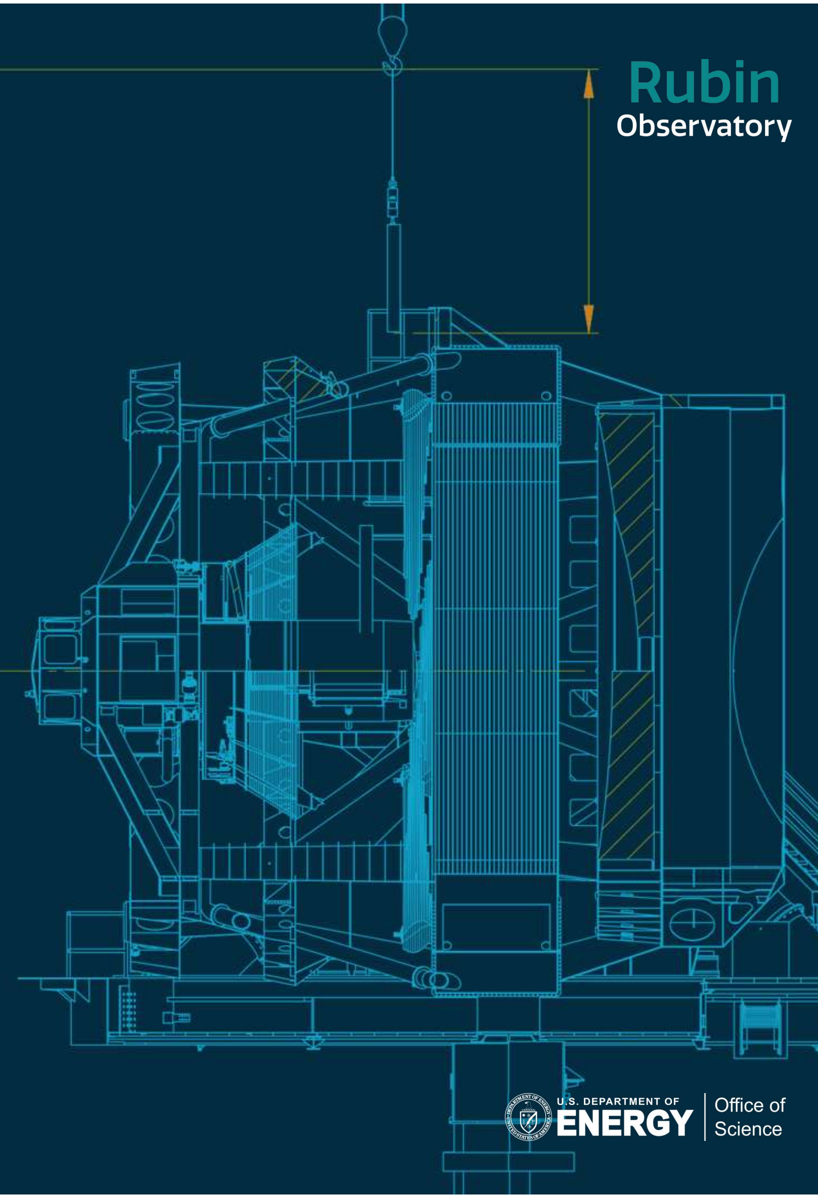
Crowded Field Processing

Colin Slater

Rubin Observatory/University of Washington



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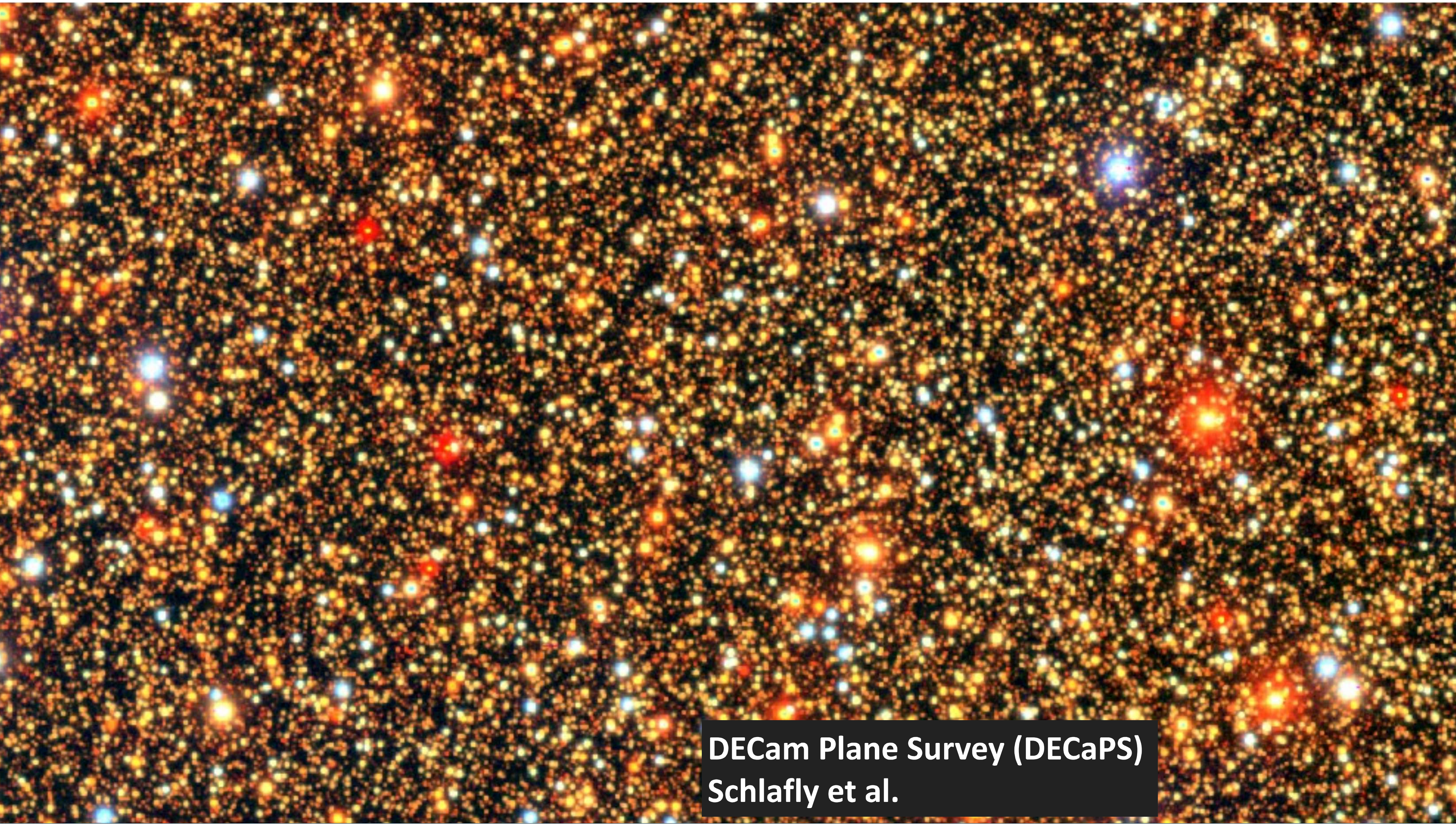
DECam Plane Survey (DECaPS)
Schlafly et al.

Milky Way science is integral to LSST

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- “Mapping the Milky Way” is one of the survey's four science pillars.
- All parts of the MW are important
  - E.g., there’s greater interested today in interactions between the MW disk and the stellar halo; one benefit of the uniform coverage of surveys like PS1 and Gaia. Lots of value in measuring the MW uniformly.
- “Exploring the Transient Sky” is another science pillar
  - Galactic transients occur where the stars are, and stars in the Milky Way are predominantly in the disk. Image differencing is strongly complemented by deep, well-measured direct photometry.

