Spacewatch Preparations for the Era of Deep All-sky Surveys

By Robert S. McMillan and the
Spacewatch Team

Tom Gehrels: Founder in 1980.

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Spacewatch Project

- Discovery & followup of asteroids & comets.
- First to use CCDs for solar system astrometry.
- Continuous operation since 1984.
- Detection statistics have supported studies of:
  - NEOs
  - Centaurs
  - Main Belt
  - TNOs

Discoveries as of 2006 May 23

- 68 PHAs w/ $H \leq 22$ (diameter $\approx$ 140 m).
- 59 NEOs w/ $H \leq 18$.
- 520 total NEOs.

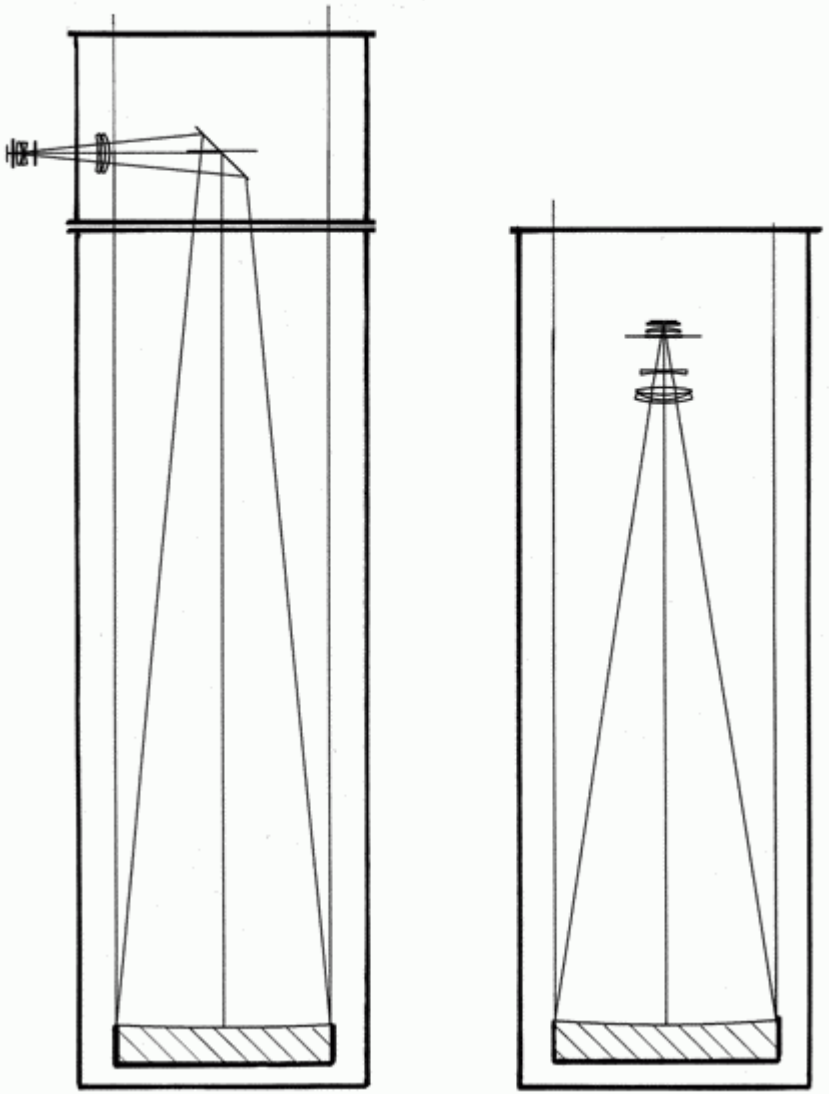
Current Systems

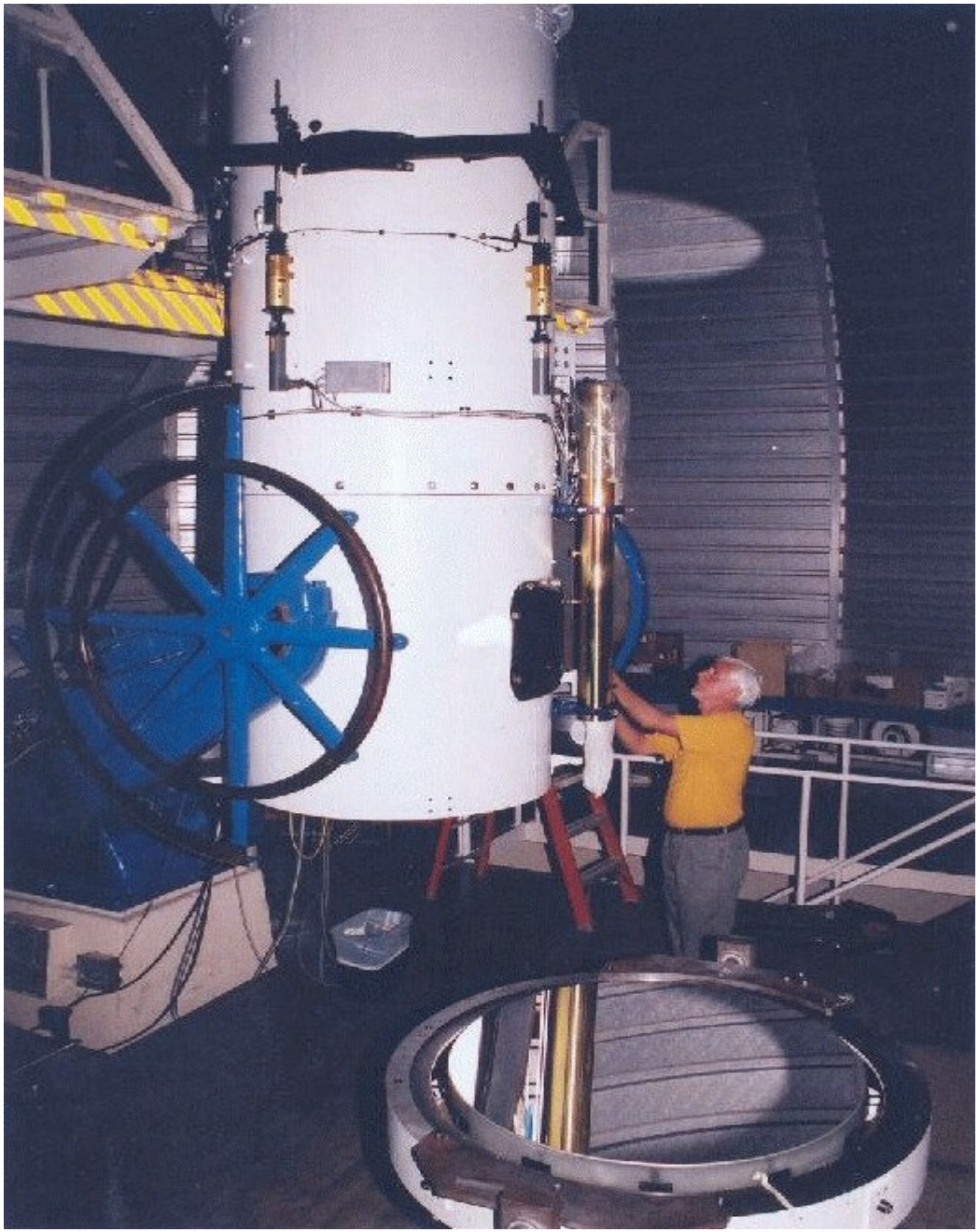
- 0.9-meter telescope refurbished in 2002.
- 1.8-meter telescope built in 2001.
- Emphasis on followup of NEOs when faint.
- Reporting on performance 2003-2006.
- Relevance to future of NEO surveys.

