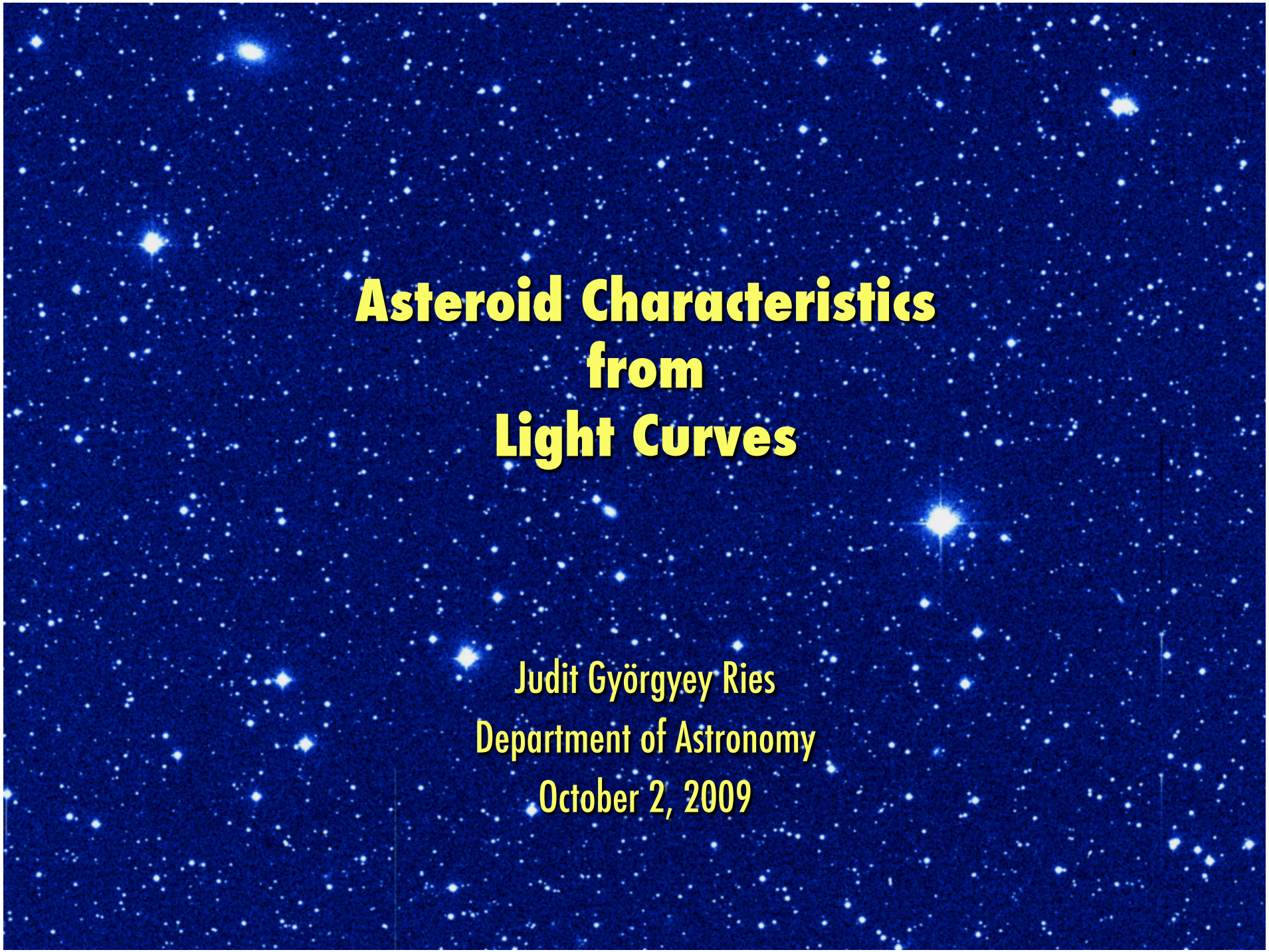

Asteroid Characteristics
from
Light Curves
Judit Györgyey Ries
Department of Astronomy
October 2, 2009

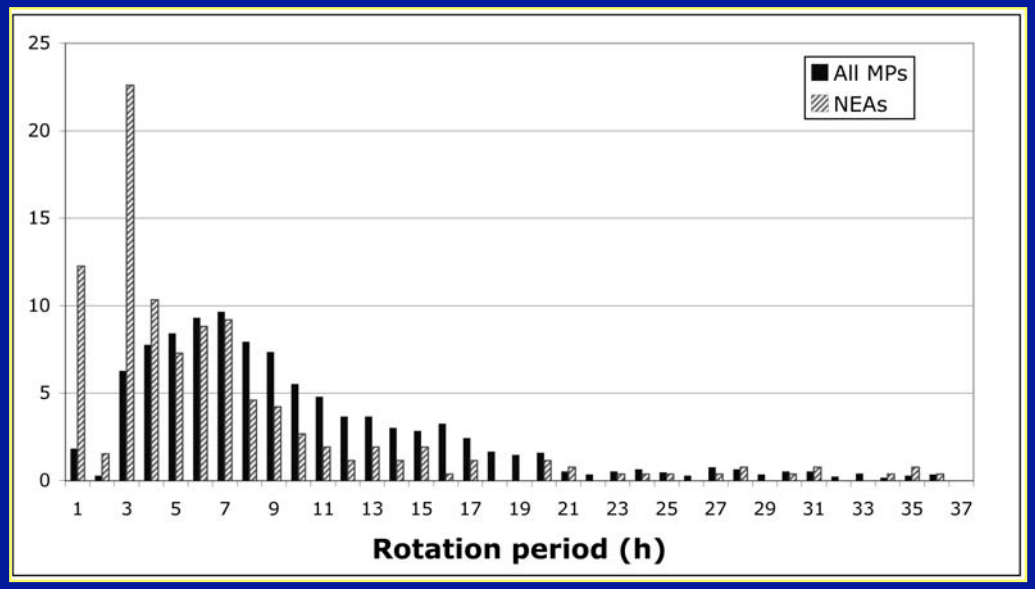
Why bother with Asteroids?

