TIME-DOMAIN ASTRONOMY

Lectures 10: Astrostatistics Future

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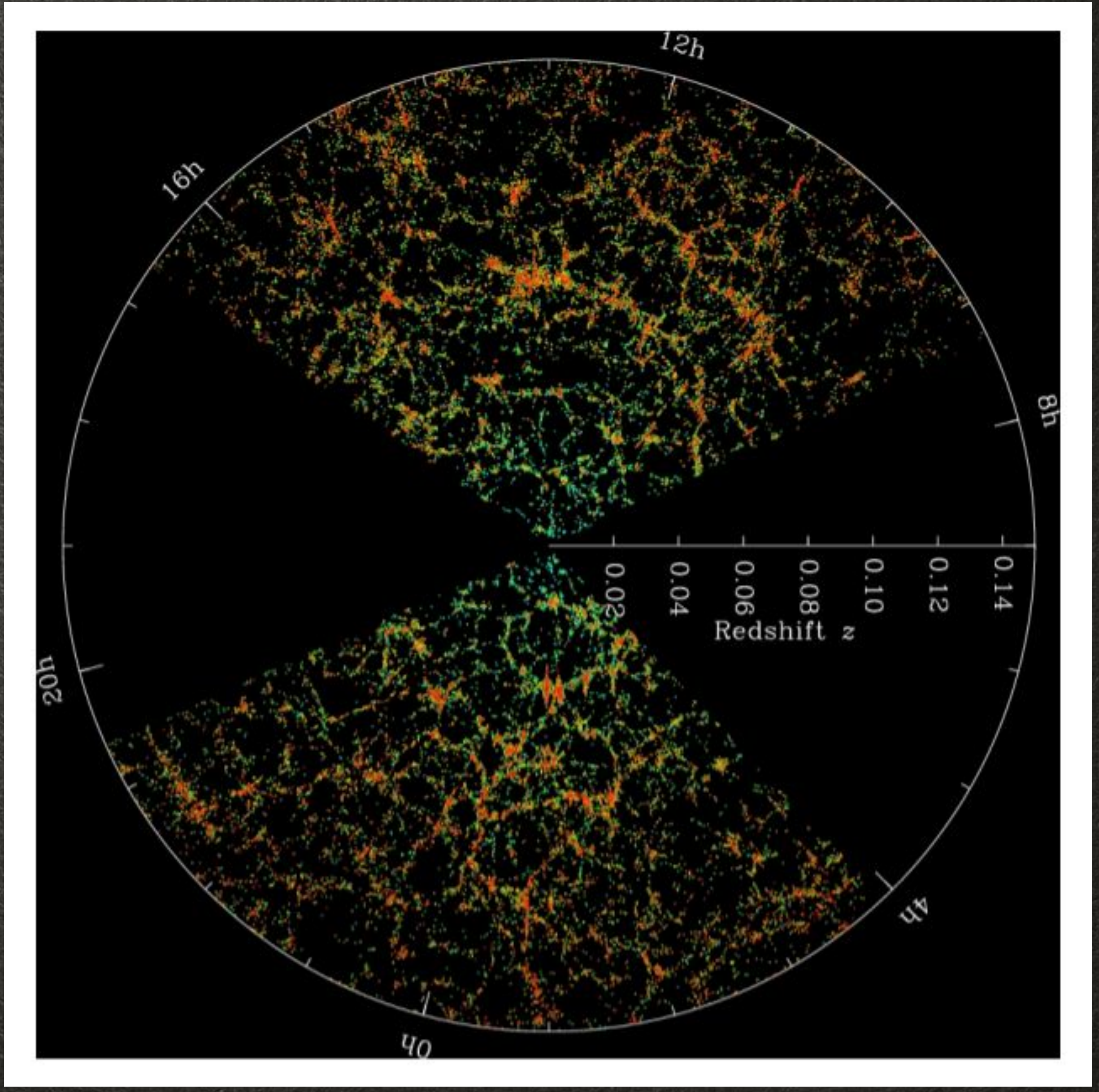
21st Century Challenges

- Big data in modern astronomy is not just a “hot keyword”
- Observational astronomy today is a considerable enterprise with billions of dollars supporting ~20,000 scientists producing ~15,000 refereed papers annually.
- Not to mention the theoretical efforts, often based on profitable synergies with other fields.
- Astrostatistics is playing an increasing role in the analysis of astronomical observations and linking data to astrophysical theory.

Open problems in astrostatistics

- Galaxy clustering: the distribution of galaxies in space proves to be surprising complex from the viewpoint of spatial point processes.