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- We’ve done testing of our current deblender, see DMTN-077.lsst.io
  - The first-order effect is that deblending drops in completeness with increasing source density, as closely-neighboring fail to get detected and passed to the deblender.
  - This affects ~8% of wide-fast-deep area at single-visit depth, 15% at 10-year depth. Affects substantially all of the Galactic plane area.

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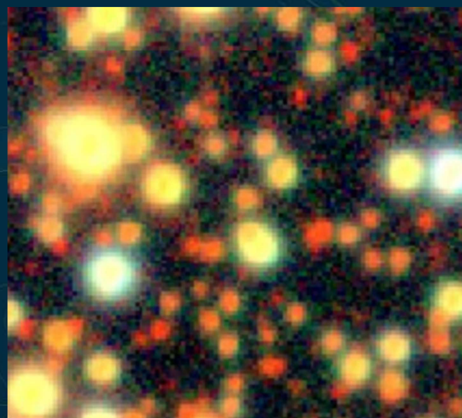

- But crowded fields have very different needs from high-latitude, and might not be well suited to deblender assumptions
- The ideal solution would be one deblender that smoothly transitions to heavily-point-source biased solutions at low Galactic latitude
- That is a serious challenge, and there's already lots of work that needs to be done on the deblender for high latitude cases.
- There are easier, well-known solutions for crowded fields. Risk-reduction.

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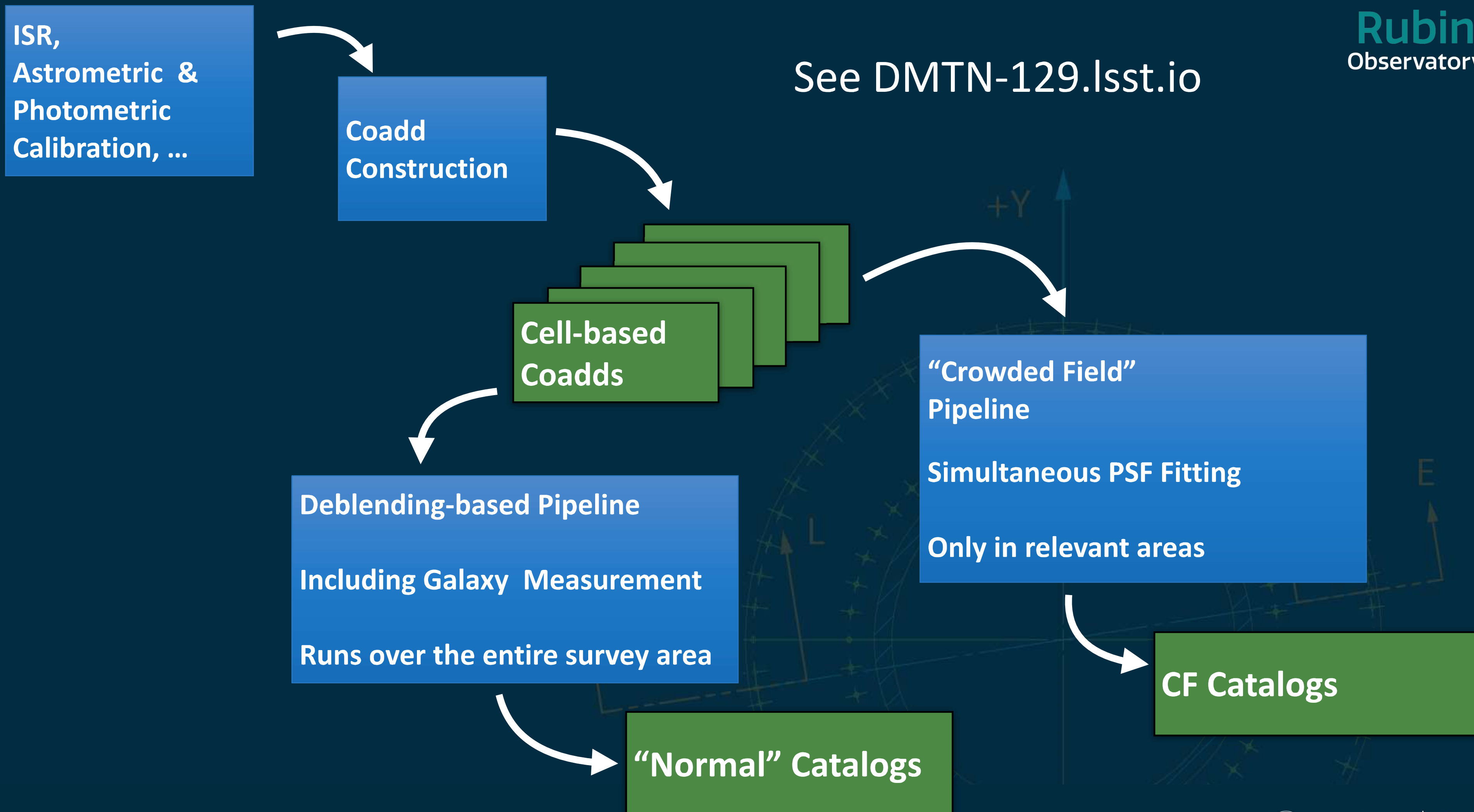
See DMTN-129.lsst.io



