Welcome to IS507!

“Statistics is the study of how best to collect, analyze, and draw conclusions from data…” - OpenIntro Statistics

Intro to Moodle class website

Quick plug: IS400

https://ischool.illinois.edu/degrees-programs/courses/is400

Outline of lectures:

- **Lecture ~60 minutes on concepts**
- **Coding follow along**
- **Occasional group activities**

Note: today will be a little lecture heavy

Orientation

Course Description

An introduction to statistical and probabilistic models as they pertain to quantifying information, assessing information quality, and principled application of information to decision-making. The increasing prevalence of massive data sets and falling computational barriers have rendered statistical modeling an integral part of contemporary information management. With this in mind, this class prepares students to select and properly undertake con mphasizing the merits and limitations of famili s parametric and non-parametric predictive m ut these discussions, the course focuses on sks in information management (e.g. prec

How well can we know anything, really?

What kinds of questions can we ask with data?

How accurately can we answer those questions from a particular dataset? How does this depend on features of this dataset (e.g. how it was procured)?

How can we make predictions from collected data? What is the "accuracy" of those predictions?

How can we use computational tools to answer statistical questions.

Learning Objectives

Students will demonstr s of a diverse range of data sets. By the en what one can feasibly learn and predict with c cular, each student will be able to:

- Articulate the rol
- Select, paramete
- Specify, estimate and evaluate elementary parametric statistical models.
- Specify, estimate and evaluate elementary non-parametric statistical models.
- Articulate professional responsibilities with respect to creating, describing and using models built from data.

Orientation

Course Description

An introduction to statistical and probabilistic models as they pertain to quantifying information, assessing information quality, and principled application of information to decision-making. The increasing prevalence of massive data sets and falling computational barriers have rendered statistical modeling an integral part of contemporary information management. With this in mind, this class prepares students to select and properly undertake com mphasizing the merits and limitations of famili s parametric and non-parametric predictive m ut these discussions, the course focuses on sks in information management (e.g. prec

How well can we know anything, really?

What lata?

How accurate m a particular dataset? How s dataset (e.g.

How can we ? What is the

How can w statistical questions.

Learning Objectives

Students will demonstr s of a diverse range of data sets. By the en what one can feasibly learn and predict with c cular, each student will be able to:

- Articulate the rol
- Select, paramete
- Specify, estimate and evaluate elementary parametric statistical models.
- Specify, estimate and evaluate elementary non-parametric statistical models.
- Articulate professional responsibilities with respect to creating, describing and using models built from data.

Orientation

Required Texts

James, G., Witten, D., Hastie, T., and Tibshirani, R. (2013) *An Introduction to Statistical Learning.* New York: Springer. [**abbreviated ISL**]
http://www-bcf.usc.edu/~gareth/ISL/

Diez, D., Barr, C., and Cetinkaya-Rundel, M. (2015) *OpenIntro Statistics* Fourth Edition, [available online, https://www.openintro.org/stat/textbook.php?stat_book=os, **abbreviated OIS**]

Venables, W.N., Smith, D.M and the R Core Team (2012) *An Introduction to R*. [available online, http://cran.r-project.org/doc/manuals/R-intro.pdf, [**abbreviated ITR**]

Week	Topic	Reading
1	• Data, Models, and Information • Elementary statistics: Definitions • Overview of R	OIS 1 (ISL 1)
2	• Elementary statistics: Applications & Plots	OIS 1 (ISL 1)
3	• Introduction to data analysis with R • Review of tabular and graphical displays of data	ITR 1, 2, 5, 6, 7, 12
4	• Random variables: expectation and variance • Joint and conditional probability • Bayes rule	OIS 2
5	• Random variables: distributions (normal, binomial, poisson)	OIS 3

Definitions, basic concepts, R practice

Week	Topic	Reading
1	• Data, Models, and Information • Elementary statistics: Definitions • Overview of R	OIS 1 (ISL 1)
2	• Elementary statistics: Applications & Plots	OIS 1 (ISL 1)
3	• Introduction to data analysis with R • Review of tabular and graphical displays of data	ITR 1, 2, 5, 6, 7, 12
4	• Random variables: expectation and variance • Joint and conditional probability • Bayes rule	OIS 2
5	• Random variables: distributions (normal, binomial, poisson)	OIS 3

Probability basics, typical distributions

6	• Modeling data with probability distributions • Foundations for inference	OIS 4
7	• Inference for numerical data • Inference for categorical data	OIS 5, OIS 6
8	• Linear regression	OIS 7 (ISL 3)
9	• Multiple linear regression	OIS 8 (ISL 3)
10	• Logical regression	OIS 8 (ISL 4)
12	• *k*-Nearest neighbor classification and regression	ISL 2.2.3, 4.6.5
13	• Intro to Unsupervised linear models: Principle component analysis	ISL 10.0-10.2

How well can we answer questions with our data?

6	• Modeling data with probability distributions • Foundations for inference	OIS 4
7	• Inference for numerical data • Inference for categorical data	OIS 5, OIS 6
8	• Linear regression	OIS 7 (ISL 3)
9	• Multiple linear regression	OIS 8 (ISL 3)
10	• Logical regression	OIS 8 (ISL 4)
12	• *k*-Nearest neighbor classification and regression	ISL 2.2.3, 4.6.5
13	• Intro to Unsupervised linear models: Principle component analysis	ISL 10.0-10.2

Making predictions from data

6	• Modeling data with probability distributions • Foundations for inference	OIS 4
7	• Inference for numerical data • Inference for categorical data	OIS 5, OIS 6
8	• Linear regression	OIS 7 (ISL 3)
9	• Multiple linear regression	OIS 8 (ISL 3)
10	• Logical regression	OIS 8 (ISL 4)
12	• *k*-Nearest neighbor classification and regression	ISL 2.2.3, 4.6.5
13	• Intro to Unsupervised linear models: Principle component analysis	ISL 10.0-10.2

Classification and unsupervised learning

6	• Modeling data with probability distributions • Foundations for inference	OIS 4
7	• Inference for numerical data • Inference for categorical data	OIS 5, OIS 6
8	• Linear regression	OIS 7 (ISL 3)
9	• Multiple linear regression	OIS 8 (ISL 3)
10	• Logical regression	OIS 8 (ISL 4)
12	• *k*-Nearest neighbor classification and regression	ISL 2.2.3, 4.6.5
13	• Intro to Unsupervised linear models: Principle component analysis	ISL 10.0-10.2

Midterms + Final will be a guided application of these principles (more on that in the next few weeks)

Pre- and Co-requisite

IS430(452) Foundations of Information Processing is strongly recommended as a prerequisite. A highly motivated student could pass this course without IS452 (so the prerequisite is not enforced), but programming will not be covered in this course. Students who have not completed an introductory course on statistics will need to come up to speed quickly on material covered early in the semester.

Assignment	
Weekly homework	55%
Midterm exam	20%
Final exam	25%

See Syllabus for late HW policies, and we will drop your lowest HW score.

HW and Exam Formats

File name structure: lastname-first-module.ext
(e.g, naiman-jill-assignment1.pdf).

The submission must include:

1) A narrative document as a PDF file (to be read by a human). To preserve the natural flow of the narrative, figures (e.g., screenshots, code snippets) and tables should be embedded into the document near their first mention. Any supplementary files containing R programs or data should be referenced in the text and separately uploaded.

AND

2) All R code as separate files with an .R extension (to be read by a computer).

HW — Self Grading (We will go over this again in week 3)

		Assignment #3 self-grading	
		Fill in the orange area. Explanations for incorrect answers are optional, but will help your grade if they are good.	
		Correct:	0.00
		Incorrect:	0.00
		Explanation score:	0.00
		Estimated score:	0.0%
Exercise	**Weight**	**Correct (Y or N)**	**Explanation for incorrect answer**
OIS 1.2a	0.25		
OIS 1.2b	0.25		
OIS 1.2c	0.25		

Timeline

Fri: HW submitted → **Fri/Sat: Solutions released** → **Fri: Previous HW Solutions due & Next HW due**

General Adulting Policies

- Come to class
- Participate in class
- Don’t get in the way of the learning process of others/keep a Growth Mindset
- Do your own work

Course Strategies:

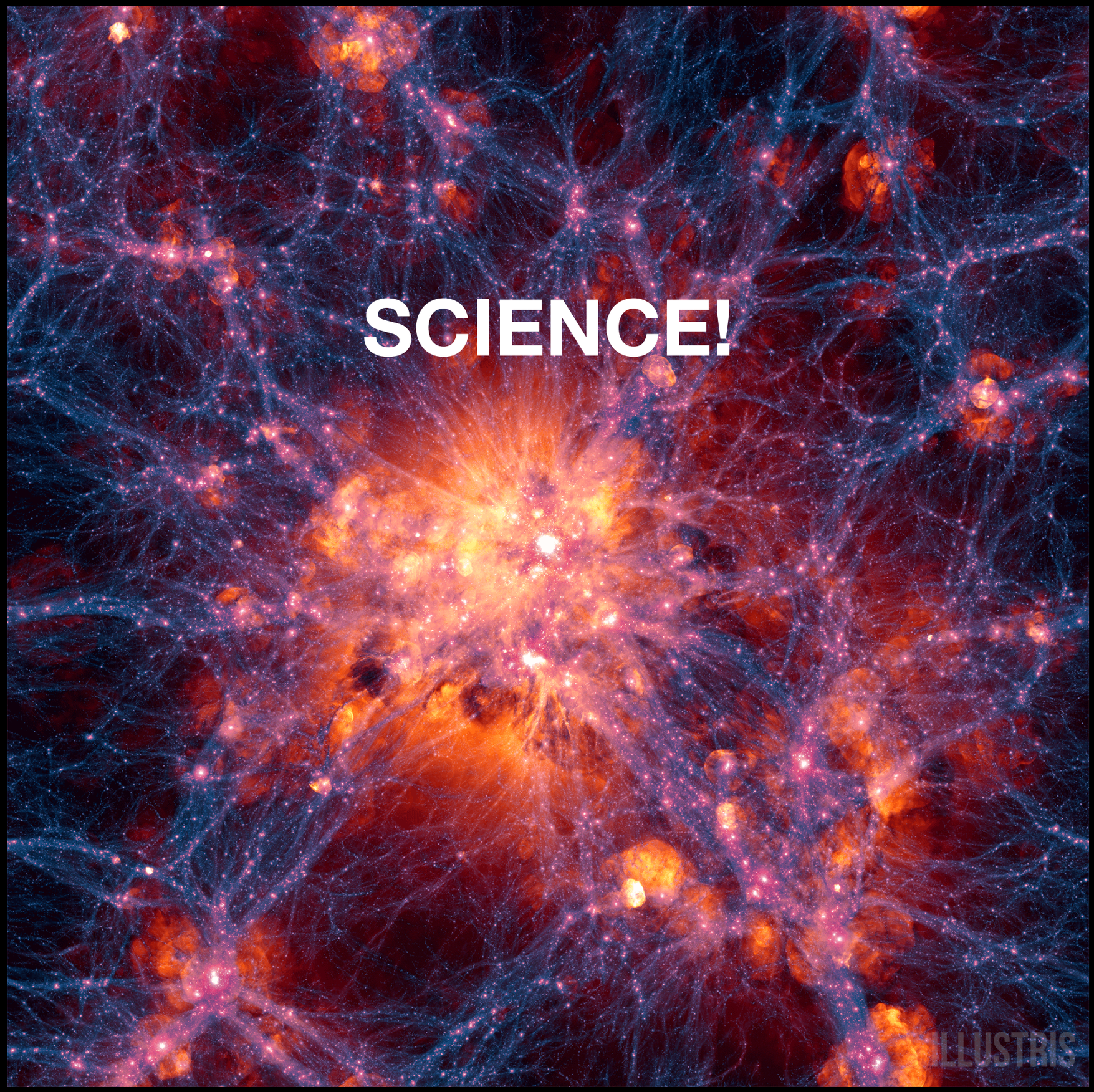
- Come to class & Participate in class
- New to coding: read the prep notebooks before class!

