PICASSSO

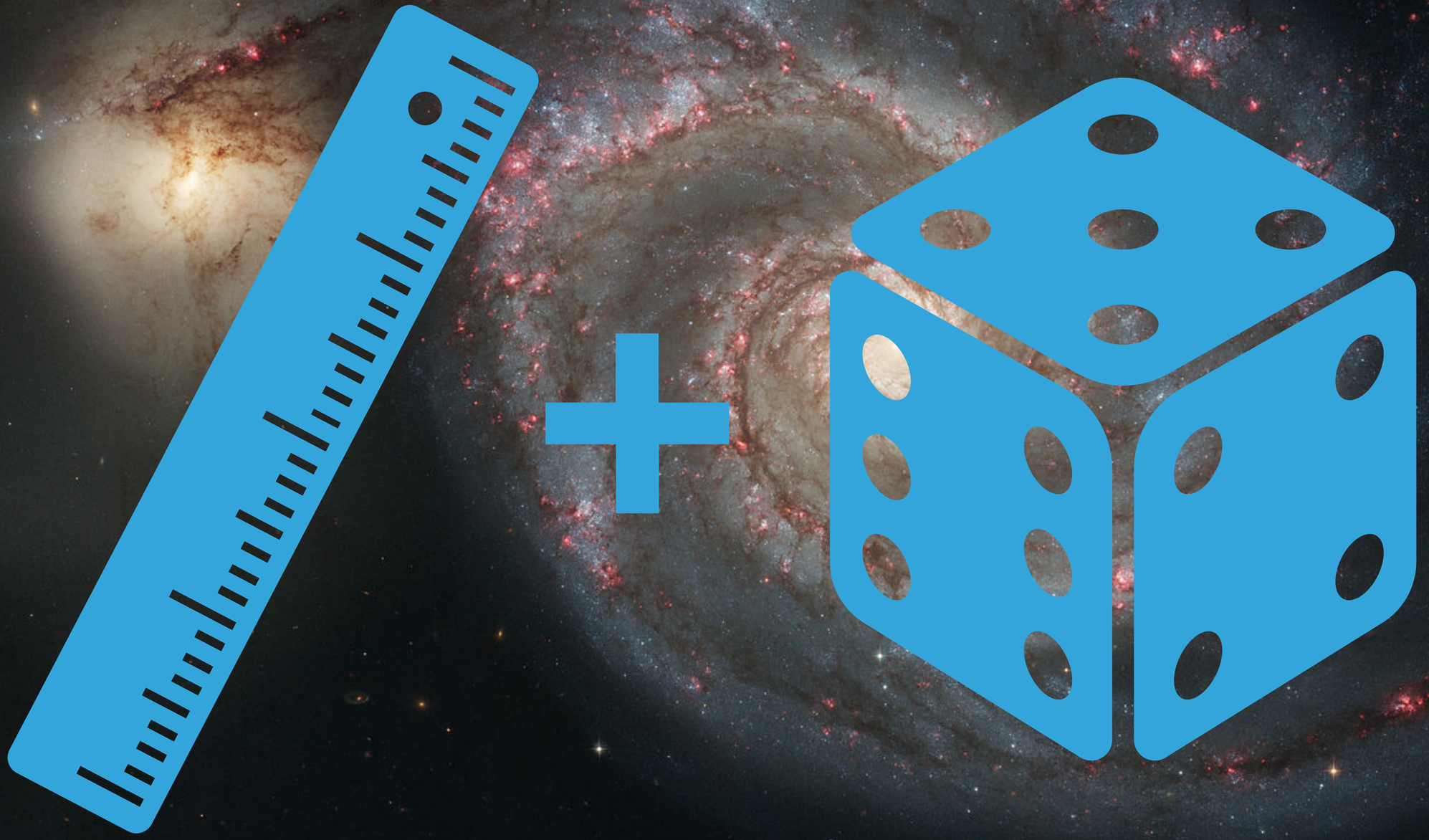
Visage dans étoile,
Pablo Picasso (1947)

TOBIAS BUCK & STEFFEN WOLF

PAINTING INTRINSIC ATTRIBUTES ONTO SDSS OBJECTS

LEIBNIZ-INSTITUT FÜR ASTROPHYSIK POTSDAM (AIP),
tbuck@aip.de

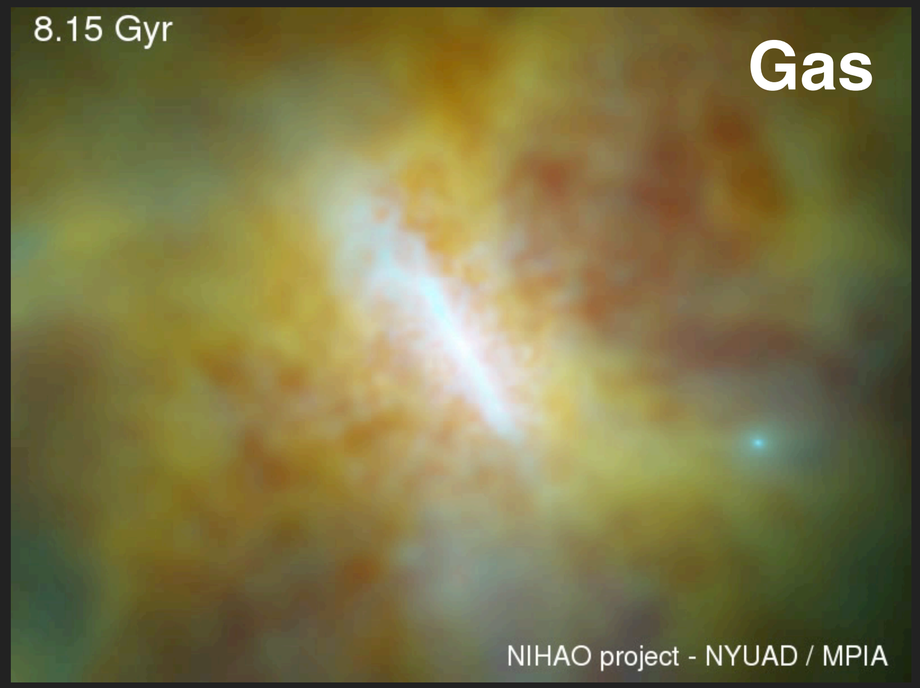
FORWARD MODELLING FOR SIMULATORS

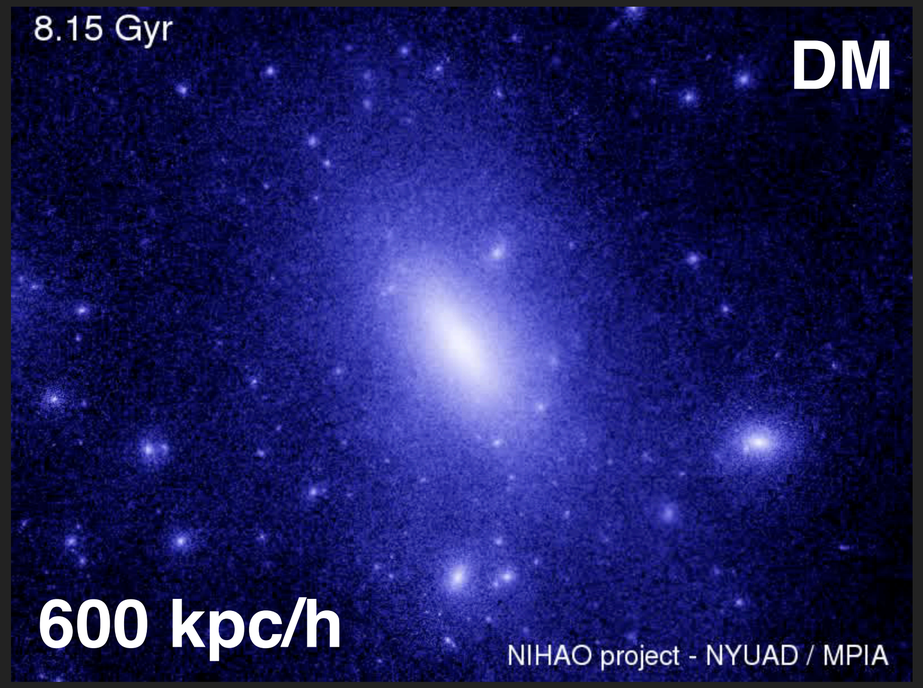


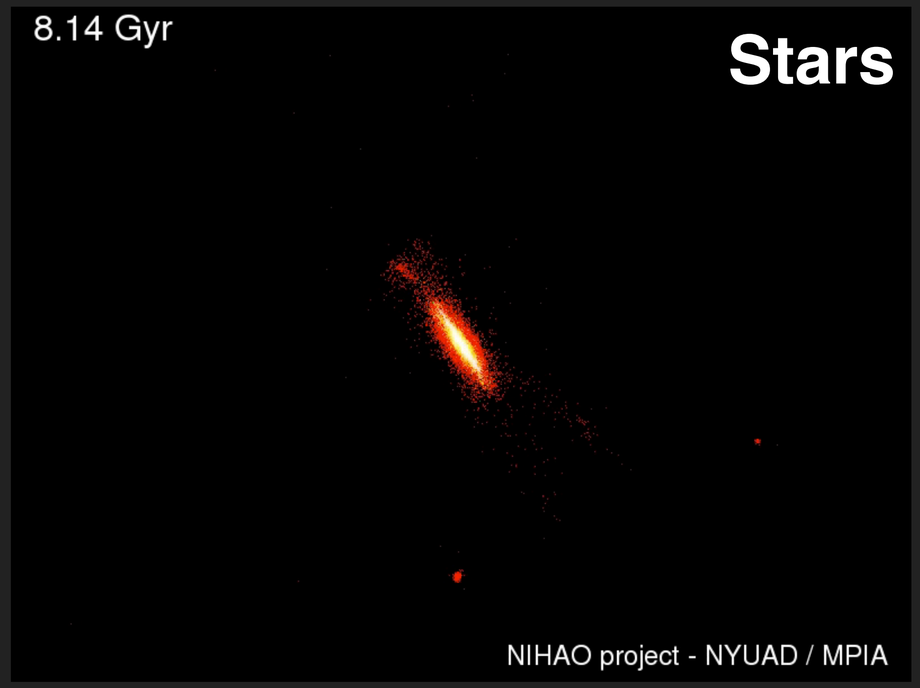
MY DAILY WORK...

