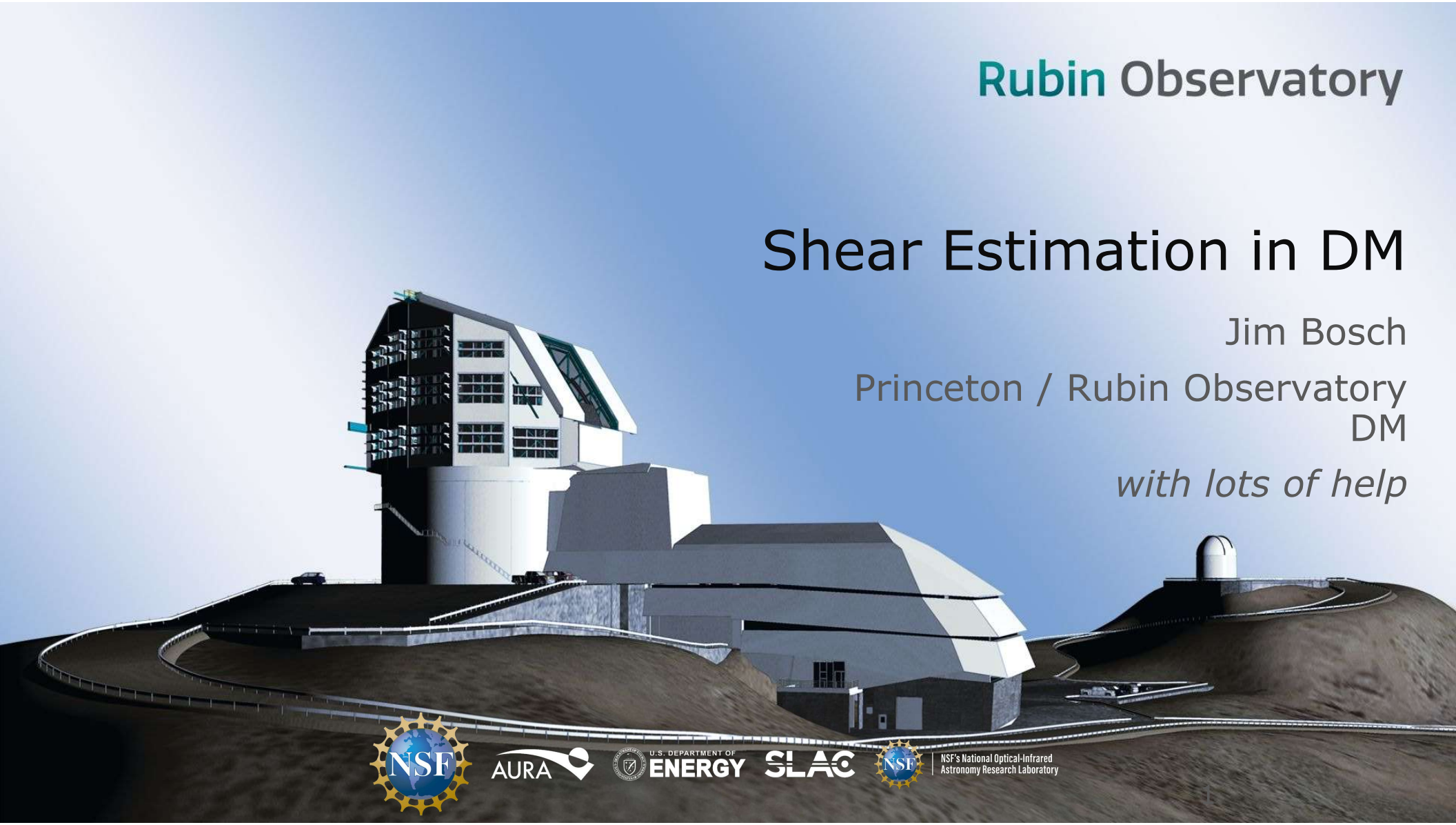
Rubin Observatory

Shear Estimation in DM

Jim Bosch

Princeton / Rubin Observatory DM

with lots of help



Outline

Rubin Observatory

- What we're doing now
- What we'd like to do
  - Integrate and run a *battle-tested* state-of-the-art third-party code
    - with our PSF models;
    - on our coadds;
    - on detections that we can relate somehow to the rest of our Object catalog.
  - Leave it to SCs to do any post-pixel processing.
  - Get help from SCs on validation.
- Constraints and scenarios
- No more multifit here, either.

What we're doing now

Rubin Observatory

Shear estimation is a full-pipeline problem, and our work so far has focused on making the earlier stages usable for downstream shape measurements.

- Integration/fork of PSFEx (as a library rather than an executable).
- Fixes to PSFEx interpolation logic to work better on barely-sampled images.
- Careful propagation of PSF models and masking through coaddition (at HSC scale).

What we're doing now

Rubin Observatory

For shape measurement itself, we have:

- full integration of GalSim-based HSM algorithms (e.g. Regaussianization);
- a prototype/placeholder integration of ngmix/metacalibration on coadds (co-developed with DESC, especially Erin Sheldon).

