Precision cosmology with Vera C. Rubin Observatory

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LSST project/NSF/Aura

how did structures form in the universe?

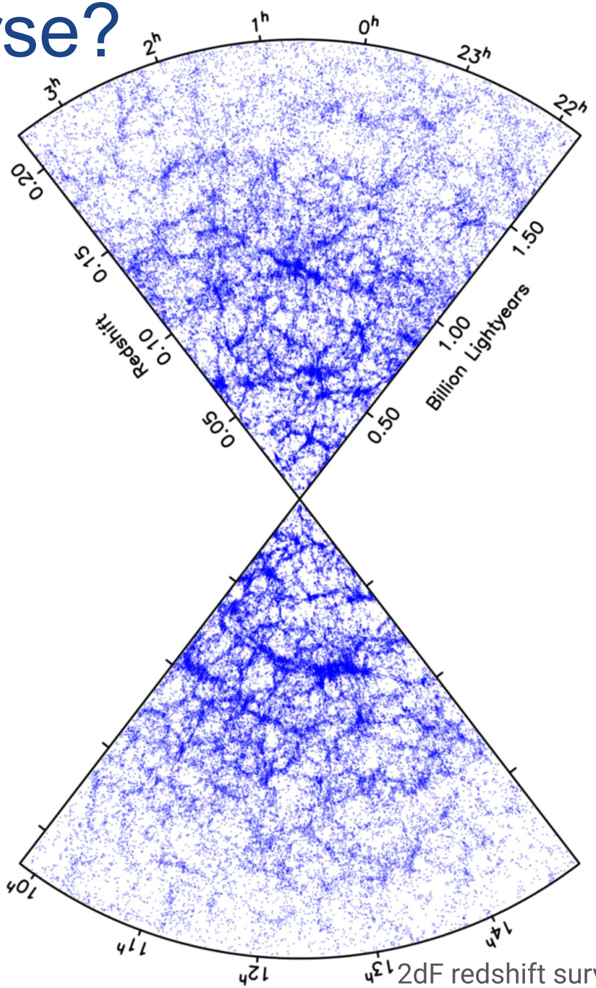
structure = stars, galaxies, galaxy clusters, etc.

Early universe: almost uniform density of matter

Growth of structure, influenced by:

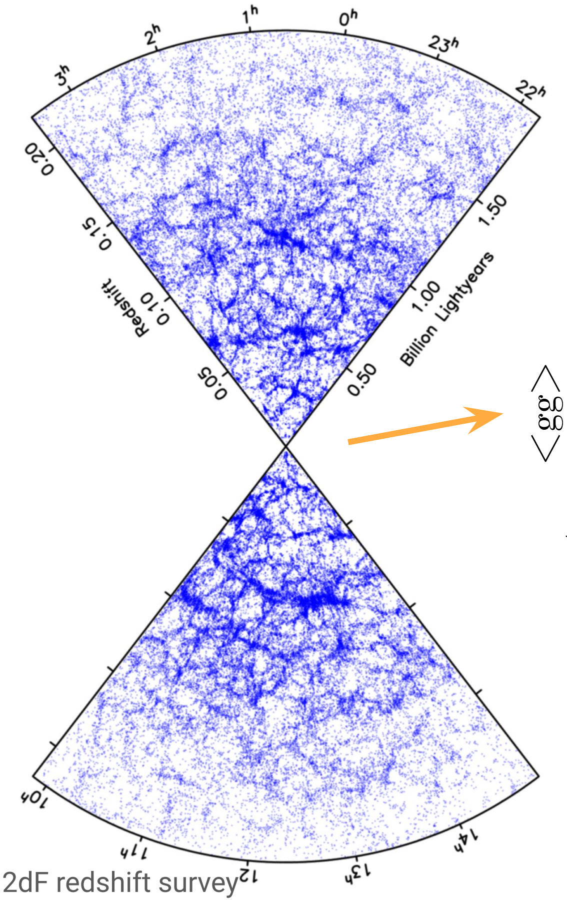
1. **Gravity**. tiny fluctuations in density of matter grew into stars, galaxies, cosmic web

