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# LSST, Euclid, and WFIRST

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# SMK Perspective

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- \* I believe I bring three potentially useful perspectives to this discussion:
  1. I am the Deputy Project Director for the Large Synoptic Survey Telescope, a ground-based “Dark Energy Experiment” with complementary capabilities to Euclid and WFIRST.
  2. I was a Co-Investigator on the original DUNE proposal, and remain a Co-Investigator on Euclid. I was also a Co-I on a proposal for the US Euclid Survey Science Team, before NASA canceled that competition.
  3. I was the U.S. Principal Investigator for an experiment on a major ESA mission, XMM, proposed at a time when a competing American mission, AXAF, was still awaiting formal approval to begin construction. There are some interesting parallels to the ongoing discussion over how US involvement in Euclid may or may not affect WFIRST.
- \* The views that I express re Euclid and WFIRST in this talk are purely my own. However, there has been discussion amongst the leaders of the LSST Project about these issues, and my comments will reflect those discussions. Note that in this respect, I represent the Project, NOT the agencies who are funding its development.

# Euclid Synergy With LSST

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- \* The Large Synoptic Survey Telescope was the top-rated major new ground-based facility recommended in the NWNH Decadal Survey.
- \* It is a large-aperture wide-field telescope that will provide time-lapse digital imaging of faint astronomical objects in six optical bands over half the sky.
- \* The scientific program of LSST is extremely broad. However, constraining the properties of dark energy, at a sensitivity level appropriate to a DETF “Stage IV” experiment, is one of its principal design goals. LSST will enable all four of the principal dark energy probes:
  - Measurements of Type 1a SNe.
  - Weak Gravitational Lensing.
  - Baryon Acoustic Oscillations.
  - Statistics of Clusters of Galaxies.

# Summary of LSST Survey Characteristics

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Survey Property	Performance
Main Survey Area	18000 sq. deg.
Total visits per sky patch	825
Filter set	6 filters (ugrizy) from 320-1050nm
Single visit	2 x 15 second exposures
Single Visit Limiting Magnitude	$u = 23.9; g = 25.0; r = 24.7; i = 24.0; z = 23.3;$ $y = 22.1$
Photometric calibration	< 2% absolute, < 0.5% repeatability & colors
Median delivered image quality	~ 0.7 arcsec. FWHM
Transient processing latency	< 60 sec after last visit exposure
Data release	Full reprocessing of survey data annually

# Euclid Synergy With LSST

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- \* Euclid performs NIR band photometry in three colors (YJH), and visible band imaging over a broad spectral range. To determine photometric redshifts for the galaxies it will use in its weak lensing and other cosmological investigations, Euclid requires multicolor visible band photometry in narrower filter bands. This is planned to be obtained from the ground, using complementary facilities. LSST will be the premier facility to provide such measurements in the southern hemisphere.
- \* LSST and Euclid each cover 20,000 square degrees of sky. The overlap area is  $\sim$  11,000 square degrees. LSST will measure the sizes and shapes  $\sim$  4 billion galaxies. We estimate that at least 1 billion will have measurable NIR colors from Euclid.
- \* While the combined ground-based visible and space-based NIR photometry is essential for Euclid, it is also useful for LSST. The use of YJH photometry from Euclid does yield a modest but significant improvement in photo-z determination over what LSST can provide alone with its 6-color photometry.

