

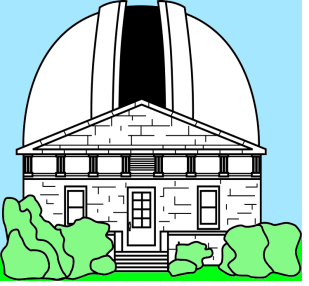
U S N O
R o b o t i c
A s t r o m e t r i c
T e l e s c o p e

PI: Norbert Zacharias

Operations lead: Charlie Finch

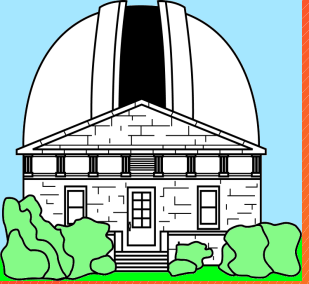
Astrometry Department

U.S. Naval Observatory



layout of talk

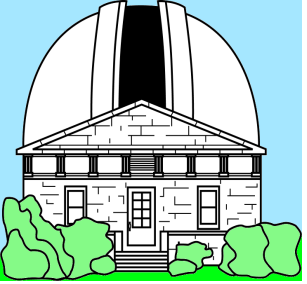
- History: plan and construction
- URAT operations north (NOFS)
- URAT operations south (CTIO)
- Results, Catalogs
- Future: what is next?



History: project plan and construction of the URAT instrument

“UCAC dome” at CTIO





USNO Instrument Shop(s)

- in Washington, DC
 - lead by Gary Wieder, latest machines
 - design and build astronomical instrumentation
 - highly regarded (NPOI, SDSS, URAT, clocks)
- at NOFS (Naval Observatory Flagstaff Station)
 - lead by Mike DiVittorio
 - maintenance of telescopes and instrumentation
 - adaptive optics design, NPOI

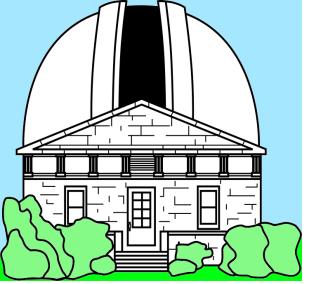


CAUTION
HOT SURFACES
MAY BE PRESENT
WHILE RUNNING
THIS MACHINE

ST

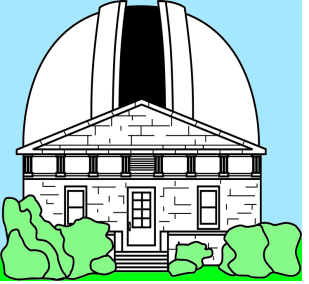
HNS





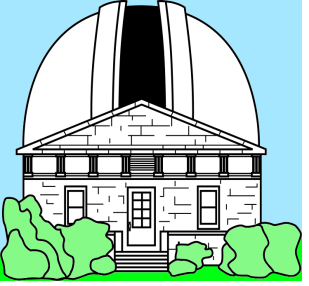
URAT project

- **Goal #1:** follow-up of UCAC in pre-Gaia era
 - go **deeper**, many more stars
 - more **precise**: many sky overlaps
 - more **accurate**: new detectors, no CTE problem
 - get **parallaxes** of nearby stars without pre-selection
- **Solution:** “**red lens**” with modified **astrograph**
 - 4-shooter camera: each 10,560 x 10,560 pixel
 - each exposure covers **28 sq.deg** (about 1 GB)
 - use UCAC reference stars, survey to $R = 18$ mag



URAT project (cont.)

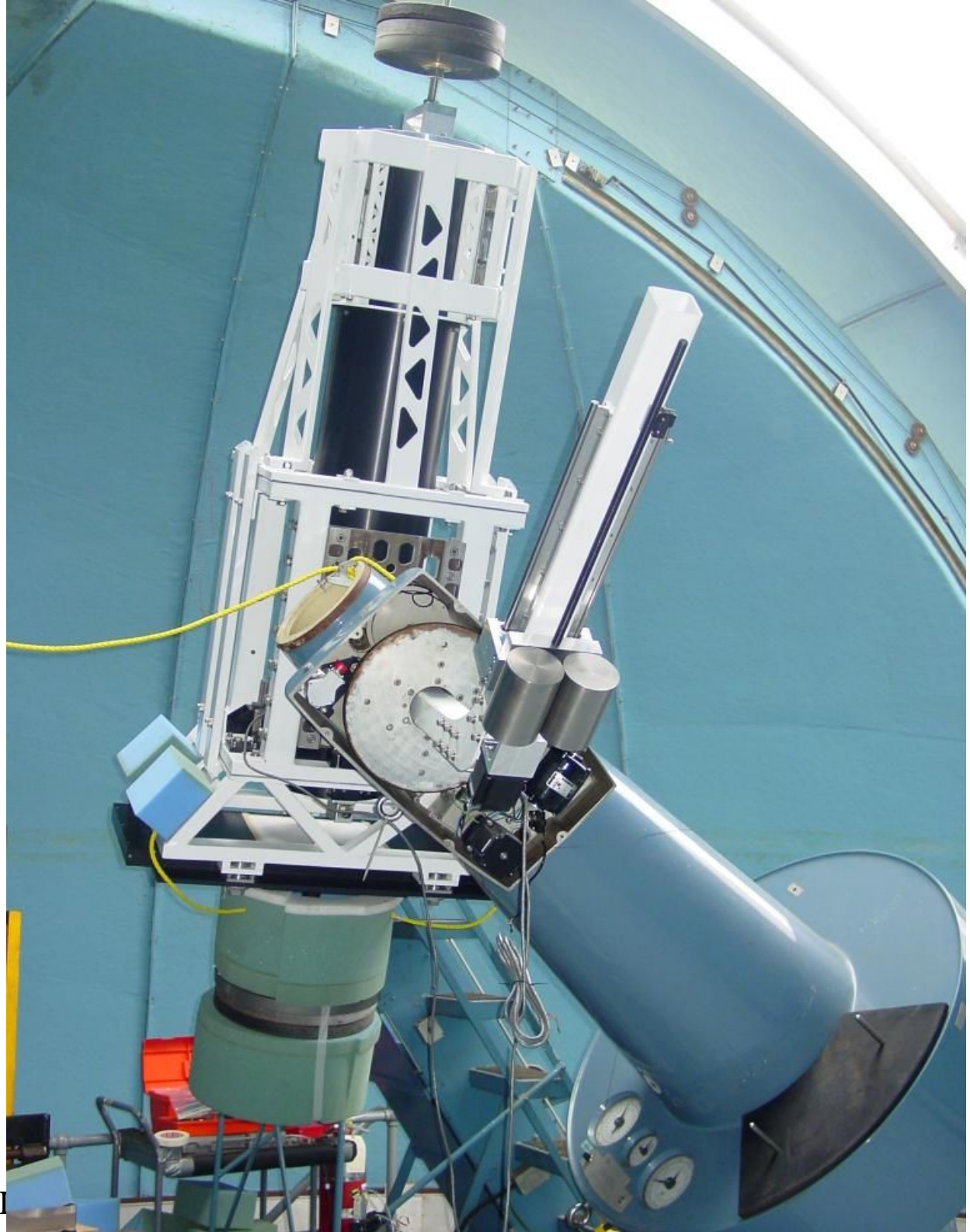
- **Goal #2:** bright stars = supplement Gaia
 - use new **neutral density spot** + objective **grating**
 - access **all bright** stars up to Sirius
- **Milestones**
 - 10k test camera: 1st light October 2007
 - funding for 4-shooter camera in FY2008
 - 1st light in Washington DC: Sept. 2011
 - operations at NOFS: April 2012 – June 2015
 - begin operations at CTIO: Oct. 2015

