Gaia DR1 + Pan-STARRS DR1
Comparisons and Synergies

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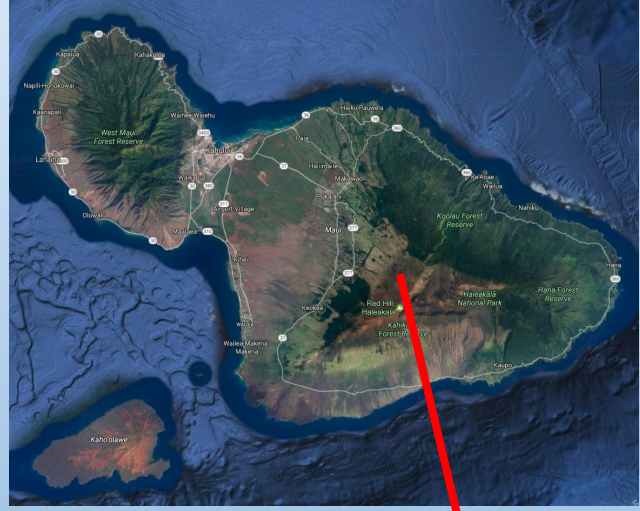
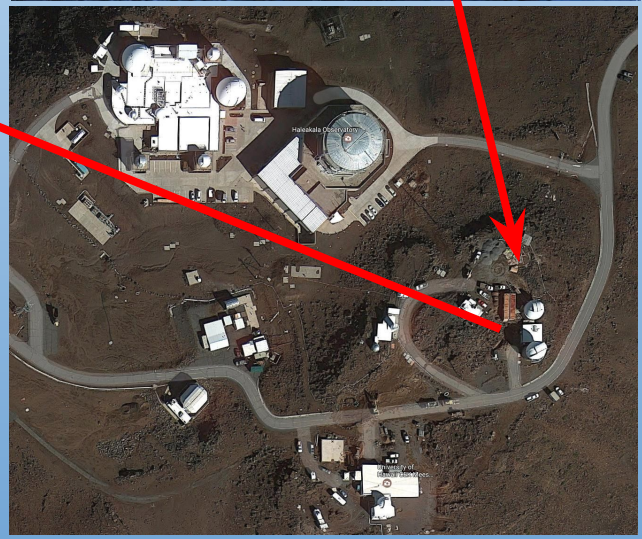
The Pan-STARRS 1 Telescope

- 1.8m primary
- 7 square degree FOV
- 1.4 Billion pixel camera
- 0.257 arcsec pixels
- *grizy* + *w* filters





The Pan-STARRS 1 Science Consortium Survey

- Survey Observations : 2010 May - 2014 March
  - Extra data from as early as 2009.06 and as late as 2015.02
- Survey Components: 3π (56%), Medium Deep (25%), other (19%)
- Public Data Release 1 : December 19, 2016

PS1 consortium members

University of Hawai'i
UH Institute for Astronomy
Max Planck Institute for Extraterrestrial Physics
Max Planck Institute for Astronomy
JOHNS HOPKINS UNIVERSITY
Department of Physics and Astronomy
Harvard-Smithsonian Center for Astrophysics
Queen's University, Belfast
University of Edinburgh
Durham University
Institute for Computational Cosmology
National Central University, Taiwan
Las Cumbres Observatory
Global Telescope Network

Pan-STARRS 3π Survey : Characteristics

- *grizy* over 75% of the full sky, ~50 - 100 visits
- stack depths : (*grizy*) = (23.3, 23.2, 23.1, 22.3, 21.4)
- single epoch: (*grizy*) = (22.0, 21.8, 21.5, 20.9, 19.7)
- observing strategy chosen to enable parallaxes

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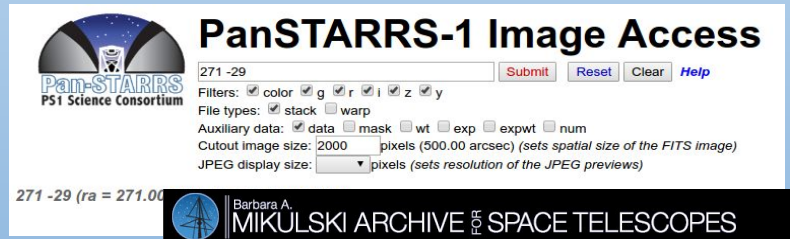
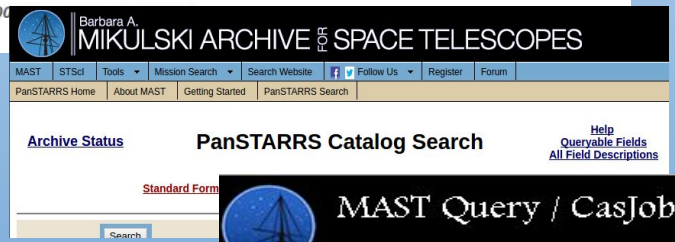
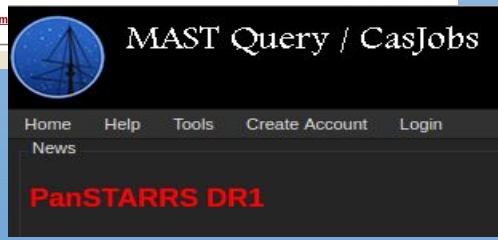
Pan-STARRS 3π Survey : Public Data Release 1

- Opened to the public : 2016 Dec 19 : `panstarrs.stsci.edu`
- Served from Space Telescope Science Institute
  - Mikulski Archive for Space Telescopes
- Contents: stack images, stack measurements, average objects
- ~3 Billion objects
- Query Statistics:
  - Image Extractions
    - 23TB, 8.5M images
  - VO Cone Search
    - 6,430,066 queries, 2,205,935,739 objects
  - CasJobs
    - 3,860,407 queries, 12,108,956,415 rows

