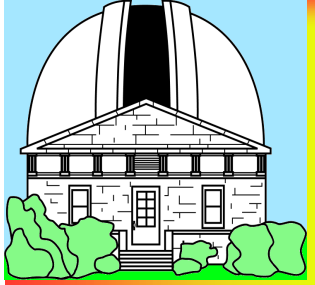

# Extragalactic Optical-Radio Link Research at USNO

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Dave Boboltz, Alan Fey, Ralph Gaume,
Greg Hennessy, Ken Johnston, Roopesh Ojha

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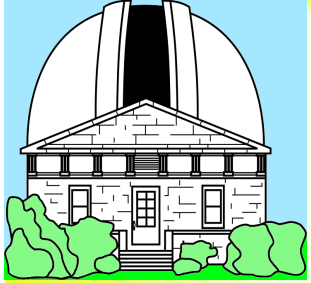


# layout of talk

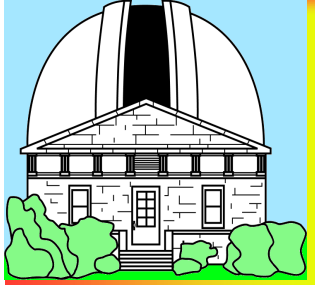
1) optical counterparts of ICRF sources

2) optical astrometric stability on mas level

3) high resolution optical imaging

4) bright quasar photometry

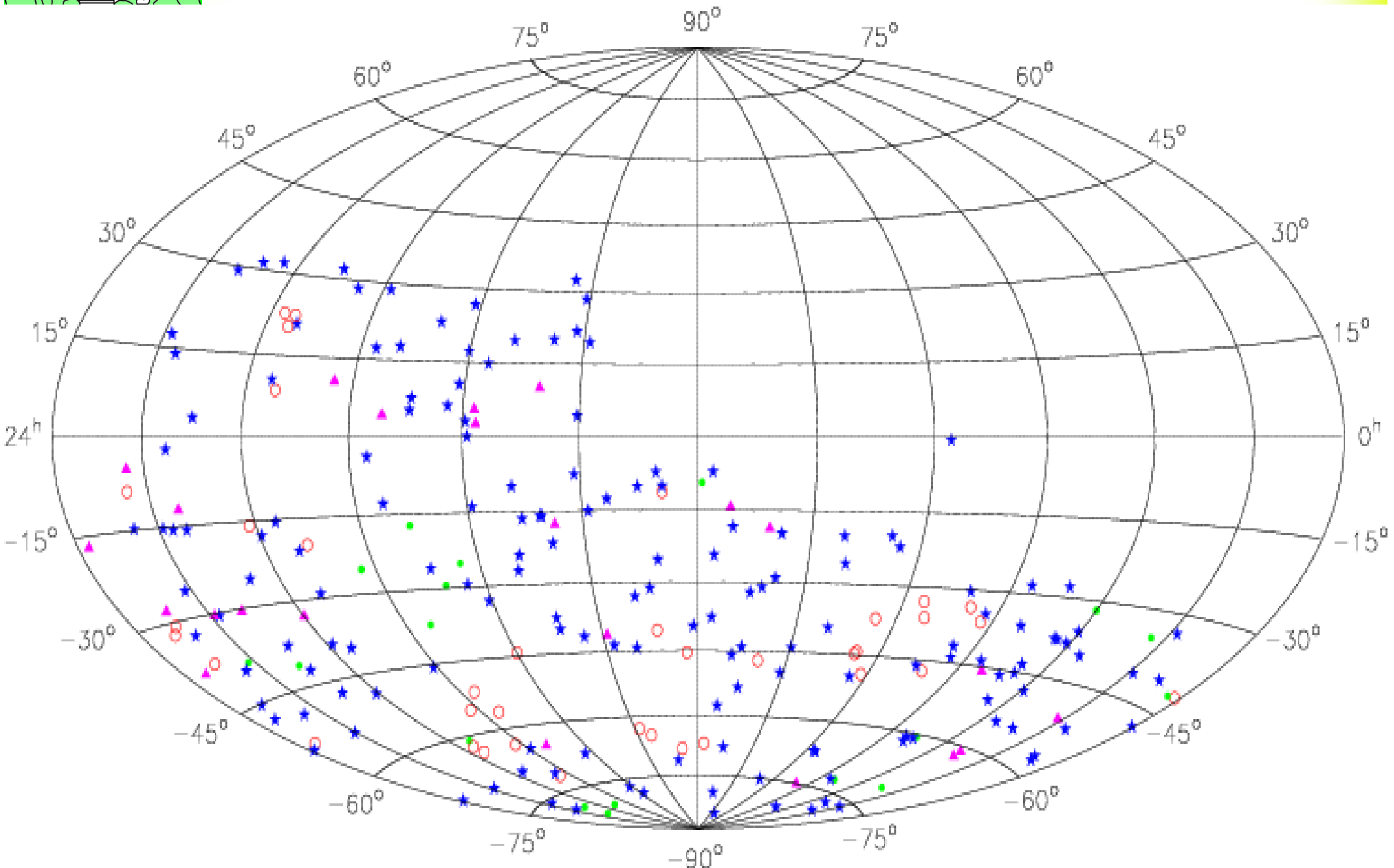
5) URAT project



