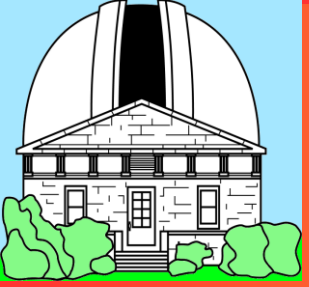

Star catalogs, photogr.plates and errors for solar system astrometry improvements

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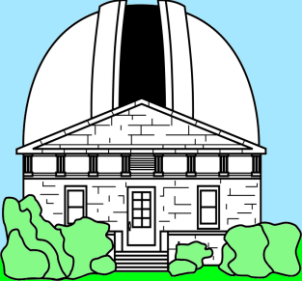
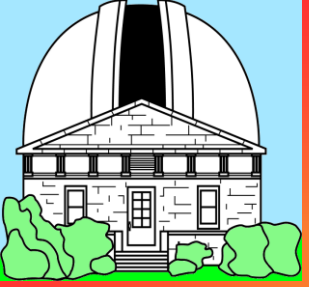
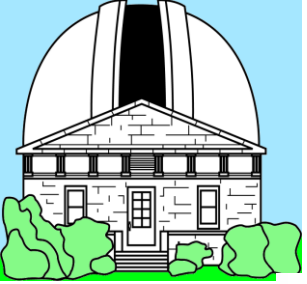


layout of talk

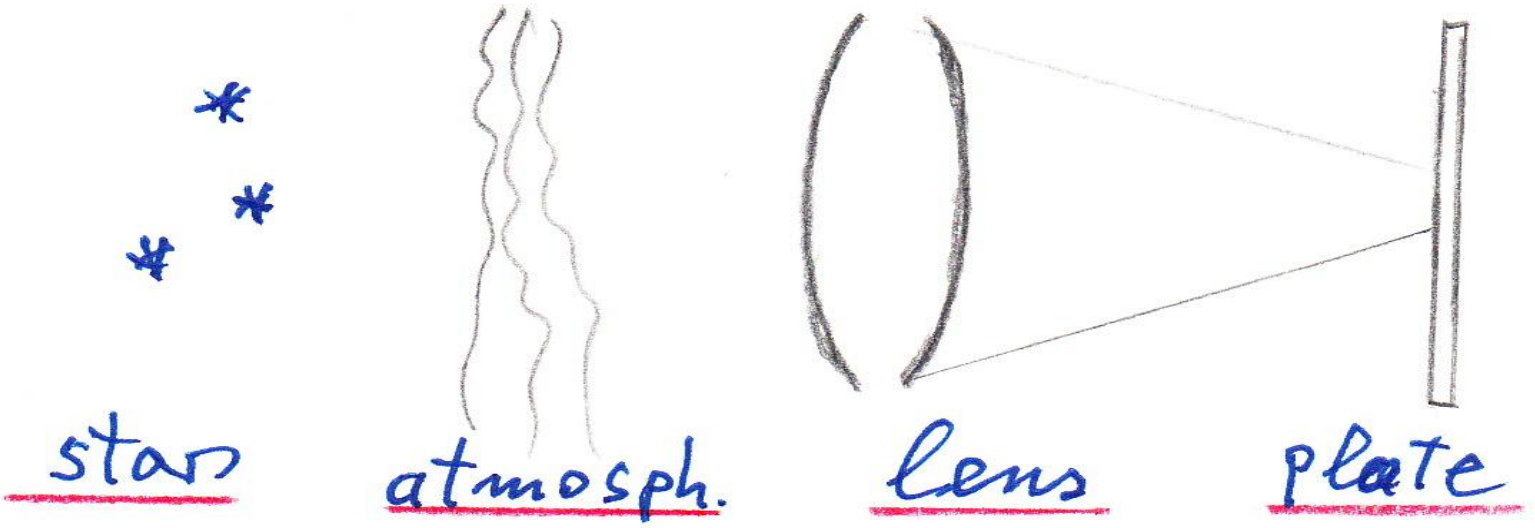
- sources of errors in photogr.plate + scan process
  - plate scans: mosaic vs. overlap images
  - concept of reversal for magnitude equations
  - plate models and error propagations
  - sums and differences of errors
  - other comments
- new reference stars:
  - UCAC
  - URAT
  - Gaia + what is useful for photogr. data



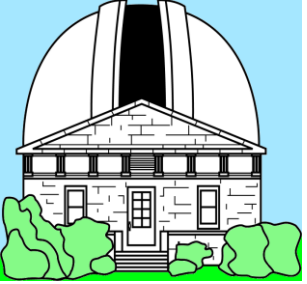
major sources of errors in the process
from photographic plates to RA, Dec