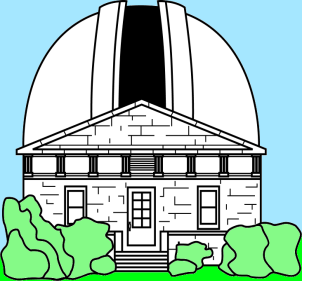


astrograph
May 2009
at USNO

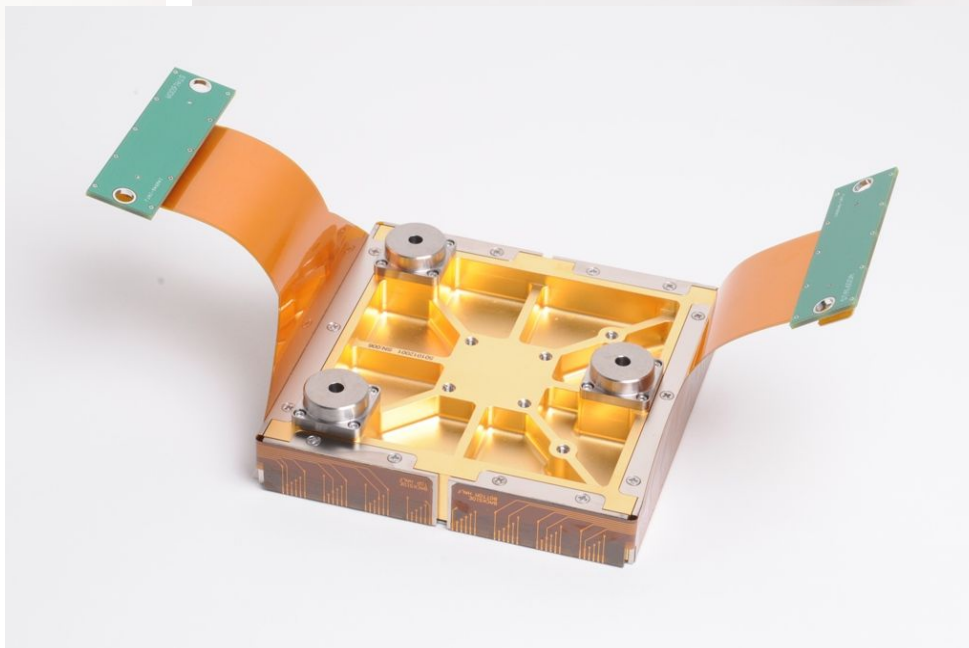
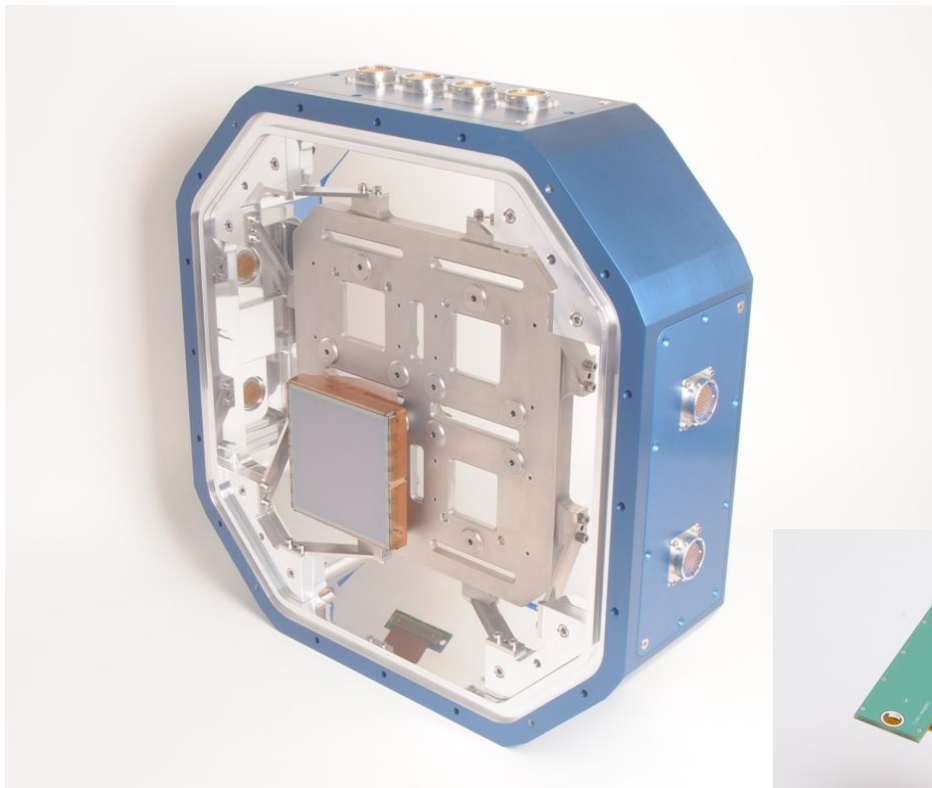
2016 Sept 28

