TIME-DOMAIN ASTRONOMY

Lectures 1: Introduction

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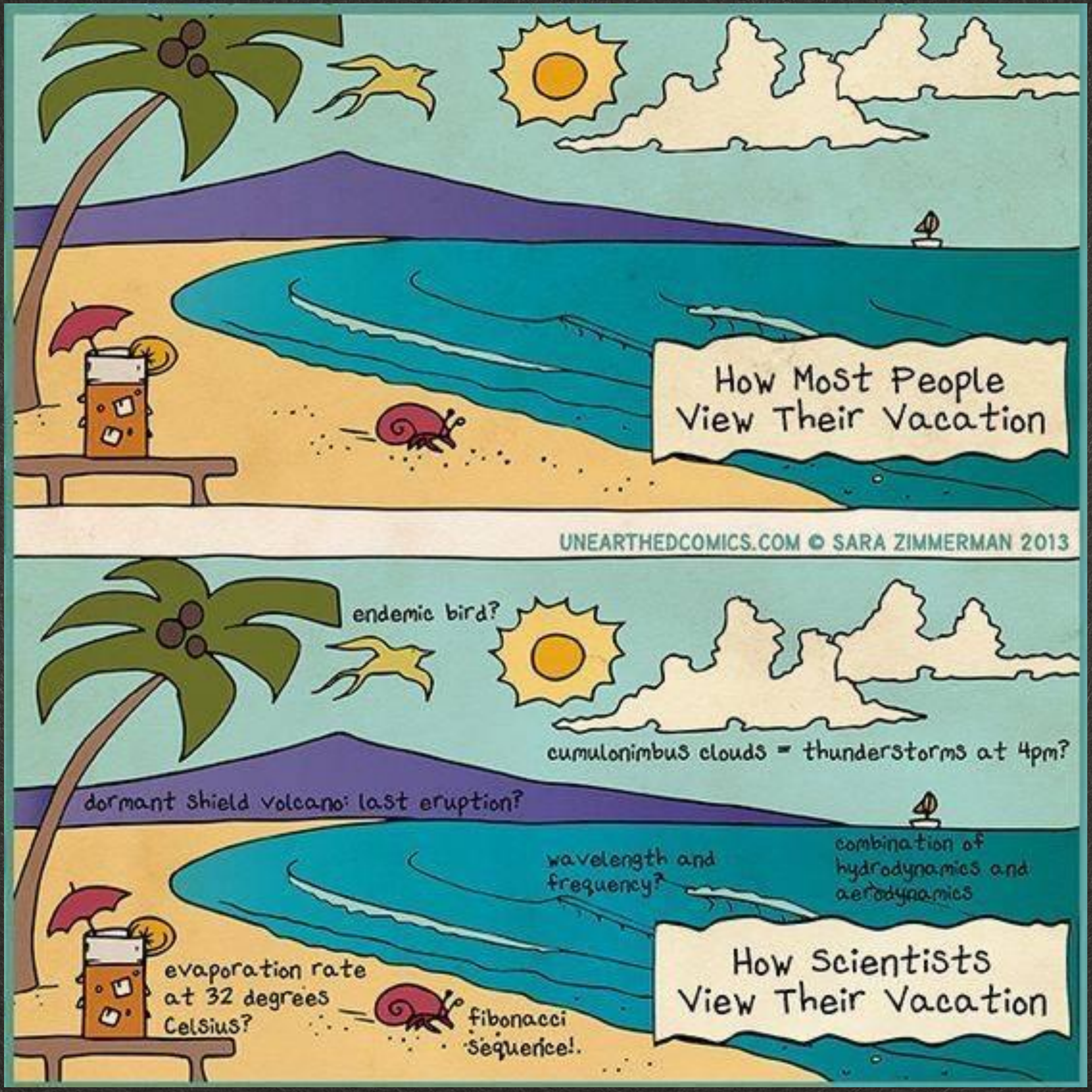
Main goal: Have Fun!

The most exciting phrase to hear in science, the one that heralds new discoveries, is not "Eureka!" but "That's funny..."