~~What are we doing?~~

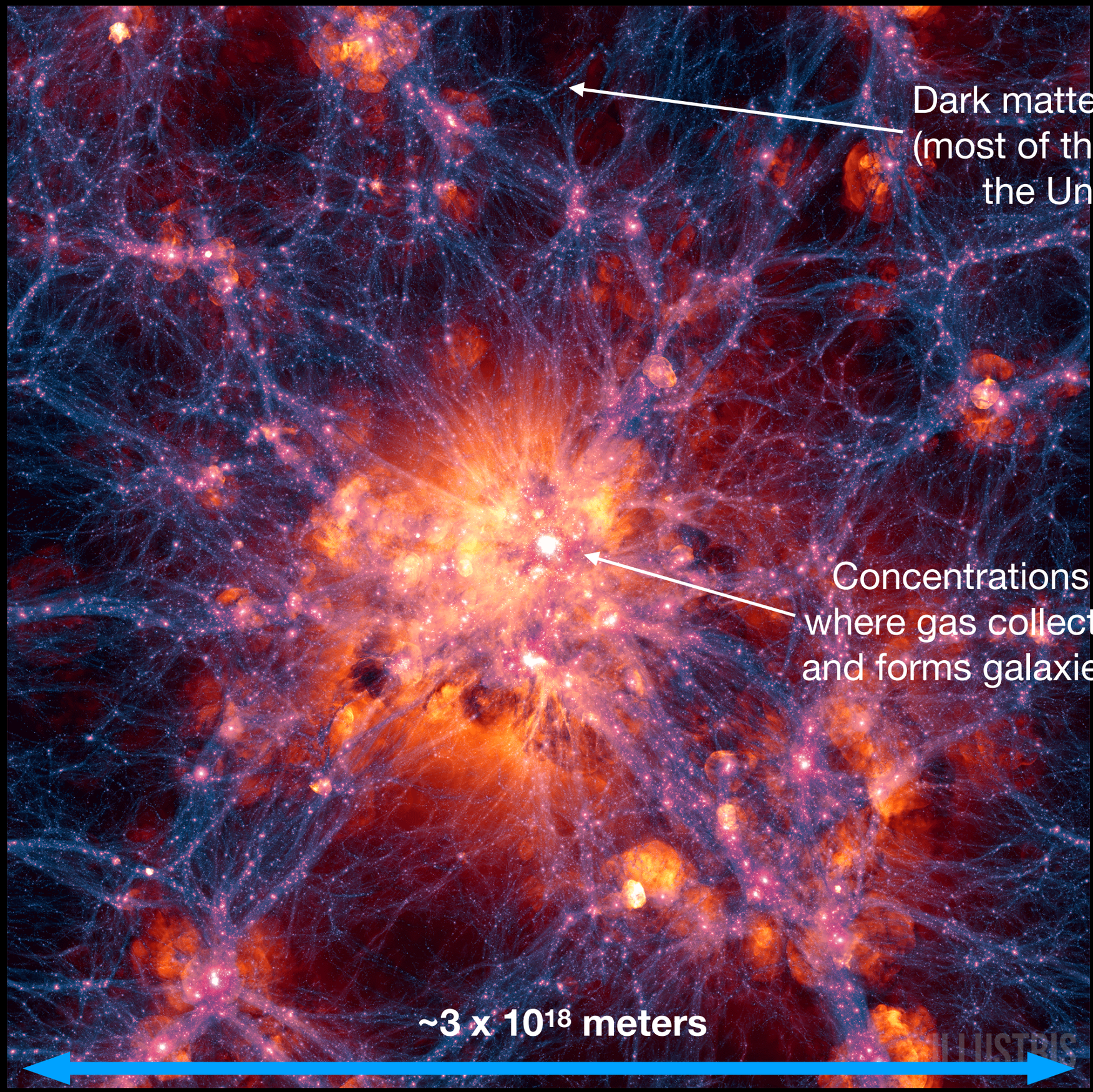
~~How are we going to do it?~~

Who are you?