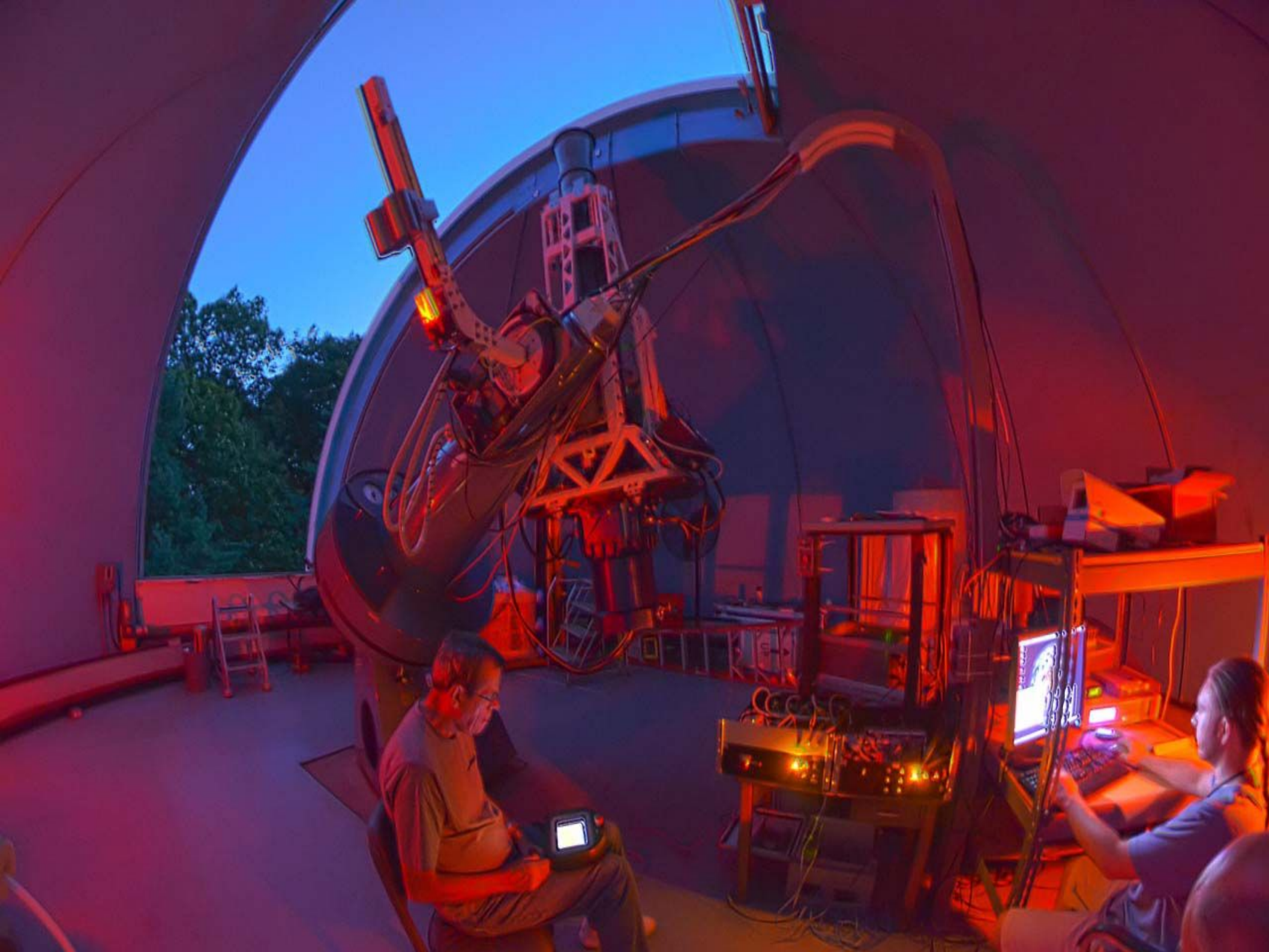
Adel

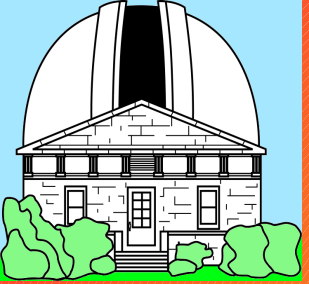




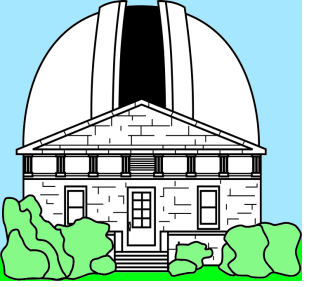
spring 2010, 10k packaging







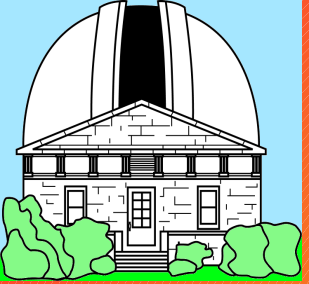
URAT operations:
Northern Hemisphere
NOFS, Arizona