SIMULTANEOUS PSF FITTING

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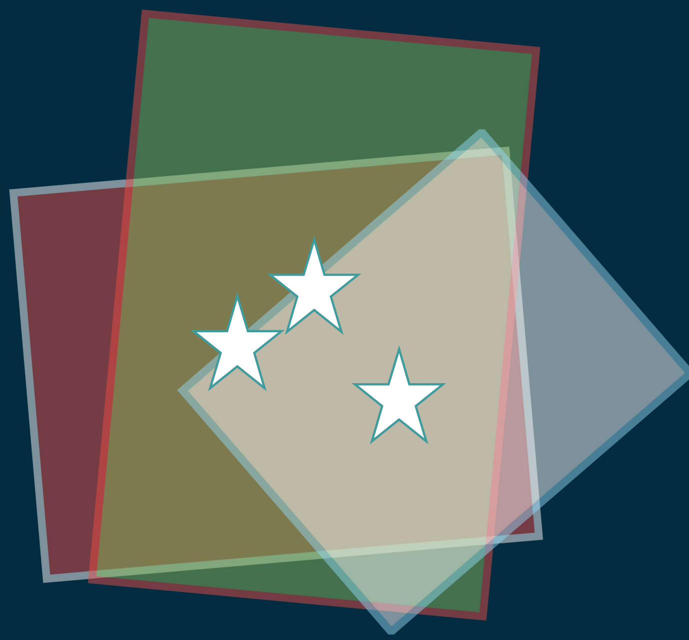
- The “Crowded Field Branch” would only fit PSFs to sources, no galaxy model fitting.
- The core of the photometry algorithm is DAOPHOT-like. Because we know the PSF model, we can compute every star’s contribution to the counts in a given pixel.
- Uses a sparse matrix with source fluxes and pixel values as parameters, least-squares problem to solve. Early prototype running inside the LSST stack.

Coadd measurements for deep detection

- Need to use coadds for detecting sources deeper than single-epoch imaging.
- We’ve already heard about the benefits of cell-based coadds
- All the same benefits apply to crowded fields as well



Challenges at LSST-scale

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- LSST is not just a static-sky survey. There's lots of Milky Way science in stellar motions and variability.
- Want to also use the extra depth from many exposures, without having resort to full multifit.

