



UK participation in the 2004 GEO debris campaign with the PIMS network

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What is the PIMS Network?

PASSIVE IMAGING METRIC SENSOR



PIMS



An advanced satellite tracker for the
optical surveillance of space

UK Ministry of Defence

Project Manager: Dr David Holland

Prime contractor

Project Manager: Dr James Dick, Observatory Sciences Ltd



What is the PIMS Network?



PIMS is a network of optical sensors at three geographic locations

Each sensor is a fully automated robotic optical telescope in a fully enclosed dome equipped with a 1024x1024 pixel CCD detector

Each sensor is computer driven using customised software and hardware to control the telescope, dome and detector

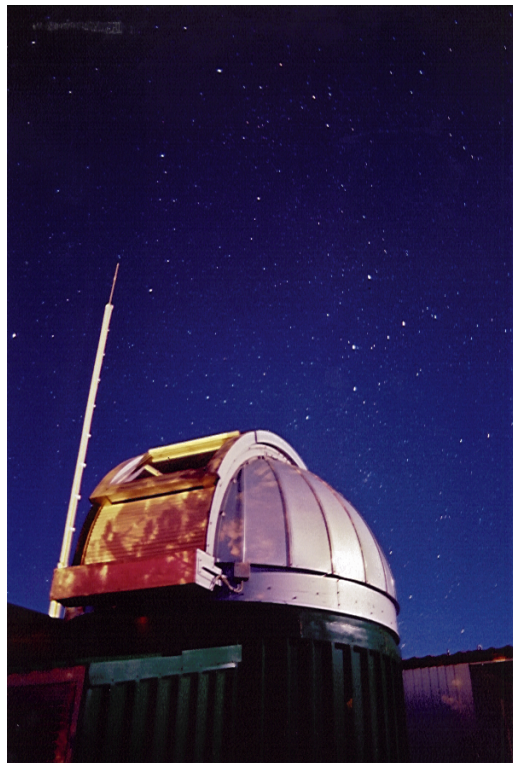
Image timing is taken from GPS clock signals

The sensor tasking is determined from schedule files generated and downloaded to the sensor automatically before the start of each night





PIMS site views



Troodos Mountains
(Cyprus)

Herstmonceux
(United Kingdom)





PIMS sites and GEO coverage

- Herstmonceux, UK (1995)
- Gibraltar (1996)
- Troodos Mountains, Cyprus (1998)





PIMS scheduling



The PIMS sensors run a time windowed priority based schedule

This allows each sensor to run a mixture of different types of task at different times during each night



The scheduling system allows for two main types of tasks, target based and search based.

Target based

- free target based scheduling
- time slot target scheduling
- long-track scheduling
- multiple revisit scheduling

Search based

- pseudo elset
- RA-Dec
- GEO longitude-latitude



PIMS performance

- *accuracy*: typically ~ 1.5 arcseconds = ~ 6 micro-radians
- *detection size in GEO*: smaller than 1 m diameter
- *throughput*: four $0.6^\circ \times 0.6^\circ$ images/minute
- *all targets* in image measured simultaneously
- *capable of tracking* GEO, GTO, MEO, HEO, & high-LEO
- *average monthly output*: 20,000 observations on 2,000+ objects
- *GEO population coverage*: 50% in 10 nights, 90% in 40 nights (orbit propagation good for ~ 200 nights)
- *sensor faults requiring on-site support*: ~ 1 per month
- *operators required*: NONE



PIMS and the IADC



PIMS has been making contributions to the IADC GEO campaigns since 2001



2001:
Orbits of uncorrelated targets from serendipitous observations

2002:
Trial simultaneous bistatic and long-track multi-site observations
in collaboration with Thomas Schildnecht

2003:
Orbits from observations using sensors dedicated to campaign

2004:
Orbits from observations using sensors dedicated to campaign



2004 observations



PIMS supplied orbits from sensors dedicated to observing scheme circulated by Thomas Schildnecht and John Africano



Due to time of year observing was disrupted by weather problems

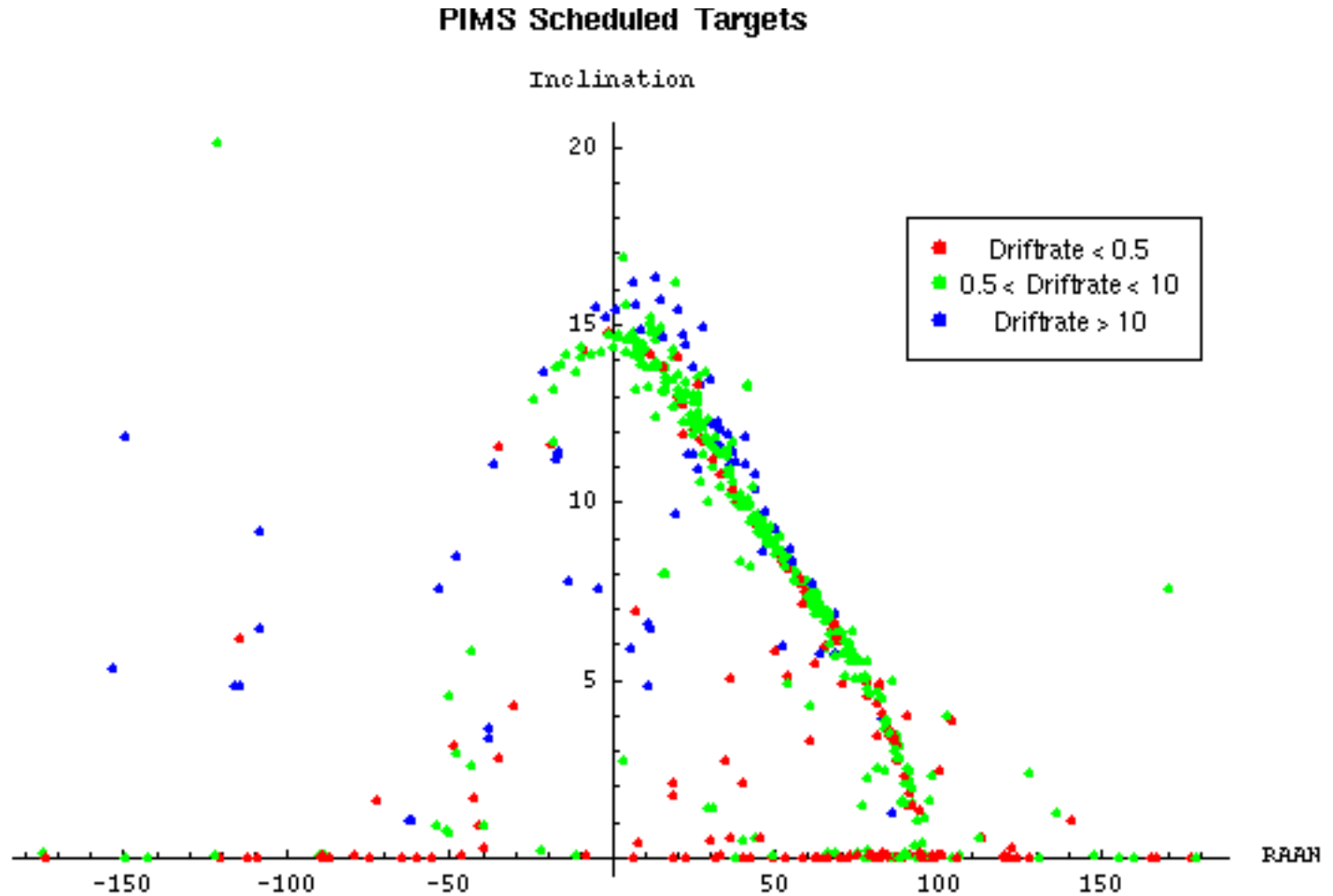
PIMS obtained observations on three nights in each of January and March 2004