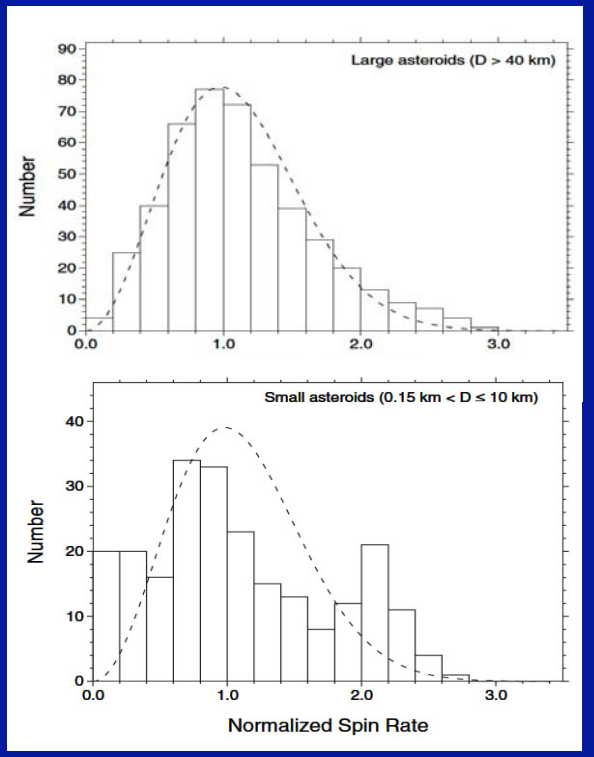
- Impact hazard 2008 TC3 October 7, 2008(UT)
- Tracers of dynamical evolution of the asteroid belt
  - Gravitation: resonances, close encounters
  - Collision
  - Non-gravitational accelerations: YORP

Need to know

- Orbits
- Mass, size, shape
- Rotational state
- Surface and bulk properties

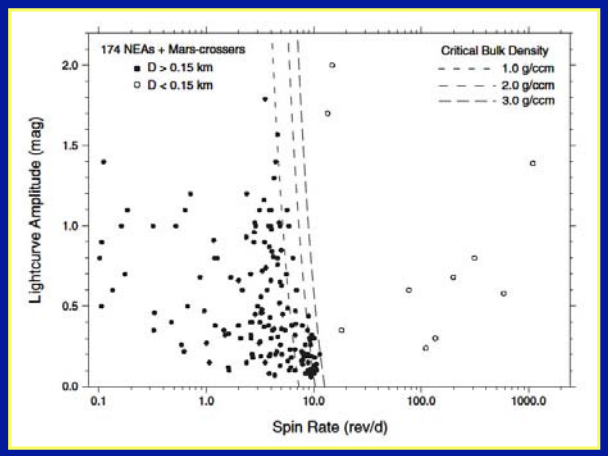
Distribution of Rotation rates





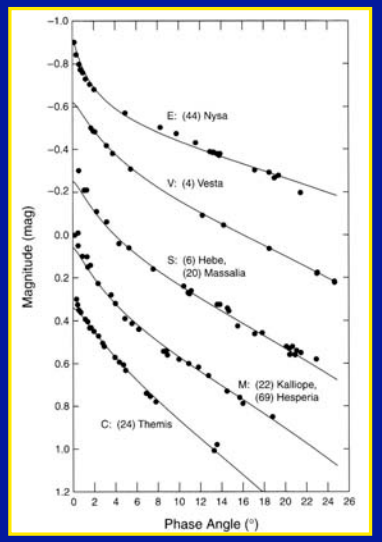
Indicator of dynamical evolution and the processes driving the evolution:

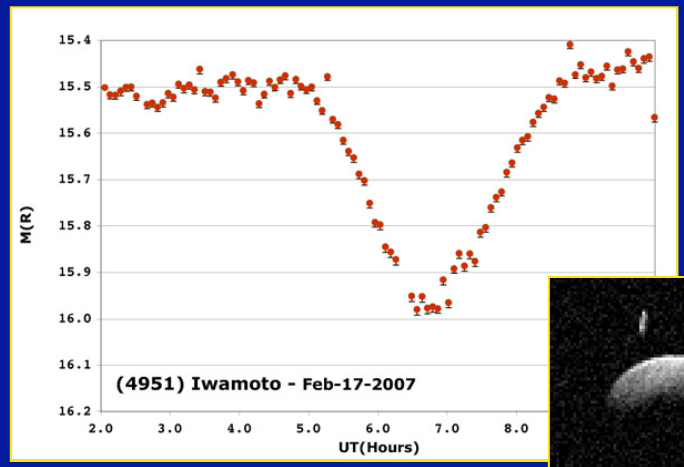
- Collision
- YORP effect
- Bulk properties



Asteroid brightness variations due to:

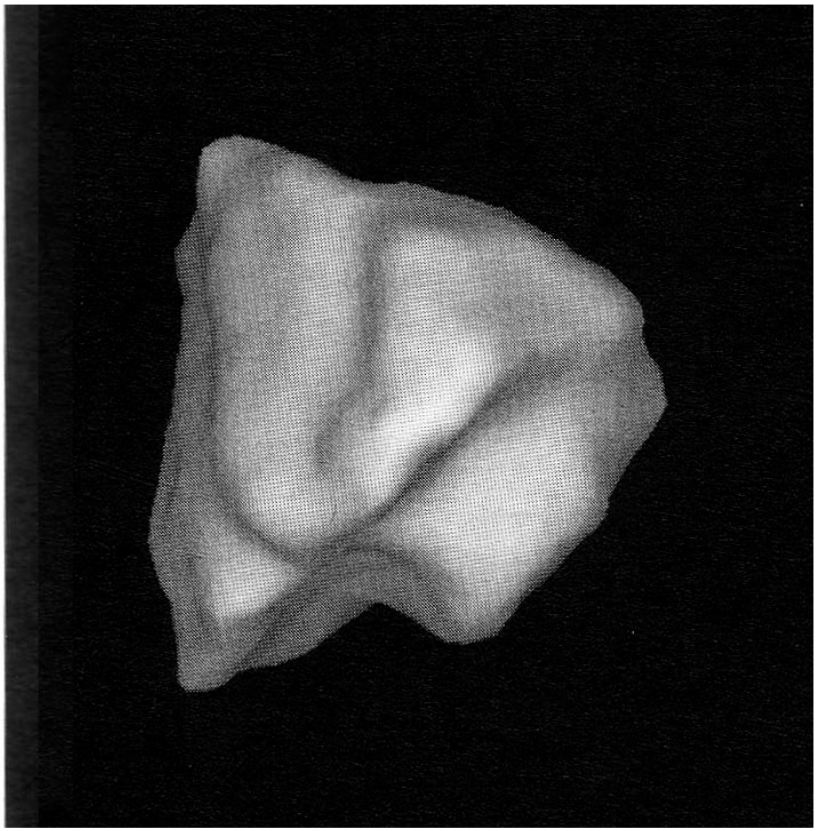
- Changing distance form Sun and Earth
- Amount of light reflected depends on projected surface area and surface properties
  - How much of the illuminated portion is visible (phase angle)
  - Opposition effect body dependent
  - Shape, composition surface roughness
  - $V = H_v + f(\alpha) - 5*\log(r_{sun}*r_{earth})$
  - Rotation of the body
- The object is not a single body
  - Eclipses
- Inversion is not trivial and not necessarily unique

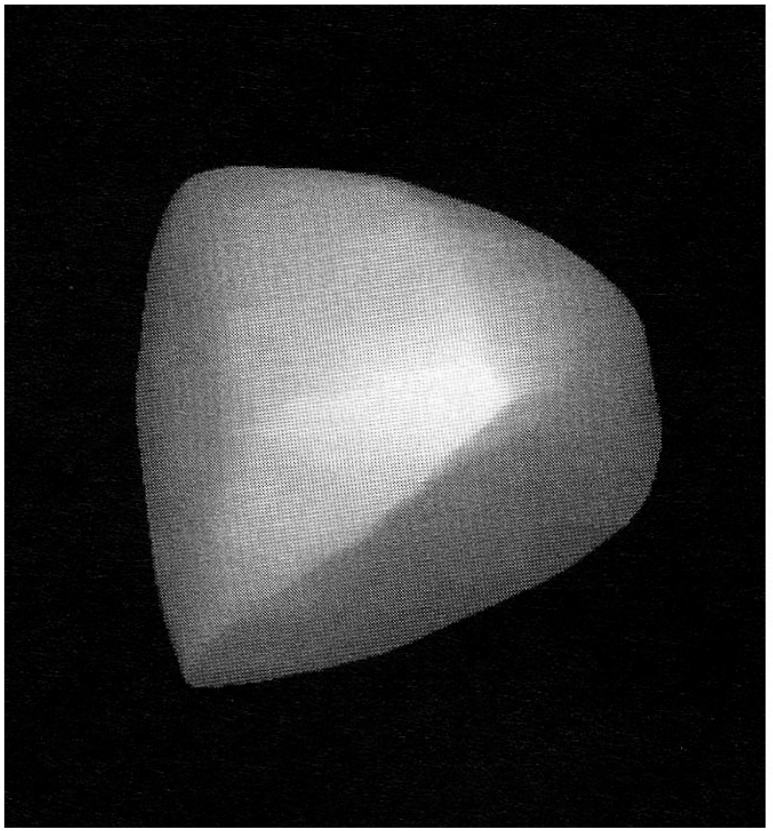




2001 SN263

6489 Golevka





Radar

Lightcurve inversion

Kaasalainen,Mottola, Fulchignoni, 2002, in Asteroids III.

NEA photometry

- Most NEAs are faint
- NEAs are not necessarily the brightest at opposition, where H_v is defined
- Fast moving at flyby when viewing conditions are favorable
  - –Relative photometry can be problematic (reference stars)
- Favorable viewing conditions repeat on 2 to 7 year scale

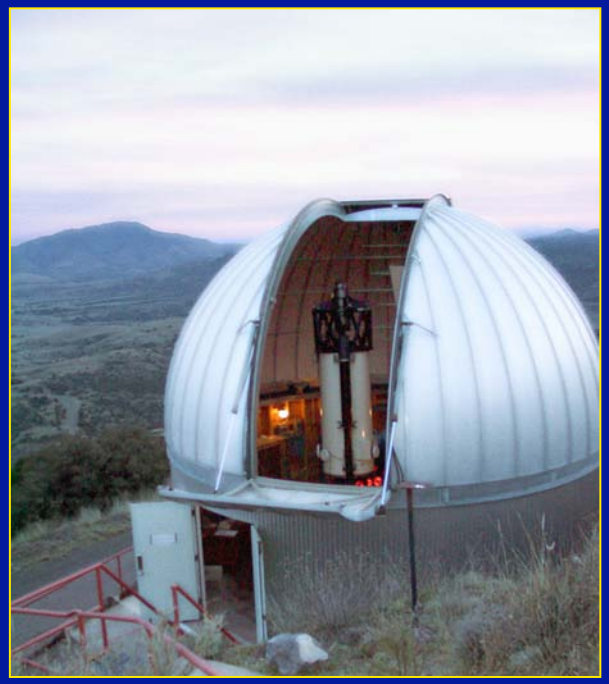
- **Primary Mirror**
  - D: 76.7cm (30.2")
  - f-ratio: 3.0
- **Prime Focus Corrector (PFC)**
  - field angle: 1.1°
- **Instrument**
  - Loral Fairchild 2048 x 2048 CCD, covering 46.5 arcmin
  - plate scale:1.3553 arcsec/pixel