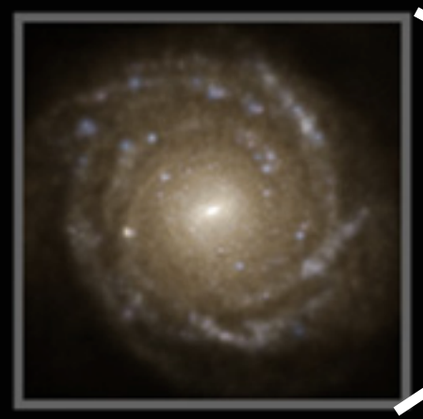
My background

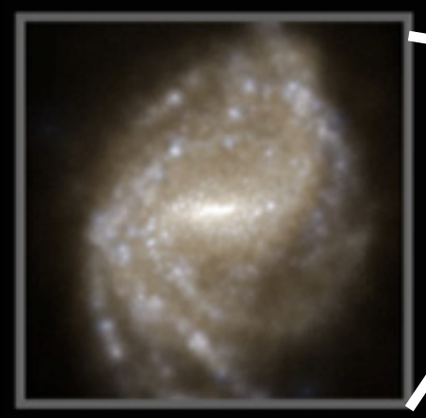


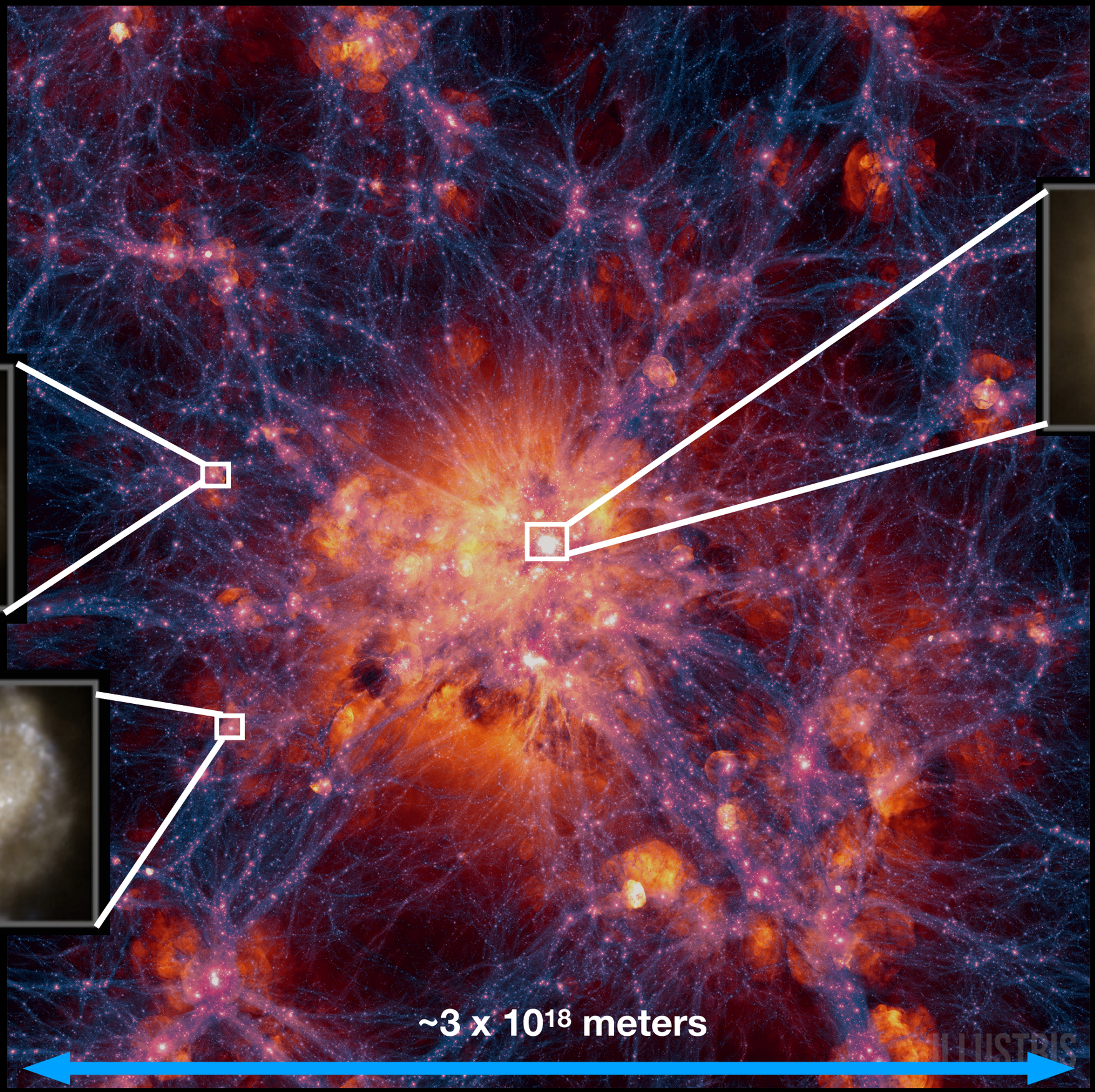
My background

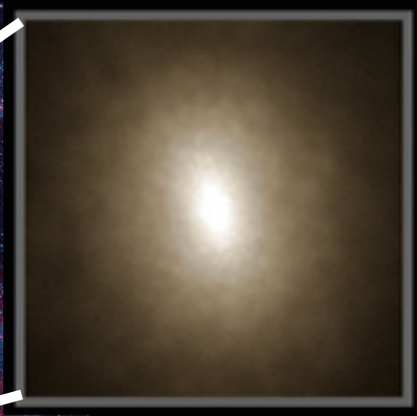


My background



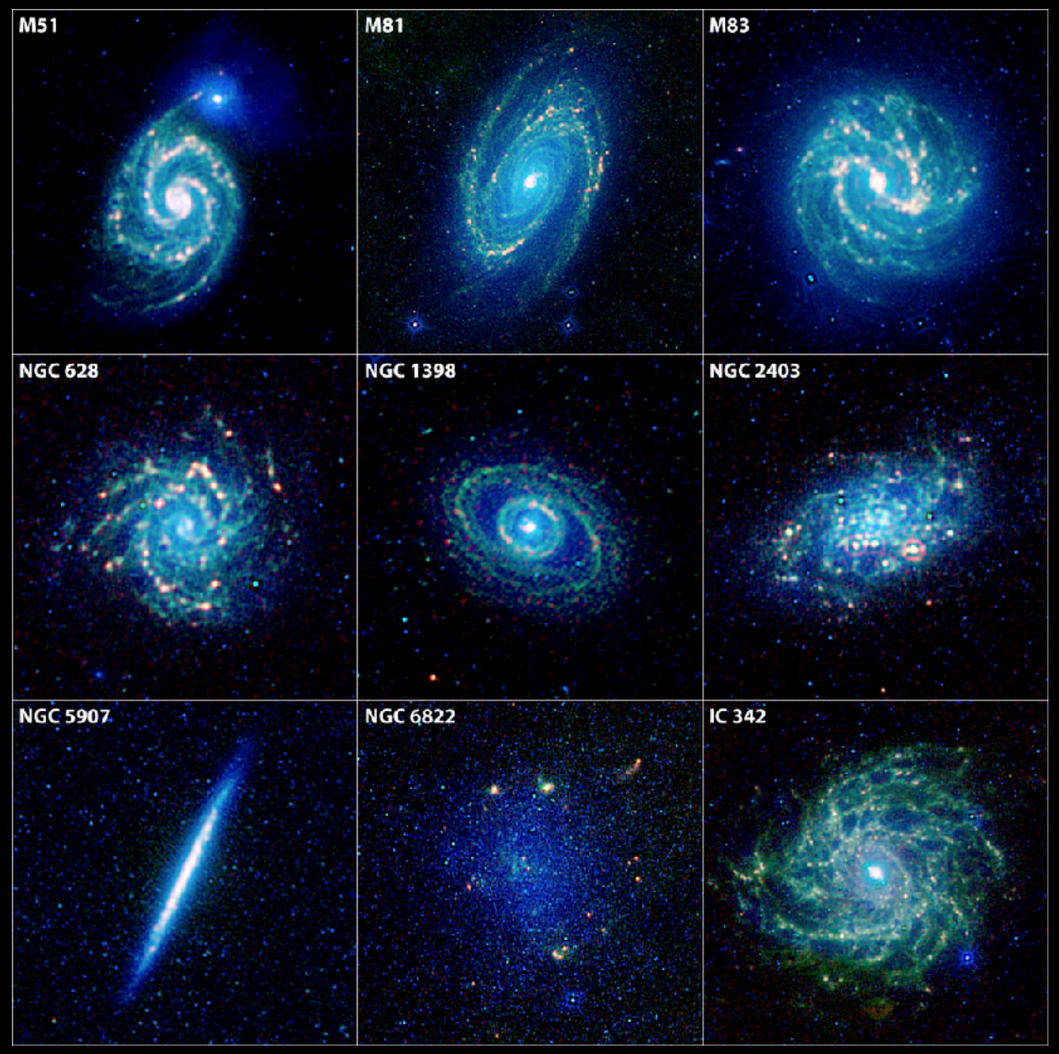




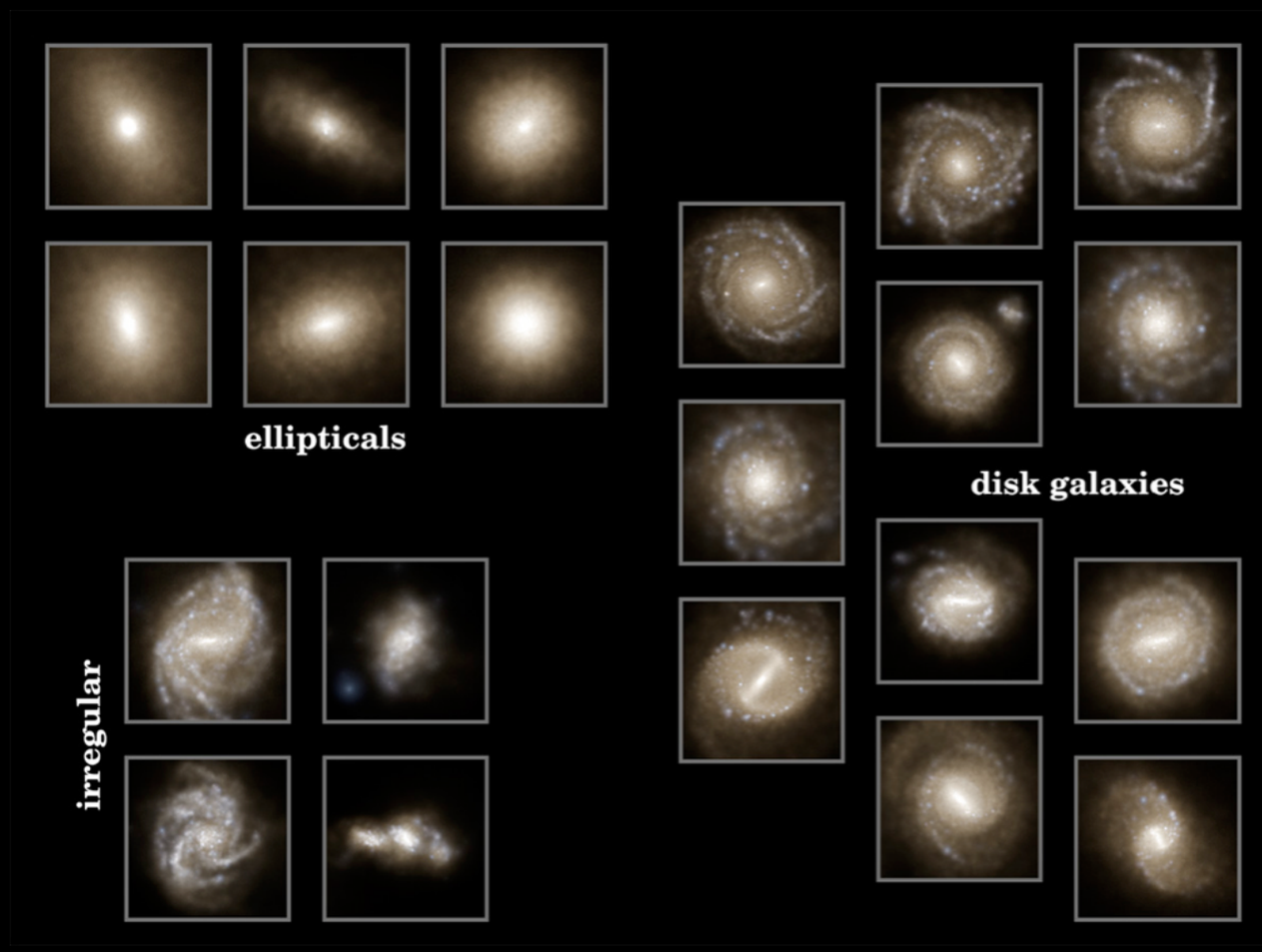


Statistical comparison between Observations & Models

Images of real galaxies from NASA's Wide-field Infrared Survey Explorer



Images of "fake" galaxies simulated in a super computer



(differences in colors due to color schemes chosen for each image)

Recent Machine Learning Work

Stickland, we define phase 0.0 to be superior conjunction of the primary star.

The spectra were reduced by standard techniques (see Paper I) which included the removal of atmospheric telluric lines. The final step yields rectified spectra transformed to a uniform heliocentric wavelength grid. The resulting spectra appear in Figures 1 and 2 for Hα and He I λ6678, respectively. In these figures we plot the spectra as a function of radial velocity assuming rest wavelengths of 6562.682 Å and 6678.148 Å for Hα and He I, respectively. The spectra are placed in the upper portion of each diagram so that their continua are aligned with the orbital phase of observation. The bar at the upper right indicates the intensity scale relative to the continuum. The lower portion of the figure shows the same spectra portrayed as a gray-scale image in which spectral intensity is transformed

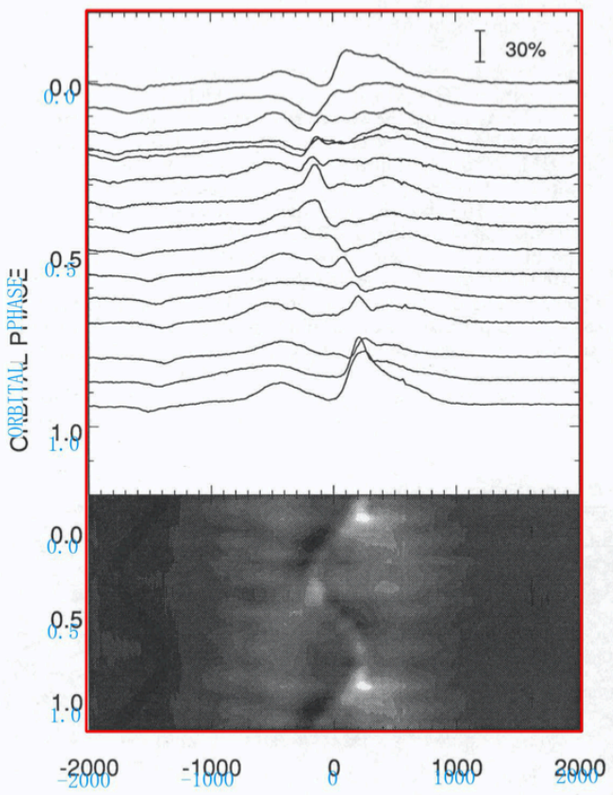


FIG. 1.—*Top*: Hα line profiles plotted against heliocentric radial velocity. The profiles are arranged in order of increasing orbital phase and each spectrum is placed in the *y*-ordinate so that the continuum equals the phase of observation (phase 0.0 = superior conjunction of the primary). The bar in the upper right gives the spectrum intensity scale relative to a unit continuum. The fourth spectrum from the top was obtained two years after the other spectra. *Bottom*: A gray-scale representation of the profile variations shown above. Here each spectral intensity is assigned one of 16 gray levels based on its value between the minimum (deepest absorption) and maximum (highest emission) observed values. The spectrum at each phase in the image is calculated by a linear interpolation between the closest observed phases. The spectral image for the first and last 20% of the orbit are reproduced at the bottom and top of the image, respectively, to improve the sense of phase continuity.

