ZTF Science Data System: Progress & Plans

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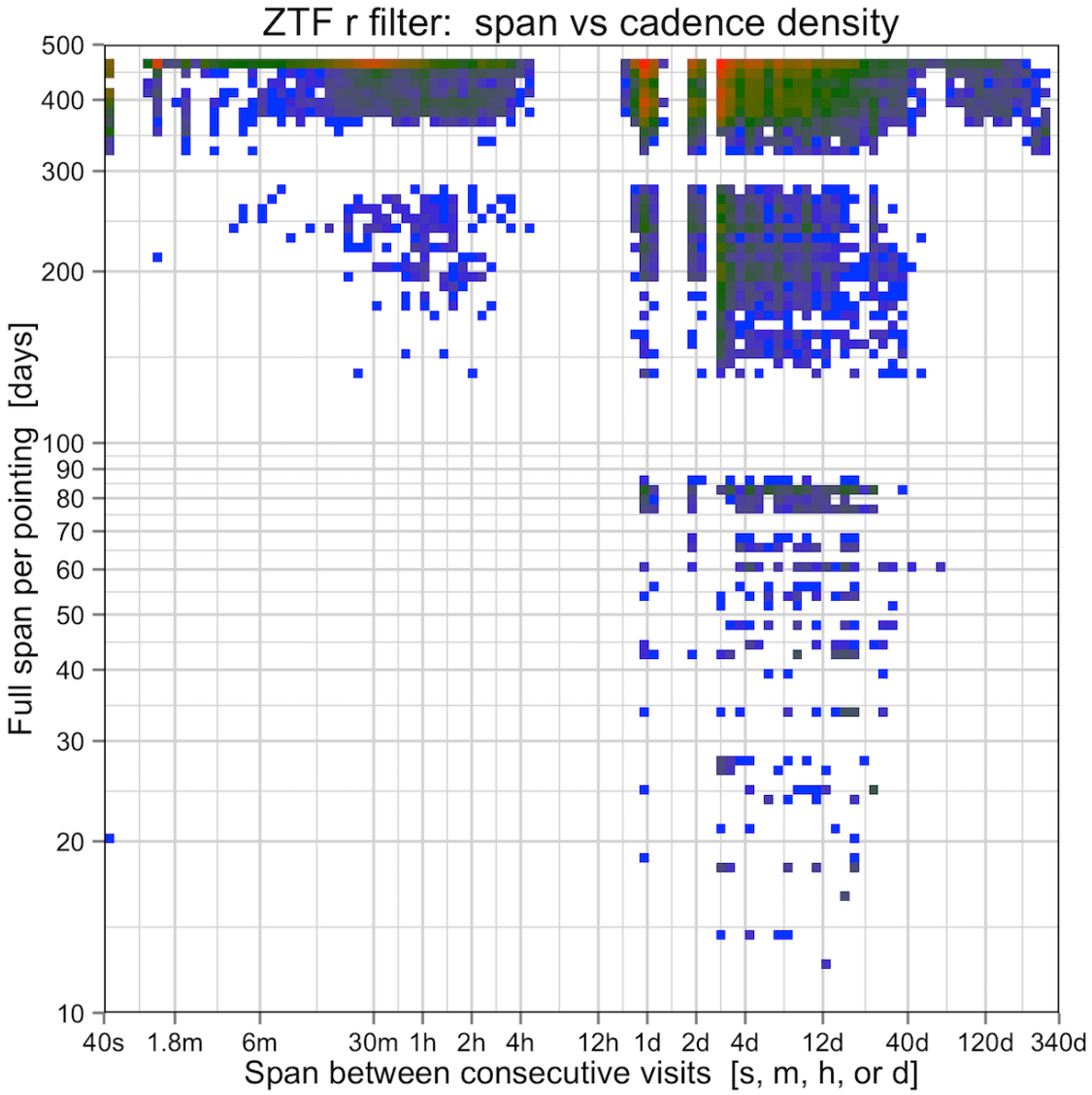
Outline

- Recent updates
- Reference image status
- Third Public Data Release
- Photometric corrections (in context of *lightcurve matchfiles*)
- Phase I tasks in progress and planned
- Phase II thoughts

