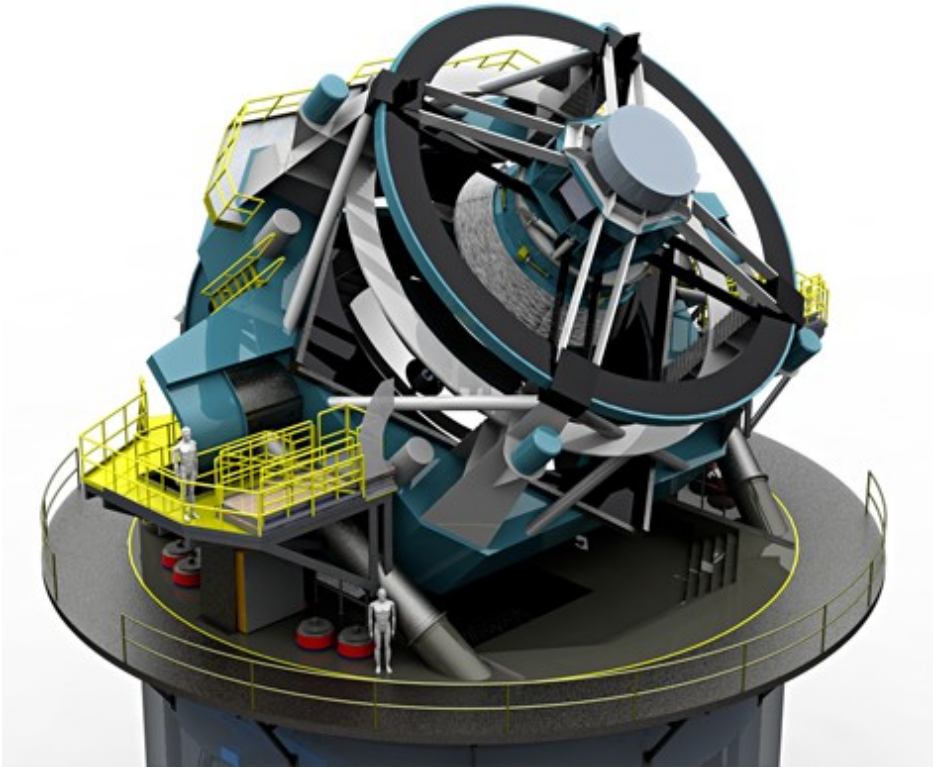
Shear Measurement and MultiFit for LSST



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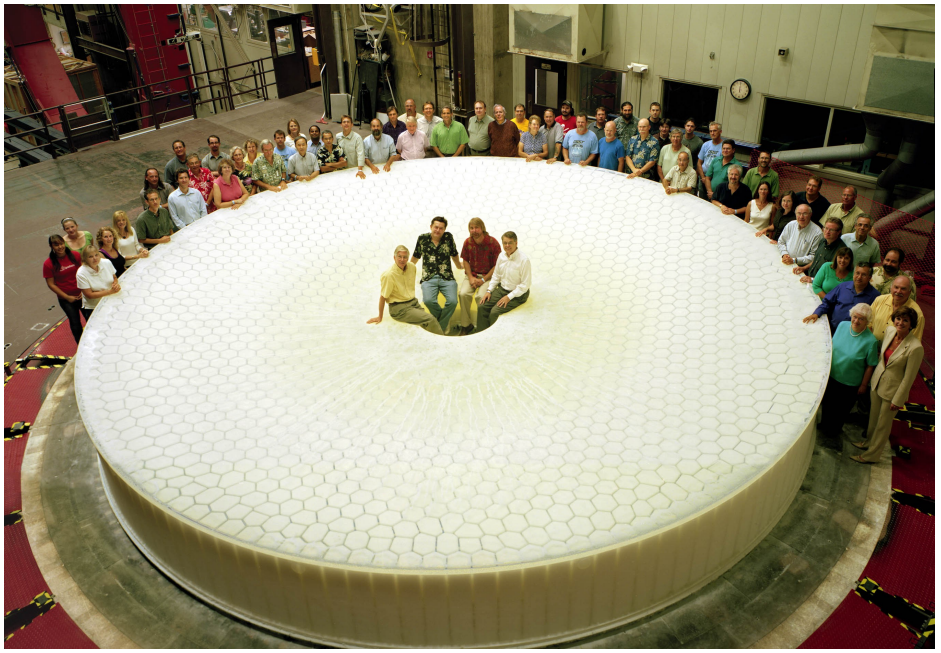
with thanks to Tony Tyson and the LSST Data Management team