2. **Dark energy** causes cosmic acceleration, reduces structure on large scales



2dF redshift survey

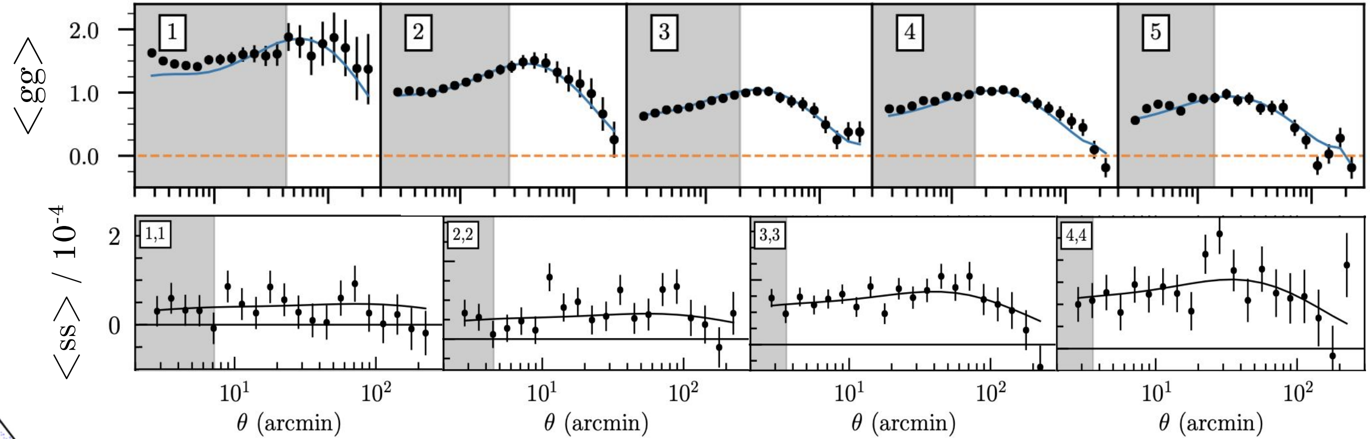
how do we measure dark energy?



2dF redshift survey

- Growth of structure is sensitive to dark energy: we can use it as a powerful probe
- Measure correlations in distribution of matter

redshift / distance →



- Need LOTS of data for precise measurements

Dark Energy Survey Y1 results (previous experiment)

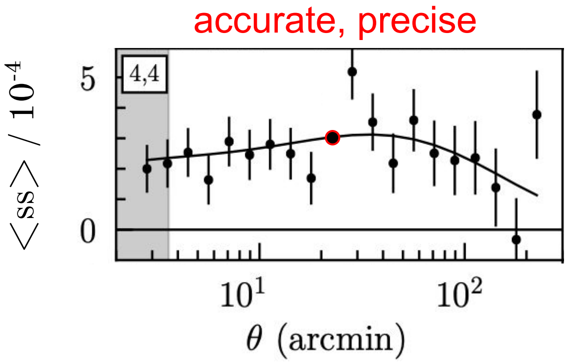
Vera C. Rubin Observatory

- Astronomical observatory in Chilean Andes
  - first light expected 2021
  - huge “light collecting area”: 3.5 degree field of view, 8m primary mirror
- *Legacy Survey of Space and Time* (LSST)
  - survey: not pointing at specific objects, but mapping out entire visible sky
  - observe **billions of galaxies** over 10 years: **60 PB of images**!

LSST project/NSF/Aura

challenges for Rubin Observatory

- 60 PB of data: must guarantee amazing measurements, right?
- We have statistical ***precision***, does not guarantee ***accurate*** results!