In total orbits of 96 objects were obtained based on 538 observations

Of these 8 objects could not be correlated by the PIMS team with any object in their catalogue of unclassified objects



Comparison of i-node plots of PIMS targets with search campaign results



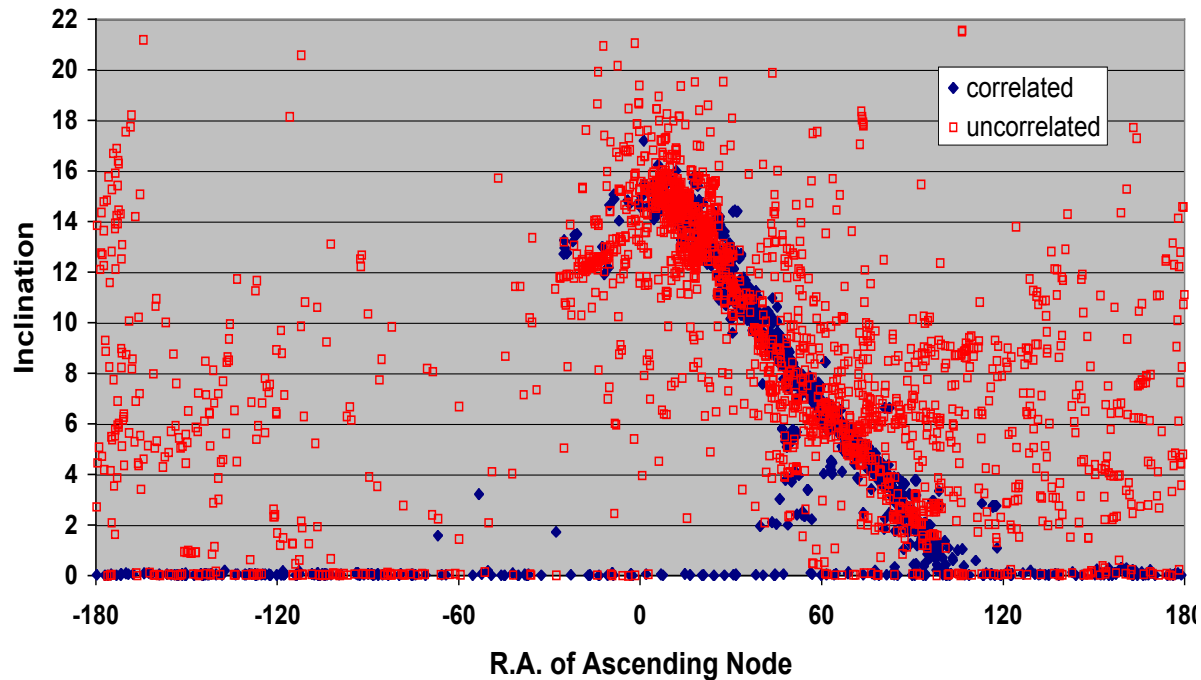
PIMS observations, January/February 2004



Comparison of i-node plots of PIMS targets with search campaign results



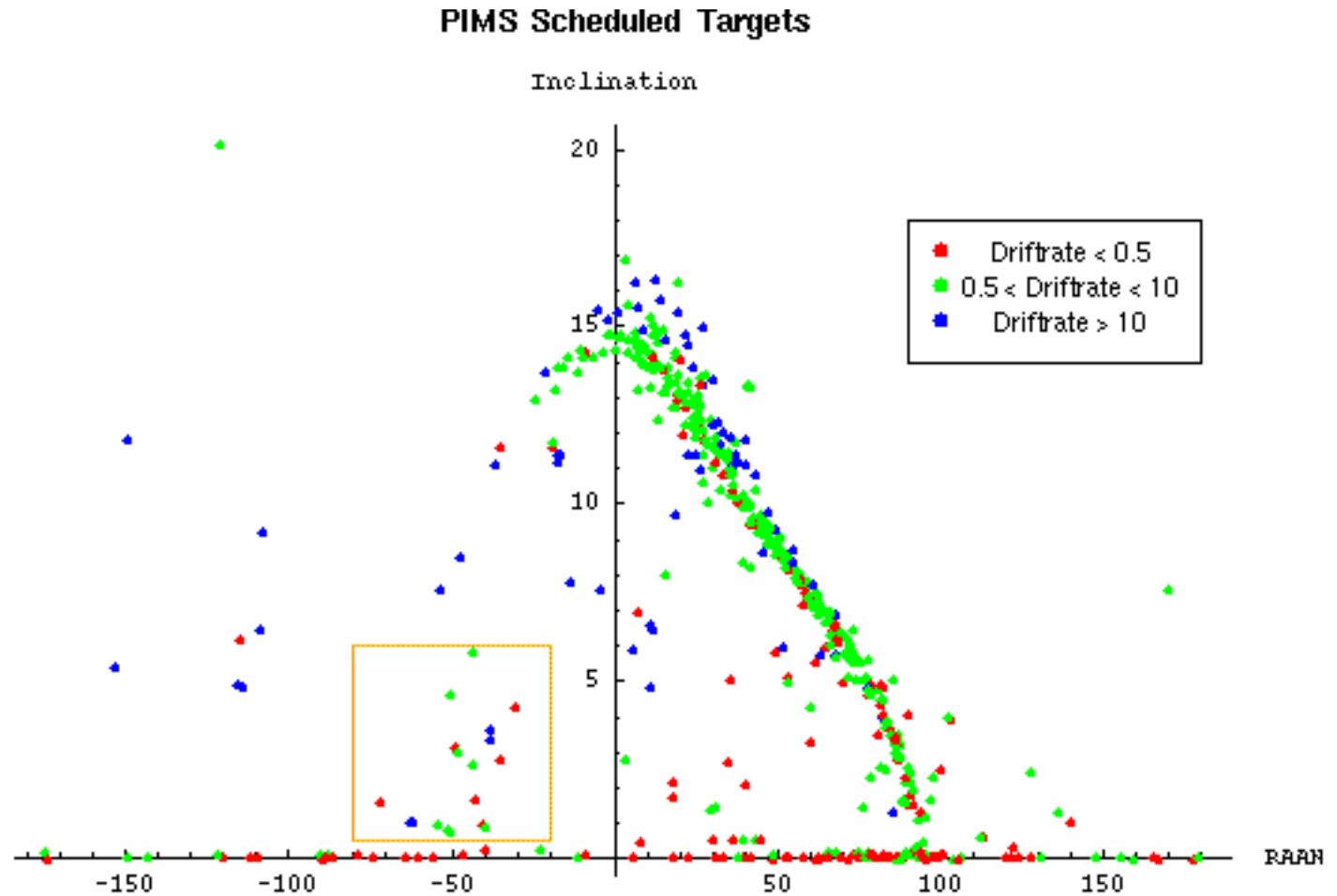
Orbital Elements (Jan - Dec 2002)



ESA survey plot by Thomas Schildnecht



Comparison of i-node plots of PIMS targets with search campaign results





Comparison of i-node plots of PIMS targets with search campaign results



PIMS target driven observations compared with IADC area search

PIMS observing method takes “random” snapshots compared with systematic approach of IADC GEO campaign