Refurbished 0.9-meter Telescope

- Primary mirror & field lenses in Oct. 2002.
- New mosaic of CCDs & new software.
- Software-controlled servo motors on original dome, mount & gears.
- Safety features & interlocks for unattended operation.

Spacewatch 0.9-meter Telescope Upgrade for Mosaic of CCDs



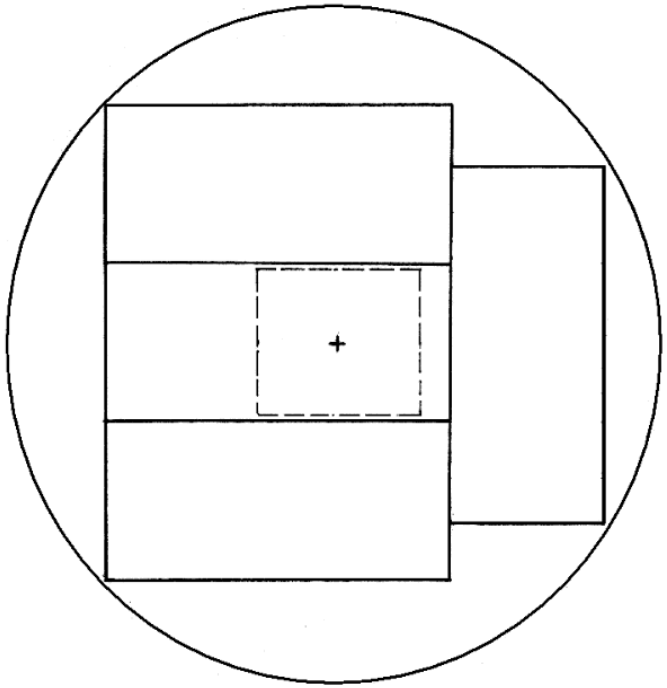


Mosaic of CCDs

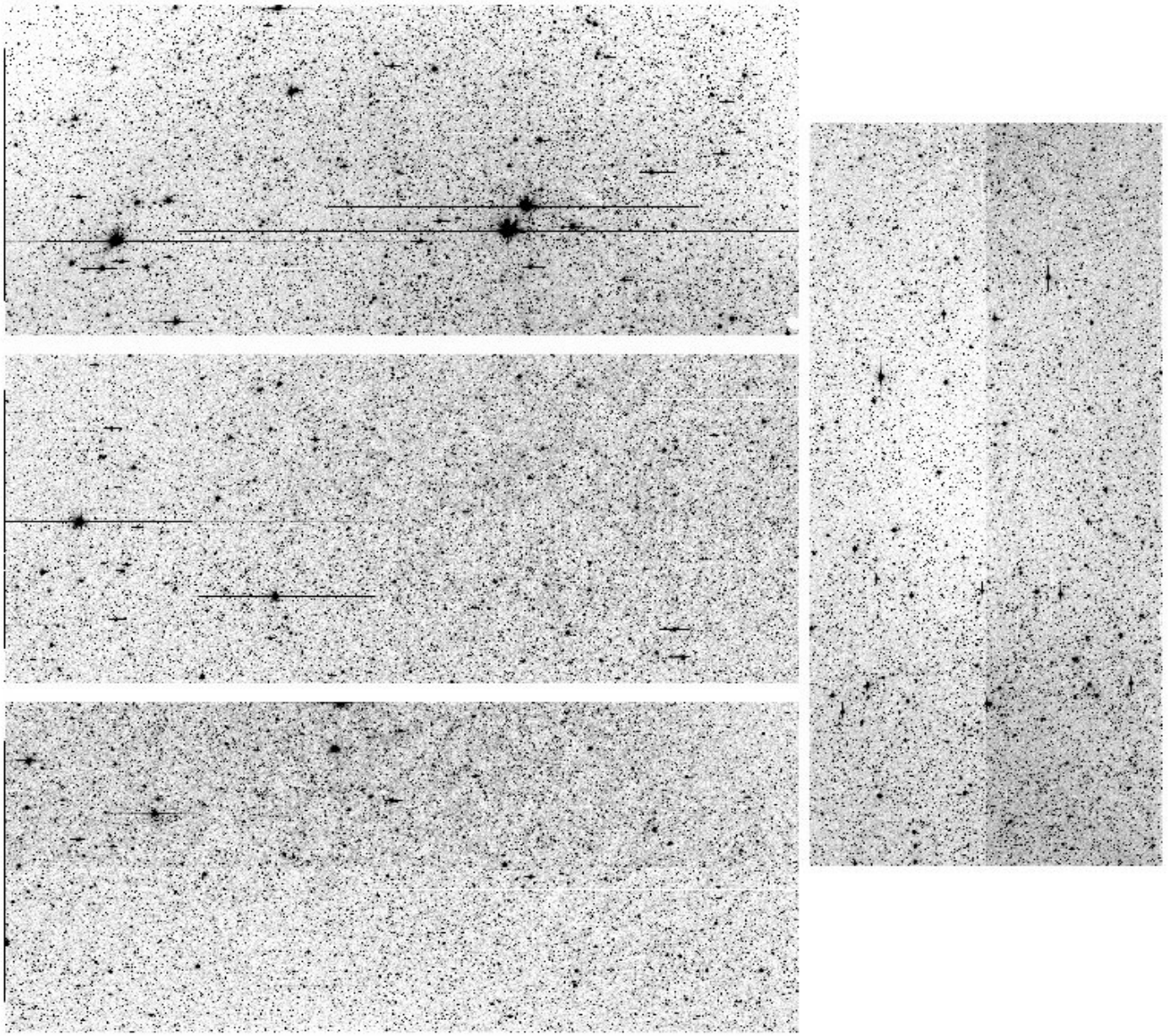
- Four thinned, back-illuminated EEV CCDs.
- Format of each = 4608 x 2048.
- 1 arcsec pixels covering 2.9 deg^2.
- Wavelength bandpass 515-950 nm.
- Effective $\lambda \approx 700$ nm on asteroids.
- Photometry zero pointed to V mag scale.