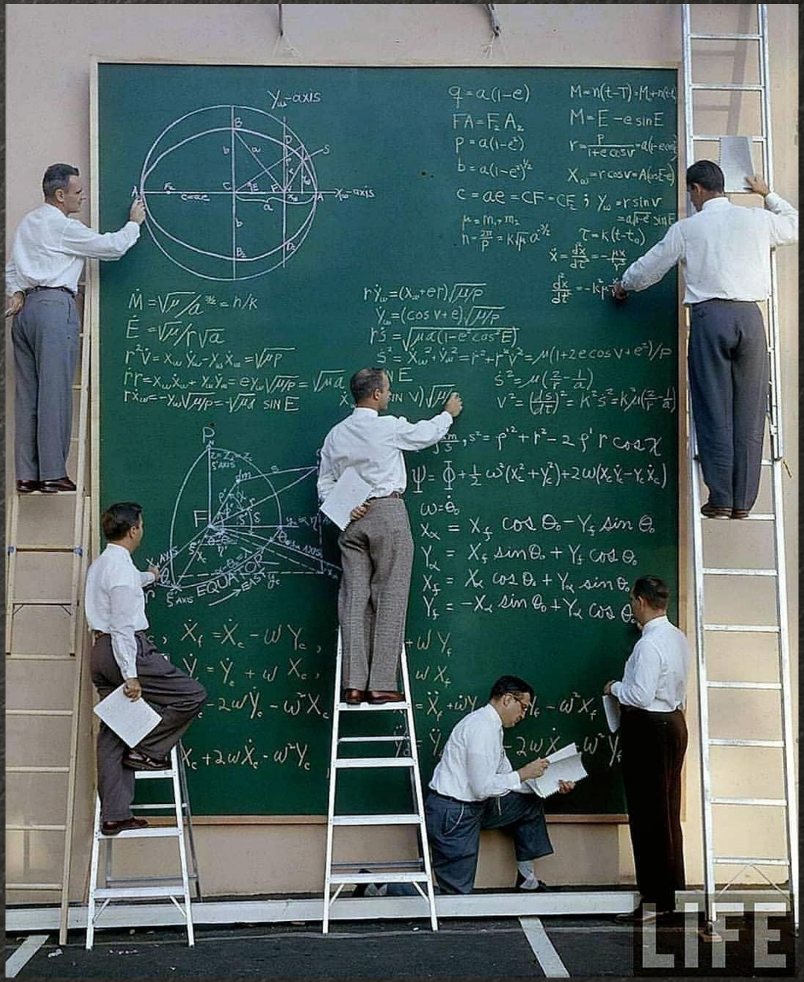
Isaac Asimov

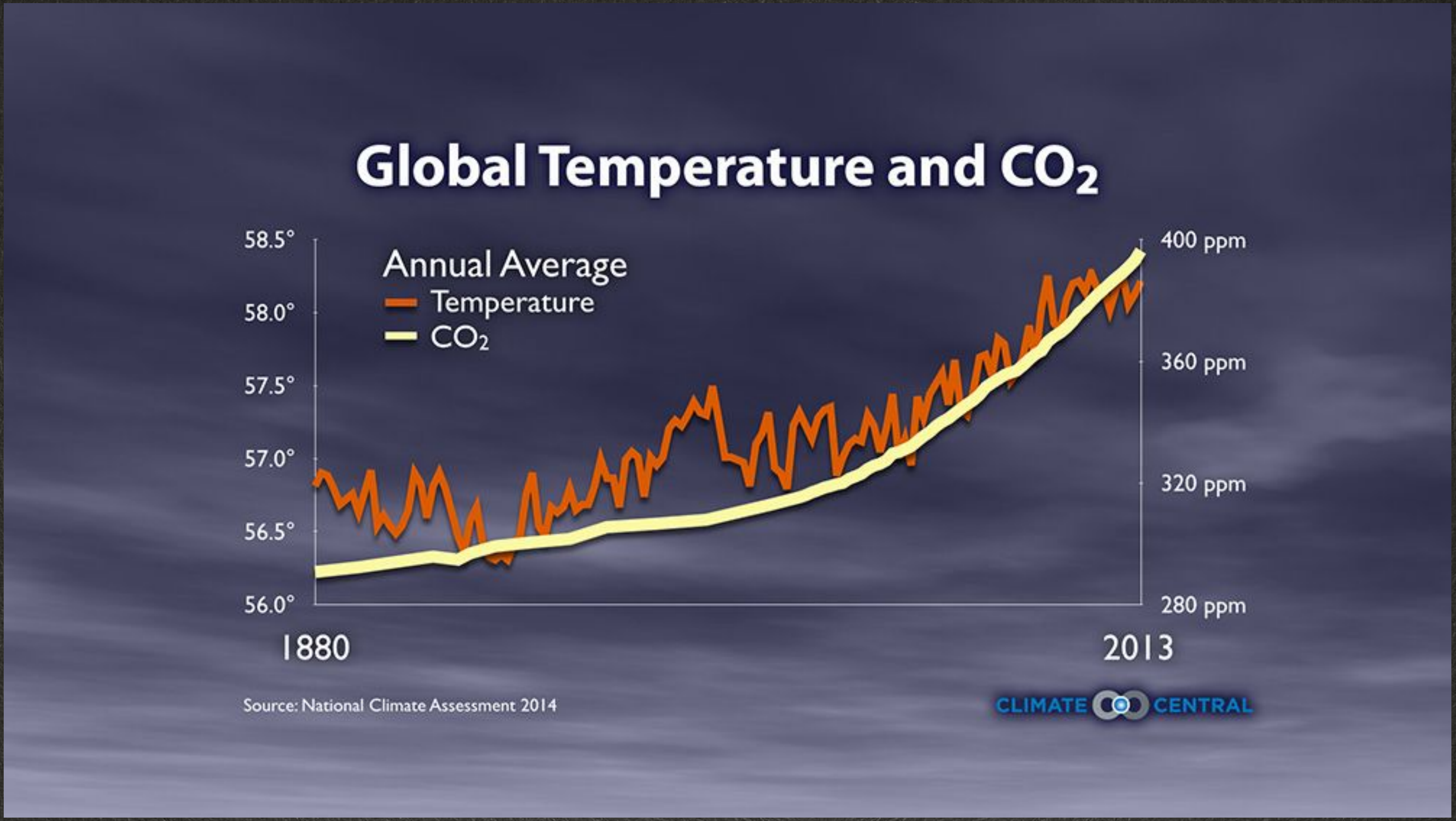
Although one must admit that...



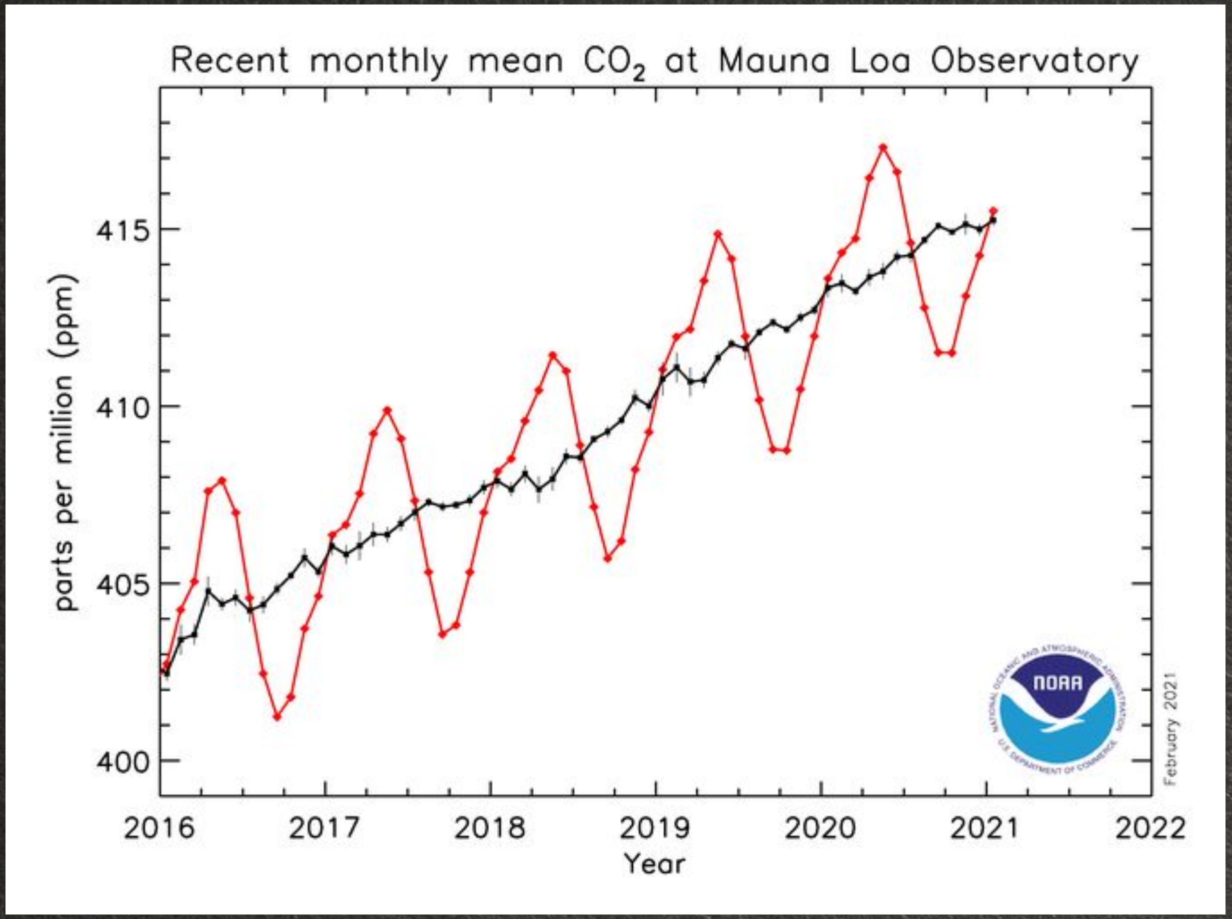
Program (for 6 or 7 courses, roughly...)