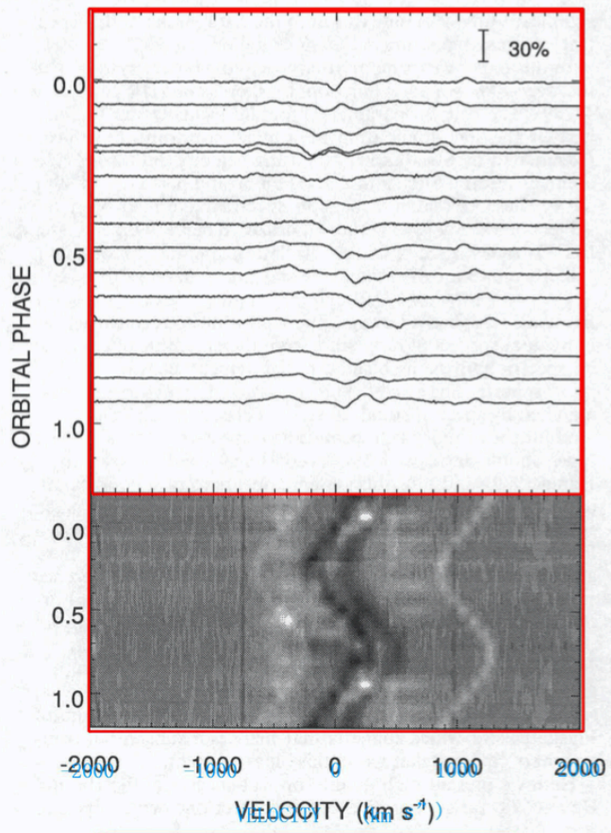


FIG. 2.—He I λ6678 profiles in the same format as Fig. 1

into a gray-scale intensity (dark in the absorption cores and bright at the emission peaks). The spectrum at each orbital phase in the image was calculated by a linear interpolation between observations with the closest phases. In some cases, the interpolation method causes narrow features to appear as discrete circles near conjunction phases (0.0 and 0.5) where the velocity changes rapidly between observations (see, for example, Si IV λ6701 located near $V_r = 1050$ km s^{-1} in Fig. 2).

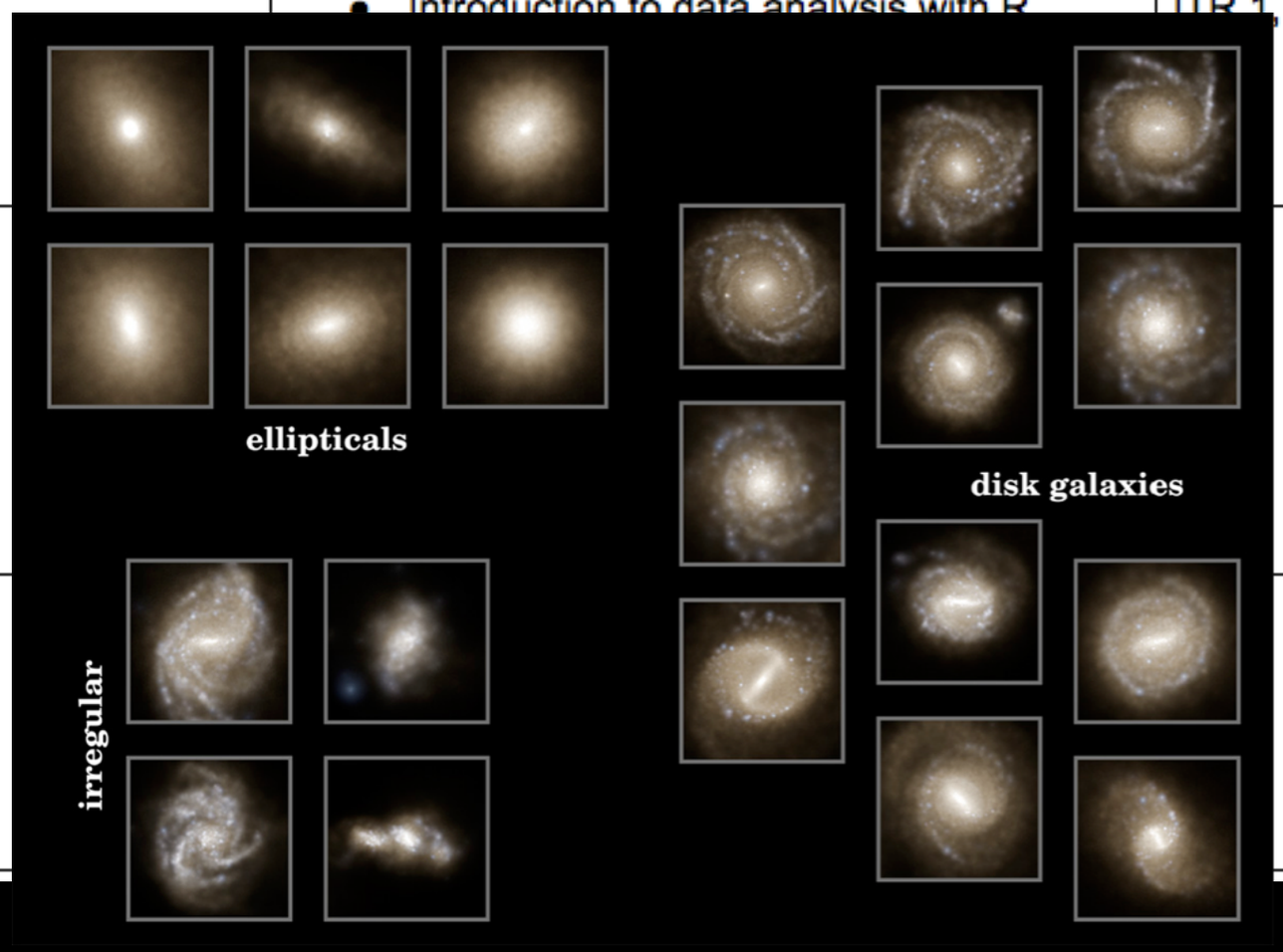
In the following subsections, we first describe the orbital phase-related variations in features associated with the primary star and then those in lines associated with circumstellar gas. The last subsection deals with variations unrelated to orbital phase in the Hα emission line.

2.1. *Spectral Lines Associated with the Primary Star*

There are several lines in Figures 1 and 2 which show the familiar "s" shape corresponding to the velocity curve of the primary star. These include the absorption lines He I λ6678 and He II λλ6527.13, 6683.20 and the emission lines Si IV λλ6667.56, 6701.21 (Fullerton 1989). All of these lines are typically found in mid-O supergiants (Conti 1974; Ninkov, Walker, & Yang 1987a; Ninkov et al. 1987b). In addition, we observed a weak emission line (maximum intensity ≈4% of the continuum) near 6610 Å which we tentatively identify as N II λ6610.58. Meinel, Aveni, & Stockton (1981) offer this iden-

Fig. 1—Top: Ha line profiles plotted against heliocentric radial velocity. The profiles are arranged in order of increasing orbital phase and each spectrum is placed in the y-ordinate so that the continuum equals the phase of observation (phase 0.0 = superior conjunction of the primary). The bar in the upper right gives the spectrum intensity scale relative to a unit continuum. The fourth spectrum from the top was obtained two years after the other spectra. Bottom: A gray-scale representation of the profile variations shown above. Here each spectral intensity is assigned one of 16 gray levels based on its value between the minimum (deepest absorption) and maximum (highest emission) observed values. The spectrum at each phase in the image is calculated by a linear interpolation between the closest observed phases. The spectral image for the first and last 20% of the orbit are reproduced at the bottom and top of the image, respectively, to improve the sense of phase continuity.

Week	Topic	Reading
1	• Data, Models, and Information • Elementary statistics: Definitions • Overview of R	OIS 1 (ISL 1)
2	• Elementary statistics: Applications & Plots	OIS 1 (ISL 1)
	• Introduction to data analysis with R	ITR 1, 2, 5, 6, 7, 12
		OIS 2
		OIS 3