Unsurprisingly the plot of PIMS targets is broadly similar to the results of the ESA survey supplied by Thomas Schildnecht

The one region where PIMS does differ is in the region around $\Omega = -50$ to -40 degrees (310 to 320 degrees)

Examination of the data shows these differences to be predominantly the result of uncorrelated objects found serendipitously

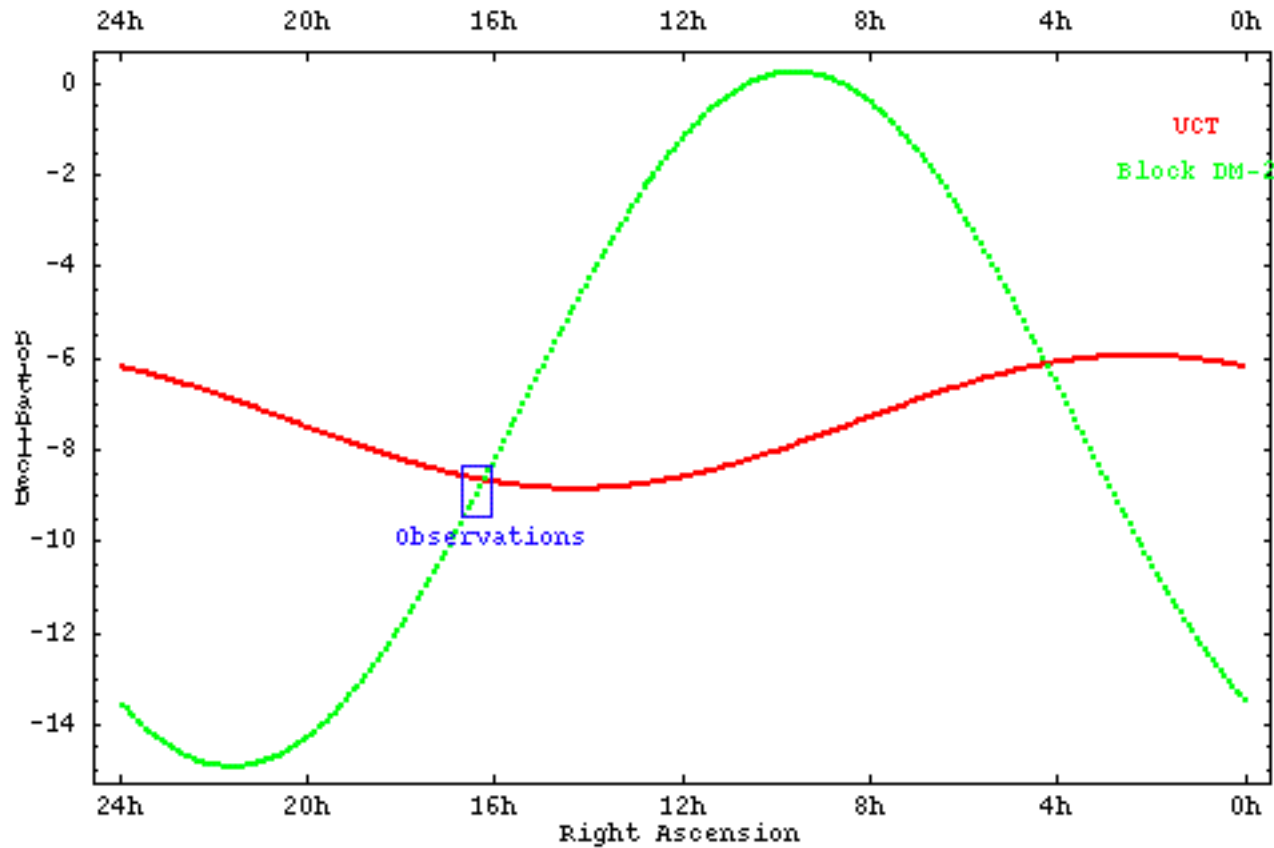


Serendipitous observations

PIMS observes all objects within the field of view



Block DM-2 and Uncorrelated Target



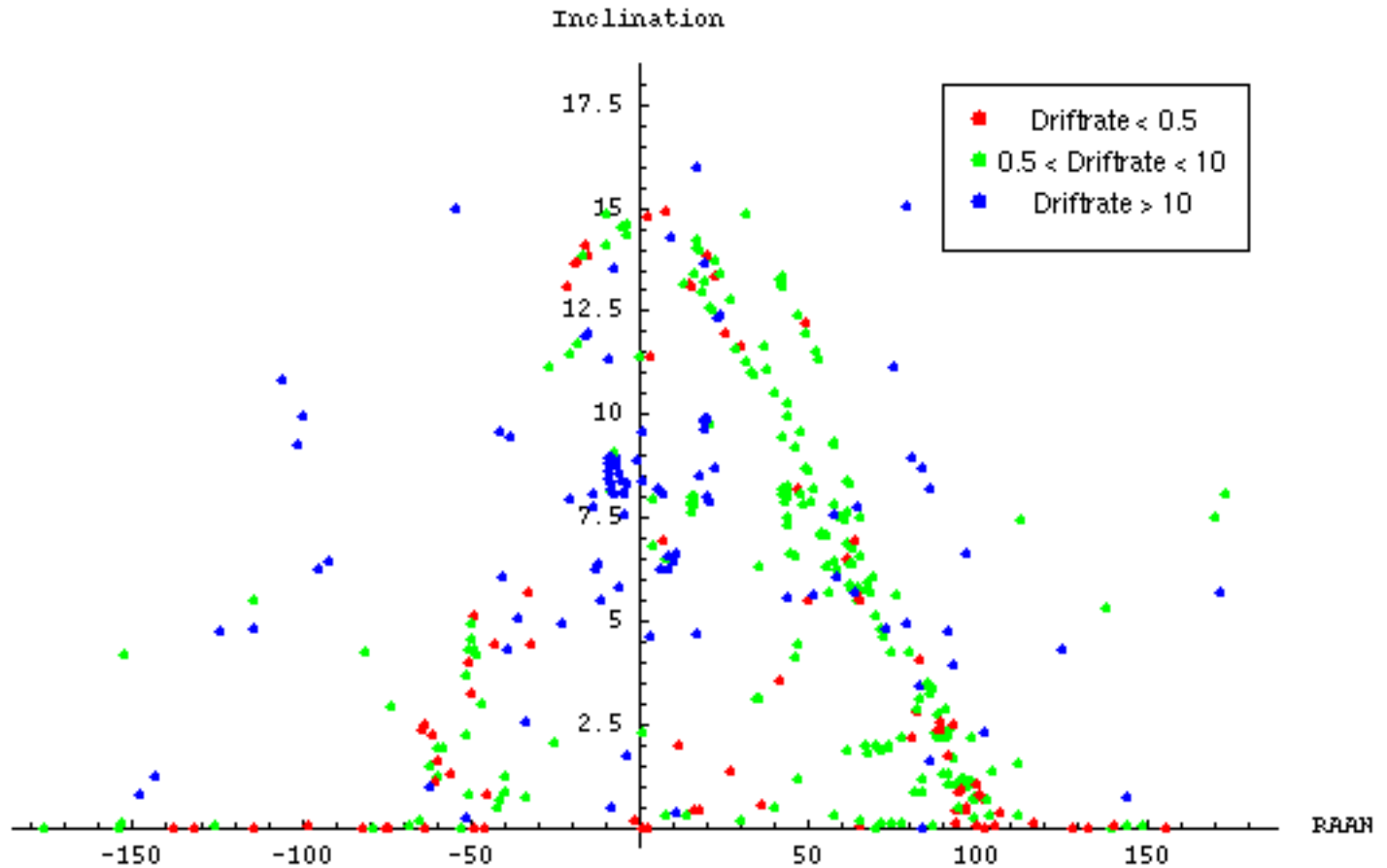