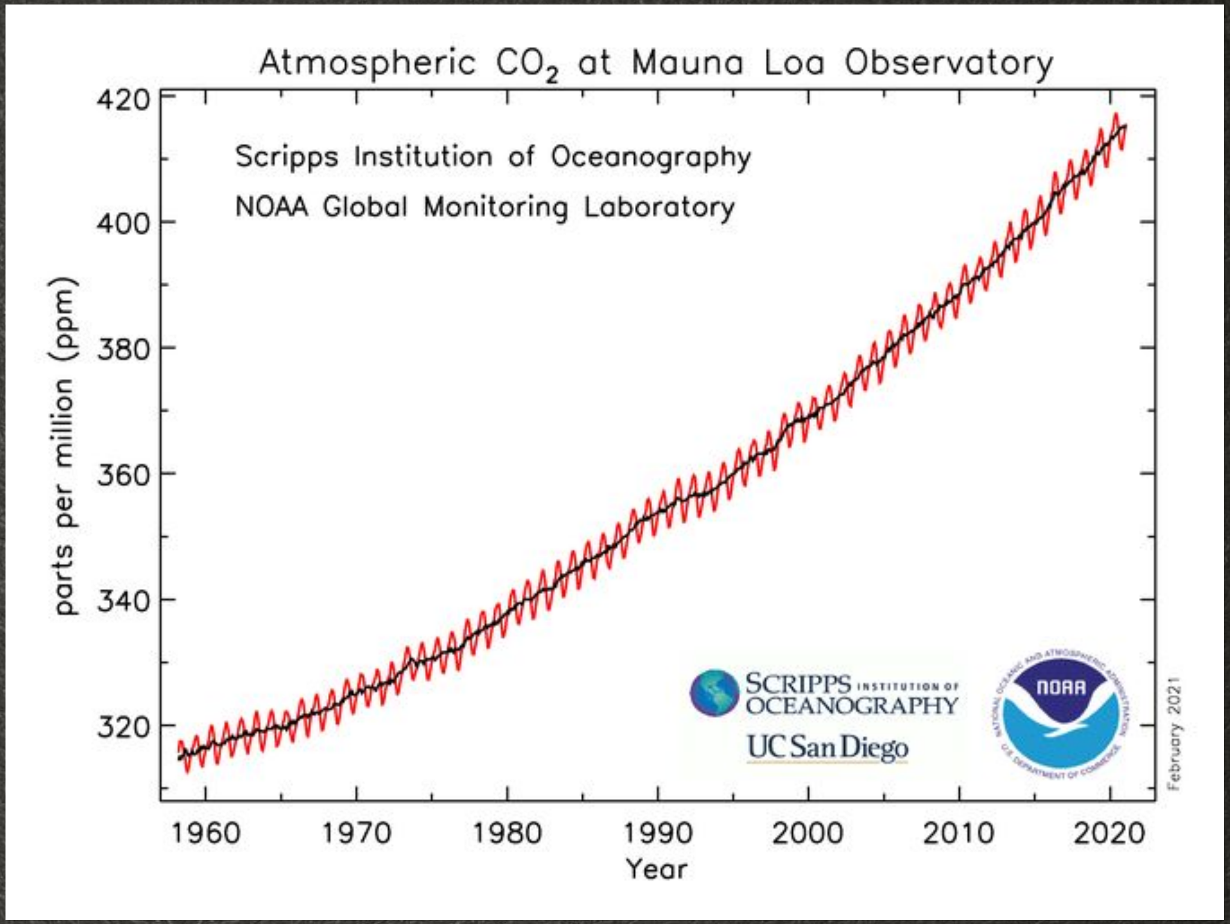
- Introduction to time series
- Time (and spatial) variability in astrophysics
- Fourier analysis and noise characterization
    - Case study: stellar variability
    - Case study: exo-planet transits
    - Case study: pulsars
- Time-domain analysis and auto-regressive processe
- Irregular sampling, Lomb-Scargle periodograms
    - Case studies: AGN variability
- Advanced topics: non-parametric analysis
- Matching filters
    - Case study: LIGO/Virgo gravitational wave signals
- Data exploration
    - Case study: SETI data analysis
- Big-data, machine learning and "intelligent" systems for time-series analysis
    - Case studies: spatial variability (CMB, large scale structure)
- Final topics: forecasting