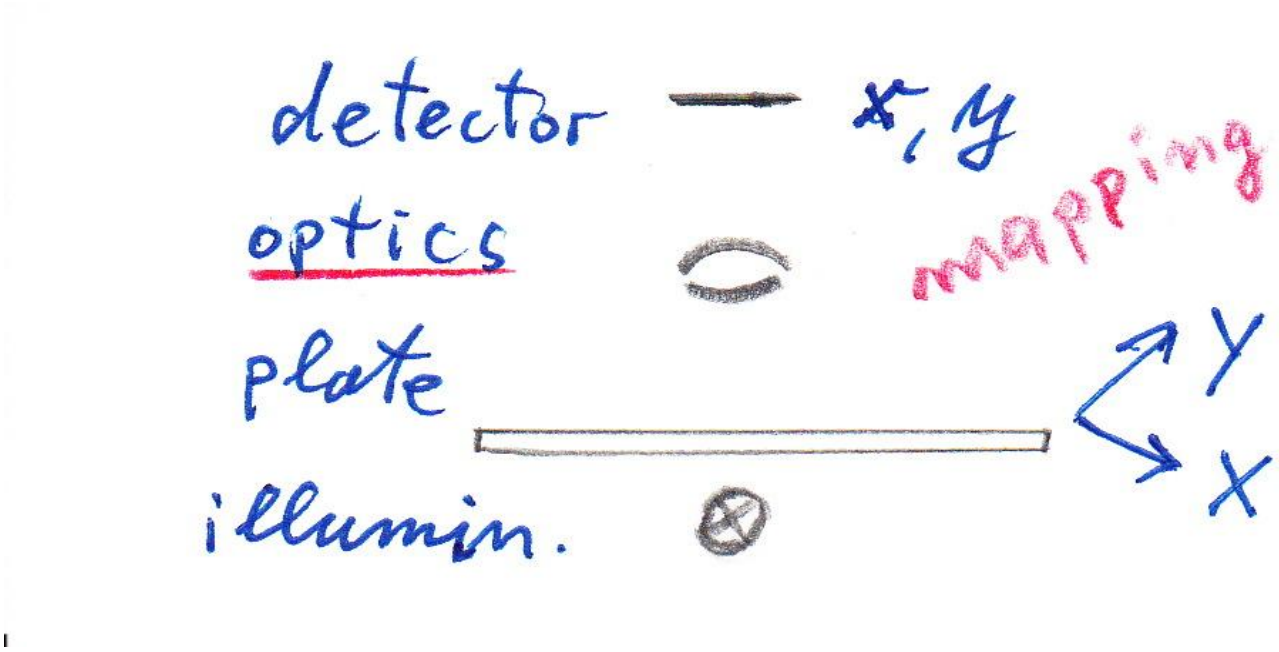
overview, part 1: exposure



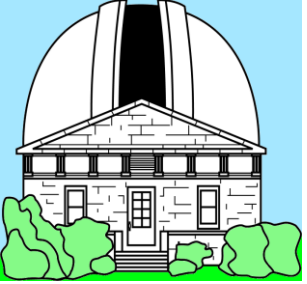
reference star errors = 20 mas level
sigma_atm = 100 mas / sqrt(exp.time[sec])
lens: aberrations (optical distortion, mag.eq.)
plate: emulsion shifts, wet process



