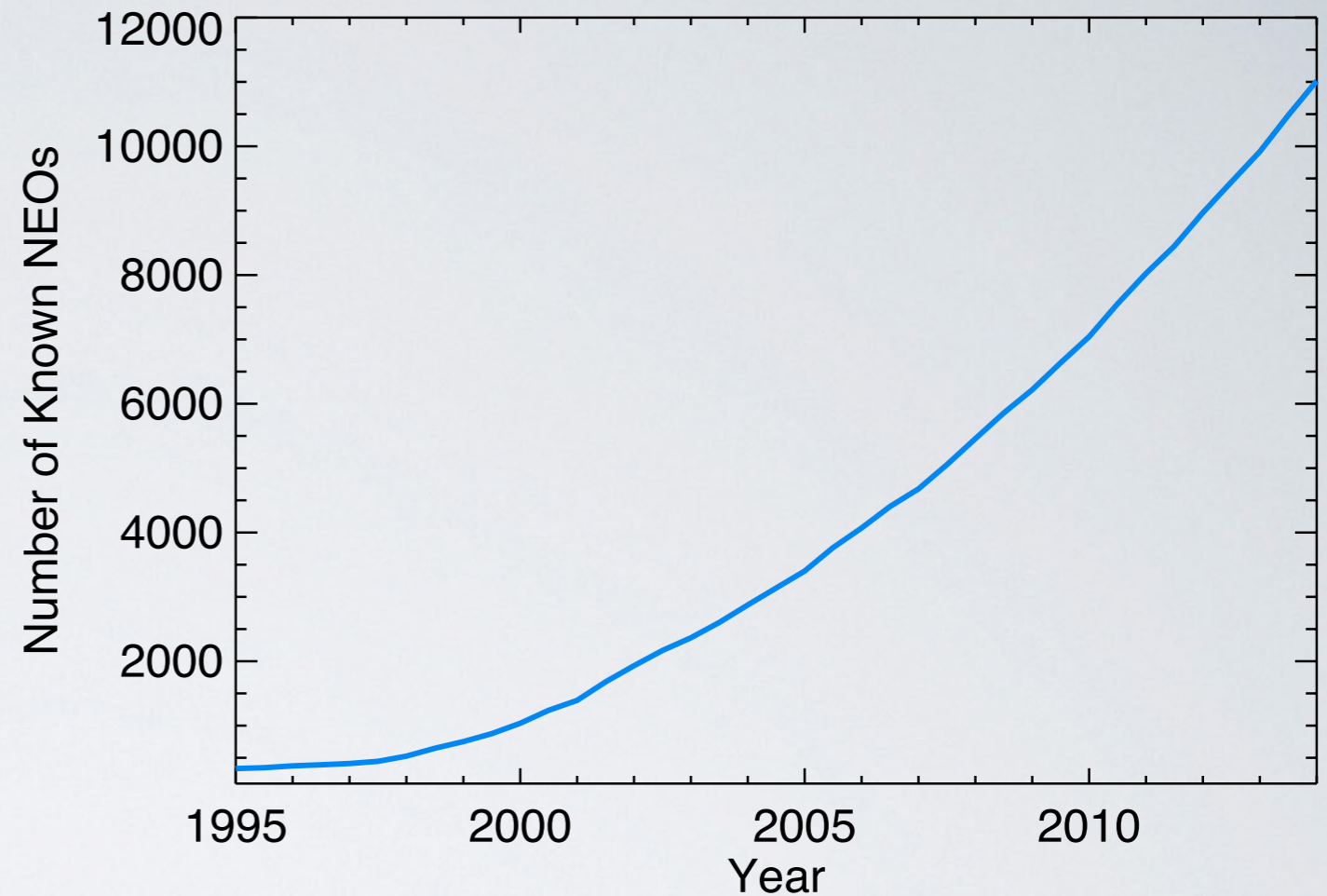




Credit: A. Harris

Discovery surveys
continue to increase
yield

>100 NEOs / month

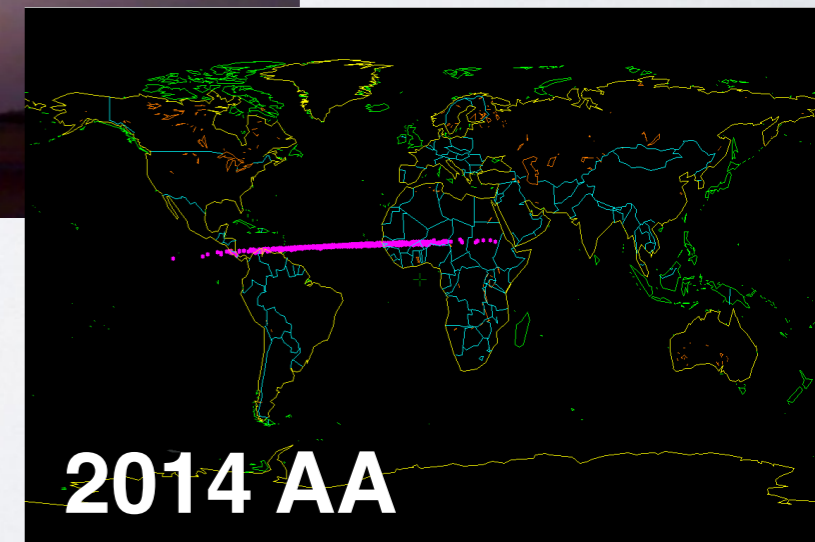
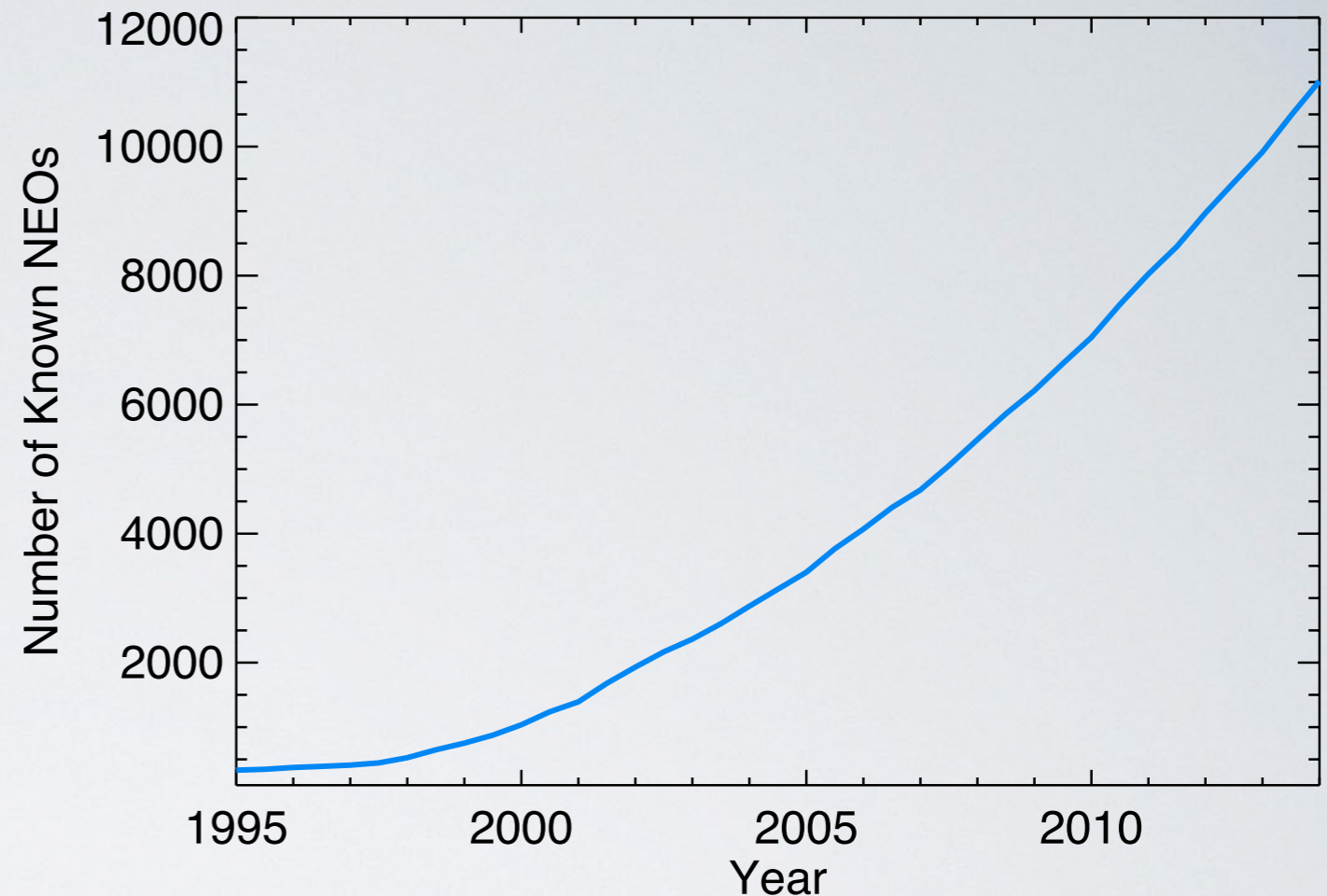