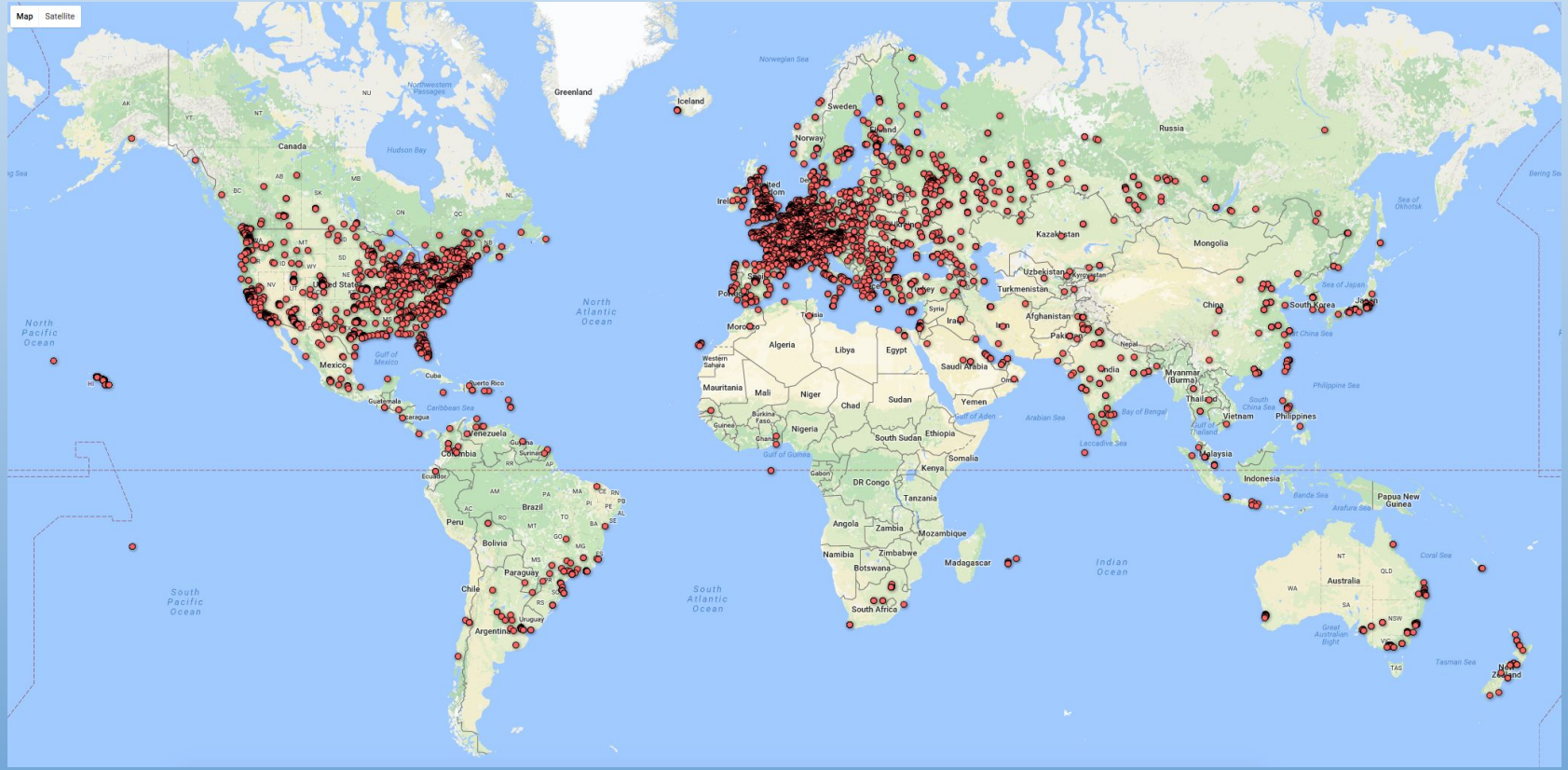






Pan-STARRS 3π Survey : Public Data Release 1

Geographical Distribution of PS1 DR1 Queries (>10.000 unique IPs)



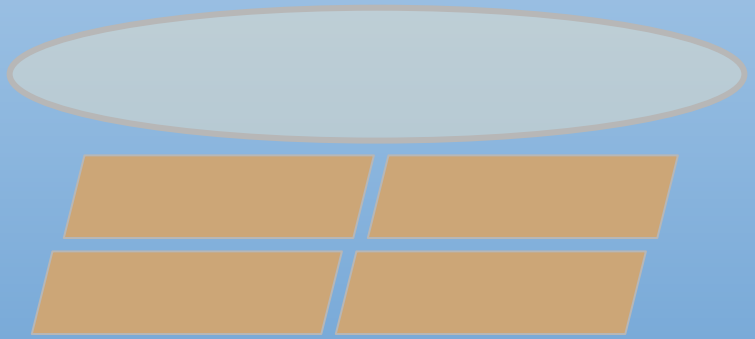
Astrometry Calibration : Systematics and other effects

Pan-STARRS Astrometry Calibration steps:

- initial calibration of exposures (wrt reference catalog)
- ingest measurements into database
- systematic corrections in database
- relative calibration in database (chip parameters only)
- external reference (Gaia or 2MASS) provides constraint

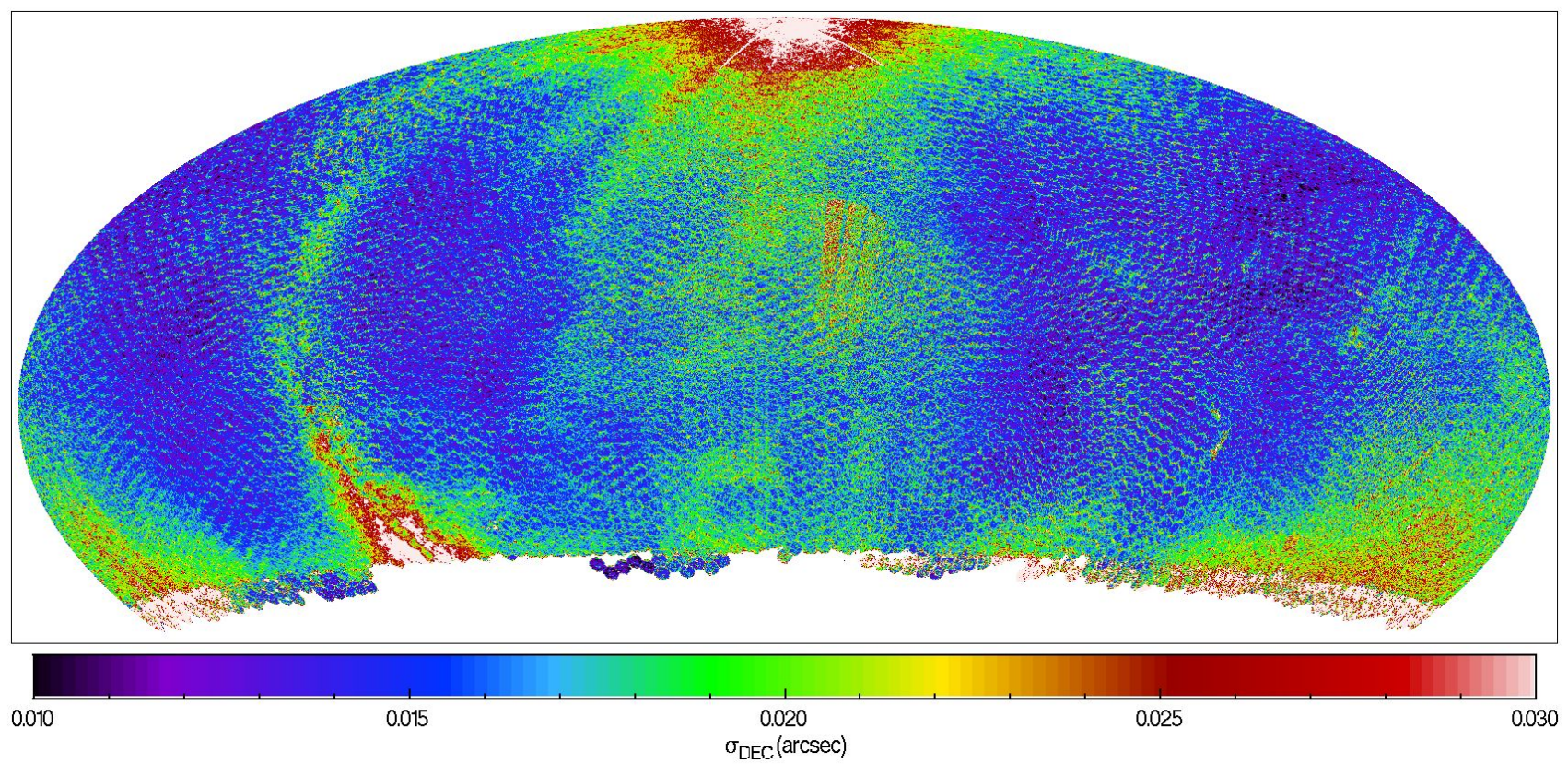
Systematic Corrections:

- Differential Chromatic Refraction
- “Koppenhoefer Effect”
- Effect of Optics
- Cell Biases
- Effect of the Atmosphere



Internal Astrometric Residuals

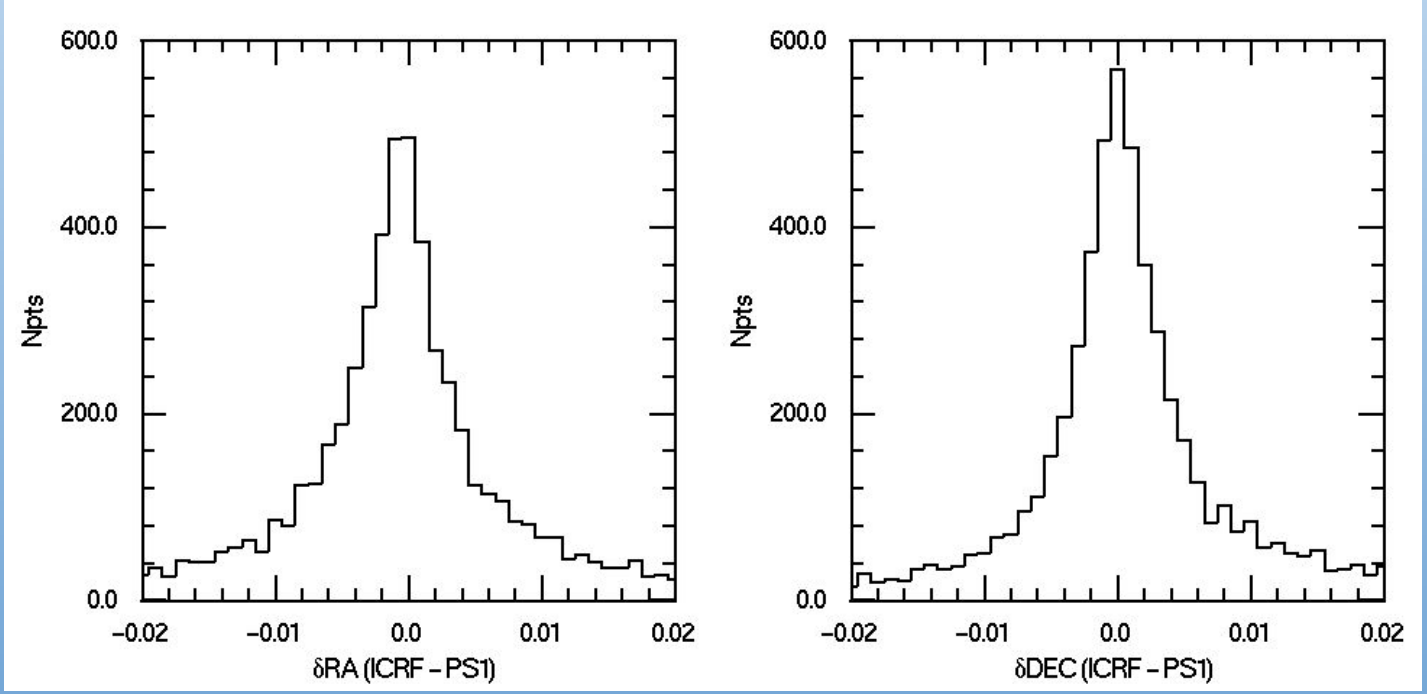
- Scatter of 10 - 20 mas per epoch



Pan-STARS vs ICRF QSOs

PV3 PS1 vs ICRF QSOs (RFC 2014c, L. Petrov):

- average difference : (α,δ) = (-0.7, 0.2) milliarcseconds
- Gaussian fit σ : (α,δ) = (5.6, 4.9) milliarcseconds

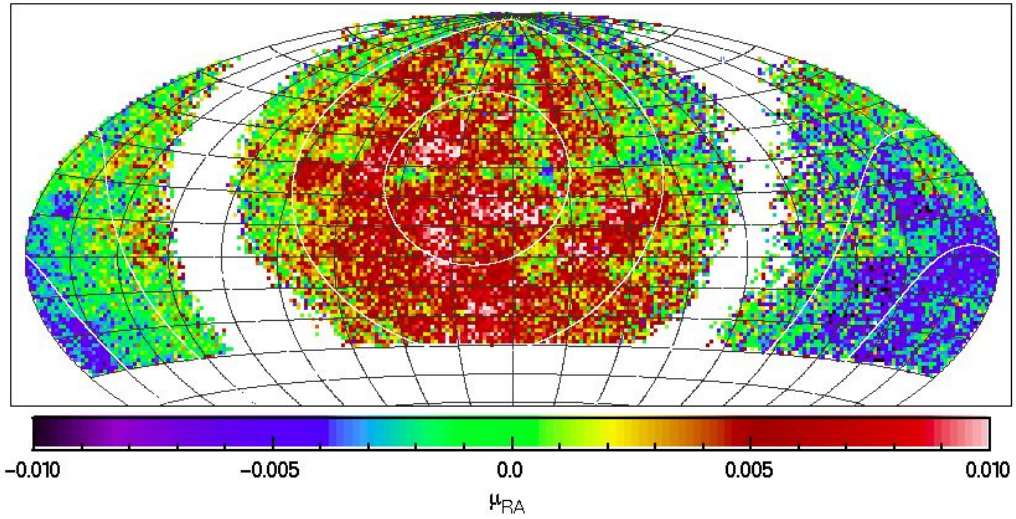


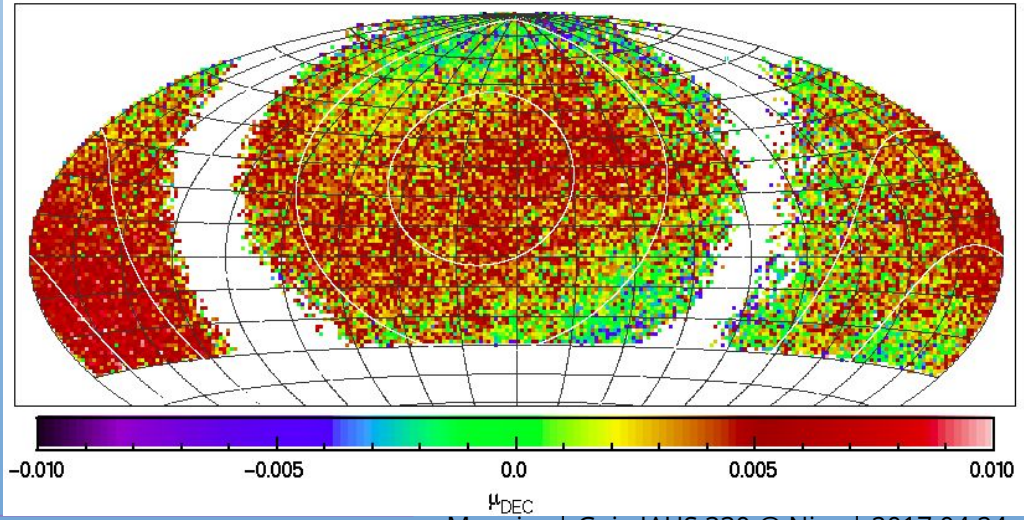
QSO tests: PV2

Average Proper Motions of color-selected QSOs from PS1 (Hernitcshek et al 2015)

PV2 shows large systematic trends

Elena Schillbach & Siegfried Roesser showed this comes from the motion of the reference stars.