What we're doing now

Rubin Observatory

Our current pipelines control systematics well enough for a DETF Stage II survey (HSC@PDR1), *if* they're combined with a major simulations-based calibration effort.

LSST is Stage IV.

We have a lot of work to do. Everything on the last two slides will need to be improved or replaced in time for DR1.

What we're doing now

Rubin Observatory

Shear estimation is a full-pipeline problem, and our work so far has focused on making the earlier stages usable for downstream shape measurements.

- ~~Integration/fork of PSFEx (as a library rather than an executable).~~
- ~~Fixes to PSFEx interpolation logic to work better on barely-sampled images.~~
- Careful … coaddition (at HSC sc…

We plan to drop PSFEx entirely in favor of Piff, and contribute wavefront-domain modeling code there (see Josh Meyers' talk from Tuesday).

What we're doing now

Rubin Observatory

Shear estimation is a full-pipeline problem, and our work so far has focused on making the earlier stages usable for downstream shape measuremen

- Integrati cutable).
- Fixes to y-sampled images.
- ~~Careful propagation of PSF models and masking through coaddition (at HSC scale).~~

We have learned a lot from our current code, but we need to rewrite a lot of it to manage discontinuities vs. PSF propagation better (see my coaddition talk from Tuesday).

What we're doing now

Rubin Observatory

For shape measurement itself, we have:

- full integration of GalSim-based HSM algorithms (e.g. Regaussianization);
- a prot…bration on coadd…on).

This will probably stick around (it's very useful to have something simple for diagnostics), but it won't play a role in the production shear pipeline.

What we're doing now

Rubin Observatory

For shape measurement itself, we have:

- full integration of GalSim-based HSM algorithms (e.g. Regaussianization);
- ~~a prototype/placeholder integration of ngmix/metacalibration on coadds (co-developed with DESC, especially Erin Sheldon).~~

Not really maintainable in its current form, and the right relationship between deblending and shape measurement is an area of very active research.

We'll need to rewrite this integration layer.

There's a theme here

Rubin Observatory

Across the board, DM:

- has a placeholder working that corresponds to what the state of the art was 5-10 years ago;
- has contributed to the algorithmic ideas that have replaced them;
- is working with DESC members (in many cases people you've heard speak at this workshop) to implement those ideas in external-to-DM codebases and/or integrate those codebases with the DM pipelines.

There's a theme here

Rubin Observatory

Across the board, DM:

- has a placeholder working that corresponds to what the state of the art was 5-10 years ago;
- has contributed t
- is working with D rd speak at this workshop) to implement those ideas in external-to-DM codebases and/or integrate those codebases with the DM pipelines.

This is unfair to our coadds, actually, which really are state of the art, even if we know they'll need to improve further.

There's a theme here

Rubin Observatory

Across the board, DM:

- has a placeholder working that corresponds to what the state of the art was 5-10 years ago;
- has contributed to the algorithmic ideas that have replaced them;
- is working with DES[illegible] **Especially in coaddition and PSF modeling.** [illegible]ve heard speak at this workshop) to implement those ideas in external-to-DM codebases and/or integrate those codebases with the DM pipelines.

There's a theme here

Rubin Observatory

Across the board, DM:

- has a placeholder working that corresponds to what the state of the art was 5-10 years ago;
- has contributed to the algorithmic ideas that have replaced them;
- is working with DESC members (in many cases people you've heard speak at this workshop) to implement those ideas in external-to-DM codebases and/or integrate those codebases with the DM pipelines.

...but nearly not as much as we need to.

We've been understaffed in this area and focused on other problems, but that's changing (welcome on board, Arun!).

DM's ideal shape measurement code

Rubin Observatory

- uses the same PSF models as the rest of our measurements;
- runs on the same coadds as the rest of our measurements;
- is applied to [a subset of] the same detections as the rest of our measurements;
- will have already been battle-tested at scale on a Stage III survey (and used for science);
- processes >100 objects/second/core;
- has compact outputs (i.e. a few numbers, not a huge likelihood).

DM's ideal shape measurement code

Rubin Observatory

- uses the same PSF models as the rest of our measurements;
- runs on the same coadds as the rest of our measurements;
- is applied to [a subset of] the same detections as the rest of our measurements;
- will have already been battle-tested at scale on a Stage III survey (and used for science);
- processes >100 o
- has compact outp

This probably means it's something developed primarily outside DM.

ngmix/metacal is what we've followed mostly closely; BFD is promising but still unproven. There are others we should be following more than we have.

DM's ideal shape measurement code

- uses the same PSF models as the rest of our measurements;
- runs on the same coadds as the rest of our measurements;
- is applied to [a subs[illegible]f] the same detections as the rest of our measurements
- will have alrea[illegible] on a Stage III survey (and used for [illegible]
- processes >10[illegible]
- has compact outputs (i.e. a few numbers, not a huge likelihood).

We will be very sad if we can't accomplish at least this much.

To a large extent, weak lensing needs will be what drives our algorithmic improvements in these areas.