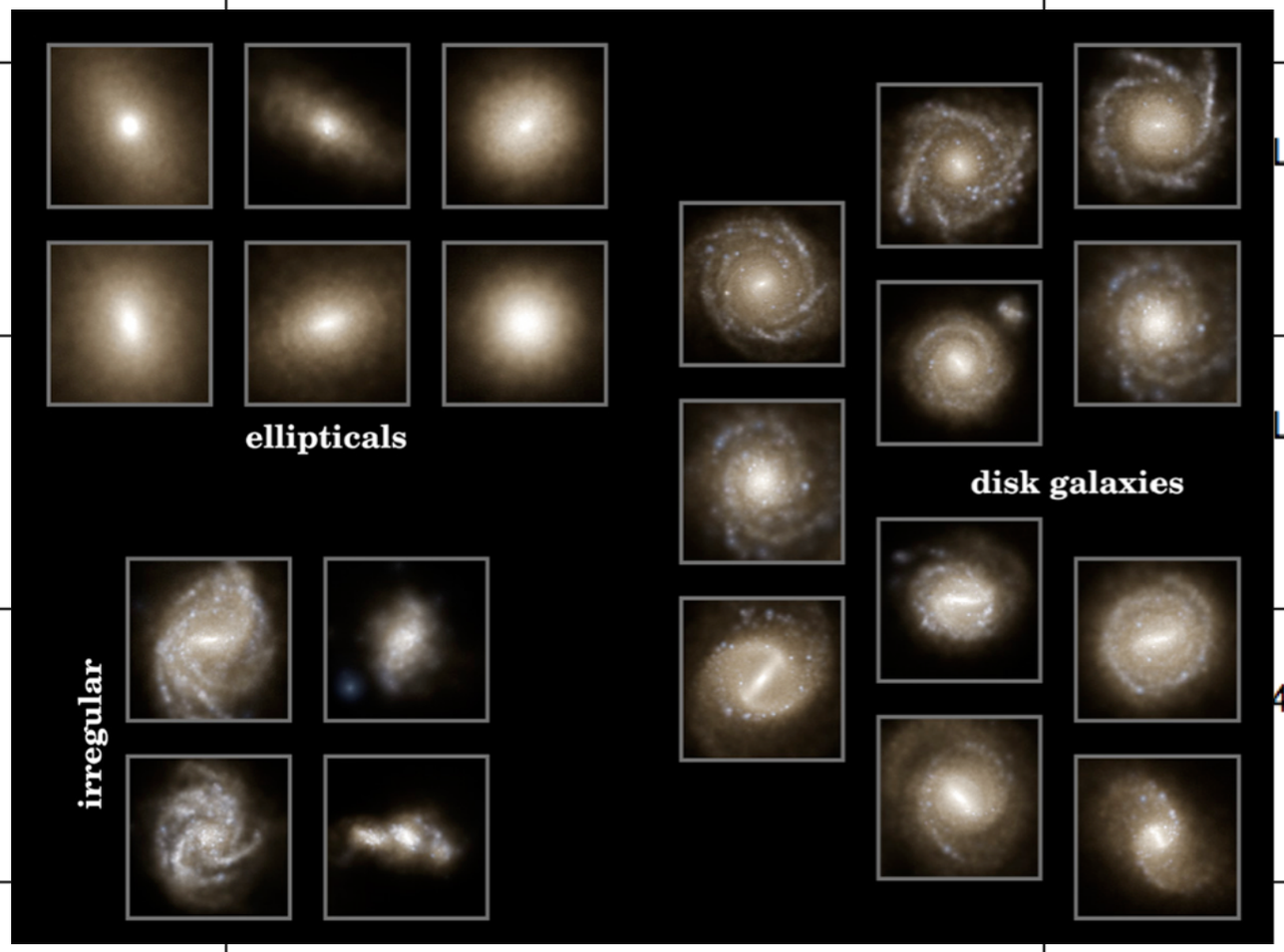


Definitions, basic concepts, R practice

What is the “typical” value of a dataset? (median)

What is the typical deviation of any model around this typical value? (standard deviation)

6	• Modeling data with probability distributions • Foundations for inference	OIS 4
7	• Inference for numerical data • Inference for categorical data	OIS 5, OIS 6
8	• Linear regression	OIS 7 (ISL 3)
		L 3)
		L 4)
		4.6.5
13	• Intro to Unsupervised linear models: Principle component analysis	ISL 10.0-10.2

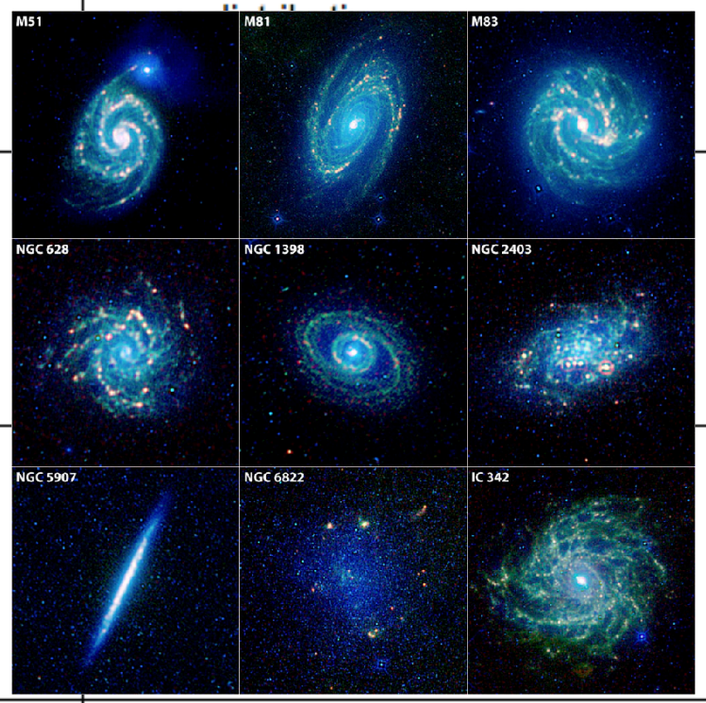


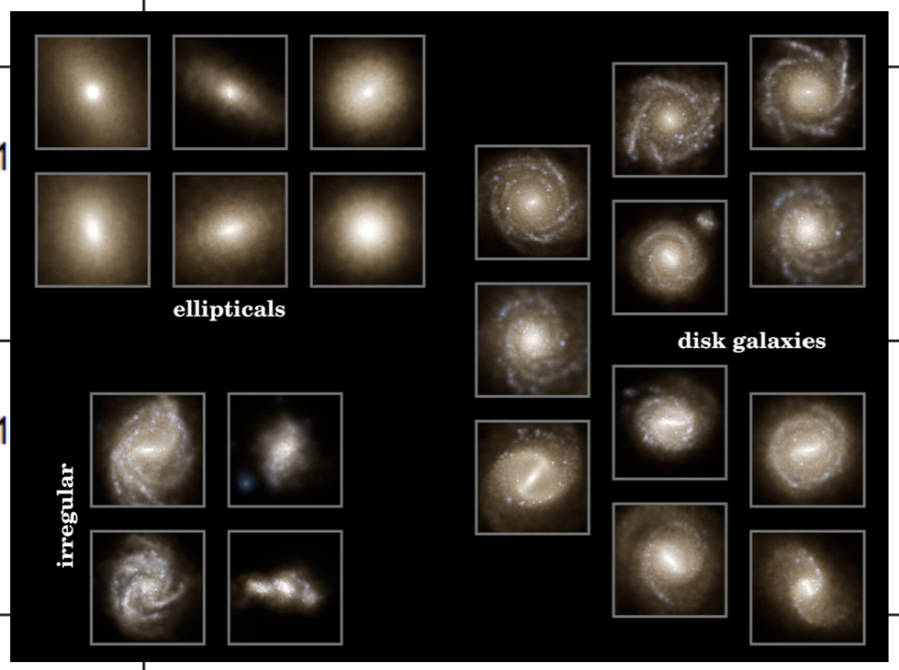
How well can we answer questions with our data?

How do different "variables" in our dataset (like supernova rate and galaxy mass) depend on one another?

How sure can we be that one variable depends on another?

6	• Modeling data with probability	OIS 4
7		OIS 5, OIS 6
8		OIS 7 (ISL 3)
9	• Multiple linear regression	OIS 8 (ISL 3)
1		OIS 8 (ISL 4)
1		ISL 2.2.3, 4.6.5
13	• Intro to Unsupervised linear models: Principle component analysis	ISL 10.0-10.2





Making predictions from data

Stickland, we define phase 0.0 to be superior conjunction of the primary star.

The spectra were reduced by standard techniques (see Paper I) which included the removal of atmospheric telluric lines. The final step yields rectified spectra transformed to a uniform heliocentric wavelength grid. The resulting spectra appear in Figures 1 and 2 for Hα and He I λ6678, respectively. In these figures we plot the spectra as a function of radial velocity assuming rest wavelengths of 6562.682 Å and 6678.148 Å for Hα and He I, respectively. The spectra are placed in the upper portion of each diagram so that their continua are aligned with the orbital phase of observation. The bar at the upper right indicates the intensity scale relative to the continuum. The lower portion of the figure shows the same spectra portrayed as a gray-scale image in which spectral intensity is transformed into a gray-scale intensity (dark in the absorption cores and bright at the emission peaks). The spectrum at each orbital phase in the image was calculated by a linear interpolation between observations with the closest phases. In some cases, the interpolation method causes narrow features to appear as discrete circles near conjunction phases (0.0 and 0.5) where the velocity changes rapidly between observations (see, for example, Si IV λ6701 located near V_r = 1050 km s^{-1} in Fig. 2).

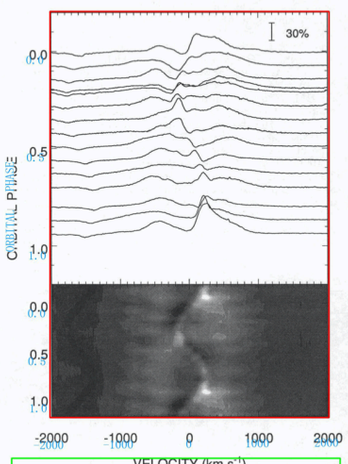


FIG. 1.—*Top*: Hα line profiles plotted against heliocentric radial velocity. The profiles are arranged in order of increasing orbital phase and each spectrum is placed in the y-ordinate so that the continuum equals the phase of observation (phase 0.0 = superior conjunction of the primary). The bar in the upper right gives the spectrum intensity scale relative to a unit continuum. The fourth spectrum from the top was obtained two years after the other spectra. *Bottom*: A gray-scale representation of the profile variations shown above. Here each spectral intensity is assigned one of 16 gray levels based on its value between the minimum (deepest absorption) and maximum (highest emission) observed values. The spectrum at each phase in the image is calculated by a linear interpolation between the closest observed phases. The spectral image for the first and last 20% of the orbit are reproduced at the bottom and top of the image, respectively, to improve the sense of phase continuity.

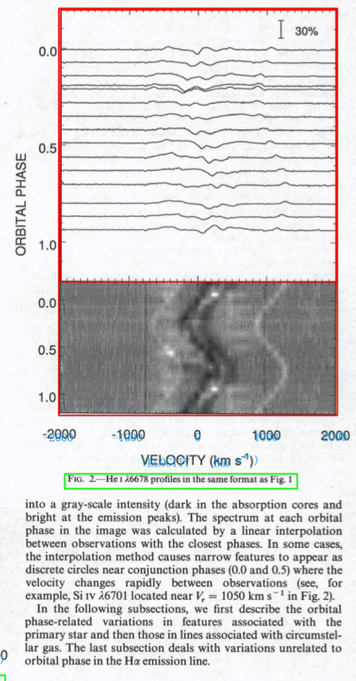


FIG. 2.—He I λ6678 profiles in the same format as Fig. 1

In the following subsections, we first describe the orbital phase-related variations in features associated with the primary star and then those in lines associated with circumstellar gas. The last subsection deals with variations unrelated to orbital phase in the Hα emission line.

