AstroML: Machine Learning for Astronomy

CIDU: 24 Oct 2012

Jake Vanderplas
Andrew Connolly
Zeljko Ivezic
Alex Gray

Python is becoming a new standard tool in Astronomy, and will remain important for the foreseeable future

LSST
Large Synoptic Survey Telescope

Astro
PY

DARK ENERGY SURVEY

Kepler

SDSS

Machine Learning / Statistical Data Analysis tasks in Astronomy:

- Photometric Redshifts (Regression)
- Source Classification
- Dimensionality Reduction / Visualization
- Clustering
- N-point Statistics
- Period Finding
- Transient & Outlier Detection
- Density Estimation
- Matched Filtering
- Source Extraction
- Cross-matching
- ...

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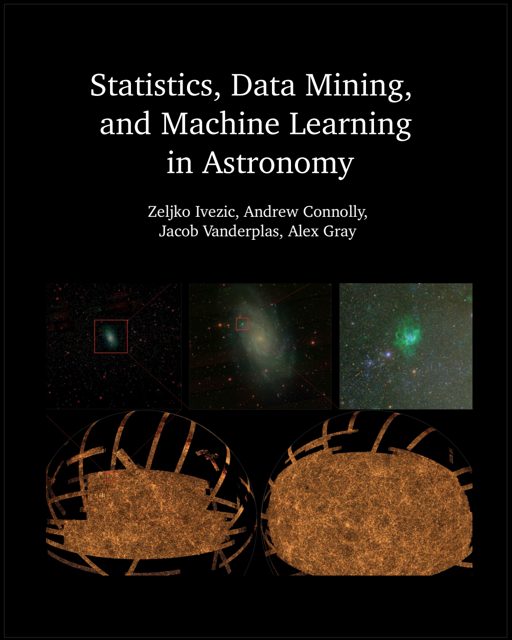
Every astronomer needs these sorts of tools, and existing Python packages provide an easy interface to many powerful algorithms.

Statistics, Data Mining and Machine Learning in Astronomy

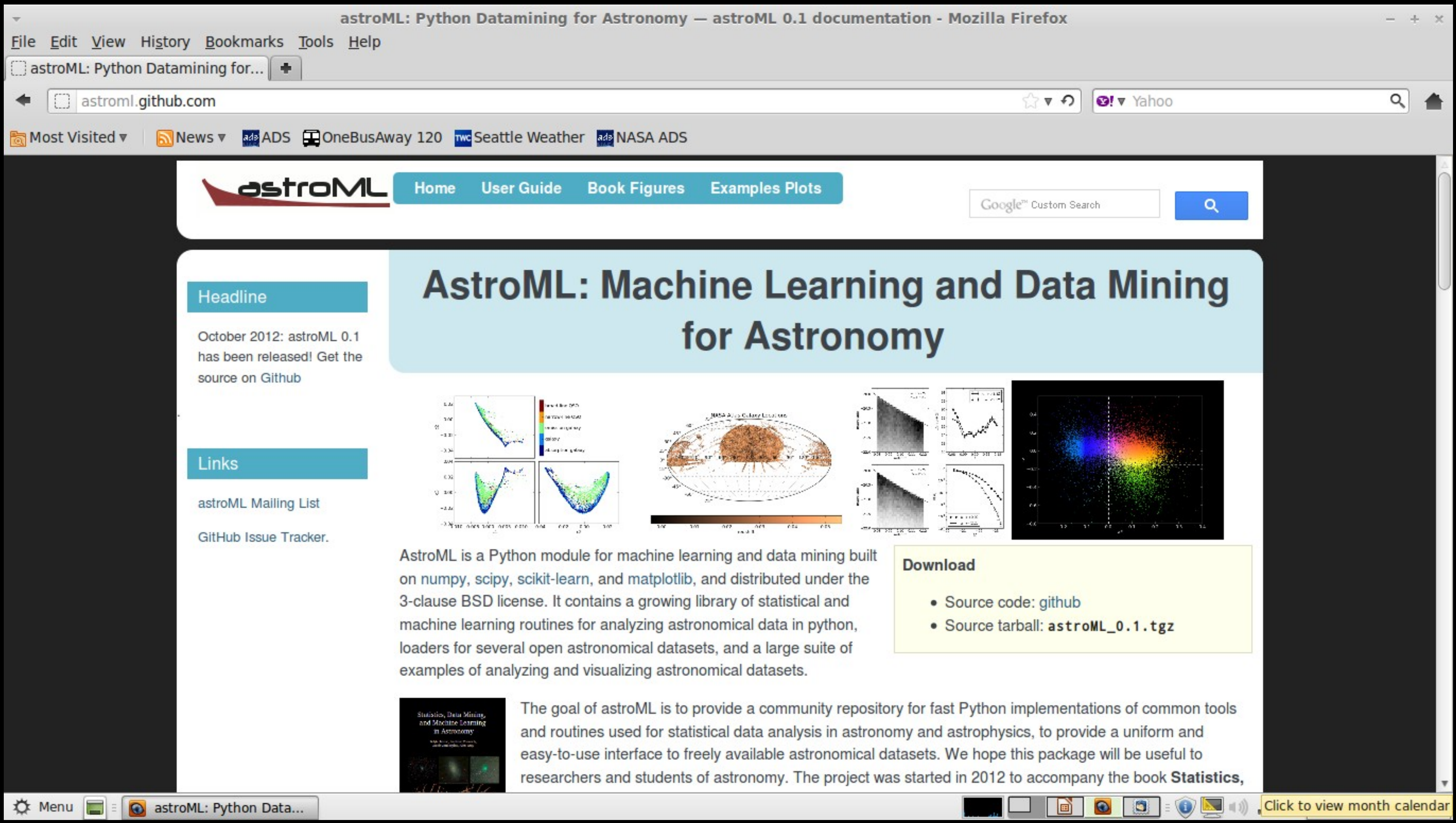


Zeljko Ivezic, Andrew Connolly,
Jacob Vanderplas, Alex Gray

Princeton University Press, 2013

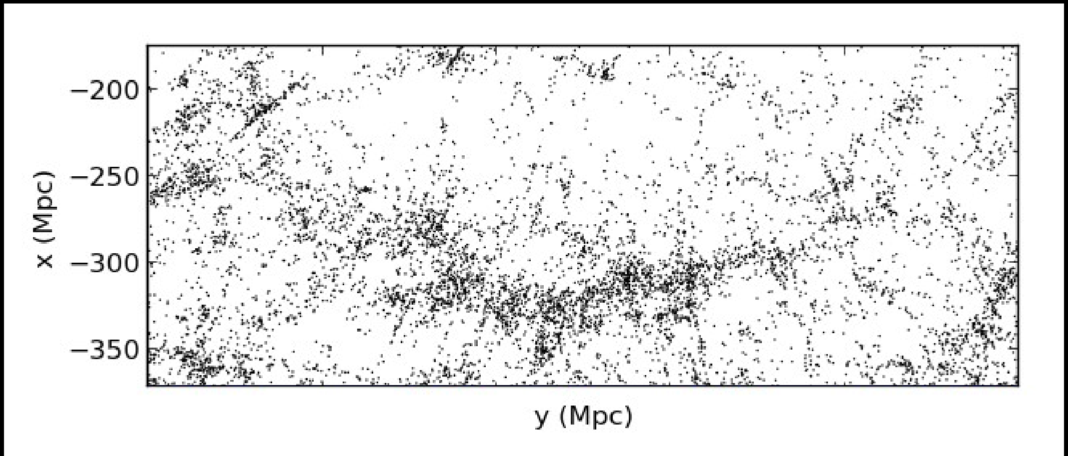
- Complete *Practical* guide to statistical analysis, data exploration, and machine learning
- Example-driven approach, using real data (SDSS, LIGO, LINEAR, WMAP, and others)
- All book figures and examples generated in python (matplotlib), with code available online – for free!
- Supporting python package: *astroML*
- Makes use of *numpy, scipy, matplotlib, scikit-learn, pymc, healpy,* and others where possible: limited code duplication