- We care about ***spatially correlated*** noise

Dark Energy Survey Y1 results

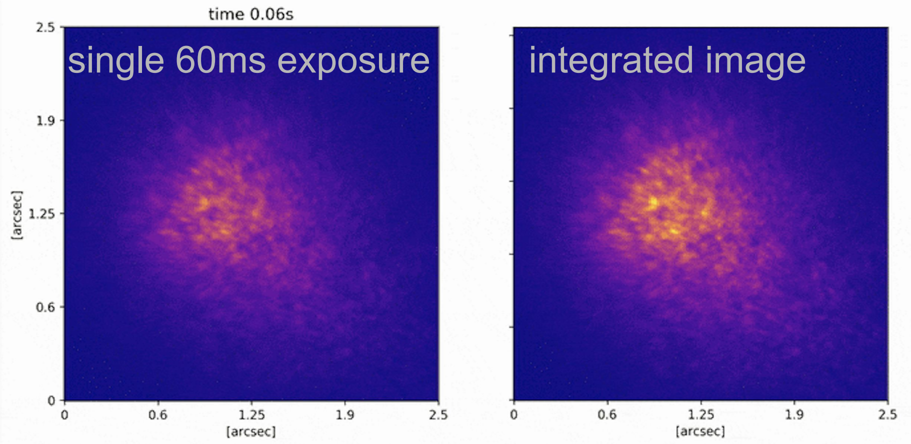
challenges for Rubin Observatory

- Many spatially correlated effects that *could* bias cosmology results
- Each needs careful study to evaluate impact
- I have focused on two:

  1. atmospheric turbulence
  2. instrument noise

1. atmospheric turbulence

- The atmosphere distorts light from far-away objects (e.g. a star “twinkles”)

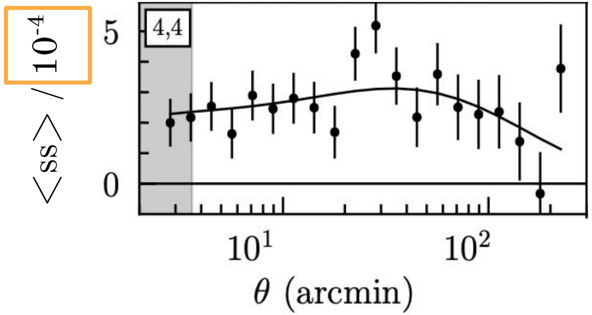


data: Zorro team, visualization: C-A Hébert

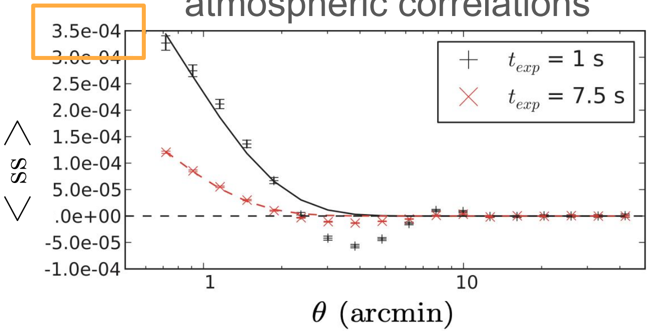
1. atmospheric turbulence

- The atmosphere distorts light from far-away objects (e.g. a star “twinkles”)
- Effect is spatially correlated

cosmological signal



atmospheric correlations



Heymans et al 2012

Dark Energy Survey Y1 results

1. atmospheric turbulence

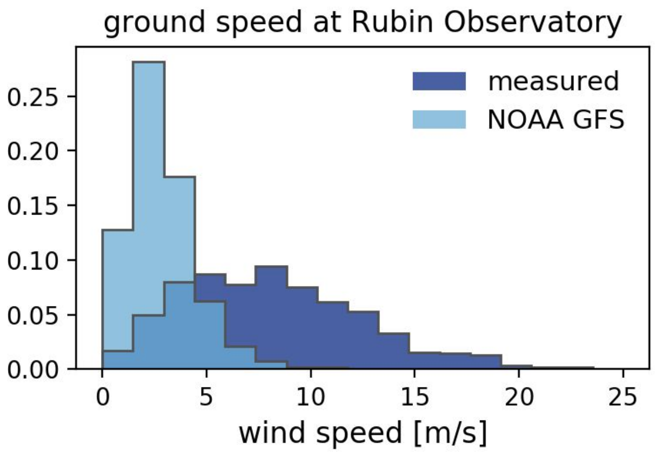
- Algorithms to model and mitigate these effects are optimized with simulations
- Simulations need to be realistic for robust performance on real data!