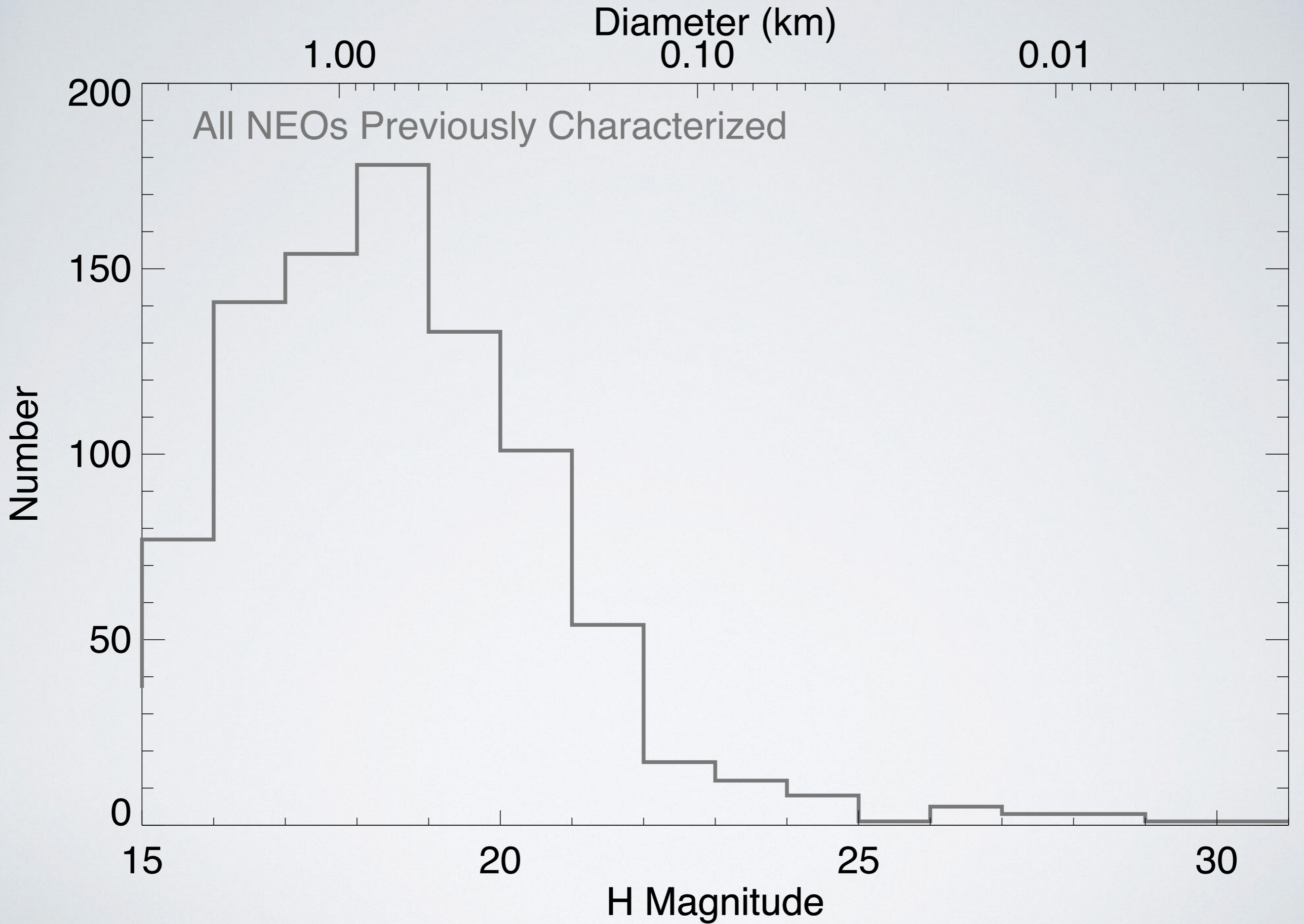
Discovery surveys
continue to increase
yield

>100 NEOs / month

Highly interesting objects
at small sizes ($\approx 100\text{m}$):

- Close encounters
- Impactors
- Meteorite parents





Characterization demands urgency

2014 HW

Discovered April 20, Mt Lemmon

$H = 28.4 \rightarrow \sim 5\text{-}10\text{m}$

$\Delta v = 4.5 \text{ km/s}$

K14H00W		[H=28.4]														
Date	UT			R.A. (J2000)			Decl.	Delta	r	El.	Ph.	V	Sky Motion			
	h	m	s										"/min	P.A.		
2014 04 20	00	00	00	14 40	36.3	+08 37 38	0.019	1.022	156.4	23.1	20.9	5.49	158.6			
2014 04 21	00	00	00	14 44	16.0	+06 16 30	0.016	1.020	158.1	21.5	20.6	7.23	159.1			
2014 04 22	00	00	00	14 49	03.4	+03 06 26	0.014	1.018	160.2	19.5	20.2	9.89	159.6			
2014 04 23	00	00	00	14 55	37.4	-01 19 54	0.012	1.017	162.6	17.2	19.7	14.12	159.8			
2014 04 24	00	00	00	15 05	14.2	-07 51 18	0.010	1.015	164.5	15.4	19.2	21.26	159.8			
2014 04 25	00	00	00	15 20	42.5	-17 55 26	0.0076	1.013	162.1	17.8	18.8	33.58	159.1			
2014 04 26	00	00	00	15 49	36.6	-33 42 26	0.0061	1.011	150.0	29.8	18.6	52.62	156.0			
2014 04 27	00	00	00	16 58	52.0	-55 13 07	0.0053	1.010	128.0	51.8	19.0	67.97	143.6			
2014 04 28	00	00	00	20 19	18.2	-70 00 58	0.0057	1.008	103.2	76.5	19.9	59.15	098.2			
2014 04 29	00	00	00	23 40	04.0	-64 23 04	0.0070	1.006	84.7	95.0	21.0	39.11	051.5			
2014 04 30	00	00	00	00 49	17.9	-55 17 22	0.0089	1.005	72.9	106.6	22.1	24.61	036.4			
2014 05 01	00	00	00	01 18	00.1	-48 37 17	0.011	1.003	65.6	113.8	23.0	16.13	030.8			
2014 05 02	00	00	00	01 33	14.5	-43 56 08	0.013	1.001	60.9	118.5	23.7	11.17	027.9			
2014 05 03	00	00	00	01 42	37.5	-40 32 29	0.015	1.000	57.6	121.7	24.3	8.13	026.3			
2014 05 04	00	00	00	01 48	58.1	-37 59 21	0.018	0.998	55.3	123.9	24.8	6.17	025.1			
2014 05 05	00	00	00	01 53	32.6	-36 00 08	0.020	0.997	53.6	125.4	25.2	4.85	024.3			
2014 05 06	00	00	00	01 57	00.0	-34 24 31	0.023	0.995	52.4	126.6	25.5	3.92	023.5			
2014 05 07	00	00	00	01 59	42.7	-33 05 49	0.025	0.994	51.5	127.4	25.8	3.25	022.9			