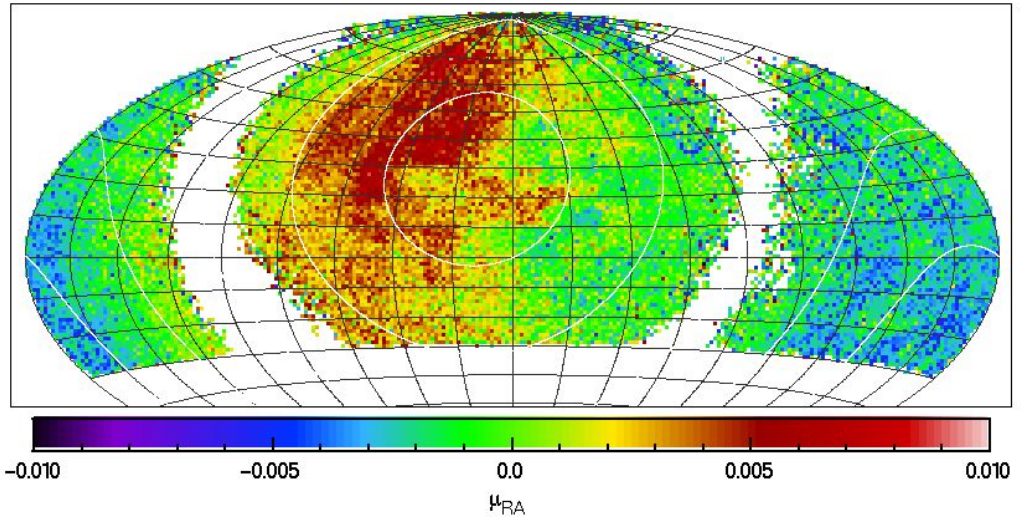


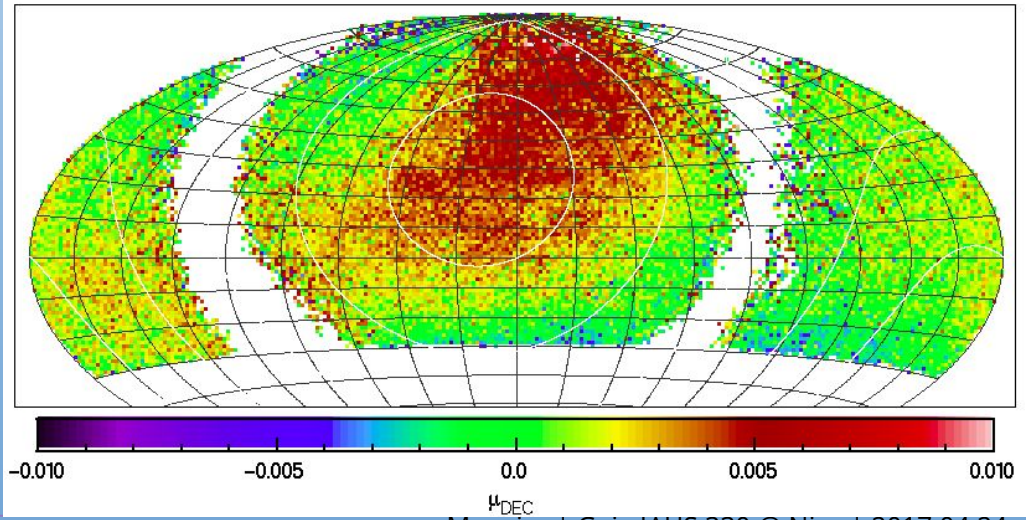


QSO tests: PV3.3

Correction for Galactic Rotation and Solar Motion:

- Use distances calculated by Greg Green & Eddie Schlafly for the dust analysis.
- Predict proper motion based on distance & model.
- move Gaia references to image epoch.



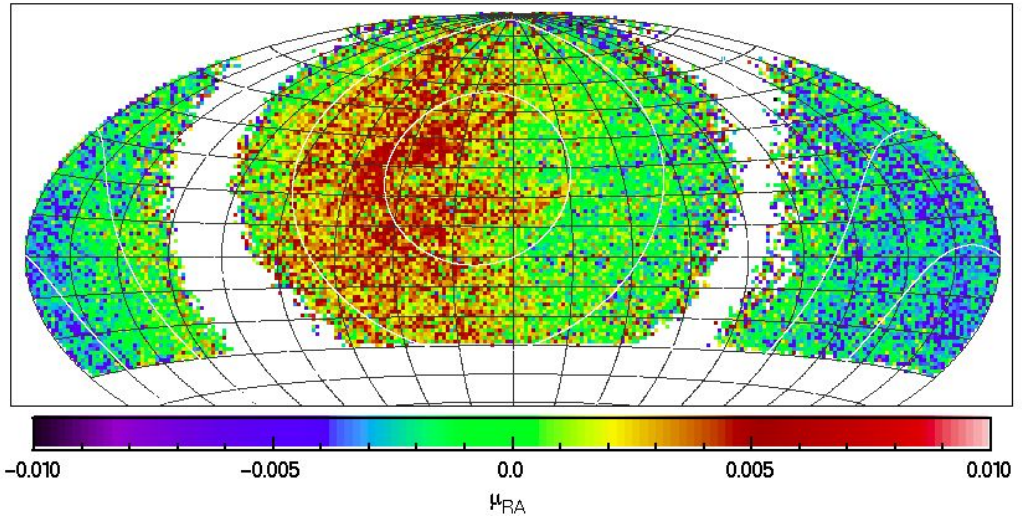


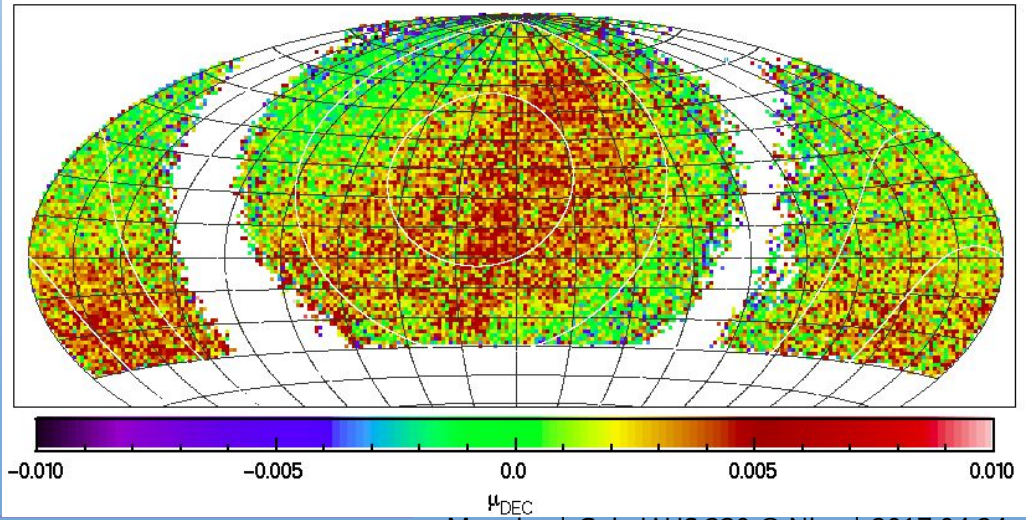
QSO tests: PV3.1

PV3.1 used 2MASS as a dynamic reference.