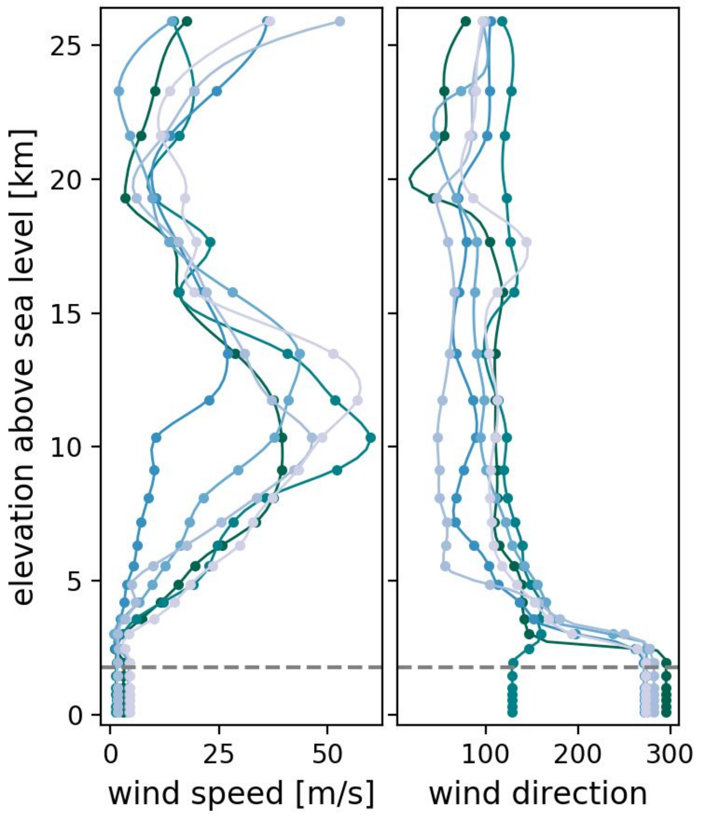
Two of my projects

- Establishing realistic input parameters for simulations
- Validation of simulations on high-quality data

1. atmospheric turbulence: realistic sims

- 2+ years of NOAA Global Forecasting System (GFS) outputs
  - Predictions for 20 altitudes, 4x/day
  - Of interest: wind speeds and directions
- Wind measurements from telescope site