AstroML: Python Machine Learning for Astronomy



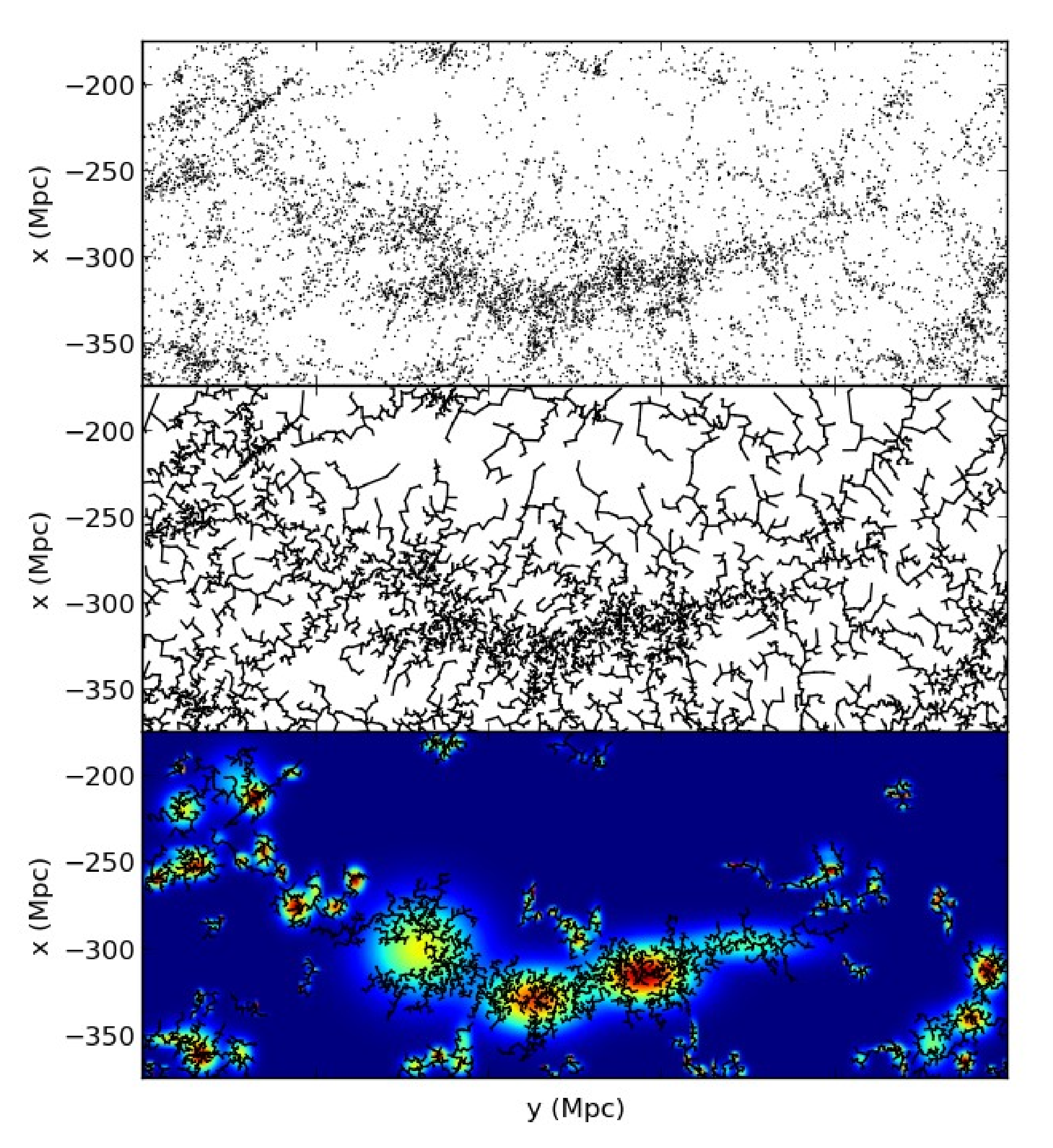
http://astroML.github.com

Clustering and Density Estimation: SDSS Great Wall



Projected Galaxy Locations

Clustering and Density Estimation: SDSS Great Wall

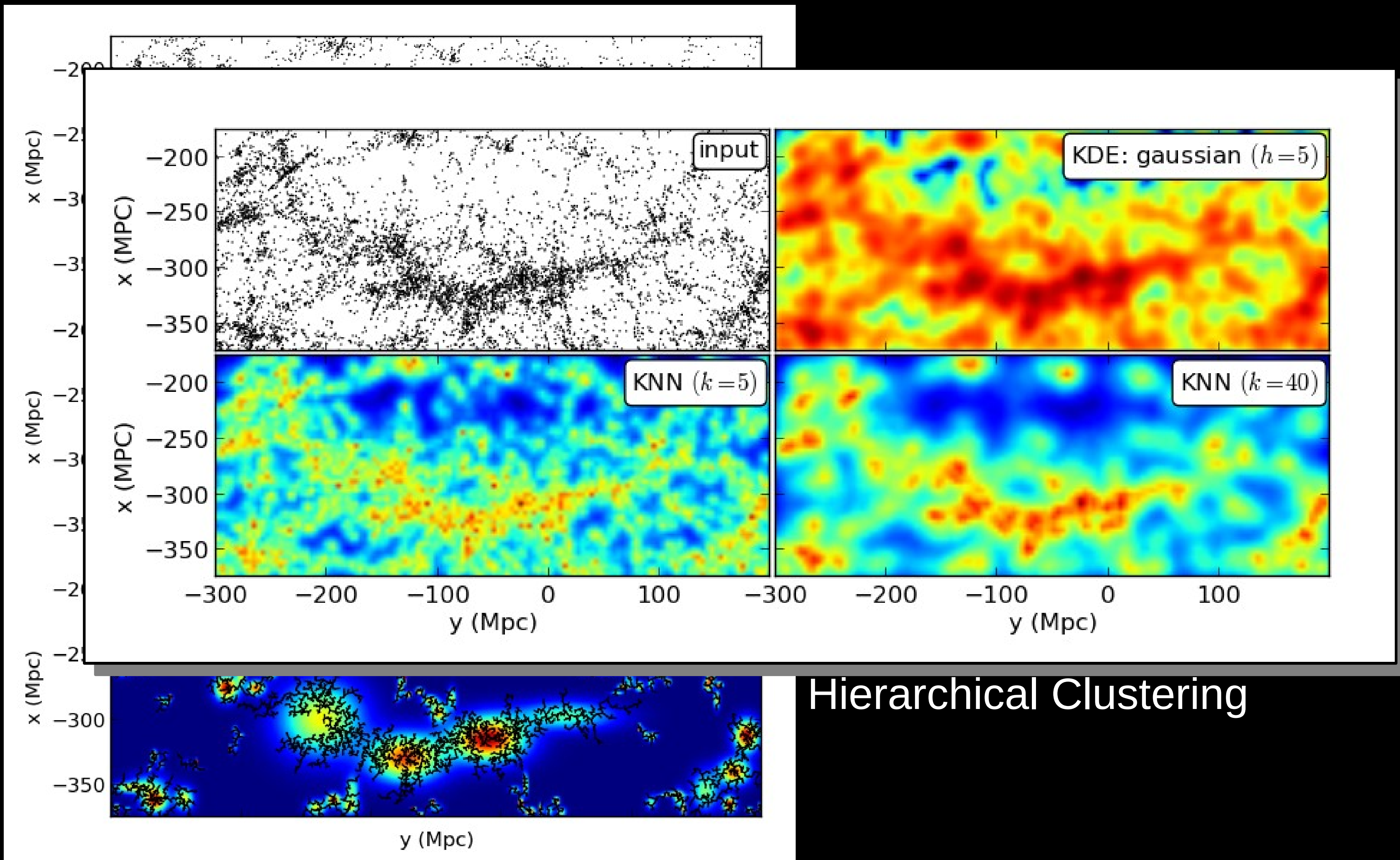


