# Class 6: plot workshop; variable background distributions

Starting to put it together

#### Plot workshop

## Kinds of plots

- Plots for answering a question (plots for you)
- Plots for monitoring data (readability)
- Plots for publication & presentation (pedagogical)

Systematic scavenger hunts

#### Is your background constant?

- The performance of an instrument—and thus the background pdf()—is almost never constant.
- This tells you about the physics of your experiment.

#### Changing background



#### Two levels of exploration

- 1. Scavenger hunt, looking for the unexpected
- 2. Jackknife tests to hunt for very subtle effects (specific worries)

## Scavenger hunt, step 1)

- Explore your data
- Try and find gross variations
- Best done with plots

### Scavenger hunt, step 2)

- Make a list of worries
- For each worry, come up with a plot and/or jackknife that highlights effect
- Keep track of both confirmed and unconfirmed worries!

## Case study: Vera Rubin Telescope (LSST) camera



#### Case study with LSST

## Worry: is the sensitivity constant across the CCD?



## WTF?



#### Is it related to color?



**Figure 5.** Uniformly illuminated images for the sensor ITL-3800C-017 taken at different wavelengths: 320, 400, 540, 770, 850, 900, 970, and 1080 nm (from top-left to bottom-right).

#### Not really...

#### How was it made?





polysilicon, doping

of the seed crystal

the crystal growth

with a residue of melted silicon

#### Boule sliced to form wafers









#### 4 CCDs per wafer



**Figure 2.** Layout of the silicon wafer. Because the wafer is cut into four sensors, tree rings on each sensor will have four possilble orientations.

# Brainstorming...





**Figure 3.** Examples of flat images recorded for sensors ITL-3800C-021 (a), ITL-3800C-022 (b), ITL-3800C-032 (c) and ITL-3800C-017 (d). Red dots are the points on radius of 4400 pixels. Sensors in (b) and (d) originate from the same wafer.

#### Looking in more detail



Figure 6. Relative flux variation as function of tree ring radius for the sensor ITL-3800C-017.



**Figure 8.** Comparison of the tree rings for sensor pairs originating from the same wafer. Relative flux variation as function of the tree ring radius in the range from 4500 to 5300 pixels for (a) ITL-3800C-017 (die4, red) and 022 (die2, blue), (b) 145 (die2, red) and 107 (die3, blue), and 097 (die4, red) and 091 (die2, blue).

#### Metadata!



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PRECISION ASTRONOMY WITH FULLY DEPLETED CCDS 1–2 DECEMBER 2016 BROOKHAVEN NATIONAL LABORATORY, U.S.A.

#### Properties of tree rings in LSST sensors

#### H.Y. Park, a,b,1 A. Nomerotski<sup>b</sup> and D. Tsybychev<sup>a</sup>

<sup>a</sup> Stony Brook University,
100 Nicolls Rd, Stony Brook, NY 11794, U.S.A.
<sup>b</sup> Brookhaven National Laboratory,
Brookhaven Avenue, Upton, NY 11973, U.S.A.

*E-mail:* hyeyun.park@stonybrook.edu

ABSTRACT: Images of uniformly illuminated sensors for the Large Synoptic Survey Telescope have circular periodic patterns with an appearance similar to tree rings. These patterns are caused by circularly symmetric variations of the dopant concentration in the monocrystal silicon boule induced by the manufacturing process. Non-uniform charge density results in the parasitic electric field inside the silicon sensor, which may distort shapes of astronomical sources. In this study we analyzed data from fifteen LSST sensors produced by ITL to determine the main parameters of the tree rings: amplitude and period, and also variability across the sensors tested at Brookhaven National Laboratory. Tree ring pattern has a weak dependence on the wavelength. However the ring amplitude gets smaller as wavelength gets longer, since longer wavelengths penetrate deeper into the silicon. Tree ring amplitude gets larger as it gets closer to the outer part of the wafer, from 0.1 to 1.0%, indicating that the resistivity variation is larger for larger radii.

KEYWORDS: Detectors for UV, visible and IR photons; Photon detectors for UV, visible and IR photons (solid-state) (PIN diodes, APDs, Si-PMTs, G-APDs, CCDs, EBCCDs, EMCCDs etc); Systematic effects

<sup>&</sup>lt;sup>1</sup>Corresponding author.



Fig. 8. The response of a single pixel (the POI) for each of the (x, y) positions of the  $9 \times 9$  optical spots, aggregated into a 2D raster. These measurements were fitted to our model (3). The color scale represents the pixel signal value in digital number (DN).



#### Spurious shear induced by the tree rings of the LSST CCDs

Yuki Okura<sup>*ab*</sup>, Andrés A. Plazas<sup>*cd*</sup>, Morgan May<sup>*c*</sup>, Toru Tamagawa<sup>*a*</sup>

<sup>a</sup>RIKEN,

2-1 Hirosawa, Wako, Saitama 351-0198, Japan

<sup>b</sup>RIKEN-BNL Research Center,

Department of Physics, Brookhaven National Laboratory, Bldg. 510, Upton, NY, 11792, USA <sup>c</sup>Brookhaven National Laboratory,

Department of Physics, Brookhaven National Laboratory, Bldg. 510, Upton, NY, 11792, USA <sup>d</sup> Jet Propulsion Laboratory,

California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109, USA E-mail: yuki.okura@riken.jp

ABSTRACT: We present an analysis of the impact of the tree rings seen in the candidate sensors

#### Review

- Using successive plots to isolate an issue
  - Each plot asks an improved question
- 2 classes of plot
  - Exploratory
  - Jackknife
- · Usually based off of 'worries'

#### Where next

Developing & planning analysis chains