The Mission Accessible Near-Earth Object Survey (MANOS)

Nick Moskovitz (PI, Lowell)

Paul Abell (NASA/JSC)

Richard Binzel (MIT)

Brian Burt (MIT, Lowell)

Eric Christensen (UA)

Francesca DeMeo (CfA)

Tom Endicott (UMass Boston)

Will Grundy (Lowell)

Mary Hinkle (NAU)

Michael Mommert (NAU)

Katheryn Neugent (Lowell)

Michael Person (MIT)

David Polishook (MIT)

Lowell Putnam (Lowell)

Henry Roe (Lowell)

Rob Schottland (Kelis Innovations)

Hosea Siu (MIT)

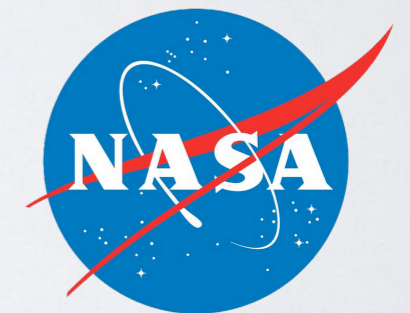
Audrey Thirouin (Lowell)

Cristina Thomas (GSFC)

David Trilling (NAU)

Larry Wasserman (Lowell)

Mark Willman (IfA)



MANOS



Goals

Catalog physical properties of several hundred sub-km NEOs

MAN S

Goals

Catalog physical properties of several hundred sub-km NEOs

Methods

Rapid follow-up with queue and remote observing

Astrometry → **Refine orbits**

Photometry → **Rotational properties, morphology**

Spectroscopy → **Composition, link to meteorites**

MAN S

Goals

Catalog physical properties of several hundred sub-km NEOs

Methods

Rapid follow-up with queue and remote observing

Astrometry → **Refine orbits**

Photometry → **Rotational properties, morphology**

Spectroscopy → **Composition, link to meteorites**

Target selection

Mission accessible → $\Delta v < 7$ km/s

Size < 1 km



~10% of new discoveries

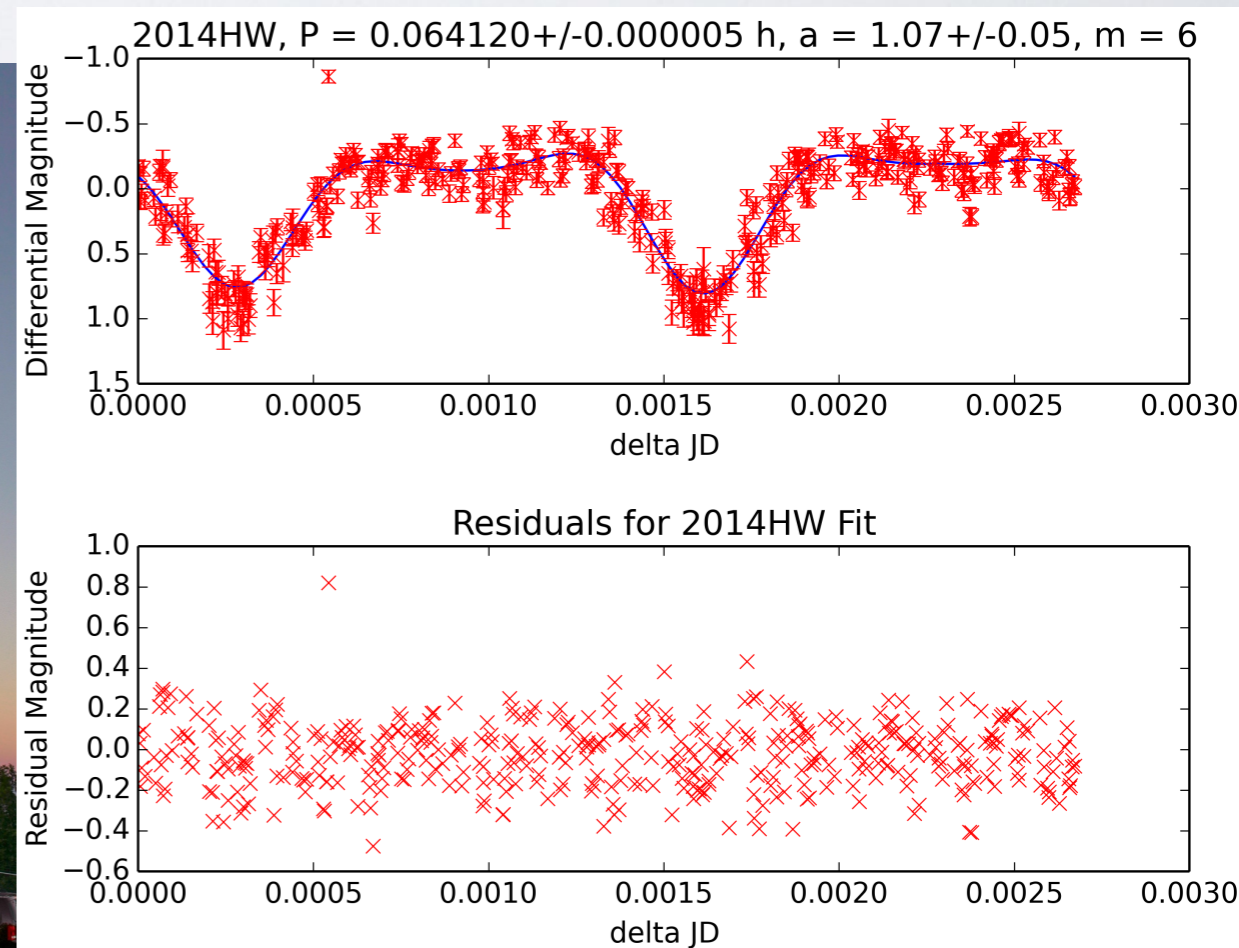
Lowell Assets

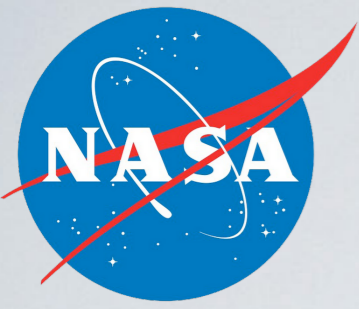


Lowell's 4.3m Discovery Channel Telescope (DCT)

- Currently imaging only, 1 night/month
- 2015 Q2: New spectroscopic instruments, 2 nights/month

Also using 72", 42" and 28" LONEOS

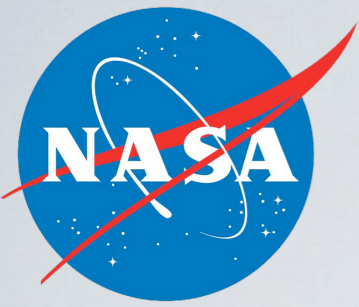




NASA's IRTF SpeX

NEO Interrupt Program

- Multi-semester, started in 2010
by R. Binzel
- ~1 interrupt per year:
encounter < 0.001 AU
- Results released within 24 hours