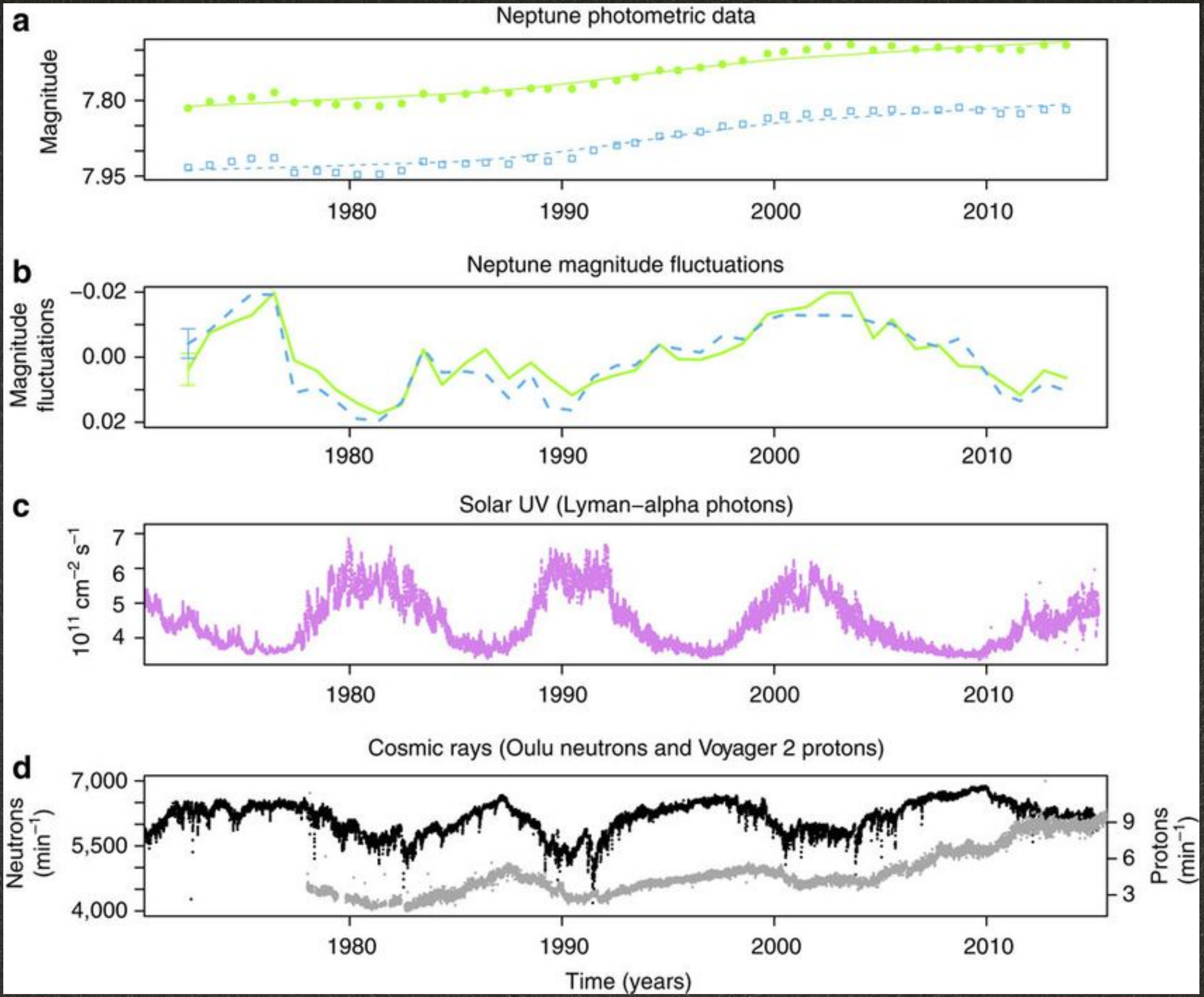
Typical examples of temporal series of great interest...