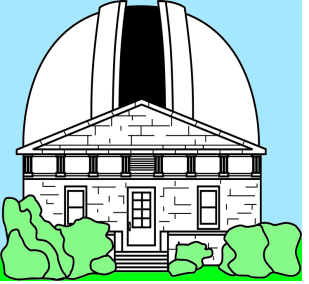
URAT observations north

- complete re-make of astrograph 2008-2010
- Naval Obs. Flagstaff Station: 2012-2015
- **28 sq. deg.** per exposure! (4 detectors)
- 10 mas per image (well exposed stars)
- multiple sky overlaps / year, **7 - 18 mag**
 - clocked anti-blooming: extend dynamic range
 - around full Moon: short expos. grating: **3 - 15 mag**
- solve for **positions, motions + parallax**



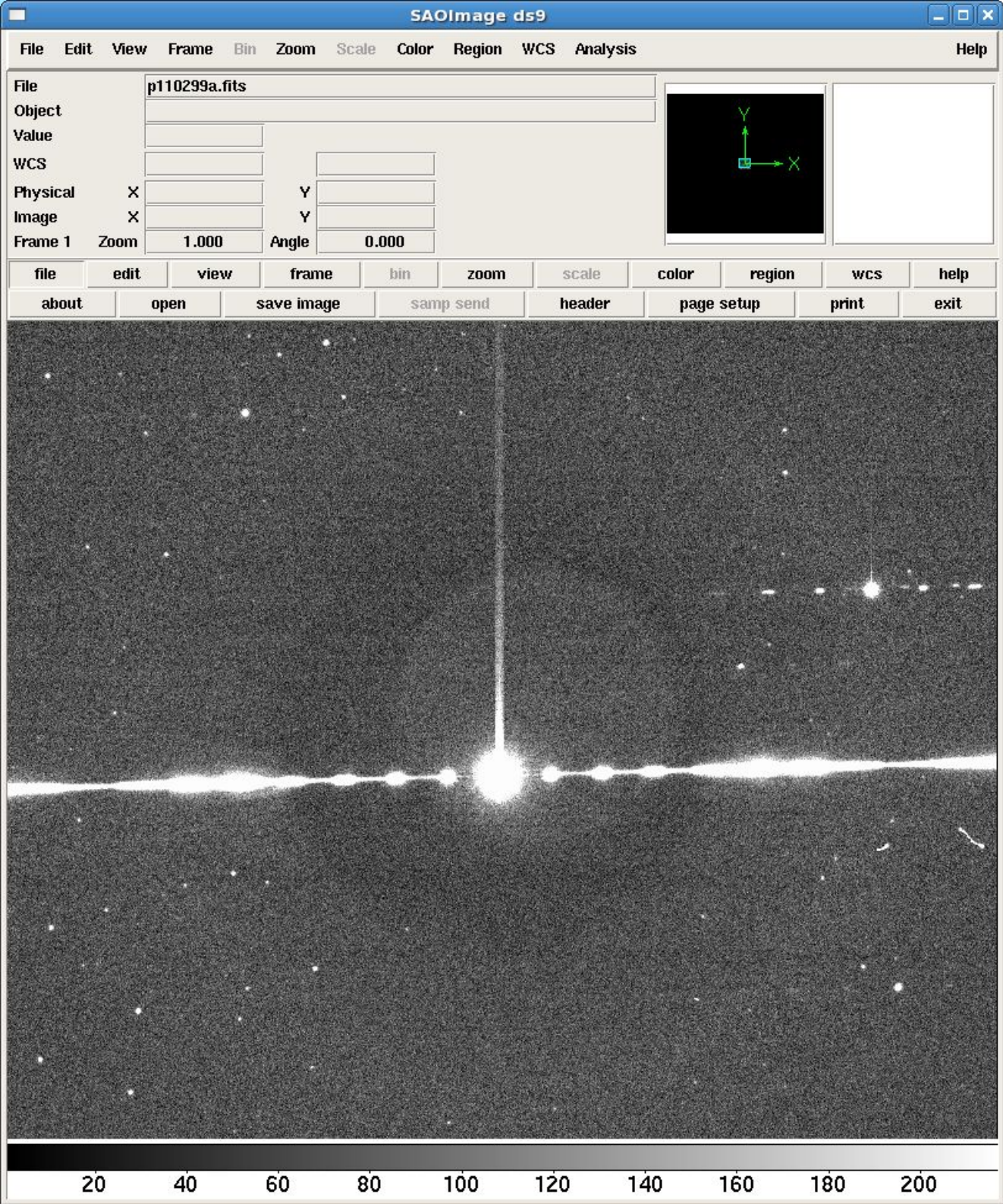


URAT operations:
Southern Hemisphere
CTIO, Chile

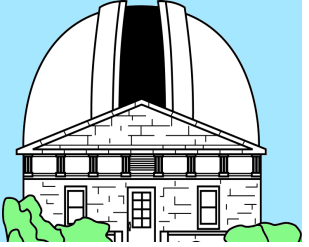


URAT operations south

- by 2014 known: Gaia will be successful:
 - shift from goal #1 to #2: **bright stars only**
- move instrument
 - pack up at NOFS (June 2015)
 - ship dewar window out to get new ND spot
 - deploy at CTIO (Sept / Oct 2015)
- 10, 30, 60 sec exposures:
 - general, shallow, **quick survey**: 3.5 to 17 mag
 - **targeted** observations: -1.5 to 4.5 mag stars