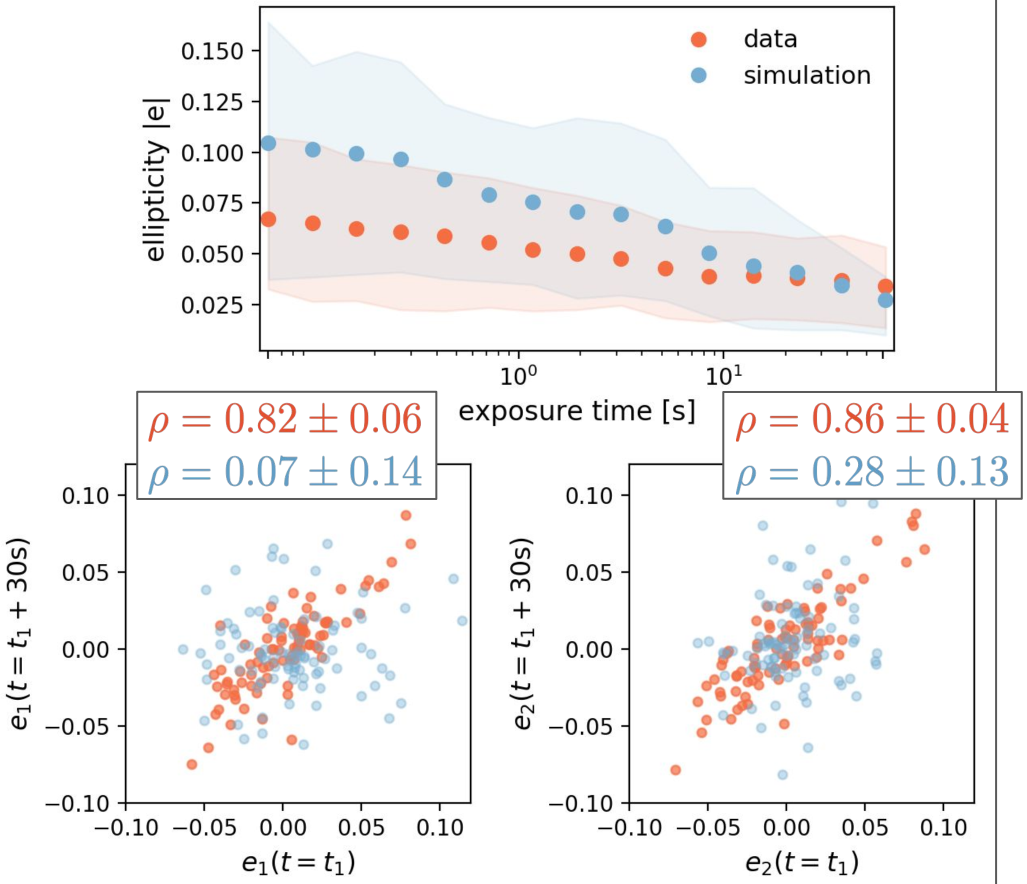




Hébert, C.-A. et al., *in prep*

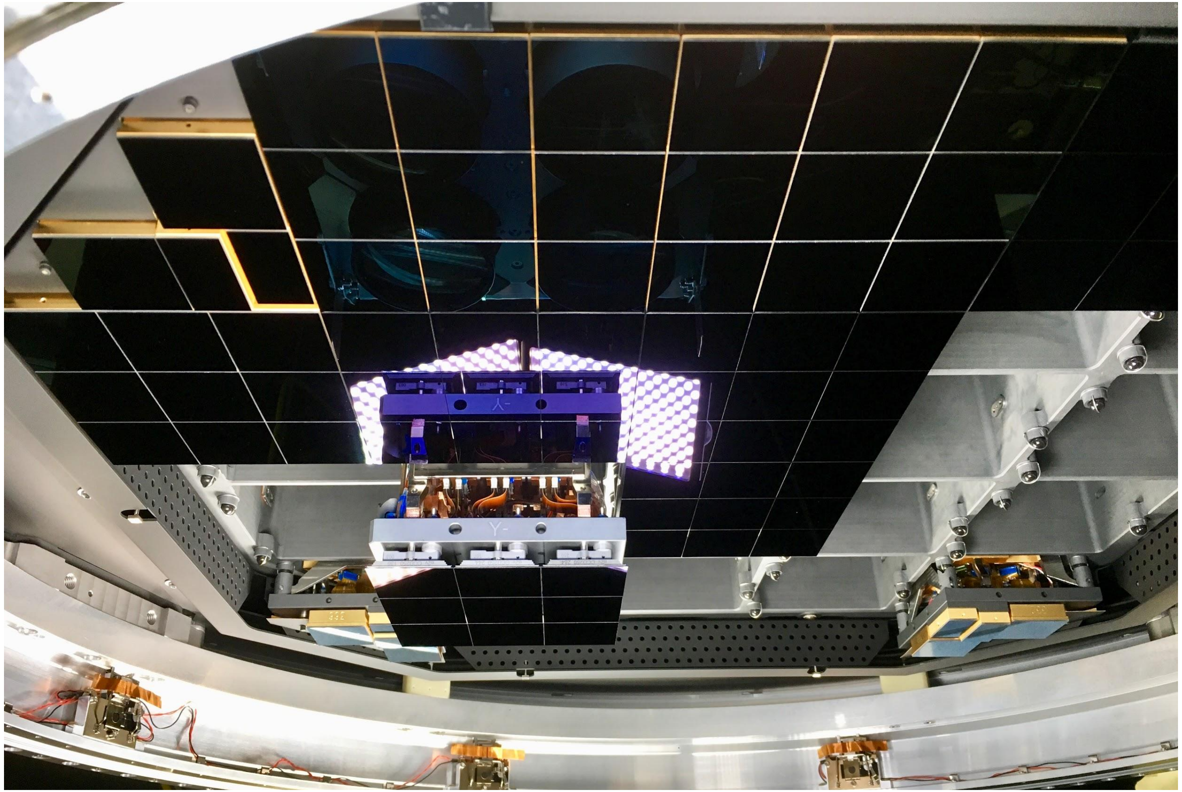
1. atmospheric turbulence: validating sims