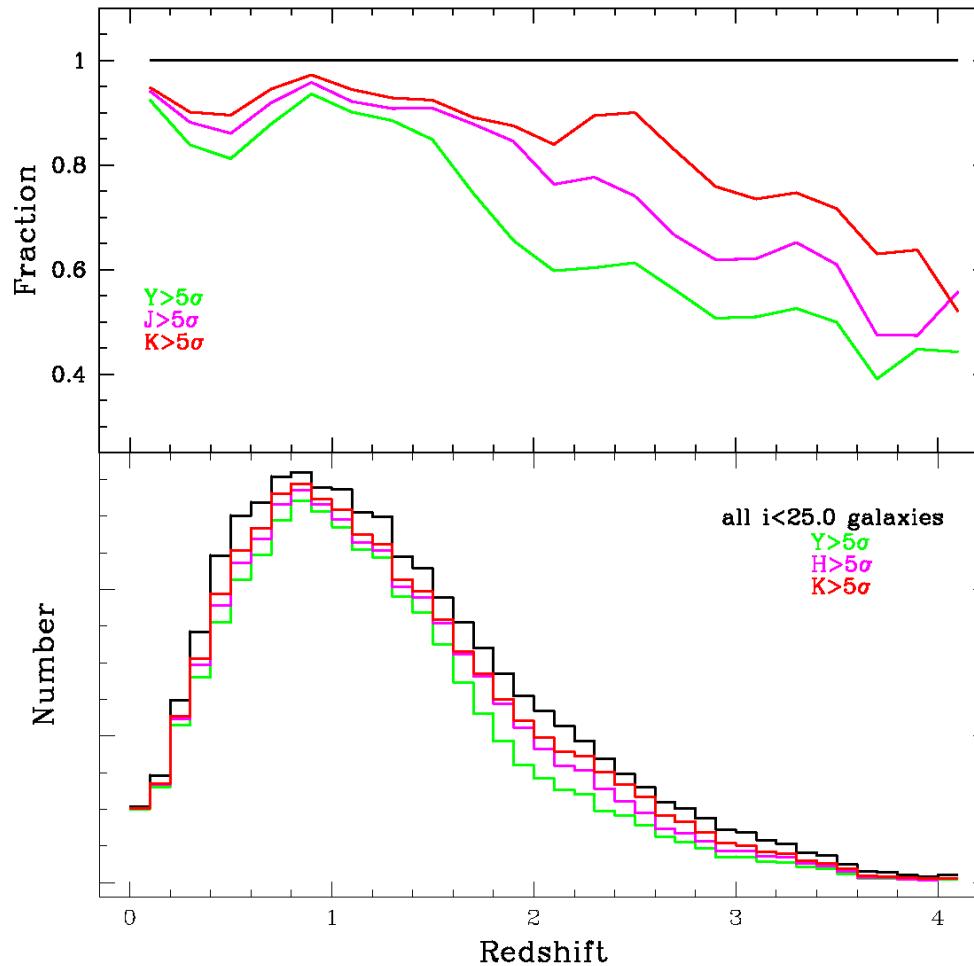
# Euclid Synergy with LSST

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- ＊ Euclid spectroscopic data may also play a significant role in helping to calibrate photo-z determination, especially at higher redshifts.
- ＊ Finally, comparison of Euclid and LSST shear determination for common fields will be helpful in understanding shape measurement systematics for weak lensing investigations with both facilities.