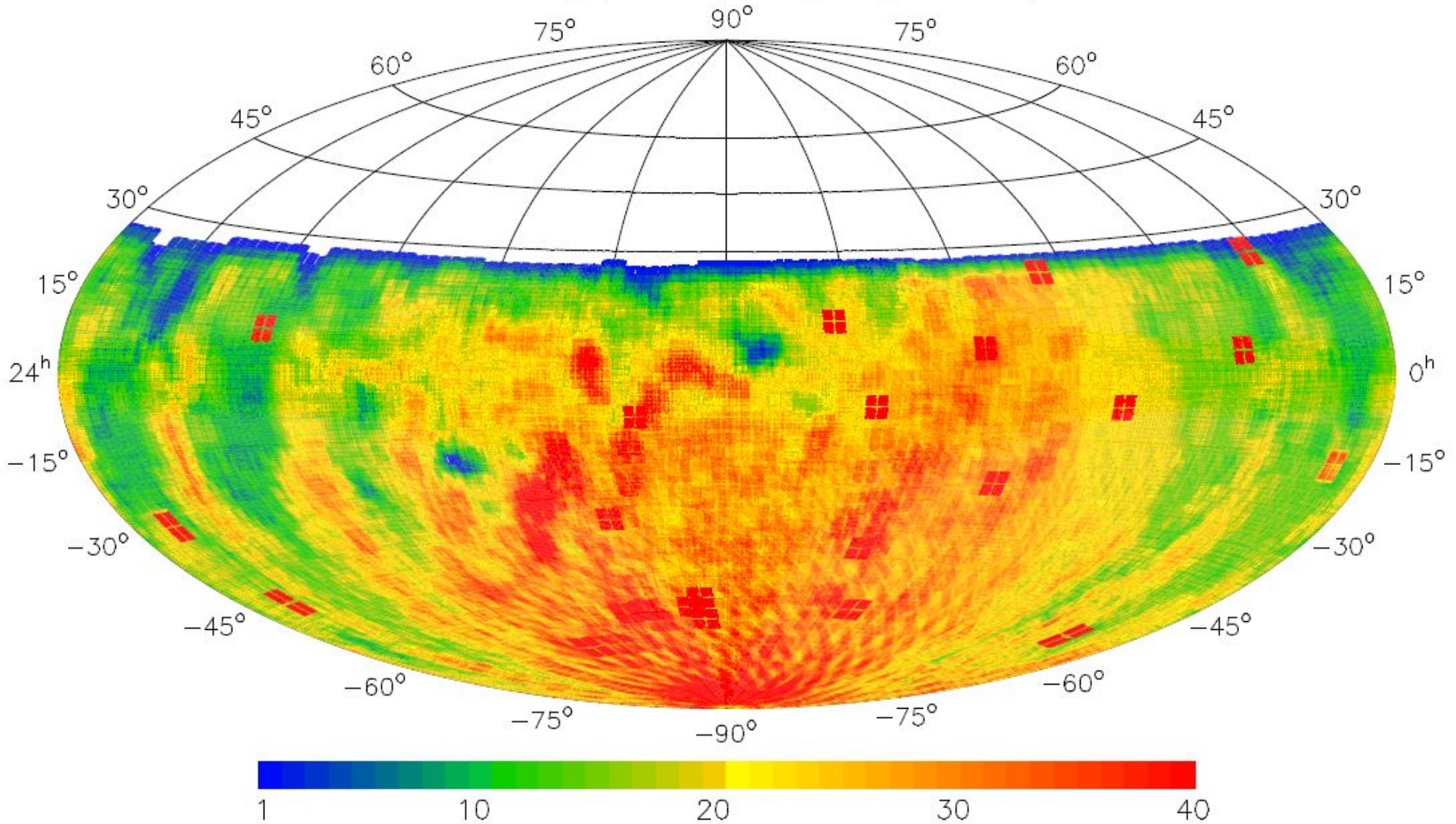


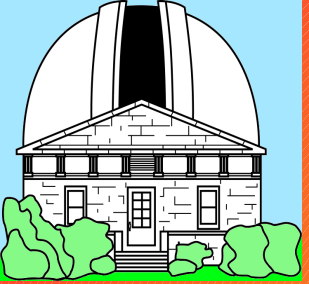
**5 sec
exposure of
Sirius with
ND spot filter
and grating**



observing progress mid Aug 2016

URAT CTIO survey j7327 to j7611 grating 10 sec expos.

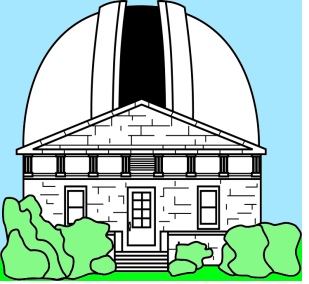




Results:

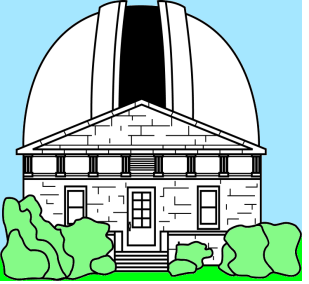
published catalogs

data mining efforts



products

- **URAT1** = public star catalog (north)
 - based on first 2 years of operations at NOFS
 - typically 5 to 30 mas precision = $f(\text{mag})$
 - preliminary proper motions with 2MASS
- **UPC** = URAT parallax catalog (Finch+2016)
 - over 100,000 entries = largest since Hipparcos
 - precision on 3 to 12 mas level = $f(\text{obs.history})$
- **URAT2** = all data from 3 years at NOFS
 - not public, internal use only at this point