Projected Galaxy Locations

Minimum Spanning Tree

Hierarchical Clustering

Clustering and Density Estimation: SDSS Great Wall



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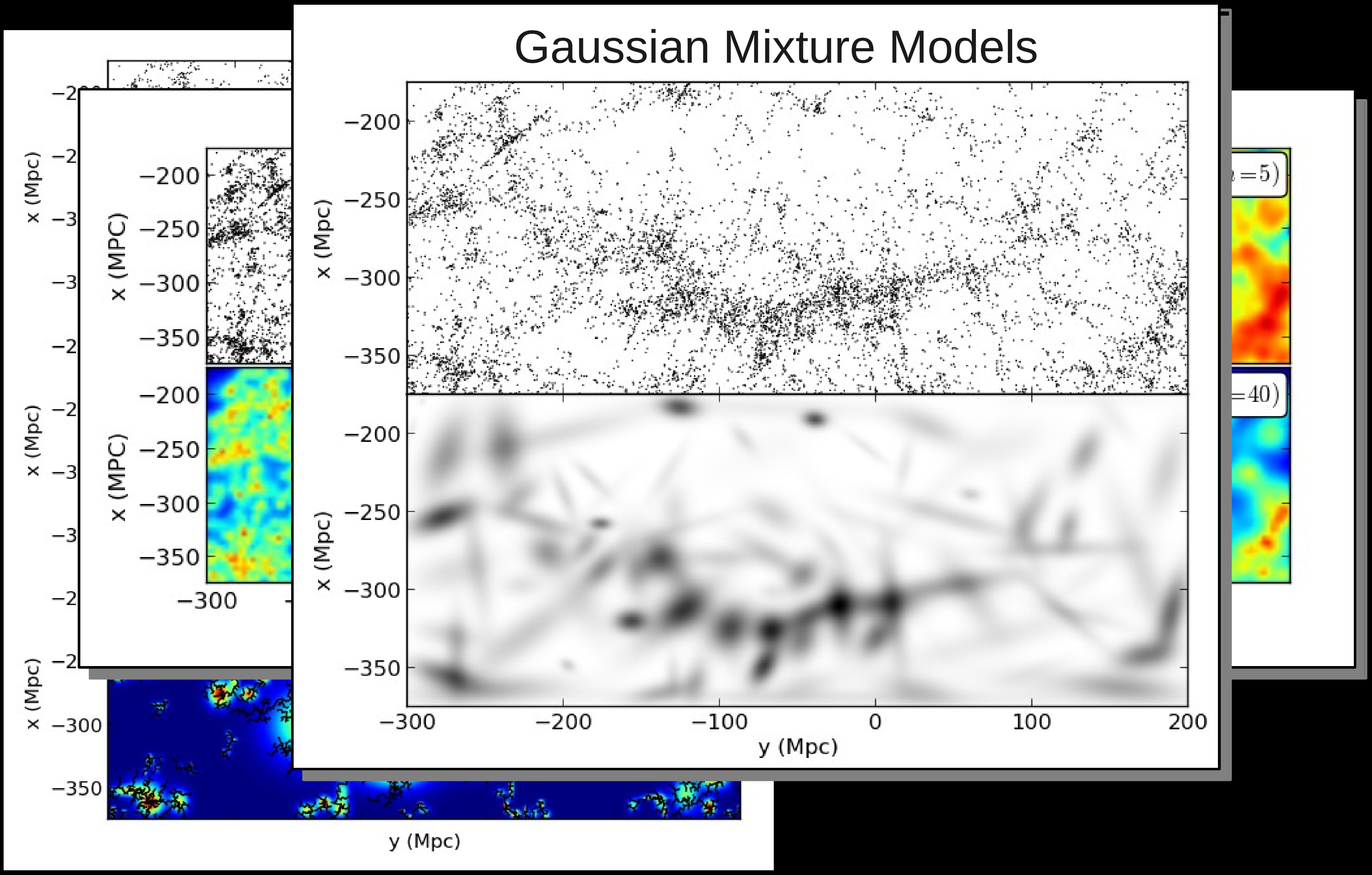
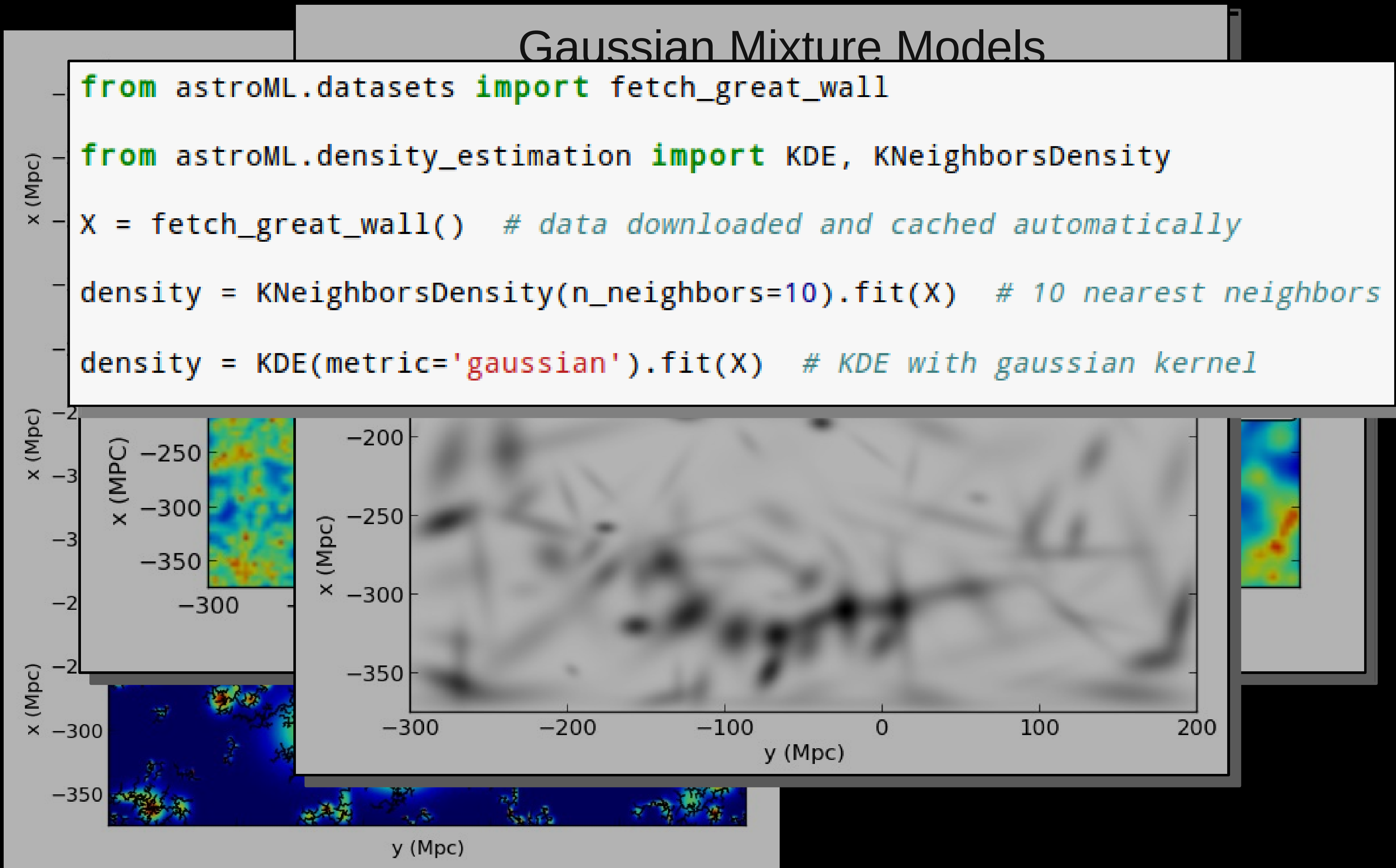
Clustering and Density Estimation: SDSS Great Wall