i-node plot of PIMS uncorrelated targets

All UCTs 2001 to March 2004



PIMS Uncorrelated Targets

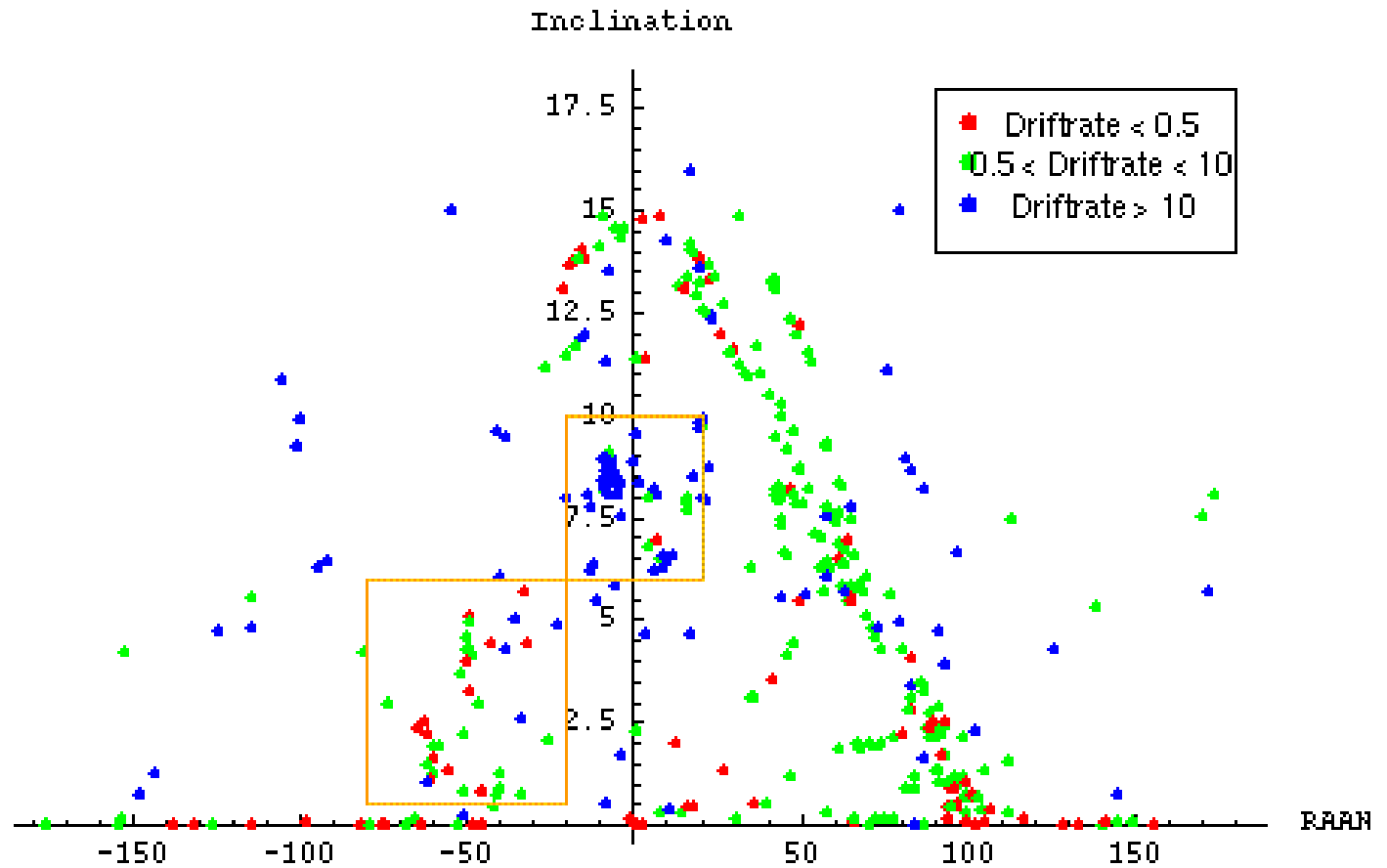




i-node plot of PIMS uncorrelated targets



PIMS Uncorrelated Targets





Comparison of i-node plots of PIMS uncorrelated targets with search campaign results



Two main areas where objects appear on PIMS i-node plot where the population is sparse in search campaign



$\Omega = -60^\circ$ to -20° , $i < 6^\circ$

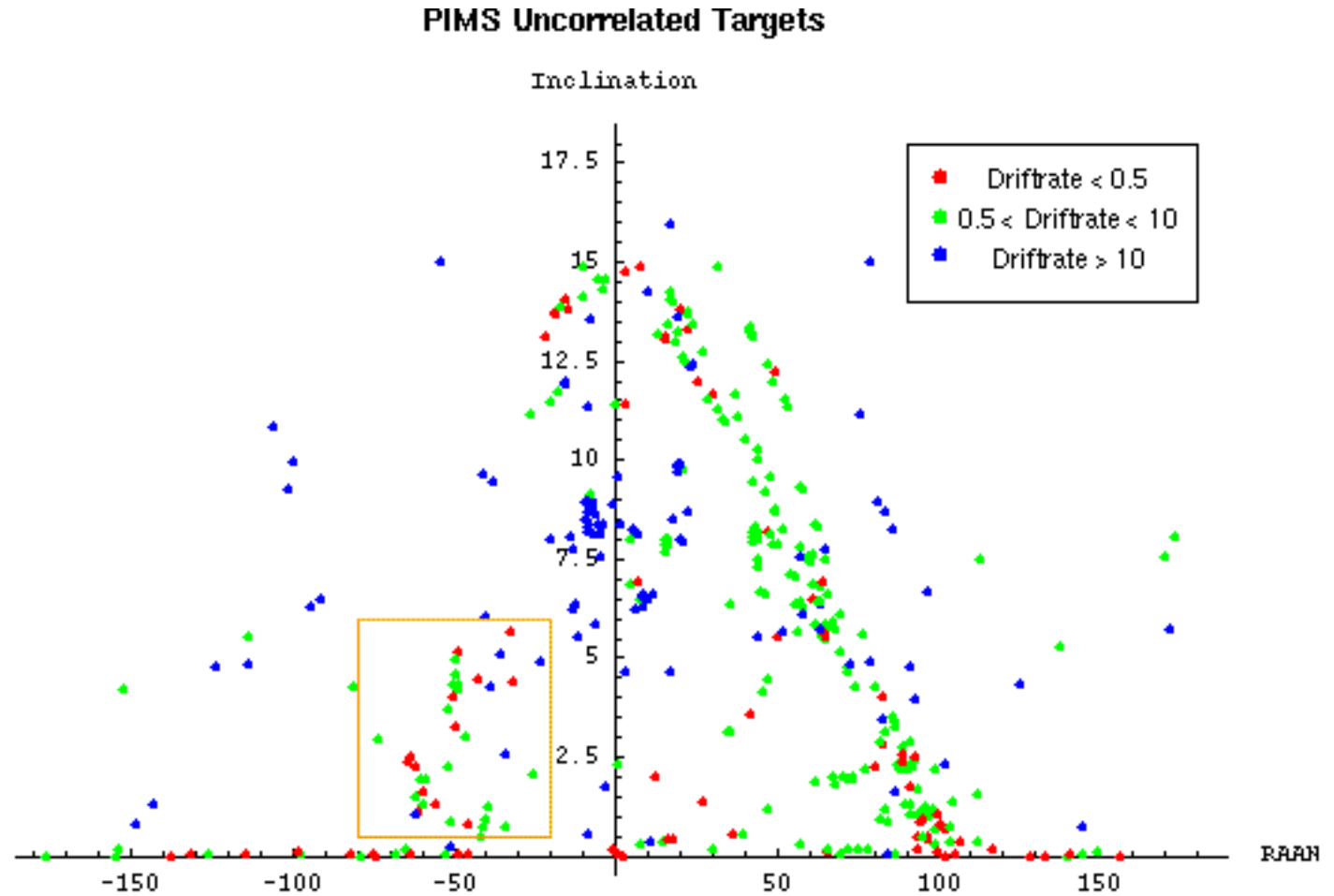
$\Omega = -20^\circ$ to $+20^\circ$, $i = 6^\circ$ to 10°