- Data taken at telescope <2km from Rubin site
- Series of very short exposures
  - Each image: 60ms
  - Each series: 1000 images
- Enables unprecedented study of atmosphere-imprinted shape as function of exposure time



Hébert, C.-A. et al., *in prep*

2. instrument noise



LSST camera

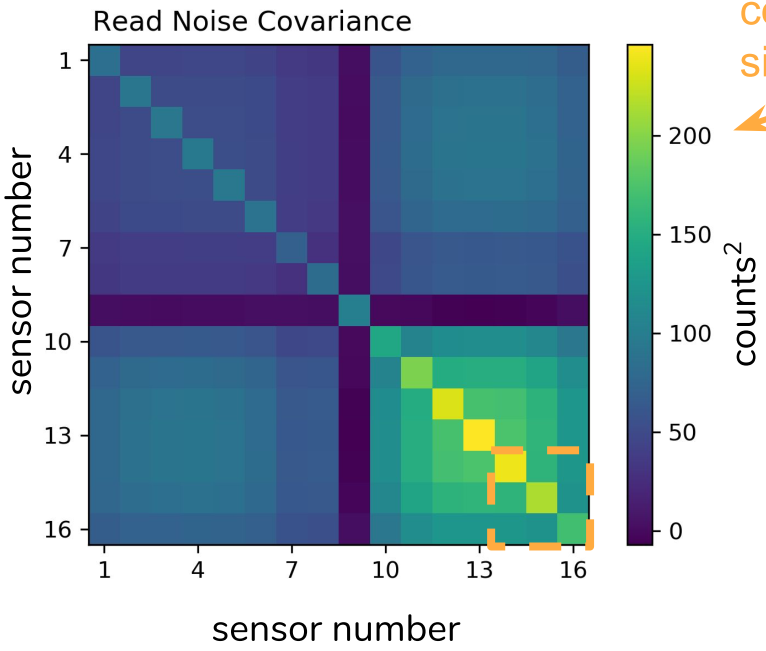
3.2 gigapixels

Very strict requirements on quality of sensors

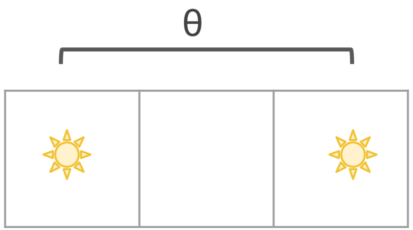
LSST camera project

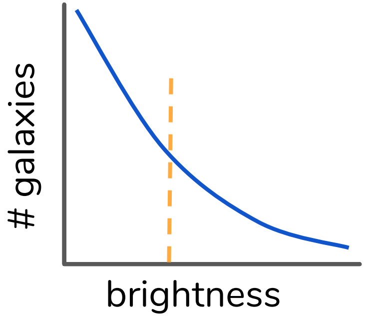
2. instrument noise

- Read noise: fluctuations in recorded counts during digitization



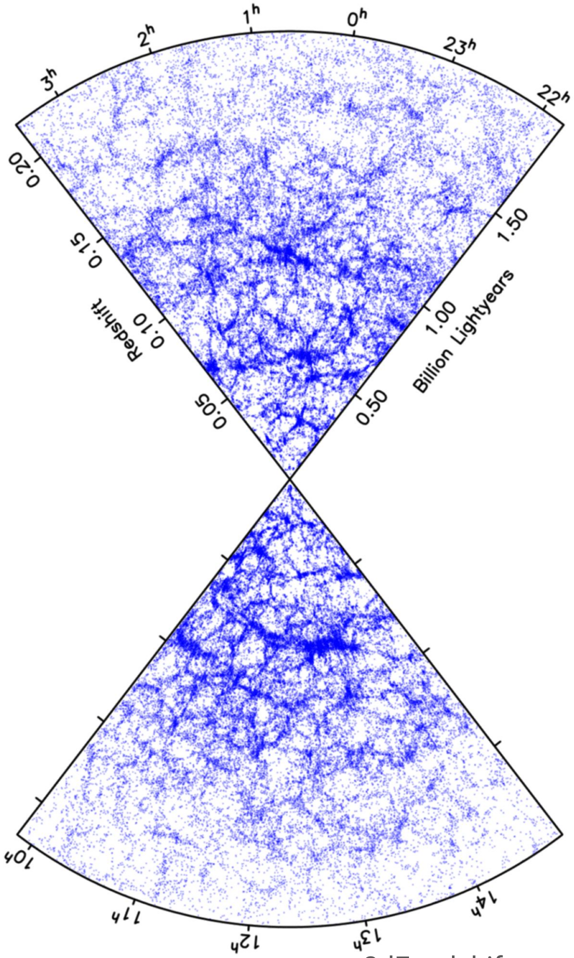
corresponds to ~ ⅙ the signal of faint star/galaxy





Looking forward

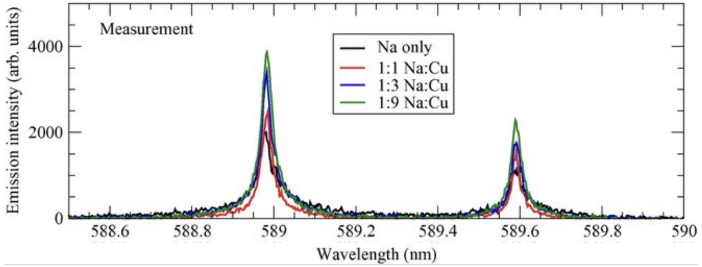
- Rubin Observatory will enable the most precise measurements of dark energy