Result is similar or better than PV3.3.

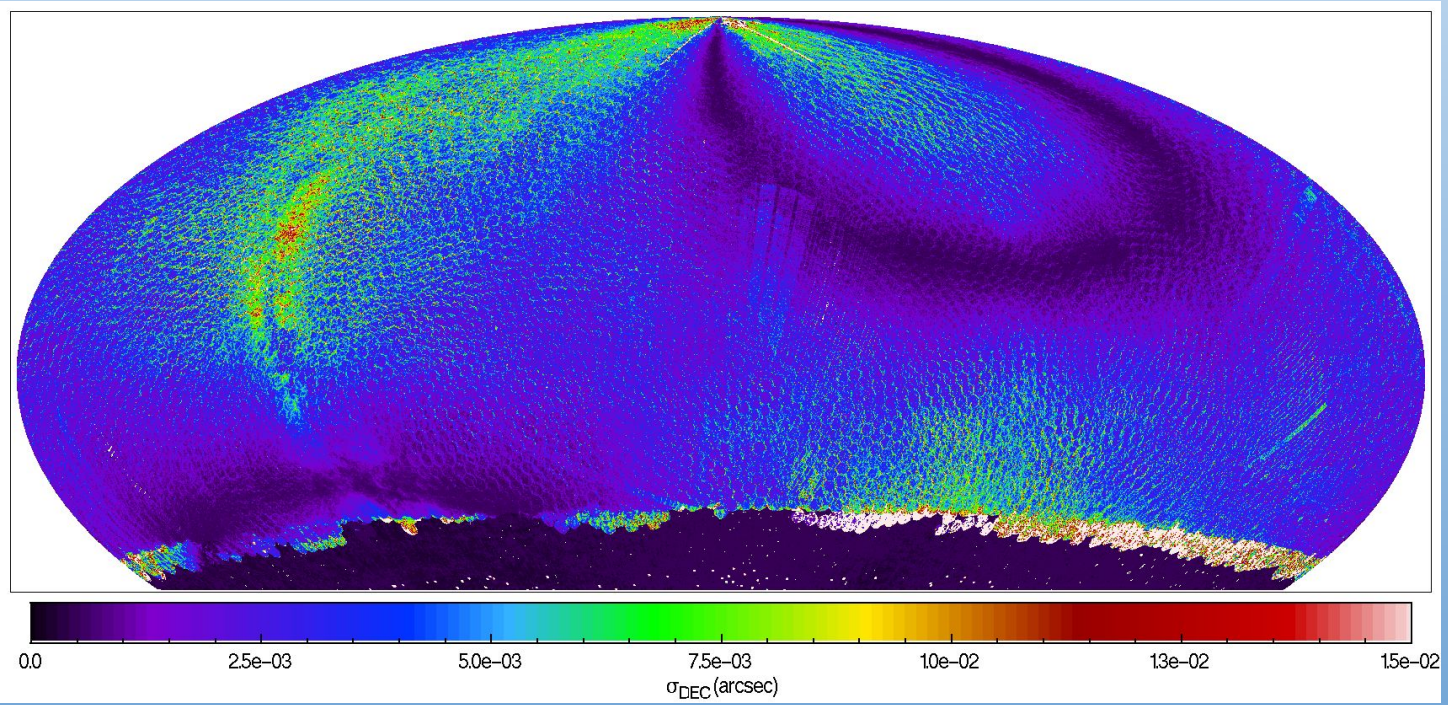
Longer baseline?





Pan-STARRS - Gaia : Astrometry comparison

- Average PS1 position vs Gaia position (at common epoch)
- Typical scatter is ~3 mas
- **Low scatter regions not understood**