# Fraction of LSST “Gold Sample” Galaxies Detectable by Euclid

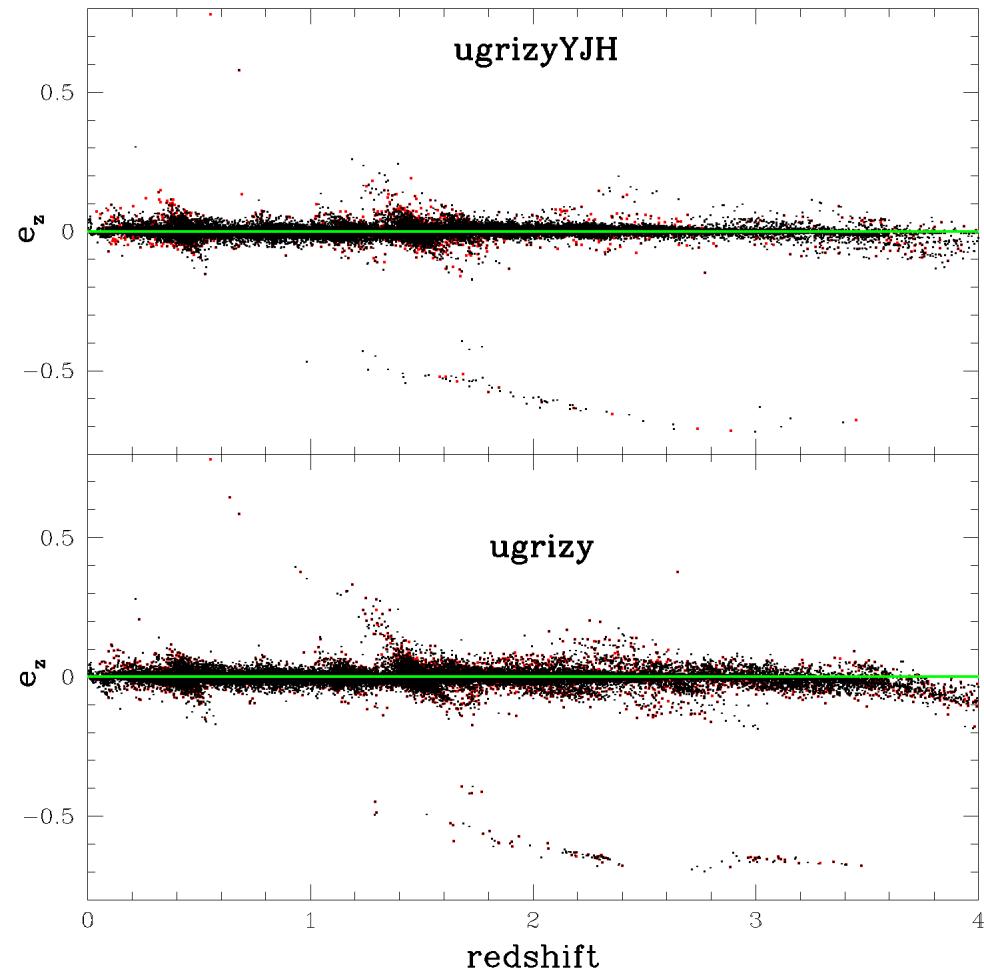
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(Courtesy S. Schmidt)