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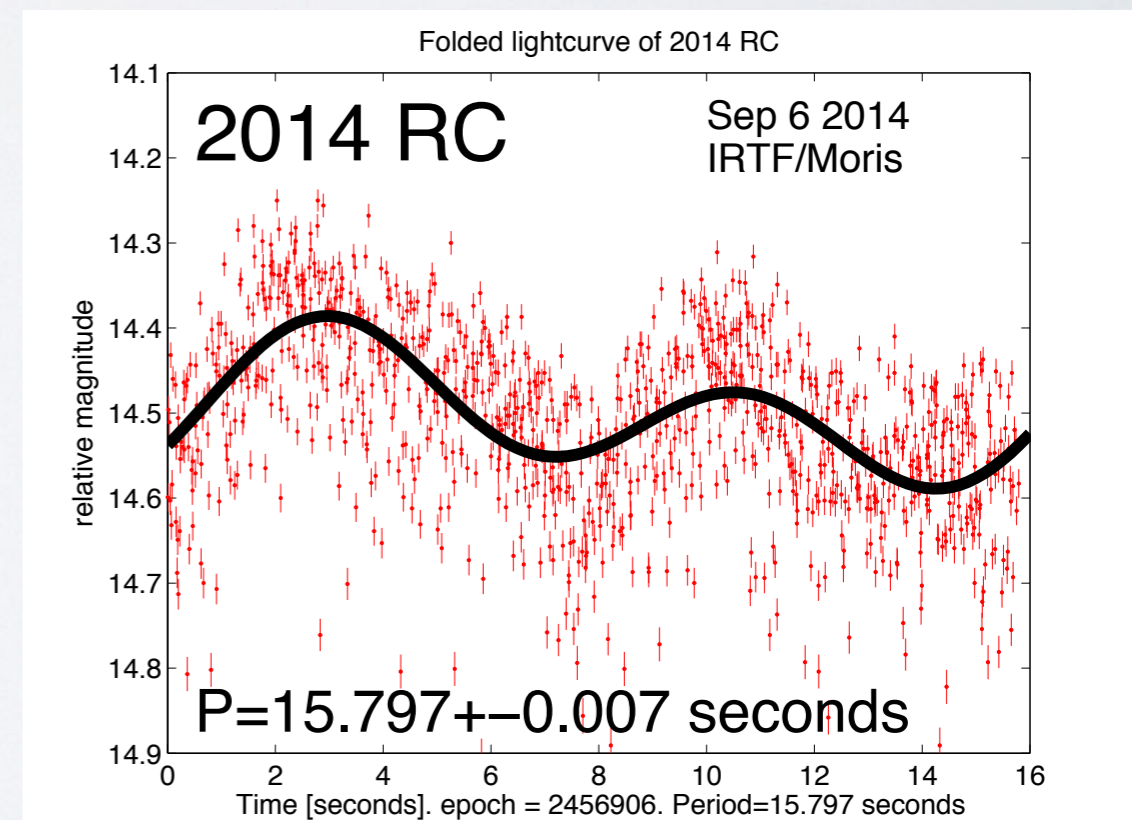
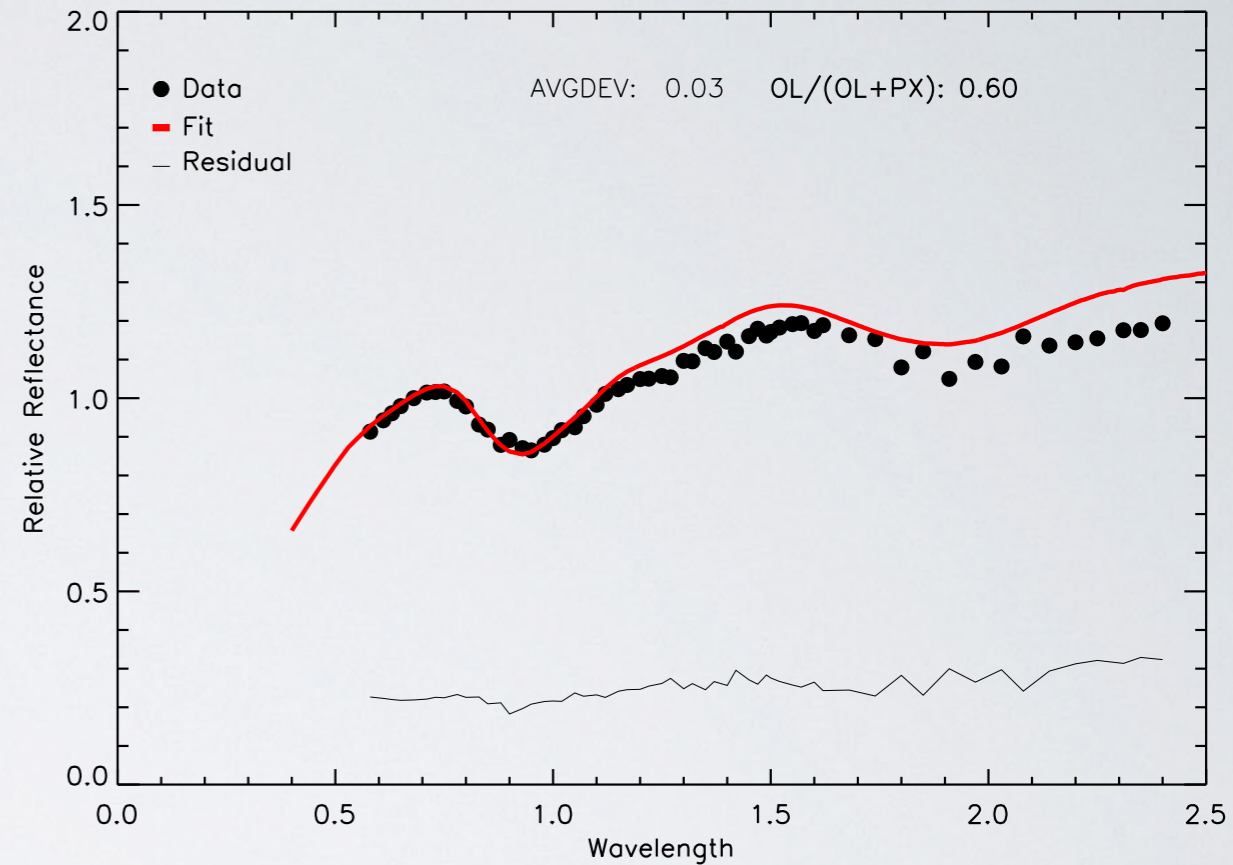
2014 RC

Flyby at 39,000km on 7 Sept 2014

Sq-type \rightarrow ~20% albedo \rightarrow Size ~15-20m

Rotation Period = 15.8sec

Fastest rotator ever observed!