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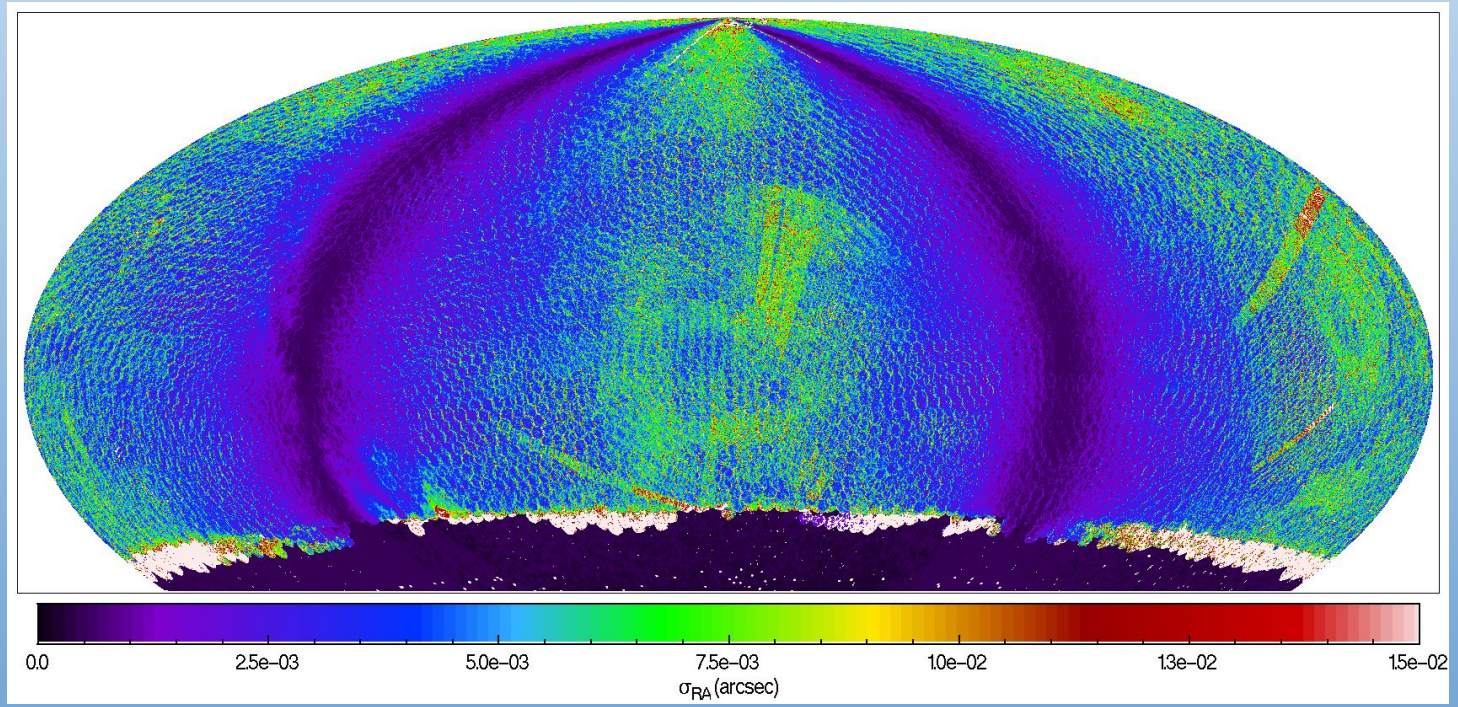
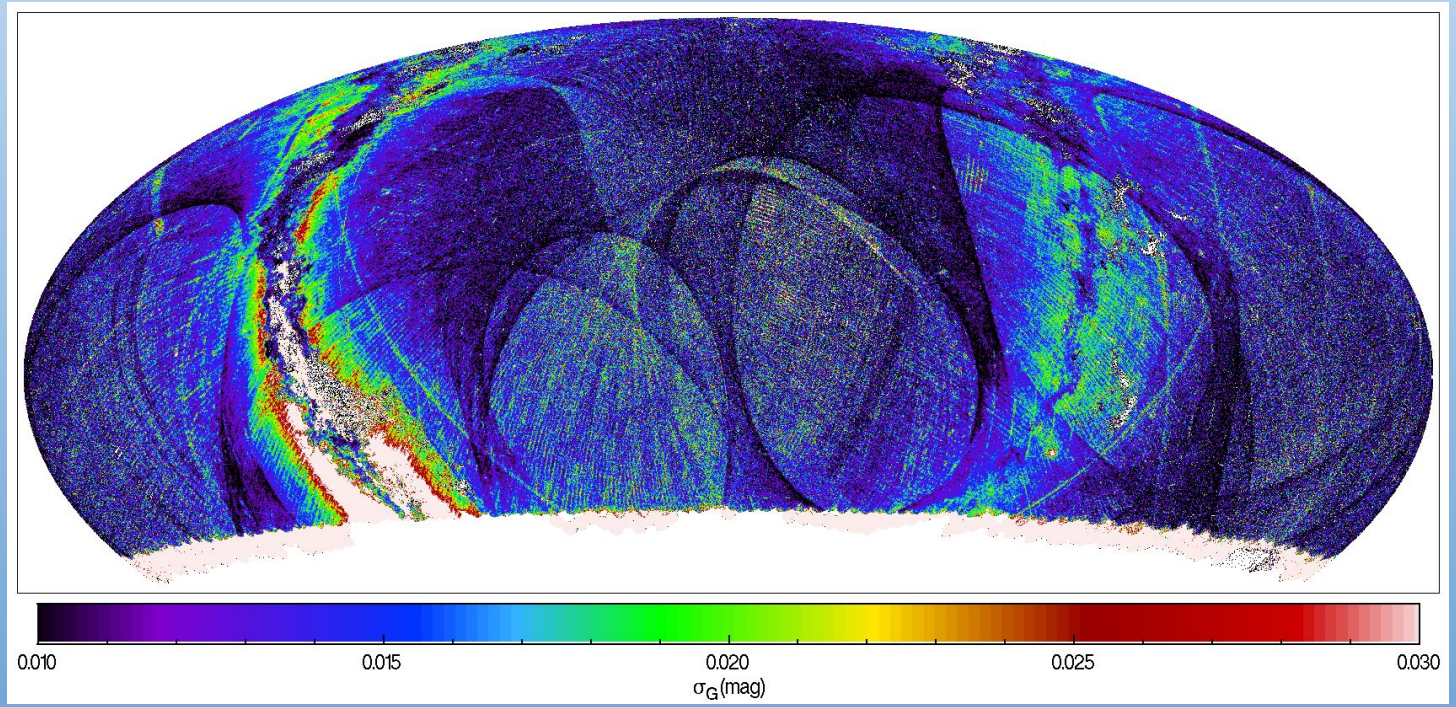


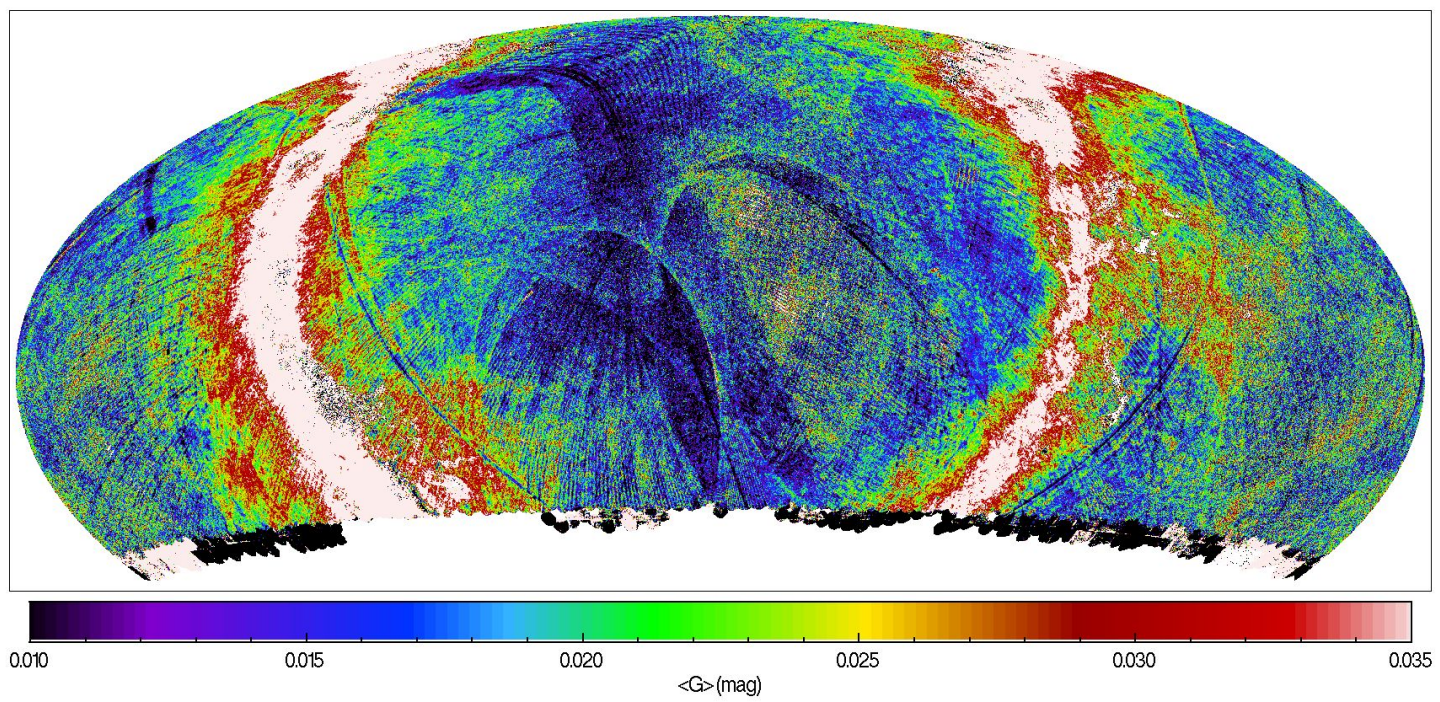
Pan-STARRS - Gaia : Photometry Comparison