Recent Updates

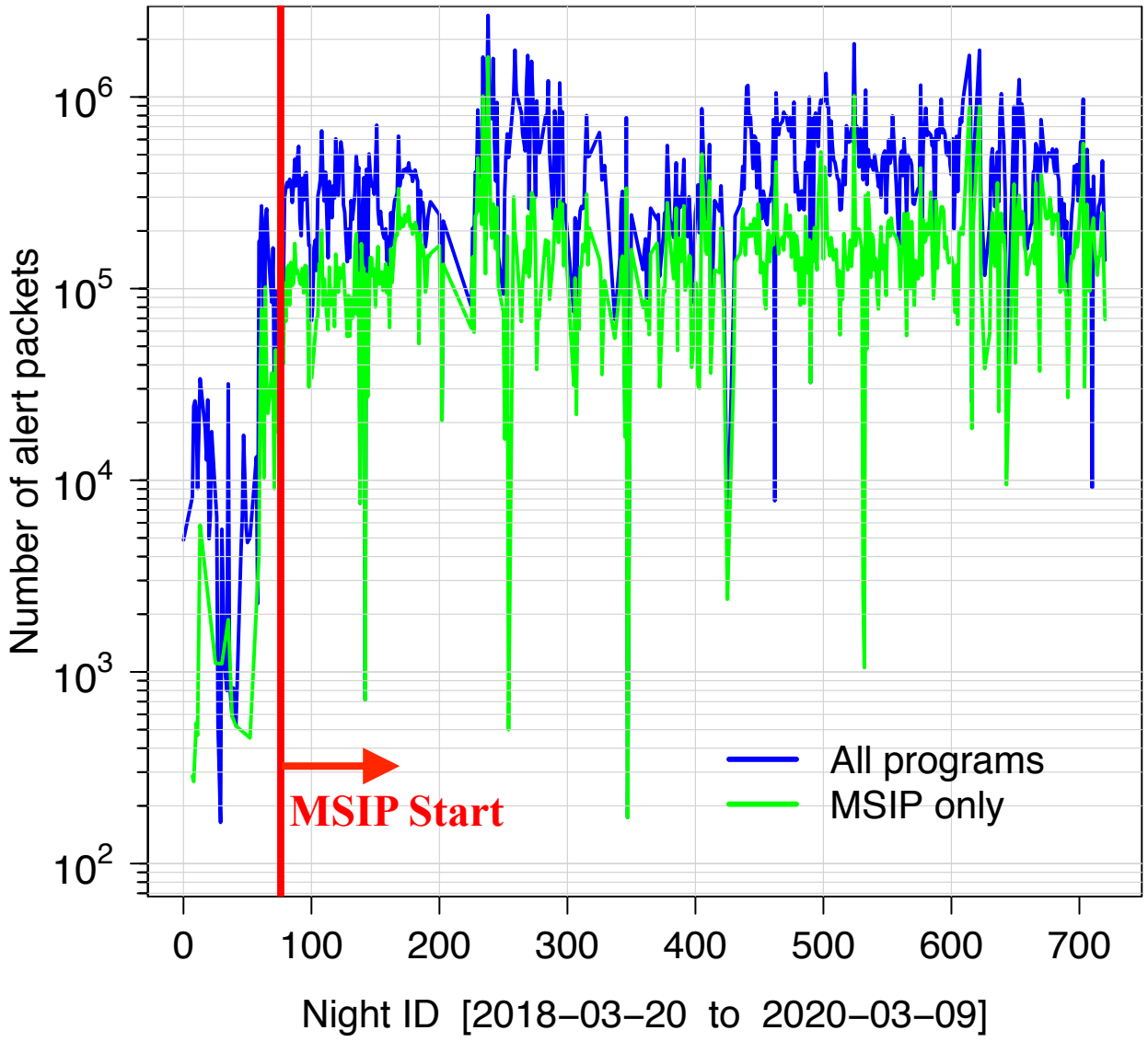
- Generation of better quality and deeper reference images in *g, r, i* to support ToOs only.
  - Included "spatial flatness" criterion when selecting epochal science images for reference image generation.
- All archived *i*-band science data were fringe-corrected and new reference images generated therefrom (see above).
- Second public data release occurred on Dec 11, 2019.
- Made over-scan correction more robust (to mitigate bad fits from saturated stars near over-scan edges).
- Masking of charge-spillage ghost artifacts for data acquired <= 2019-10-23.
- Updates to accommodate new linearity calibration, saturation thresholds, gains, and larger dynamic range.
- Optimization and tailoring of Moving Object Detection (ZMODE) for twilight survey.
- Detection of shorter streaks in "fast" moving object pipeline: velocity limit reduced to ~ 3 deg/day.
- Trimming of *matchfile* contents with new metrics (lightcurves from un-differenced photometry) to support DR3.
- Provide image subtraction statistics from public survey to facilitate efficiency calculations from alert stream.
- Reprocessing and backfilling of subtraction images in archive (in progress).

Second Public Data Release (Dec 2019)



Summary of overall temporal sampling of lightcuves in DR2 (pointing = per 7° × 7° field).

Alert Statistics (Mar 20, 2018 – Mar 9, 2020)