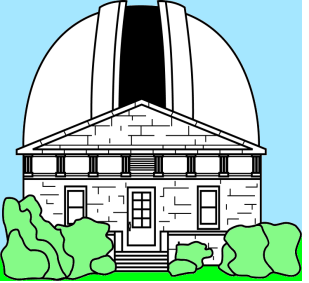


URAT1 catalog (2015)

```
total numb. URAT1 stars = 228276482
number stars with 1 obs = 10309229
number stars with 2 obs = 8875122
average numb. obs/star = 24.3

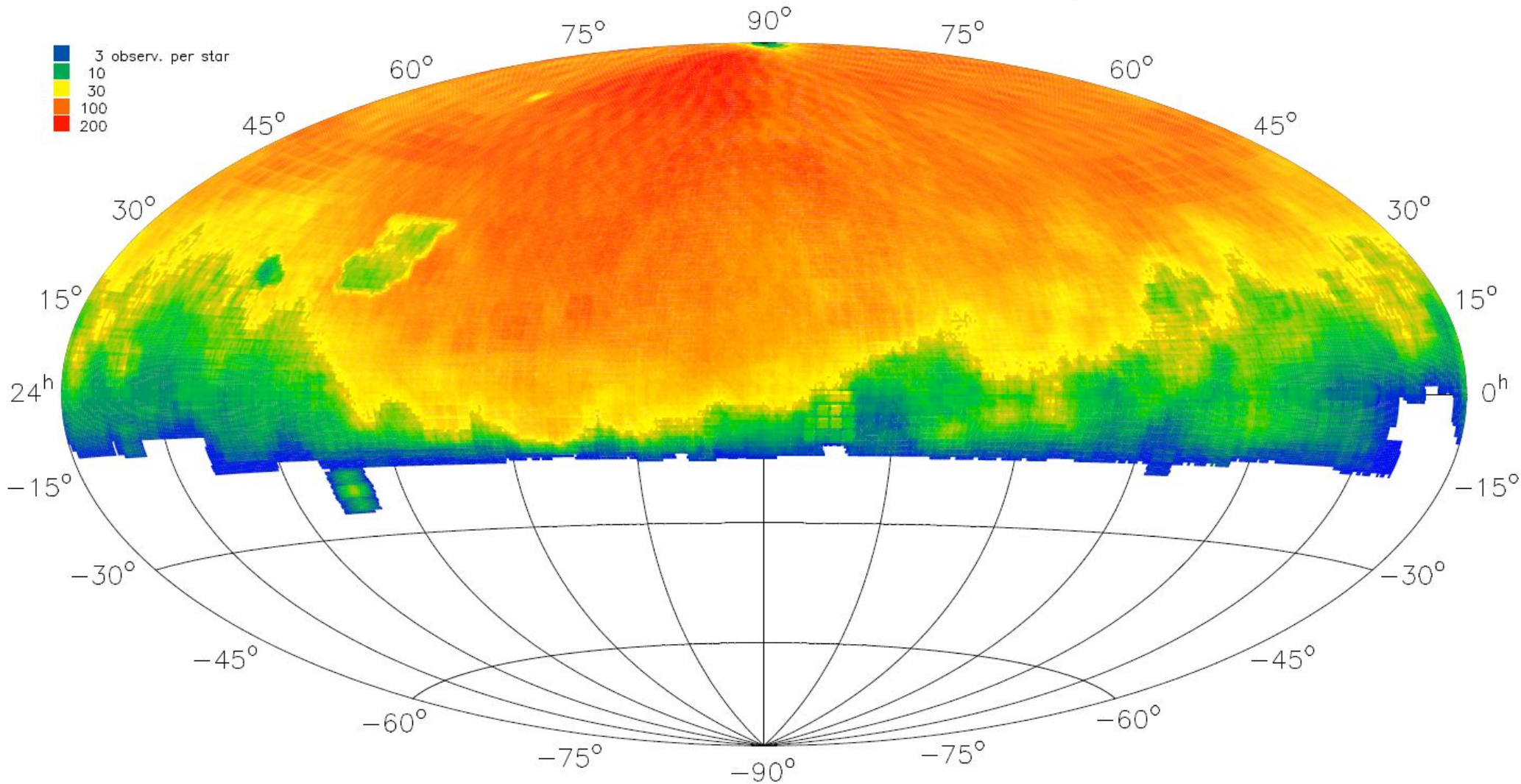
number valid 2MASS data = 188656145 82.64%
no 2MASS match stars = 39620337 of
stars >=3 obs., no 2MASS= 39079551 URAT1