- Generate a synthetic G-band from PS1 g,r,i
- calculate $\delta G = G_{Gaia} - G_{PS1}$
- Standard Deviation of δG vs position on the sky



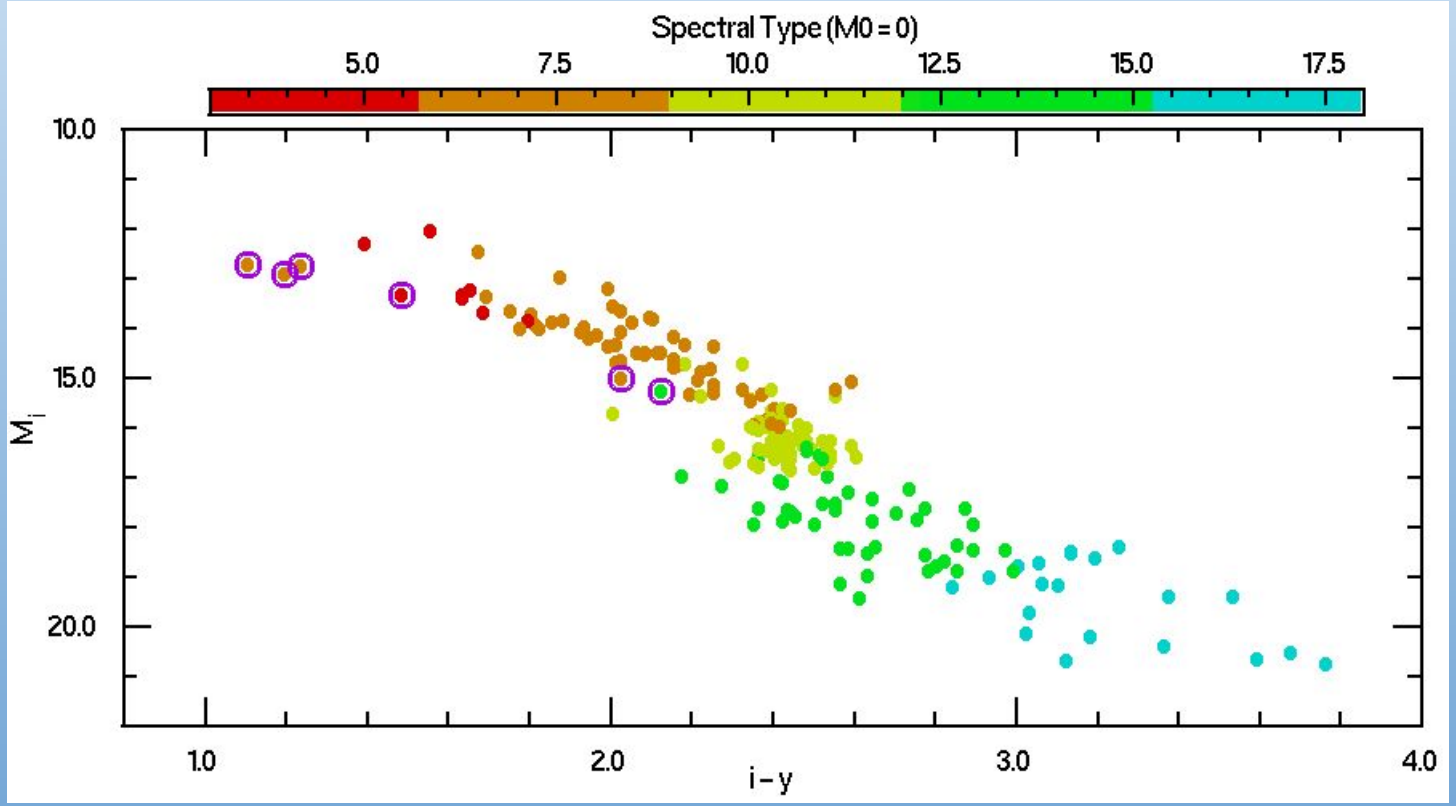
Pan-STARRS - Gaia : Photometry Comparison

- Generate a synthetic G-band from PS1 g,r,i
- calculate $\delta G = G_{Gaia} - G_{PS1}$
- Average of δG vs position on the sky



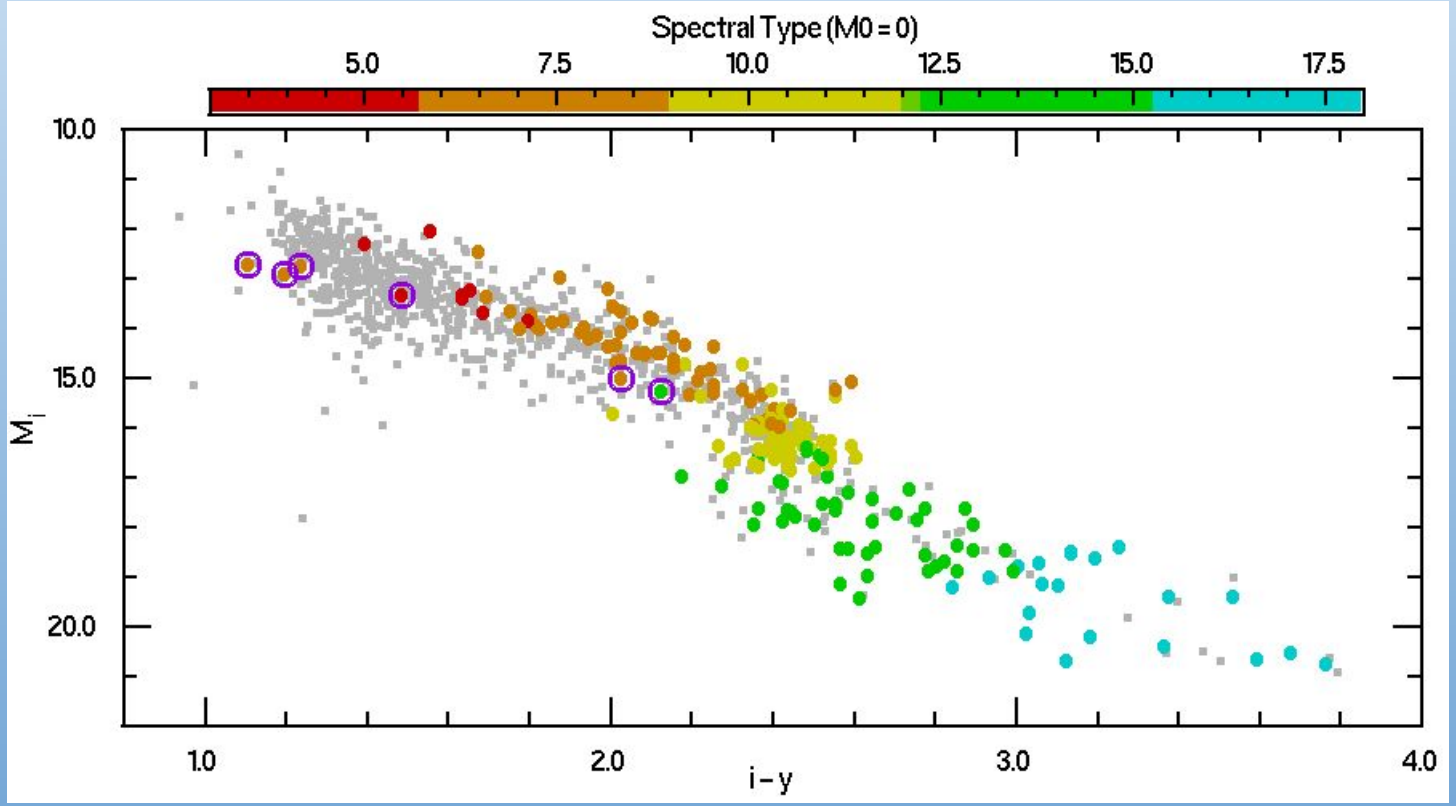
Using PS1 Parallaxes : Ultra-cool dwarfs