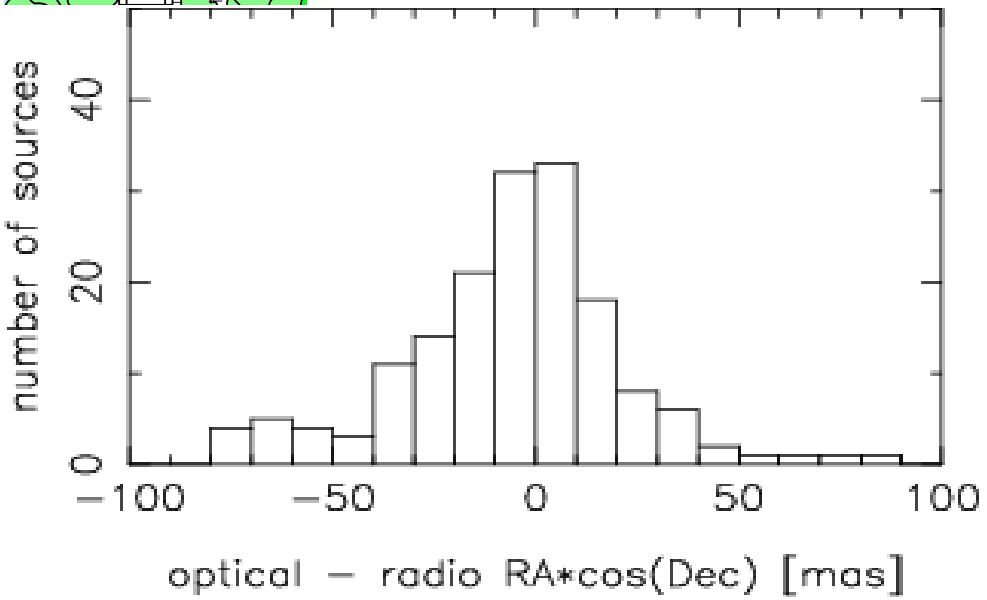
# optical counterparts of ICRF sources

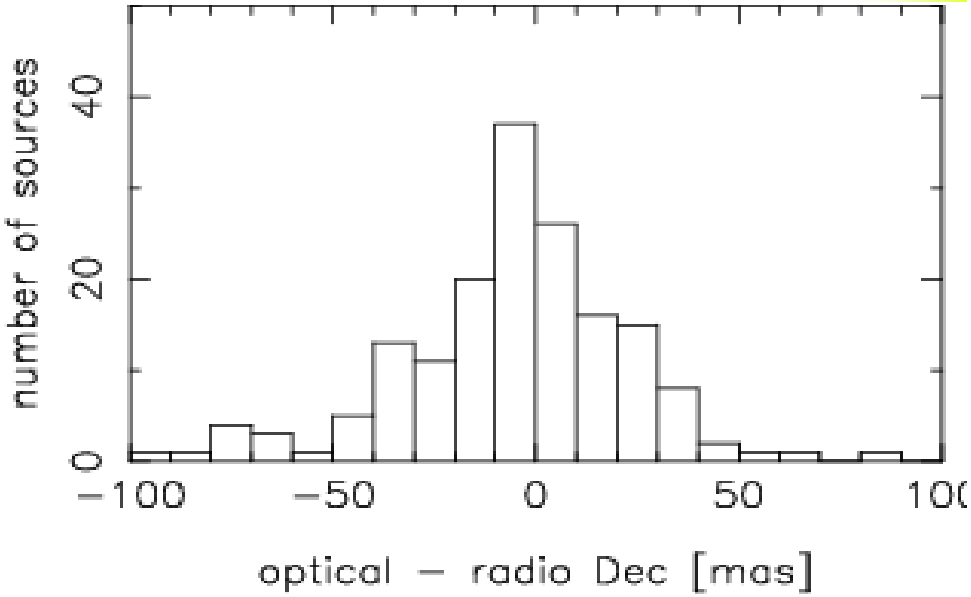
- long-term program (1997 - 2004)
- concurrent with UCAC observing
- use CTIO 0.9m and KPNO 2.1m, 0.9m
- over 500 sources (ICRF + extensions)
- high accuracy (10 .. 20 mas) “good source”
- maintenance of Hipparcos - ICRF link
- final reductions in progress

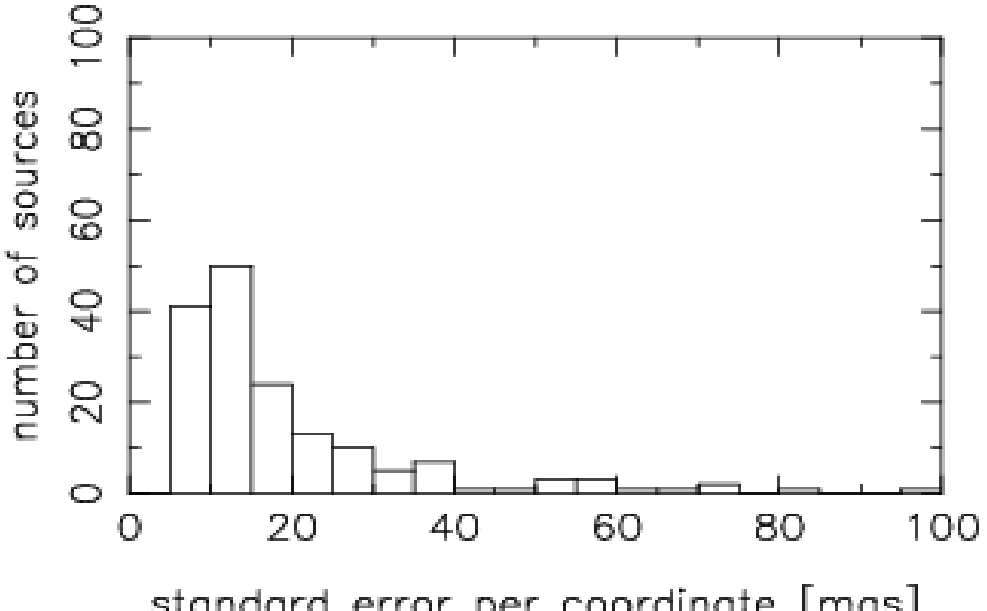
# optical positions reduced sources

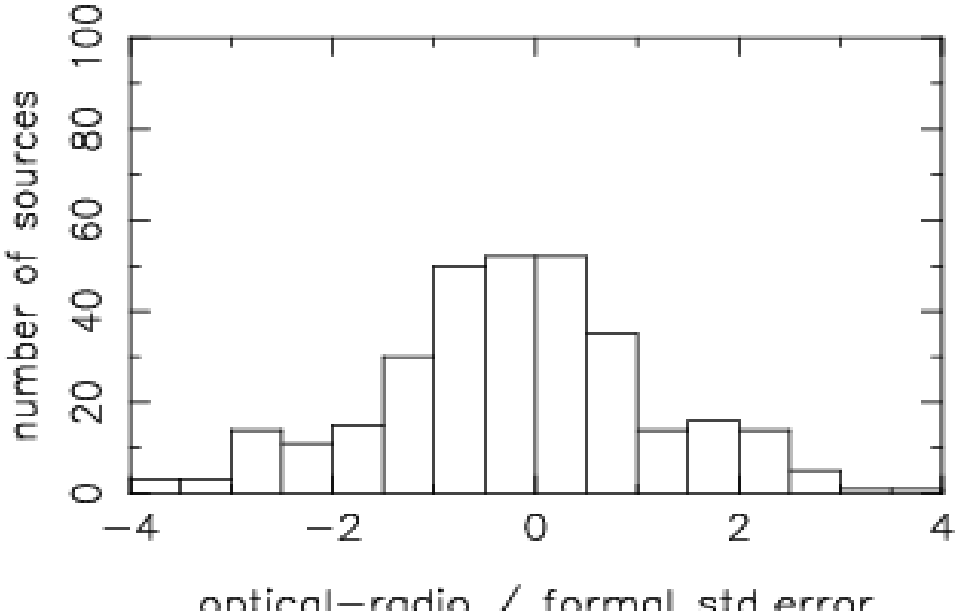


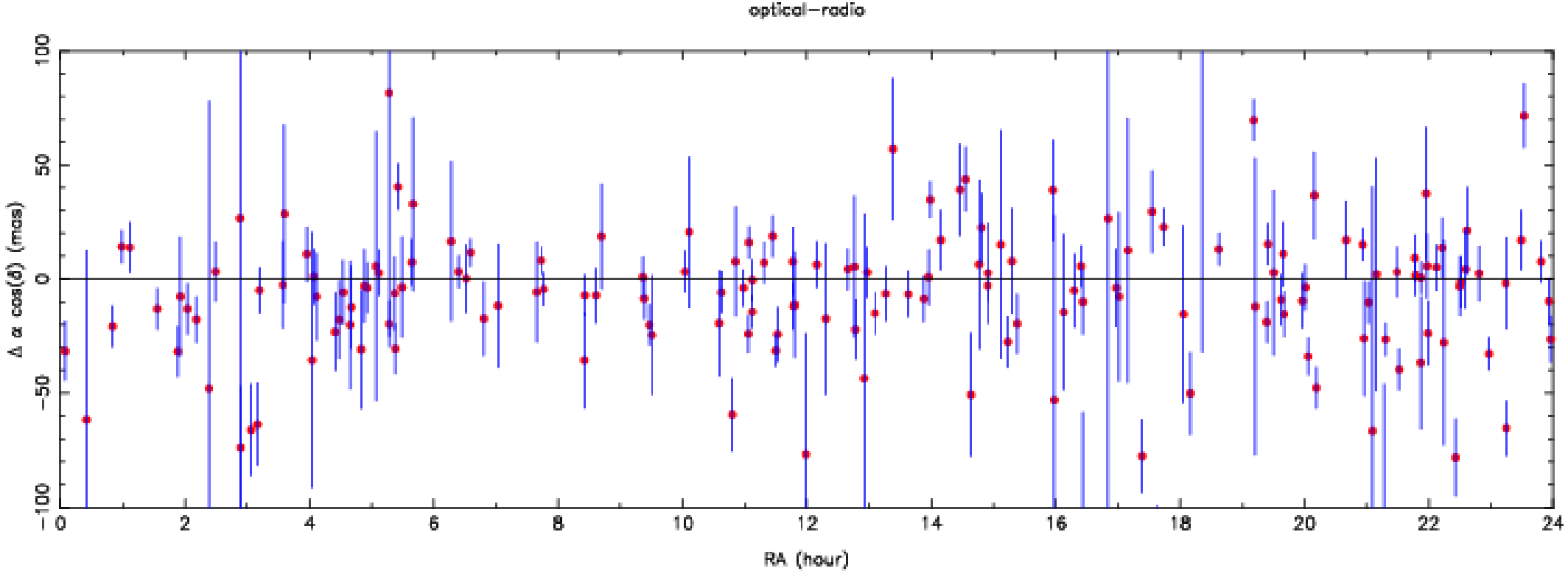
# optical-radio results (200 sources)