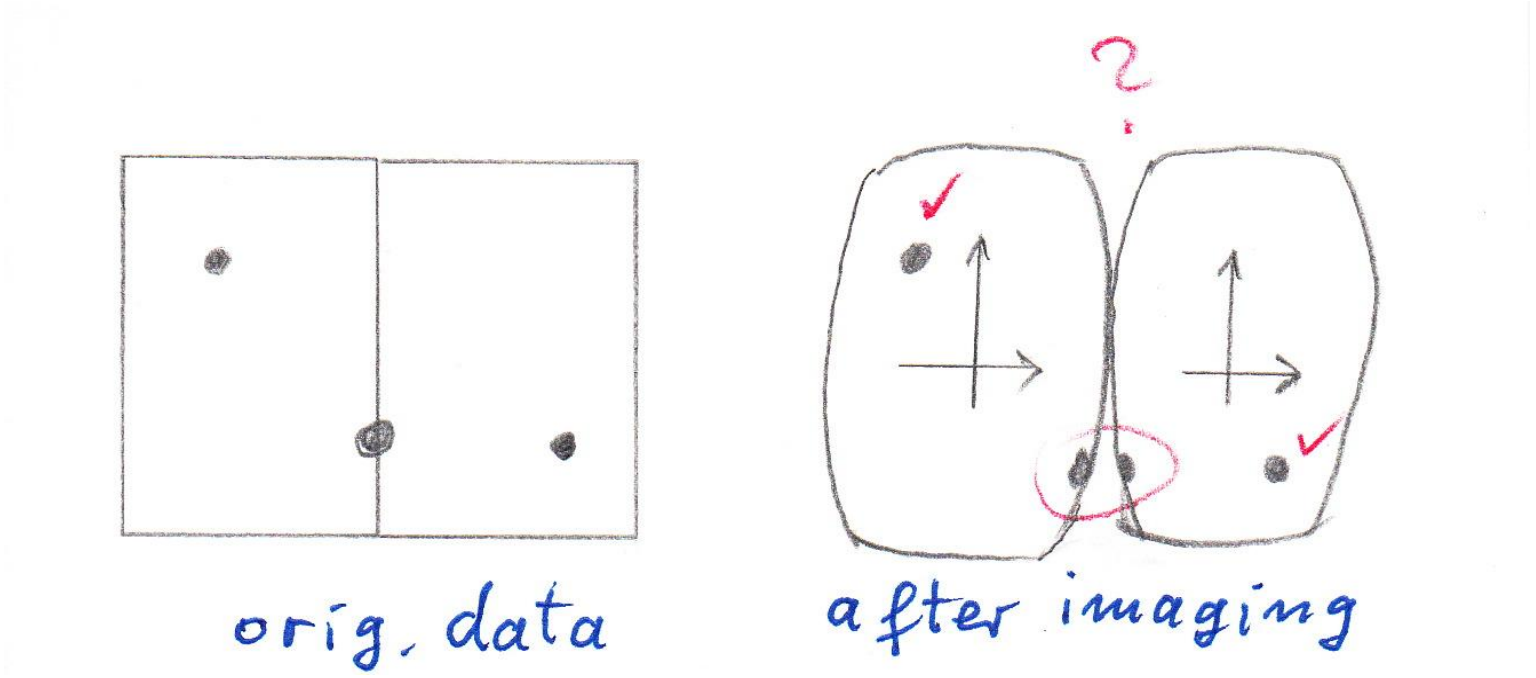
overview, part 2 : plate scan



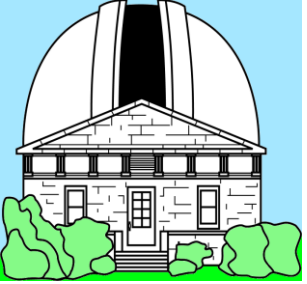
optics: optical distortion again
mapping between table (X,Y) and detector (x,y)



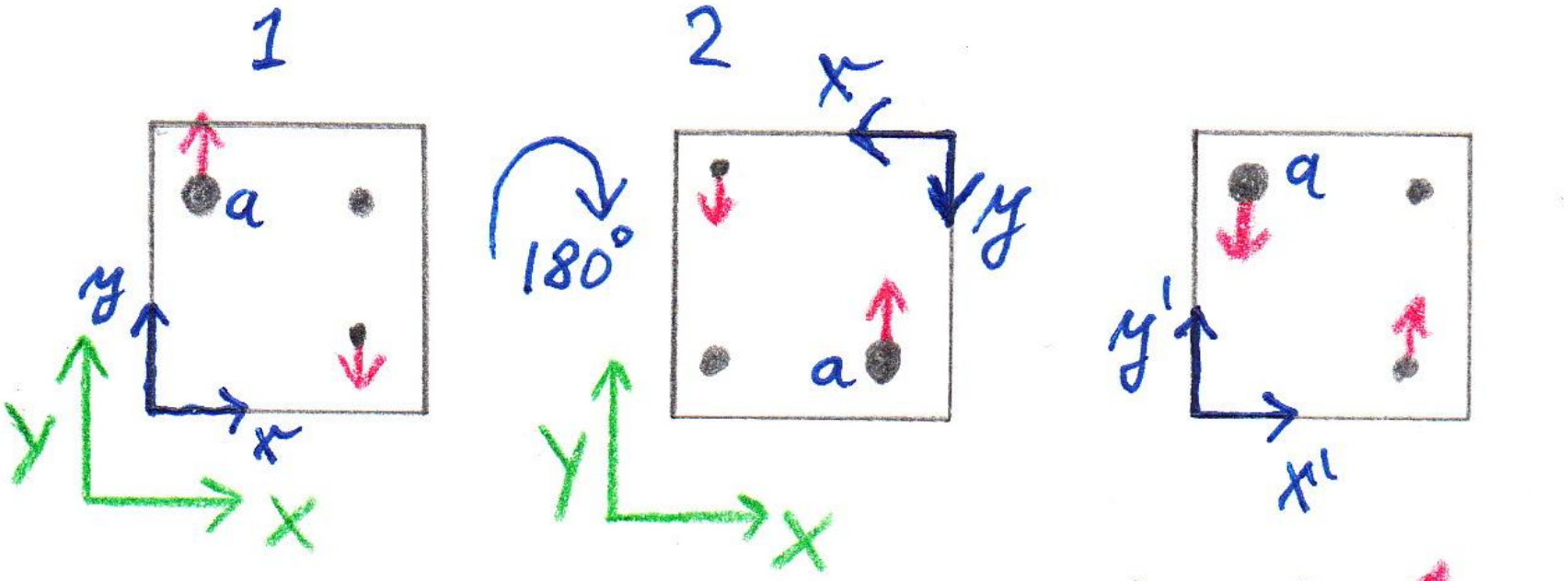
scanning: mosaic vs. overlap



mosaic stitch together: can't be done properly due to optical distortion of projection