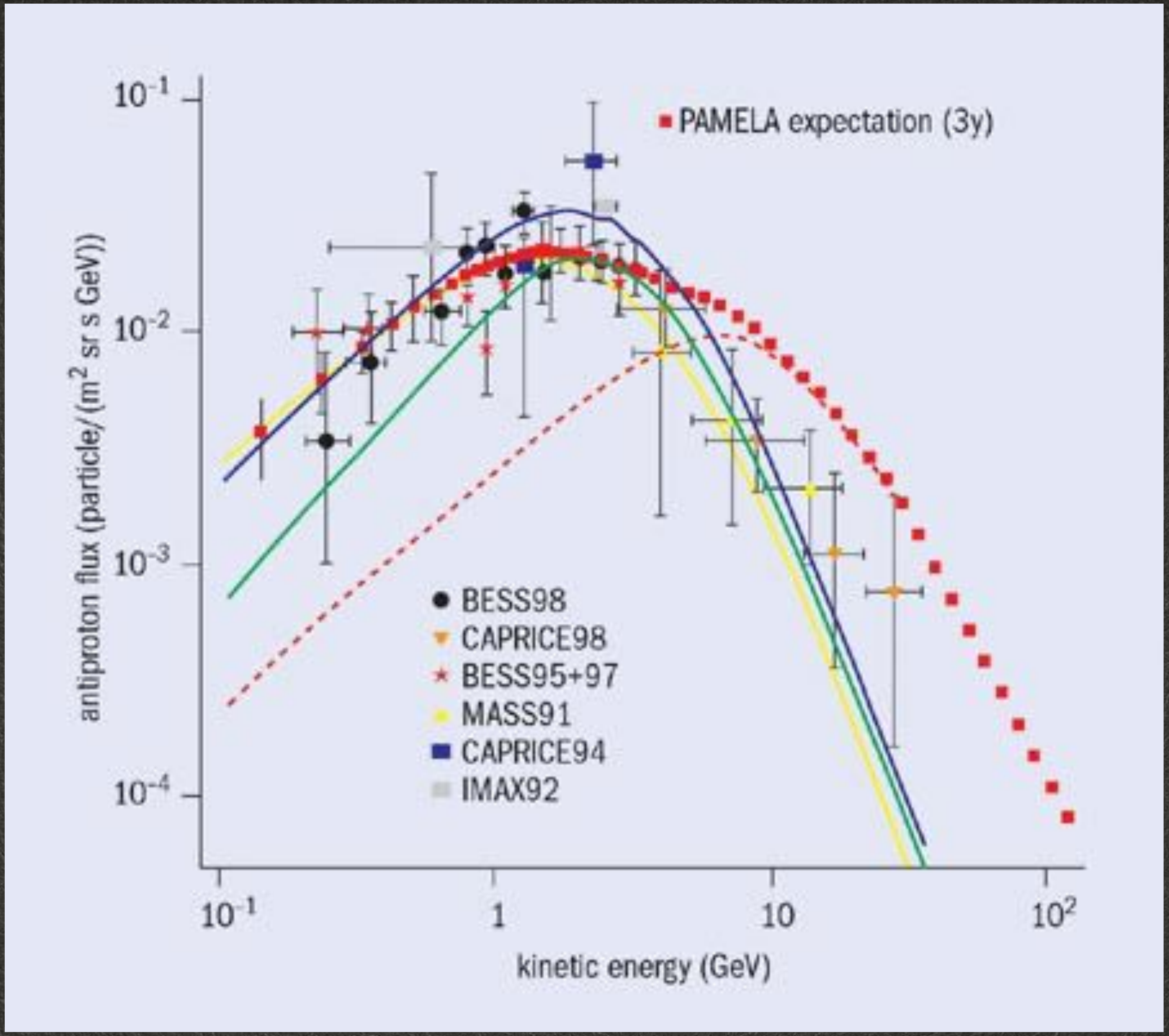


And with some more detail for CO_2...

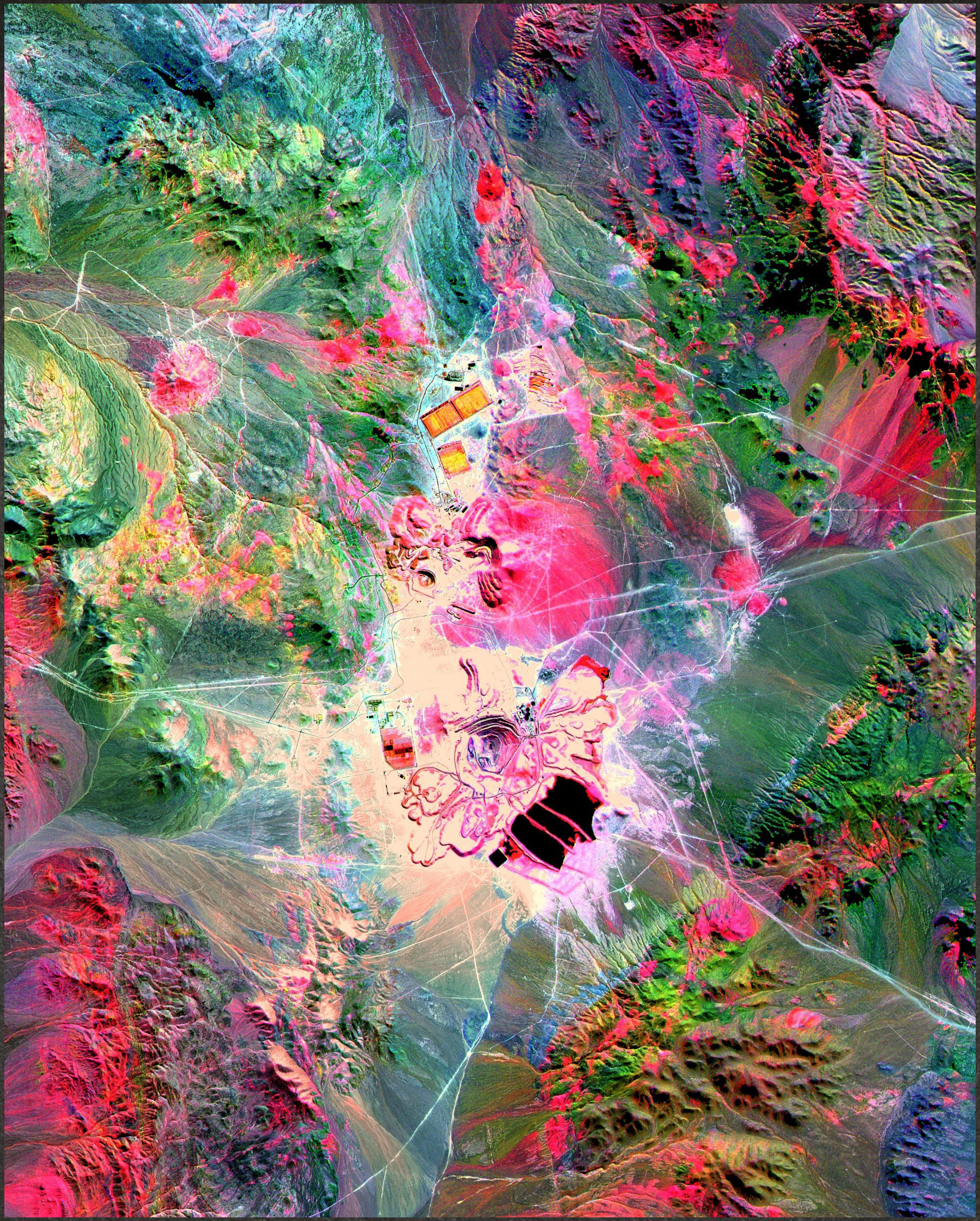
Aplin & Harrison (2016)



What does drive Neptune brightness variations?



Energy spectra, for instance, are just “time-series”… with “energy” rather than “time”…



Even maps are 2D “time-series”... with “Lat/Long” rather than ”time”...

Temptative schedule (don't trust it...)