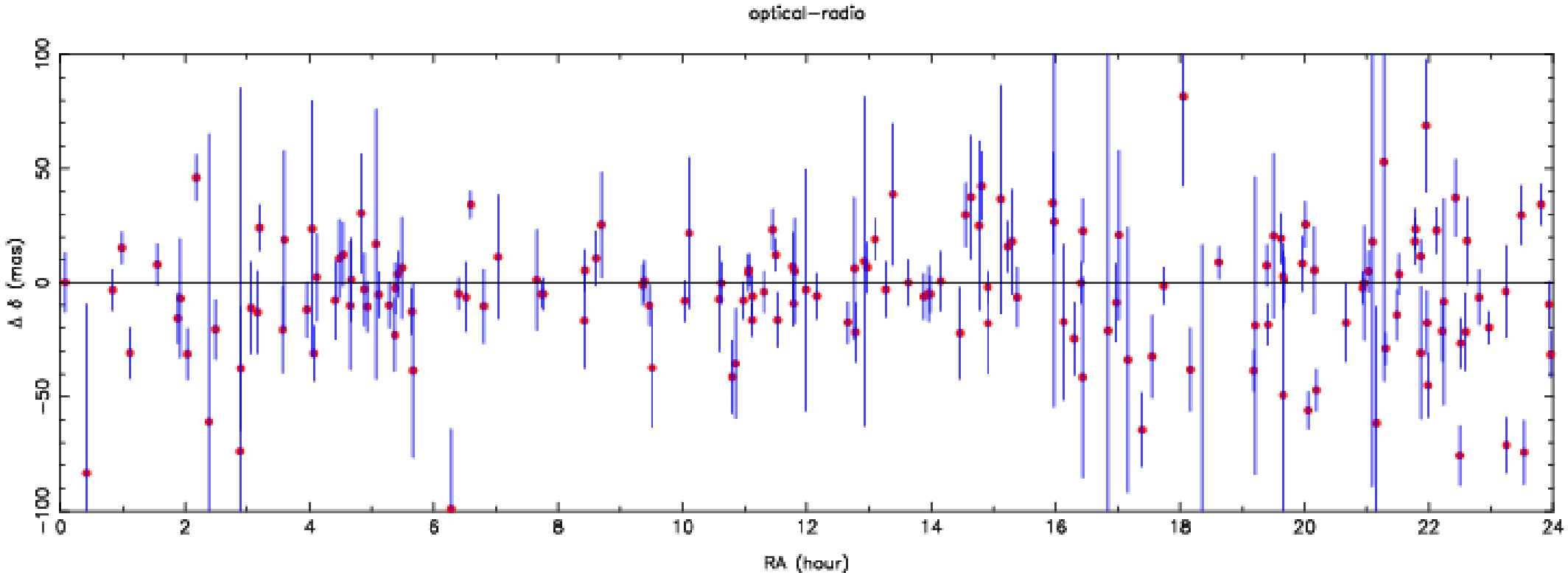



optical−radio
Δ α cos(δ) (mas)
RA (hour)
100
50
0
−50
−100
0
2
4
6
8
10
12
14
16
18
20
22
24


optical−radio
Δ δ (mas)
RA (hour)
100
50
0
−50
−100
0
2
4
6
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10
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20
22
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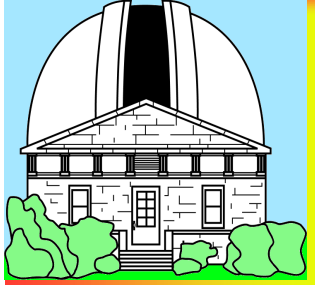
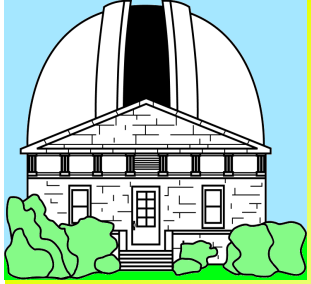
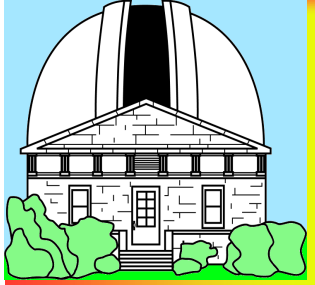


# optical astrometric stability on mas level

- use NOFS 1.55 m telescope
- 12 sources
- relative positions to 3 mas per exposure
- > 15 observations per source over years
- 2002 - 2007, > 200 frames taken
- complete program in 2008

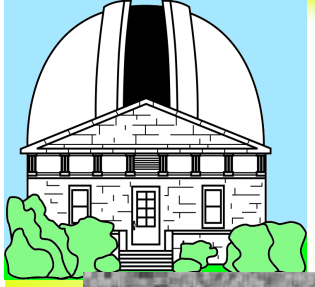


| source | I | t | mag | z | Q | SIX |
|---|---|---|---|---|---|---|
| 0241+622 | C | Q | 12.2 | .04 | 18 | 2 |
| 0552+398 | C | Q | 18.0 | 2.37 | 96 | 2 |
| 0738+313 | D | Q | 16.1 | .63 | 61 | 4 |
| 0754+100 | D | L | 15.0 | .66 | 68 | 2 |
| 0839+187 | D | Q | 16.4 | 1.27 | 46 | 4 |
| 0851+202 | C | L | 15.4 | .31 | 83 | 2 |
| 0912+297 | D | L | 16.4 | ? | -- | 1 |
| 1656+053 | C | Q | 16.5 | .89 | 57 | 3 |
| 1830+285 | D | Q | 17.2 | .59 | 58 | 3 |
| 1937-101 | C | Q | 17.0 | 3.79 | 52 | 3 |
| 2059+034 | D | Q | 17.8 | 1.01 | 66 | 2 |
| 2201+315 | O | Q | 15.6 | .30 | 74 | 3 |