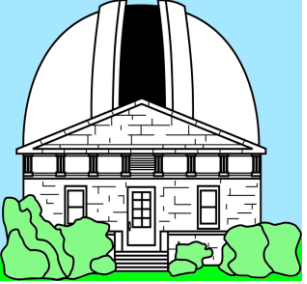
concept of reversal (mag.eq.)



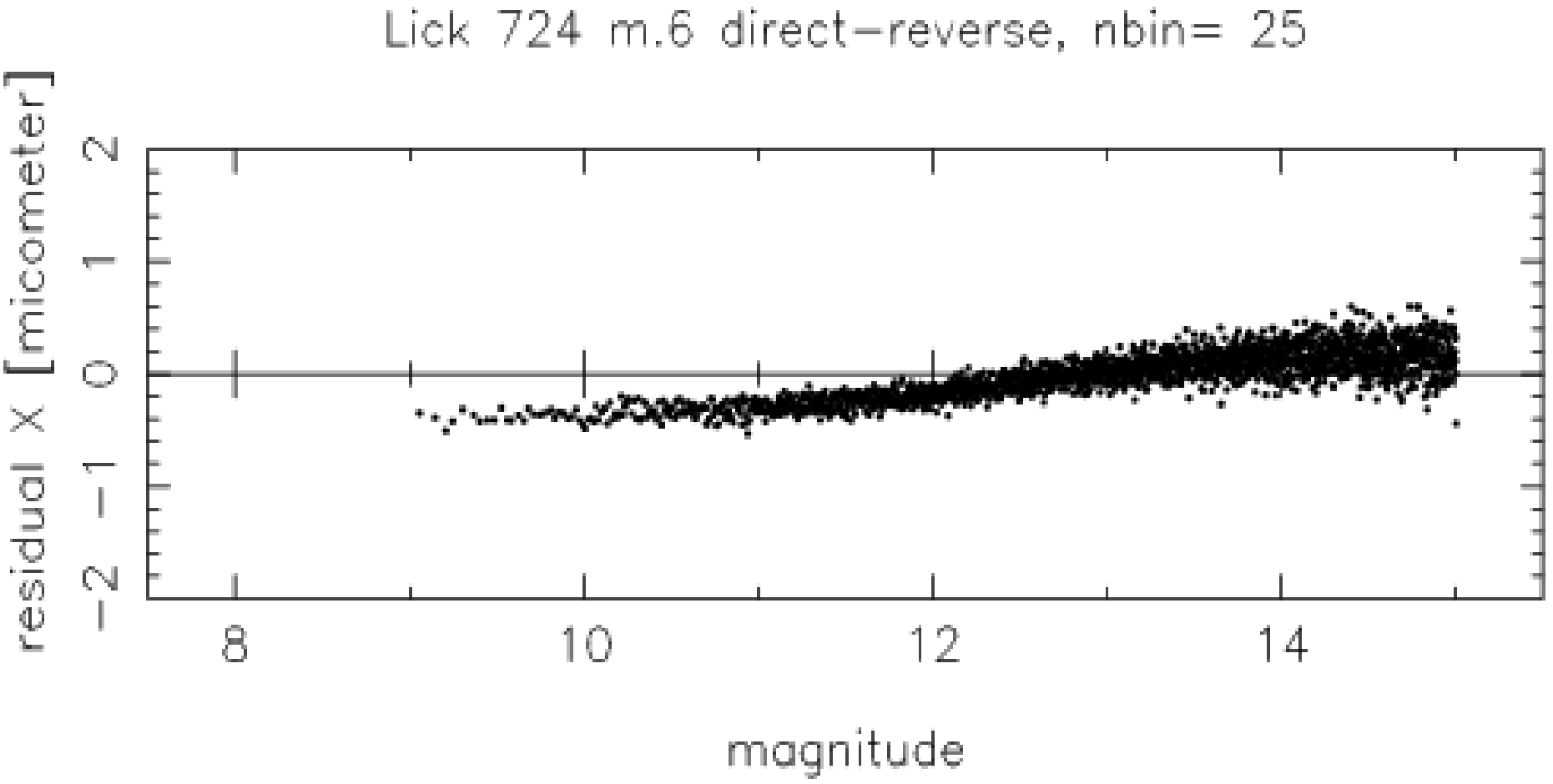
star a: $\Delta y_1 - \Delta y'_2 = 2 * f$