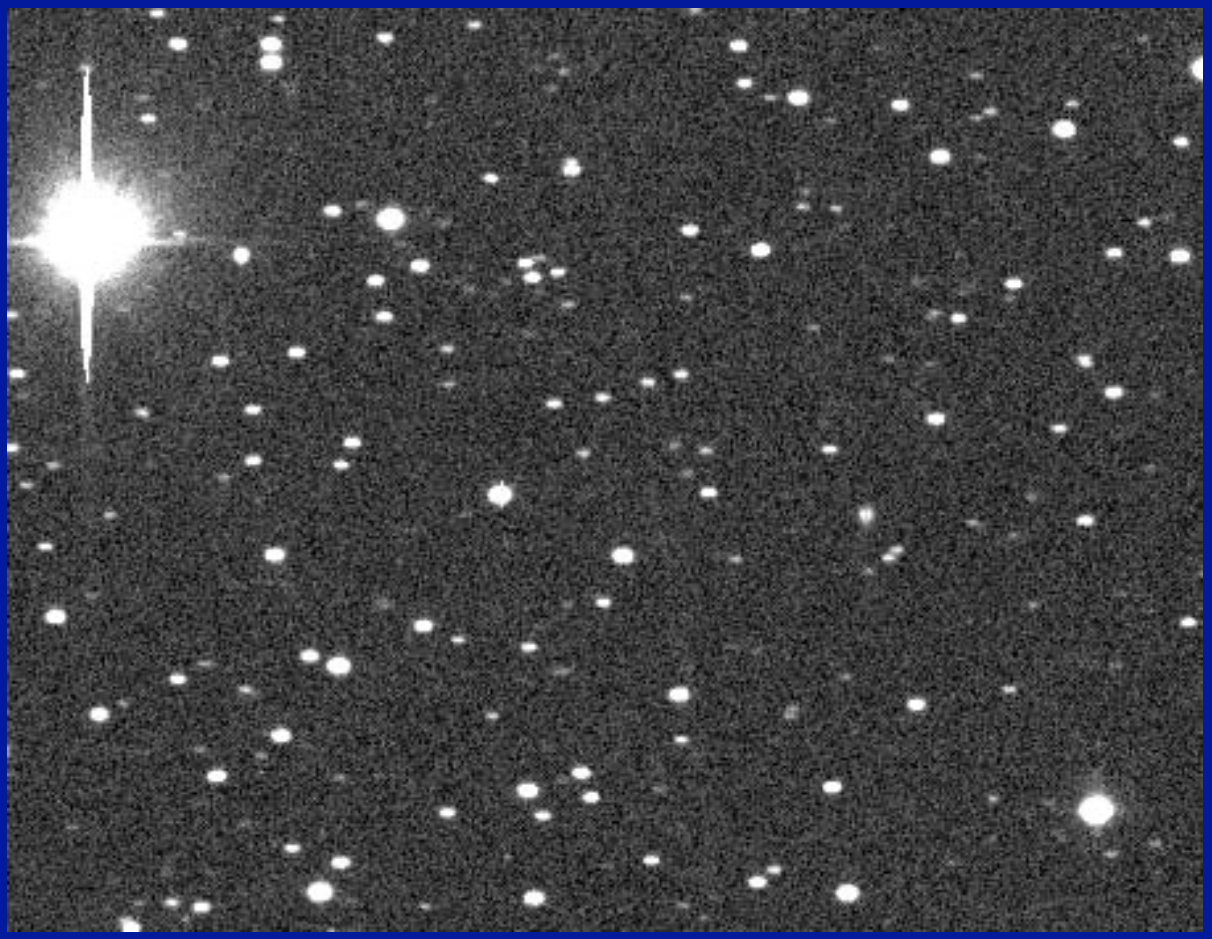
Asteroid is tracked to maximize S/N

  - stellar images and asteroid images in declination are smeared

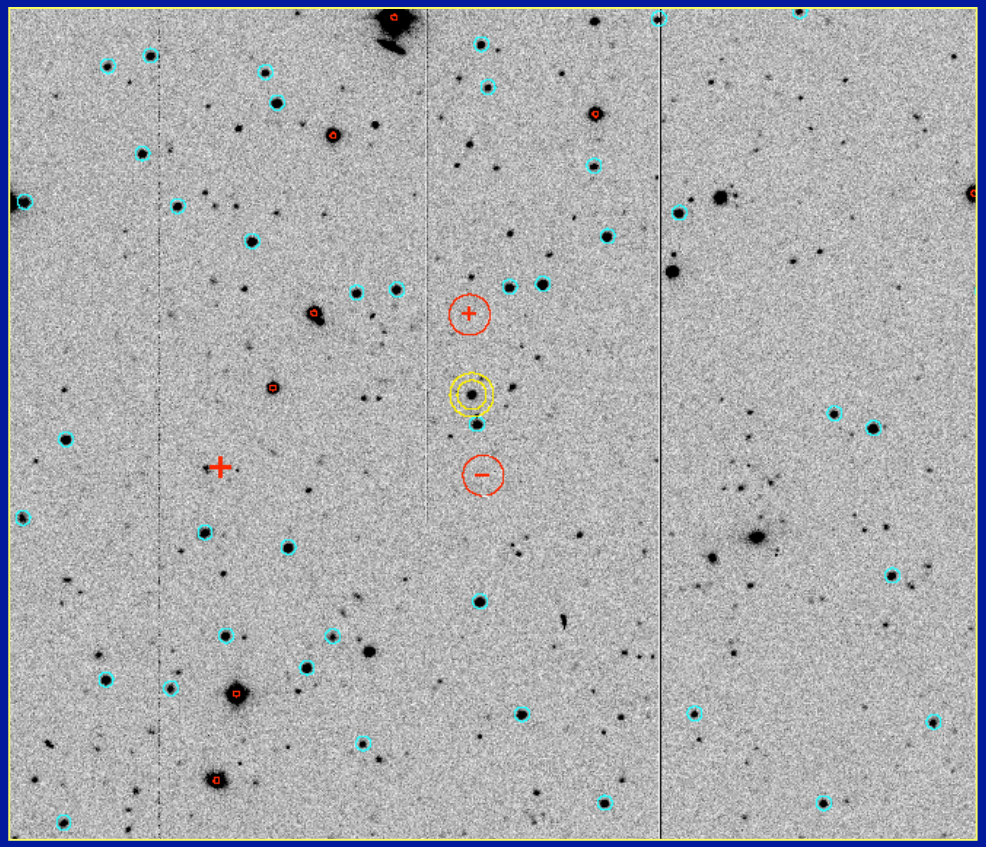
M_R<16 gives S/N >40

T_{EXP} < 150 sec





2001 CB21