First of these are mostly near GEO (not controlled)

Second relatively fast moving w.r.t. GEO, possibly GTO



i-node plot of PIMS uncorrelated targets

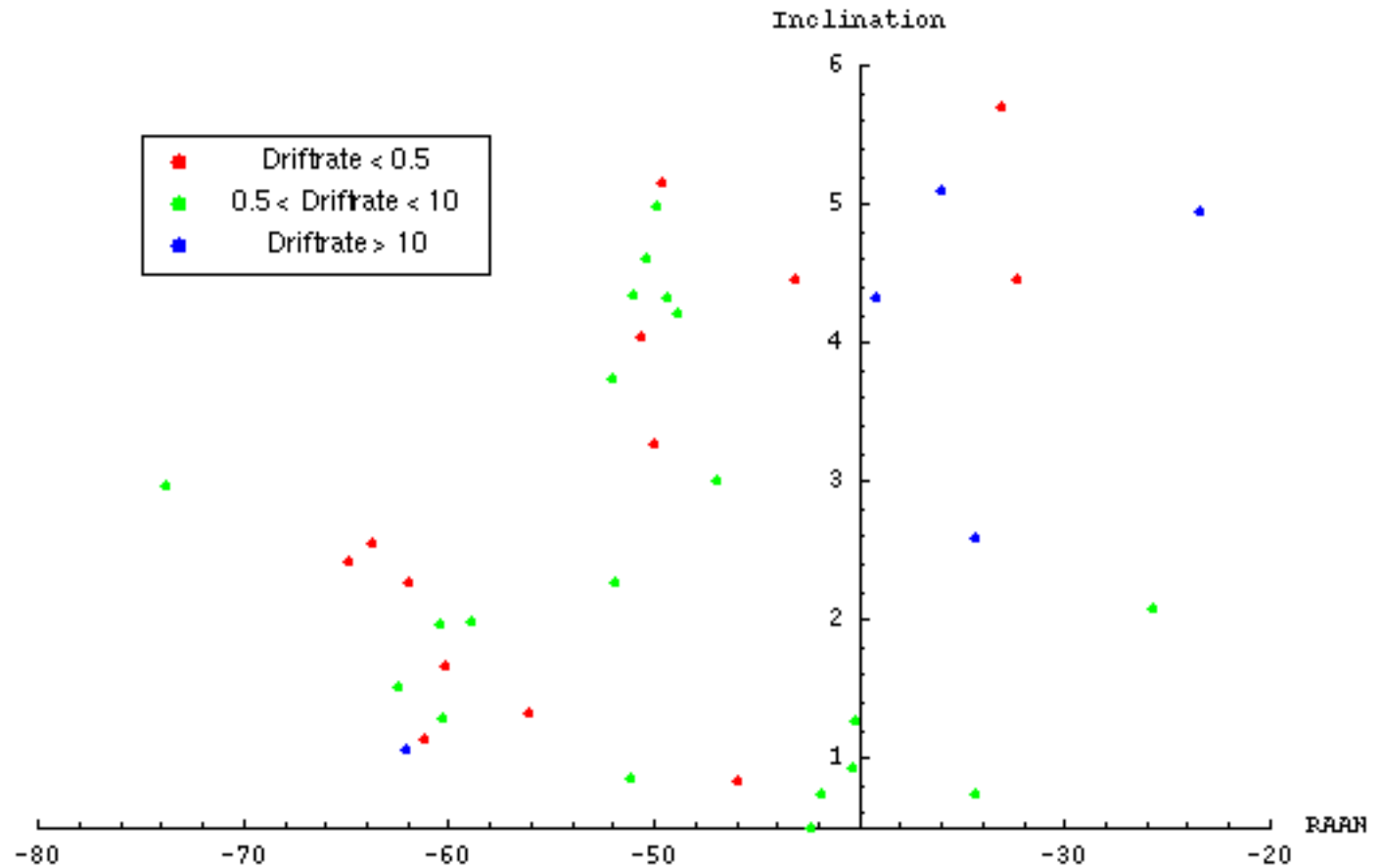




i-node plot of PIMS uncorrelated targets zoomed in on $\Omega = -40^\circ$



PIMS Uncorrelated Targets

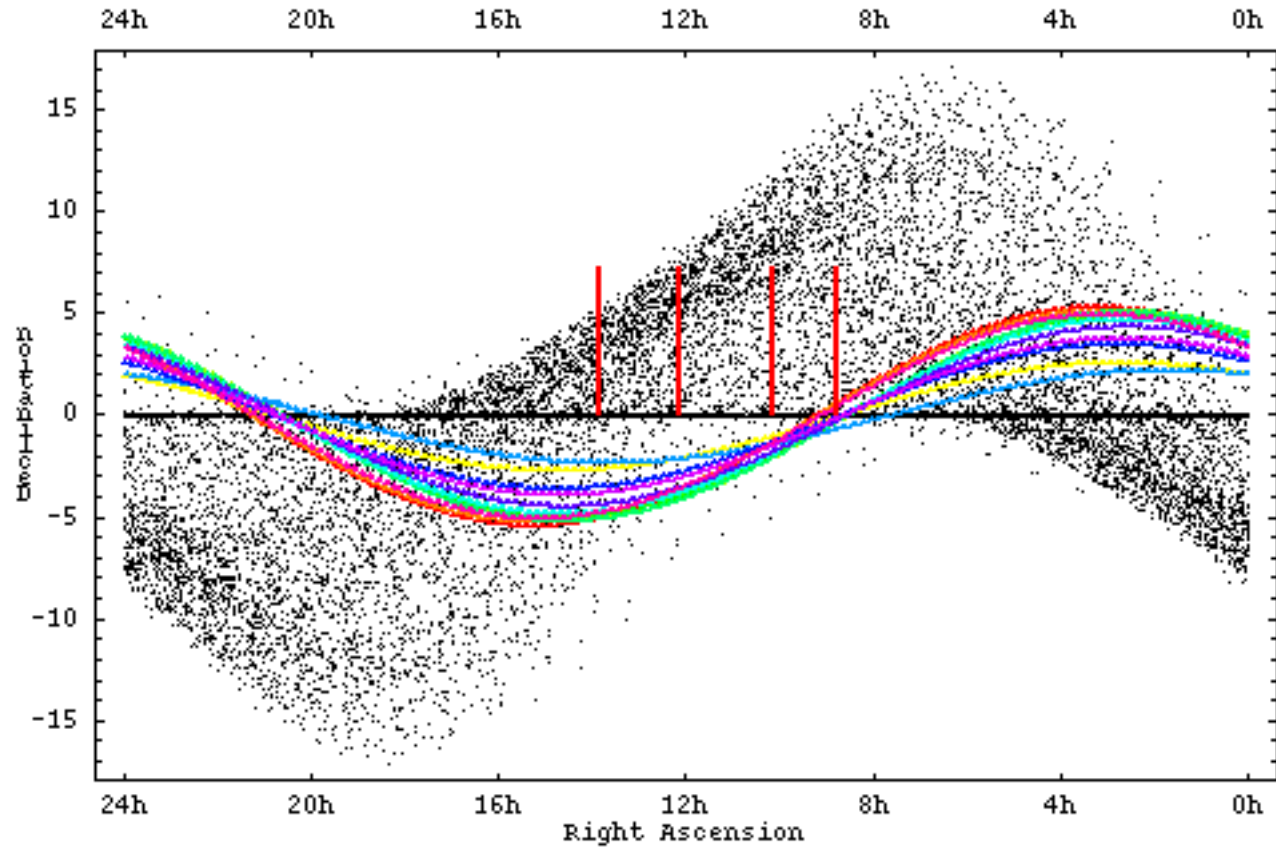




Comparison of PIMS uncorrelated objects with IADC GEO search fields



PIMS Uncorrelated Targets