NOAO Assets



Scheduled

KP 4m: 1 night/month



SOAR: 1 night/month



NOAO Assets



Scheduled

KP 4m: 1 night/month



ToO

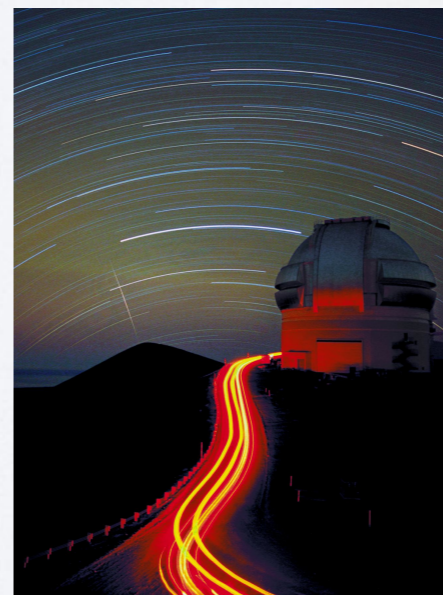
CTIO 1.3m: ~1 target/month



SOAR: 1 night/month



Gemini N+S: 1.5 hr/week

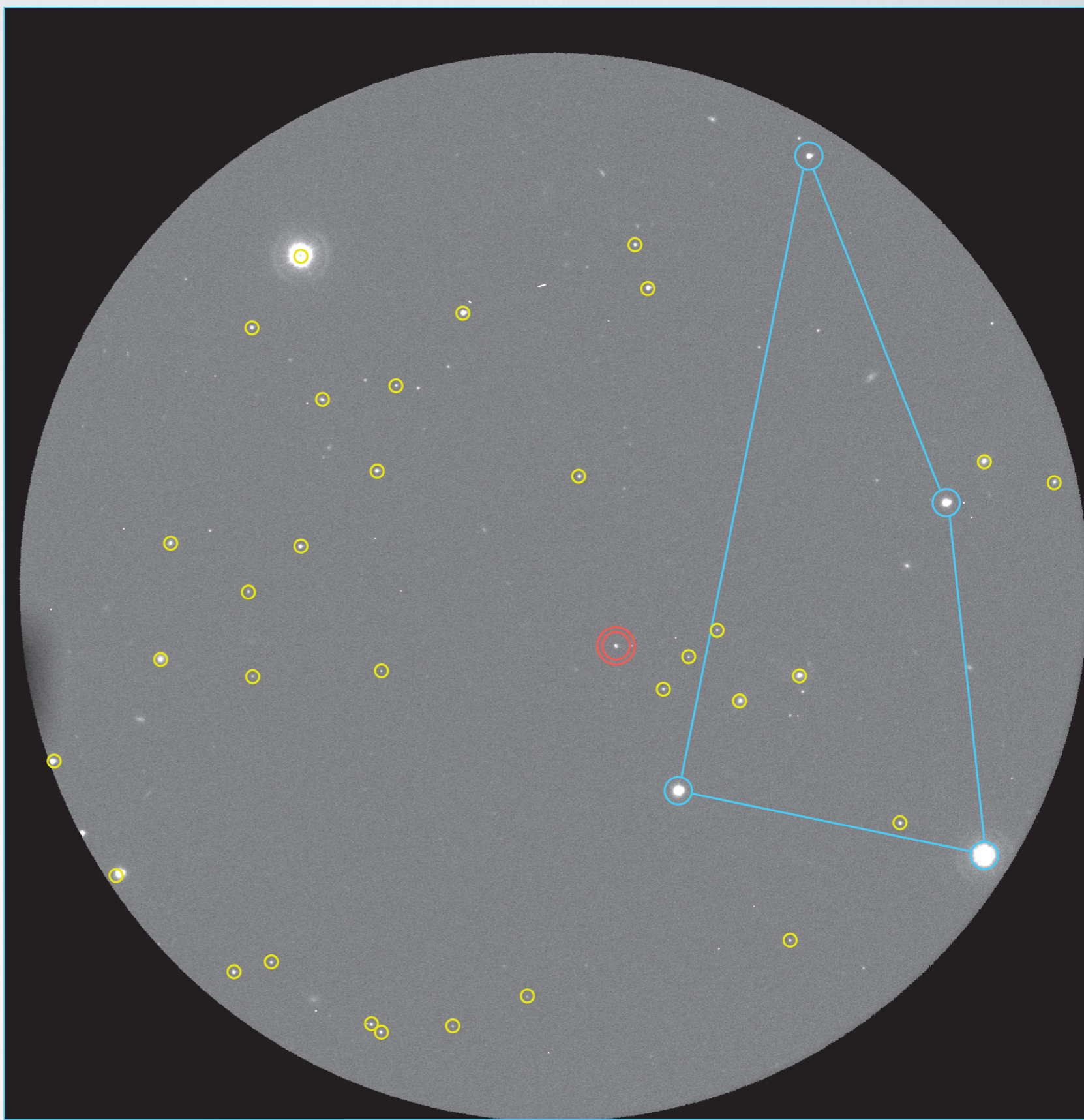




Astrometry

➔ Refine orbital solutions

- Fully automated custom-built pipeline
- Typical residuals: $\sim 0.05''$
- Working towards regular MPC uploads