Reference Image Status

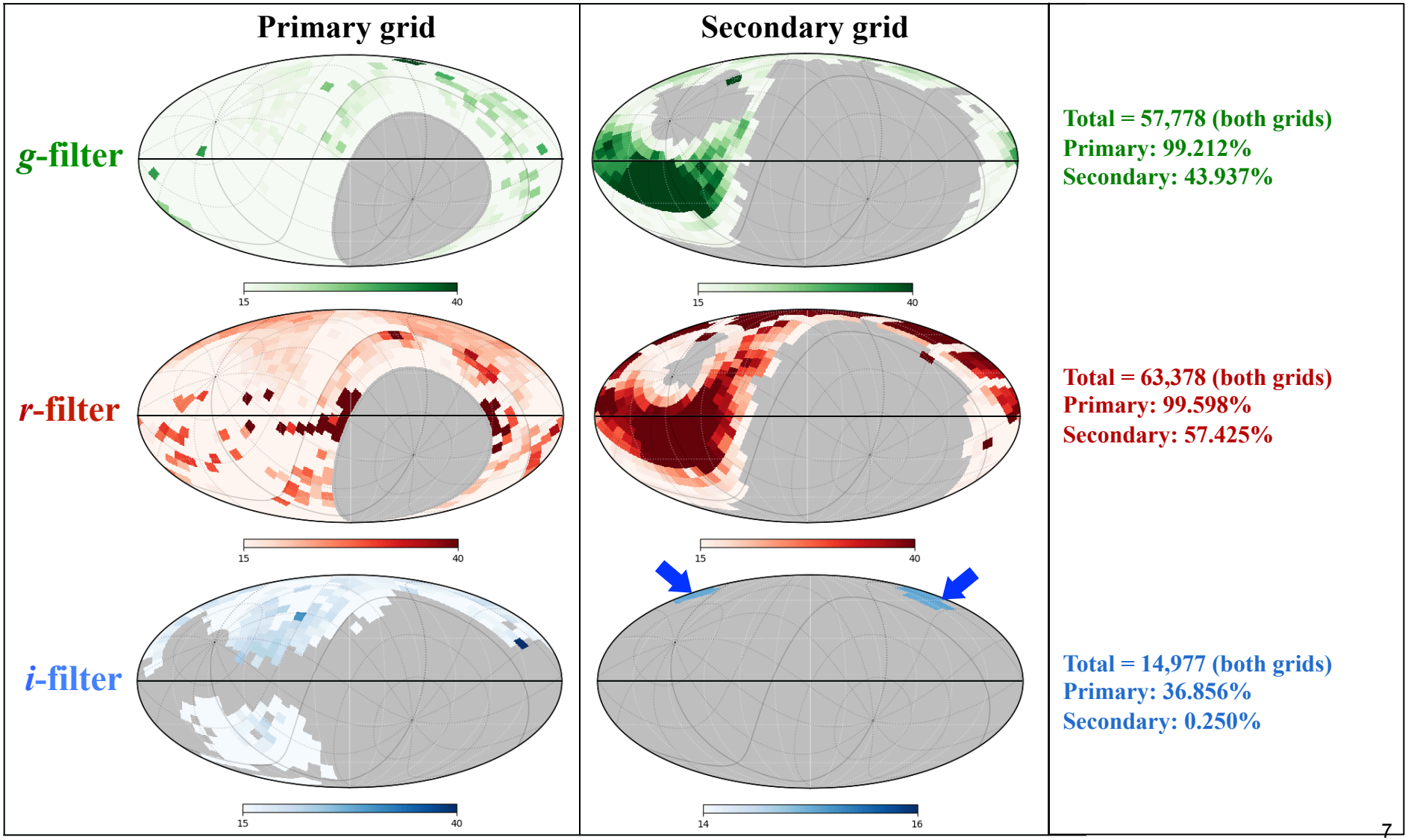
- There was a push early in survey to rapidly cover sky in reference images to enable:
  - Image subtraction → alert production, asteroid detection.
  - Creation of deeper catalogs to provide "seed positions" for generating lightcurves.

- Procedure for generating **archived** (survey-ready) references:
  - Execute reference image "checker" pipeline every morning.
  - Checks which fields / CCD-quadrants / filters are missing references.
  - As soon as N ≥ 15 science images satisfy quality criteria, generate a reference image.
  - Archive and lock-down reference image; never revisit. Max cutoff is 40 input images.

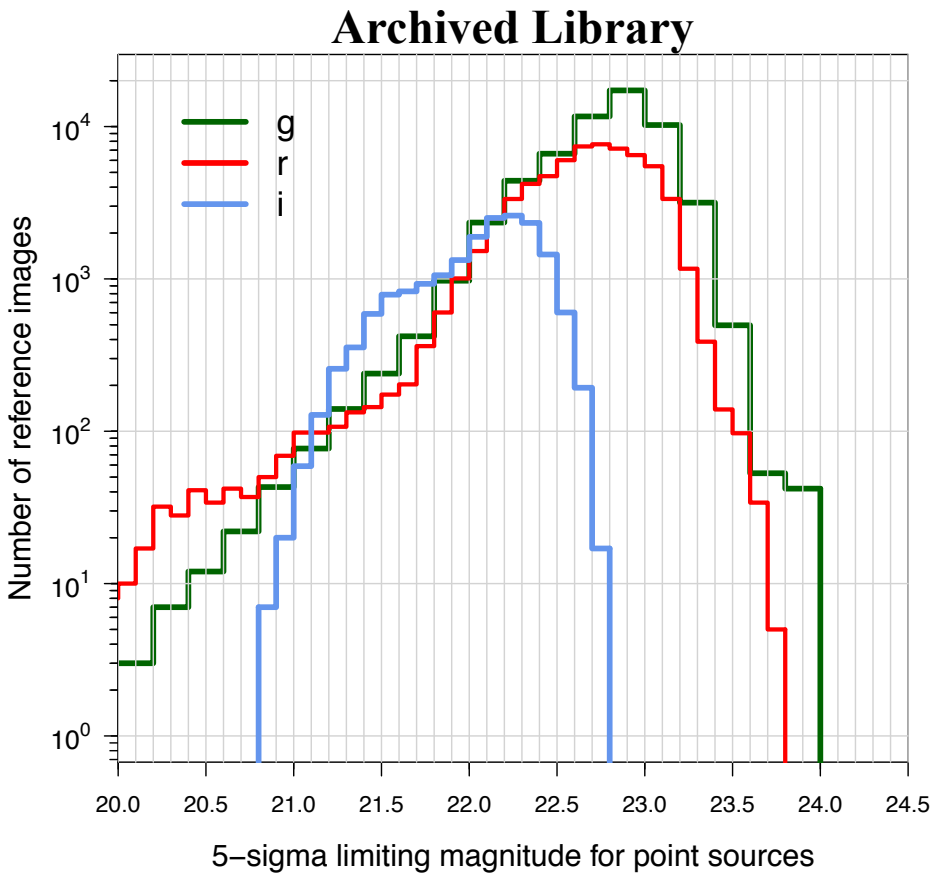
- With a lot more epochal data, we generated a "special" reference image set by being more restrictive on the input image quality criteria, hence improving overall quality and depth.
  - These special references are only queried in production for ToO observations.
  - Alert production, forced-photometry, and source-matching continue to use **archived** references