Comparison of PIMS uncorrelated objects with IADC GEO search fields



Some of these objects may be seen in the low declination
search fields of the January campaign



The rest of the 2004 IADC search fields will miss this group
of targets

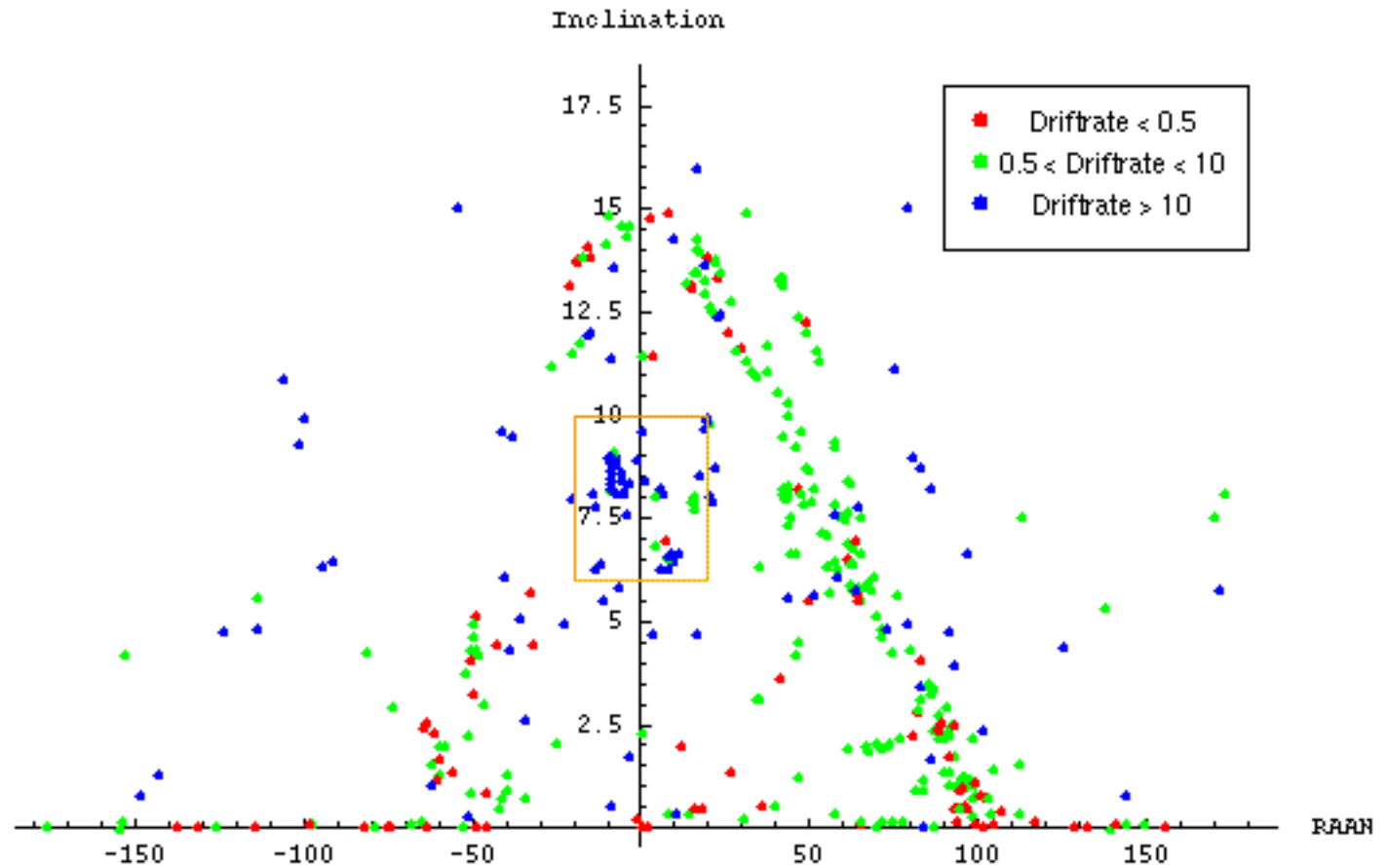
A search campaign at positive declination between
4 and 6 hours right ascension would have a reasonably high
probability of observing these objects