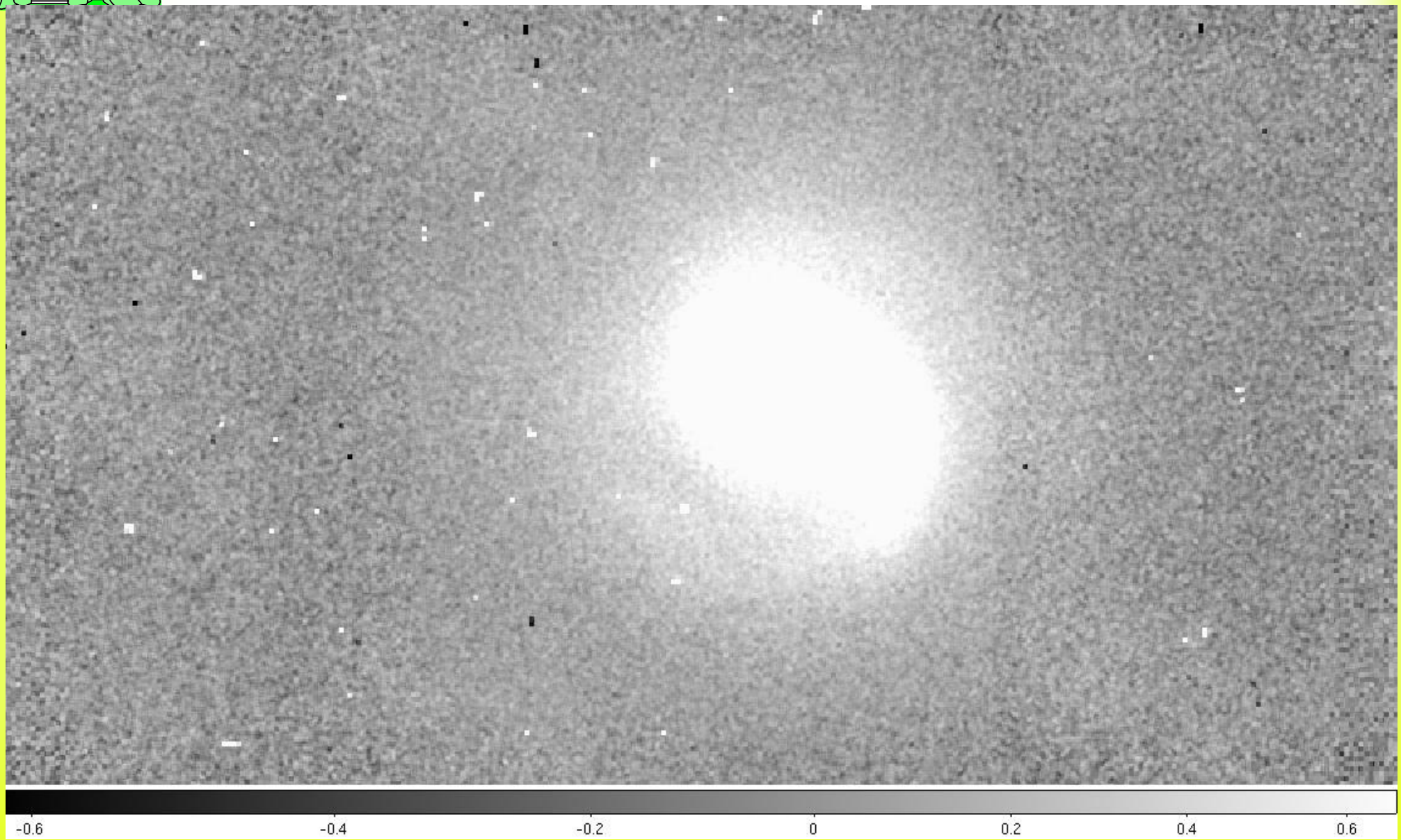


# high resolution optical imaging

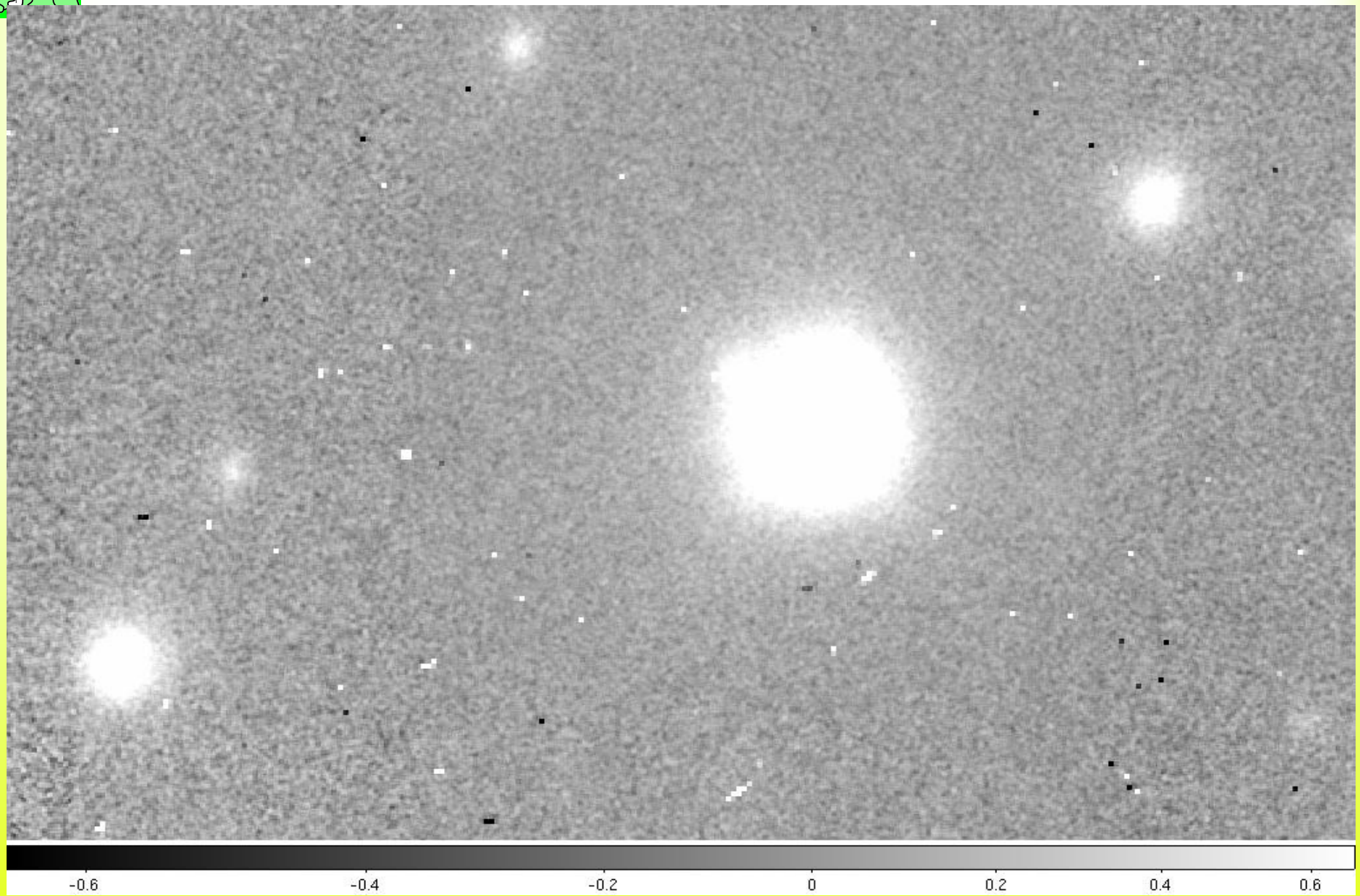
- apply for Lucky-Cam time (ESO, NNT 3.5m)
- use Lick 3 meter, AO system (Sep 2007)
- resolution about 0.3 arcsec