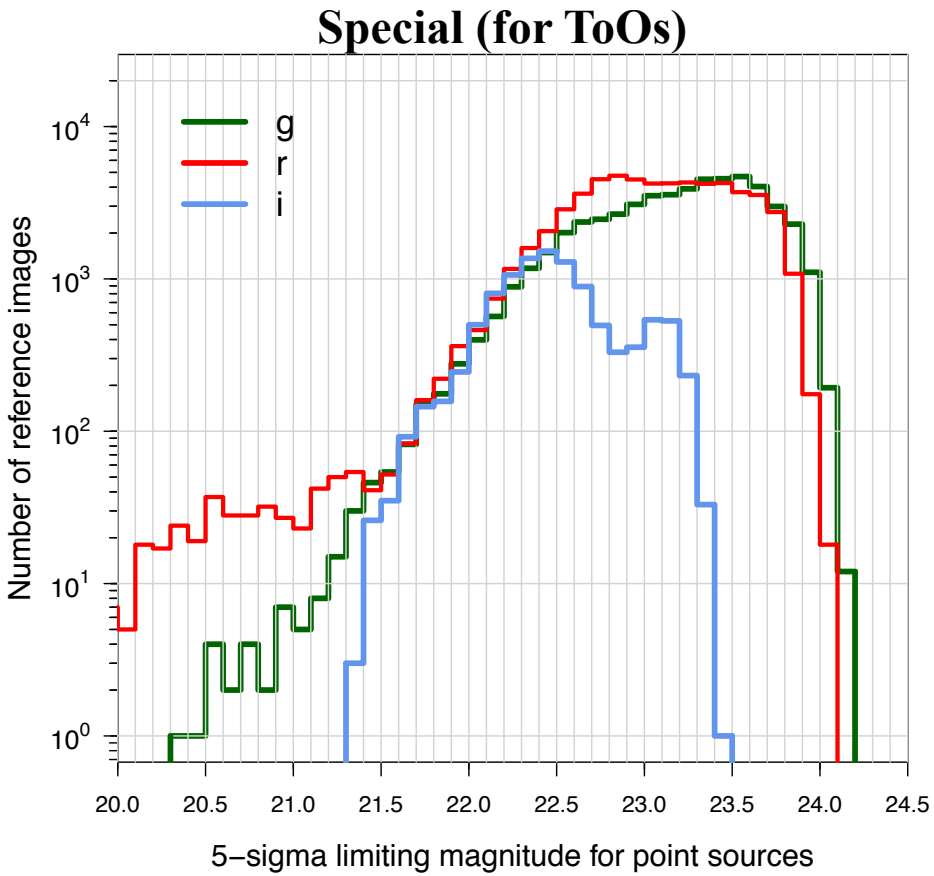
- Median number of input images per reference: ~ 18 (archive) versus ~ 65 (special) across *g, r, i*.

Archived Reference Image Coverage: Mar 9, 2020
(l, b = 0, 0 centered)