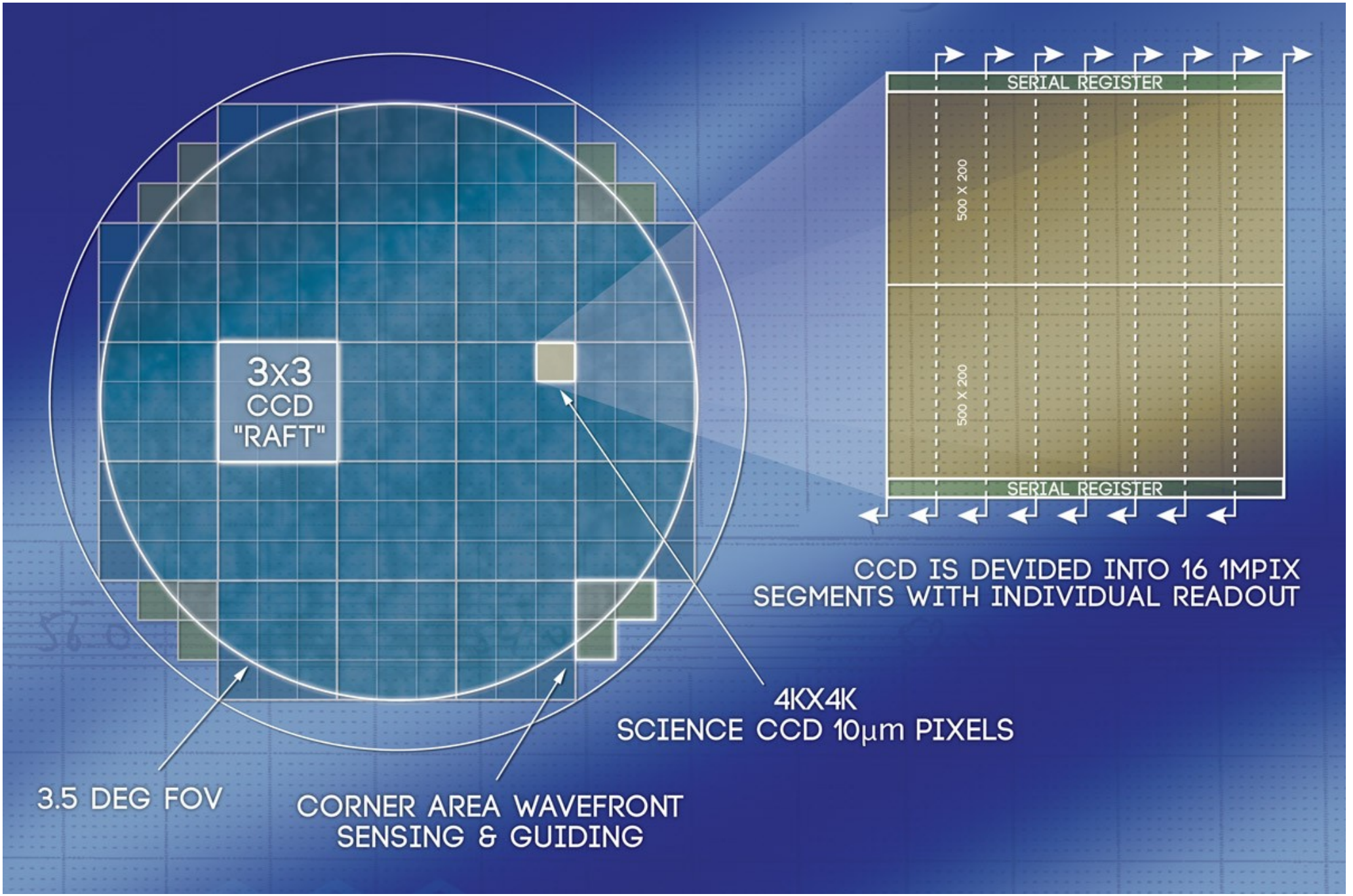
Science with LSST

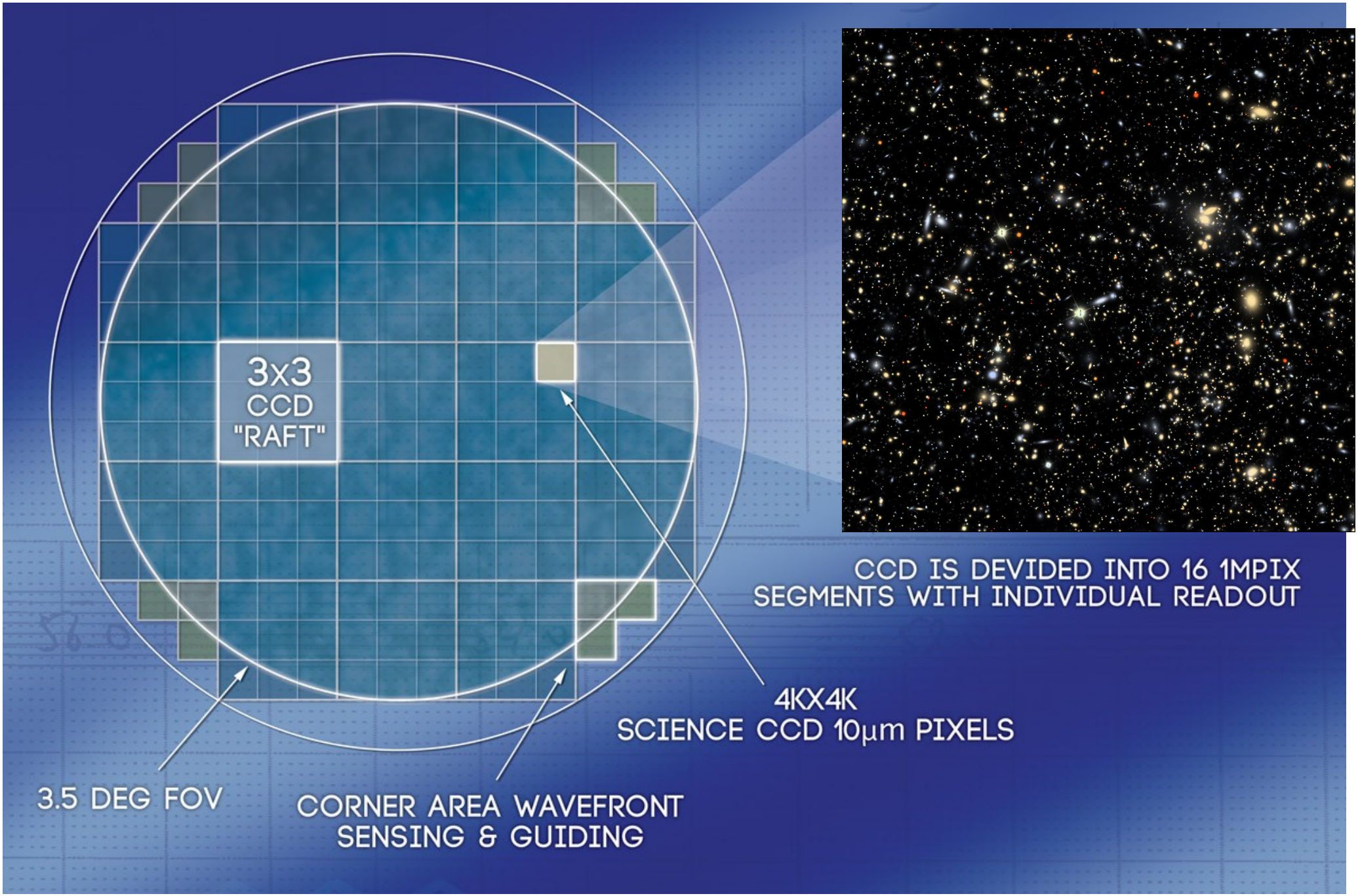
- Cosmology
  - expansion history via “standard candle” supernovae
  - large-scale cosmic structure formed by galaxies
  - gravitational lensing of distant galaxies by dark matter
- Mapping the Milky Way and Local Group
  - ~20 of the ~40 currently known nearby dwarf galaxies were found in the last big survey, SDSS, with less than 1% of the depth of LSST
- Mapping the Solar System
  - Near-Earth Objects
  - More bad news for Pluto
- Qualitatively new time-domain science

The Large Synoptic Survey Telescope



- 8.4 meter diameter primary mirror
- 3.2 gigapixel camera
- 3.5º field of view
- 2x15s exposures
- entire (visible) sky every 3 nights
- ETA ~2019


3x3
CCD
"RAFT"
SERIAL REGISTER
500 X 200
500 X 200
SERIAL REGISTER
CCD IS DEVIDED INTO 16 1MPIX
SEGMENTS WITH INDIVIDUAL READOUT
4KX4K
SCIENCE CCD 10μm PIXELS
3.5 DEG FOV
CORNER AREA WAVEFRONT
SENSING & GUIDING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The Numbers

- Images: ~20 TB per night, 60 PB over 10 years.
- 15 PB database:
  - 20 billion rows in “object” catalog (distinct astrophysical objects)
  - 3 trillion rows in “source” catalog (observations of objects)
- Alerts on transients generated in real-time.

