Observing Tools for the Dark Energy Survey and Beyond

Kyler Kuehn (Argonne National Laboratory), for the Dark Energy Survey Collaboration

The Era of Observational Cosmology

Recent observations paint a picture of the cosmos dominated by cold dark matter, augmented by the postulate that approximately 70% of the universe is composed of mysterious "**Dark Energy**" that drives the accelerated expansion of the universe.

The properties of Dark Energy can be expressed in terms of the Equation of State at different redshifts:

$w(z) = p/\rho$

We parameterize w(z) as follows:

$w(z) = w_0 + w_a(1-a)$, where $a=(1+z)^{-1}$

The Dark Energy Survey (**DES**) [1] will repeatedly observe 5000 deg^2 of the southern sky, with the ultimate goal of measuring the expansion history of the Universe through the dependence on redshift of the luminosity distance, angular diameter distance, and volume element, along with the growth rate of structure. DES will significantly improve the precision of measurements of both w_a and w_0 (see Figure 1).

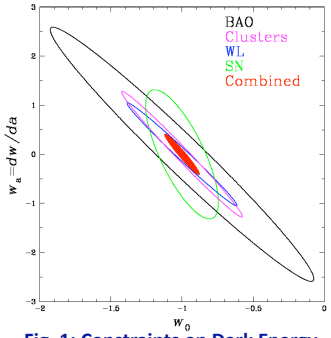

Fig. 1: Constraints on Dark Energy

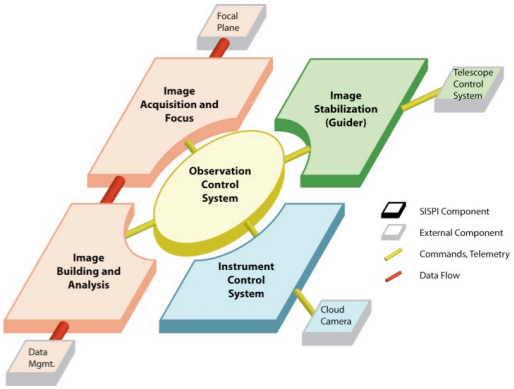

Figure 2: Schematic of SISPI Software Infrastructure

DES Observing Tools

The Dark Energy Survey Camera (**DECam**) relies on the software infrastructure of the Survey Image System Process Integration (**SISPI**), described in Figure 2.

Observer Interface Tools include:

Real-Time Displays, which compress the full 1GB image to 4MB in less than 1 second,

Interactive Tools, including Quick Look and Quick Reduce for detailed image analysis,

Instrument Health, which provides real-time telemetry data from DECam subsystems.

Quality Control with Image Health

The final component of the Observer Interface is *ImageHealth (IH)*. Because DECam will survey the sky in an automated fashion while in Survey mode, DES observers need automated tools to analyze the performance of the instrument in real time. To this end, *IH* performs the following steps:

- Finds mean of all image pixel values, yielding the Sky Background.
- Determines location of a bright pixel, which becomes the first pixel of an "Object".
- Finds all pixels associated with that Object, and determines the Object properties, including:
  - Background counts near Object,
  - Object Flux , Object Size (FWHM), Object Major and Minor Axis
  - Object Ellipticity and Orientation Angle of Object ellipse.

IH then outputs quantities for use in Image-by-Image and Time History Displays.

ImageHealth and SourceExtractor: Performance Comparison

SourceExtractor [2] is an image analysis and object-finding software package that serves as our standard of comparison for the results of *ImageHealth*. The completely new and independent *IH* algorithm shows very good agreement with this community standard—a representative sample of comparison data for objects identified in several dozen simulated DES images is shown in Table 1.

In addition to comparable performance for the specific parameters tested, *IH* is:

- More user-friendly, with streamlined processing and more focused output.
- Comprised of **only 600 lines of code**, while Source Extractor **totals 1700 lines**.
- **Modular**, with separate operations for file I/O and object analysis, making user modifications very straightforward (which is not the case for SourceExtractor).
- Requires only **30 seconds** to process a full (1GB) DES image, or as little as **six seconds** in pixel-skipping mode, whereas SourceExtractor executes in **70 seconds**.

For the DES observing cadence, *IH* will determine the quality of image N well before image N+1 is read out; thus, in the event of errors in the observation or the data, at most a single image (and two minutes of observing time) is lost.

Parameter	Full Counting	Pixel Skip = 8	Units
Position (centroid)	1.80	1.72	pixels
Object BG	0.35	0.24	% of total counts
Object Flux	0.53	0.68	% of total counts
FWHM	0.22	0.24	pixels
Ellipticity	0.03	0.04	
Position Angle	0.15	0.13	radians

Table 1: Comparison of ImageHealth Output with SourceExtractor Output

ImageHealth Beyond the Dark Energy Survey

While *ImageHealth* has been tested on many (simulated) DES images, it is not instrument-specific. The algorithm was also tested on science and engineering images of Y4KCam, and performed with comparable accuracy. Additional tests on Blanco images of the Coma Cluster show that low quality (large FWHM) images are readily and routinely identified.

Application of *ImageHealth* to non-astronomical data (e.g., nanoparticle tracking and material defect identification) is also underway by independent researchers.

The *ImageHealth* source code (in C) is freely available from the author (**kkuehn@anl.gov**) to DES Collaborators, Community Users of DECam, and all members of the astronomical community.

Citations

[1] For more information, see **http://des.fnal.gov**

[2] Bertin, E. & Arnouts, S., A & A Supp. 317 (1996) 393