Spacewatch Mosaic of CCDs

Full scale focal plane compared with projected effective size of 2k x 2k CCD used previously.

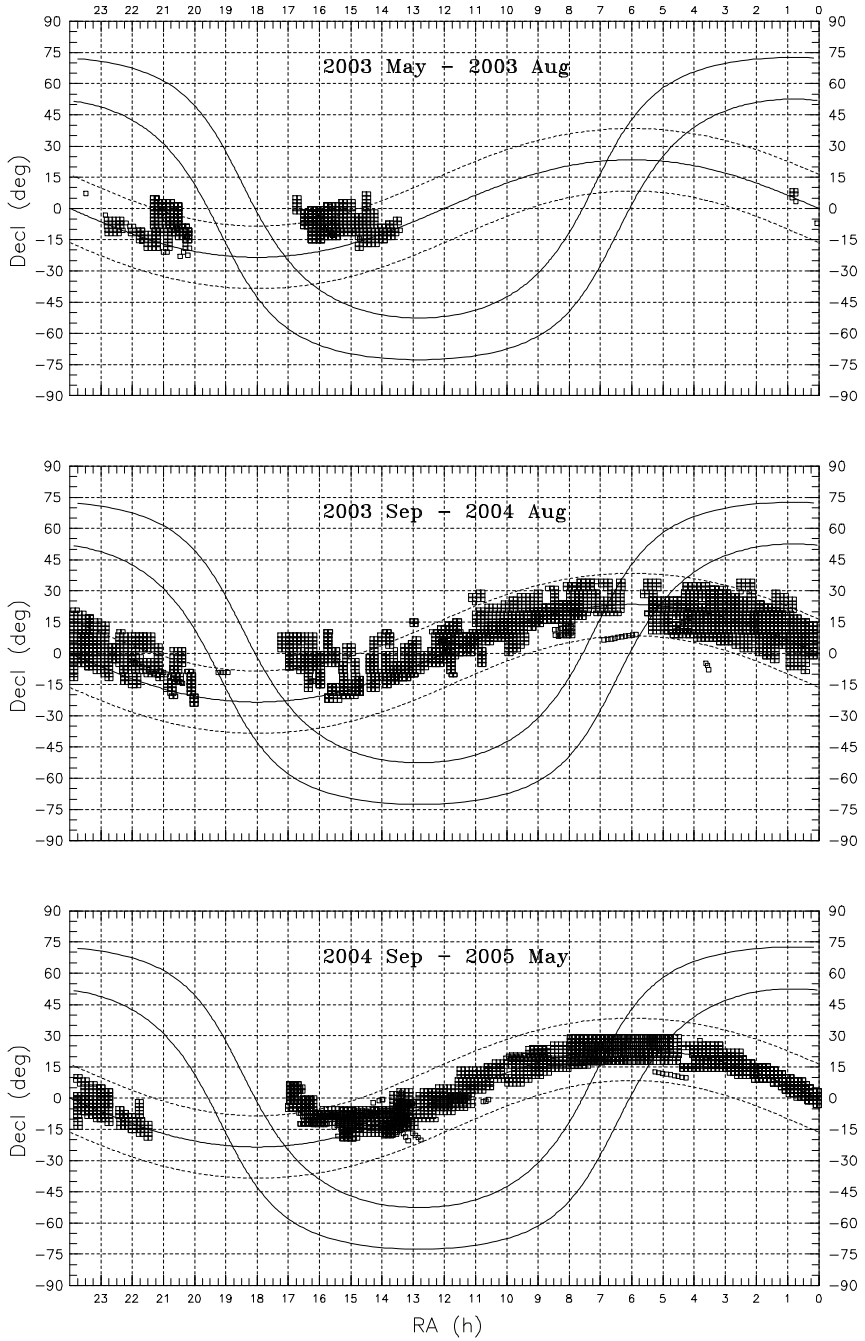


Four 4608 x 2048 Marconi Technologies thinned, back-illuminated CCDs.



0.9-meter Spacewatch Telescope

- “Step & stare” observing mode in 2002.
- Systematic surveying from April 2003.
- 24 nights scheduled per lunation.
- Fully automated in May 2005.
- Surveys near opposition & East in morning.
  - 1400 deg^2 per lunation.
  - 2 min exposure & 2 min read & slew.
  - V mag limit ≈ 21.7.
  - Revisit same cohorts of main belt objs ~4^d.