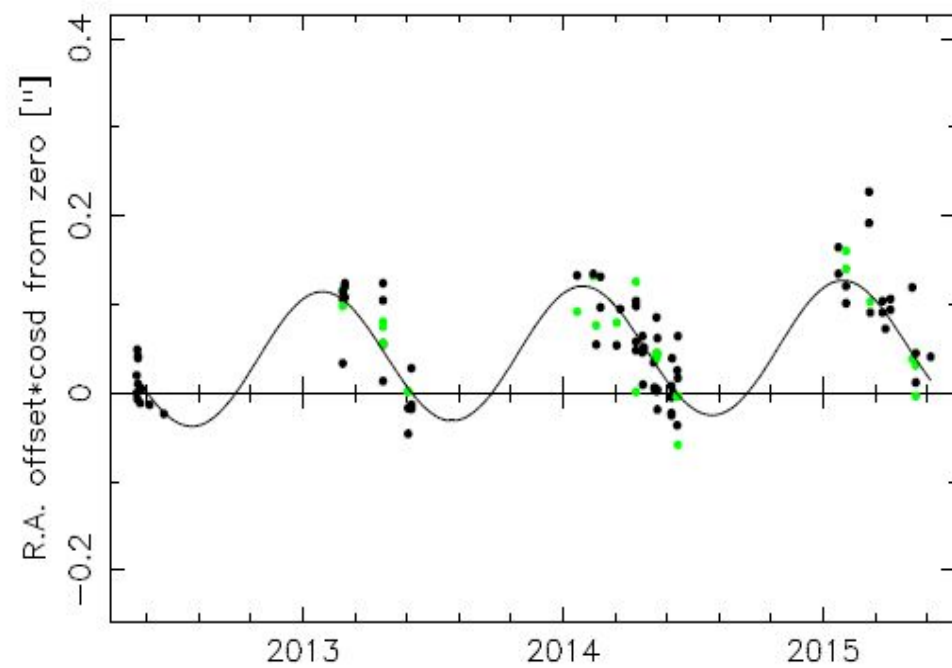
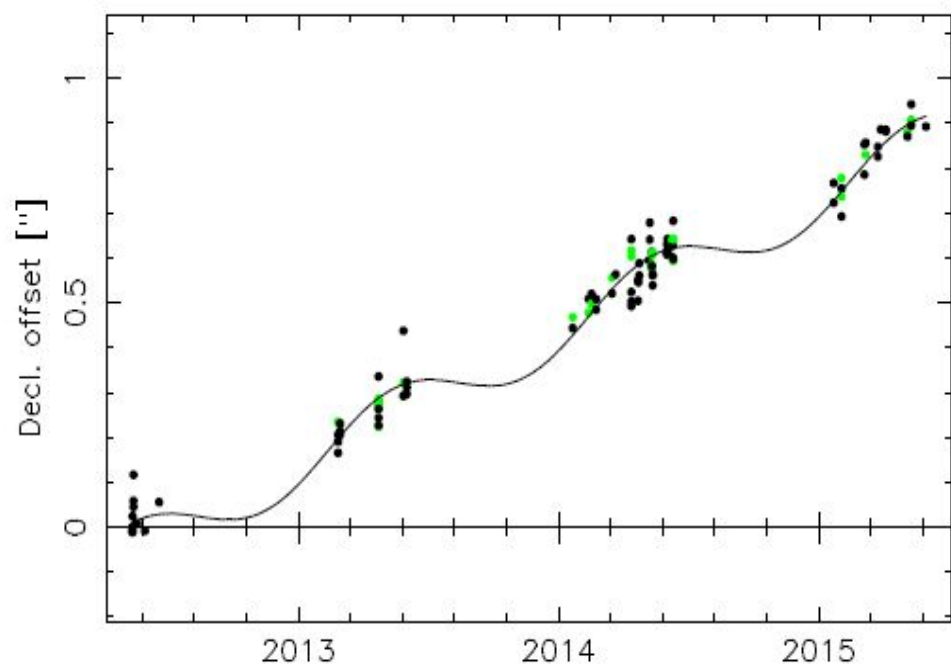
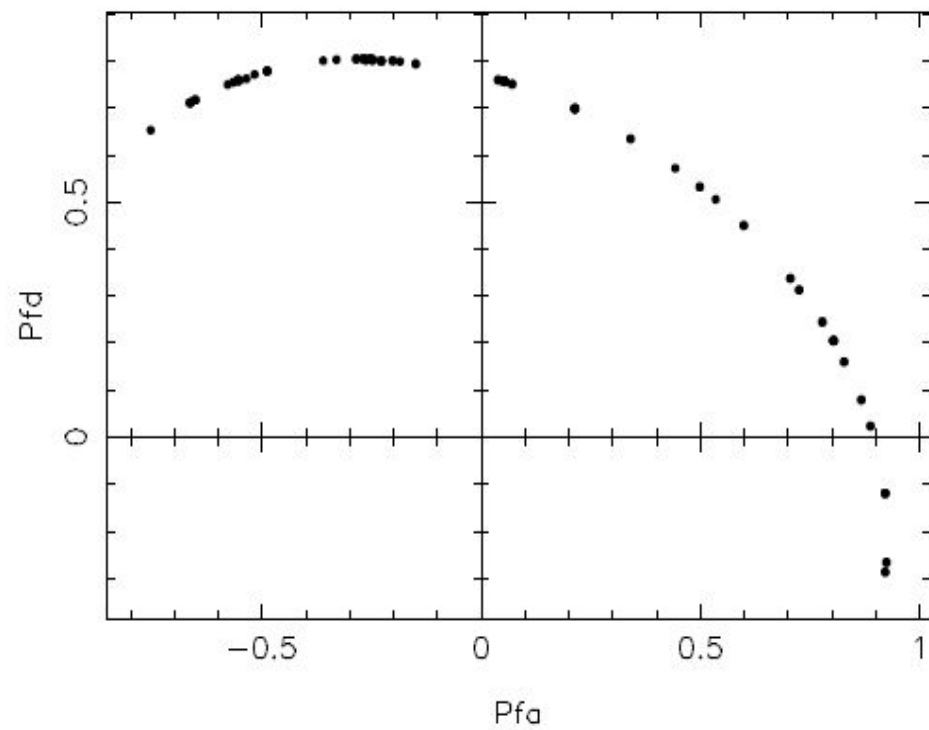
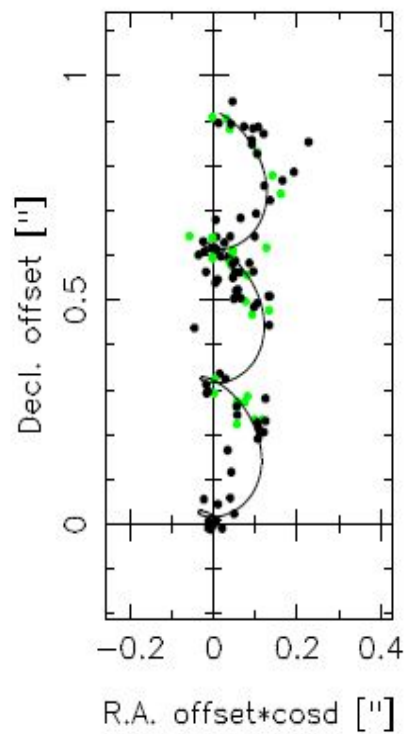
number valid APASS data = 37010348 16.21%
APASS stars valid B mag = 29313850 of
APASS stars valid V mag = 30057593 URAT1
APASS stars valid g mag = 32340624 stars
APASS stars valid r mag = 32474206
APASS stars valid i mag = 28052917
```