scene taken from: The Marsian

cosmological zoom-in hydro simulations of a Milky Way analogue



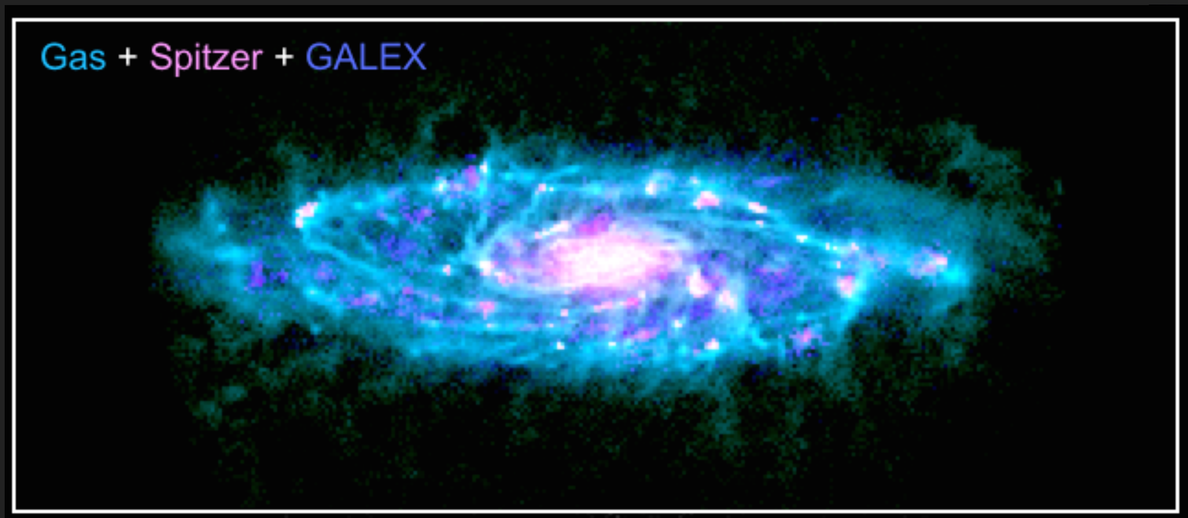


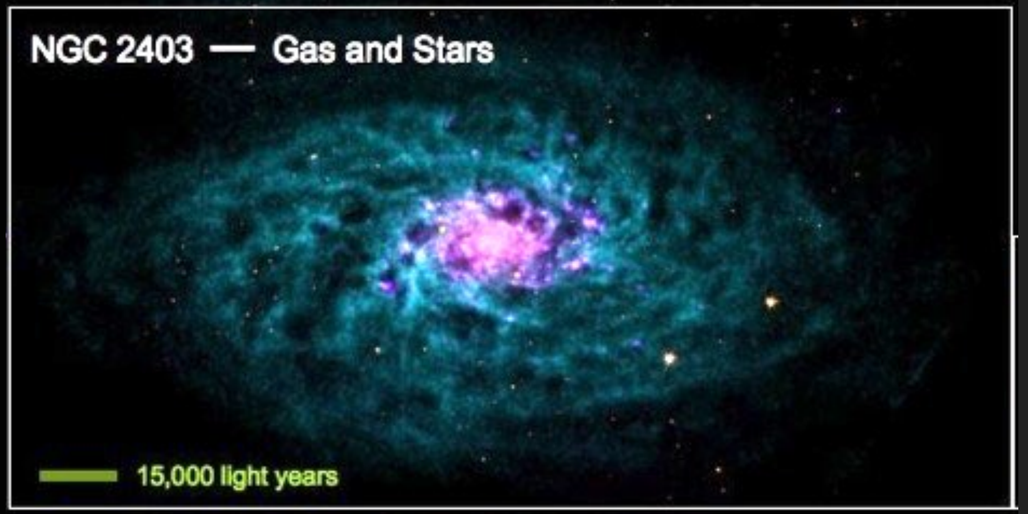


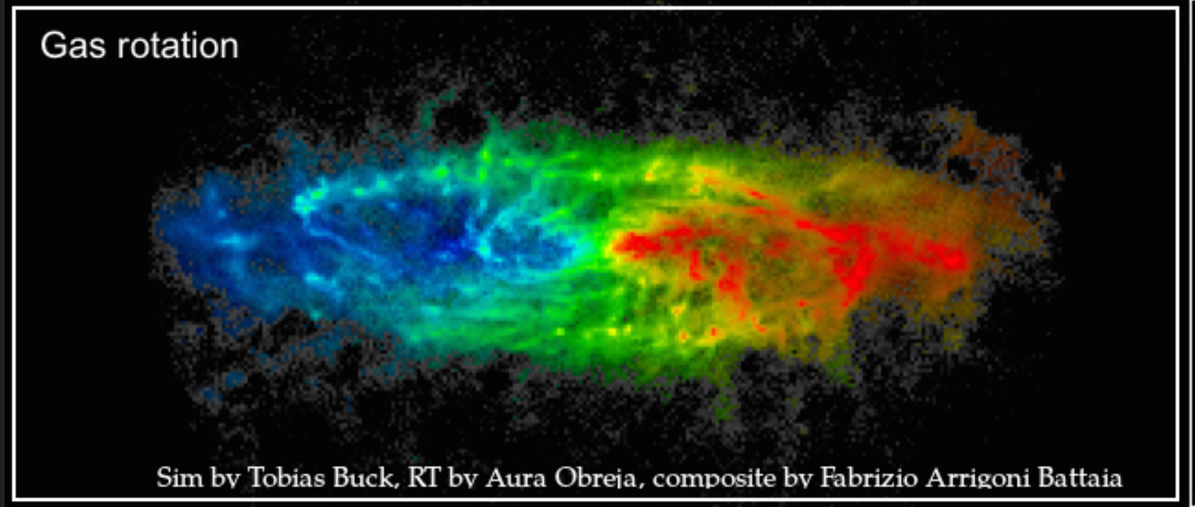
POST-PROCESSING BY RADIATIVE TRANSFER

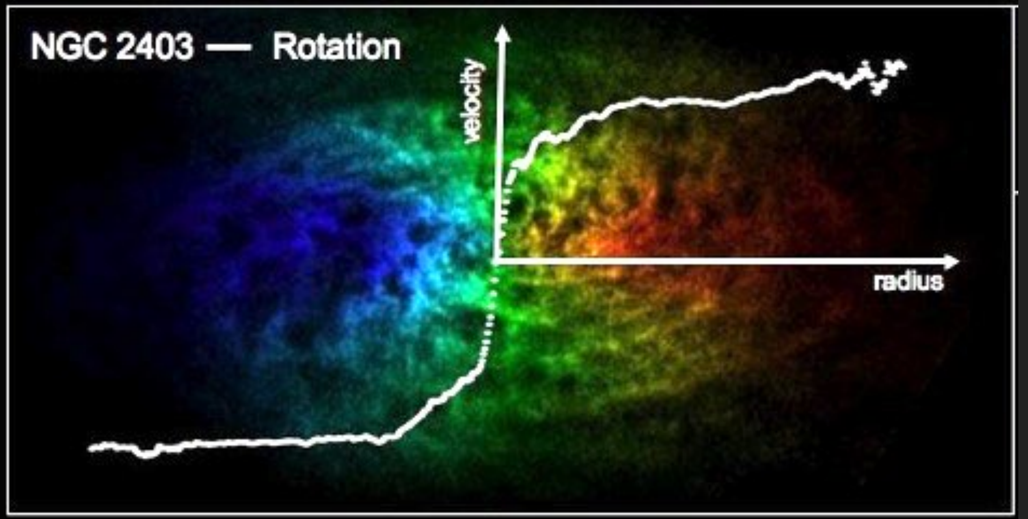
simulation

observation









LARGE SCALE SURVEYS: CHALLENGE FOR CONVENTIONAL ANALYSIS / MODELLING

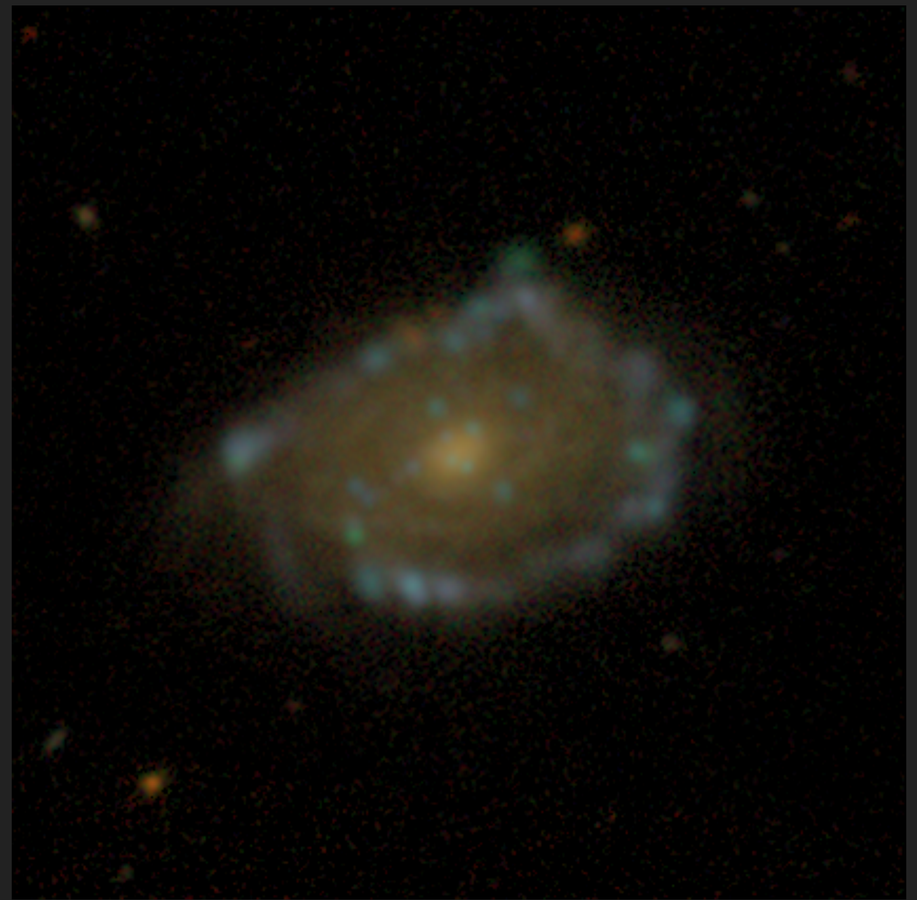
PHOTOMETRIC DATA FOR MILLIONS OF GALAXIES,
(EUCLID, LSST, DES, COSMOS, DEEP2, BUT ALSO LEGACY DATA LIKE SDSS)