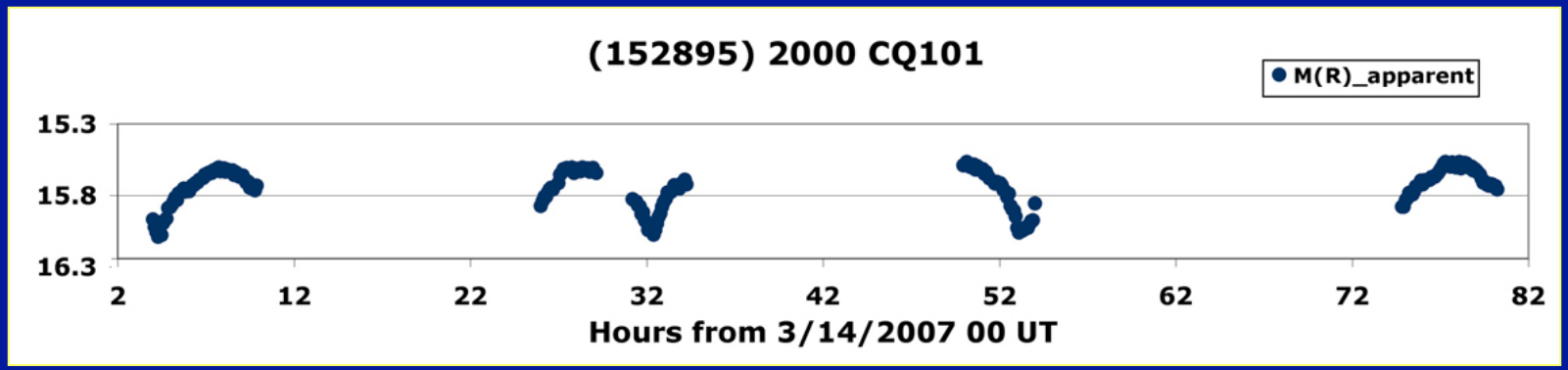


Relative Photometry

- USNO B1.0 (edited)
- $M_R = M_{ins} - (M_{cat} - M_{plt})$

Before time series analysis correction is necessary for:

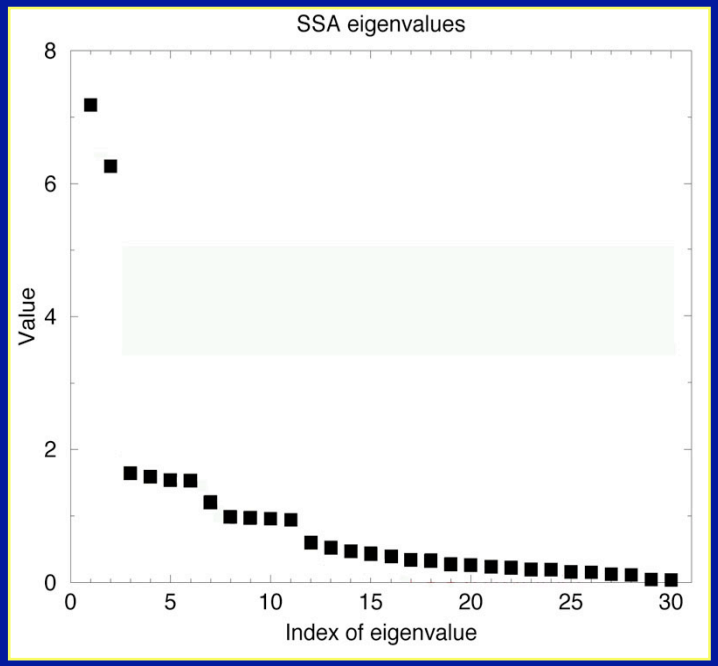
- R_{sun} and Δr_{Earth}
- Phase angle
- Light travel time