Nightly Processing

- Difference imaging
  - Warp and PSF-match a template (coadd image) to each new exposure.
  - Subtract images, threshold-based detection.
- Alert Characterization / Orbit Determination
  - Hundreds of thousands of candidates each night.
  - What is interesting for follow-up, and how soon?

40 seconds per vist

Data Access and User Support

- SQL-like access to catalogs (without a traditional relational database underneath).
- Difficult (naively $O(n^2)$ or $O(n^3)$) queries, such as correlation functions, will be common.
- Compute resources and development environment for user-submitted jobs on the image data.

Data Release Processing

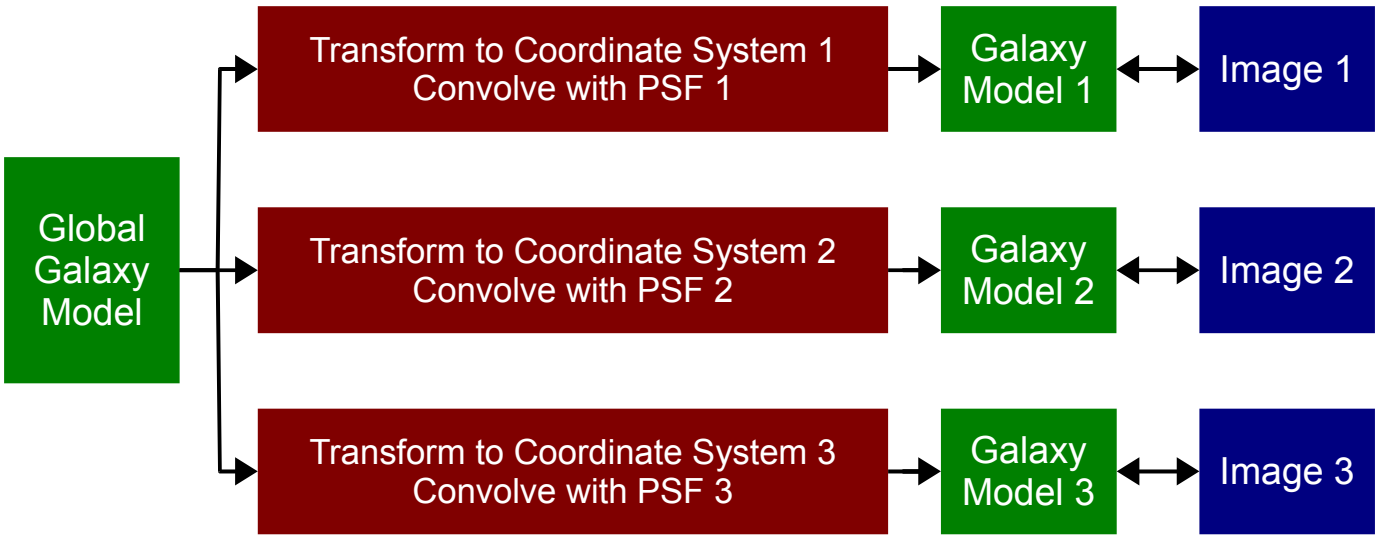
- Re-run nightly processing for better transient classification.
- Resample and coadd images for detection.
- Measure properties of objects using simultaneous modeling on original exposures ("multifit"):
  - Higher S/N measurements of static objects.
  - Light curves for variables/transients.
  - Stellar motion and parallax for nearby stars.