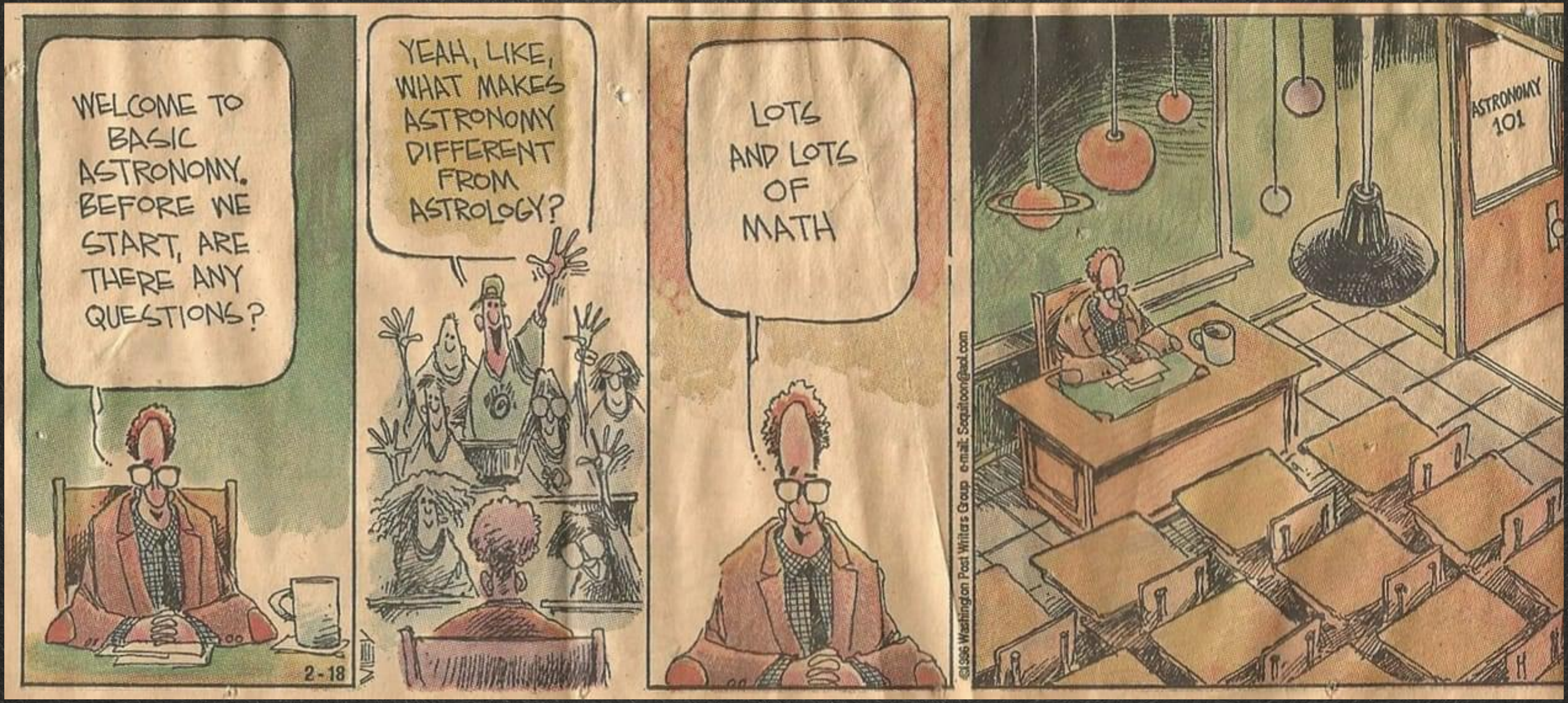
1. 28/2 - Introduction
2. 1/3 - Statistics reminder - part I
3. 6/3 - Statistics reminder - part II
4. 8/3 - Spectral analysis - part I
5. 13/3 - Spectral analysis - part II
6. 15/3 - Science cases: Sunspots Number - X-ray Binaries
7. 20/3 - Irregularly sampled time series - part I
8. 22/3 - Irregularly sampled time series - part II
9. 3/5 - Science Cases - Variable Stars - AGN and blazars
10. 5/4 - Time domain analysis - part I
11. 10/4 - Guest lecture - Spectral analysis in Cosmology
12. 12/4 - Guest lecture - X-ray pulsators

Temptative schedule (don't trust it…)

13. 17/4 - Time domain analysis - part II
14. 19/4 - Time domain analysis - ARIMA models
15. 23/4 - Time domain analysis - Advanced tools
16. 3/5 - Wavelet analysis
17. 8/5 - Time of arrival analysis
18. 10/5 - Non-parametric methods
19. 15/5 - Gaussian processes
20. 17/5 - Science case: GRBs
21. 22/5 - Astrostatistics final considerations
22. 24/5 - Guest lecture - Exoplanets

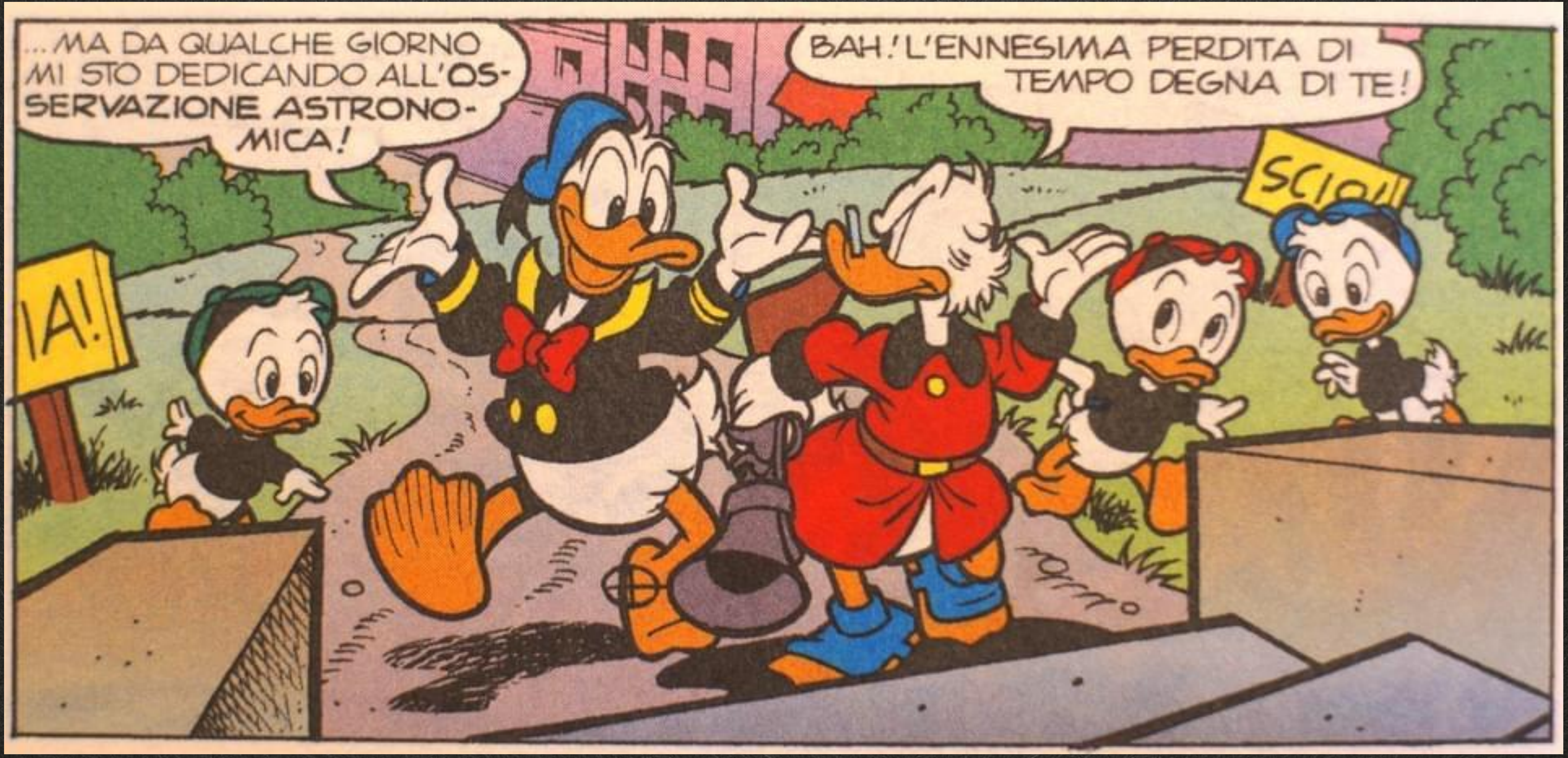
How?