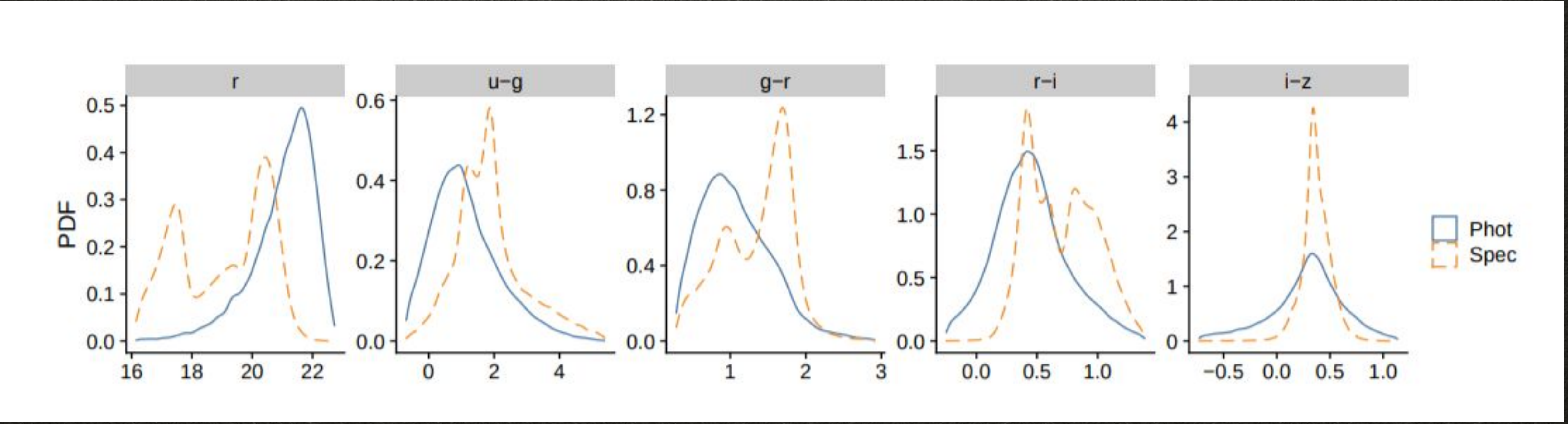
- Many statistical studies of large-scale structure rely on isotropic two- and three-point correlation functions as well as Fourier power spectra.

- Other studies seek to locate particular clusters, filaments or voids.

Open problems in astrostatistics

- The Photo-Z Conundrum: photometric redshift (photo-z) estimation has become a vital tool in the extragalactic astronomy and observational cosmology.