2.1. *Spectral Lines Associated with the Primary Star*

There are several lines in Figures 1 and 2 which show the familiar "s" shape corresponding to the velocity curve of the primary star. These include the absorption lines He I λ6678 and He II λλ6527.13, 6683.20 and the emission lines Si IV λλ6667.56, 6701.21 (Fullerton 1989). All of these lines are typically found in mid-O supergiants (Conti 1974; Ninkov, Walker, & Yang 1987a; Ninkov et al. 1987b). In addition, we observed a weak emission line (maximum intensity ≈4% of the continuum) near 6610 Å which we tentatively identify as N II λ6610.58. Meinel, Aveni, & Stockton (1981) offer this iden-

Fig. 1—Top: Hα line profiles plotted against heliocentric radial velocity. The profiles are arranged in order of increasing orbital phase and each spectrum is placed in the y-ordinate so that the continuum equals the phase of observation (phase 0.0 = superior conjunction of the primary). The bar in the upper right gives the spectrum intensity scale relative to a unit continuum. The fourth spectrum from the top was obtained two years after the other spectra. Bottom: A gray-scale representation of the profile variations shown above. Here each spectral intensity is assigned one of 16 gray levels based on its value between the minimum (deepest absorption) and maximum (highest emission) observed values. The spectrum at each phase in the image is calculated by a linear interpolation between the closest observed phases. The spectral image for the first and last 20% of the orbit are reproduced at the bottom and top of the image, respectively, to improve the sense of phase continuity.

10	• Logical regression	OIS 8 (ISL 4)
12	• *k*-Nearest neighbor classification and regression	ISL 2.2.3, 4.6.5
13	• Intro to Unsupervised linear models: Principle component analysis	ISL 10.0-10.2

Making predictions from data = intro to machine learning methods

A Jamboard moment!

Quick activity!

On a piece of paper or in notes on your computer:

- What are the most memorable movies you saw over the last year?
- Do you prefer cats or dogs?
- How would you quantify your experience in statistics?
- How many chairs or tables are there in your room?

Breakout group & Jamboard - if you were to summarize your datasets with 1 or 2 numbers (or something else…?) how would you do it?

Use jamboard to draw the approximate distributions in the survey and show visually what this measurement would look like. Actual calculations not required!

Don’t forget to say hi to each other!

Quick activity!

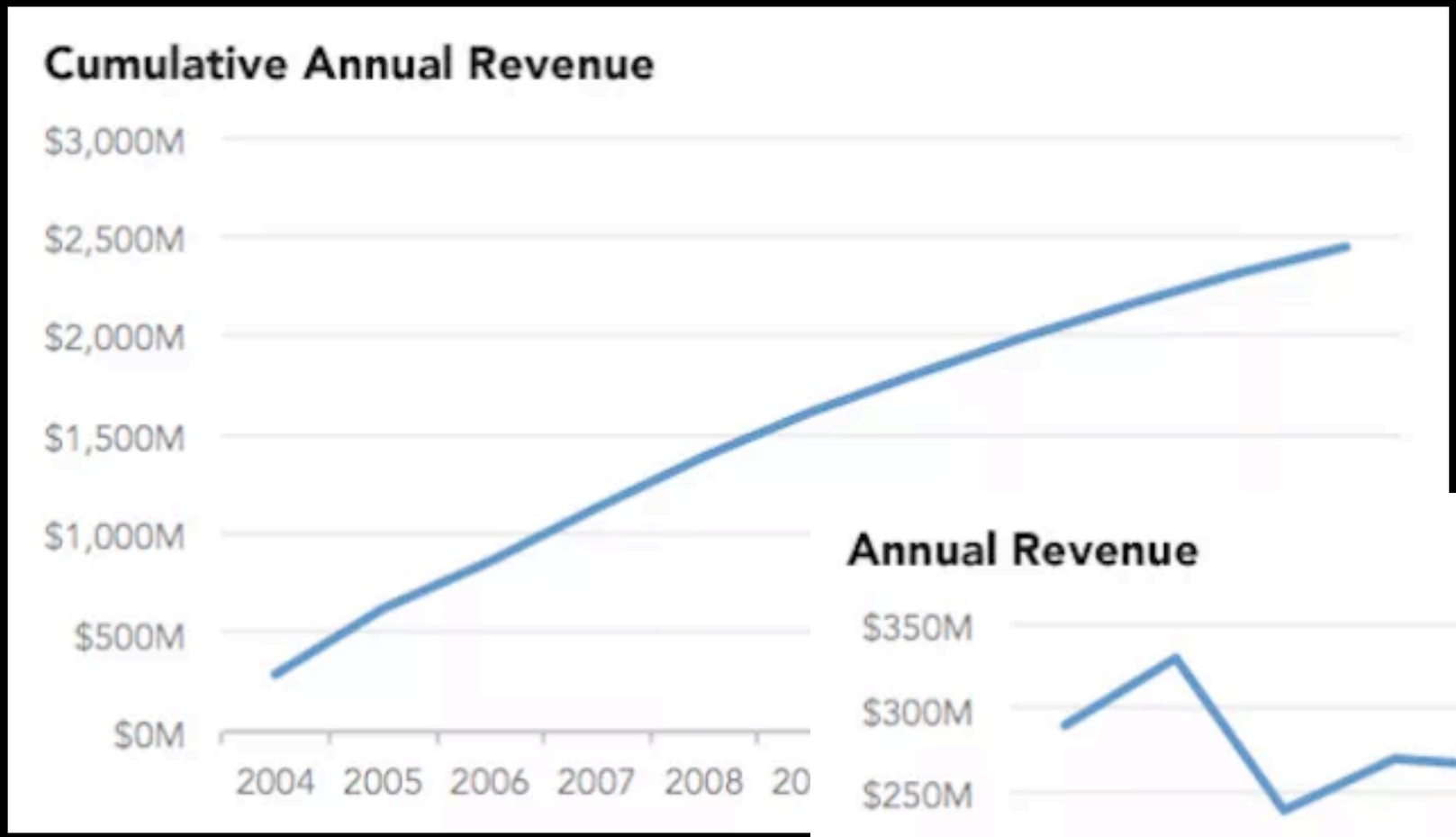
On a piece of paper or in notes on your computer:

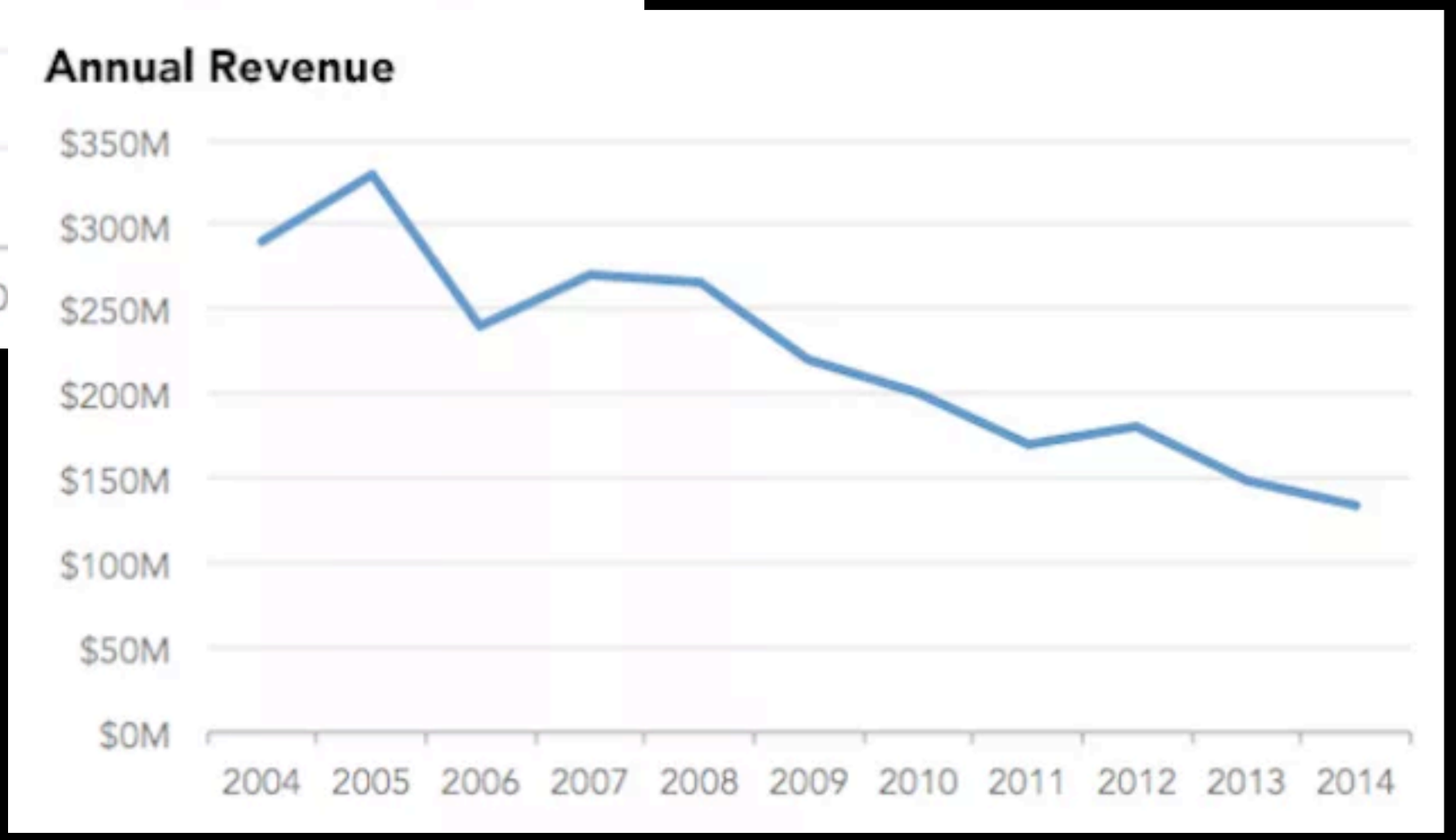
- What are the most memorable movies you saw over the last year?
- Do you prefer cats or dogs?
- How would you quantify your experience in statistics?
- How many chairs or tables are there in your room?

As a group: what was easy/hard about summarizing your datasets in this way? How confident are you of your summaries?

Lying… with Data!