i-node plot of PIMS uncorrelated targets



PIMS Uncorrelated Targets

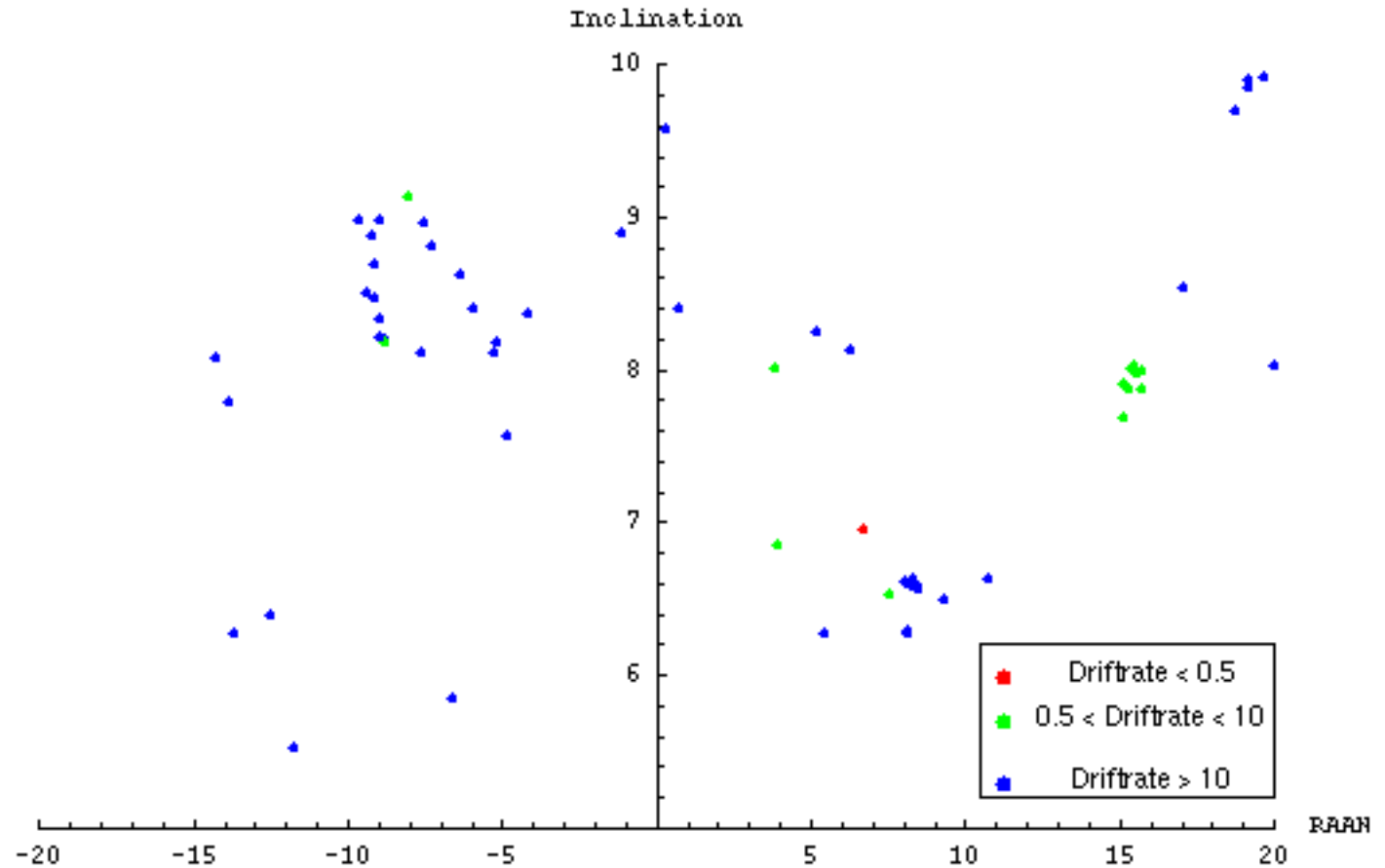




i-node plot of PIMS uncorrelated targets zoomed in on $\Omega = 0^\circ$, $i = 8^\circ$



PIMS Uncorrelated Targets





Probably elliptical orbits?



Looked for objects with similar i and Ω

Only catalogued objects with appropriate values were debris from 1986-006B (Ariane 2 3rd stage) breakup in early 2001

These have $a \sim 24000\text{km}$, $e \sim 0.72$ and wide range of Ω

Investigated whether these would produce objects which gave required equivalent circular orbits

Plausible that some of detected objects in highlighted region of plot come from this family

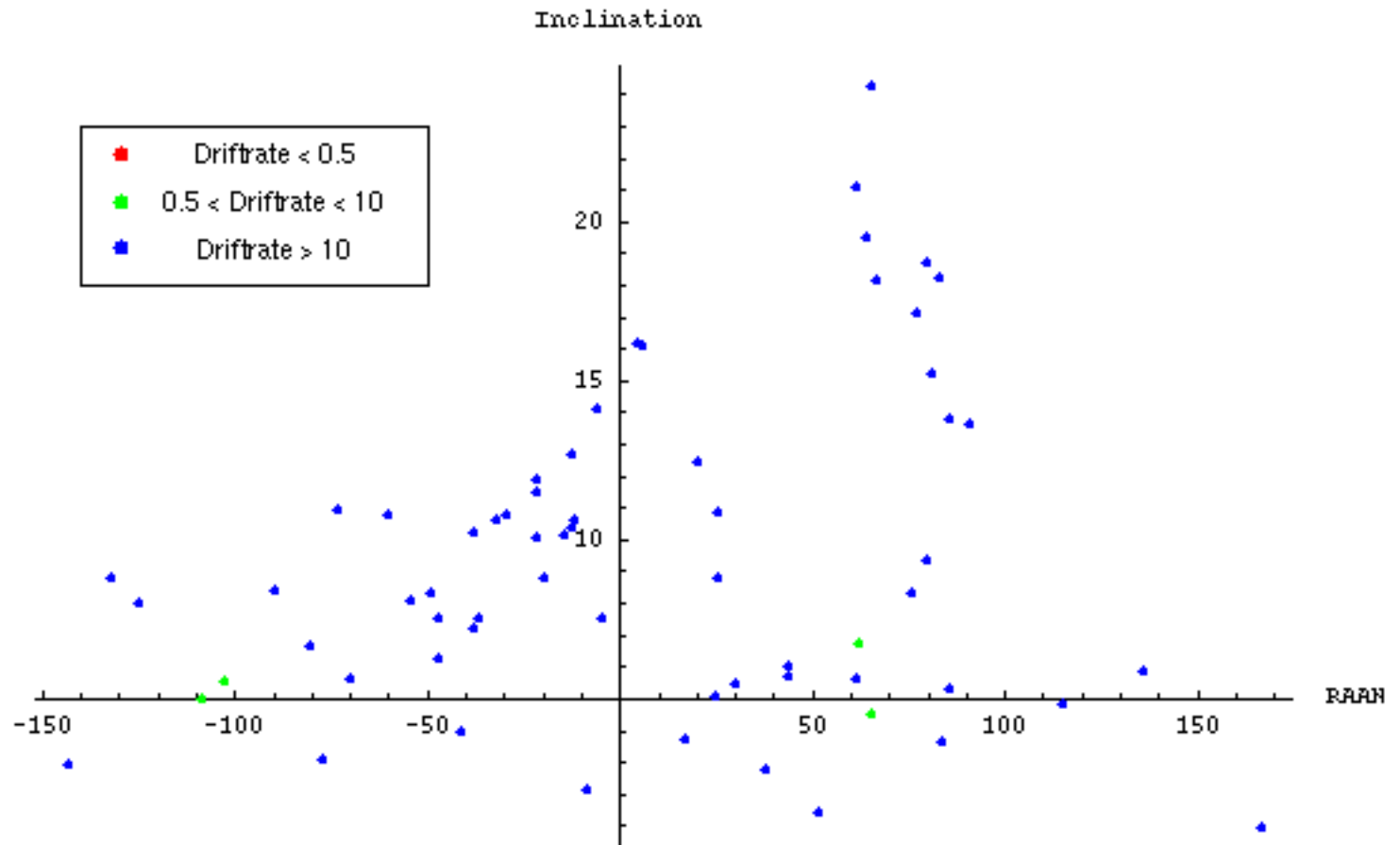




i-node plot of circular orbits calculated from PIMS observations of Ariane 2 debris