- Short-period coadds (think 6-12 months) give us depth, without washing out motion.
- For light curves, fit fluxes on individual images, but with coadd-defined positions

"Crowded Field" Pipeline Branch

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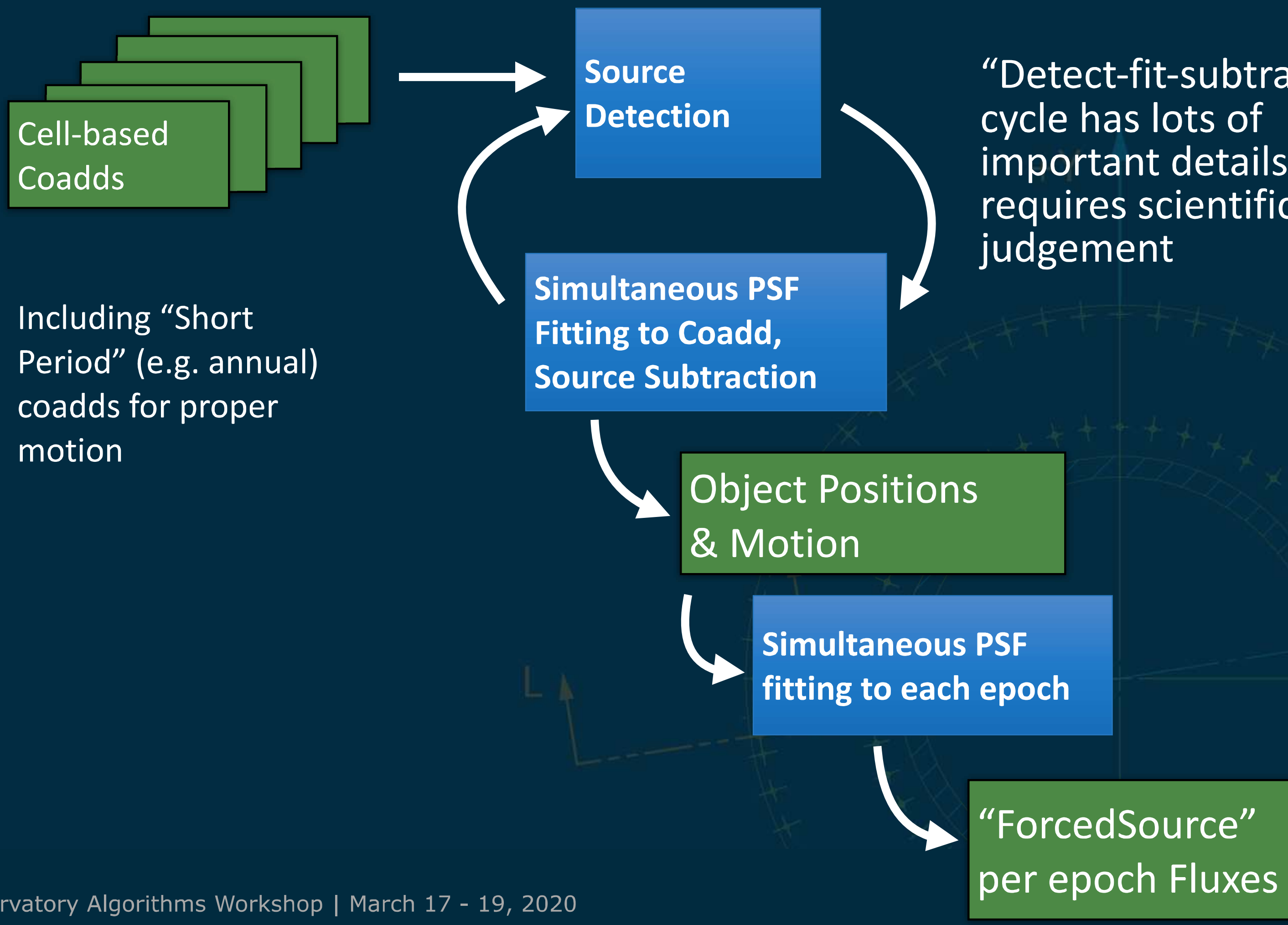
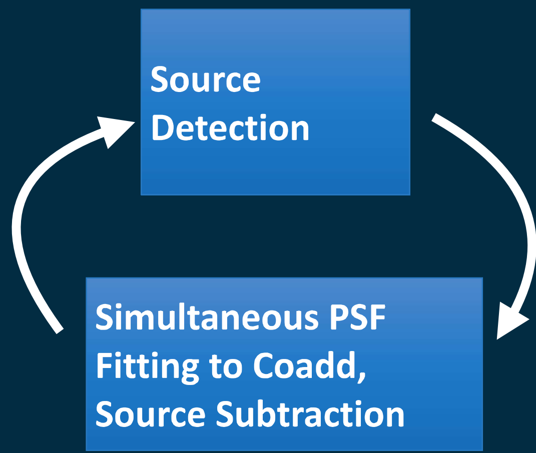