DM's ideal shape measurement code

Rubin Observatory

- uses the same PSF models as the rest of our measurements;
- runs on the same coadds as the rest of our measurements;
- is applied to [a subset of] the same detections as the rest of our measurements;
- will have alre e III survey (and used fo
- processes >1
- has compact outputs (i.e. a few numbers, not a huge likelihood).

Metadetection would make this tricky, but not necessarily impossible.

Algorithms for shear vs. blending (vs. photometric redshifts!) are far from settled.

DM's ideal shape measurement code

- uses the same PSF[illegible]ents;
- runs on the same [illegible]nts;
- is applied to [a su[illegible]est of our measurements;
- will have already b[illegible]e III survey (and used for science);
- processes >100 objects/second/core;
- has compact outputs (i.e. a few numbers, not a huge likelihood).

This is how fast codes would need to go for me to feel confident in our compute budget (or for us to consider running multiple shape codes).

Slower codes may still be viable, but there are a lot of other pipeline stages that are hungry for more compute.

Scenarios

Rubin Observatory

Ideal

Multiple codes meet or exceed our criteria, and we run them all because we can afford to.

Resource Constrained

Multiple codes meet our criteria, but we can only afford to run one. We need a high-level joint decision between Project and Science Collaborations.

Technical Tradeoffs

No codes meet all of our criteria, but several meet most. Another decision point, but constrained to those that are fast enough.

Scenarios

Rubin Observatory

Worst Case

Nothing endorsed by SCs as "good enough" meets our criteria for "fast enough", and we cannot find ways to add enough new compute resources.

DM focuses development on earlier steps of the pipelines (PSFs, coadds, etc.), runs *something* fast enough (e.g. an unproven BFD variant, older KSB-like methods), and leaves the rest to the community.

So, that was scary.

Rubin Observatory

I don't think the worst case scenario is the most likely one, but it's not out of the question.

- DM's compute budget for shape measurement has a ceiling;
- we don't know exactly what that ceiling is, because there's competition *within* DM pipelines for compute resources;
- the shape measurement code we will run (even for DR1) does not yet exist in its final form, so we can't know yet what its resource needs will be.

Roles

Rubin Observatory

DM does not expect to play a production role in:

- running catalog-space operations that transform uncalibrated per-object estimators to calibrated ensemble shears;
- major simulation campaigns for shear calibration (or testing that no simulation-based shear calibration is necessary).

We may do a small amount of both internally for initial validation, but overall we expect to rely heavily on SCs for help in validating shape measurement algorithms.

This will require a seamless relationship between SCs and the Ops project in validating data releases!

Conspicuously absent, again: multifit

Rubin Observatory

Many of DM's baseline documents (particularly the Data Products Definition Document, LSE-163) were written around 2013, when a reasonable best guess at what the state-of-the-art shear estimation would look like in 2020 was:

1. Monte Carlo sample from the posterior of a PSF-convolved galaxy model, computed jointly (and simultaneously) over all epochs.
2. Hope that you can get away with just ~200 samples / galaxy.
3. Hope that if you use the right priors, shear biases go away.
4. Hope that blending isn't a problem.

No more Monte Carlo sampling in galaxy models

Rubin Observatory

Nobody is asking for those Monte Carlo samples today, and we no longer plan to produce them.

We will still do galaxy fitting for photometry, but with greedy optimizers (see my talk and Dan Taranu's from earlier today).

Changes to the DPDD are in the works.

No more multifit

Rubin Observatory

It may come as more of a surprise that we are now planning to do all of our shear estimation on coadds, rather than via multi-epoch fitting.

Here's why:

- the mathematics say coadds ought to be good enough;
- we think shape measurement on *very careful* coadds can be proven to be good enough by DR1;
- we never had a coherent story for deblended multi-epoch fitting;
- multi-epoch fitting for shape measurement is prohibitively expensive.

No more multifit: the mathematics

Rubin Observatory

- The original motivation was avoiding PSF systematics that only came about due to (incorrectly!) attempting to fit a continuous PSF model to coadds that had a discontinuous PSF. This was solved years ago (Jee & Tyson 2011), with an approach (propagating PSFs through coaddition) that we've already implemented.
- Kaiser/decorrelated coaddition makes it theoretically possible to avoid *any* S/N loss, and the measured S/N losses from direct coaddition have been negligible in practice (see my coaddition talk from Tuesday).

No more multifit: proving it

Rubin Observatory

- DLS and HSC Y1 shear catalogs were built from coadds. Neither was at the level of systematics control we will need for LSST, but they were a good first steps.
- A simulation project involving both DM and DESC (led by Bob Armstrong and Erin Sheldon) has shown that shear estimation on coadds is viable for metacal and BFD, if you're very careful to resample the PSFs in *exactly* the same way as the images. Paper is in prep.
- My understanding is that DES Y6 processing will be attempting to do shape measurement on coadds.

Summary

Rubin Observatory

- The DM pipeline's current lack of shear estimation sophistication should not be construed as an indicator of future lack of sophistication; there's work behind the scenes.
- But there's lots more of work to do.
- And lots of working with many of you.
- And maybe hard choices ahead.
- But don't expect multifit to be one of those choices.
  - Find me if you're unconvinced by the math that says we can use coadds.
  - Stay tuned if you want more than math.