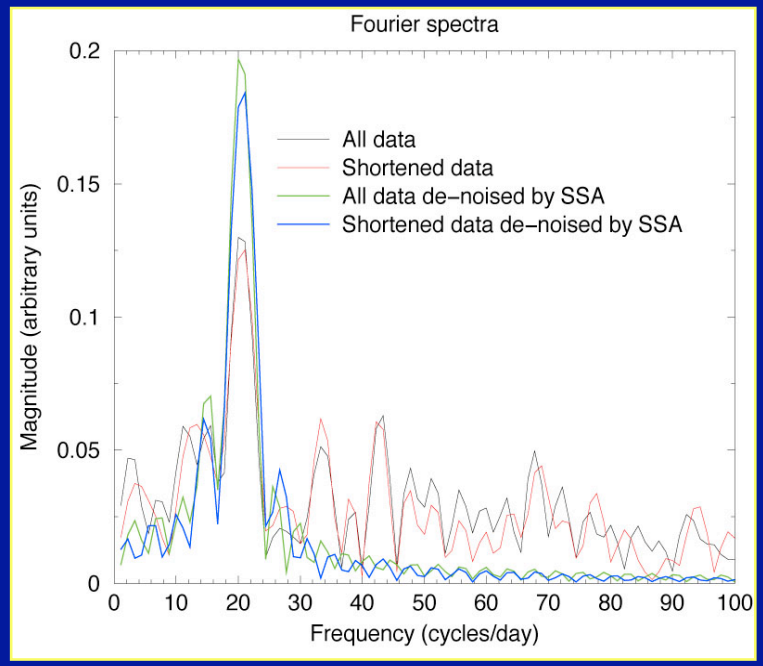


Singular Spectrum Analysis

Ghil et. al, 2002

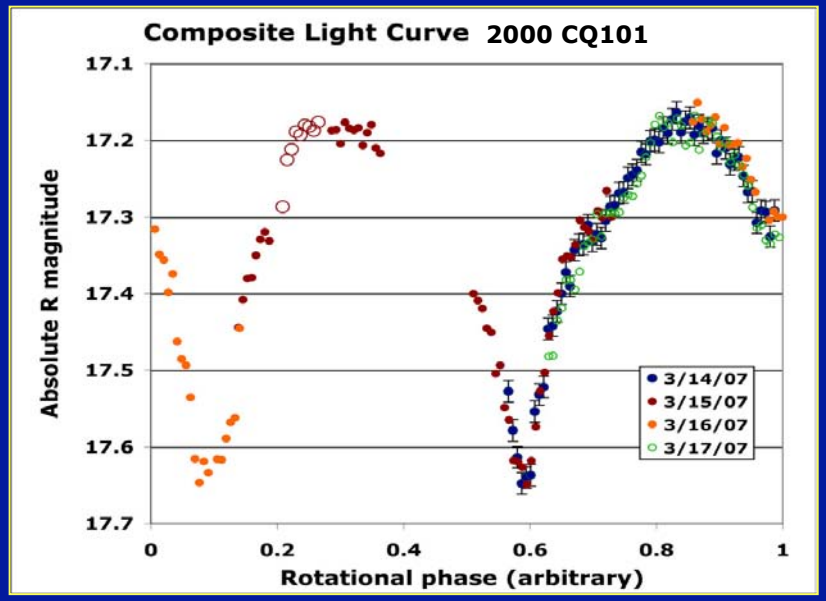
- Constructs time lag autocorrelation matrix
- Using the dominant eigenvalues as moving filters reconstructs the data above the noise FFT of de-noised data gives period (2002 EZ11)