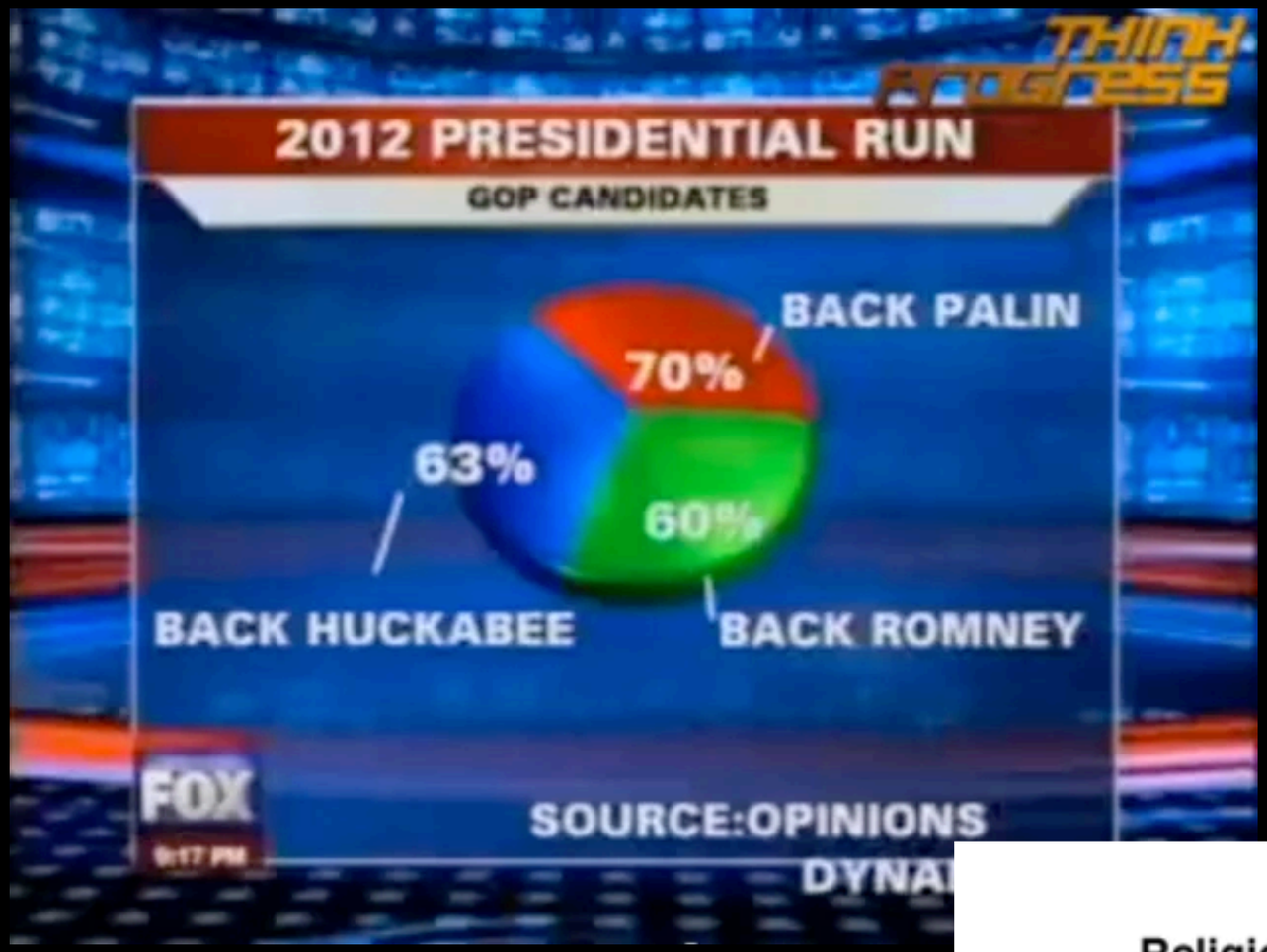
How about if I ask about how profitable your company?

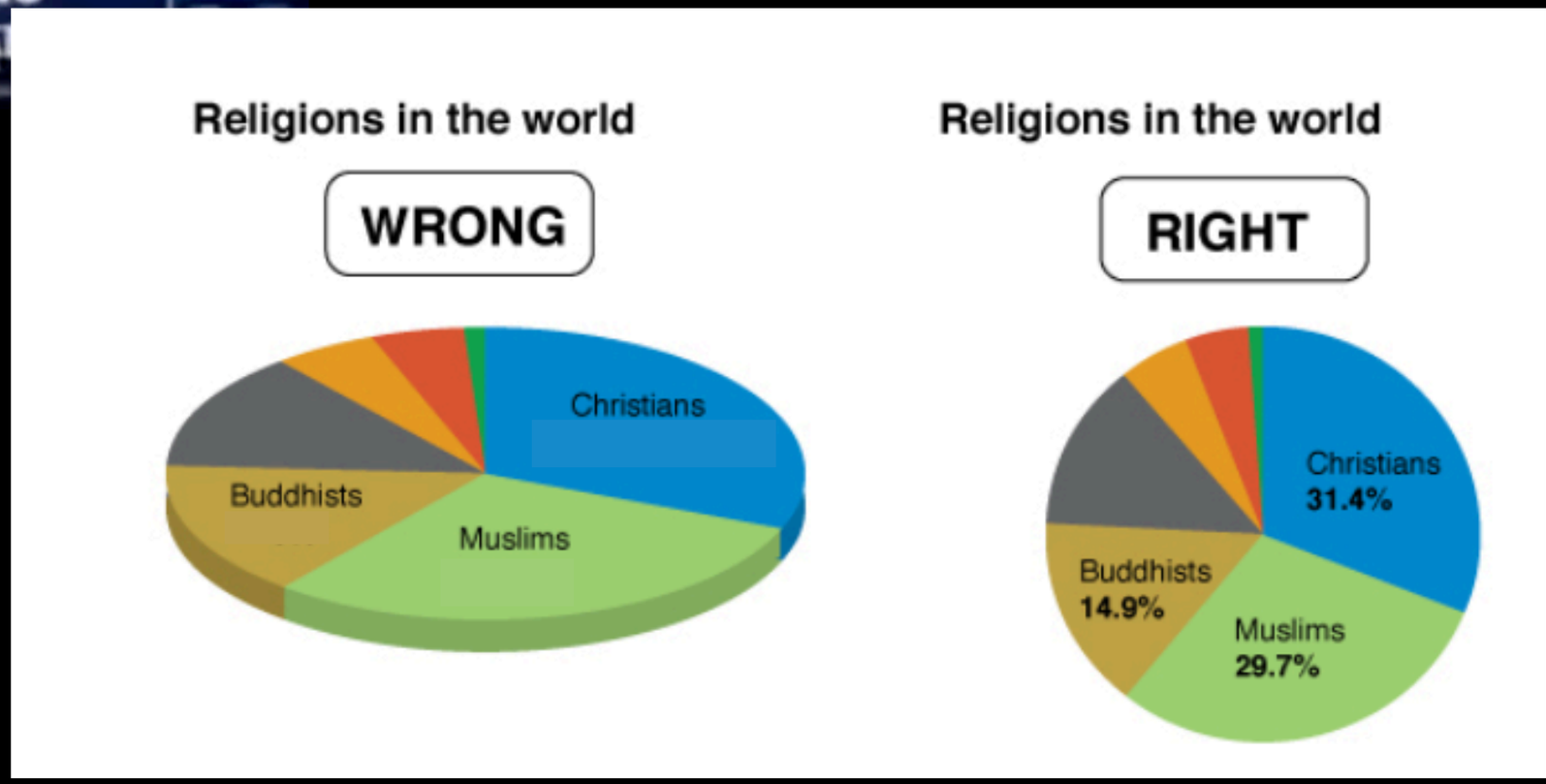




https://gizmodo.com/how-to-lie-with-data-visualization-1563576606

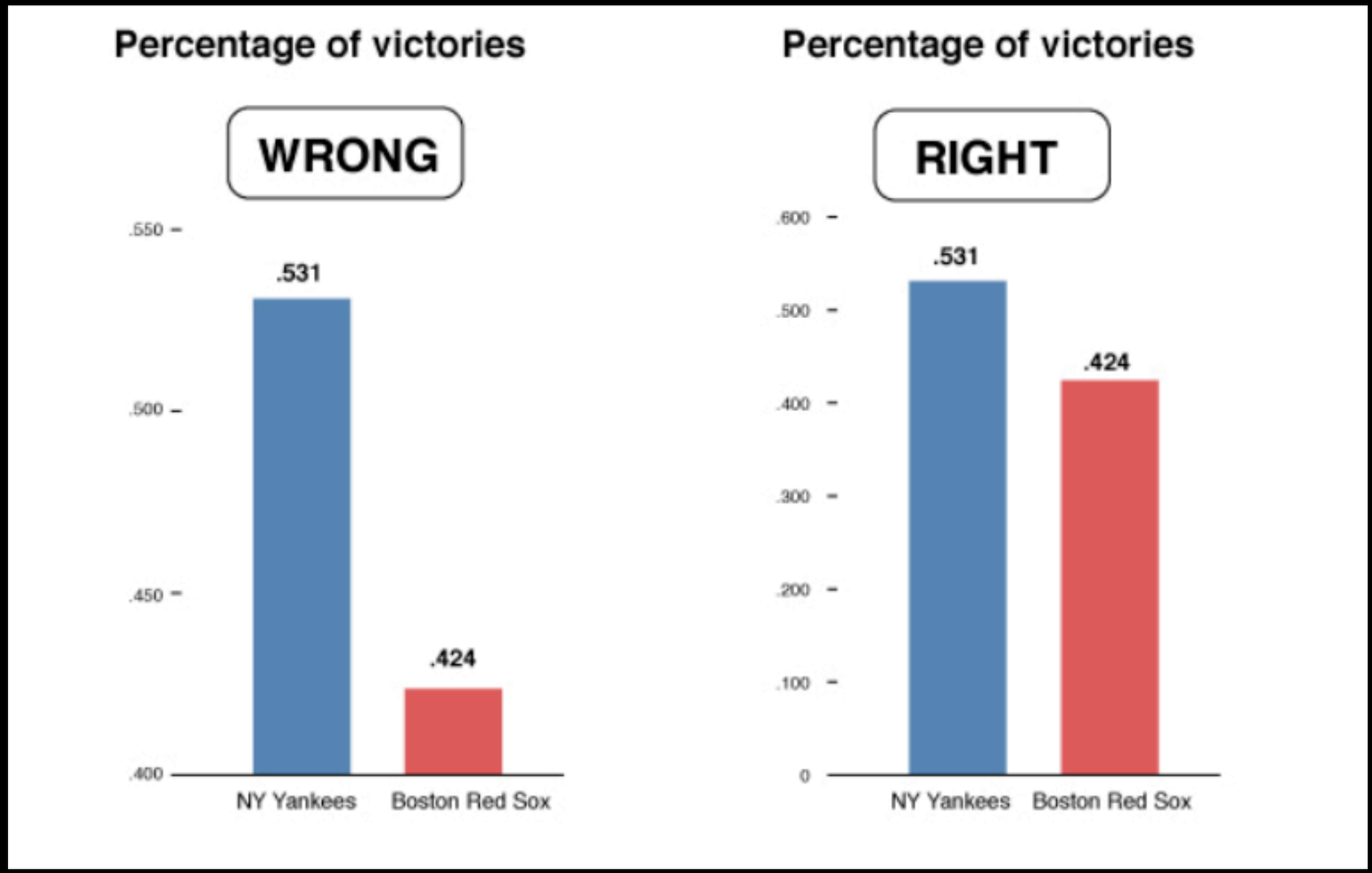
Lying… with Data!