- IRAS 01475+3554 : structure, spiral arms
- MGB 1853+2344 : likely point-like

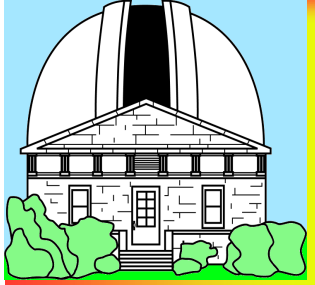


# IRAS 0147+3554 (Lick 3m AO)



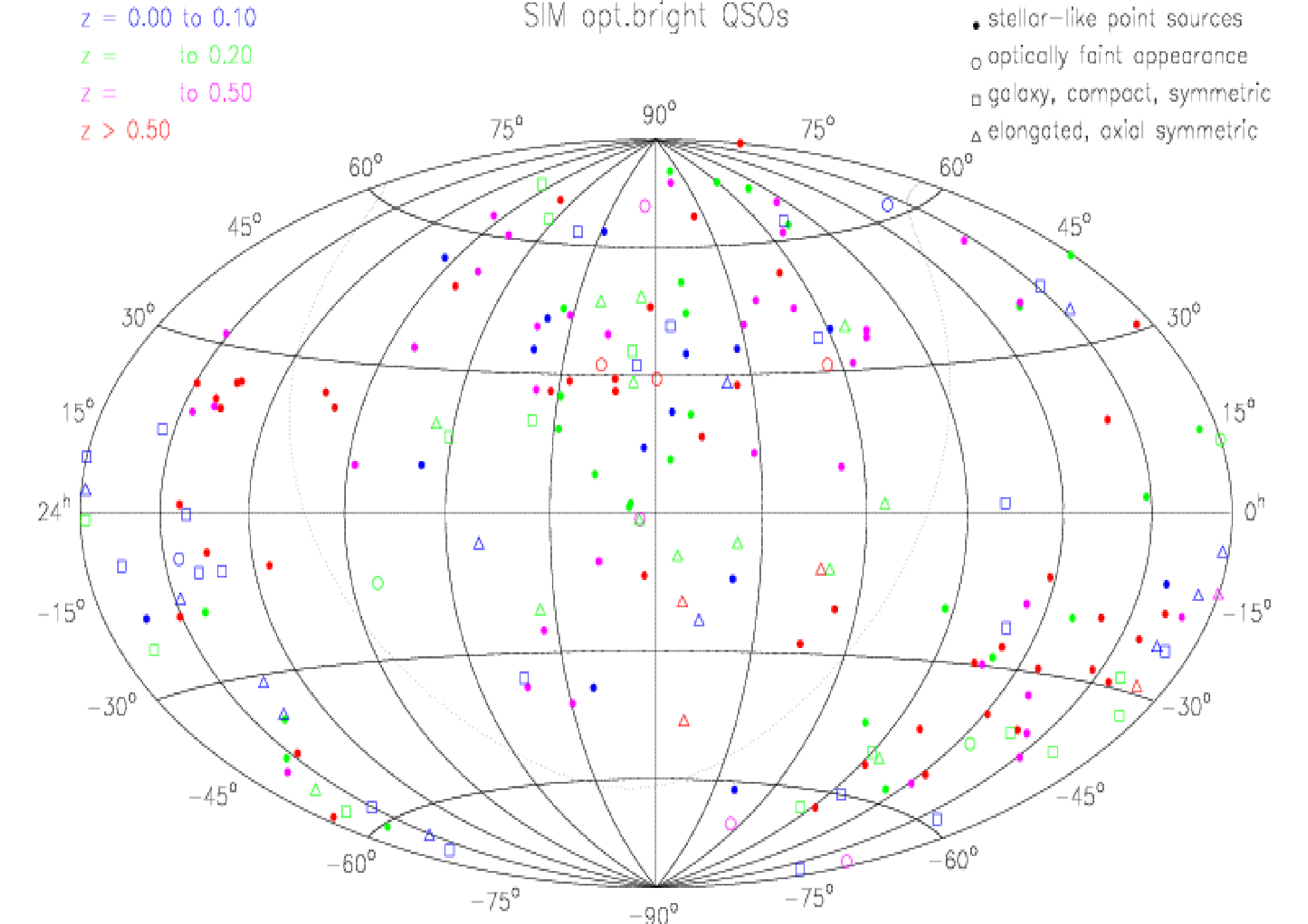
# MGB 1853+2344 (Lick 3m AO)