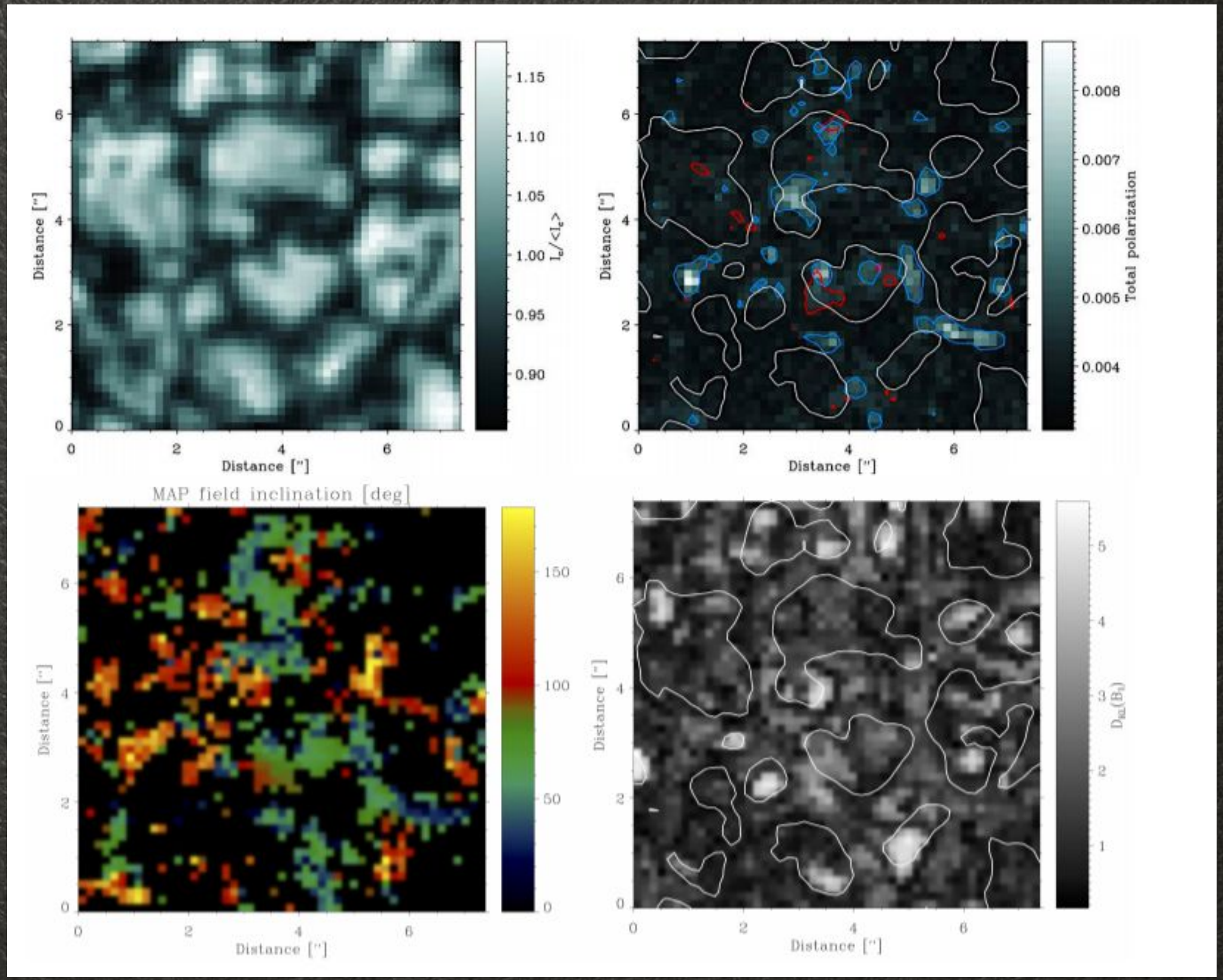
- The challenge of photo-z accuracy then depends on the statistical procedures used to calibrate photometric measurements to spectroscopic redshifts.



Open problems in astrostatistics

- Bayesian Modeling of the Sun, stars, and planetary systems.

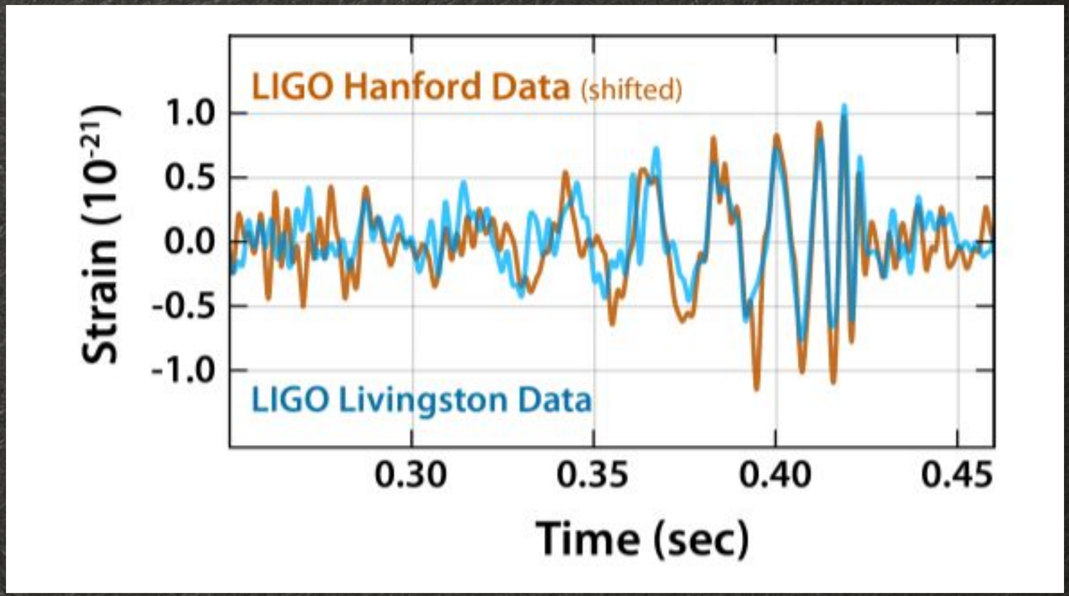
- Sampling algorithms, theoretical advancements related to prior selections, etc.
- Likelihood-free modeling: two main forms of statistical models can be distinguished: those describe by probability distributions for which an explicit likelihood can be written, and implicit or generative models.