orthog. transf. $(x_1, y_1) \rightarrow (x'_2, y'_2)$

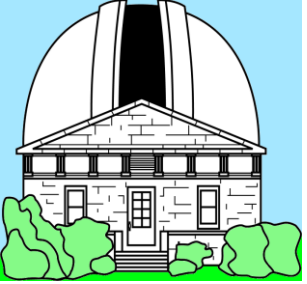
resid. = f(mag) plot



example magnitude equation

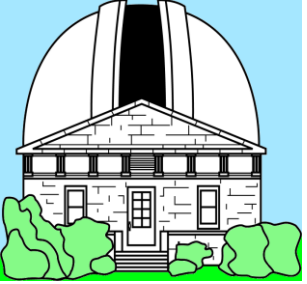


StarScan: linear model D-R



error propagation in plate models

- Eichhorn & Williams, AJ 1963
- total error = indiv. x,y error + propag.(model)
- fit x,y to ref. stars RA,Dec: errors in model para.
- xi = a x + b y + c, ...
- error in center = smallest
- further out in x,y field: addit.err.contr. a,b,..
- also: external errors larger than formal for small number of reference stars (“sigma” can be misleading; adjust weights)



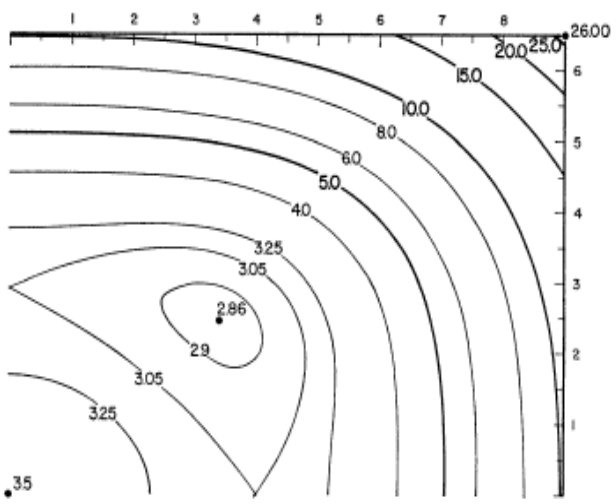
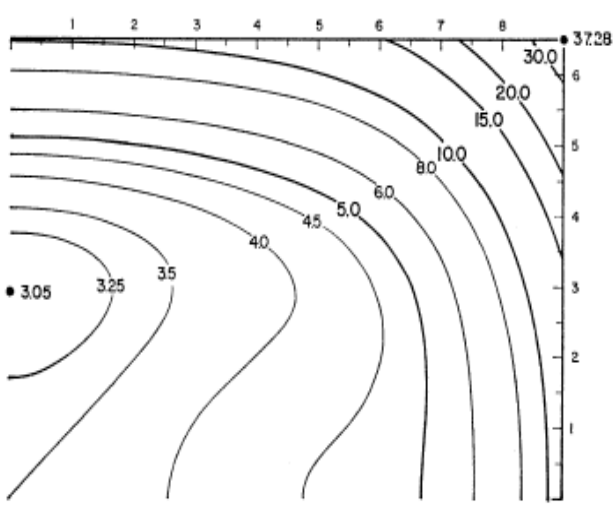


FIG. 1 (*Continued*)



Case III. Four linear constants with tilt terms.

$$\xi = Ax + By + C \quad + px^2 + qxy,$$
$$\eta = Ay - Bx \quad + D + pxy + qy^2.$$

The following nonzero terms appear in the covariance matrix:

$$nQ_{AA} = \frac{12}{J} = nQ_{BB}; \quad nQ_{CC} = \frac{N}{K}; \quad nQ_{Cp} = -\frac{60}{K};$$
$$nQ_{DD} = \frac{M}{L}; \quad nQ_{Dq} = -\frac{60}{L}; \quad nQ_{pp} = \frac{720}{a^2K}; \quad nQ_{qq} = \frac{720}{b^2L}. \qquad (9)$$

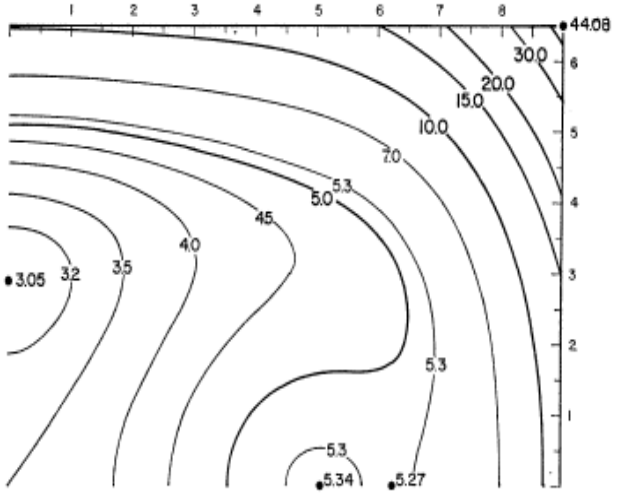
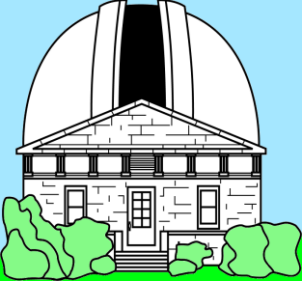