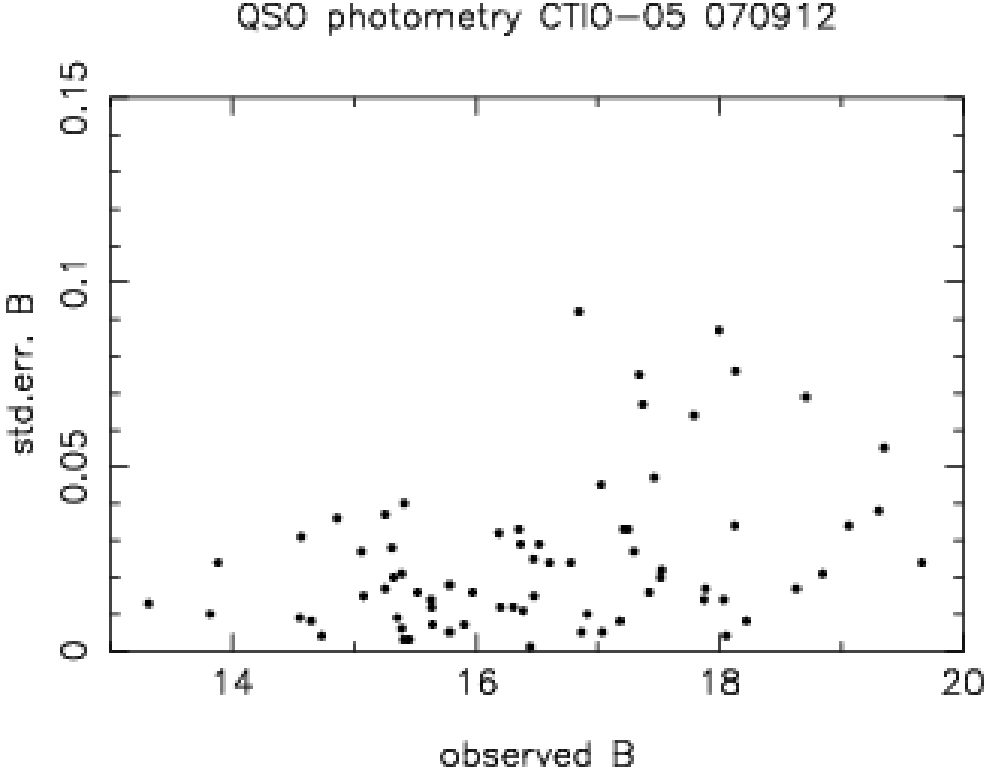


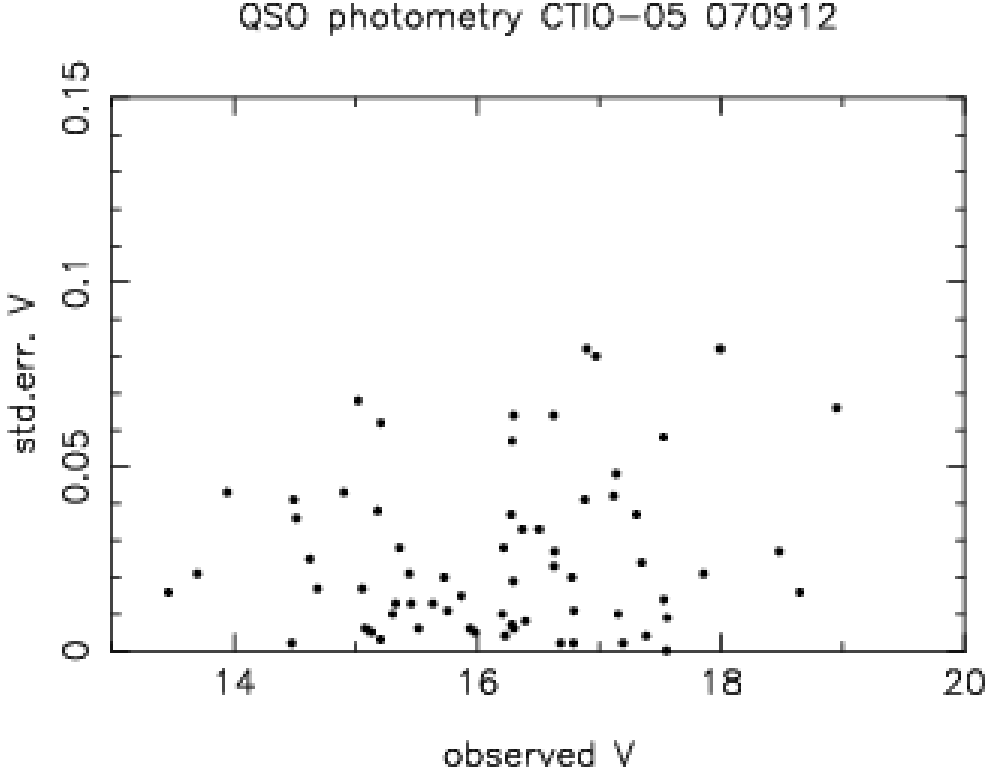


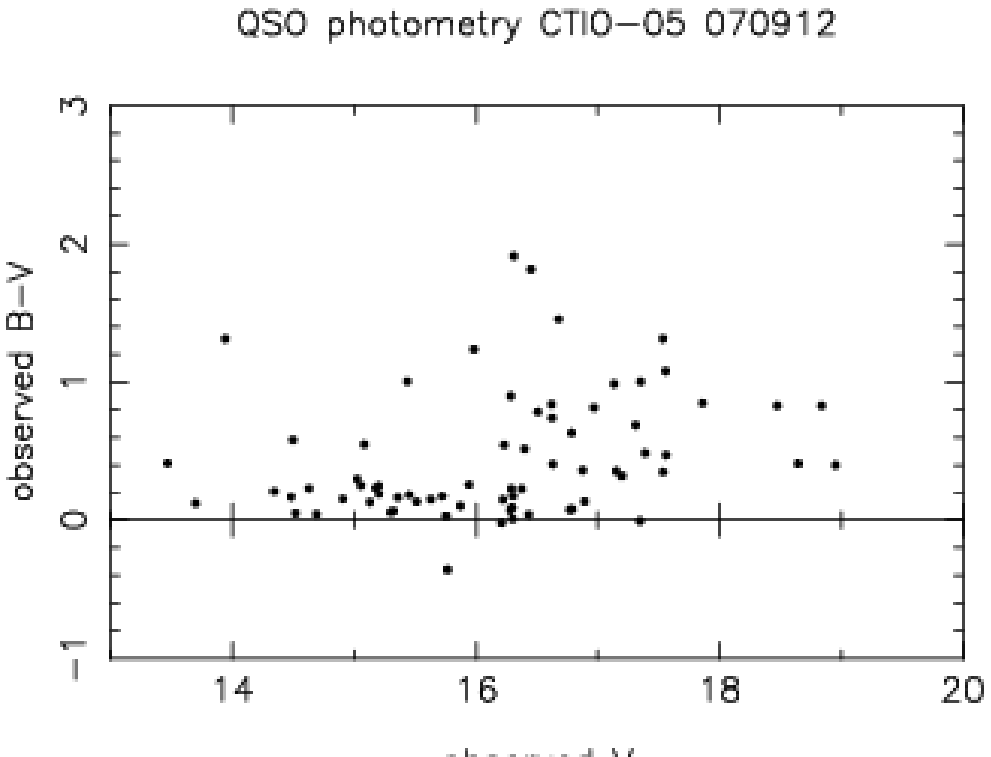
# bright quasar photometry

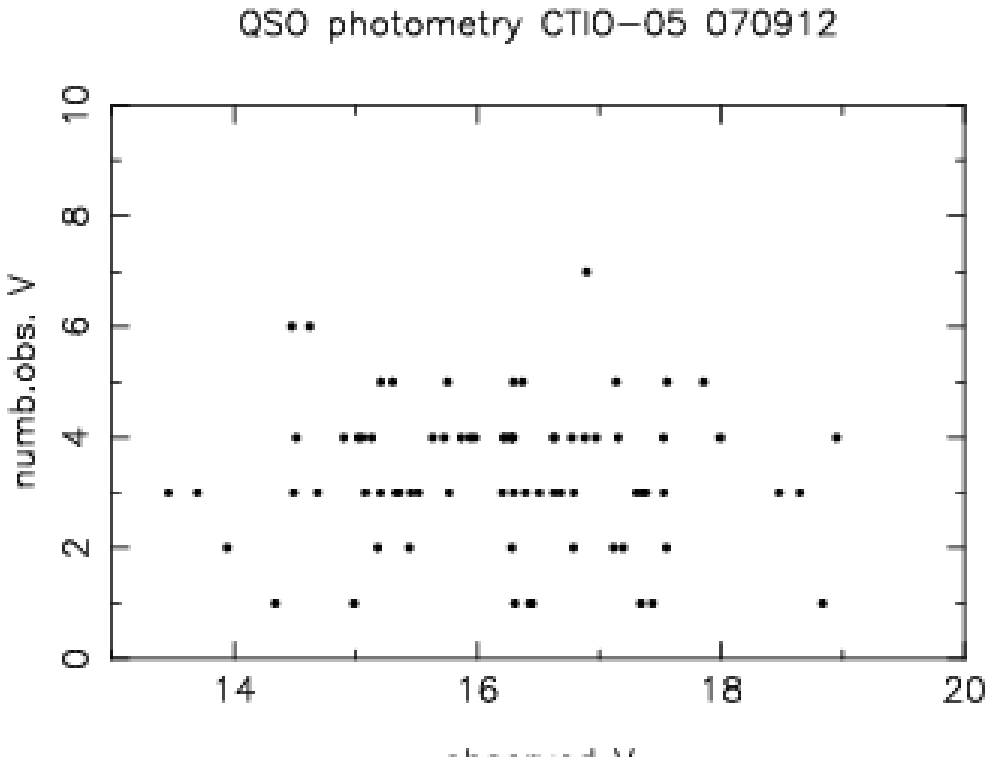
- part of SIM key science project
- photometric monitoring over several years
- 242 sources, all-sky
- select bright QSO, regardless of radio
- pre-select :  round, compact (POSS images)
- fill in sky distribution with fainter sources
- most targets are 15 - 17 mag, some 19 mag

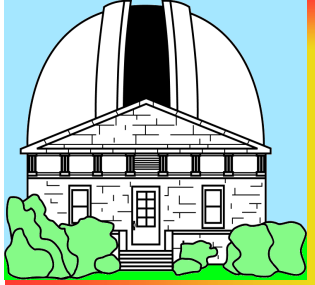

z = 0.00 to 0.10
z = to 0.20
z = to 0.50
z > 0.50
SIM opt.bright QSOs
stellar-like point sources
optically faint appearance
galaxy, compact, symmetric
elongated, axial symmetric
90°
75°
75°
60°
60°
45°
45°
30°
30°
15°
15°
24h
0h
-15°
-15°
-30°
-30°
-45°
-45°
-60°
-60°
-75°
-75°
-90°