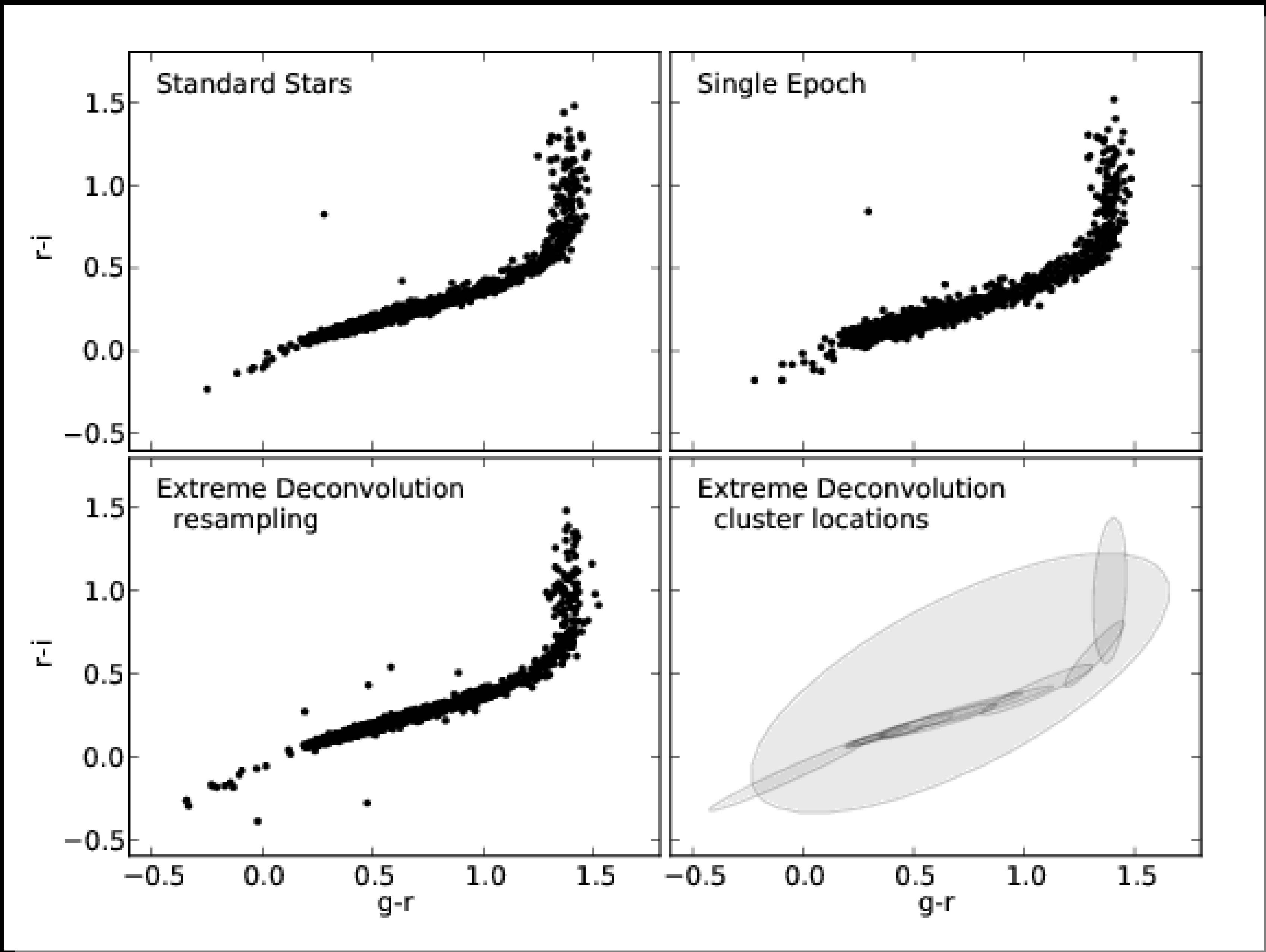


Clustering and Density Estimation: SDSS Great Wall

```python
from astroML.datasets import fetch_great_wall

from astroML.density_estimation import KDE, KNeighborsDensity

X = fetch_great_wall()  # data downloaded and cached automatically

density = KNeighborsDensity(n_neighbors=10).fit(X)  # 10 nearest neighbors

density = KDE(metric='gaussian').fit(X)  # KDE with gaussian kernel
```