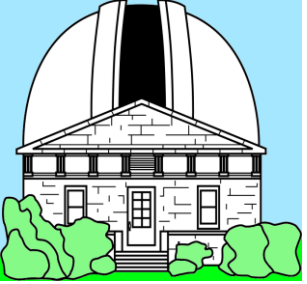
FIG. 1 (*Continued*)

Eichhorn & Williams, AJ 1963 p.5



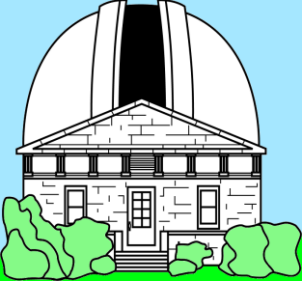
sum (difference) of errors

- random errors always add in quadrature
- sigma_total = sqrt (sigma1^2 + sigma2^2)
- compare 2 random error distributions, sigma1=30mas, sigma2= 35mas
- “difference” is error contribution of 18 mas
- not 5 mas (35^2 = 30^2 + 18^2)
- total error is often dominated by single contrib. 50 mas + 30 mas + 20 mas = 61.6 mas



higher order terms, mag,color terms

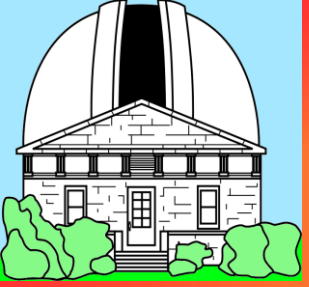
- often can not be determined from individual “plate solution”: too few reference stars, too many model parameters
- recommended approach:
  - use model with “basic” parameters
  - collect all residuals of many plates (same telescope)
  - plot residuals as function of coordinates, mag, color, coma-term, radial residuals …
- need to be done for “plate exposure” and “scan” i.e. telescope mapping and plate meas.machine



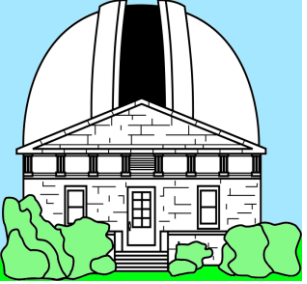
other comments

- scale change of telescope often is a function of temperature (air, lens, tube ...)
- x,y mapping: high correlation between parameters if use tilt terms and offset optical distortion together: need to decide for which to solve based on physics
- reference star errors: more important than position errors at mean cat.epoch are errors in proper motions used for position update for large epoch spans
- sometimes “strange things” happen: e.g. observed offset in Dec: mag.eq. of plate (different from coma term), differential color refraction (DCR), zonal errors in reference star catalog

...

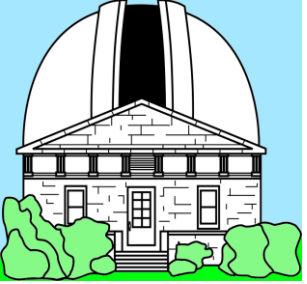


Status reference stars



UCAC4

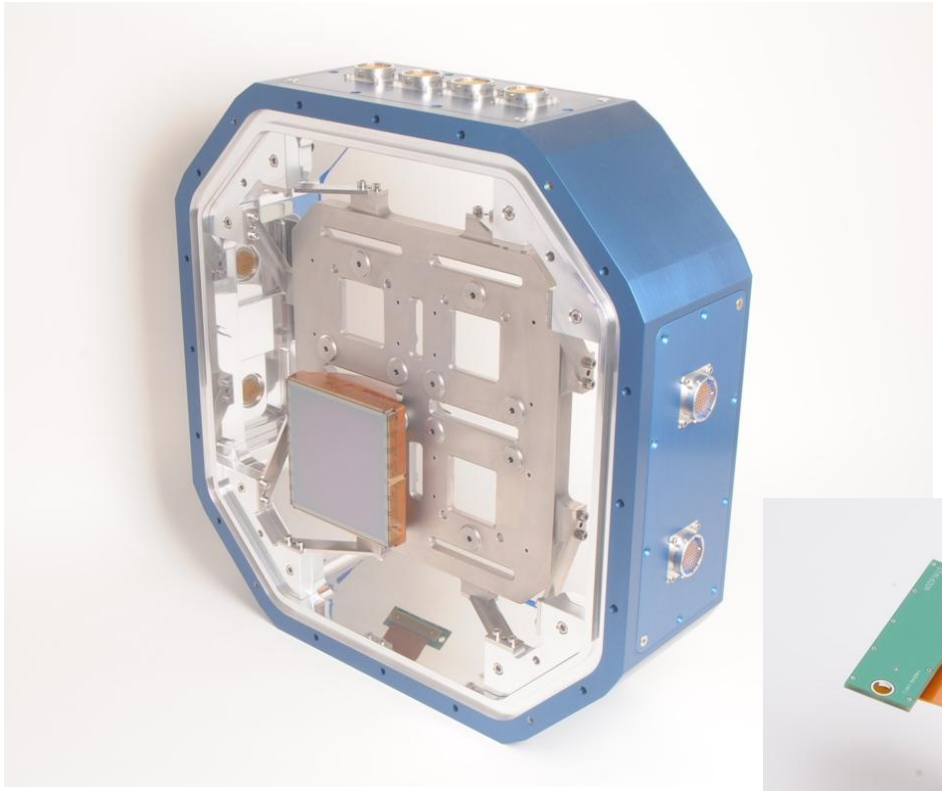
- public release in July 2012
- DR6 APASS 5-band all-sky photometry (B,V,g,r,i) to be included to 16th mag, 55 mill. stars
- 113 million total, 110 m. with PM, 2MASS
- proper motion faint stars: SPM, NPM (PMM measures, re-reductions by Yale + USNO)
- no Schmidt plate data
- bright stars supplem. from Tycho, Hip.,FK6