Reference Image Depths
Archived versus Special

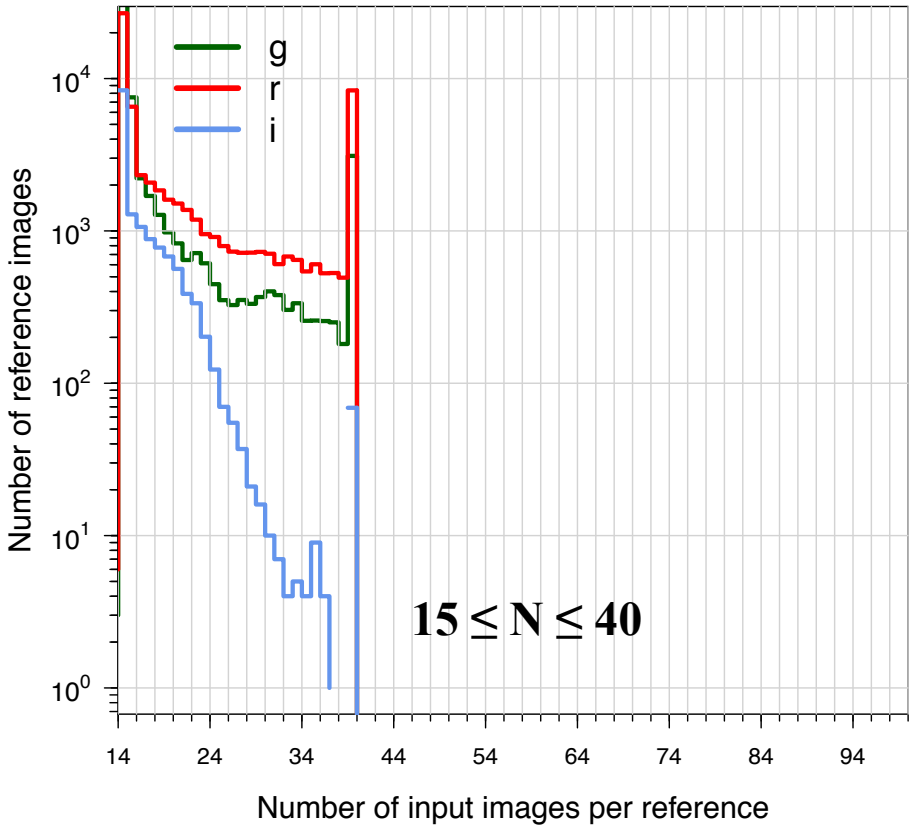




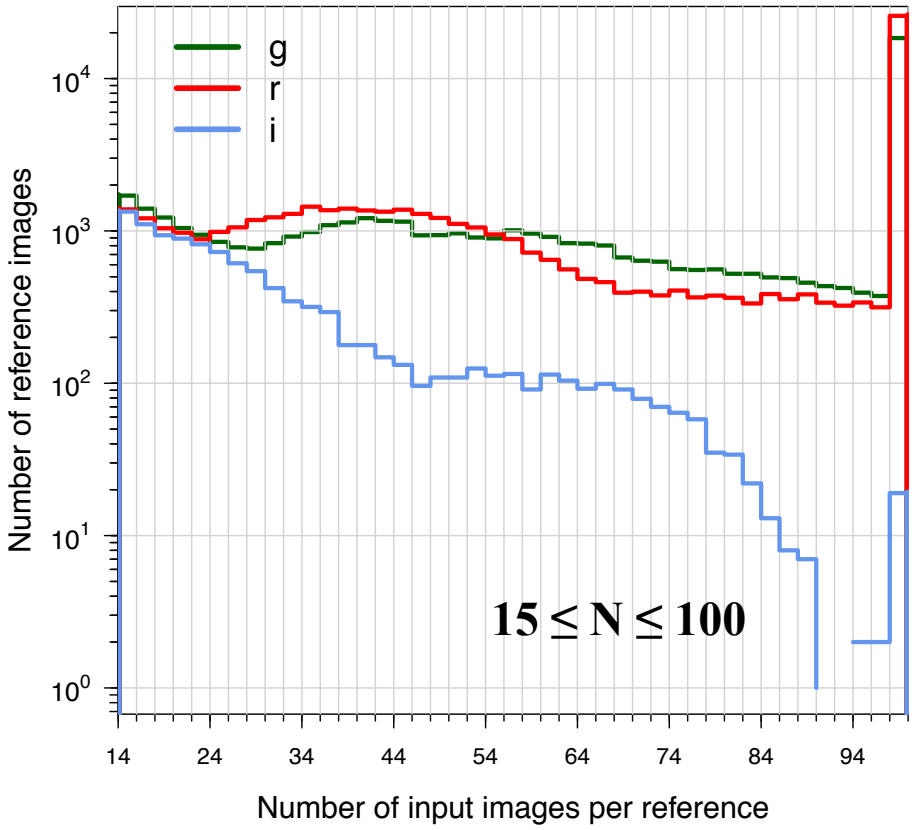
Fields with ultra-high source confusion:
noise & mag-limit estimators break down

Number of Image Inputs for References
Archived versus Special

Archived Library



Special (for ToOs)



Third Public Data Release (June 24, 2020)