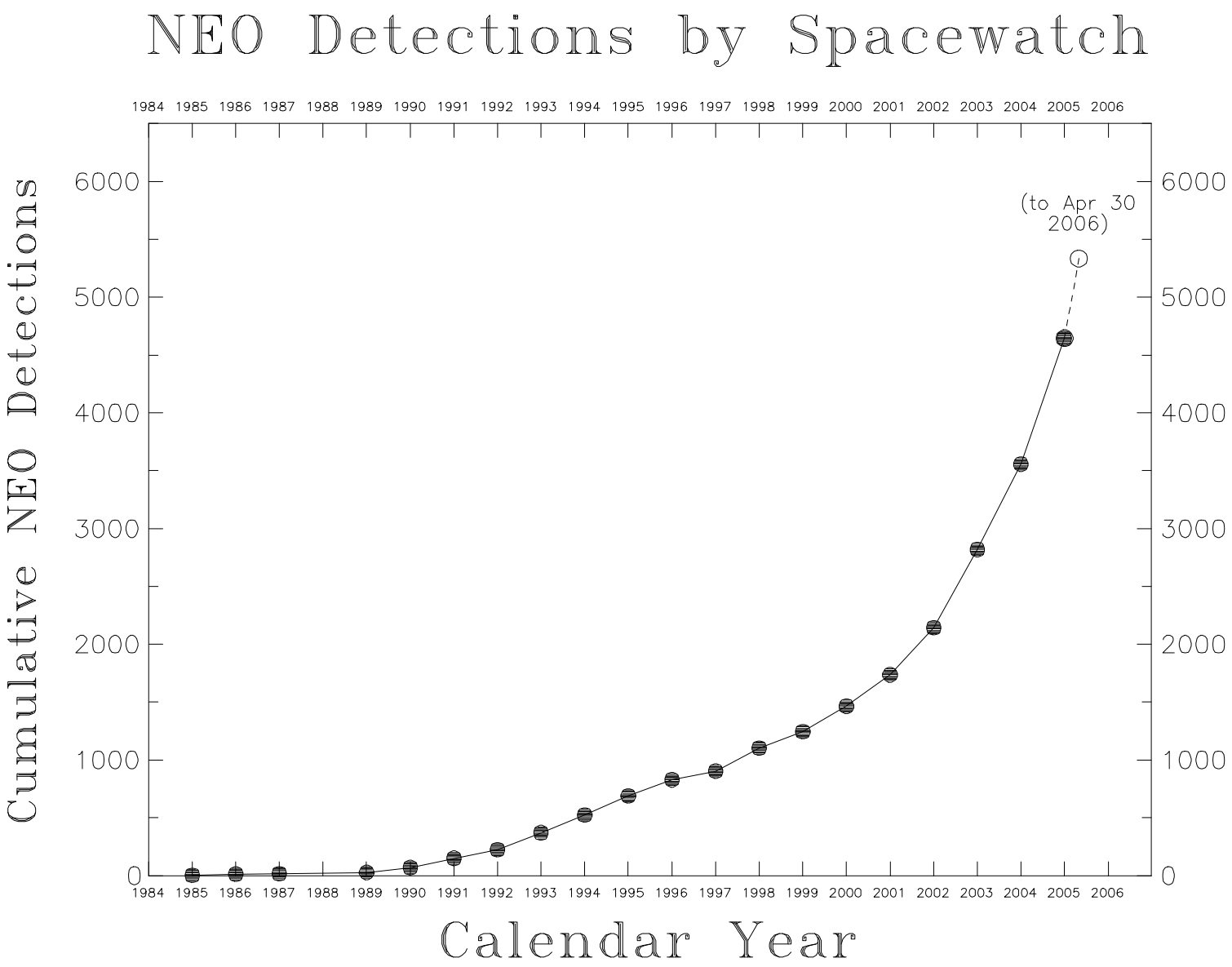

2003 May – 2003 Aug
2003 Sep – 2004 Aug
2004 Sep – 2005 May
Decl (deg)
RA (h)

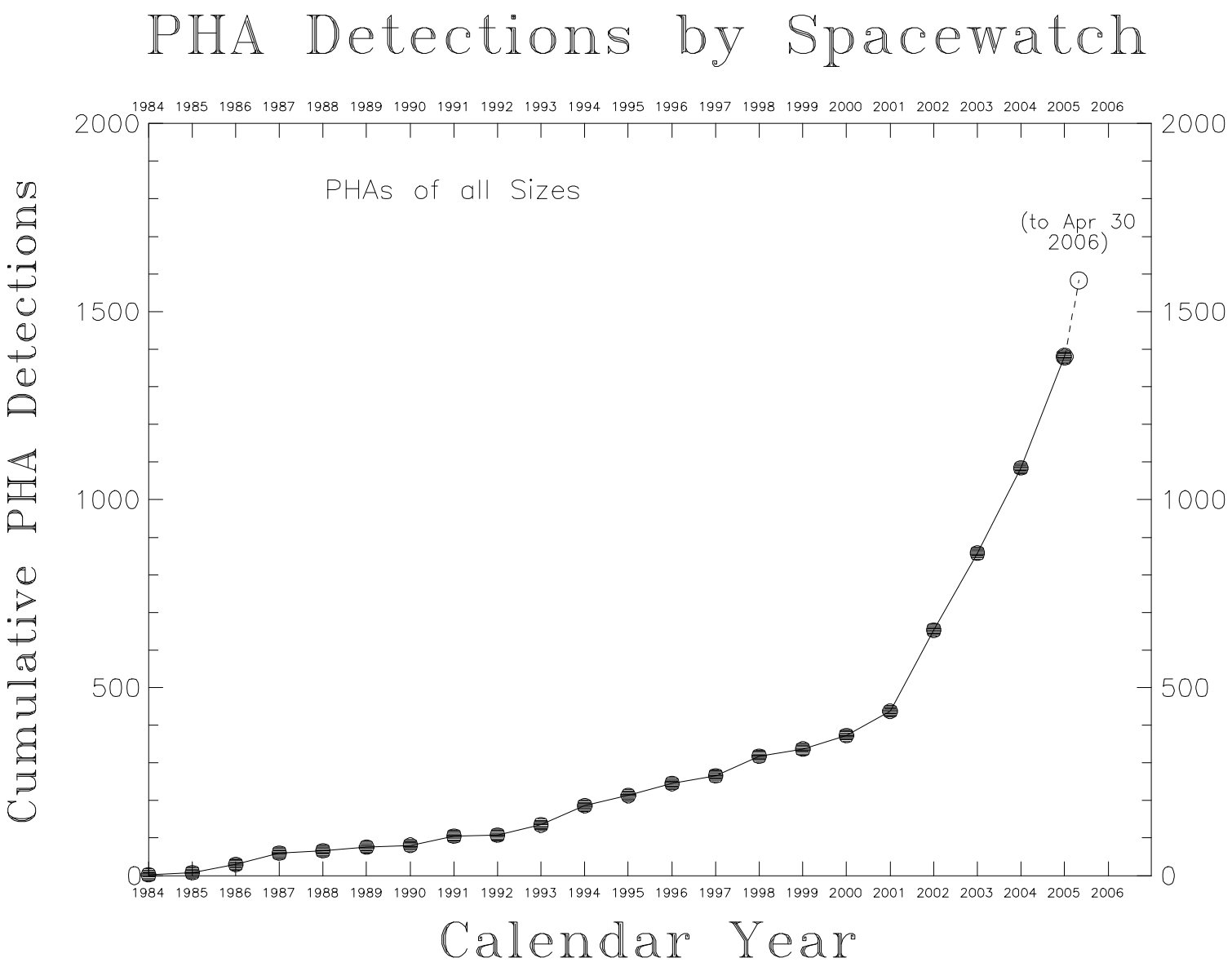
1.8-meter Telescope

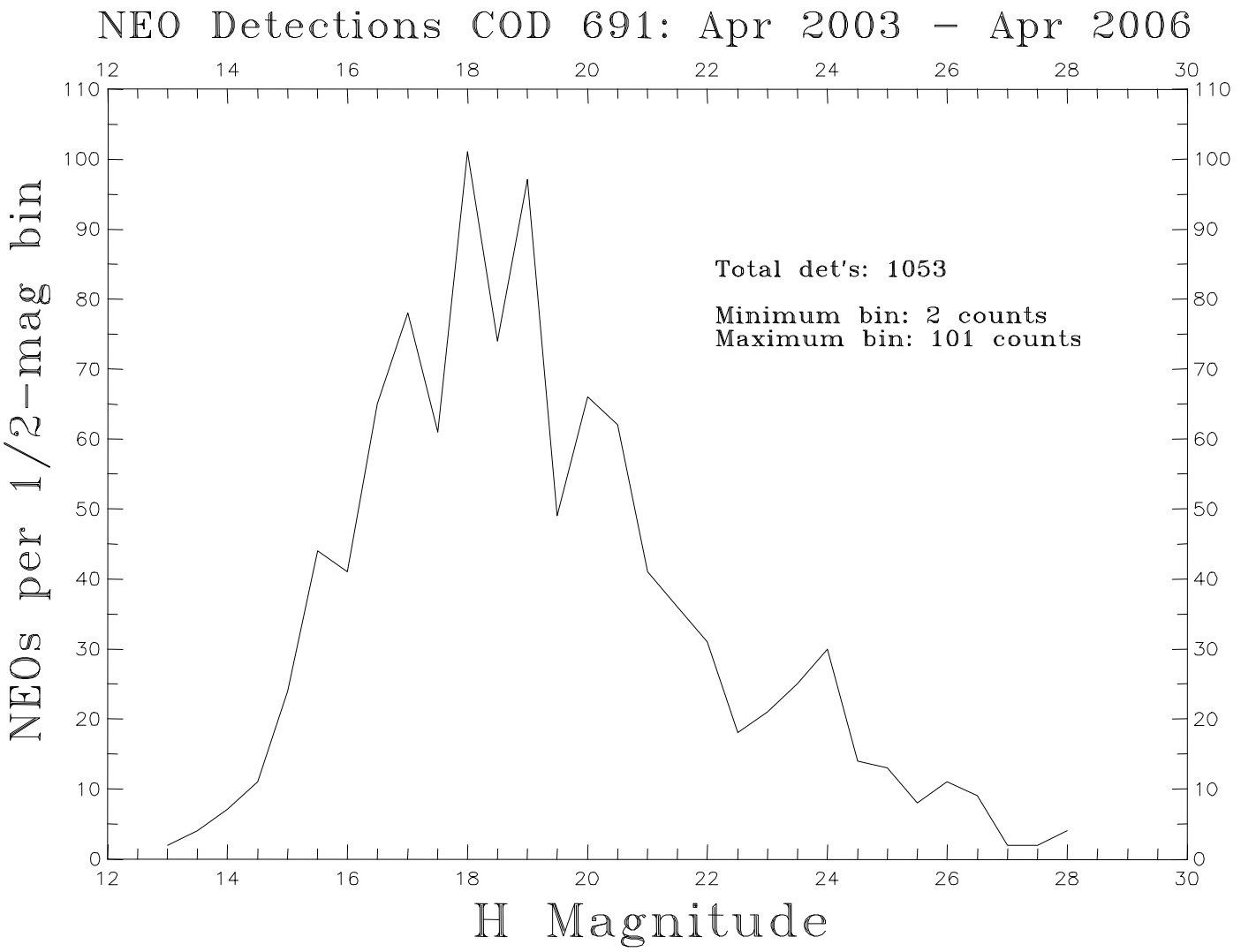
- Operational in October 2001.
- FOV= 0.6 x 0.6 deg on 2048 × 2048 CCD.
- Same bandpass as 0.9-meter.
- Has reached V=23.3 by shift & stacking. Mostly drift scanning for followup of
  - NEO Confirmation Page objects.
  - PHAs & Virtual Impactors.