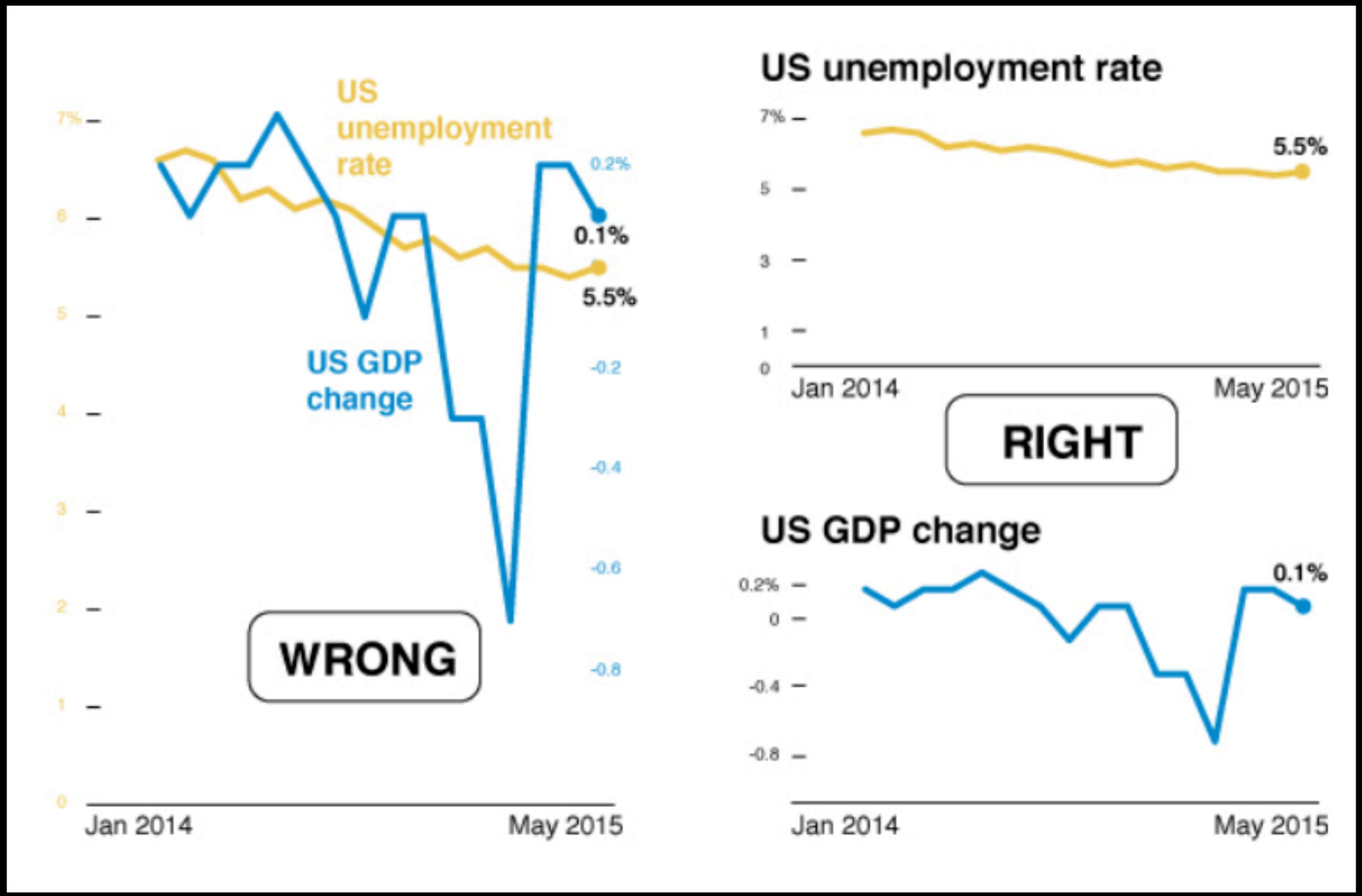
https://gizmodo.com/how-to-lie-with-data-visualization-1563576606
https://news.nationalgeographic.com/2015/06/150619-data-points-five-ways-to-lie-with-charts/

Lying… with Data!



https://news.nationalgeographic.com/2015/06/150619-data-points-five-ways-to-lie-with-charts/

Lying… with Data!



https://news.nationalgeographic.com/2015/06/150619-data-points-five-ways-to-lie-with-charts/

http://www.tylervigen.com/spurious-correlations

Plots can mislead people!

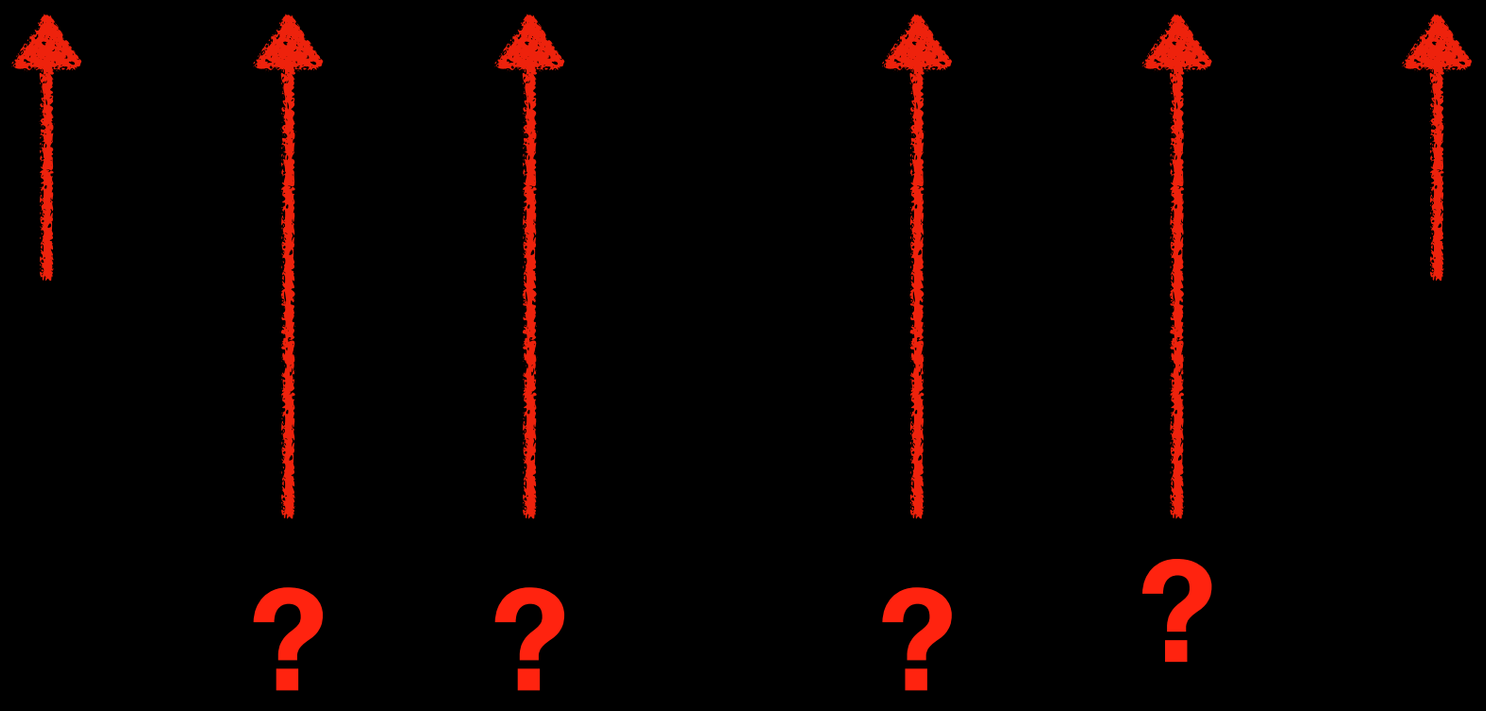
Proceed with caution.

Let’s get plotting!

… but first, let’s all make sure R & R-Studio are installed!

summary(after)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
39.00	41.25	44.50	44.21	46.75	50.00



Summary Statistic Definitions!

Mean (Sample) = sum of all data values divided by number of data points

$$\text{Mean} = \frac{\text{Sum of all values}}{\text{Number of values}}$$

$$\text{Symbolically, } \bar{x} = \frac{\sum x}{n}$$

where $\bar{x}$ (read as 'x bar') is the mean of the set of x values,
$\sum x$ is the sum of all the x values, and
n is the number of x values.

(note - only works with "numerical" data types… more about data types later)

Median = if we order the data from smallest to largest, this is the observation in the middle (splits the data in 2 halves)

First/Third Quartiles = where 25% of the data falls below/above

Standard Deviation = this is the square root of the variance, where the variance is roughly the average distance of data values from the mean

$$\text{Standard Deviation (sample)} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \text{mean})^2}{n-1}}$$

Summary Statistic Definitions!

Mean (Sample) = sum of all data values divided by number of data points

$$\text{Mean} = \frac{\text{Sum of all values}}{\text{Number of values}}$$

$$\text{Symbolically, } \bar{x} = \frac{\sum x}{n}$$

where $\bar{x}$ (read as 'x bar') is the mean of the set of x values,
$\sum x$ is the sum of all the x values, and
n is the number of x values.

(note - only works with "numerical" data types… more about data types later)

Median = if we order the data from smallest to largest, this is the observation in the middle (splits the data in 2 halves)

First/Third Quartiles = where 25% of the data falls below/above

Standard Deviation = this is the square root of the variance, where the variance is roughly the average distance of data values from the mean

$$\text{Standard Deviation (sample)} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \text{mean})^2}{n-1}}$$