Including "Short Period" (e.g. annual) coadds for proper motion

"Detect-fit-subtract" cycle has lots of important details; requires scientific judgement

Iterative Source Detection

- Because we assert that we know the shape of all sources, subtracting identified sources to find faint neighbors is possible
- This cycle happens on the coadd, not data-intensive
- Will also want to iterate on measuring the PSF; removing neighbors to get clean PSF wings
- Many heuristics and tuning parameters in this process. Requires careful testing.



Positions, motions, and fluxes

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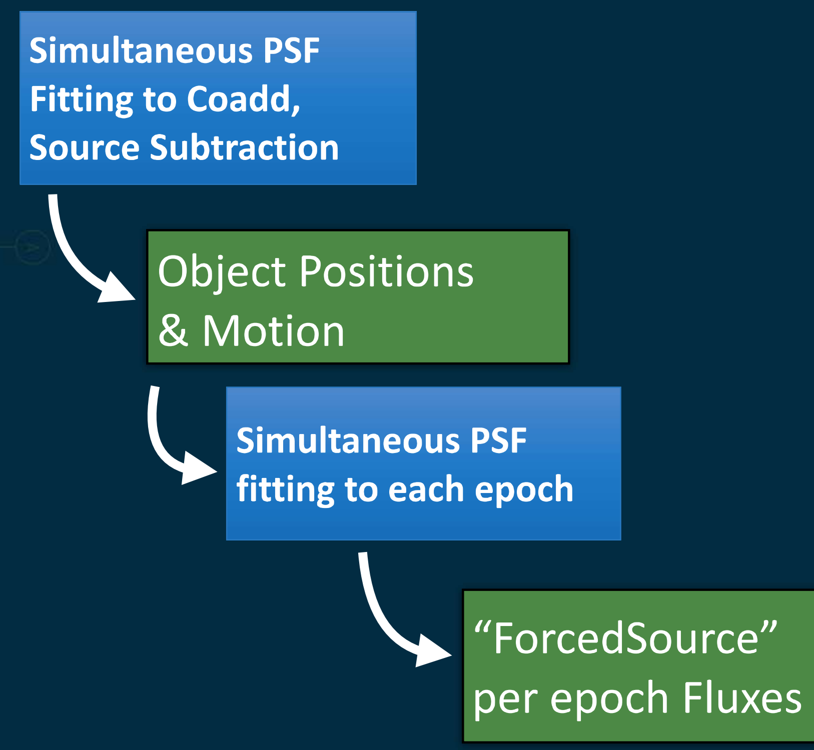
- Fits on individual short-period coadds give us positions
- Matching objects between different coadds gives us motions
- Position + motion lets us do force photometry on individual epochs



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- Mean fluxes would come from the mean of individual epoch fluxes, not from the coadd measurement.
- Possible extensions to also measure centroids or spatial derivatives to fit parallax; untested and unproven.
- Our requirements say we must measure PM down to the single epoch depth, going deeper is a bonus we want to achieve.

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- Lots of little details matter.
  - PSF accuracy is important, and it's hardest to measure in crowded fields.
  - Building a source list is full of heuristics. Will require experimentation and testing
  - Iterative detection and subtraction is sensitive to diffuse light
  - Background subtraction also plays a subtle role; may be tie-ins from here to the deblending pipeline

Conclusions

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- We have a plan for a crowded-field data product, see DMTN-129.lsst.io.
- Basic algorithmic elements are well-known.
- The challenge is in assembling the complete system, to work robustly at scale, and addressing the time-domain