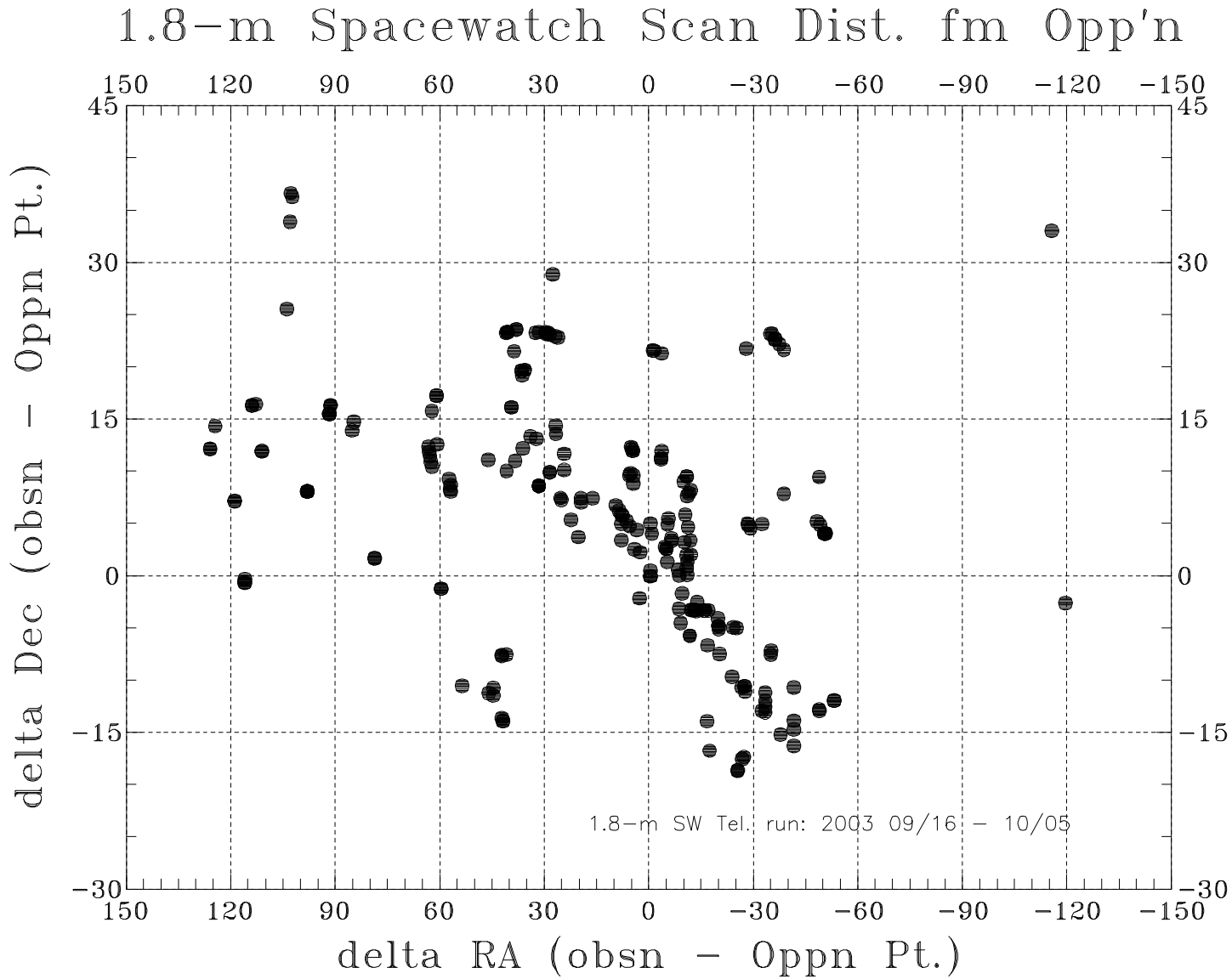
Followup of NEOs by Spacewatch

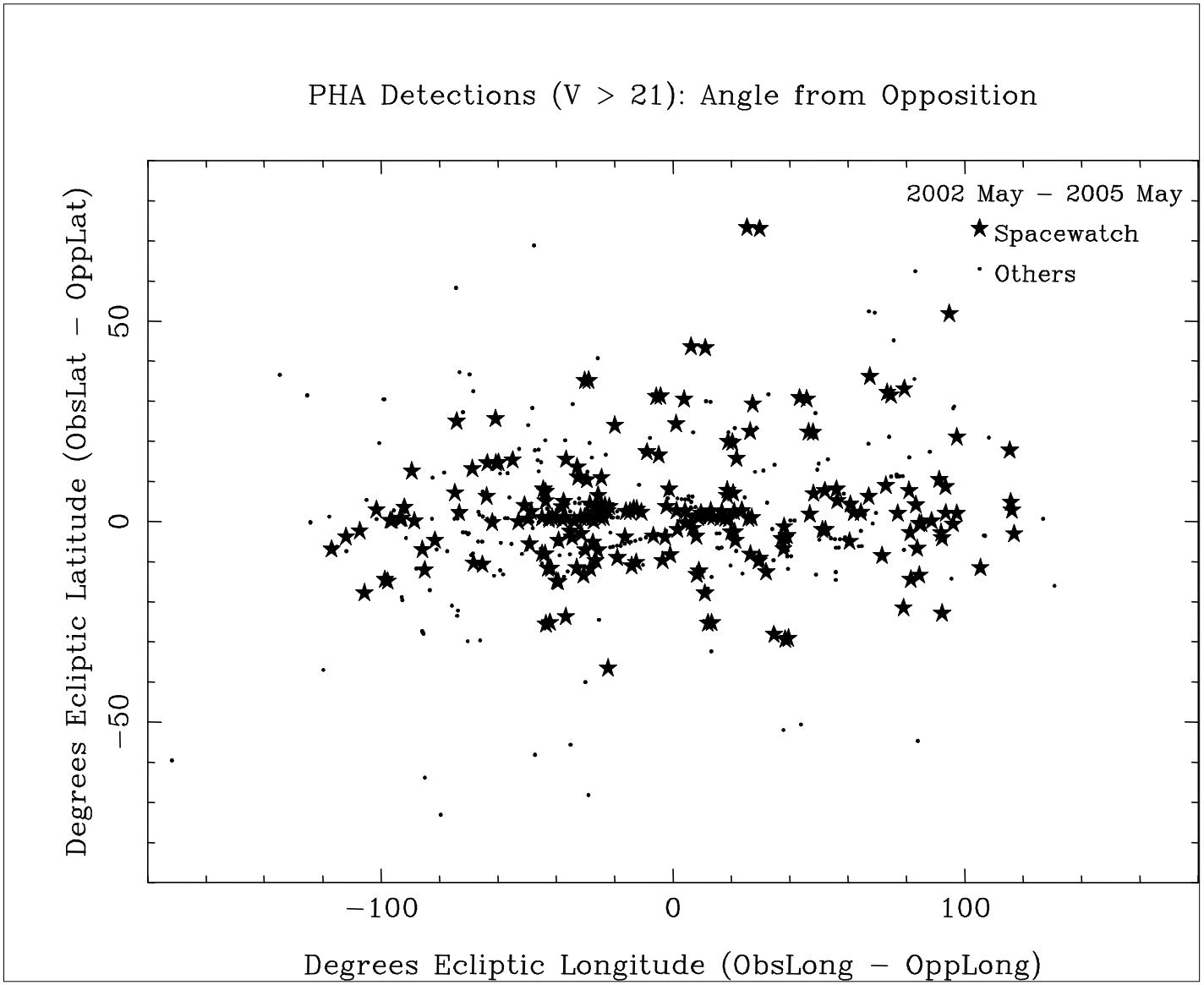
- ⅔rds by 1.8-meter scope; ⅓ by 0.9-meter.
- Concentrating on PHAs, CP objects, VIs.
- Detections compared vs. time.
- Detections compared with community.
- Elongation limits.
- Recoveries & Precoveries.