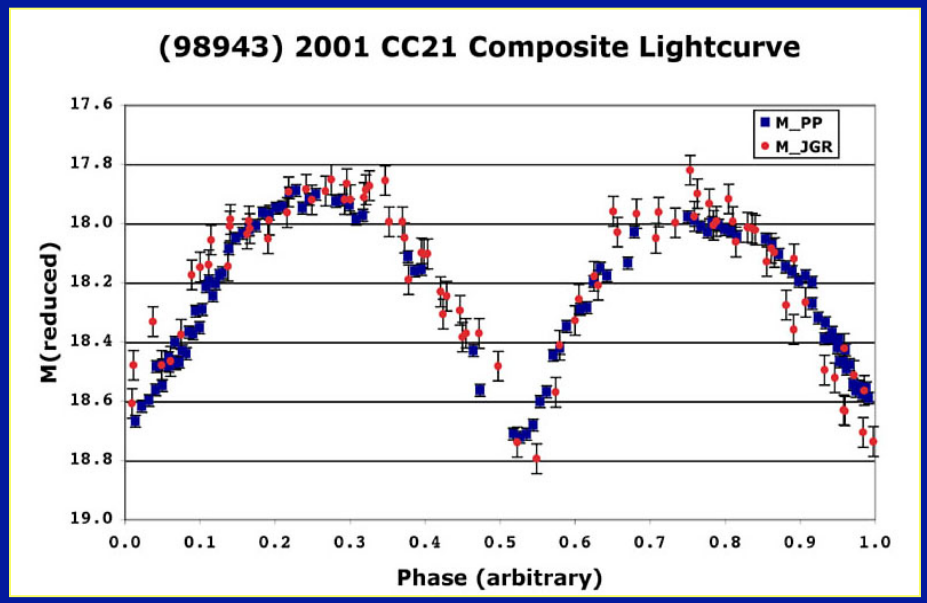


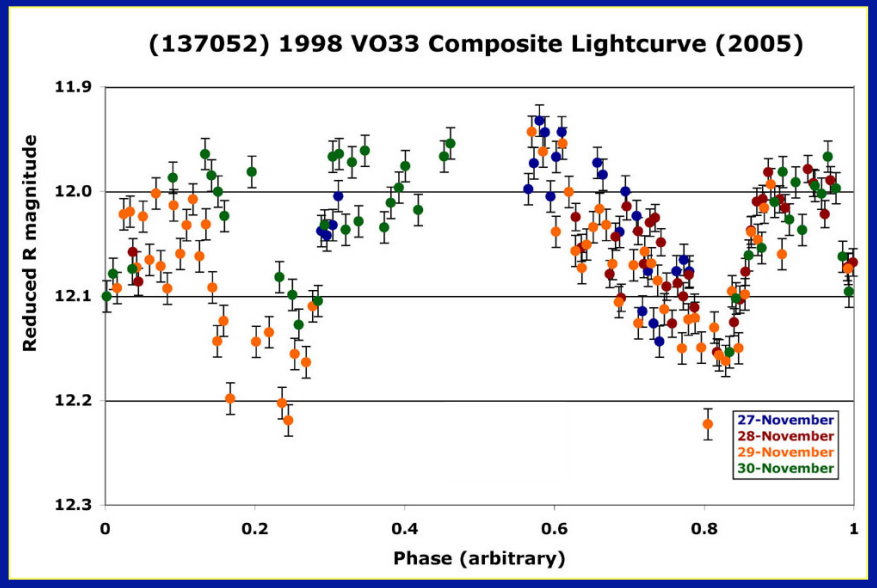


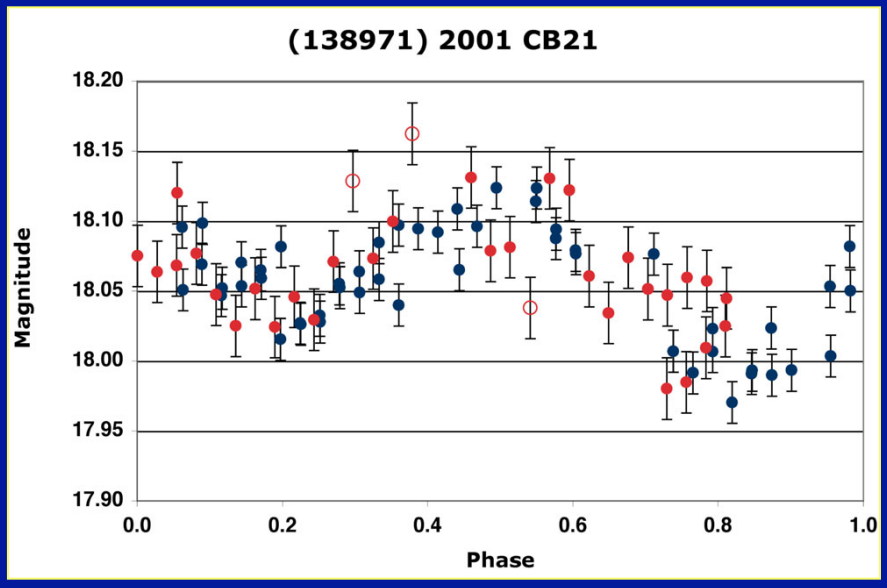
Number	Designation		H_V	M_V	$\Delta(M_R)$	Period (hours)
98943	2001 CC21 (combined with data from Pravec)	NEO	18.6	17.5	0.9	5.0227
137052	1993 VO33	NEO	16.8	16.1	0.3	11.18
138971	2001 CB21*	PHA	18.4	15.4	0.17	3.3
141495	2002 EZ11	PHA	18.2	15.6	0.15	2.33
152895	2000 CQ101	NEO	18.1	16.5	0.45	14.0
	2003 SS84*	PHA	21.8	18.1	0.35	~ 6
68216	2001 CV26*	PHA	16.3	16.1	~ 0.1	2.43
7088	Ishtar	NEO	16.7	17.4	NA	binary
4951	Iwamoto	MBA	13.2	15.8	NA	binary
5481	Kiuchi	MBA	13.0	17.5	NA	binary
4029	Bridges	MBA	12.9	17	NA	s. binary
10208	1997 QN1	MBA	14.6	16.2	NA	binary
6337	Okabayashi	MBA	13.1	15.5	NA	single
23971	1998 YU9	MBA	13.6	16.5	NA	single
16635	199QO	MBA	13.9	16.6	NA	single
	2006 RZ*	PHA	20.3	15.4	NA	single

* Denotes radar targets


Composite Light Curve 2000 CQ101
Absolute R magnitude
17.1
17.2
17.3
17.4
17.5
17.6
17.7
0
0.2
0.4
0.6
0.8
1
Rotational phase (arbitrary)
3/14/07
3/15/07
3/16/07
3/17/07


(98943) 2001 CC21 Composite Lightcurve
M(reduced)
17.6
17.8
18.0
18.2
18.4
18.6
18.8
19.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Phase (arbitrary)
M_PP
M_JGR


(137052) 1998 VO33 Composite Lightcurve (2005)
Reduced R magnitude
11.9
12.0
12.1
12.2
12.3
0
0.2
0.4
0.6
0.8
1
Phase (arbitrary)
27-November
28-November
29-November
30-November


(138971) 2001 CB21
Magnitude
18.20
18.15
18.10
18.05
18.00
17.95
17.90
0.0
0.2
0.4
0.6
0.8
1.0
Phase