CLASSICAL ANALYSIS/CLASSIFICATION (VISUAL OR GALAXY ZOO LIKE) NOT FEASIBLE

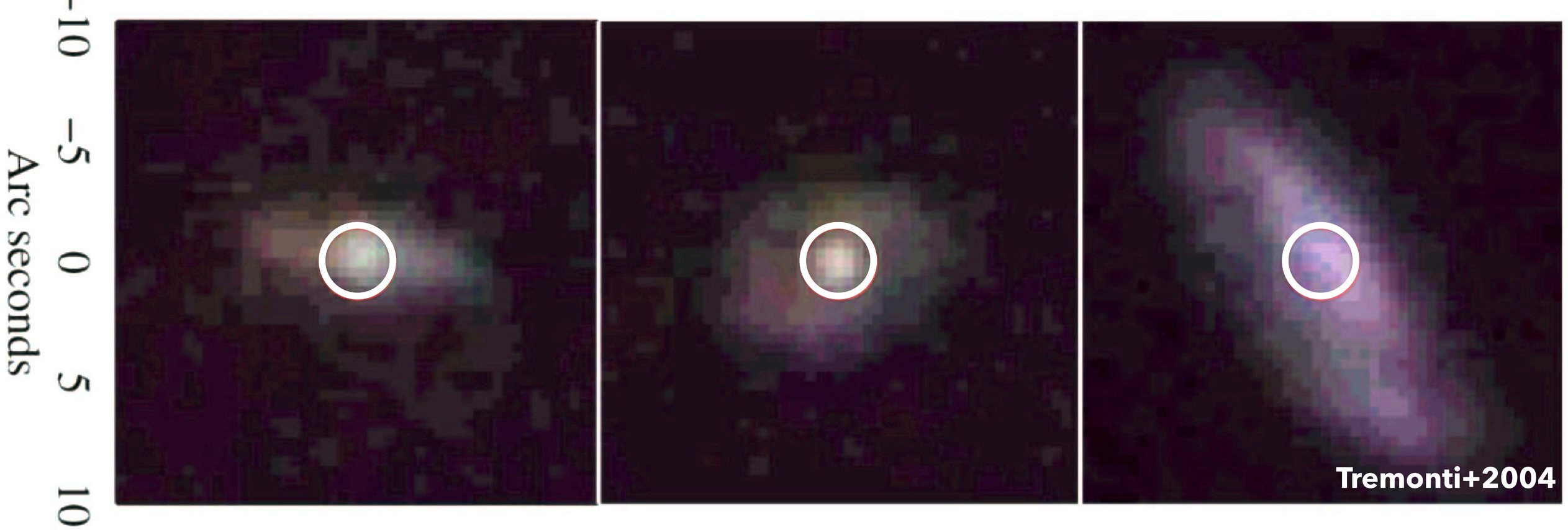
DATA EXPLORATION BEYOND (SIMPLE) MORPHOLOGICAL CLASSIFICATION

- RESOLVED GALAXY PROPERTIES

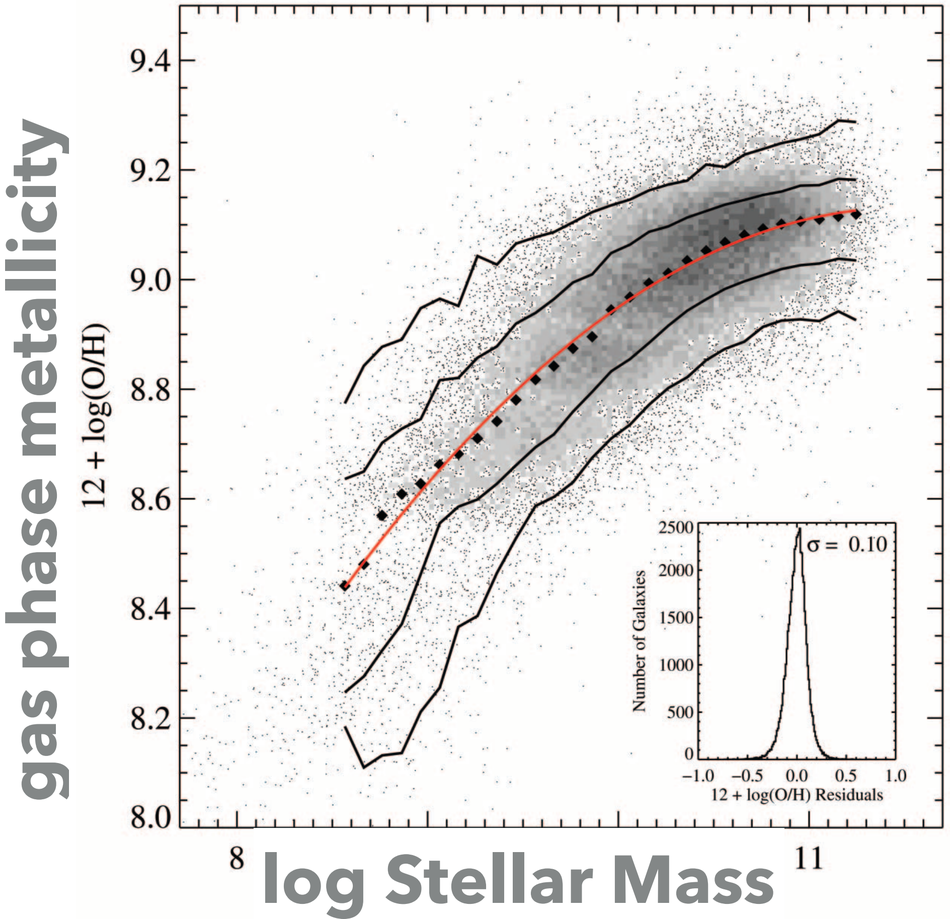
EXAMPLE: SDSS IMAGING

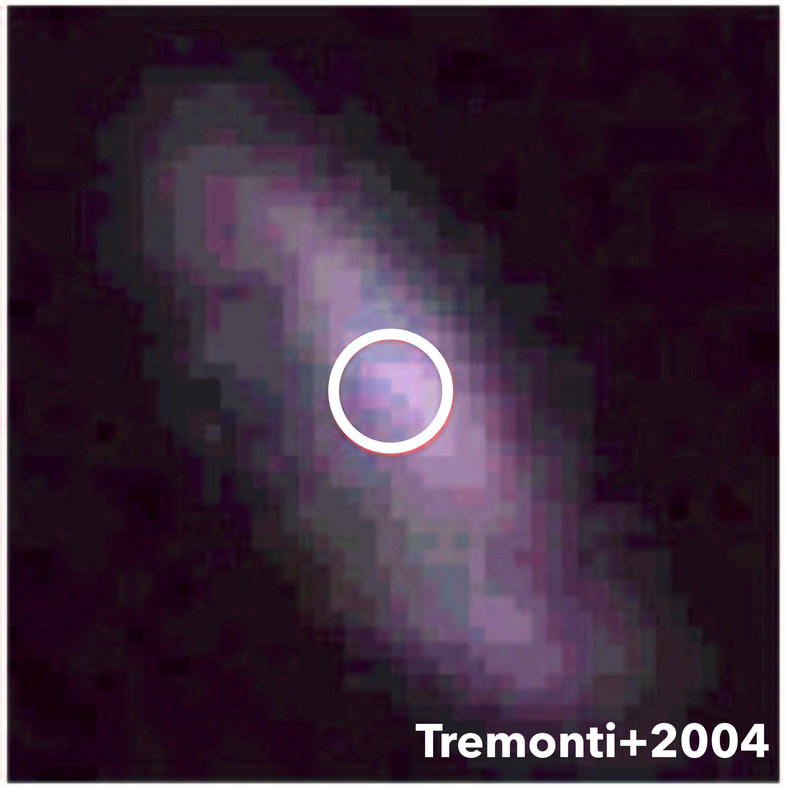


CLASSIC SDSS ~100.000 GALAXIES



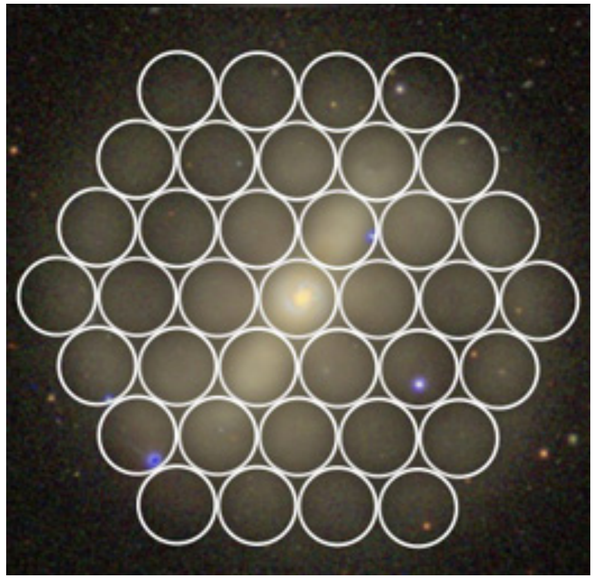
CLASSIC SDSS ~100.000 GALAXIES

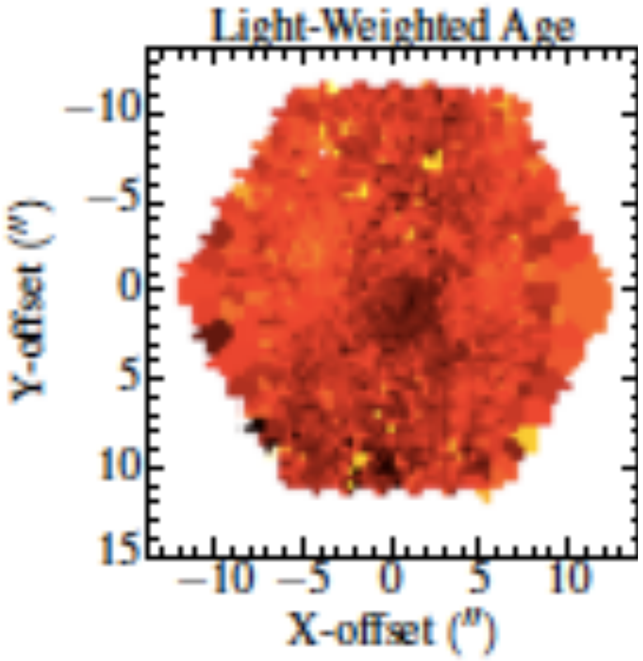


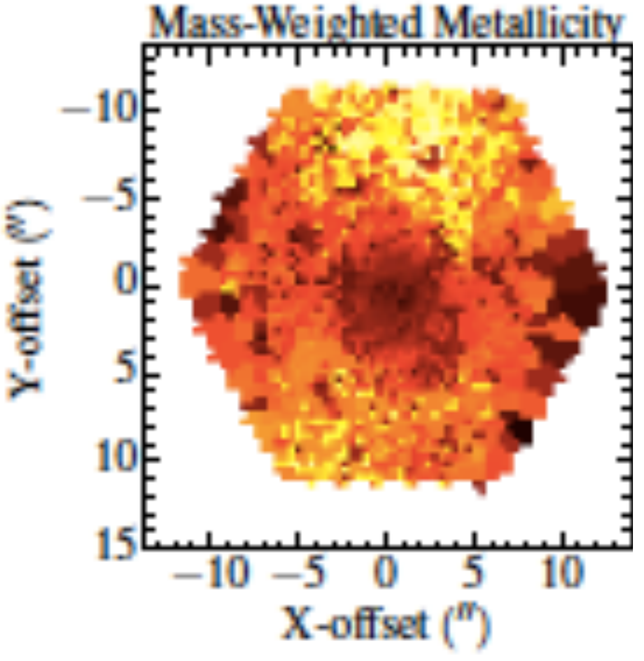


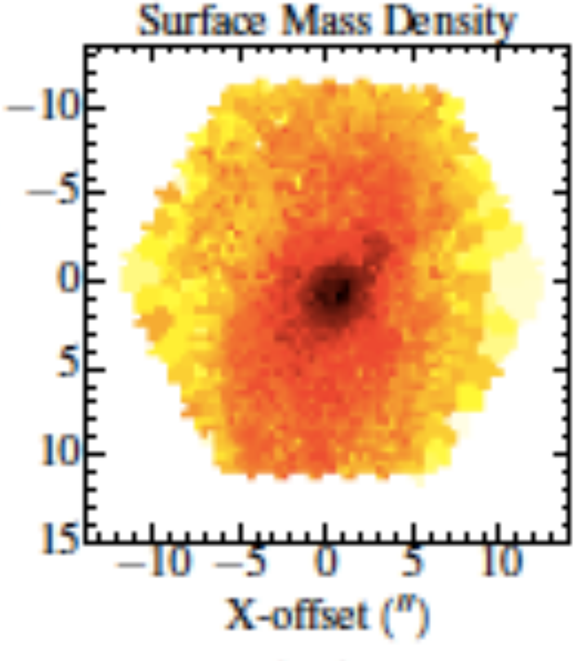
SDSS MANGA ~10.000 GALAXIES

EXPENSIVE INTEGRAL FIELD SPECTROSCOPY









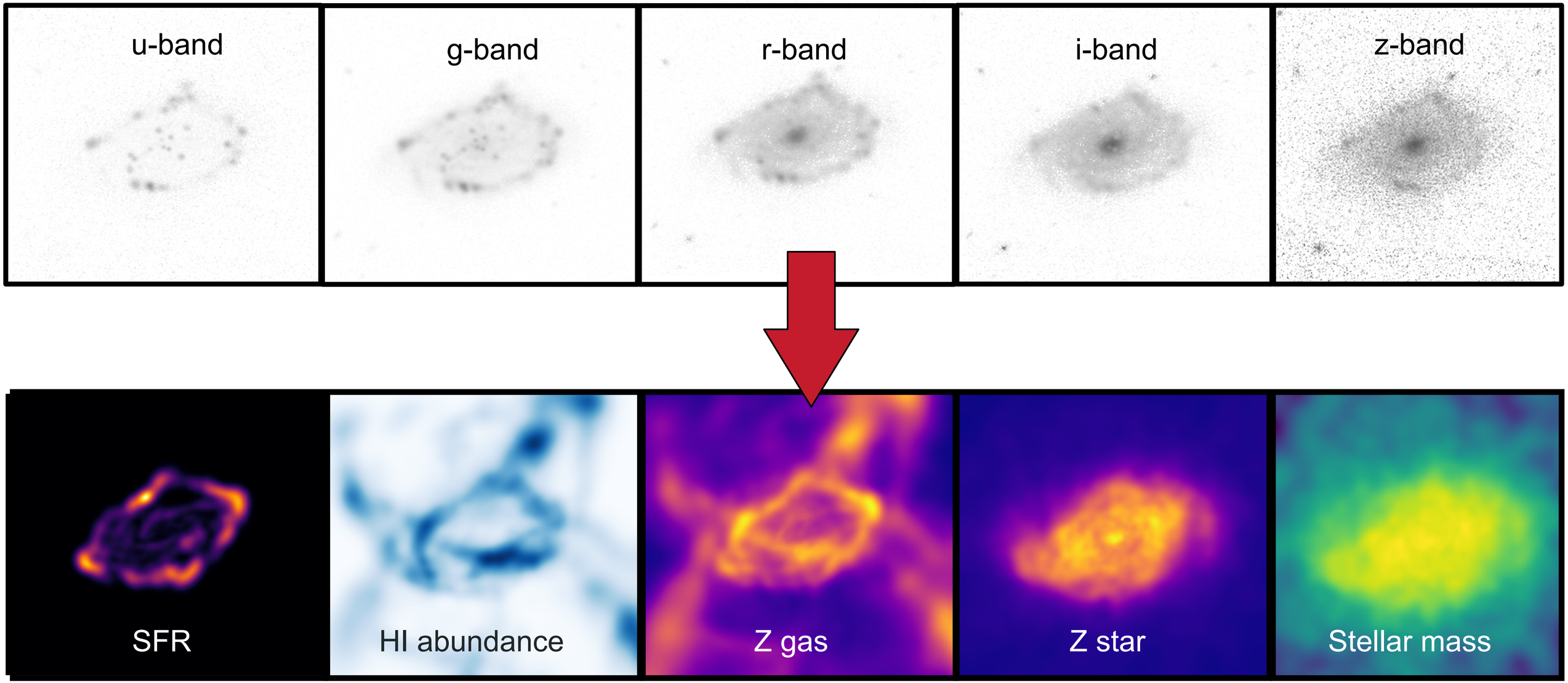
CAN WE BUILD A (SIMPLE) ANALYSIS TOOL WHICH:

- WORKS ON LARGE PHOTOMETRIC DATA SETS
  - A. FAST

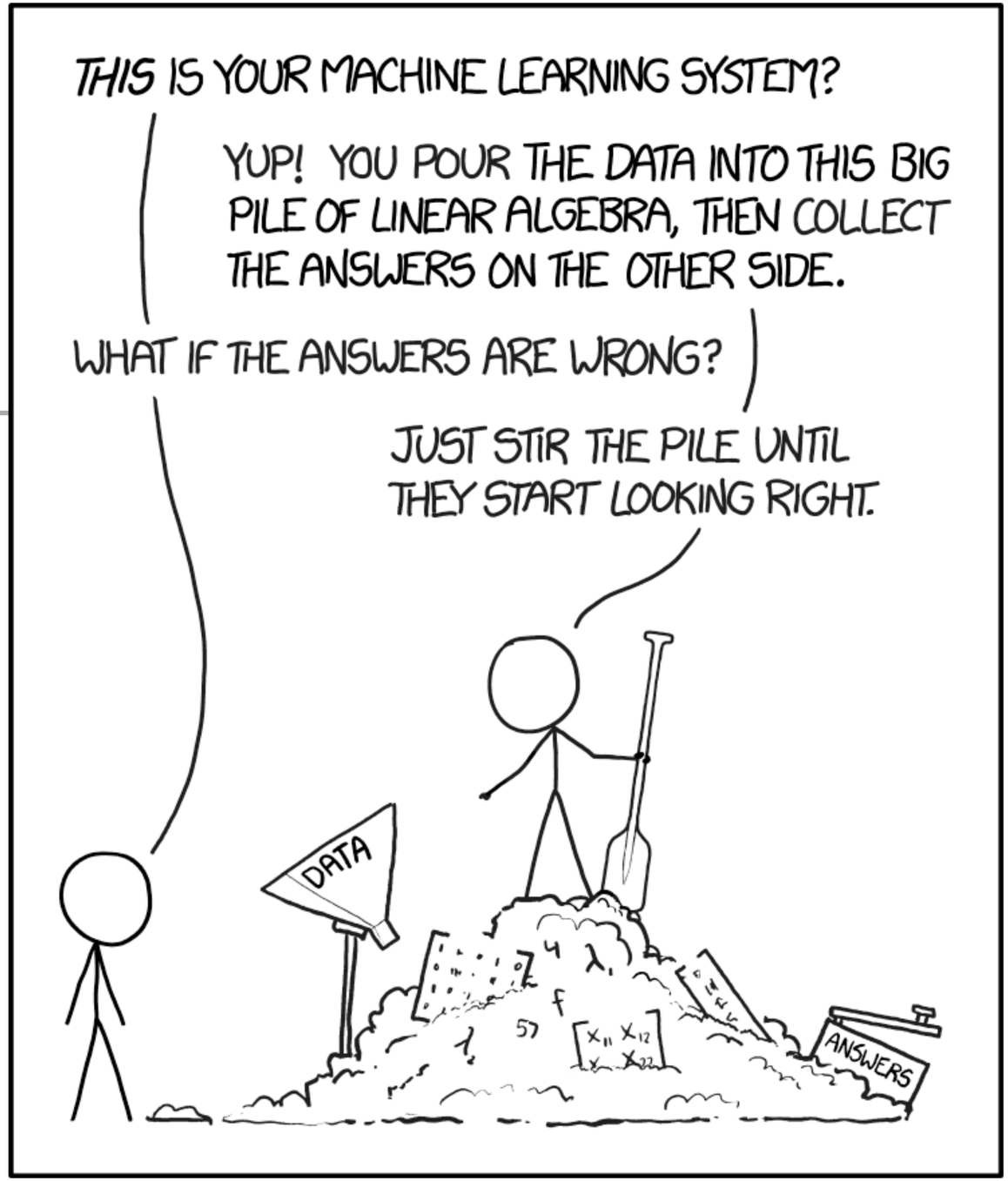
- IS EASY TO HANDLE
  - C. AUTOMATION
  - D. GENERALIZATION

➡ FAST, OFF-THE-SHELF TOOL, READY TO USE

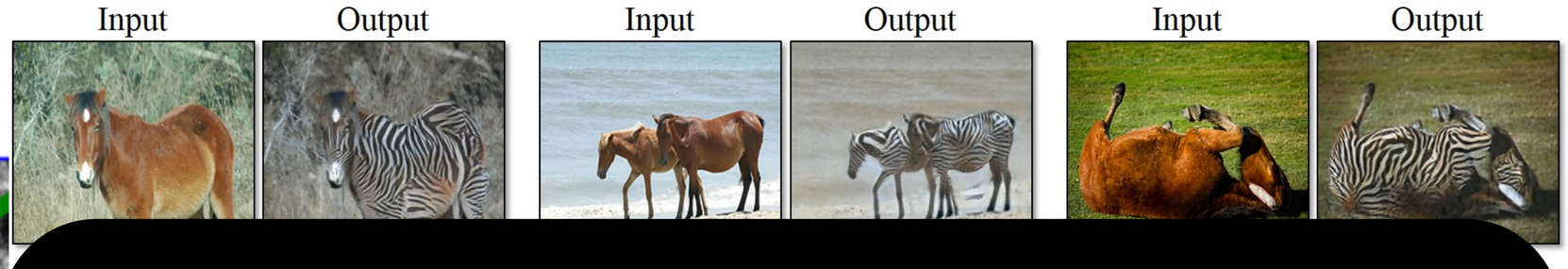
IMAGING DATA TO PHYSICAL PROPERTIES



METHOD: DEEP LEARNING



SIMILAR APPLICATIONS



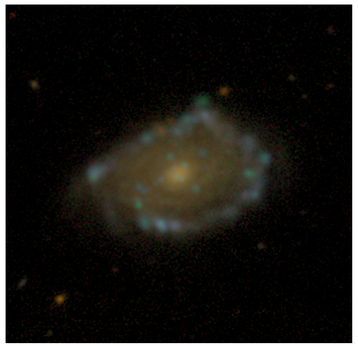
Share a common Architecture:

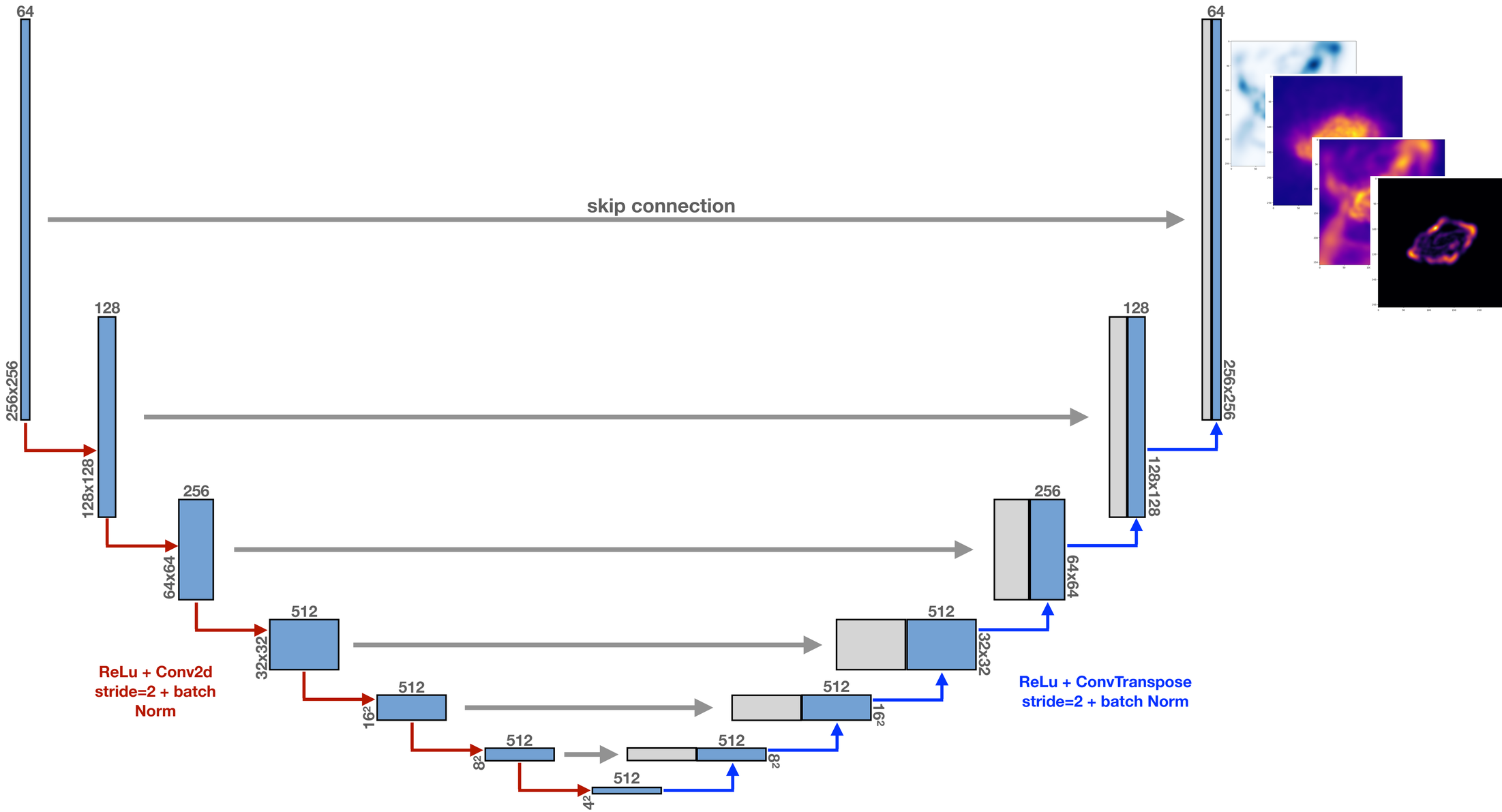
UNet (Ronneberger+2015)

U-NET ARCHITECTURE: PIX2PIX

Isola+ CVPR 2017

(CONDITIONAL GAN)





WHAT IS DIFFERENT WHEN PREDICTING PHYSICAL PROPERTIES

- Almost all CNNs are classifiers: $Y \in \{0, 1\}^N$
- Here $Y \in \mathbb{R}^N$ with multiple orders of magnitude