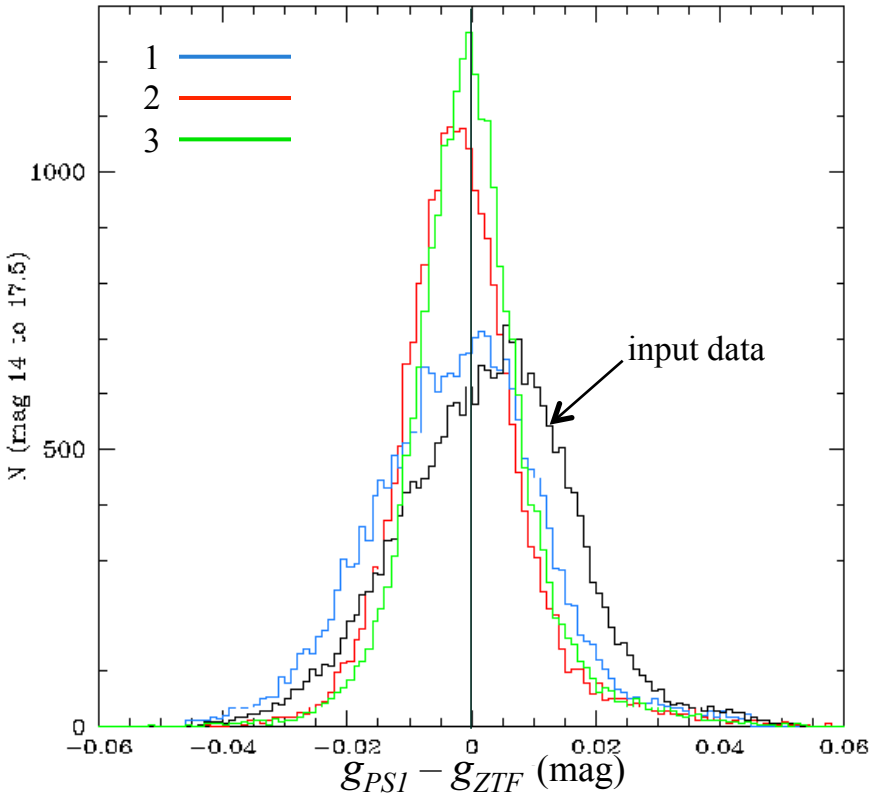
- **Content (appended to DR1 + DR2):**
  - program ID 1 (MSIP) epochs: **Jul 1 – Dec 31, 2019 (*g* and *r*)**
  - program IDs 2 & 3 (partnership and Caltech-time) epochs: **Jul 1 – Dec 31, 2018 (*g*, *r*, and *i*)**

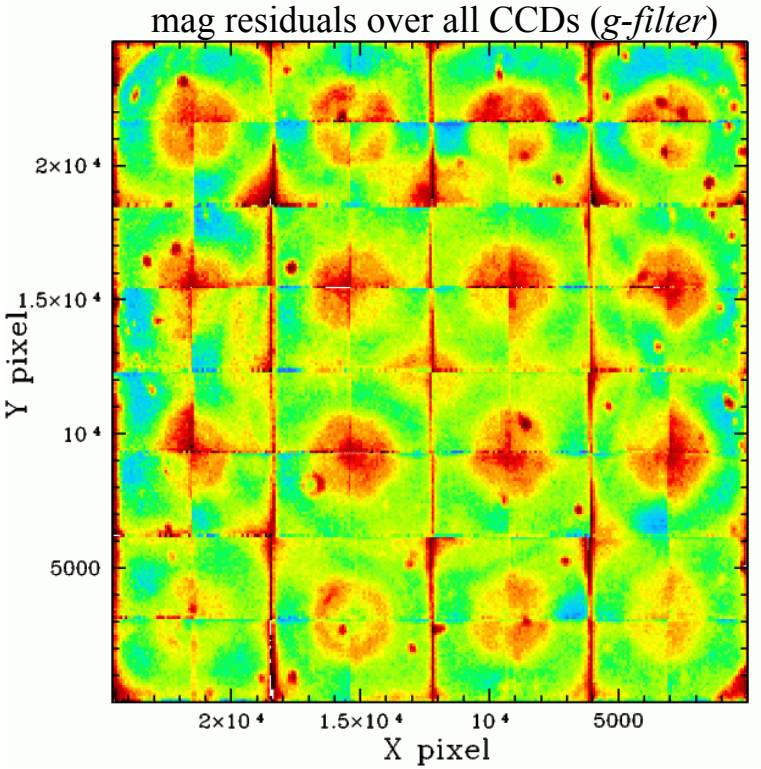
- **Release products (same as previous releases):**
  - raw CCD image files & calibration image files.
  - epochal instrumentally calibrated science images, file-based catalogs, and ancillary products
  - reference images, accompanying file-based catalogs, and ancillary products
  - object source database (reference-image drawn) to facilitate lightcurve queries
  - lightcurves derived from matched epochal PSF-fit photometry **– including tarballs for bulk download.**

- **Features:**
  - removal of redundant and useless columns from lightcurve DB. Addition of two more quality metrics.
  - refinements to *catflags* (quality flags): inclusion of more masked-pixel information (charge spillage).
  - all archived i-band images are now fringe-corrected; lightcurve photometry used de-fringed images.
  - inclusion of photometric corrections **(next slide).**

Post-corrections to epochal PSF-fit photometry

- Systematics characterized by Andrew Drake (*http://nesssi.cacr.caltech.edu/ZTF/Web/Calib.html*):
  1. magnitude-dependent biases relative to PS1: <~ 1.3% for *g*, *r* < 17.5.
  2. biases from position-dependent responsivity (flatfield) residuals: ± 3% (max at edges)
  3. global field-dependent biases (sky-location dependent): <~ 1.0%
- **Net result:** RMS in residuals relative to PS1 now typically <~ 8 millimag.