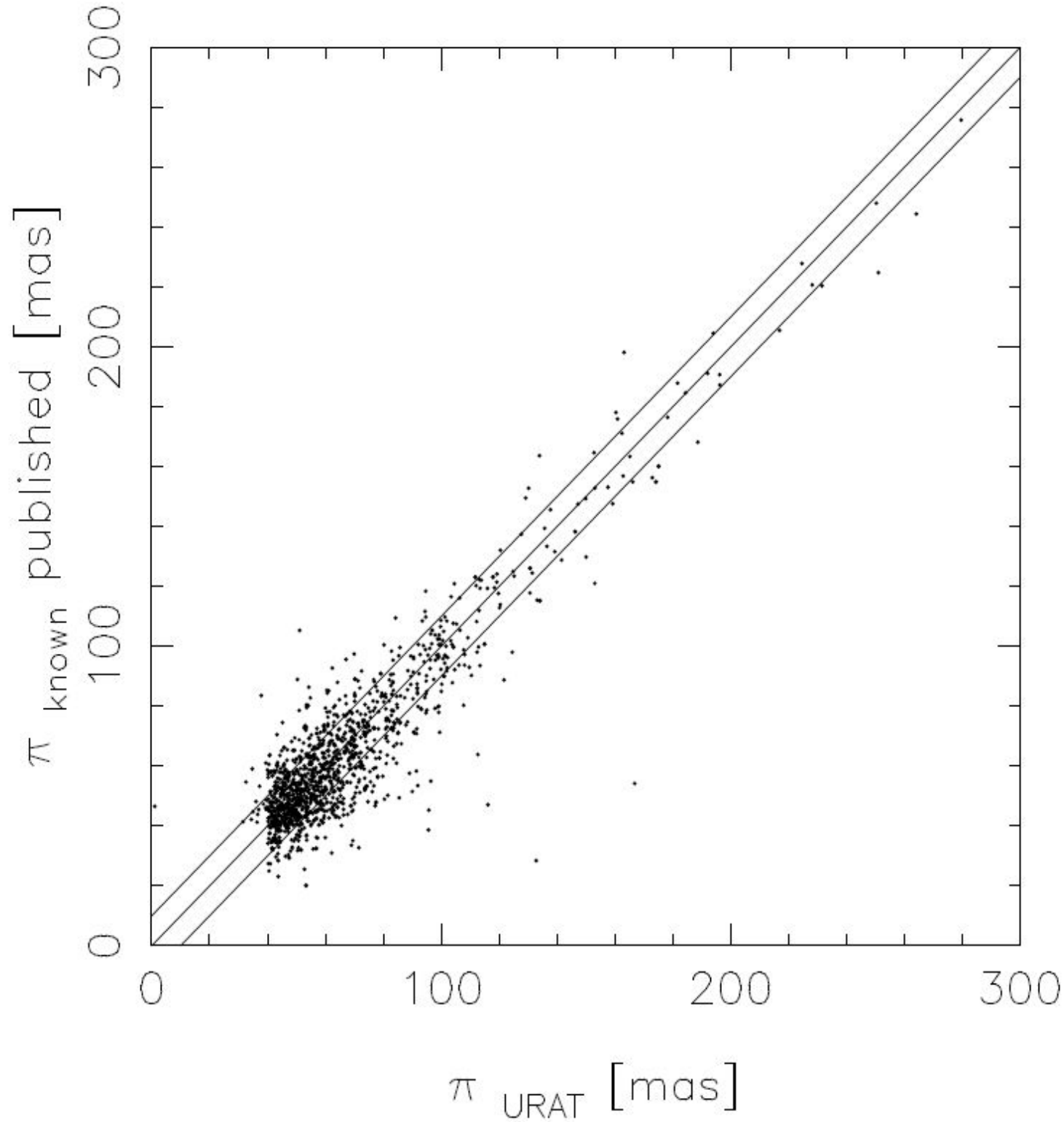


URAT1 sky coverage

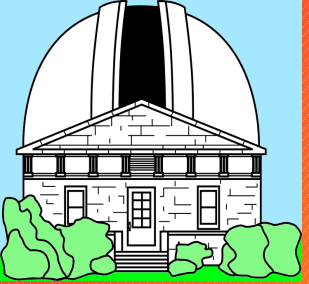
URAT1 mean observational coverage of 12 to 16 mag stars



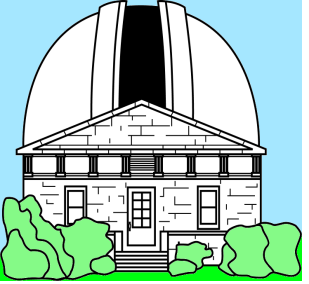




**UPC =
URAT
Parallax
Catalog
(2016)
112,177
stars**

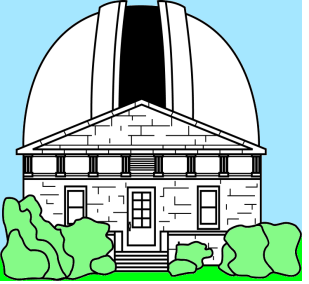


Future:
what is next?
(life after Gaia DR1)



anything useful?

- Accurate (5-10 mas) positions of **bright stars** not yet included in Gaia DR (≤ 4 mag)
- Continue URAT **observing** at CTIO until about **mid 2017**
- Data reduction with Gaia reference stars is in progress
- URAT is useful for **time-domain** astronomy: possible **collaboration** with ZTF ? **Others** ?



summary

- URAT = follow-up to successful UCAC: bright + faint
- URAT1 : 3-18 mag, 5-30 mas, NOFS, 228 mill. stars
- UPC = URAT Parallax Catalog (112,000 stars)
- Next:
 - data mining of full 3-year northern observ.: AGNs ...
 - very bright stars not published by Gaia yet
 - phase out observing at CTIO by mid 2017
- New project: time-domain astronomy (4 to 17 mag) ??