- Frontal Lectures...



How?

- Real research life examples...



How?

- (Optional) papers to deepen our knowledge…

How?

- Question time...

How?

- Lectures from specialists in the field...

CARNEGIE INSTITUTE OF TECHNOLOGY
SCHENLEY PARK
PITTSBURGH 13, PENNSYLVANIA

DEPARTMENT OF MATHEMATICS
COLLEGE OF ENGINEERING AND SCIENCE

February 11, 1948

Professor S. Lefschetz
Department of Mathematics
Princeton University
Princeton, N. J.

Dear Professor Lefschetz:

This is to recommend Mr. John F. Nash, Jr. who has applied for entrance to the graduate college at Princeton.

Mr. Nash is nineteen years old and is graduating from Carnegie Tech in June. He is a mathematical genius.

Yours sincerely,

Richard J. Duffin

RJD:hl

How?

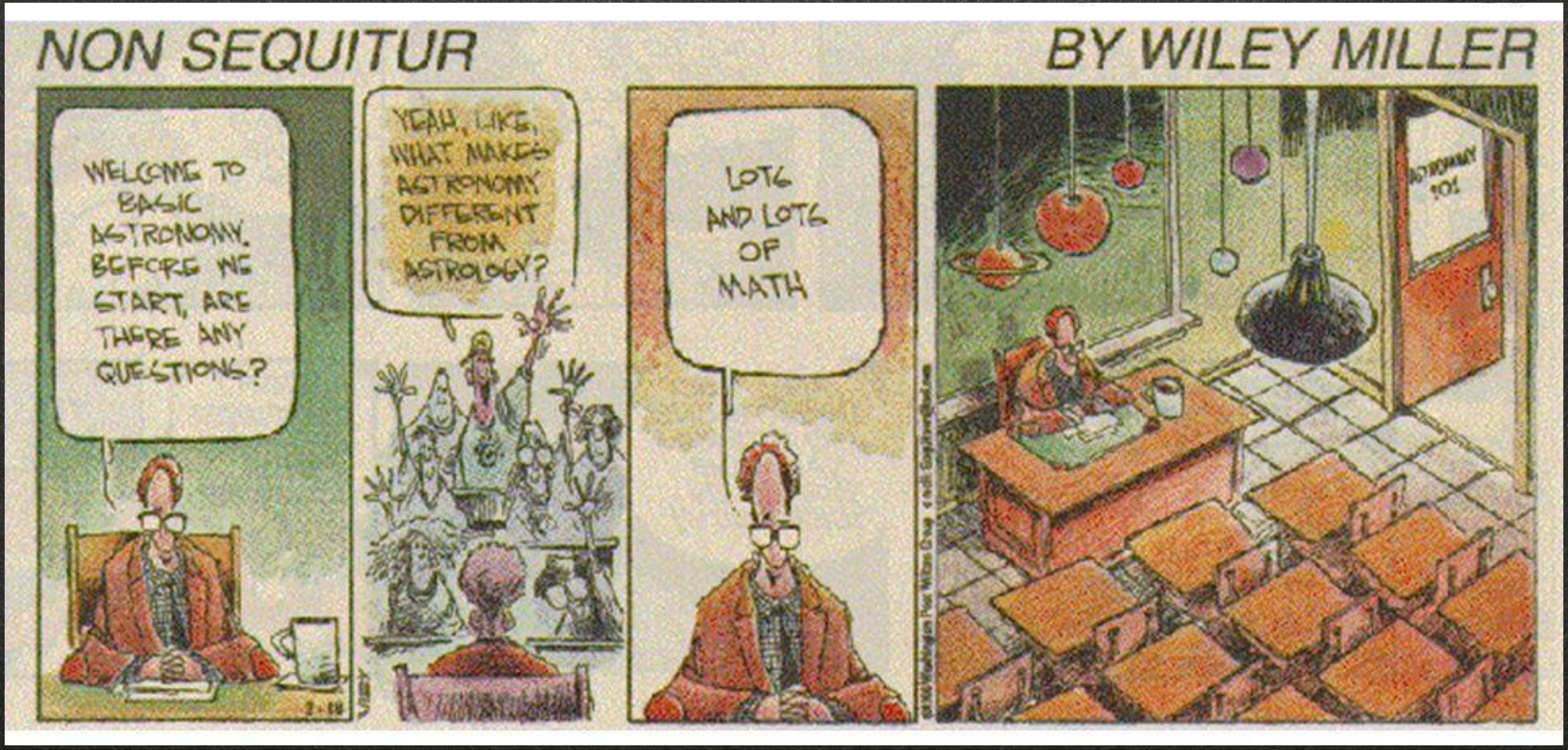
- Language...

Not only for astrophysicists!

- Examples, specialist lectures, etc. are thought for astrophysicists, but good for everyone in physics.

Final Assessment

The final examination is an oral one. Students must interact with the teacher in advance of the examination and a science case obtained by the modern literature will be selected. The student will be asked to properly describe the main formal aspects of the study and discuss critically the reliability and limits of the presented results.