Tasks: in progress & remainder of Phase I

- Preparations for Third Public Data Release.
- Continued backfilling of subtraction images in archive:
  - Currently *g* and *r* bands (~ 40% done)
  - Next, will regenerate *i*-band subtractions using new (fringe-corrected) images with new references therefrom.
- Continued monitoring of reference image quality and replacement of "special" deeper references for use on ToOs.
- Continued generation of lightcurve tarballs for TESS sector observations (monthly).
- Update 'static' bad pixel masks following further camera waveform updates.
- Support QA team in improving photometric accuracy: testing and bulk reprocessing using improved methodologies.
- Phase II planning.

- Moving-object (SSO) pipeline related updates:
  - move the ZSTREAK marshal (including DeepStreaks ML execution) to an IPAC server.
  - more efficient tracking and linking of streaks across and within nights.
  - update naming of SSOs from pipeline to conform to MPC's new extended packed-naming format.
  - quasi-realtime computation of efficiency for streaking objects.

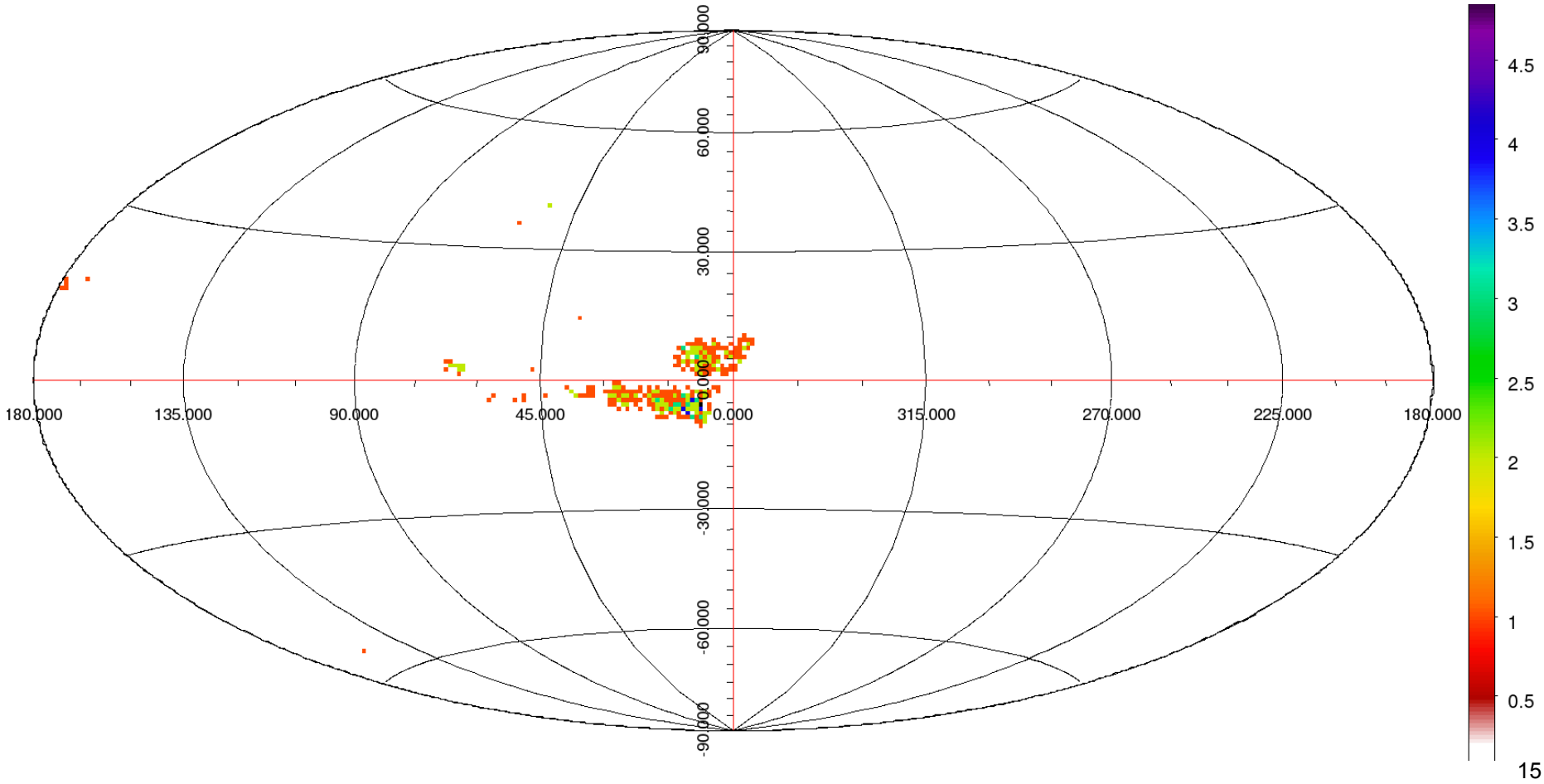
ZTF Phase II thoughts (priorities TBD)

- More frequent public data releases (monthly to bimonthly timescales).
- Updates to instrumental and photometric calibration process to achieve more accurate photometry.
- Inclusion of forced photometry measurements in alert packet histories going back N nights.
- More portable datastore for distributing (non-difference) lightcurves; optimized for cloud computing.
- SEDM / P60 archive upgrade and improvements to user-access portal.
- Allow public access to forced photometry service.