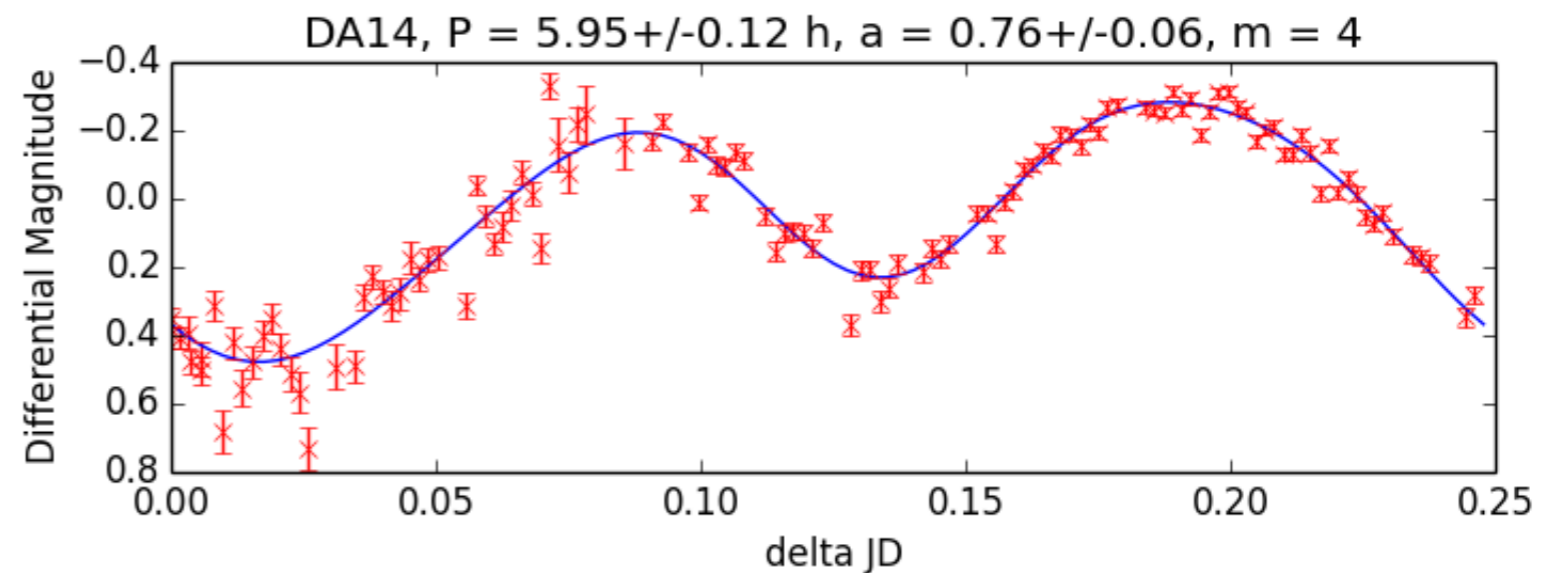




Photometry

➔ **Rotation period,
gross morphology**

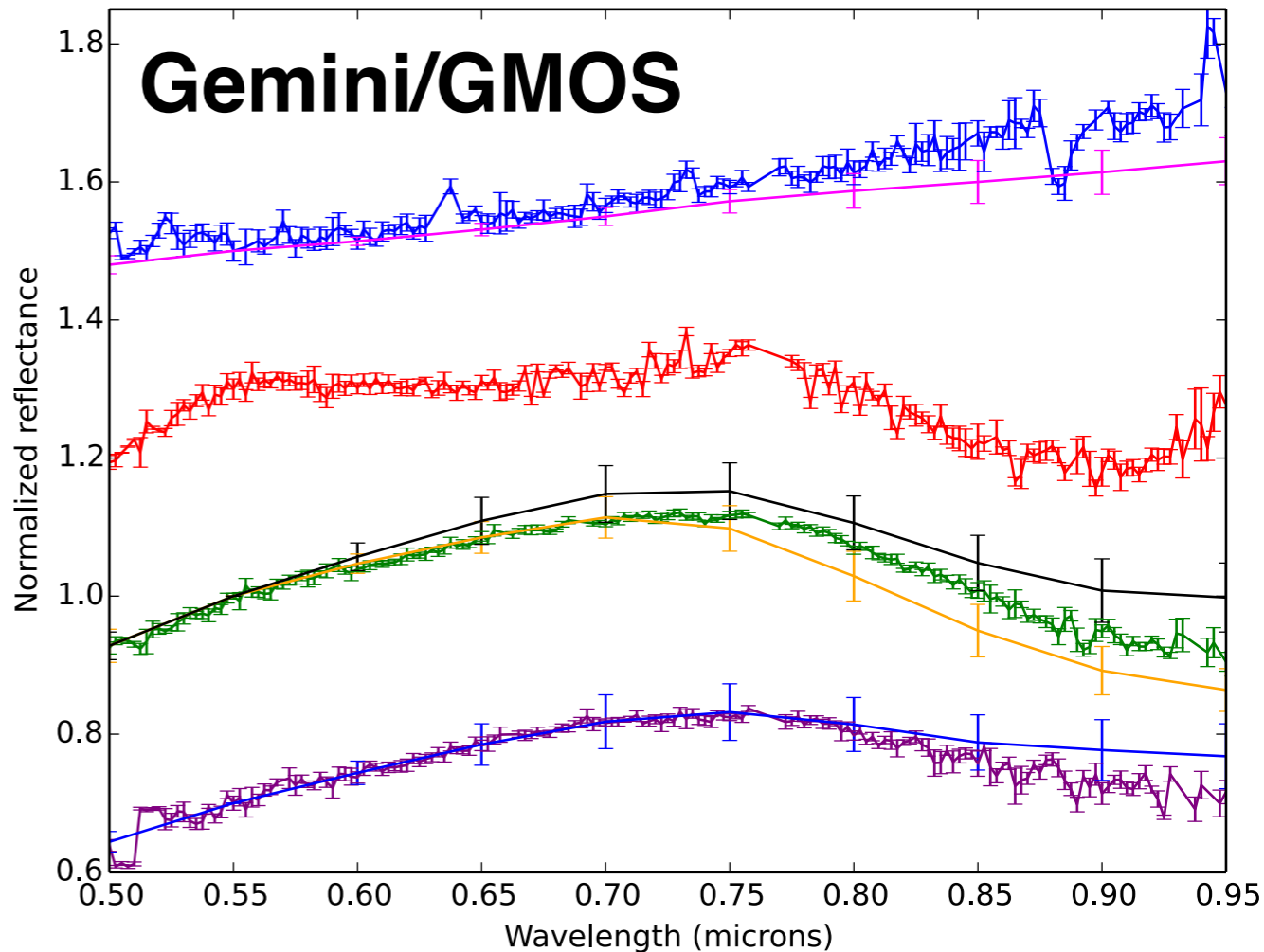
- Highly automated custom-built pipeline
- 4-m facilities open up new regimes (e.g. magnitude, rate)