1. Predict log(Y)
2. Quantized Regression [Güler et al. *CVPR* 2017]

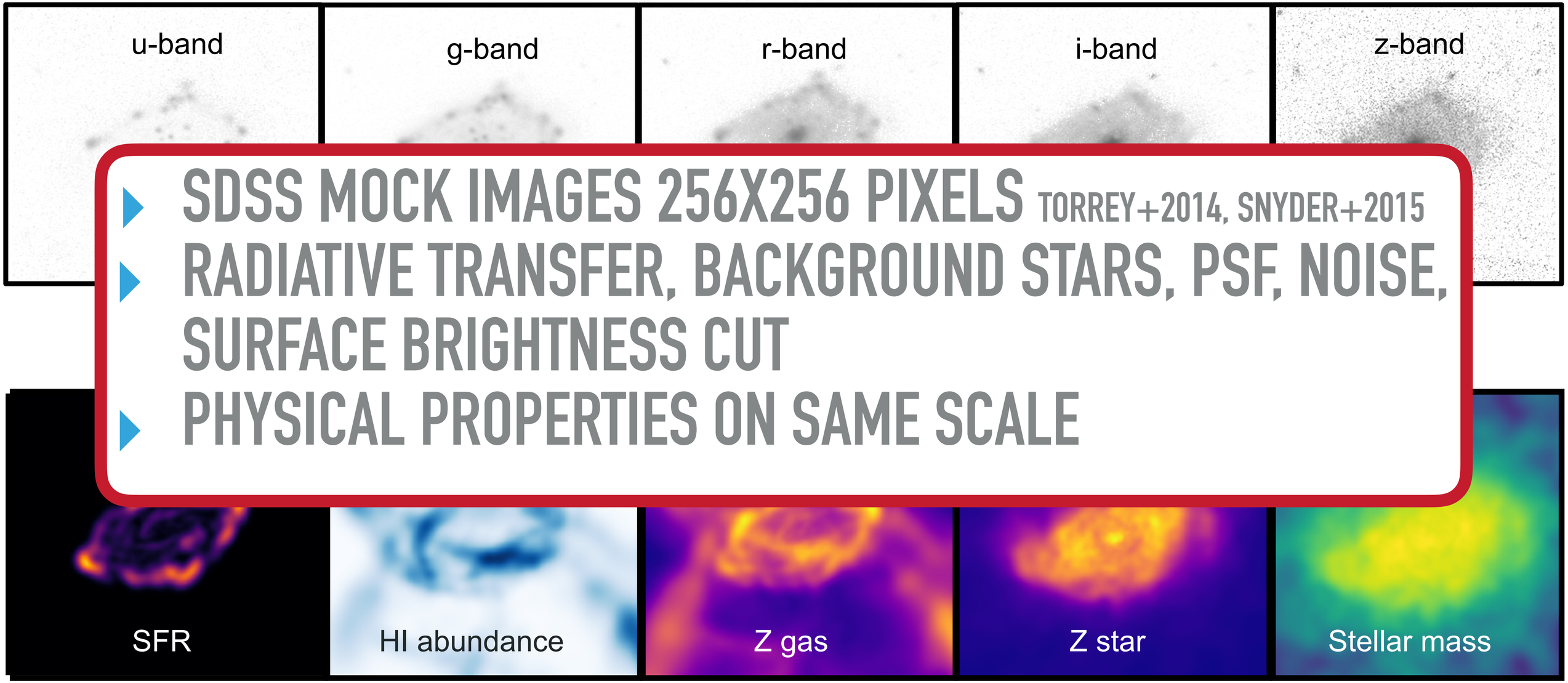
Bins $B = \{-14, -12, \ldots, 0, 2\}$

quantiles $q \in [0,1]^{|B|-1}$

residuals $r \in [0,1]^{|B|-1}$

$$f_\theta(x) = \sum_{i=0}^{|B|-2} q_i \left(B_i + r_i \left(B_{i+1} - B_i \right) \right)$$

PROOF OF CONCEPT: ILLUSTRIS DATA

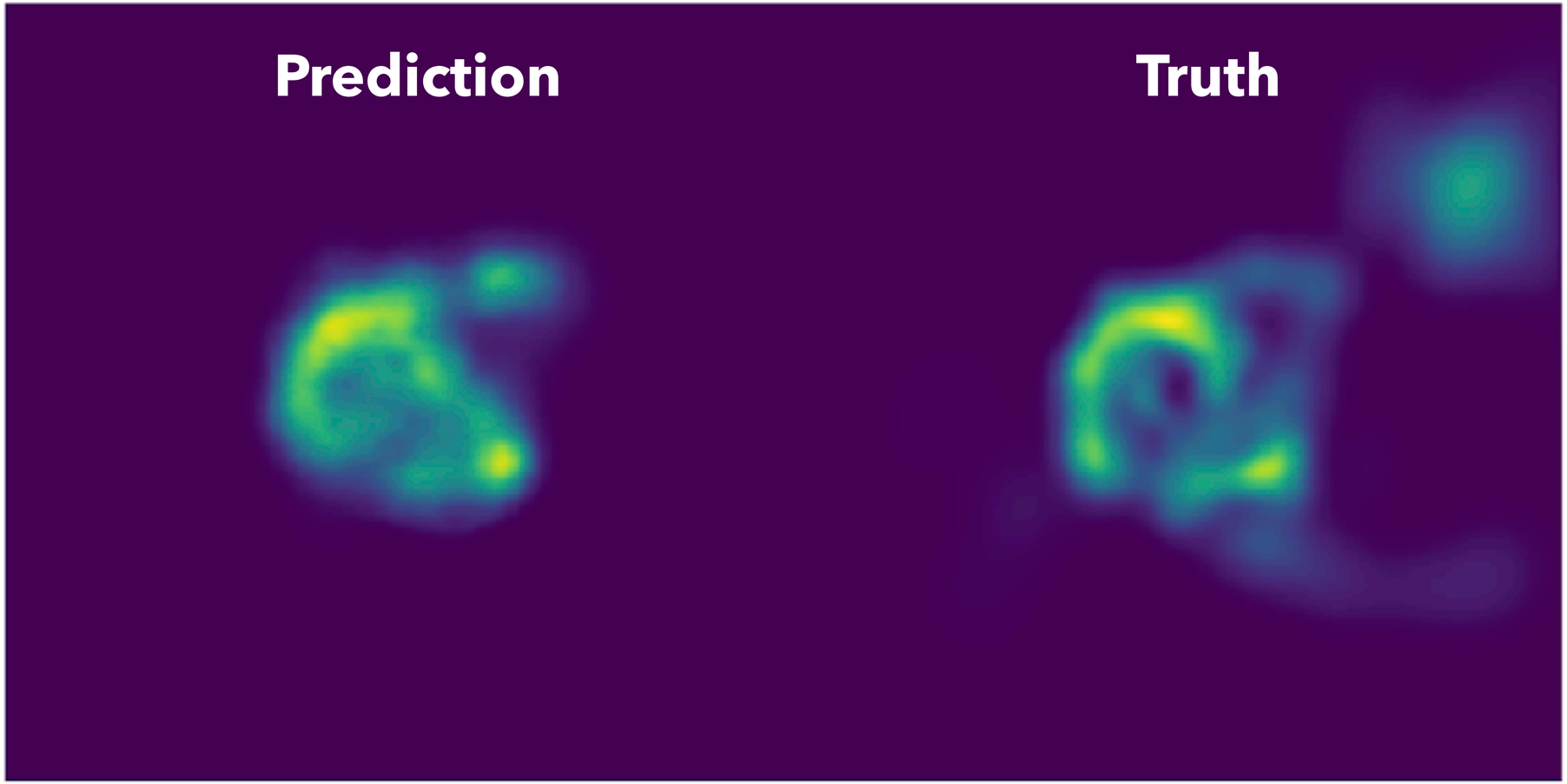


- SDSS MOCK IMAGES 256X256 PIXELS TORREY+2014, SNYDER+2015
- RADIATIVE TRANSFER, BACKGROUND STARS, PSF, NOISE, SURFACE BRIGHTNESS CUT
- PHYSICAL PROPERTIES ON SAME SCALE

RESULTS

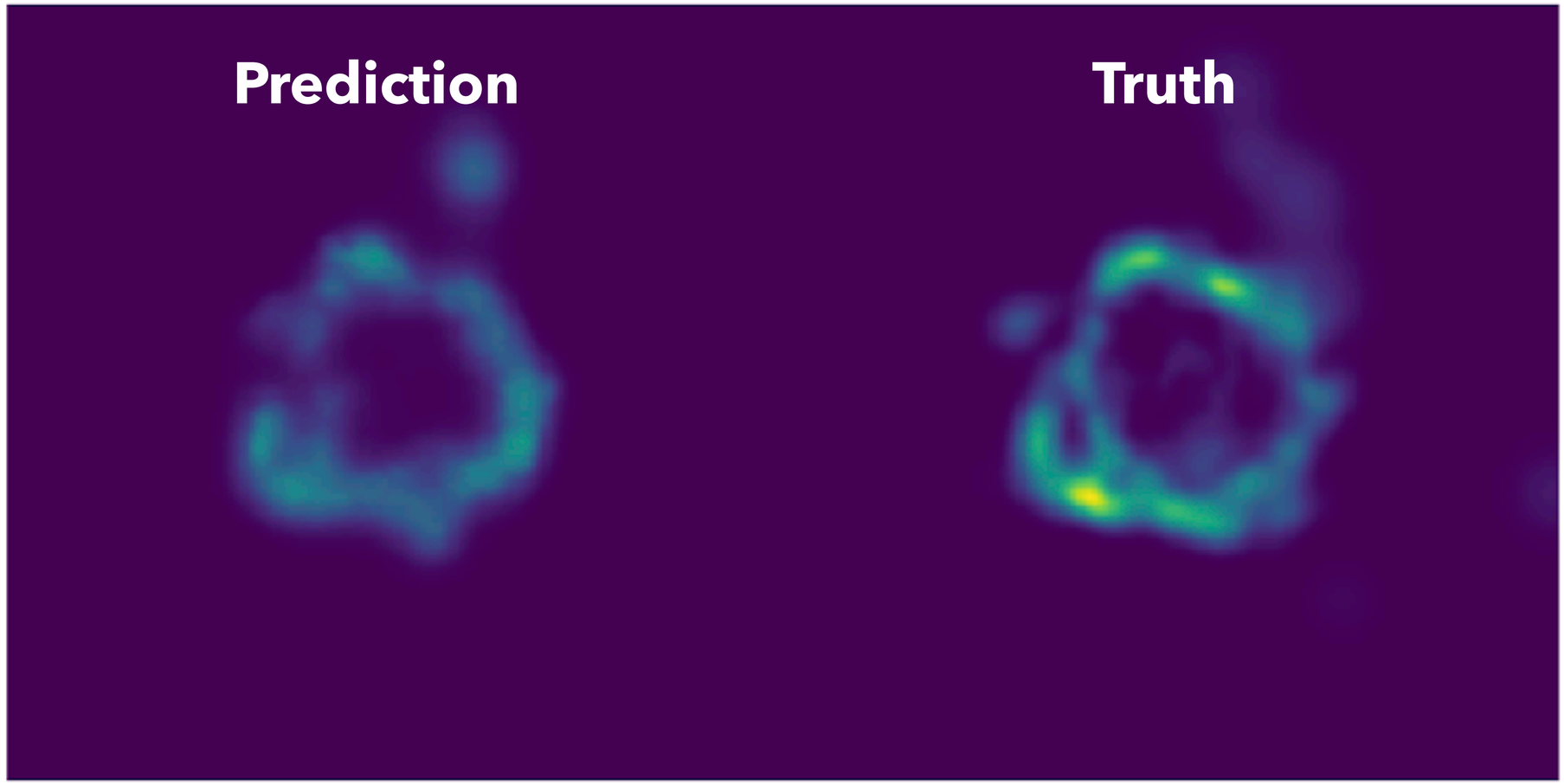
THE DATA CLEARLY PROVES THAT—
ARE YOU INDIANA JONES?
BECAUSE YOU'VE GOT A LOT OF ARTIFACTS THERE, AND I'M PRETTY SURE YOU DIDN'T HANDLE THEM RIGHT.

COMPARING TRUE AND PREDICTED SFR – 100TH QUANT.