Open problems in astrostatistics

- Challenges in signal detection: periodicity Detection in Irregular Time Series.
- The study of variable objects in the sky – time domain astronomy – is burgeoning with more than 2000 studies annually.

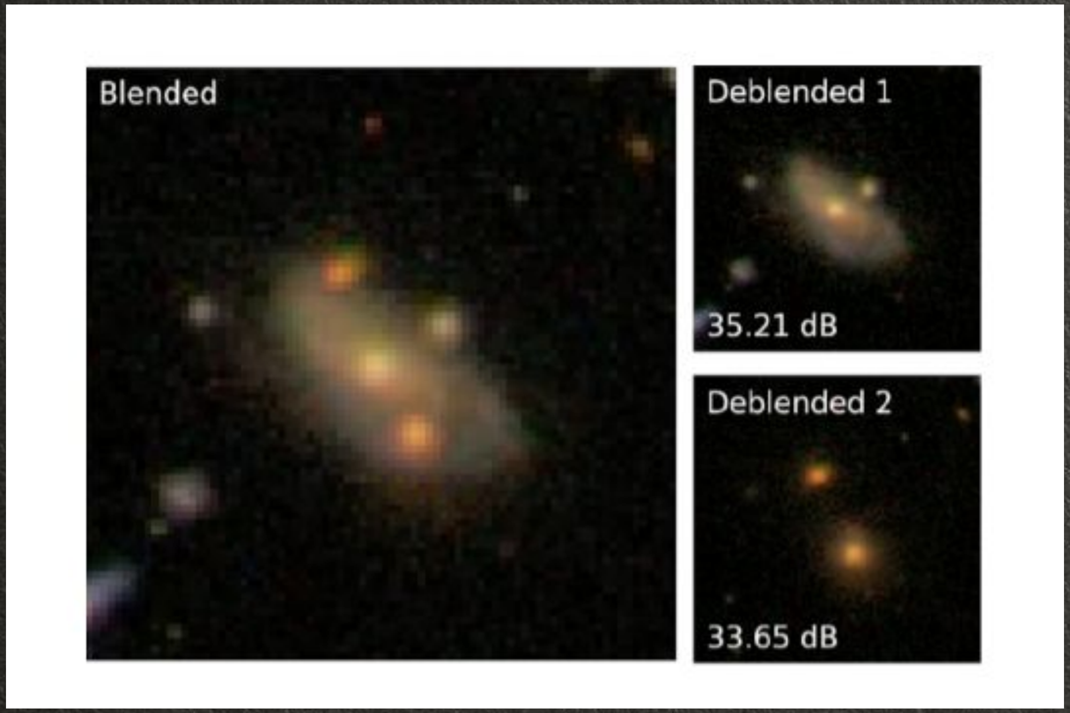
- Gravitational wave detection: the statistical challenge with is to detect short-lived chirp-like events in a continuous time series where noise is dominated by instrumental effects that can be continuous (perhaps caused by vibrations in the mirror structures) or transient (perhaps caused by minor Earth tremors).