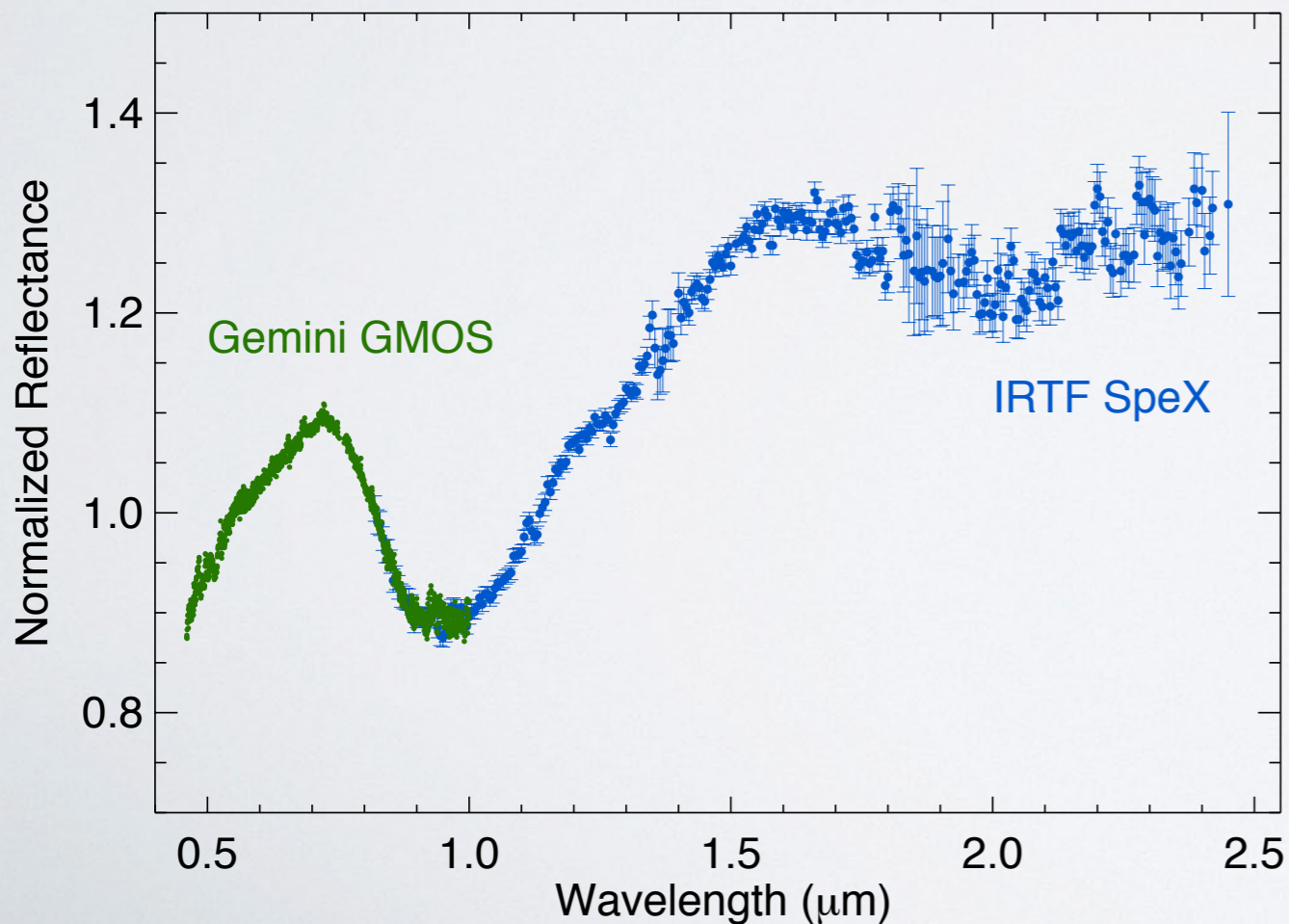


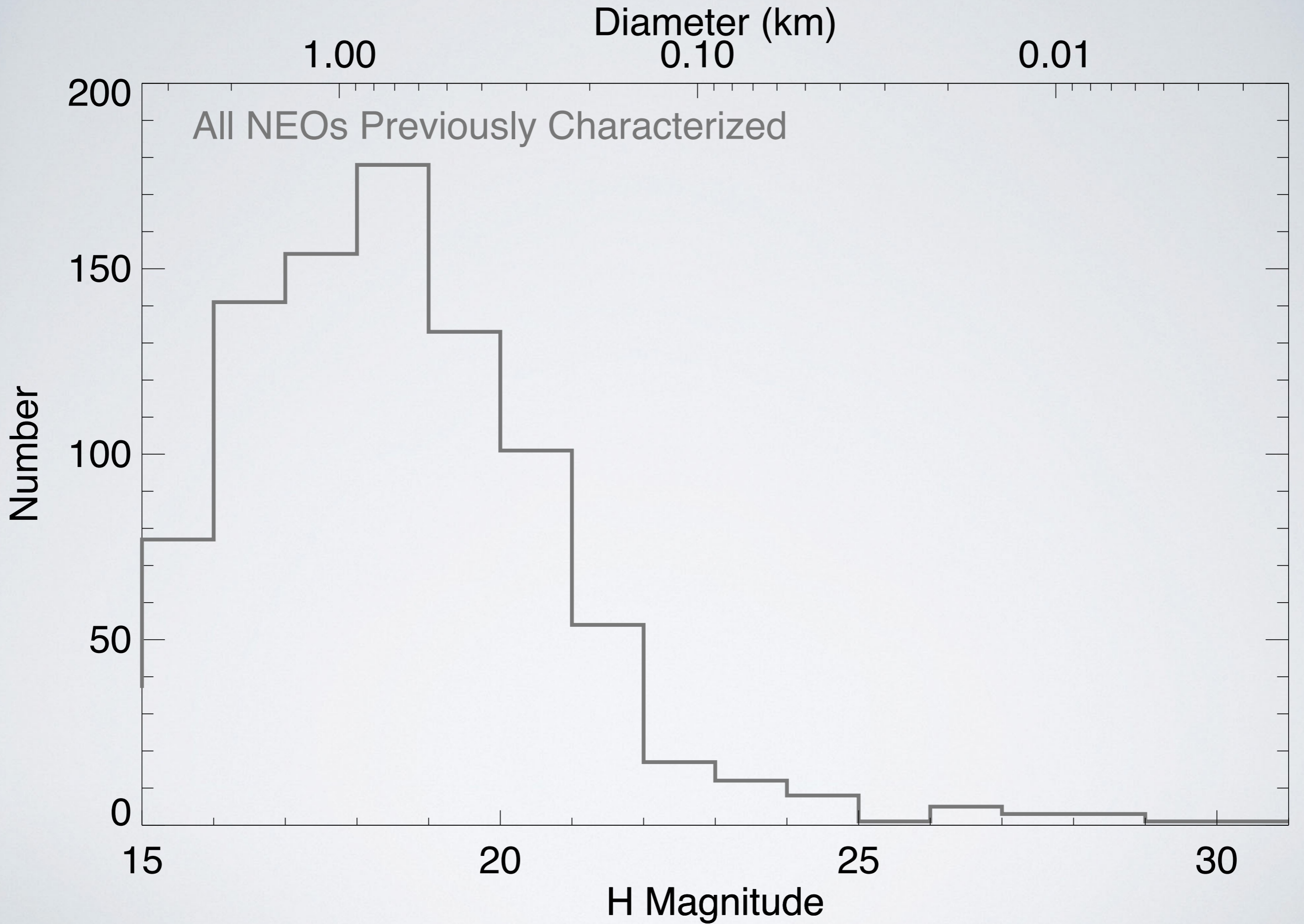
Spectra

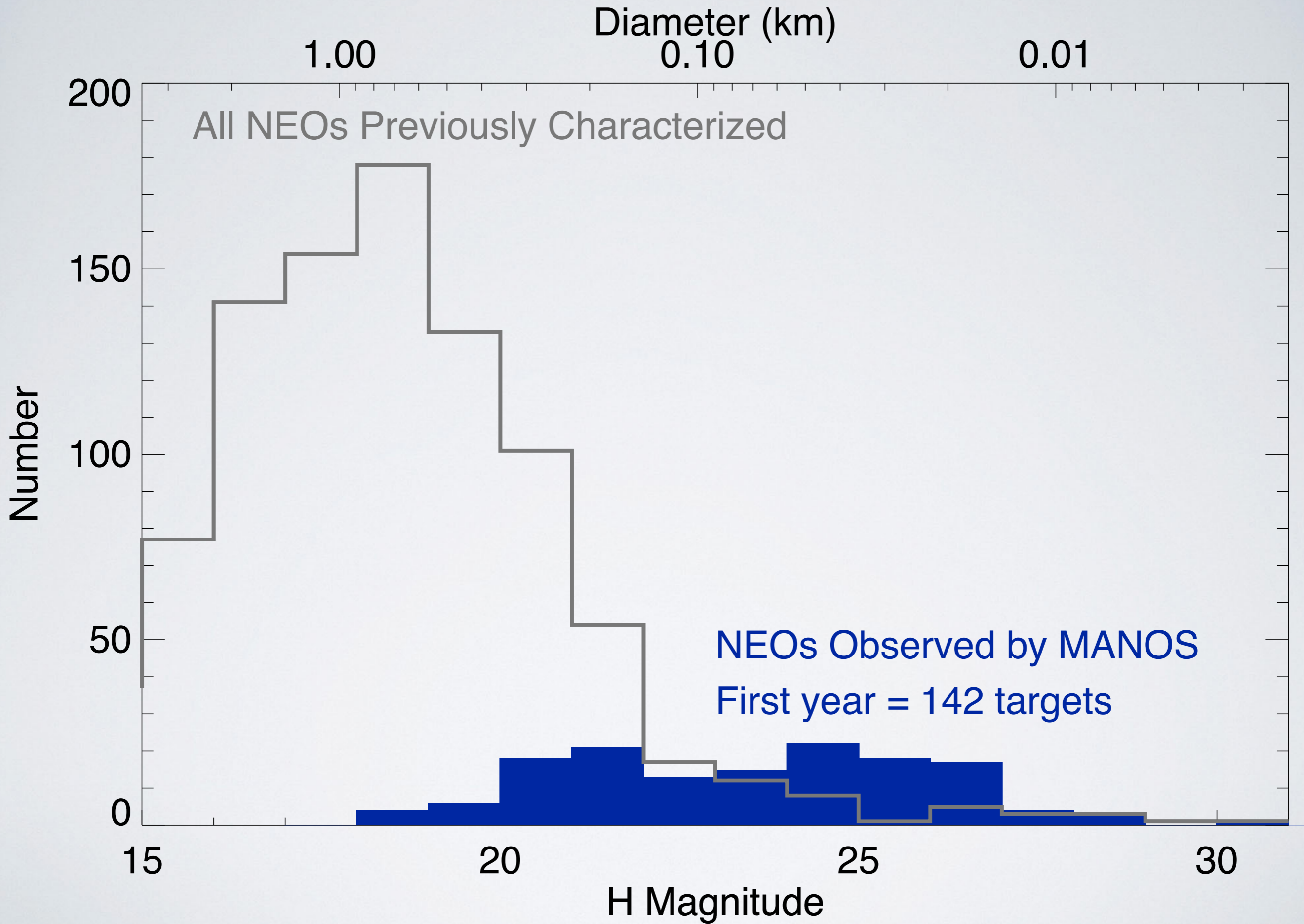
➔ **Taxonomy,
composition
(density, albedo,
size, mass)**



- Pipelines in place or near complete for: *SpeX*, *Gemini*, *SOAR*
- Working on spectral repository