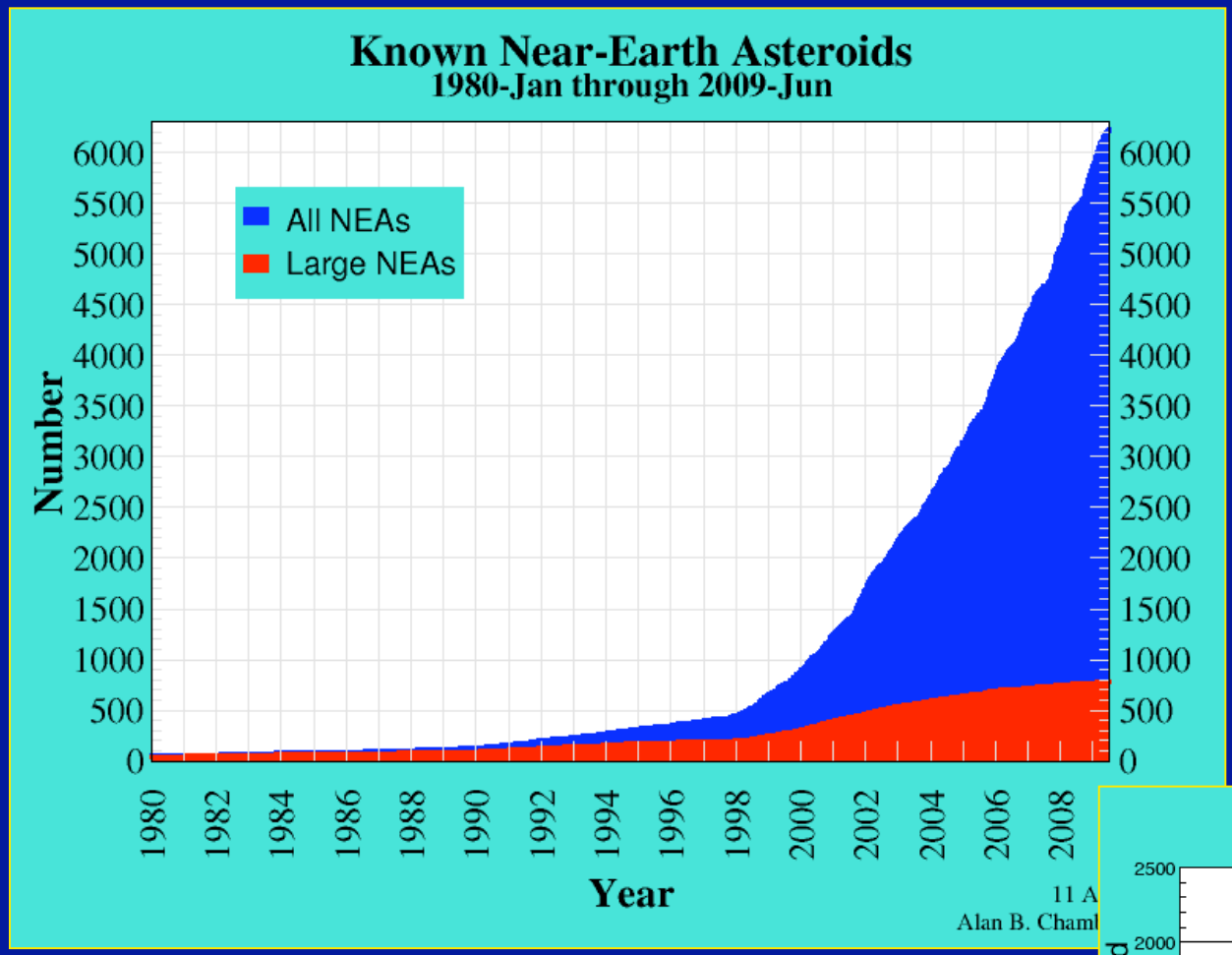
Unfinished business

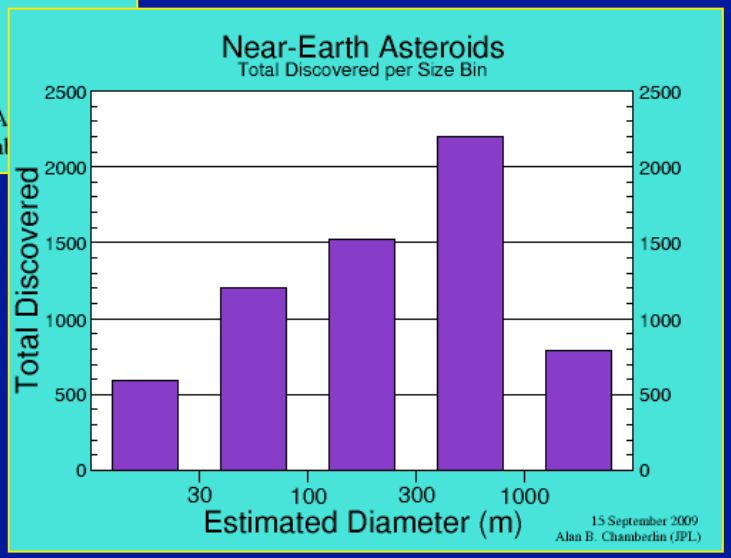
- Asteroids with not enough time coverage, sparse data:

  2003 UV11 (PHA), 2005 XJ8(PHA), 2001 PM9PHA),
  2002 OA22 (PHA), 2003 CJ11(NEA), 2003 CY18(PHA),
  2003 KO2(PHA), 2003 YG118(PHA)

- Need reduction:

  2005 GN59 (PHA)
  2005 WJ56 (NEA, probably very long period - radar obs)


Known Near-Earth Asteroids
1980-Jan through 2009-Jun
All NEAs
Large NEAs
Number
Year
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
11 A
Alan B. Chaml


Near-Earth Asteroids
Total Discovered per Size Bin
Total Discovered
Estimated Diameter (m)
0
500
1000
1500
2000
2500
30
100
300
1000
15 September 2009
Alan B. Chamberlin (JPL)

Asteroid Magnitudes

- **Absolute magnitude:**
- **The visual magnitude of an asteroid at zero phase angle and at unit heliocentric and geocentric distances**
- **Apparent magnitude**
- $V = H_v + f(\alpha) - 5*\log(r_{sun}*r_{earth})$
  - **Where**
    - H_v **is the absolute magnitude in V**
    - $f(\alpha)$ **phase function (adopted by IAU)**

$$f(\alpha) = -2.5*\log[(1-G)\Phi_1(\alpha) + G*\Phi_2(\alpha)]$$

G is the slope parameter (0.15 assumed if unknown)

(Marsden, 1986; Bowell et al. 1989)

Magnitude and Amplitude of lightcurve

- Aspect of asteroid
  - Where the rotation axis points and from where we view it
- Shape of asteroid
  - uniform, convex surface, triaxial ellipsoid
- $L^2 = 10^{-0.8H(\alpha_i)} = B_i \cos^2 f + C_i$
- $B_i = f(bc, (a/b)^2, p, Q)$
- $C_i = g(bc, (a/c)^2, p, Q)$

Magnusson et al., 1989

Yarkovsky-O'Keefe-Radzievskii-Paddack effect
2000 PH5 12.17 minutes and slowing at 1msec/yr