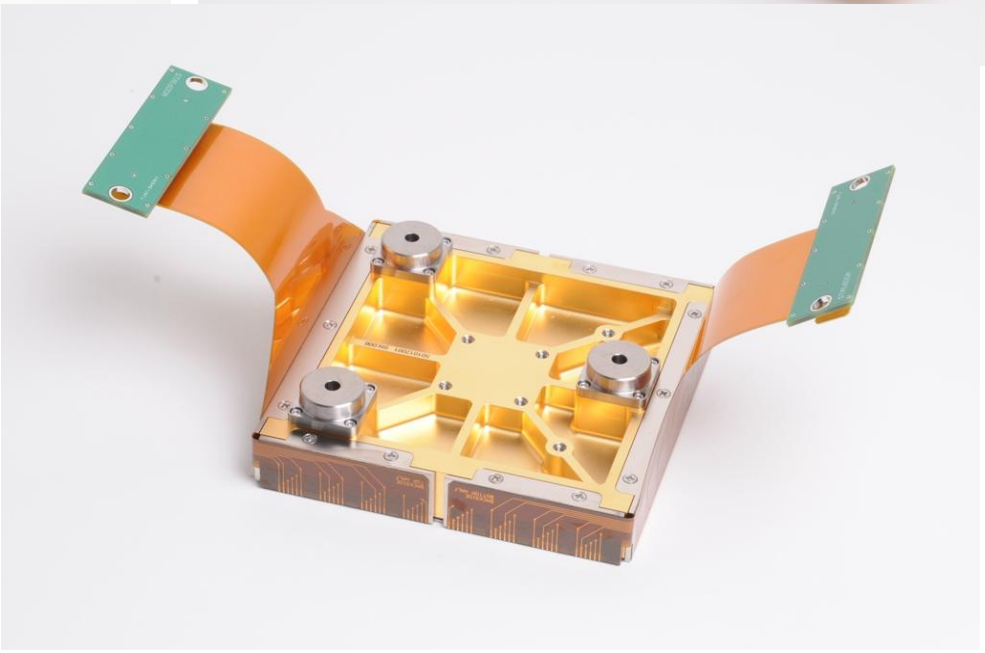


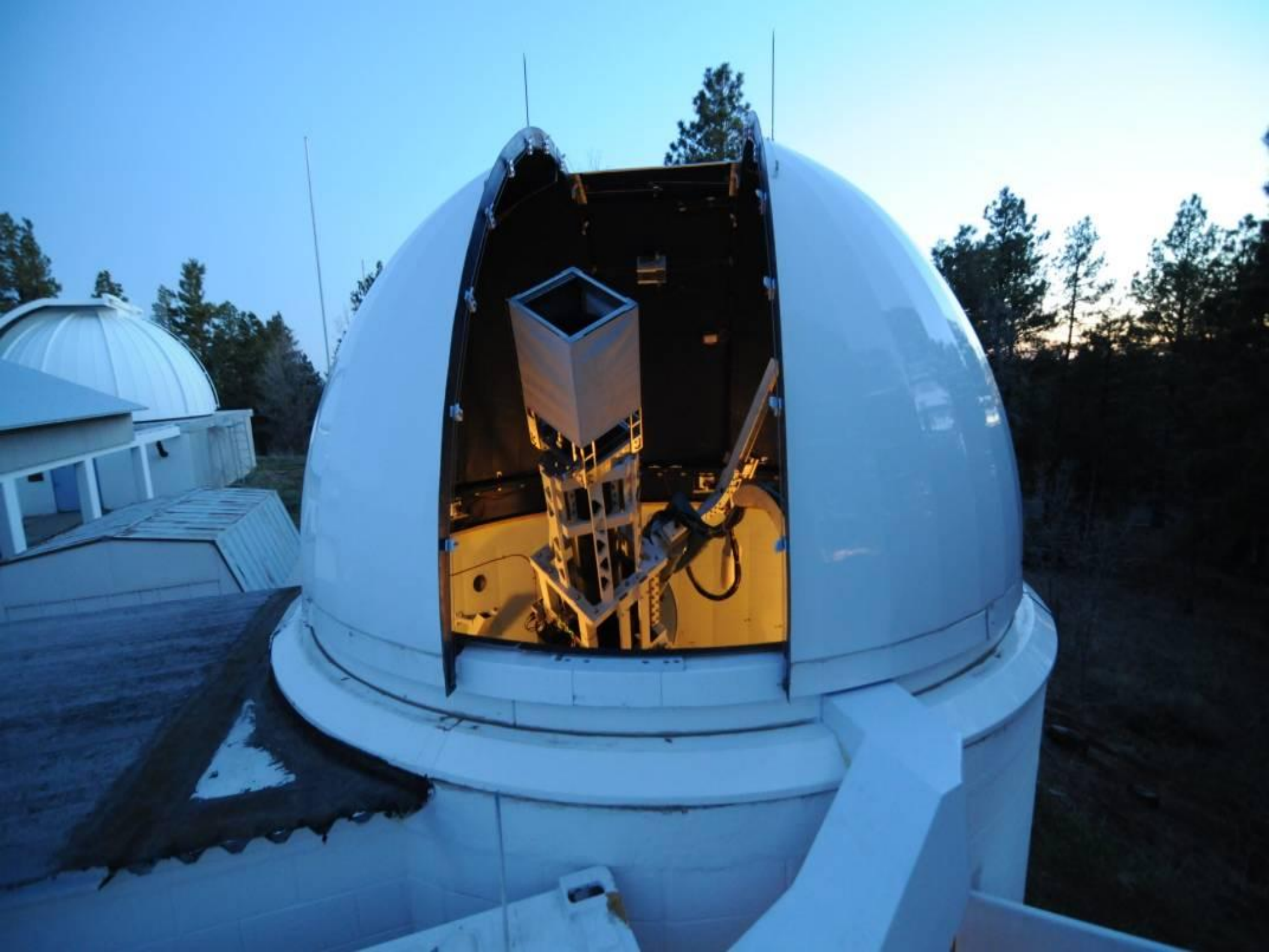
URAT

- survey begin 2012 April 24 at NOFS
- observe 2 to 3 years then move to CTIO
- 28 sq.deg single exposure, 0.9”/mm
- 4 CCDs, 10,560 x 10,560 pixels + guide CCD
- single bandpass (window = filter) 680-750 nm
- gain 2 mag dyn.range: clocked-anti-blooming
- 60s, 240s expos. each field regular survey
- 20s expos. survey with 4.5 mag grating
- total dynamic range: R = 4 … 18 mag
- 20 mas precision / exposure (mid mag range), 10 x overlap/yr

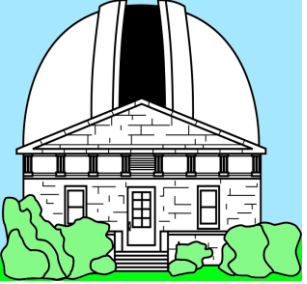
STA 1600 CCD packaging





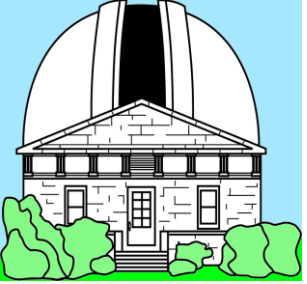



NITROGEN
NITROGEN



Gaia reference stars / error limits

- systematic errors = practically zero
- random errors position, proper motions = pr. zero
- limitation maybe for bright stars (reg.sat. 12 mag)
- ground-based, long-focus plates: 1 um = 20 mas
- errors on plates: maybe 0.2 to 0.5 um level
- errors from plate measure: ROB machine = zero
- errors from atmosphere (single expos.) about 20 mas
- requires optimal ref. Stars < 10 mas errors



summary

- room for improvements in photogr.plate reductions
- UCAC4: final release 2012, good PM, bug fixes, but no significant smaller errors than with UCAC2
- URAT: new all-sky astrometric survey
  - use re-furbished astrograph, 4-18 mag, 5-30 mas
  - 28 sq. deg / exposure, survey begun 2012 April
- Gaia even more accurate: nearly zero random and systematic errors (reference frame)
  - limit of usefulness depends on other error sources

10 mas level likely “good enough” to limit of plates