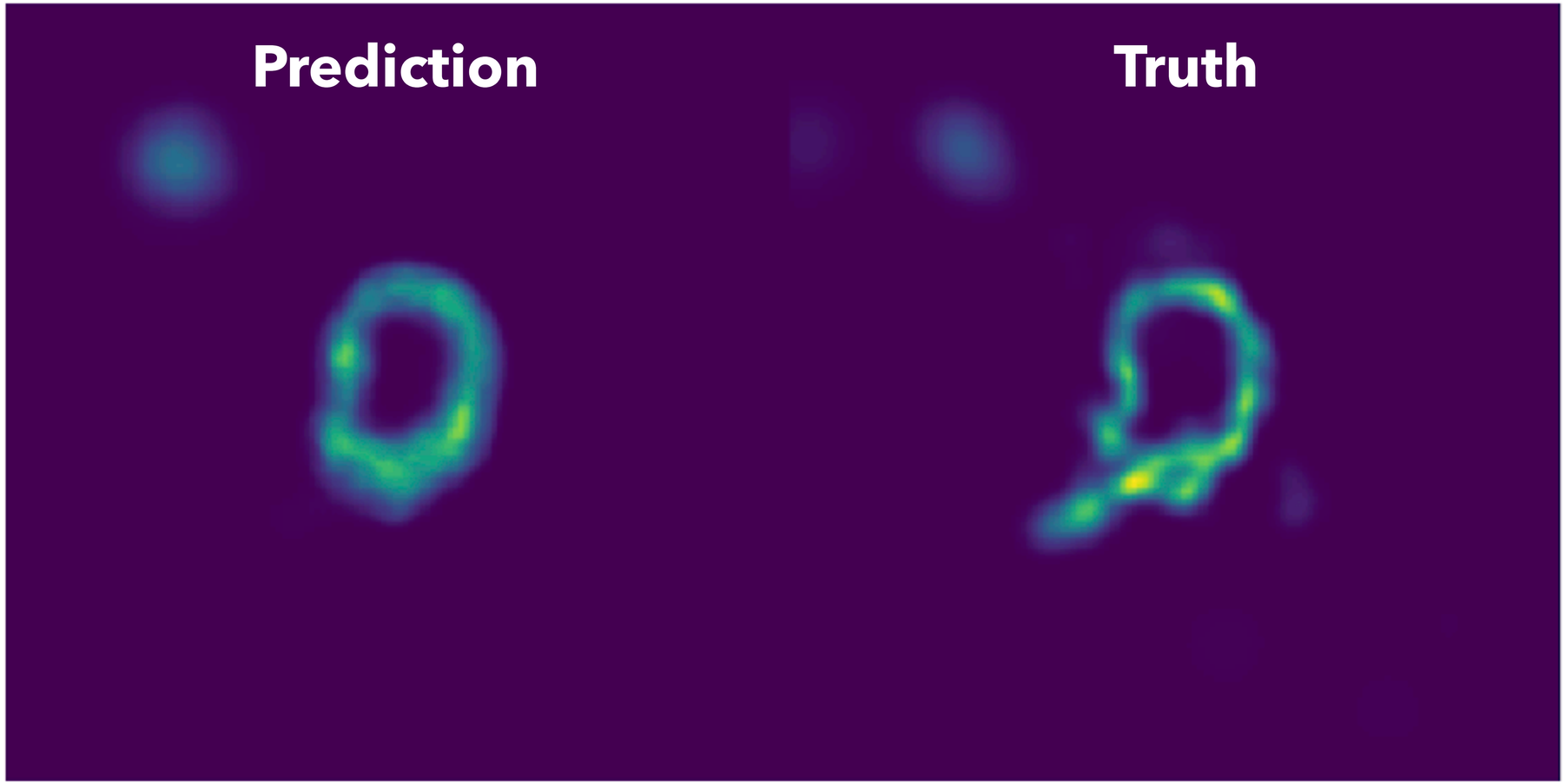


COMPARING TRUE AND PREDICTED SFR – 70TH QUANT.

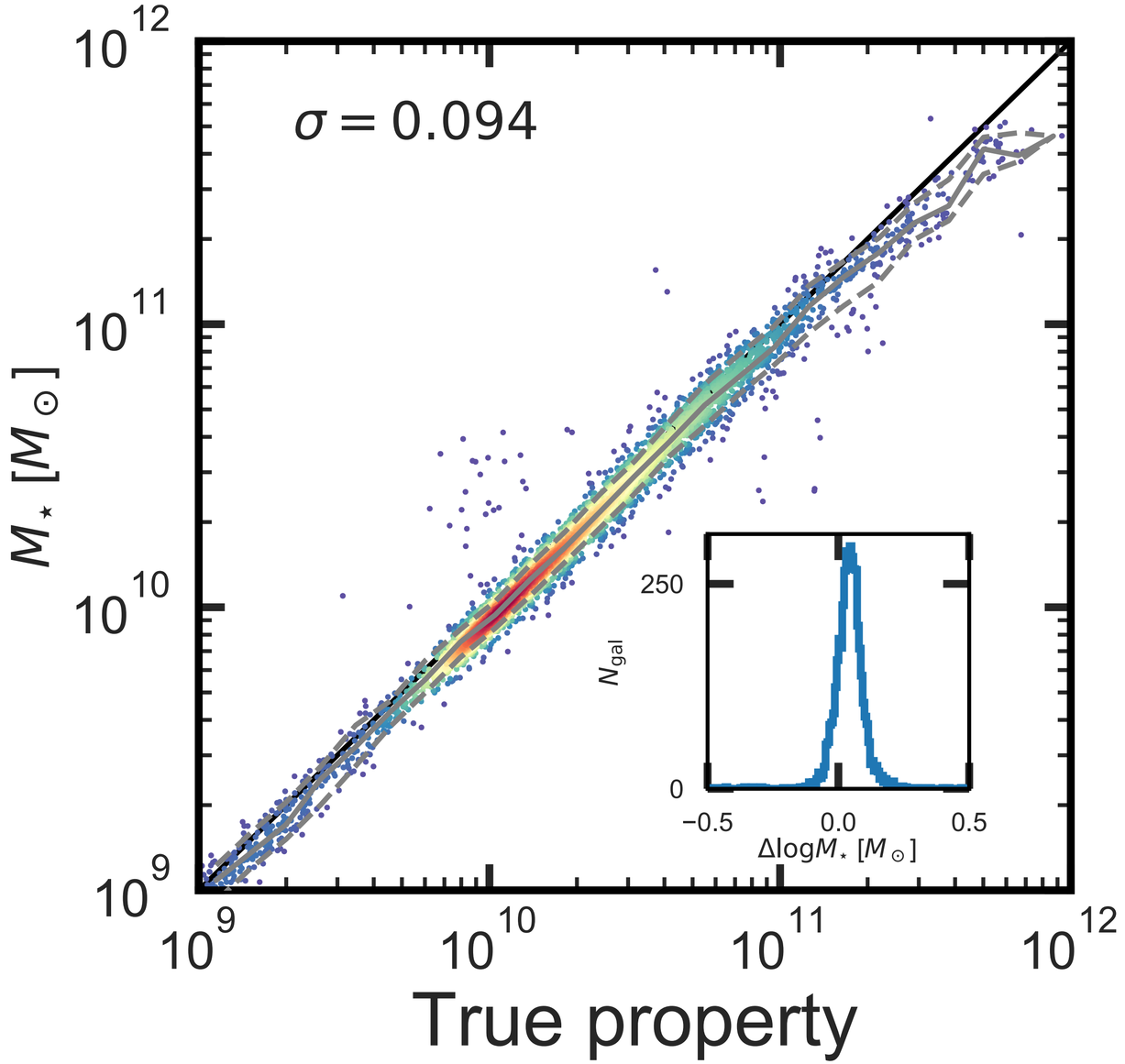
Prediction Truth

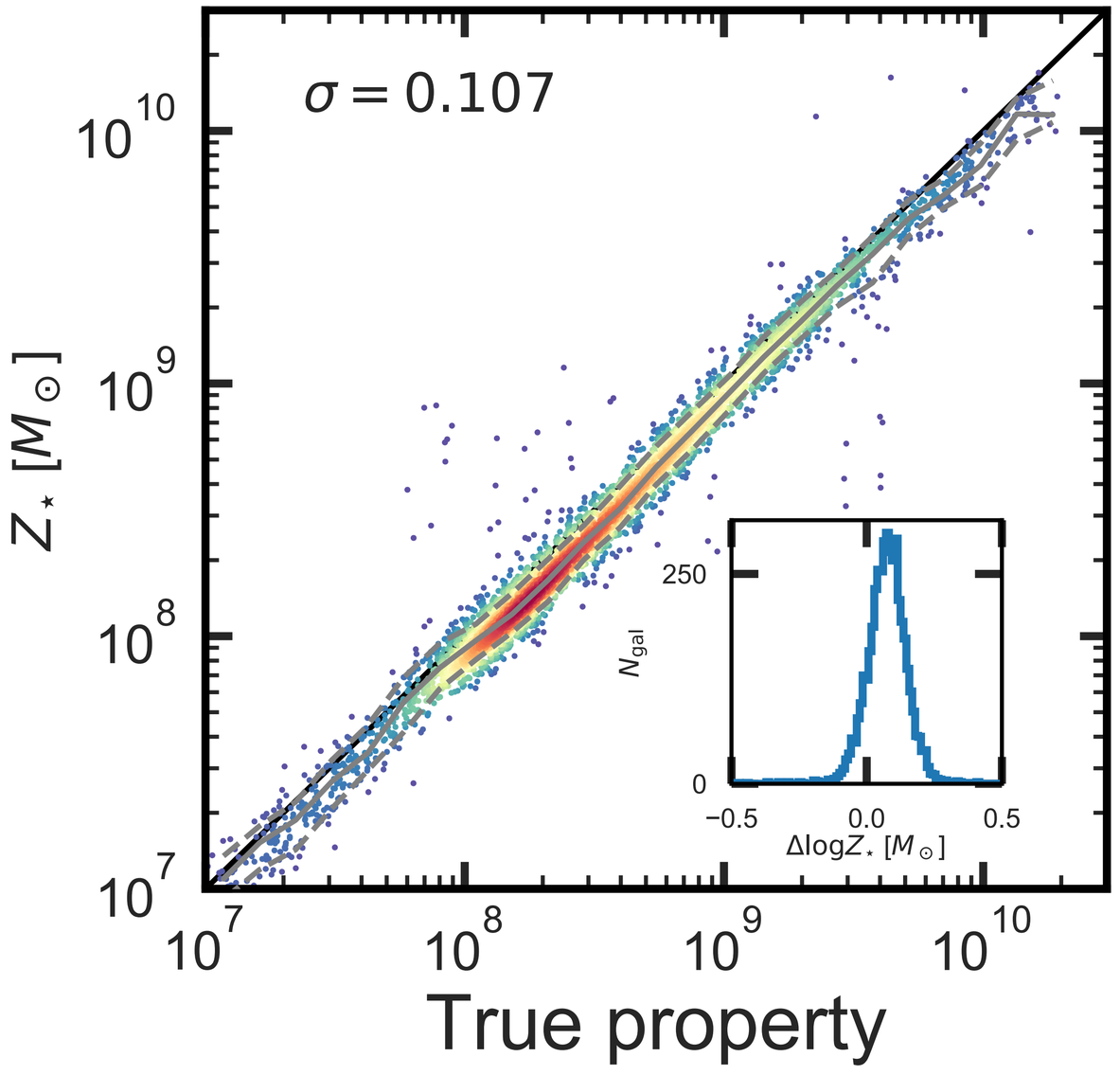


COMPARING TRUE AND PREDICTED SFR – 40TH QUANT.