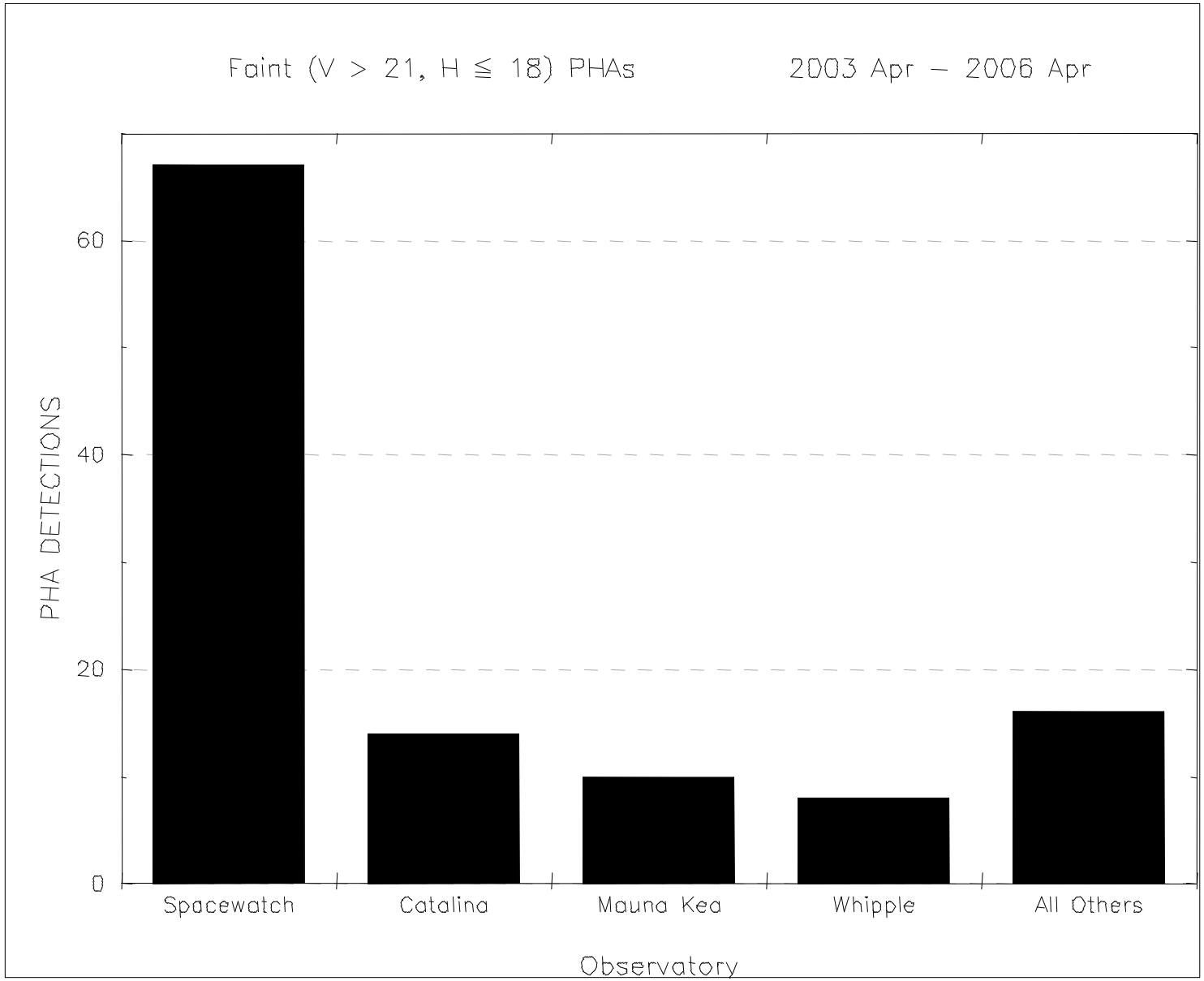

NEO Detections by Spacewatch
Cumulative NEO Detections
Calendar Year
(to Apr 30 2006)
0
1000
2000
3000
4000
5000
6000
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006