- Depends on detailed studies of potential systematic biases, based on high fidelity numerical simulations, computational and statistical techniques, and comparison with data
- Survey data and results coming soon!



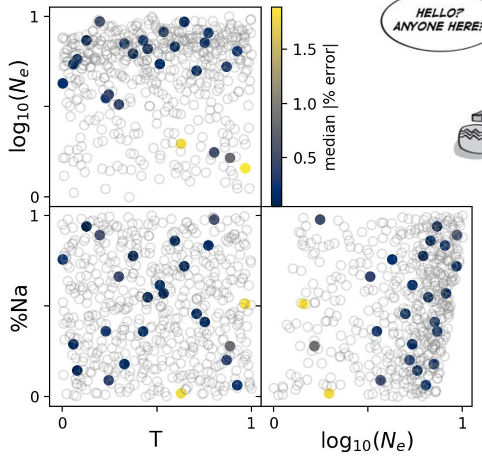
2dF redshift survey

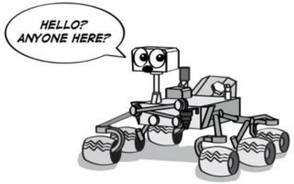
practicum (2018, 2019)

- LANL CCS-6: statistical sciences group
- Statistical models to estimate composition of Mars surface geology from Rover data



Judge, E et al. (2016), Spectrochimica Acta Part B





Hébert, C.-A. et al. *submitted*

Thank you! to some awesome people

Team Burchat + LSST Dark Energy Science Collaboration

2 x practicum hosts: Kary Myers, Earl Lawrence (LANL statistical sciences)

CSGF fellows who have become friends and colleagues

CSGF, Krell staff for making this all possible!

Stanford DOE CSGF Los Alamos NATIONAL LABORATORY EST. 1943 LSST DESC Dark Energy Science Collaboration