Circular orbits of Ariane 2 debris observations

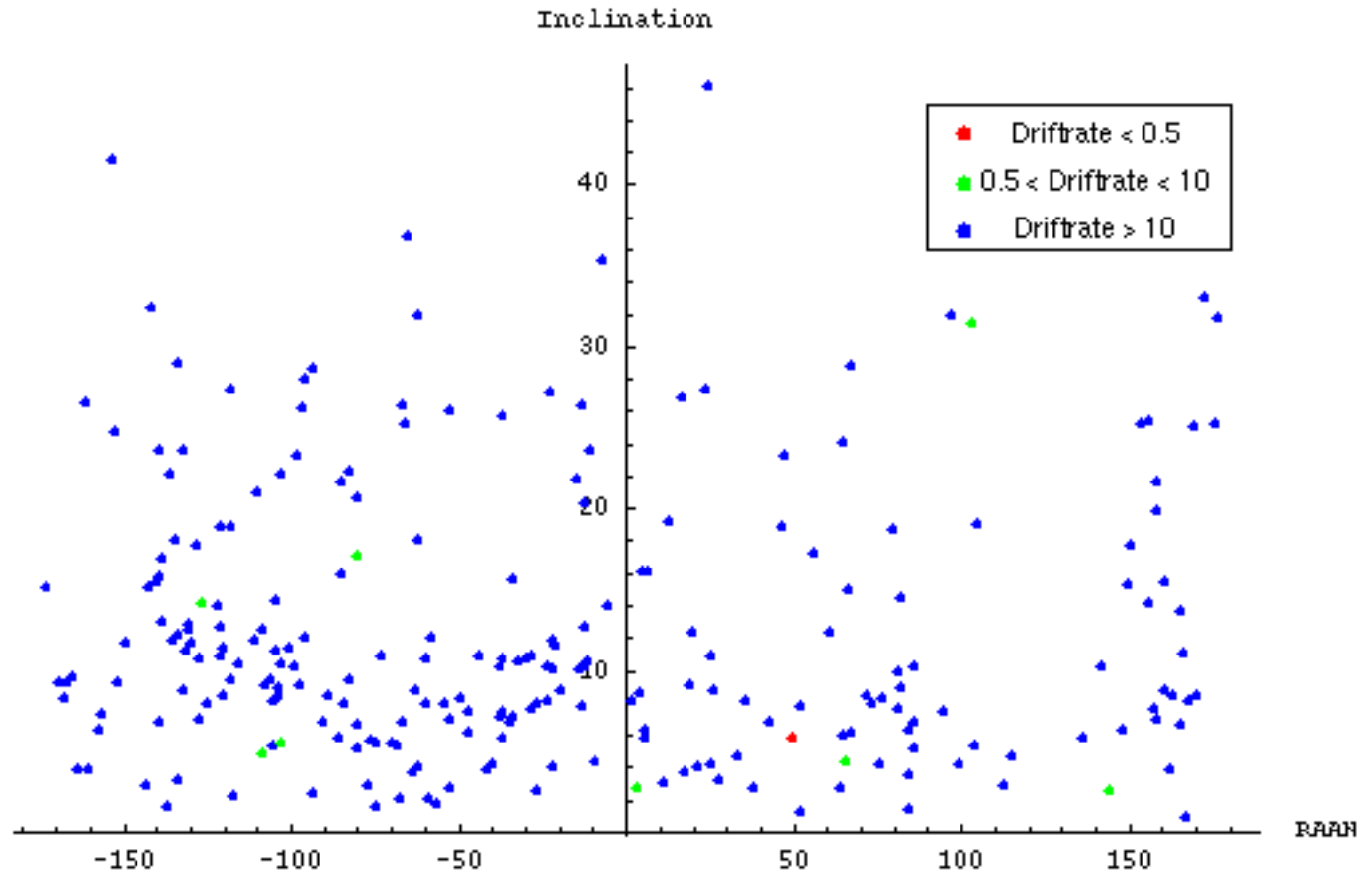




i-node plot of circular orbits calculated from PIMS observations of known GTOs



Circular orbits of GTO observations

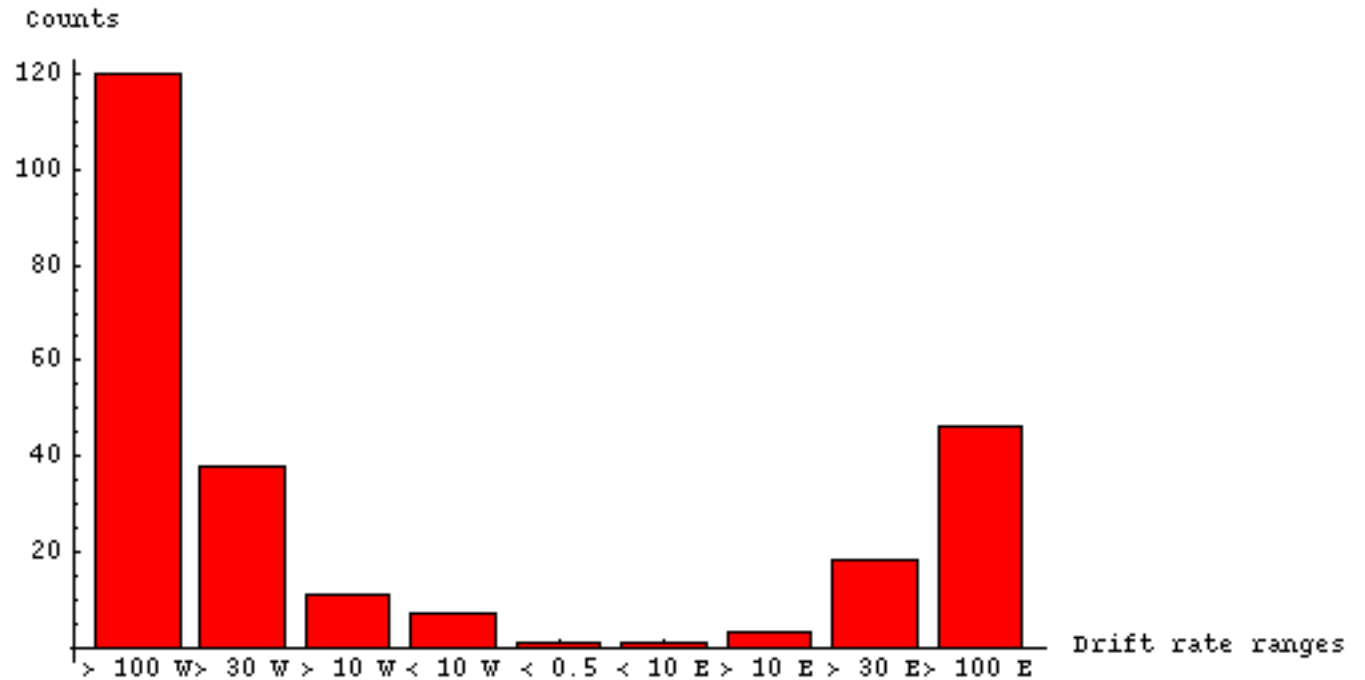




Histogram of drift rates of circular orbits Calculated from PIMS GTO observations



Drift rate frequencies of GTO observations





Circular elliptical orbits



Observations of Ariane 2 debris give widely varied equivalent circular orbits

Of 65 orbits only 4 gave low drift rate

Ariane debris i-node plot generally consistent with plot of PIMS observations of known GTOs

Of 240 circular orbits from GTO only 1 mimics a GEO orbit

Circular orbits from GTO observations predominantly have semi-major axes (radii) greater than 1000 km above or below the GEO ring





Summary



PIMS contributed, weather permitting, to the 2004 GEO campaign

Results of PIMS “random” target driven survey largely similar to results of “systematic” IADC coordinated GEO campaign

Some serendipitously observed uncorrelated targets of interest

IADC GEO campaign sampling known population well but may be neglecting unknown populations

Objects in highly elliptical orbits found to only rarely mimic GEO and near GEO population, more usually have high drift rates