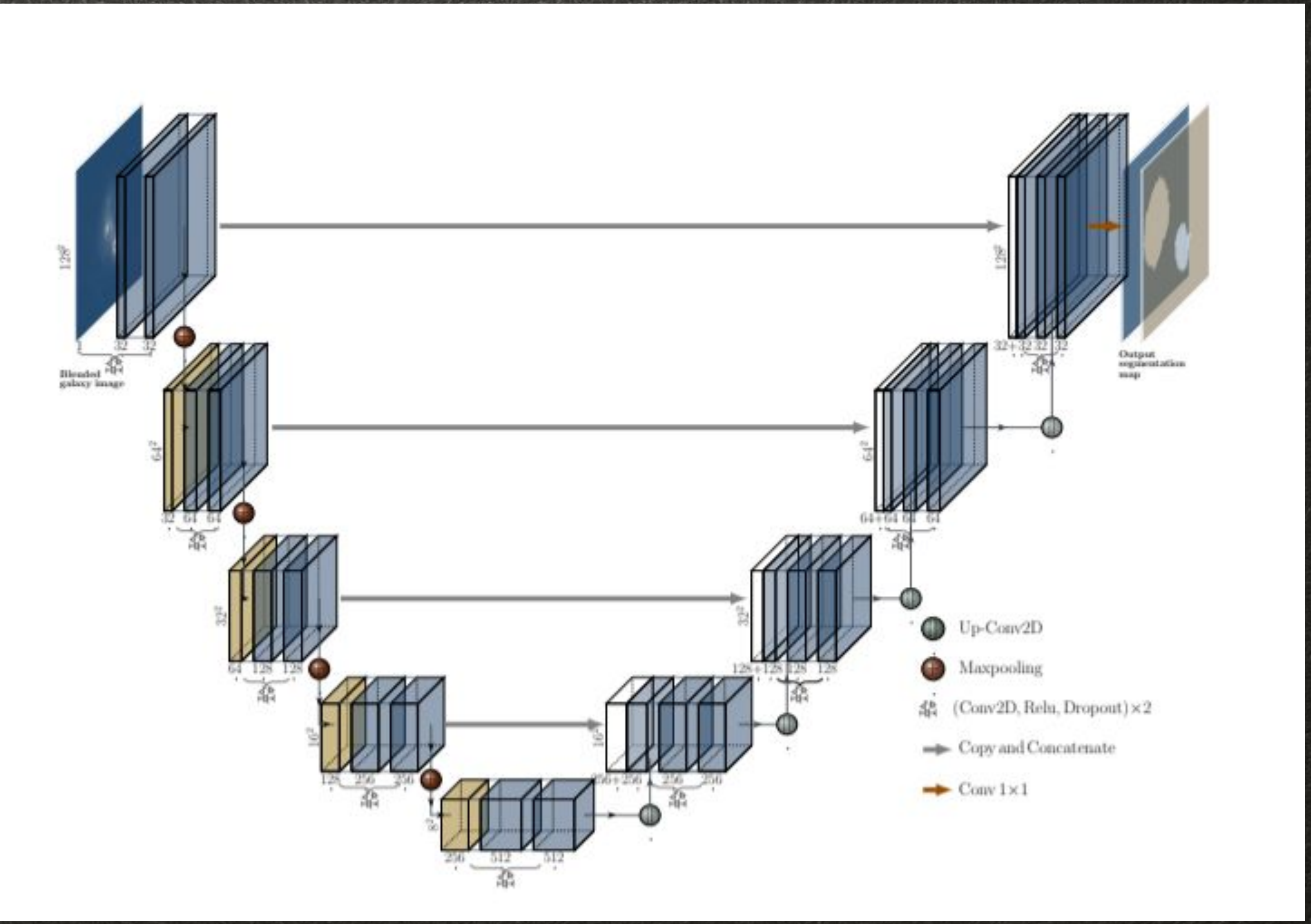


Open problems in astrostatistics

- Machine learning techniques: a literally “exploding” field.

  - Just a couple of instances: photometry of blended galaxies and the accelerated expansion of the universe.





Open problems in astrostatistics

- Contemporary astronomical data analysis often elude the capabilities of classical statistical techniques, and inevitably requires the use and development of sophisticated, and sometimes novel, statistical tools.

- Astronomy requires expertise in vast fields of statistics and information science: nonparametric and parametric inference (especially Bayesian), high-dimensional nonlinear regression, censoring and truncation, measurement error theory, spatial point processes, image analysis, time series analysis, multivariate analysis, clustering and classification, and many other forms of machine learning.

Take all of this very seriously!

REFERENCES AND DEEPENING

Eric Feigelson

21st Century Statistical and Computational Challenges in Astrophysics

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Abstract

Modern astronomy has been rapidly increasing our ability to see deeper into the universe, acquiring enormous samples of cosmic populations. Gaining astrophysical insights from these datasets requires a wide range of sophisticated statistical and machine learning methods. Long-standing problems in cosmology include characterization of galaxy clustering and estimation of galaxy distances from photometric colors. Bayesian inference, central to linking astronomical data to nonlinear astrophysical models, addresses problems in solar physics, properties of star clusters, and exoplanet systems. Likelihood-free methods are growing in importance. Detection of faint signals in complicated noise is needed to find periodic behaviors in stars and detect explosive gravitational wave events. Open issues concern treatment of heteroscedastic measurement errors and understanding probability distributions characterizing astrophysical systems. The field of astrostatistics needs increased collaboration with statisticians in the design and analysis stages of research projects, and to jointly develop new statistical methodologies. Together, they will draw more astrophysical insights into astronomical populations and the cosmos itself.


A forza di guardare il cielo e di respirare a pieni polmoni
l’aria fresca della notte, mi sembrava di riempirmi di stelle
Tiziano Terzani