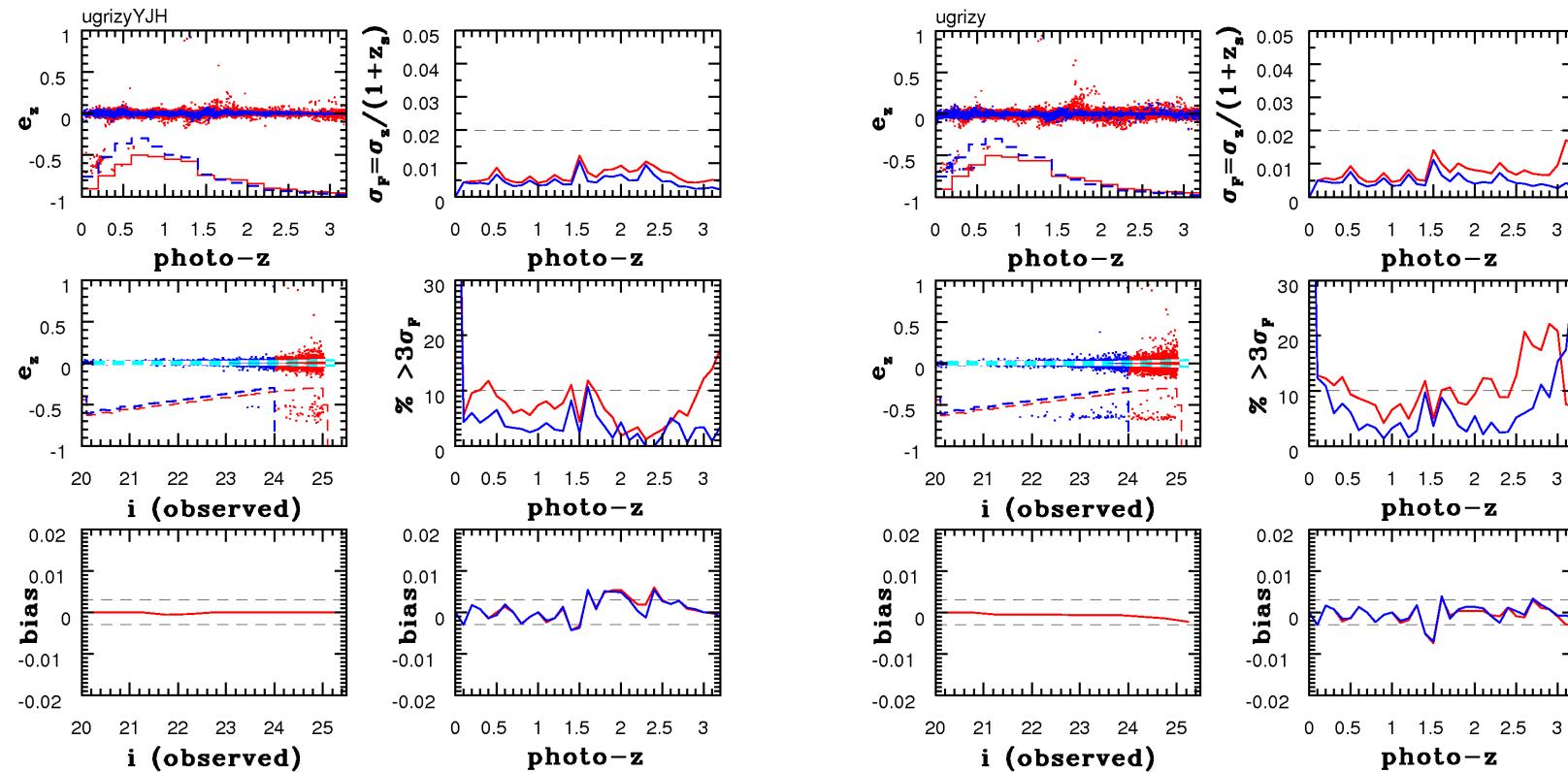
# Photo-Z From LSST: With and Without Euclid

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(Courtesy S. Schmidt)

# Photo-z From LSST: With and Without Euclid



(Courtesy: S. Schmidt)

# WFIRST Synergy with LSST

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- \* WFIRST will be a purely NIR mission. It will also require visible band photometry for photo-z determination. LSST will again be the premier ground-based facility to provide those data.
- \* For the nominal 5-year mission, the sky coverage for the weak lensing investigations is estimated to be  $2700 \text{ deg}^2$ , considerably less than for Euclid, but the survey will go deeper, yielding a galaxy density  $\sim 30 \text{ gals/sq. arc min}$ , comparable to what we estimate for LSST.
- \* As for Euclid, the baryon acoustic oscillation spectroscopic survey will be helpful for calibrating photo-z determinations for LSST.
- \* As for Euclid, the comparison of shear determinations between WFIRST and LSST measurements will be useful for understanding shape measurement systematics with both facilities.

# Question 1:

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- \* *Do you see the Euclid data as useful for LSST analysis?*
- \* The answer is certainly “Yes”. Euclid data will benefit LSST dark energy analyses in three ways:
  - The YJH color information will yield a modest improvement in photo-z determination over what LSST alone can provide for those galaxies which are detected by both facilities.
  - The spectroscopic survey will help to calibrate and understand photo-z systematics. Combined spectroscopic and imaging surveys also yield improved estimation of cosmological parameters.
  - Comparison of shear determinations for the two facilities will be helpful in constraining and understanding shape measurement systematics.
- \* The NIR survey that Euclid will provide will undoubtedly also be useful for the non-cosmological science investigations performed with LSST.

## Question 2:

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- \* *Do you see the LSST data as useful for Euclid analysis?*
- \* Euclid requires multi-color visible band photometry from the ground. LSST will be the premier facility to supply such data in the southern hemisphere.
- \* Euclid has argued that their requirements can be met through the provision of data by the Dark Energy Survey experiment in the southern hemisphere. DES goes considerably shallower than LSST, and will cover a significantly smaller fraction of the sky.
- \* Comparison of shear measurements between Euclid and LSST should be beneficial to both experiments.
- \* The LSST timing information would undoubtedly benefit Euclid analyses for non-cosmological investigations.