“Extreme Deconvolution” (GMM + errors): SDSS main sequence



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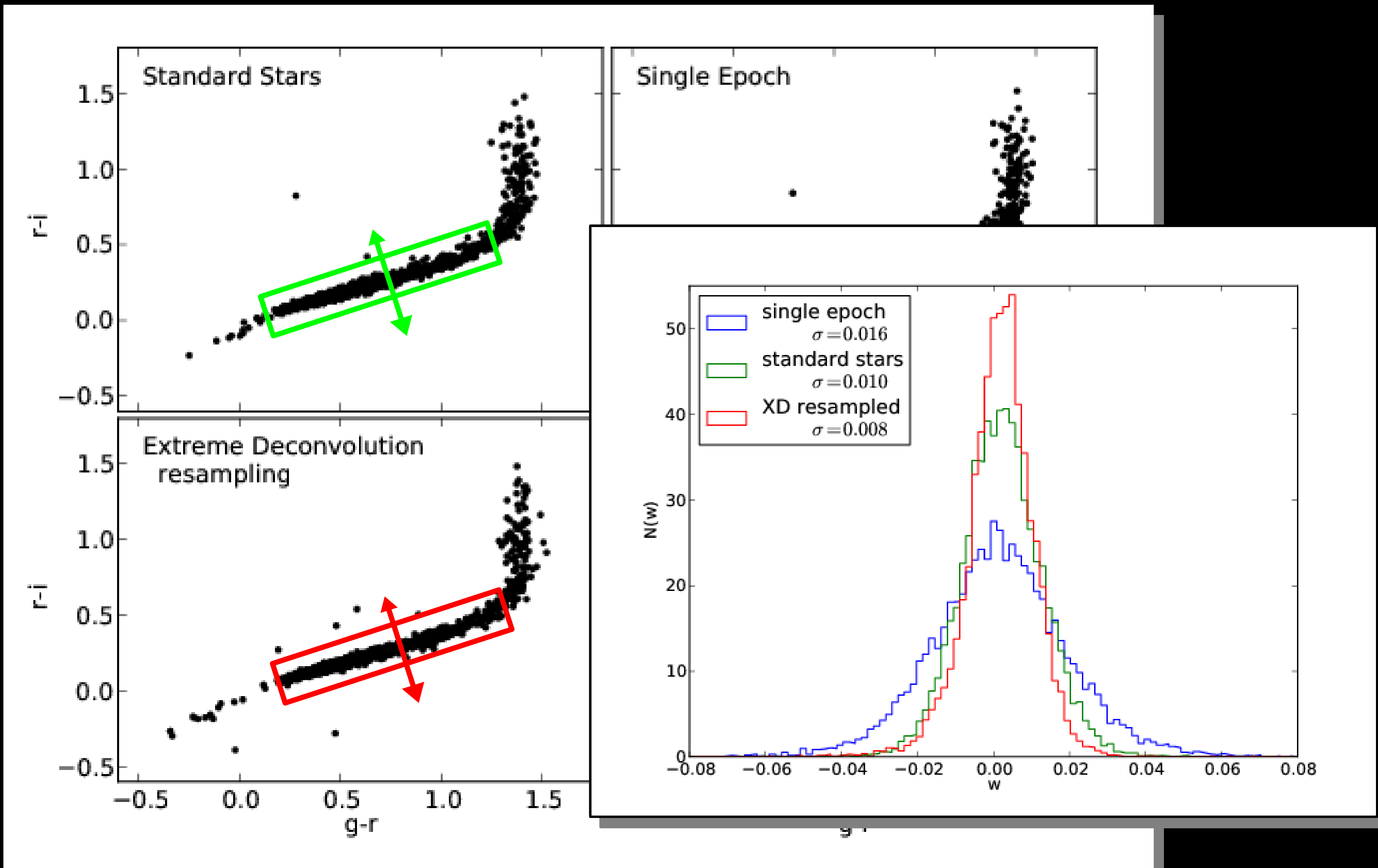

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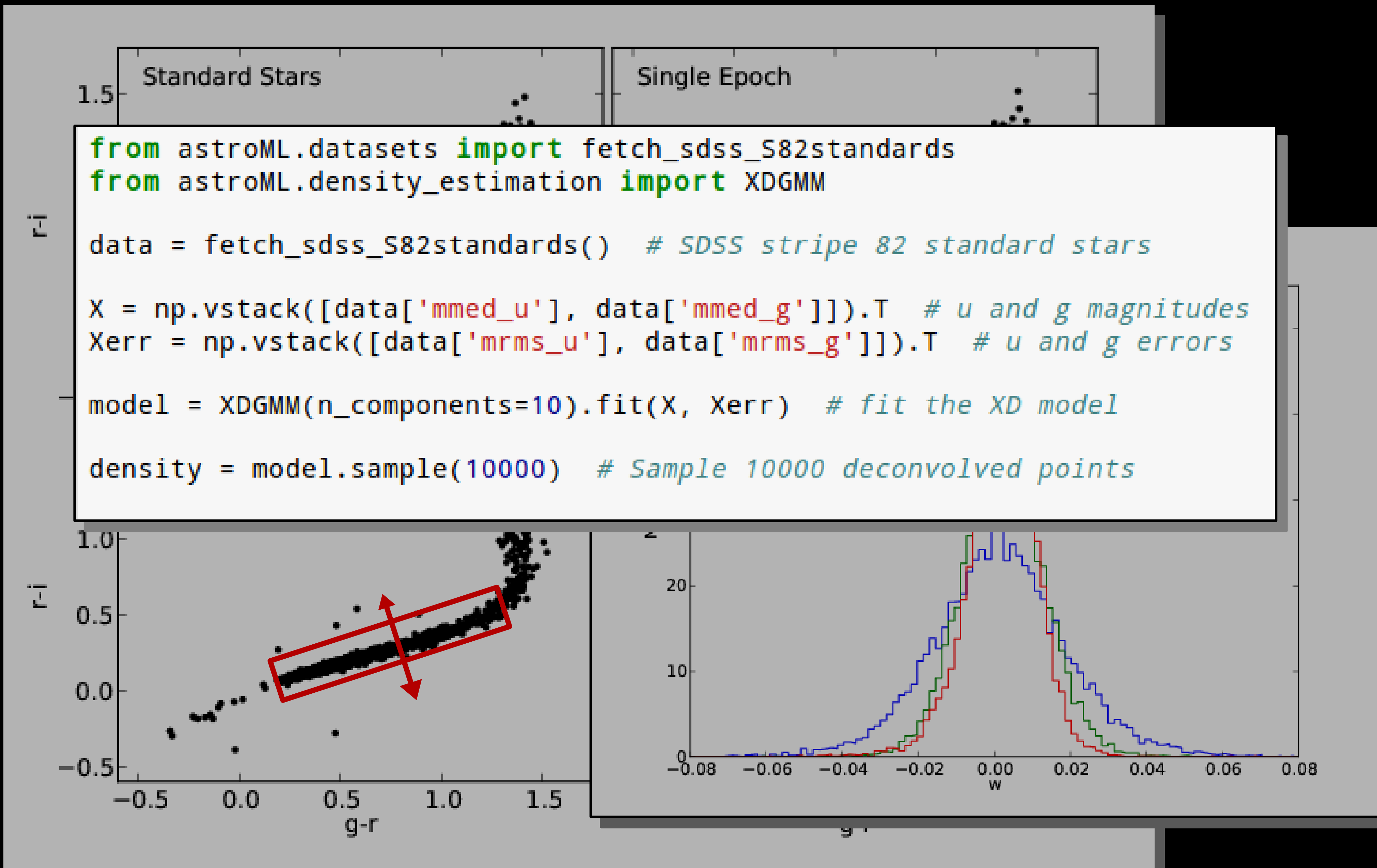
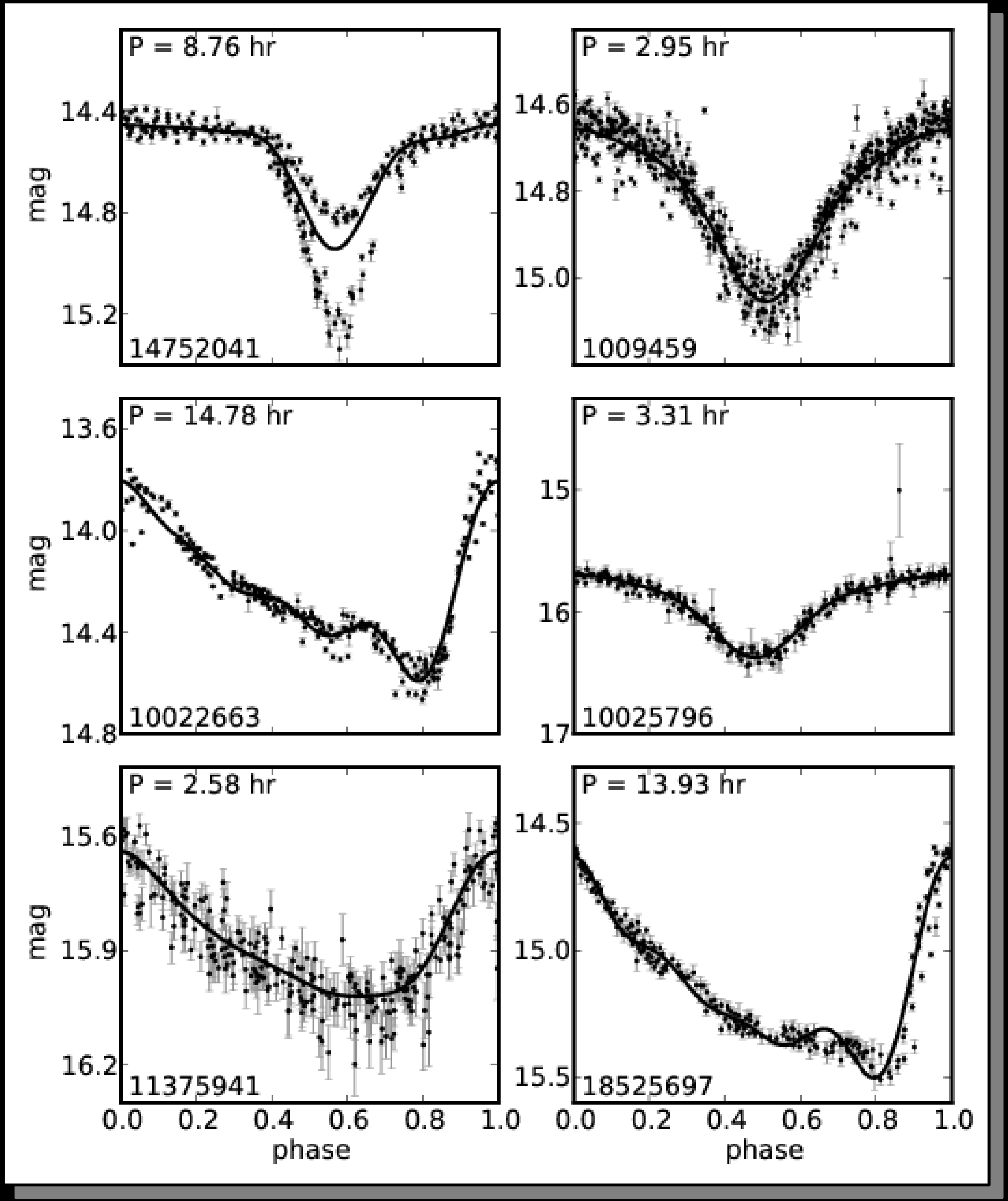



```python
from astroML.datasets import fetch_sdss_S82standards
from astroML.density_estimation import XDGMM

data = fetch_sdss_S82standards()  # SDSS stripe 82 standard stars

X = np.vstack([data['mmed_u'], data['mmed_g']]).T  # u and g magnitudes
Xerr = np.vstack([data['mrms_u'], data['mrms_g']]).T  # u and g errors

model = XDGMM(n_components=10).fit(X, Xerr)  # fit the XD model

density = model.sample(10000)  # Sample 10000 deconvolved points
```