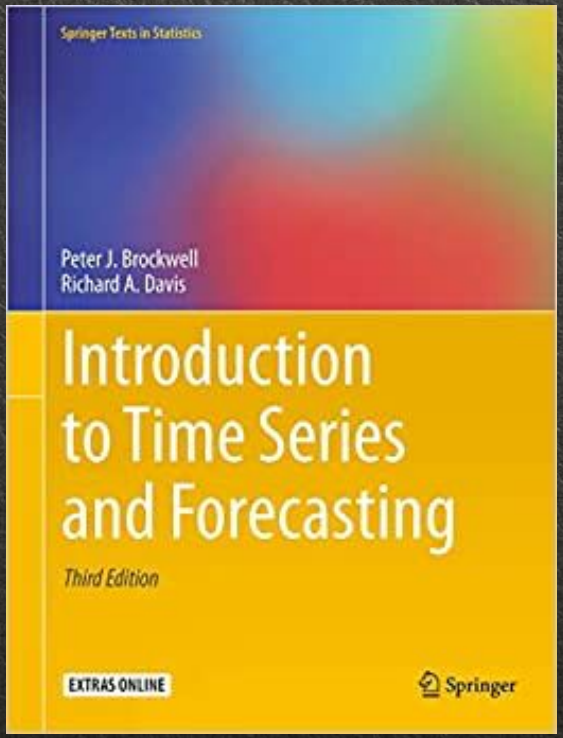


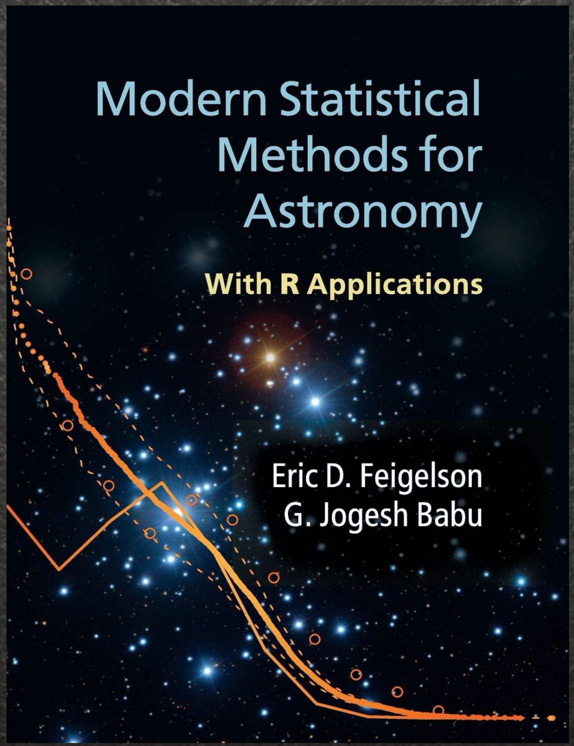
Books, papers, etc.

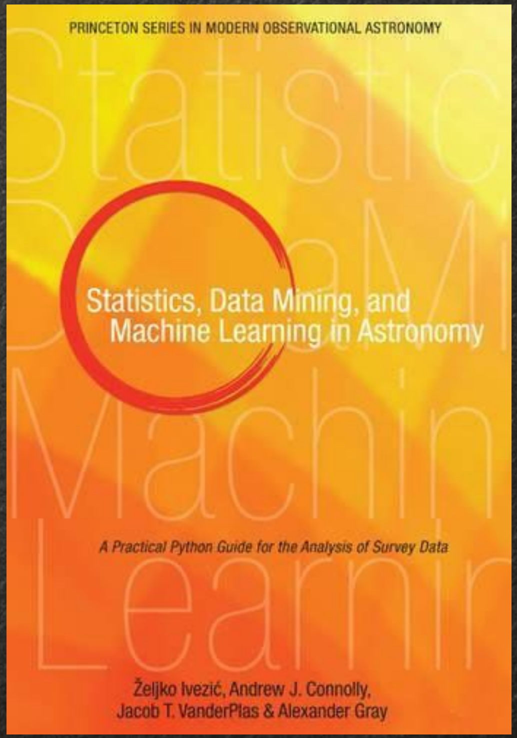
The course is based on published scientific papers distributed by the teacher before any main topic is addressed. Science cases are based on actual scientific papers as well. Slides prepared by the teacher will also be distributed.

A general introductory text to time series analysis as “Introduction to Time Series and Forecasting”, by P.J. Brockwell and R.A Davis (Springer) will be suggested. However, any other analogous text easily obtainable by the student will be fine as well.

Two more useful texts, specifically for astrophysical applications are “Modern Statistical Methods for Astronomy”, by E.D. Feigelson and G.J. Babu, and “Statistics, data Mining and Machine Learning in Astronomy”, by Ivezić et al.







Material on github

- Slides, notebooks, papers, etc. are available on github: https://github.com/stefanocovino/TimeDomainAstrophysics
- Check the repository frequently since is (often) updated during the course.

REFERENCES AND DEEPENING

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

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Review

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click for updates

Cite this article: Vaughan S. 2013 Random time series in astronomy. Phil Trans R Soc A 371: 20110549.
http://dx.doi.org/10.1098/rsta.2011.0549

One contribution of 17 to a Discussion Meeting Issue 'Signal processing and inference for the physical sciences'.

Subject Areas:
astrophysics, observational astronomy, statistics

Random time series in astronomy

Simon Vaughan

X-ray and Observational Astronomy Group, Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK

Progress in astronomy comes from interpreting the signals encoded in the light received from distant objects: the distribution of light over the sky (images), over photon wavelength (spectrum), over polarization angle and over time (usually called light curves by astronomers). In the time domain, we see transient events such as supernovae, gamma-ray bursts and other powerful explosions; we see periodic phenomena such as the orbits of planets around nearby stars, radio pulsars and pulsations of stars in nearby galaxies; and we see persistent aperiodic variations ('noise') from powerful systems such as accreting black holes. I review just a few of the recent and future challenges in the burgeoning area of time domain astrophysics, with particular attention to persistently variable sources, the recovery of reliable noise power spectra from sparsely sampled time series, higher order properties of accreting black holes, and time delays and correlations in multi-variate time series.

Simon Vaughan

Not easy to follow (now). Hopefully it'll be clear later...

Relaxing time (series)...