QSO photometry CTIO−05 070912
std.err. B
observed B
0
0.05
0.1
0.15
14
16
18
20


QSO photometry CTIO−05 070912
std.err. V
observed V
0
0.05
0.1
0.15
14
16
18
20


QSO photometry CTIO−05 070912
observed B−V
−1
0
1
2
3
14
16
18
20

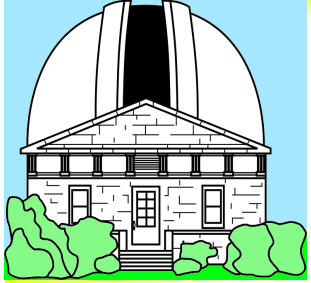

QSO photometry CTIO−05 070912
numb.obs. V
0
2
4
6
8
10
14
16
18
20



# U S N O
# R o b o t i c
# A s t r o m e t r i c
# T e l e s c o p e

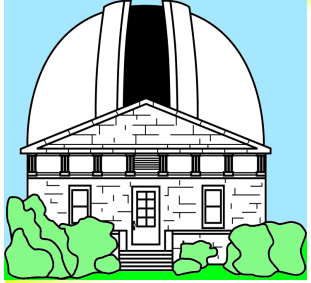
**Astrometry Department**

**U.S. Naval Observatory**

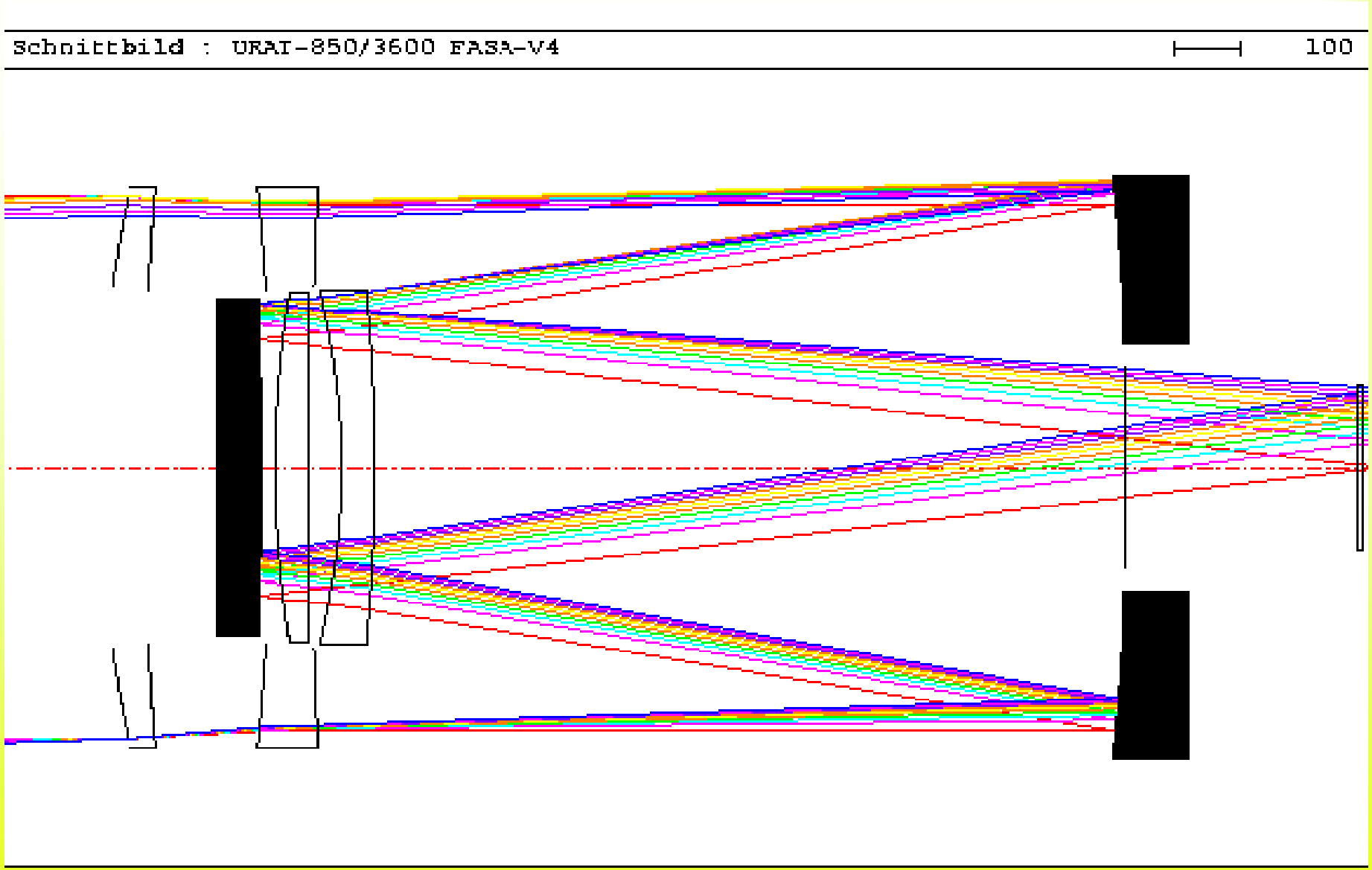


# URAT overview

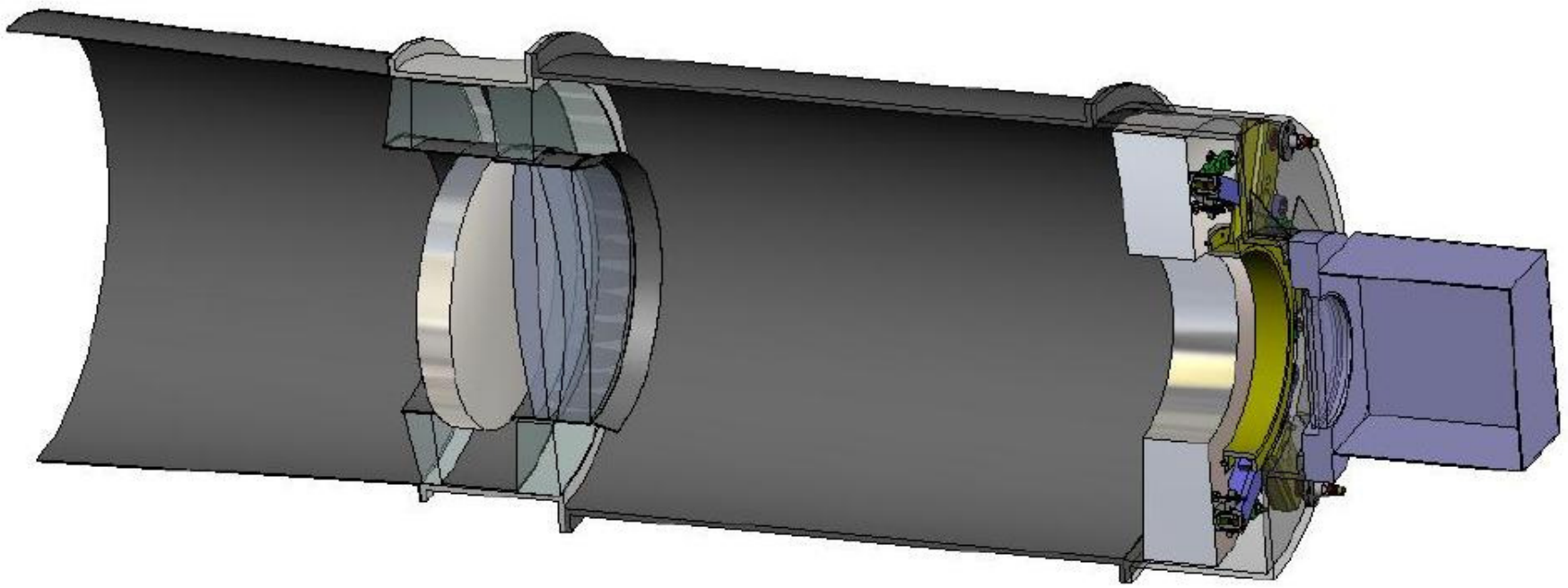
- USNO Robotic Astrometric Telescope
  - 0.85 m aperture, focal length = 3.6 m
  - 4.5 degree diameter field of view
  - large format detector (world largest CCD)
    - 2 px / FWHM at 1.0 arcsec seeing
    - 9 micrometer pixel size
    - 4 CCDs, each 95 mm on a side
  - 50 s / 250 s integration
  - 13 to 21 mag, all-sky, 2 locations >= 2 years
  - goal 5 mas for 'well exposed stars'