Lomb-Scargle Periodograms:
Light Curves



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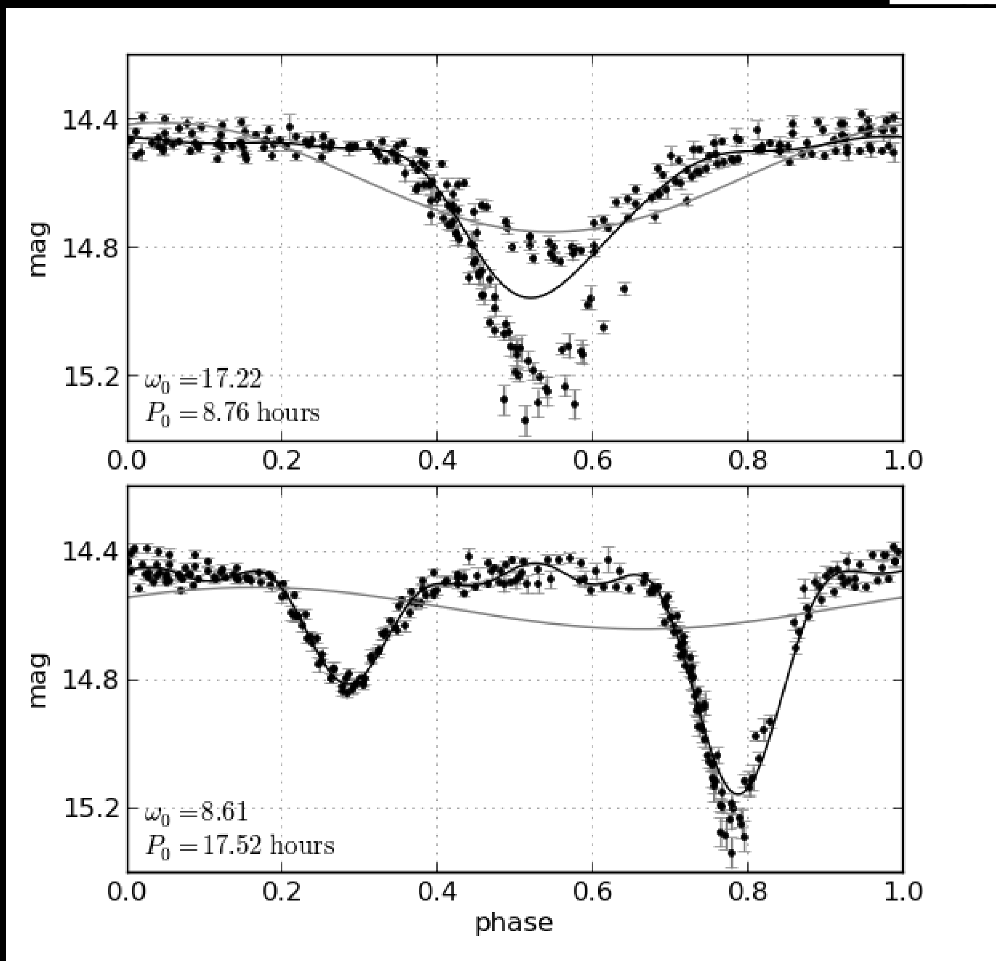