Published parallaxes for Ultra-cool dwarfs



Using PS1 Parallaxes : Ultra-cool dwarfs

Pan-STARRS adds many parallaxes (parallax errors down to 2.5 mas)



Summary

- Pan-STARRS astrometric calibration using Gaia generally OK
  - parallax errors as low as 2.5 mas
  - why are some special regions extra low scatter?
- PS1 - Gaia photometry shows some systematic structures
  - some from Gaia scans
  - some from PS1
  - the Galactic plane
- PS1 continues to mine the ultra-cool dwarfs

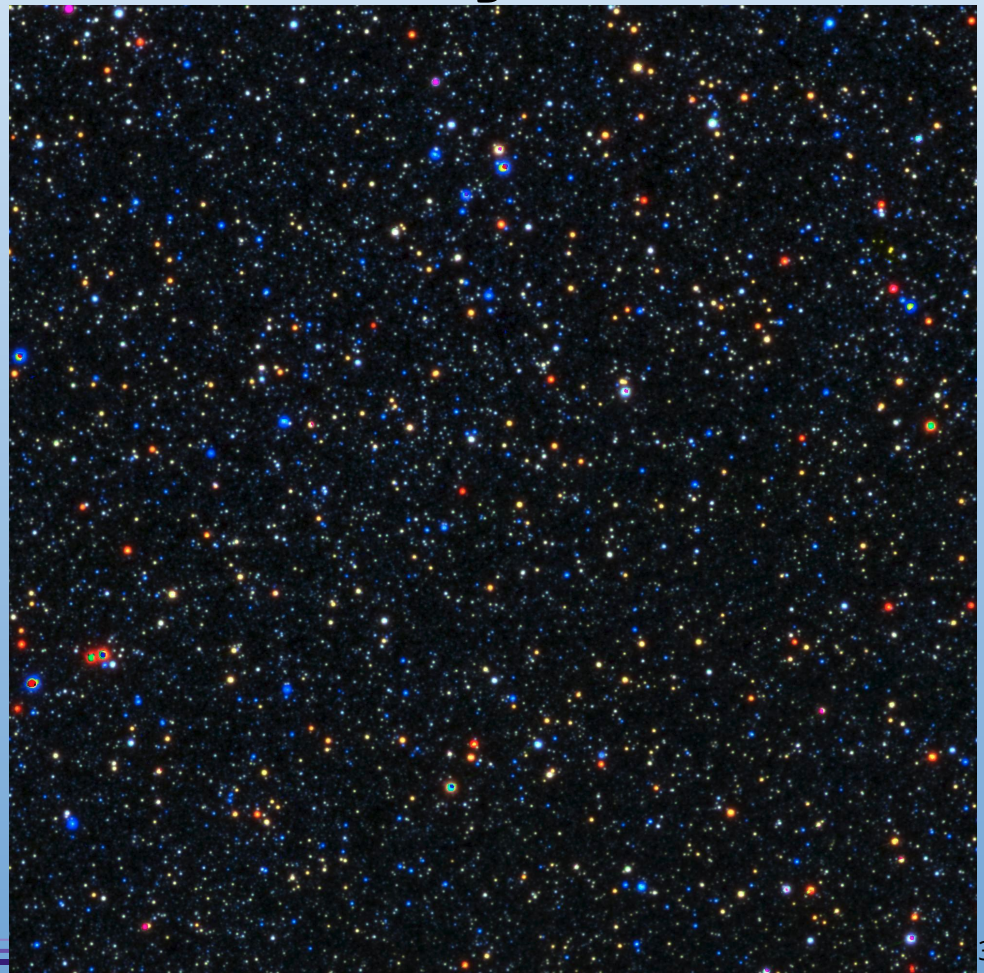
The Future:

- DR2 ~ Fall 2017
- PS2 ~ back online Summer 2017, full-scale ops ~ Winter 2017

Extra Slides Follow

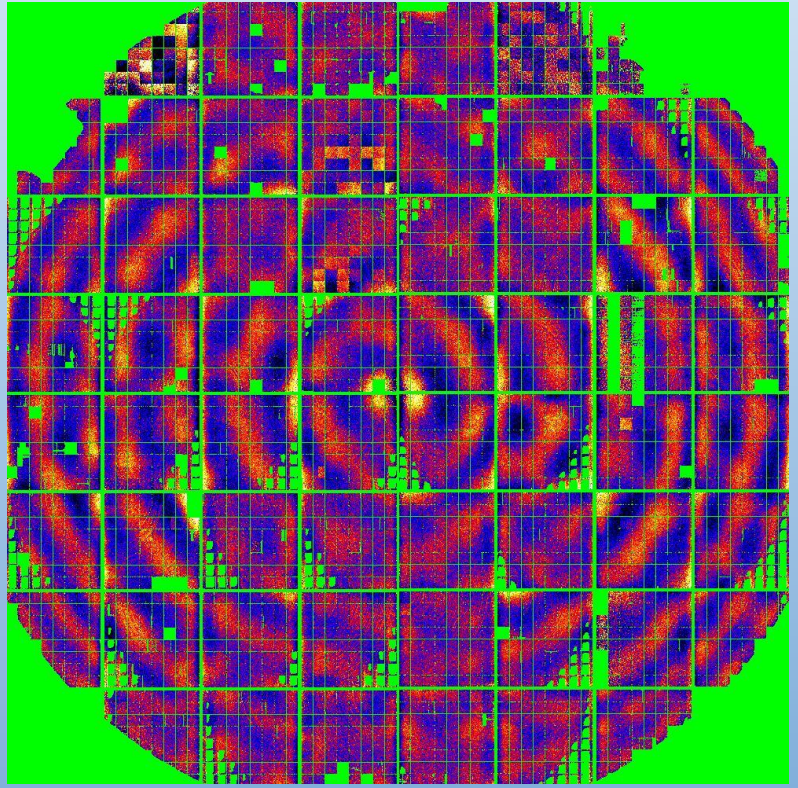
Image Access Example : near the bulge

Postage Stamp Cutout Server allows user to select FITS or JPEG images by coordinate or name



Astrometric Systematics

- mean residuals as a function of camera position in 20 x 20 pixel bins
- large-scale structure similar to focal-plane deviations
- Some cells have small offsets



Astrometric calibration is limited by stellar density

- PSF modeling and astrometric correction need references
- Limit of spatial sampling is stellar density
  - 1000 deg^{-2} -> ~6 arcmin
  - 10,000 deg^{-2} -> ~2 arcmin