MANOS Science



Mary Hinkle (NAU) - Tues PM Poster #213.07

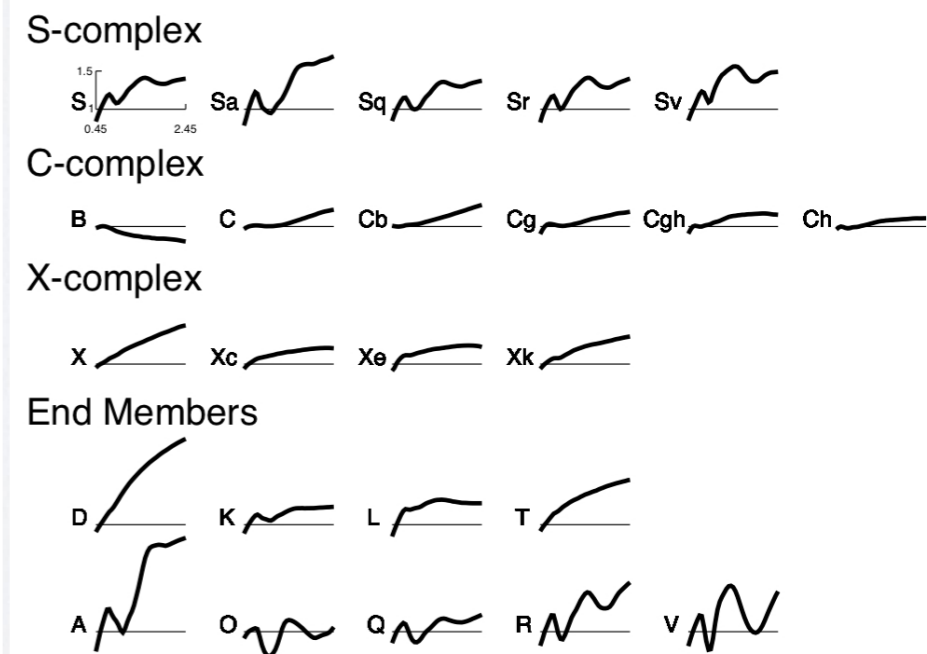
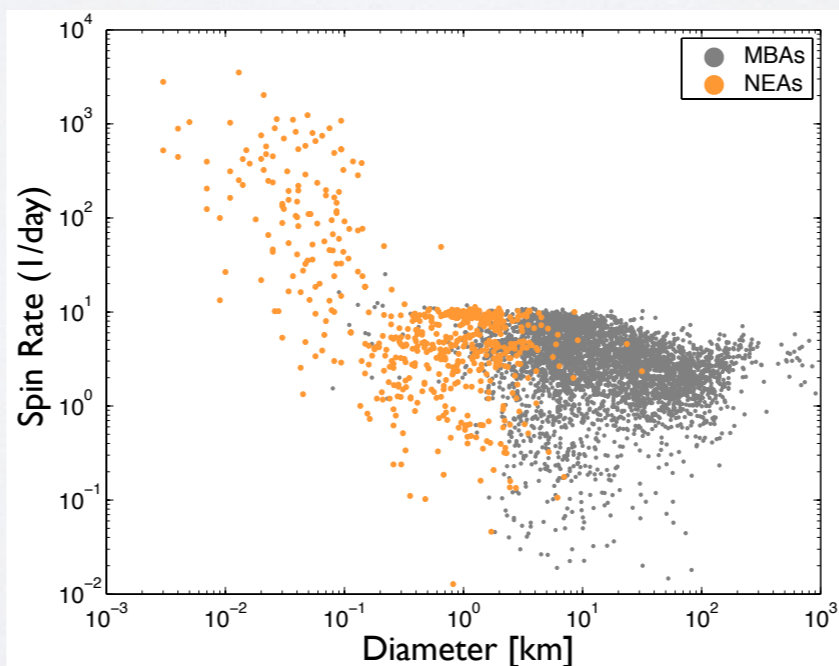
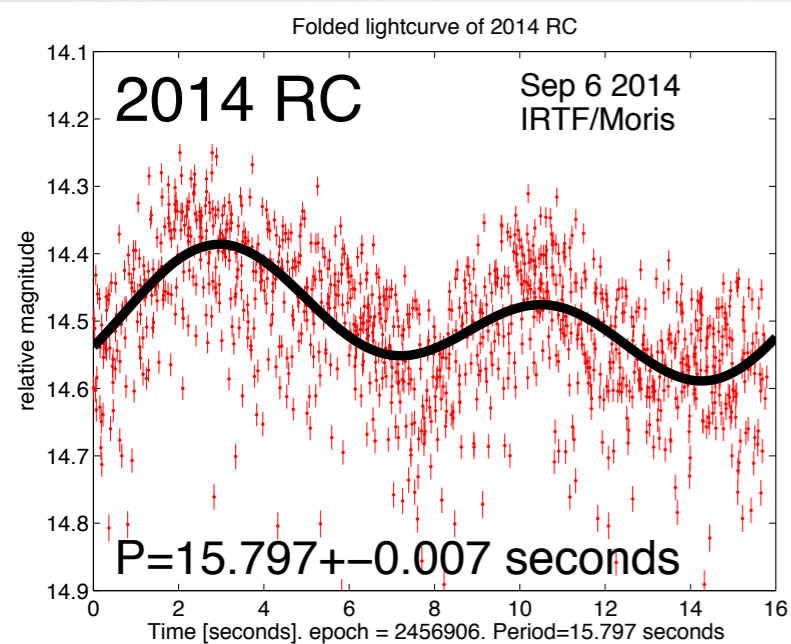
Investigating taxonomic distribution vs. size

Thomas Endicott (UMass Boston) - Wed AM Talk #304.02

Dynamical integrations of all known NEOs

Hosea Siu (MIT)

Role of Earth encounters on NEO rotation rates

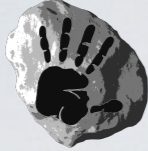


MAN S Database Project

Brian Burt (Lowell, MIT) — Poster, Thurs PM #414.02

- Need for enhanced observational planning, tracking and coordination tools
- **Goal:** couple orbital elements (*astorb*) and ephemeris tools with a physical property database
- Built in SQL + python, soon accessible at asteroid.lowell.edu
- Will allow real-time observing status updates

Summary

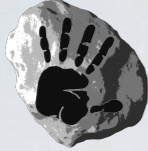
- M A N  S: Access to diverse assets enables rapid response



→ **Comprehensive** characterization for $\sim 10\%$ of new discoveries

Acknowledgment: NASA NEOO Grant NNX14AN82G + NSF AAPF


Summary

- M A N  S: Access to diverse assets enables rapid response
 - ➔ **Comprehensive** characterization for ~10% of new discoveries
- Developing system for near-realtime dissemination of data products and to facilitate observing coordination



Acknowledgment: NASA NEOO Grant NNX14AN82G + NSF AAPF

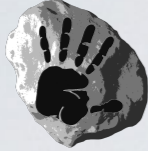
Summary

- M A N  S: Access to diverse assets enables rapid response
 - ➔ **Comprehensive** characterization for $\sim 10\%$ of new discoveries
- Developing system for near-realtime dissemination of data products and to facilitate observing coordination
- Addressing challenges associated with NEO observations (e.g. short observing windows, high non-sidereal rates)



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Summary

- M A N  S: Access to diverse assets enables rapid response
 - ➔ **Comprehensive** characterization for $\sim 10\%$ of new discoveries
- Developing system for near-realtime dissemination of data products and to facilitate observing coordination
- Addressing challenges associated with NEO observations (e.g. short observing windows, high non-sidereal rates)
- Generating data products of interest to multiple communities — science, exploration, hazard assessment



Acknowledgment: NASA NEOO Grant NNX14AN82G + NSF AAPF