Back up slides

Where are those "low-depth" reference images located?

- Shown are CCD-quadrant "footprints" mapped into galactic coordinate system.
- Only those with limiting magnitudes < 21.2 mag are shown (388 references).
- Colors refer to overlaps which include effects from resampling onto a coarser grid.



Reminder on documentation

- **ZSDS Explanatory Supplement** (linked from ZTF public website under):
  https://www.ztf.caltech.edu/page/technical#science-data-system

- **Science Data System paper**:
  https://iopscience.iop.org/article/10.1088/1538-3873/aae8ac

- **Archive access and services:**
  https://irsa.ipac.caltech.edu/Missions/ztf.html

- **Public alert archive and usage:**
  https://ztf.uw.edu/alerts/public/

- **First Public Data release:**
  https://www.ztf.caltech.edu/page/dr1

Baseline deliverables / data access portals

1. **Instrumentally calibrated, epochal image products, bit-masks, source catalogs, PSFs, and difference images**
   Archive (IRSA)

2. **Raw image data and image calibration products used in pipelines**
   Archive (IRSA)

3. **Reference images (co-adds) from combining (1):** coverage maps, uncertainty maps, and source catalogs
   Archive (IRSA)

4. **Alert (point-source event) stream** from real-time image-differencing pipeline: packetized with metadata
   Marshal(s); Public Brokers; Archived in IRSA

5. **Products to support real-time Solar System / NEO discovery and characterization:** both streaks and tracks
   ZTF-Depot (internal) and IAU-Minor Planet Center

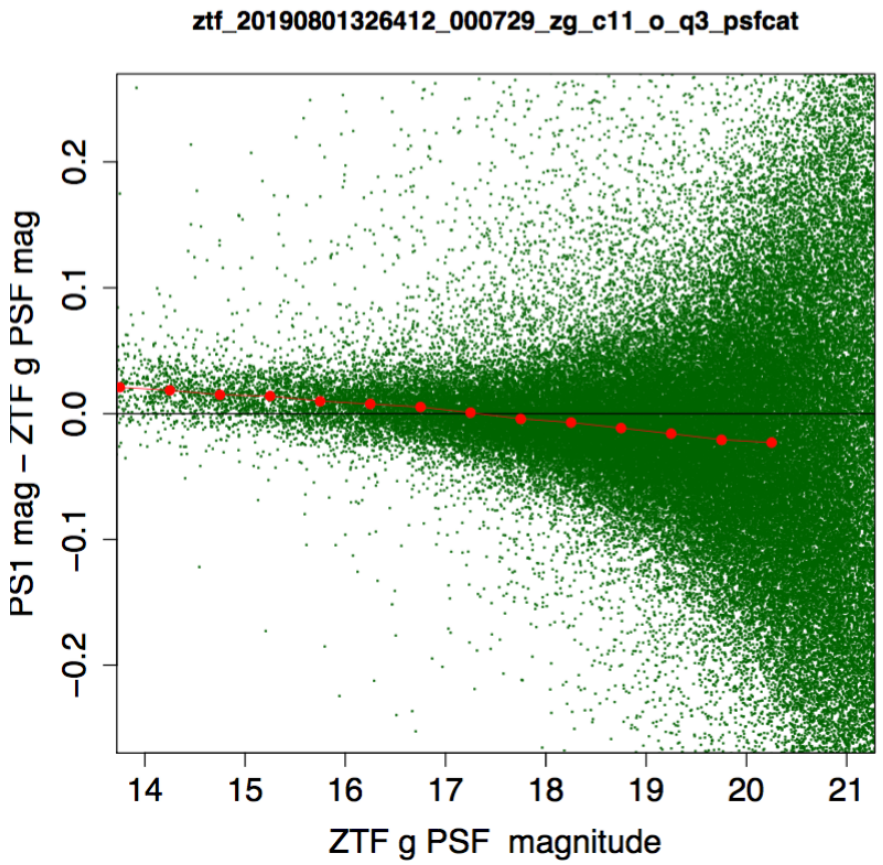
6. **Lightcurves & metrics from matching sources across individual epochs using (1) to beginning of survey**
   Archive (IRSA); ZTF-Depot (raw matchfiles)

7. **Quality assurance metrics, summary statistics, and survey coverage maps:** for performance monitoring
   ZTF-Depot (internal)

8. **Documentation:** cautionary notes, recipes, and tutorials on data-retrieval and analysis
   Explanatory Supplement on ZTF Public Website; PASP paper published in Dec 2018

Corrections to epochal PSF-fit photometry

BEFORE



AFTER