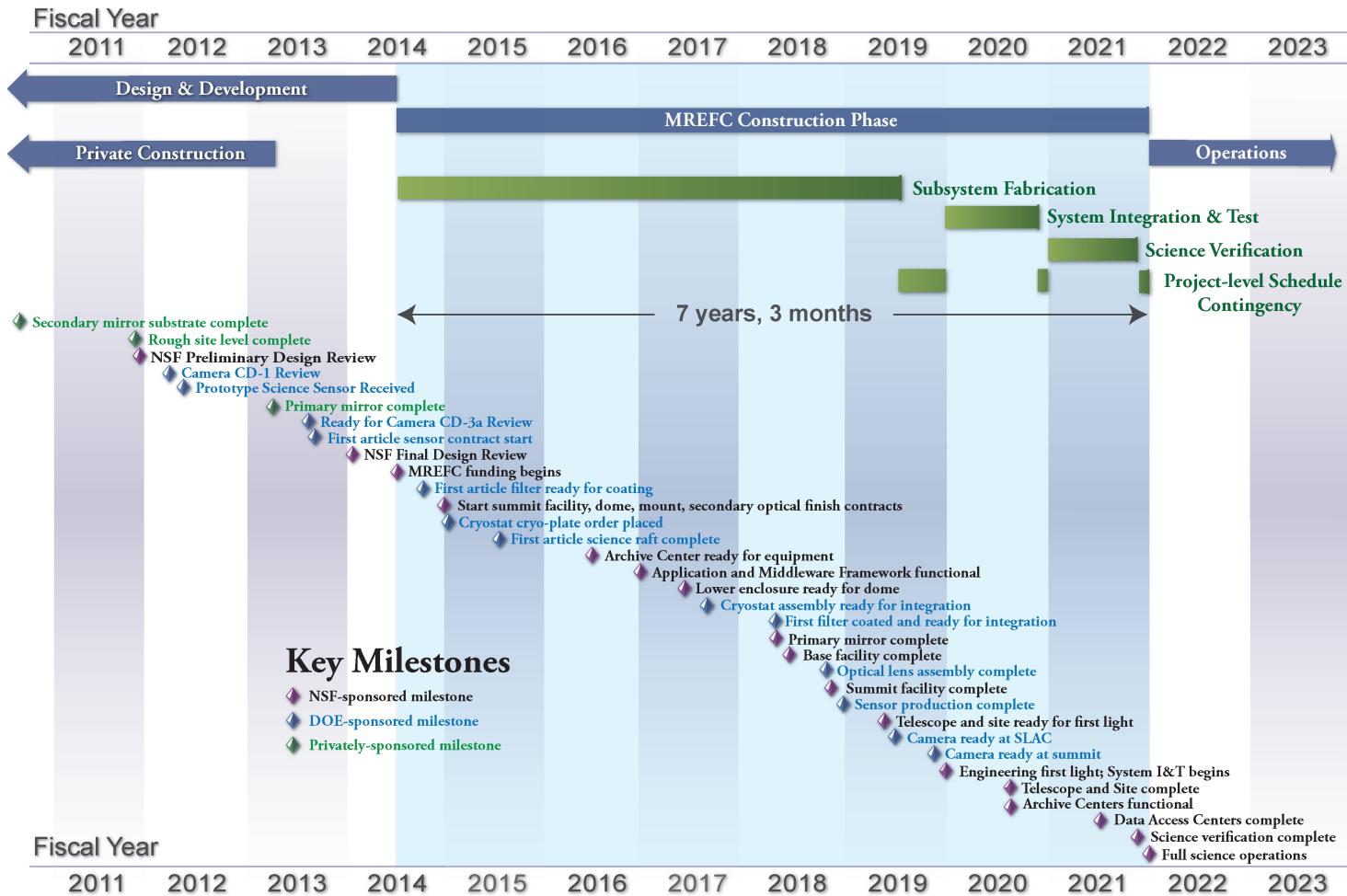
## Question 3:

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- \* *What are the plans for LSST data release?*
- \* The complete LSST survey will be processed annually, yielding calibrated images, along with a catalog of all detected sources and their measured properties, including colors, shapes, and variability indicators.
- \* At present, these data products will be released publicly to the US and Chilean communities, and selected other foreign partners, who have contributed to the construction of the facility.
- \* We have also been soliciting contributions to operations costs from other foreign institutes and funding agencies, that would also enable access to LSST processed data. As of today, we have received 55 letters of interest from around the world indicating a willingness to provide such support.
- \* Several of these foreign institutes have indicated an interest in LSST data that is expressly motivated by their involvement in Euclid. However, in our view, use of LSST data for Euclid analyses should be negotiated directly between the two projects, not through individual institutes.

# Question 4:

\* *What is the current LSST schedule?*



# Question 5:

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- ＊ *What do you see as the scientific synergies between LSST and WFIRST?*
- ＊ LSST and WFIRST are complementary facilities in many respects:
  - LSST operates in the visible band, WFIRST in the NIR.
  - LSST provides a synoptic, time-dependent survey of half the sky. WFIRST provides more detailed, targeted surveys for distinct scientific missions.
  - WFIRST includes both imaging and spectroscopic survey capabilities. LSST is purely imaging.
  - LSST provides broad sky coverage with seeing limited resolution. WFIRST provides higher angular resolution imaging over a smaller region of sky.
- ＊ Both facilities are likely to contribute significantly to dark energy investigations, as well as non-cosmological science. If past history is a guide, a combination of both space-based and ground-based facilities is especially powerful at addressing forefront questions in astronomy and astrophysics.

## Question 6:

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- \* *What do you see as the relationship between Euclid, WFIRST and the goals of the decadal survey?*
- \* Borrowing from my experience from AXAF and XMM, I believe it is unhealthy for the US community to preclude US participation in an ESA mission because of a perceived negative impact on the likelihood of a proposed NASA mission moving into development.
- \* XMM and AXAF certainly had many scientific goals in common, and they also had overlapping capabilities. Nevertheless, there were important differences between the two as well. The US contributions to XMM-Newton were crucial to that mission's success, and the US community benefitted significantly in having access to XMM-Newton data. In the end, both missions have yielded major discoveries for X-ray astrophysics. The worldwide community has learned how to optimize the observing program for these two separate facilities to ensure maximal scientific return and a minimum of redundancy.
- \* I believe the same situation could occur with Euclid and WFIRST. The two missions have some scientific goals in common, but their designs differ in details and offer complementary capabilities. It will surely further the goals of the decadal survey to have both of these space missions (and LSST!) operating by the end of the decade.

## Final Comment on a US Contribution to Euclid

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- \* To capitalize on the synergy between Euclid and LSST, it will be necessary to have a tight collaboration between the two projects to ensure that a common strategy is invoked in the derivation of the photometry in the visible and NIR bands.
- \* It is very unlikely that the “catalog magnitudes” that LSST will produce on its own will be sufficient for Euclid analyses. Rather, a dedicated reanalysis of the complete LSST data set will be required to facilitate this collaboration.
- \* That is likely to involve a significant amount of effort, and a sizable expense above and beyond what the LSST project has proposed in terms of its baseline data products.
- \* Given that LSST is primarily a US facility, I believe that the provision of LSST data for use by Euclid should be treated as an explicit component of any proposed US contribution to Euclid, and, in and of itself, should enable US participation on the Euclid science team.
- \* My suggestion would be for NSF, DOE, and/or NASA to hold some form of competition within the US to provide this opportunity. Collaborations would propose to take responsibility for jointly reprocessing LSST data in coordination with Euclid for photo-z estimation and other purposes. In exchange for that role, the members of the winning collaboration would be made explicit members of the Euclid science consortium, with full access to pre-public Euclid data.