Data Release Processing Pipelines

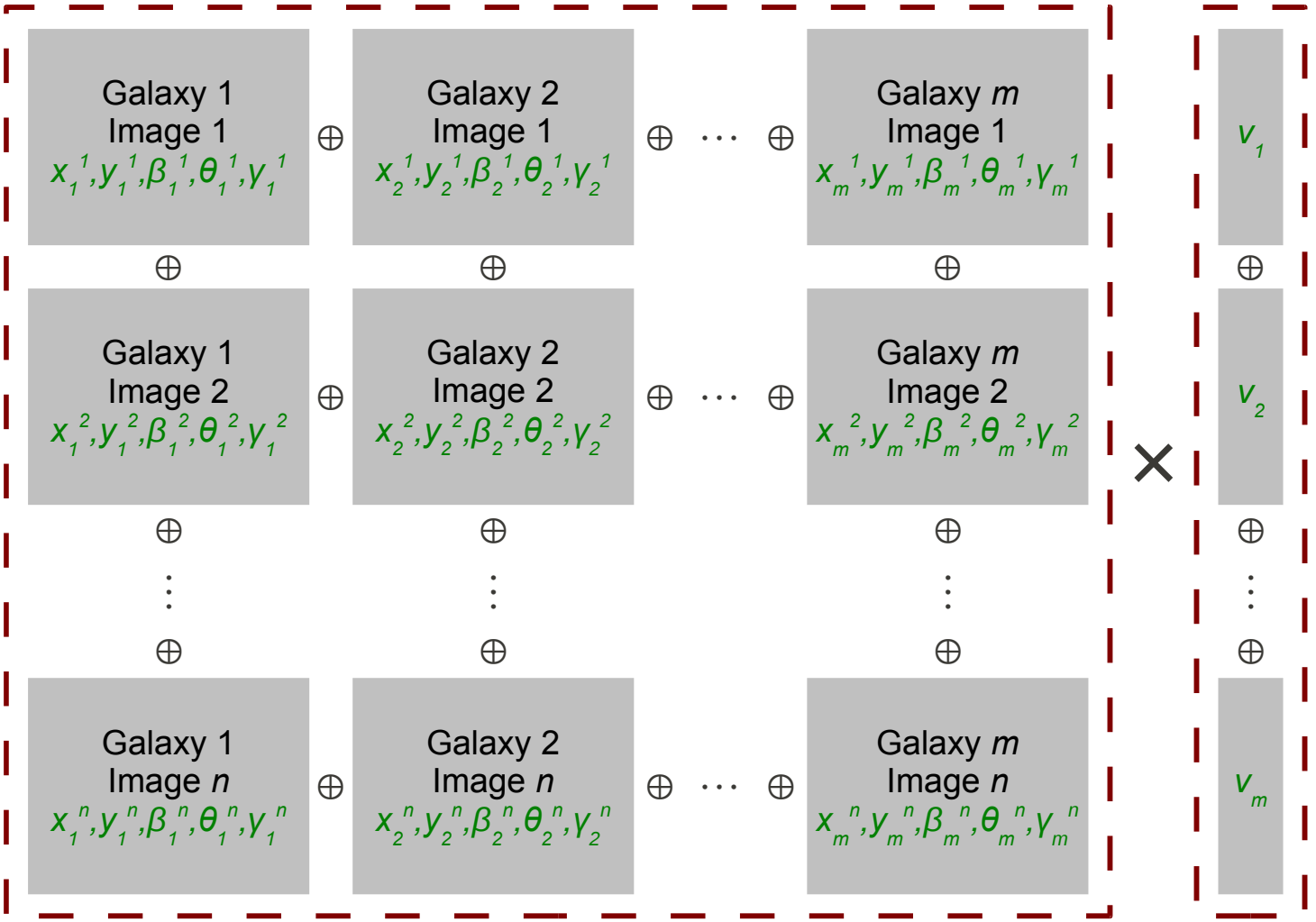
Pipeline	Coarse Unit	Operations
Instrument Signature Removal	amplifier	basic image arithmetic
Image Characterization	CCD	detection, source classification, PSF, coordinate system, background modeling
Coaddition	(none)	Lanczos resampling and addition
Deep Detection and Deblending	(none)	detection, ???
MultiFit and Forced Photometry	object	individual astronomical object modeling

Why Multifit?