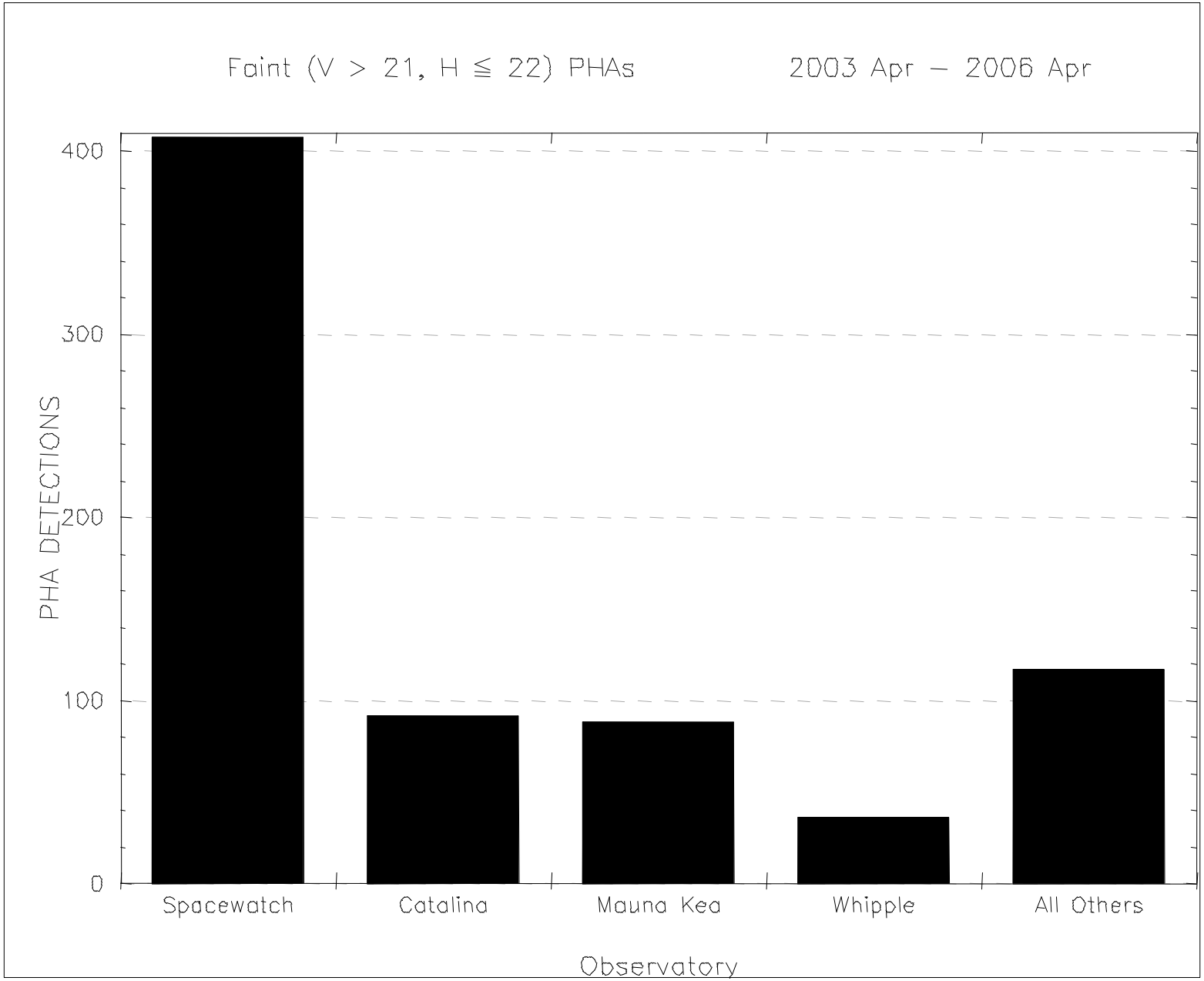

PHA Detections by Spacewatch
PHAs of all Sizes
(to Apr 30 2006)
Cumulative PHA Detections
Calendar Year
0
500
1000
1500
2000
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006


NEO Detections COD 691: Apr 2003 – Apr 2006
NEOs per 1/2-mag bin
H Magnitude
Total det's: 1053
Minimum bin: 2 counts
Maximum bin: 101 counts
12
14
16
18
20
22
24
26
28
30
0
10
20
30
40
50
60
70
80
90
100
110


1.8−m Spacewatch Scan Dist. fm Opp'n
150
120
90
60
30
0
−30
−60
−90
−120
−150
45
30
15
0
−15
−30
delta Dec (obsn − Oppn Pt.)
delta RA (obsn − Oppn Pt.)
1.8−m SW Tel. run: 2003 09/16 − 10/05


PHA Detections (V > 21): Angle from Opposition
2002 May – 2005 May
Spacewatch
Others
Degrees Ecliptic Latitude (ObsLat – OppLat)
50
0
−50
−100
0
100
Degrees Ecliptic Longitude (ObsLong – OppLong)


Faint (V > 21, H ≦ 18) PHAs
2003 Apr – 2006 Apr
PHA DETECTIONS
60
40
20
0
Spacewatch
Catalina
Mauna Kea
Whipple
All Others
Observatory


Faint (V > 21, H ≦ 22) PHAs
2003 Apr – 2006 Apr
400
300
200
100
0
PHA DETECTIONS
Spacewatch
Catalina
Mauna Kea
Whipple
All Others
Observatory

Selected PHA Recoveries

Object	Unc. (deg)	Arcs Bef.	Arcs Aft.	O-C arcsec)	
2000 UL11	2	28d	1039d	3320	
1998 VS**	4	32d	1831d	1581	
2001 US16	2	31d	802d	485	
2000 EV70	3	46d	1193d	214	
1999 VT25	3	26d	1786d	7556	
1990 SM	80	24d	5225d	23022	(H=16; was very lost.)
2002 TW55	1	52d	831d	237	
2003 BH	?	51d	844d	45	
1998 VF32	2	14d	2555d	5581	
2001 YP3	2	109d	1453d	21	
2004 JQ1	1	31d	600d	210	
2004 RY109	0	94d	510d	22	
2005 TR50**	1	2d	164d	3660	(Also G96)

Spacewatch Image Archive

- 80,000 deg^2 of sky area, 1990-present.
- ~10 Terabytes in FITS format on DVDs.
- Index of pointing centers on web site.
- 2004 MN_4 best example of use.

Incidental Astrometry (IA)

- Dates back to 1984 April.
- Saving unlinked IA was Tom Gehrels' idea.
- 130 NEOs & 6 comets found in last 3 yr alone.
  - Too distant & slow to be flagged.
  - Detected prior to scoring software.
- Millions of unlinked Spacewatch observations made public thru Minor Planet Center.

Spacewatch's Future

- Funded by NASA NEO Observation Program through 2009 April 14.
- Improving limiting magnitude of 1.8-m scope to follow up Pan-STARRS' discoveries.
- Collaboration w/ Pan-STARRS:
  - Providing lists of point sources.
  - Available to follow up discoveries.