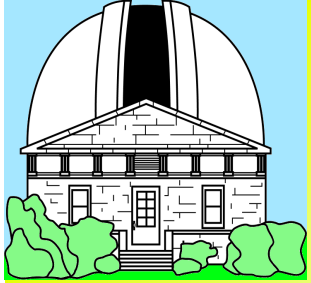
# URAT optical design



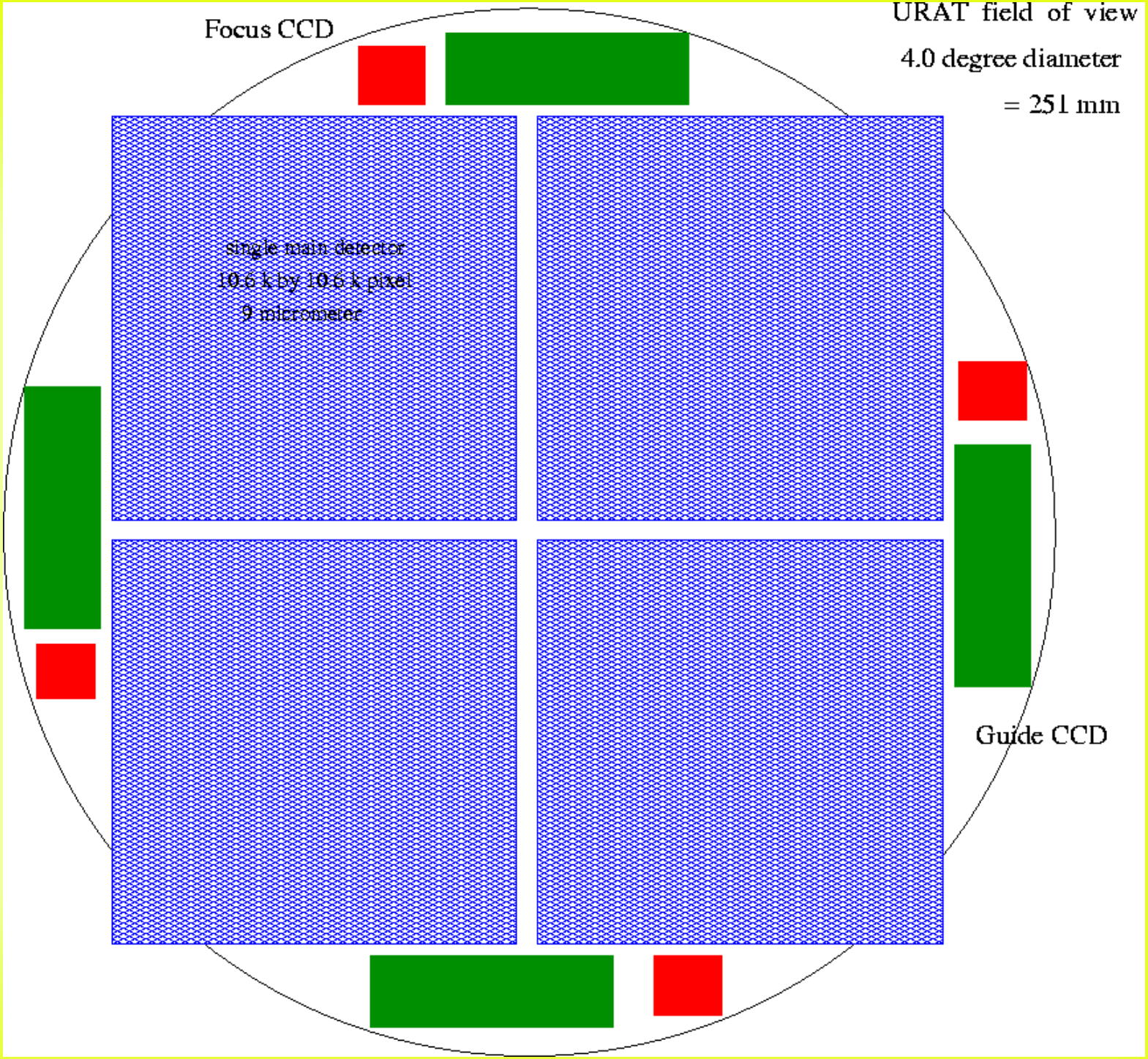
# URAT cut side view

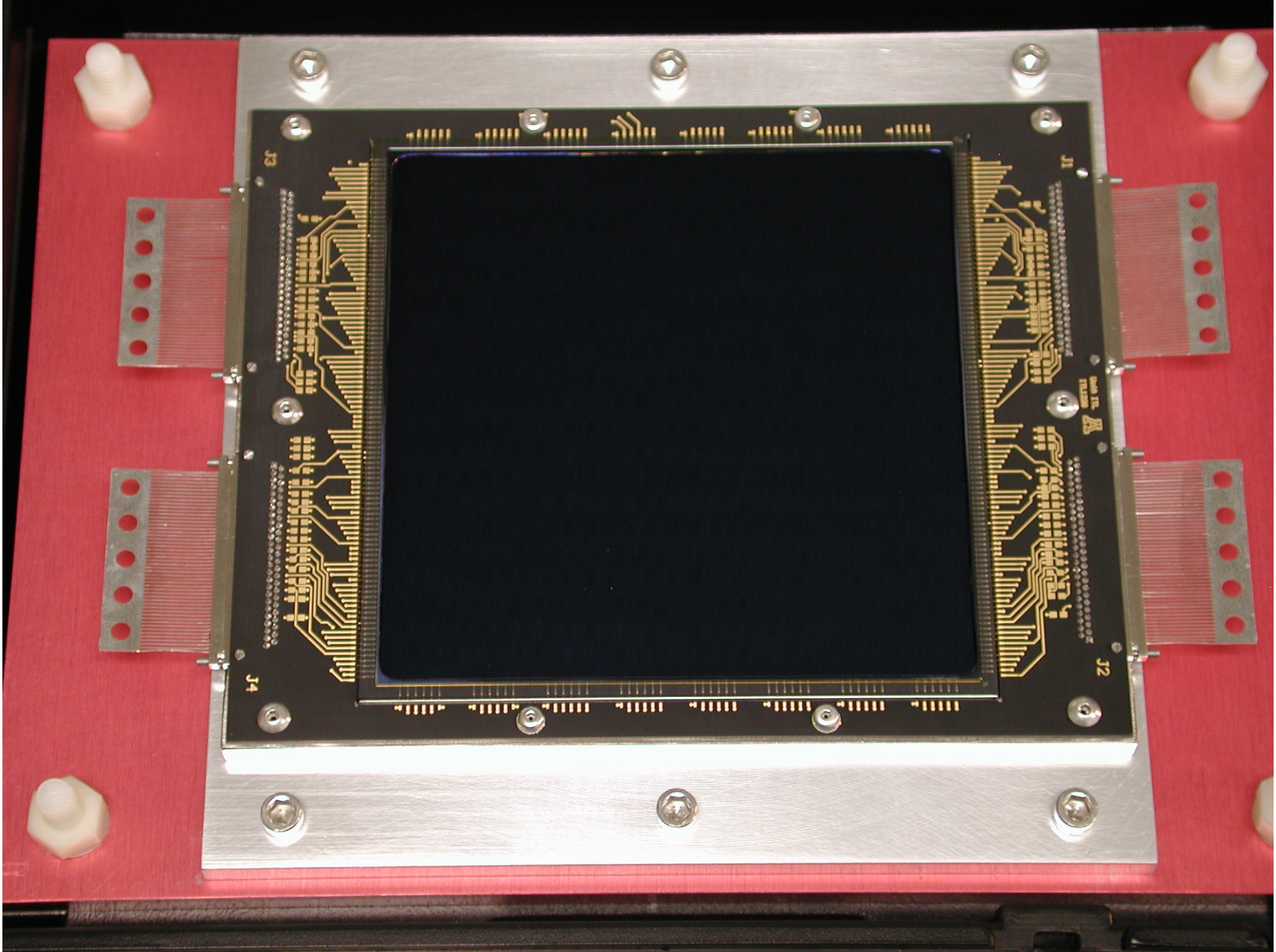


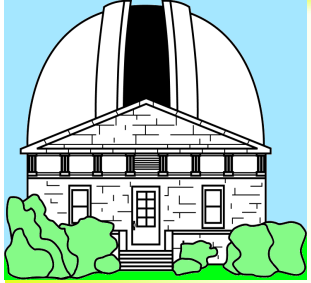
EOST, 2005



URAT
FPA
4 10.5k CCD
4 guide CCD
4 focus CCD

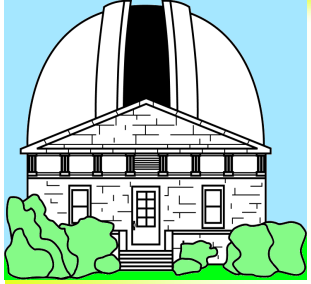



J3
J1
J4
J2



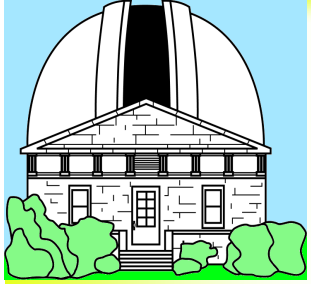
# status of URAT project

- telescope:
  - optical design studies completed
  - primary mirror: delivery Oct. 2007
- detector:
  - SBIR phase II signed Dec. 2006
  - 10.5k by 10.5k CCD chip produced successfully
  - thinning of 2 science grade chips May/July 2007
  - camera complete, expect 1st light in October
  - purchase "4-shooter" camera FY08



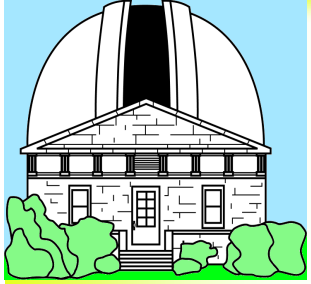
# URAT phase 1 = Umouse

- currently no funding for new telescope
- take “4-shooter” camera, put at astrograph
- complete re-make of astrograph 2007/08
- move instrument to CTIO, new survey 2009
- 27 sq. deg. per exposure!
- 10 mas per image (well exposed star)
- multiple sky overlaps / year, 7 - 18 mag
- solve for positions, motions + parallax



# summary

- extragal.link:  over 500 sources 10..50 mas, as part of the UCAC program
- URAT -> Umouse:  first light 2009, provide optical (Hipparcos, Tycho) reference frame for deep surveys and ICRF/QSO optical astrom.
- SIM:  photometry of 242 bright QSOs
- high resolution imaging: first results (Lick 3m)
- astrometric stability: 12 sources, complete program in 2008 (NOFS 1.55 m)



# what does all this mean?

- radio ICRF-2 is in good shape
- Hipparcos is still the standard in the optical
  - no significant deviation from ICRF visible
- not much progress in optical astrometry of ICRF counterparts / QSOs:
  - little high resolution imaging
  - reference system linked via UCAC (system.err.)
  - future: either deep imaging (PanSTARRS) or good astrometry (U-mouse) but not both
  - suitability on sub-mas level not known