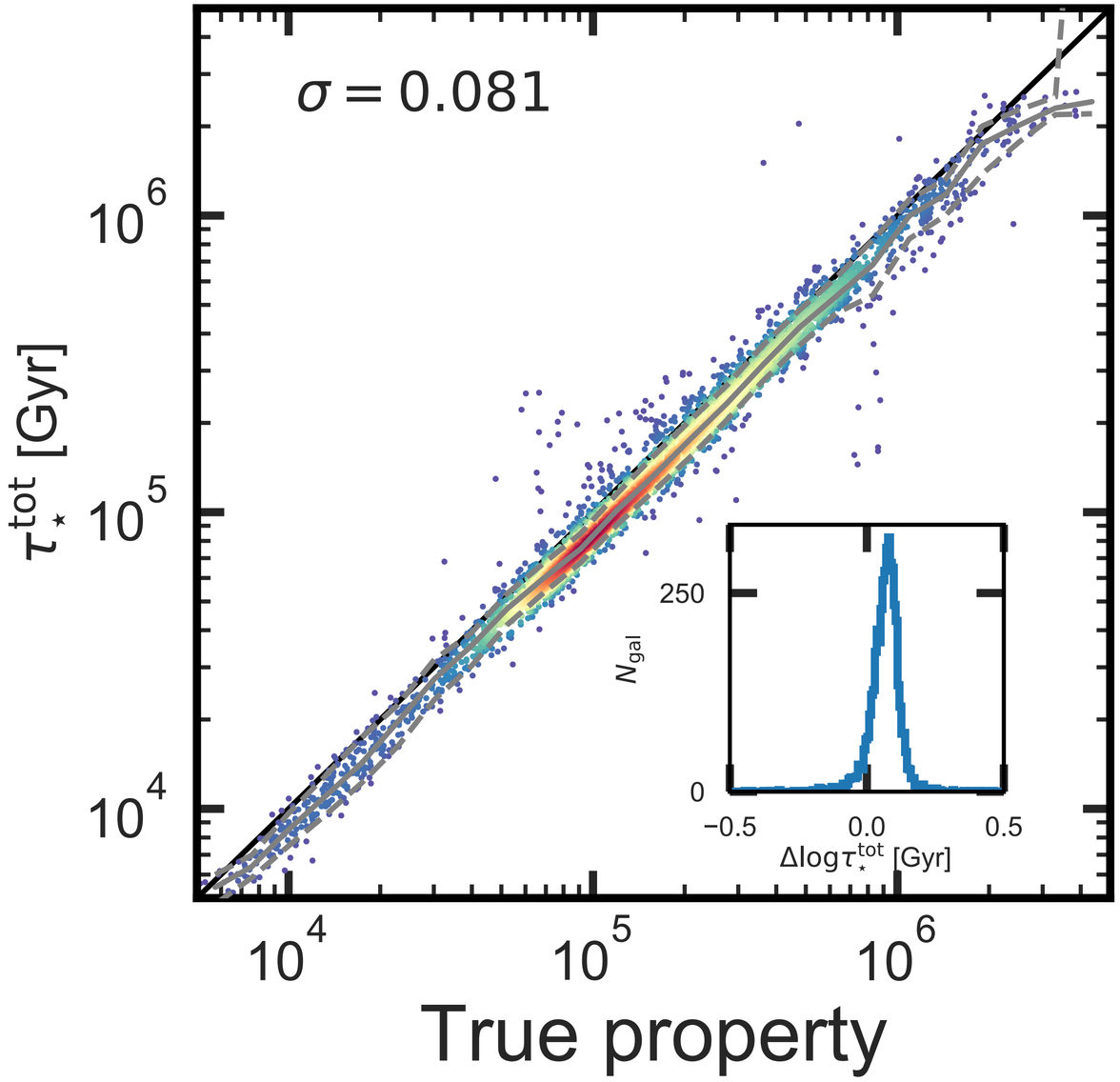


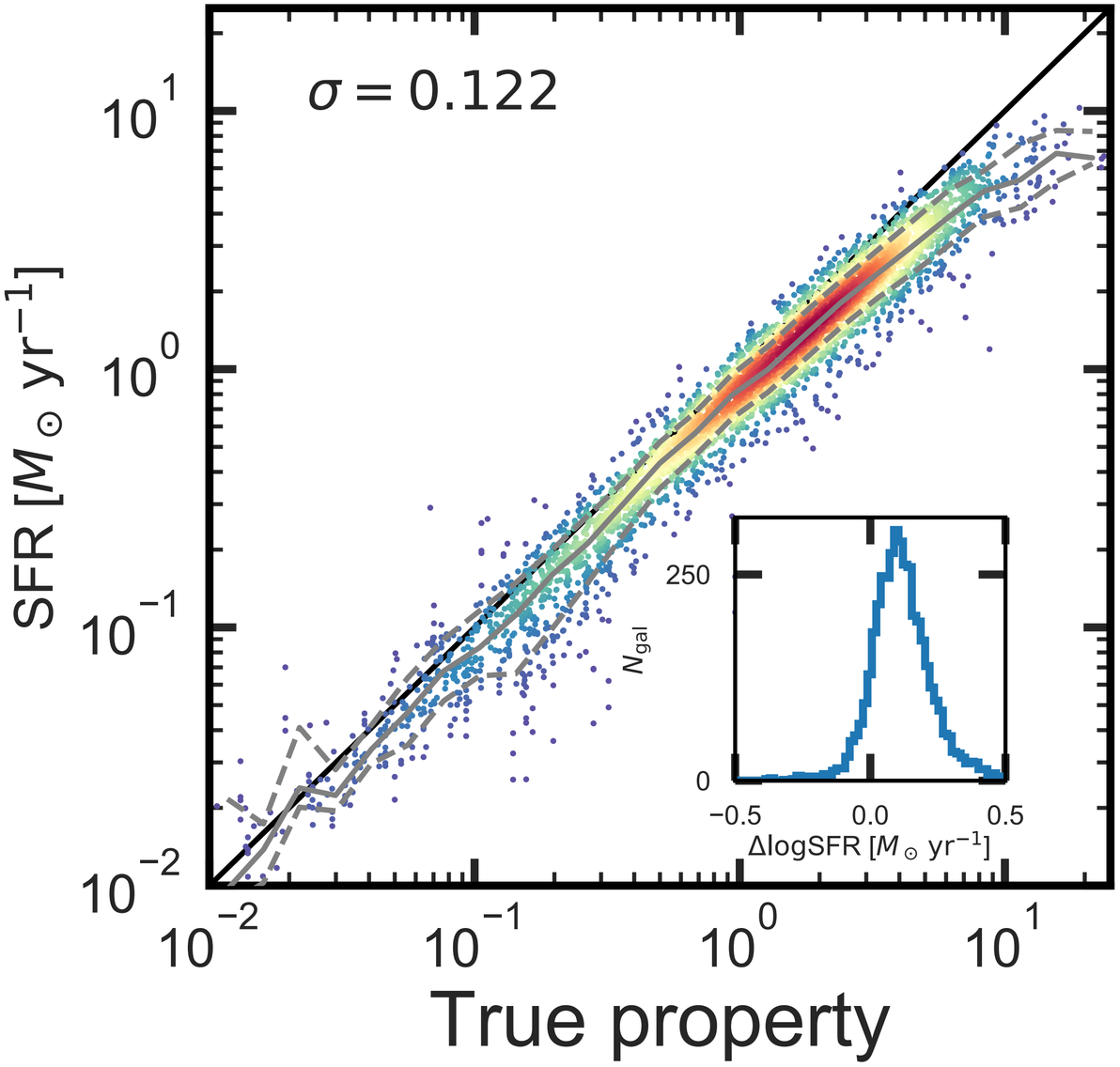
STELLAR PROPERTIES



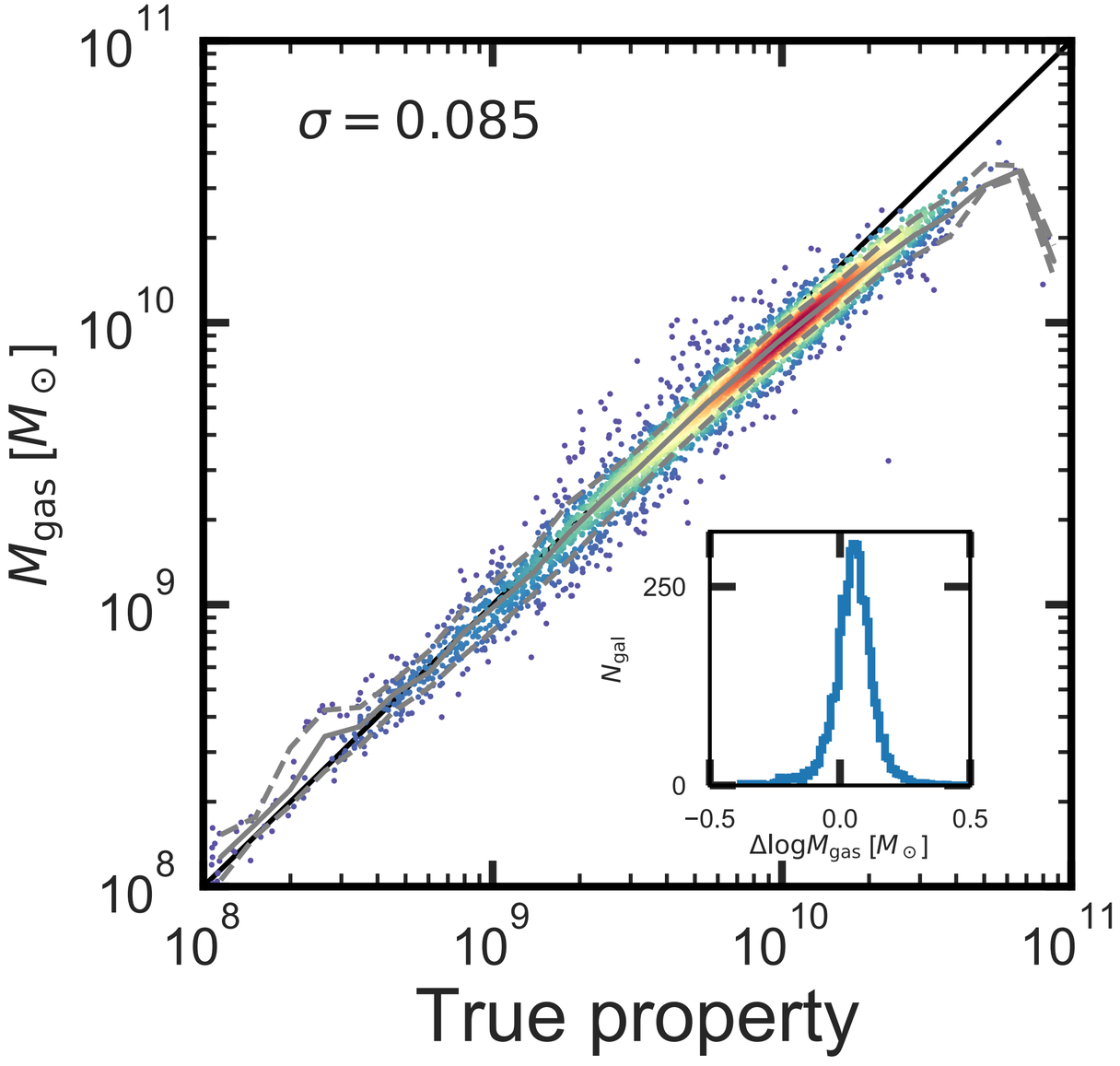


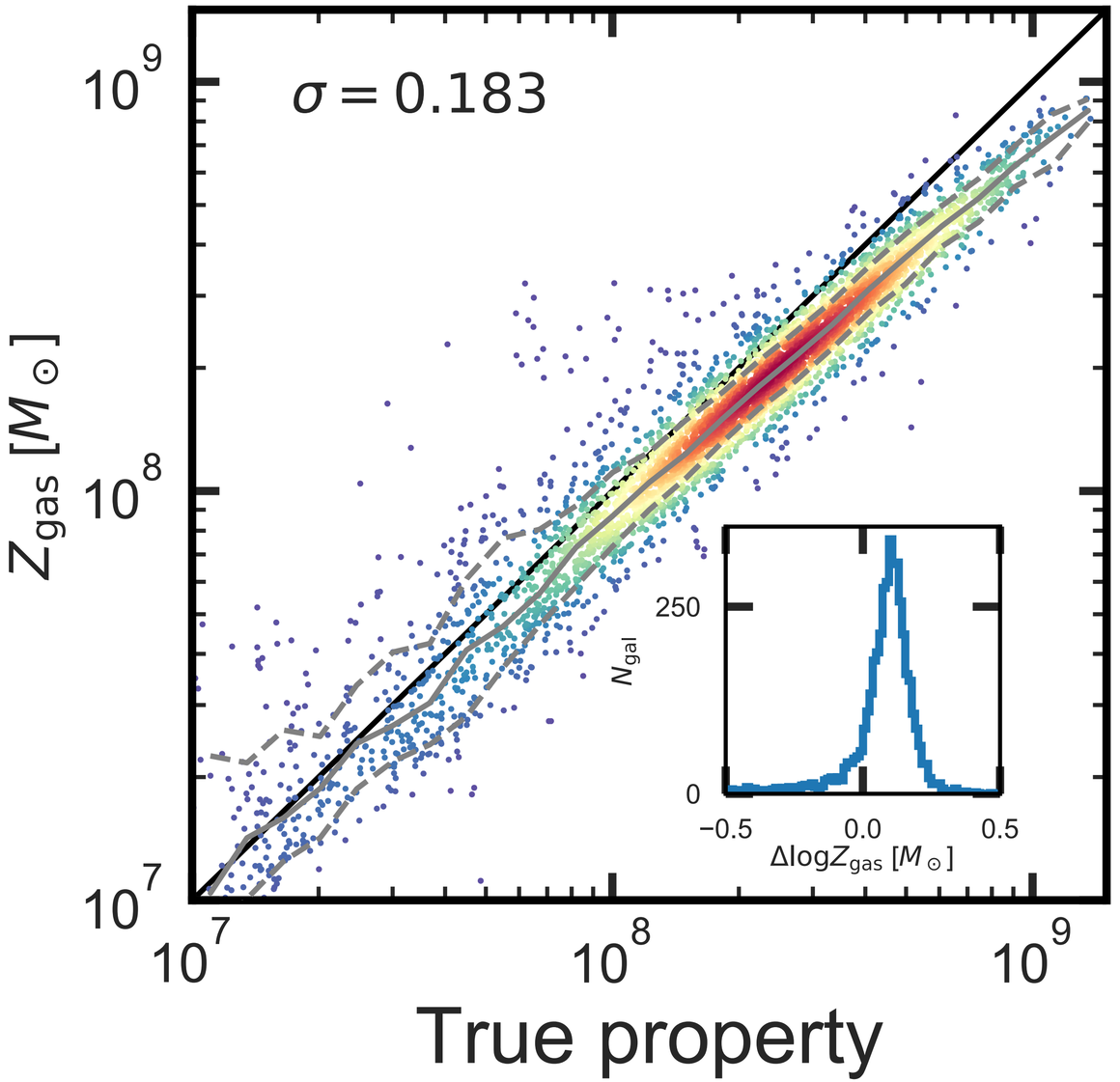
STELLAR PROPERTIES



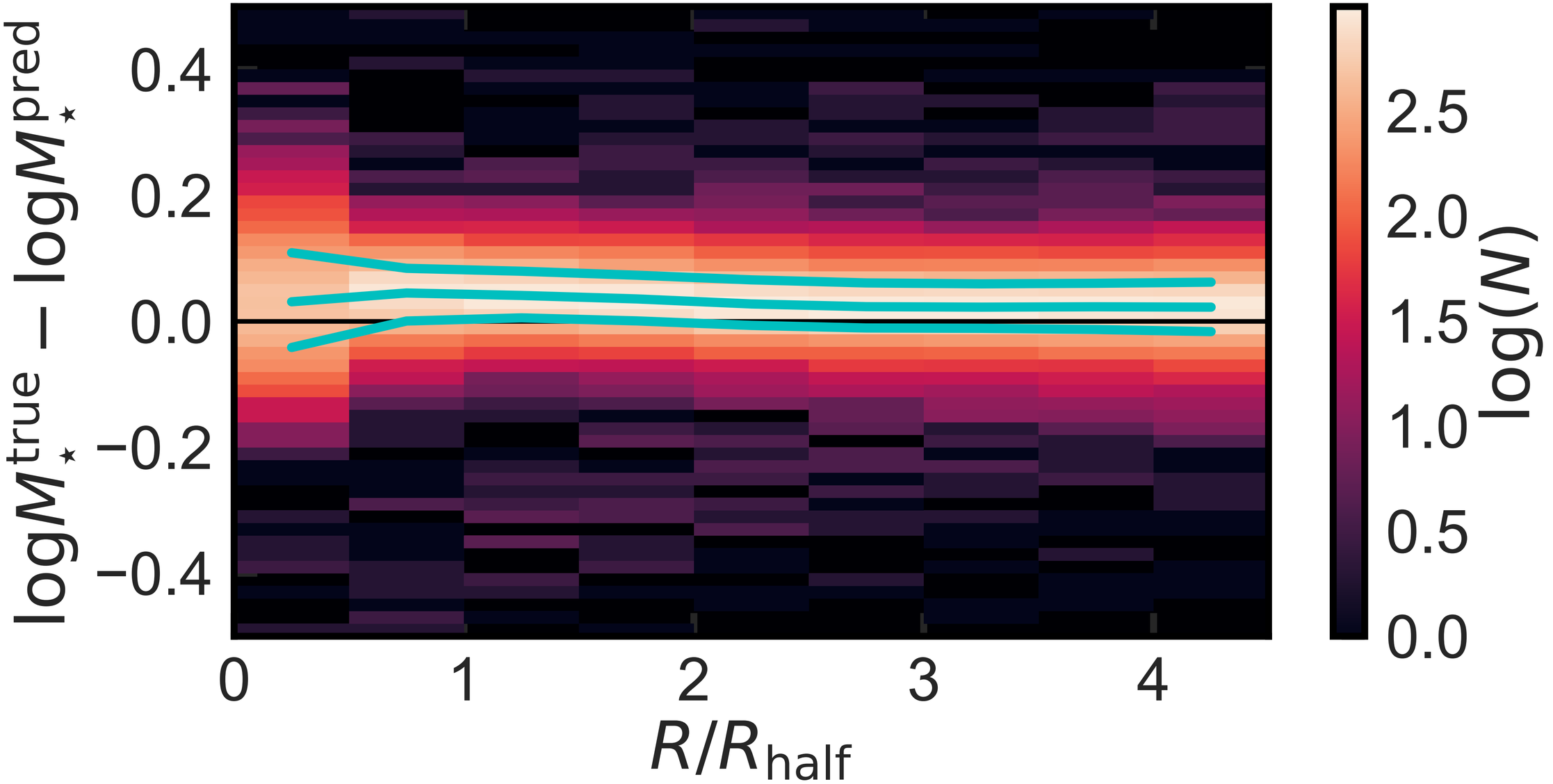


GASEOUS PROPERTIES

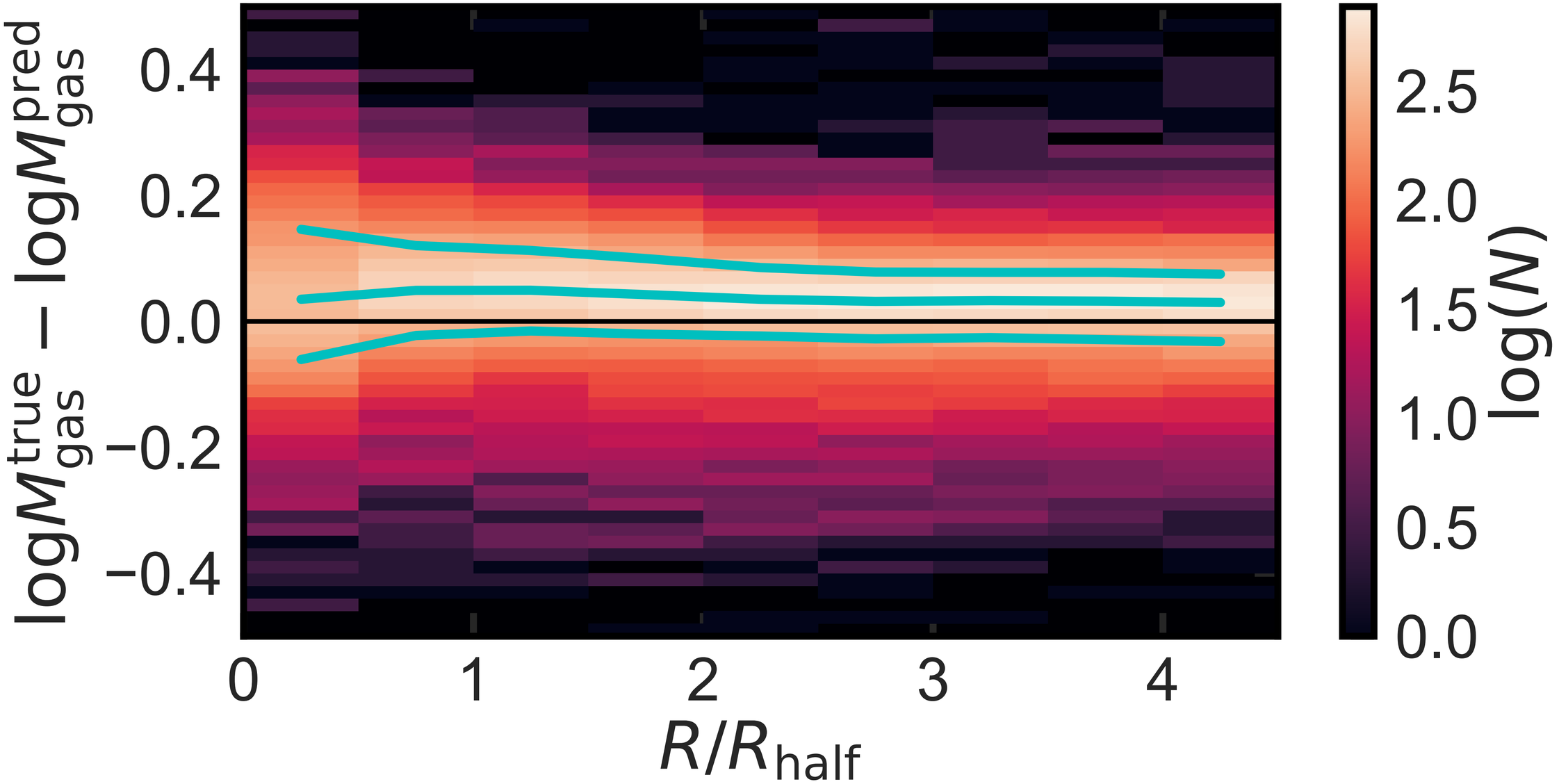




RADIAL SYSTEMATICS?



RADIAL SYSTEMATICS?



NEXT STEPS:

PROOF-OF-CONCEPT WORKS

QUANTIFY WHAT IS LEARNED: MORPHOLOGY OR COLOR?

QUANTIFY DEPENDENCE ON:

- IMAGE RESOLUTION (STABLE AGAINST FACTOR 2/4 LOWER RES)
- TRAINING SET SIZE
- NUMBER OF INPUT BANDS

REAL LIFE APPLICATION: IFU SURVEY DATA (E.G. MANGA)

MAKE PICASSSO USER FRIENDLY?

RELEASE IT AS READY-TO-USE TOOL?

QUESTIONS:

- IS SUCH AN ANALYSIS TOOL USEFUL?
- SHOULD WE PROVIDE SUCH A TOOL TO A BROADER COMMUNITY?
- HOW TO PROPERLY GAUGE ITS PERFORMANCE/ ACCURACY?
- DO WE HAVE THE RESPONSIBILITY TO PREVENT THE GENERAL ASTRONOMERS TO FOOL THEMSELVES?

CONCLUSION

SDSS (MOCK) *U,G,R,I,Z* IMAGES CONTAIN ENOUGH INFORMATION TO ***PREDICT*** PHYSICAL PROPERTIES OF GALAXIES ON A ***PIXEL-BY-PIXEL*** BASIS

NEXT STEPS: REAL LIFE APPLICATION

USE **PICASSSO** ON REAL SDSS IMAGES WITH SDSS MANGA, SAMI, OR CALIFA AS TRAININGS SAMPLE