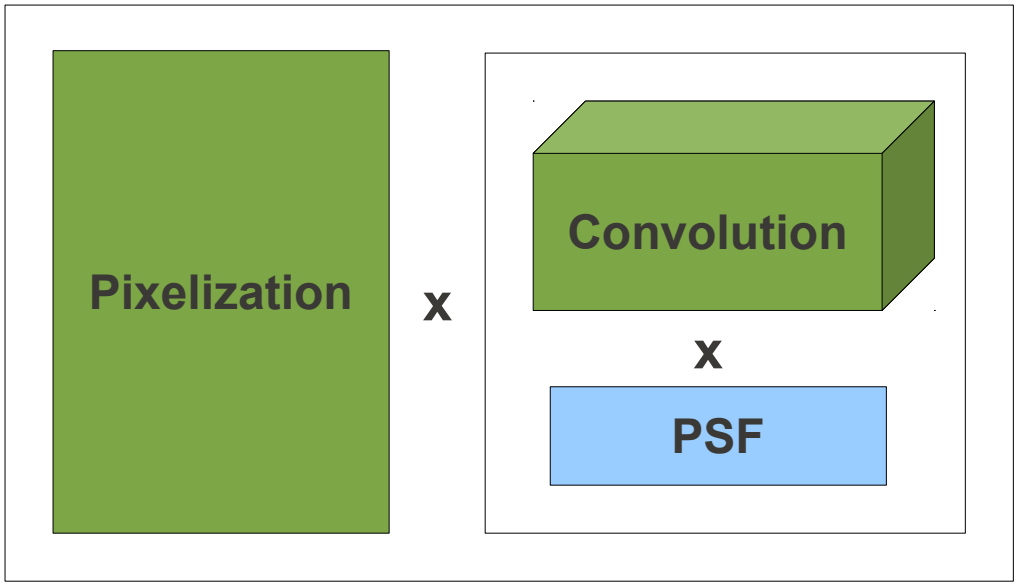
- Coadd cannot be optimized simultaneously for PSF and S/N.
- Reduction in statistical errors from survey size requires tighter control of systematic errors relative to previous surveys.
- Time-dependent phenomena are wiped out on the coadd.

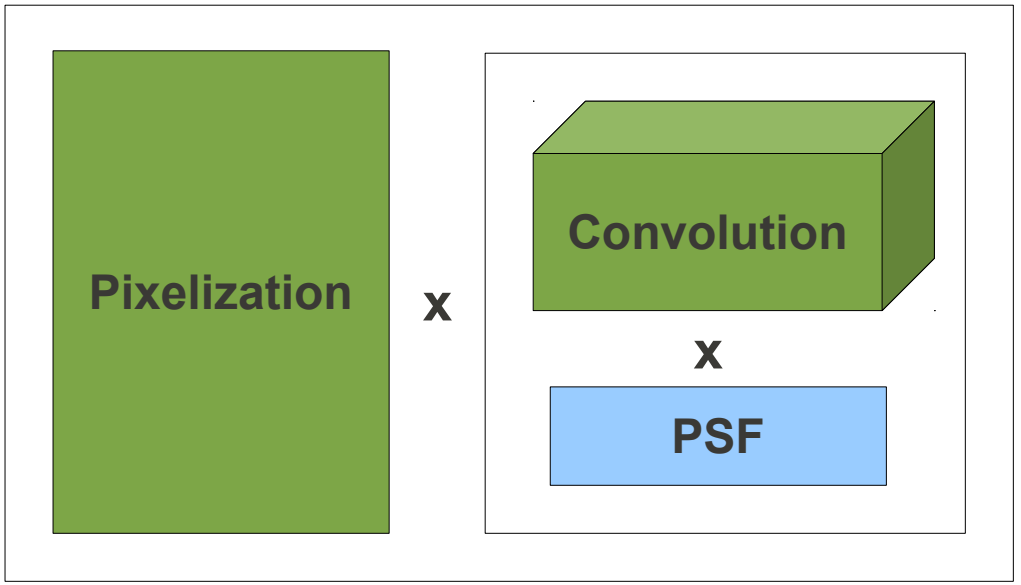


Linearized Models



Shapelet Galaxy Models





x

Pixelization matrix and **Convolution tensor** are computed using recurrence relations, and depend on nonlinear ellipse parameters.

Basis matrix and **PSF vector** are inputs, and do not depend on nonlinear ellipse parameters.

Why this is hard

- One pixelization matrix is (500-100000) x (15-45).
- 2-5 pixelization matrices per object iteration.
- Fit 200-1000 exposures together.
- For a single object, the full multi-exposure matrix is $(10^5\text{-}10^8)$ x (2-15).
- We need to construct and solve this system for every iteration in the nonlinear parameters.
- We'd prefer to Monte Carlo sample the likelihood of the nonlinear parameters (instead of using a greedy optimizer).

This is *all* future work

- Algorithms are very much in development from a scientific validity standpoint – we don't know yet what sort of sleazy shortcuts we can afford to make.
- LSST presents many technical challenges, but we still have time to do exploratory research before engineering work has to begin in earnest.