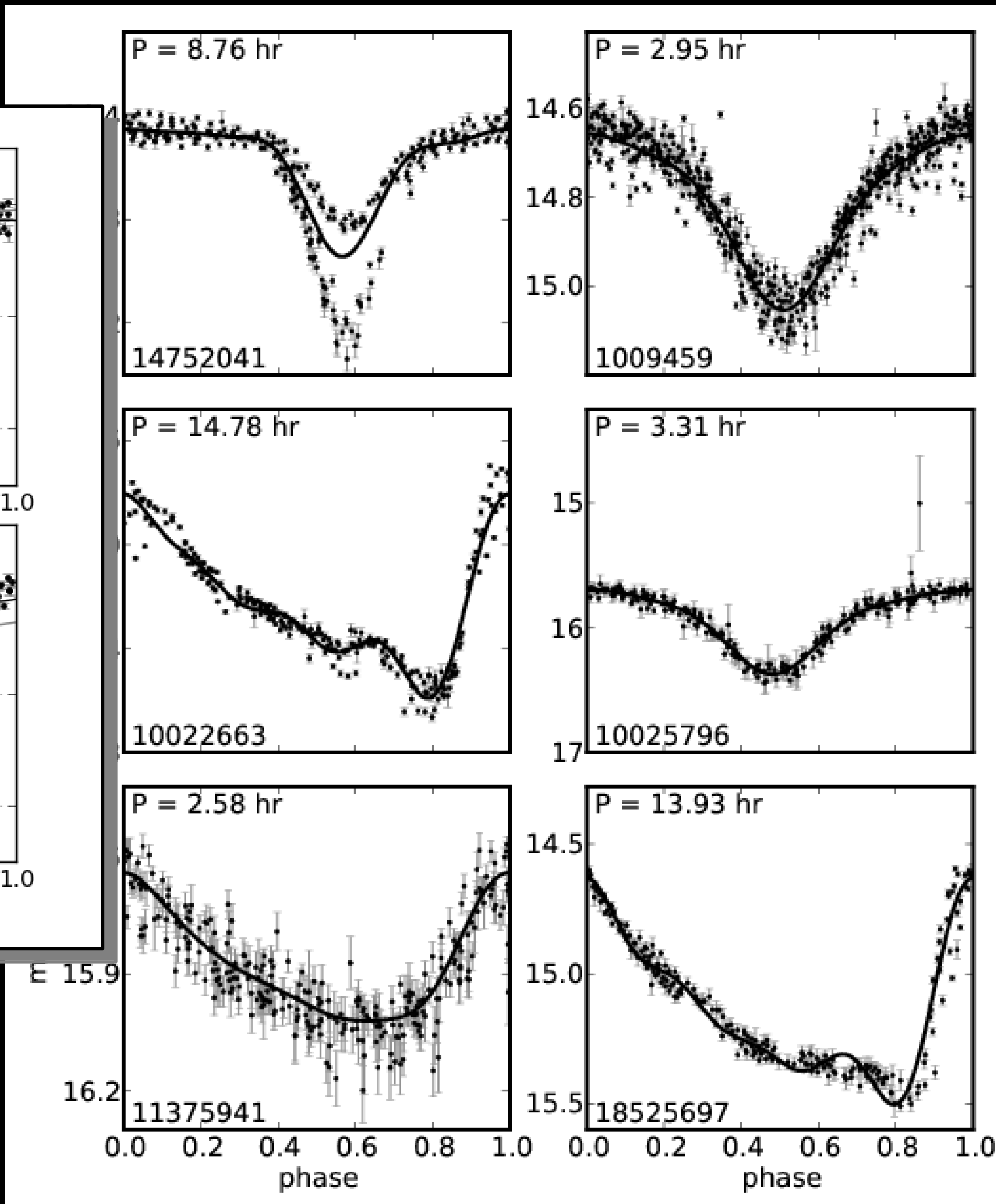

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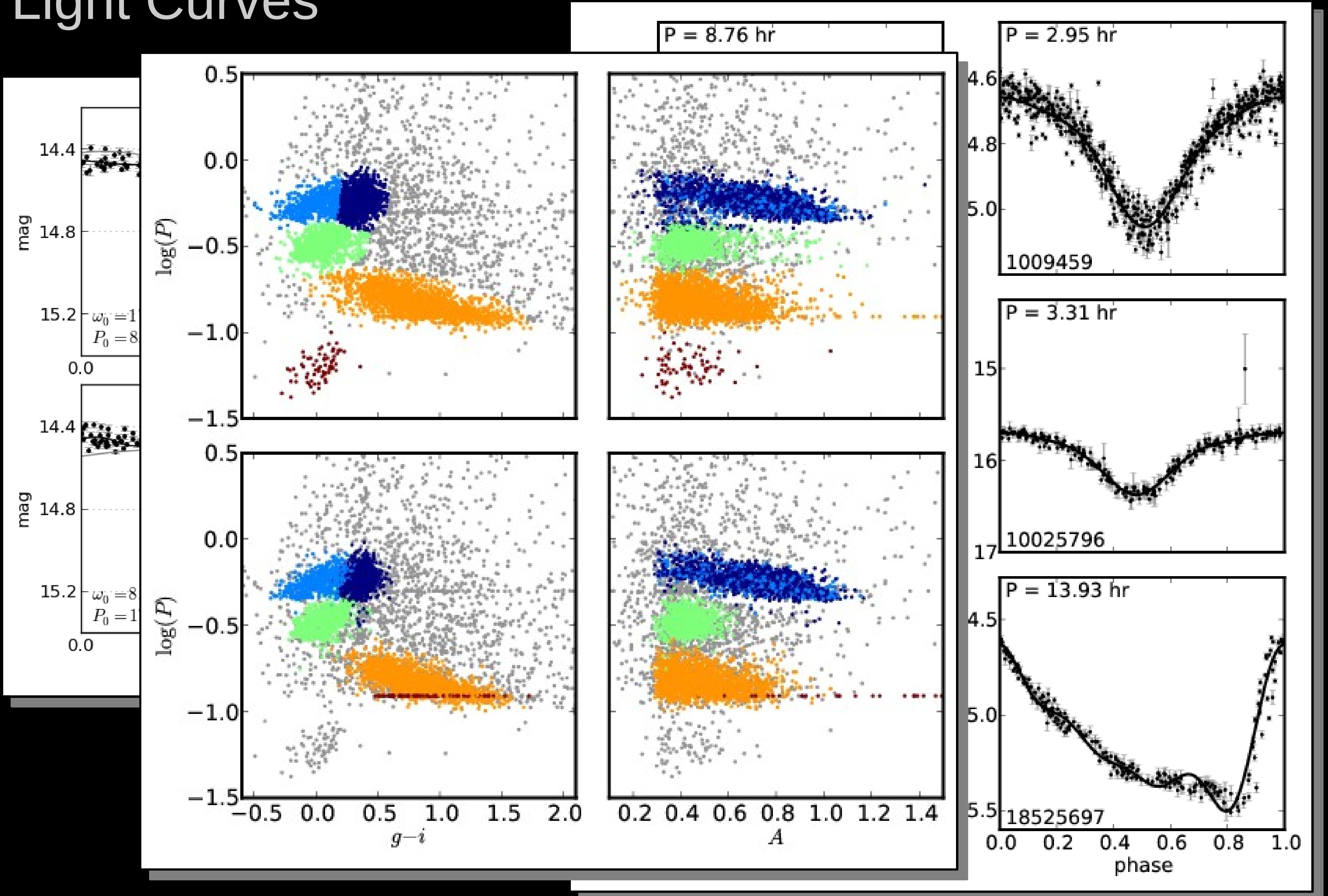
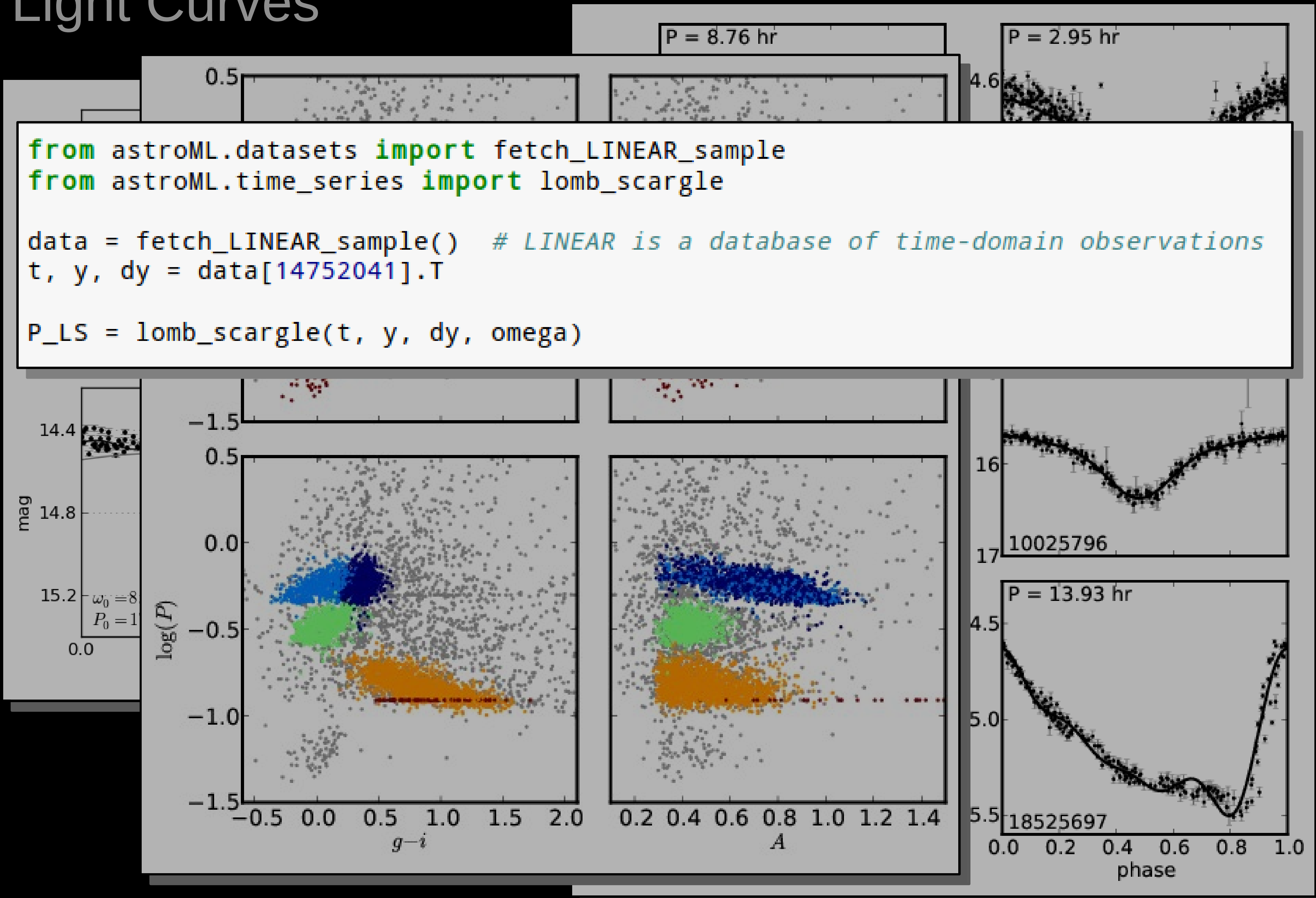


Lomb-Scargle Periodograms: Light Curves

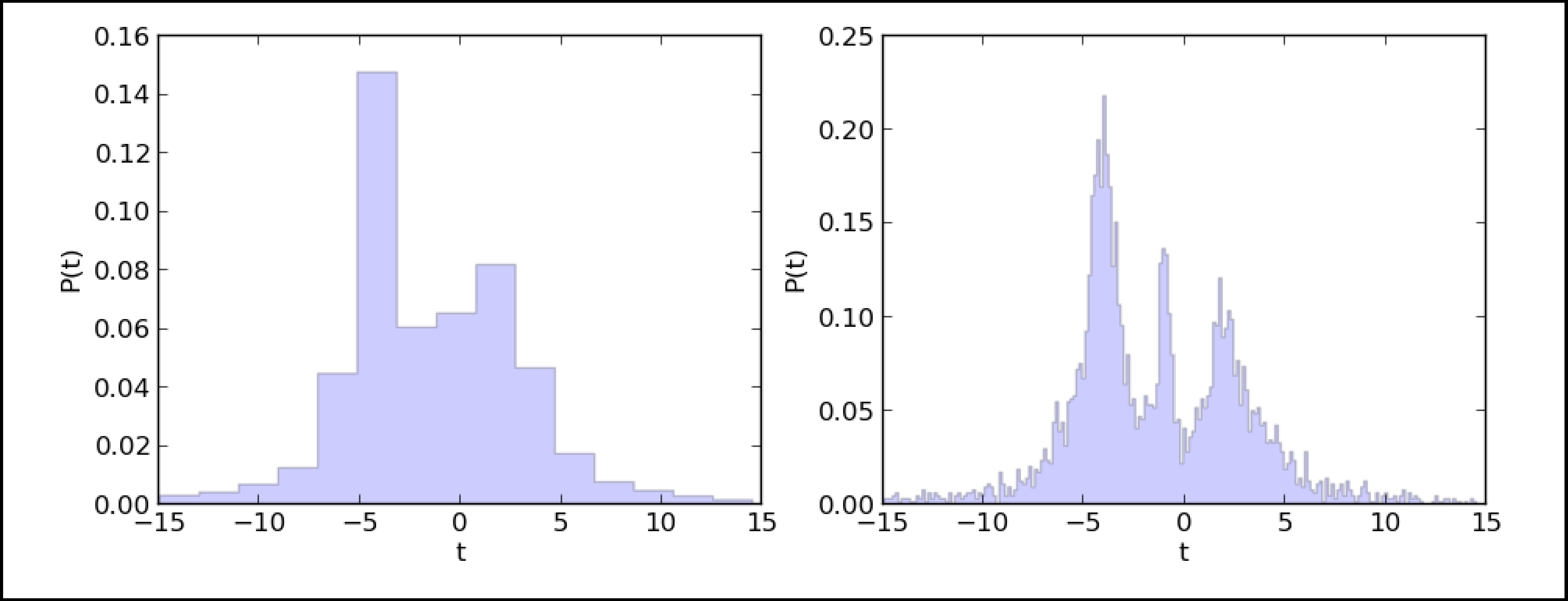
```python
from astroML.datasets import fetch_LINEAR_sample
from astroML.time_series import lomb_scargle

data = fetch_LINEAR_sample()  # LINEAR is a database of time-domain observations
t, y, dy = data[14752041].T

P_LS = lomb_scargle(t, y, dy, omega)
```



Histograms the Right Way:

The problem with histograms: choosing the bin width.

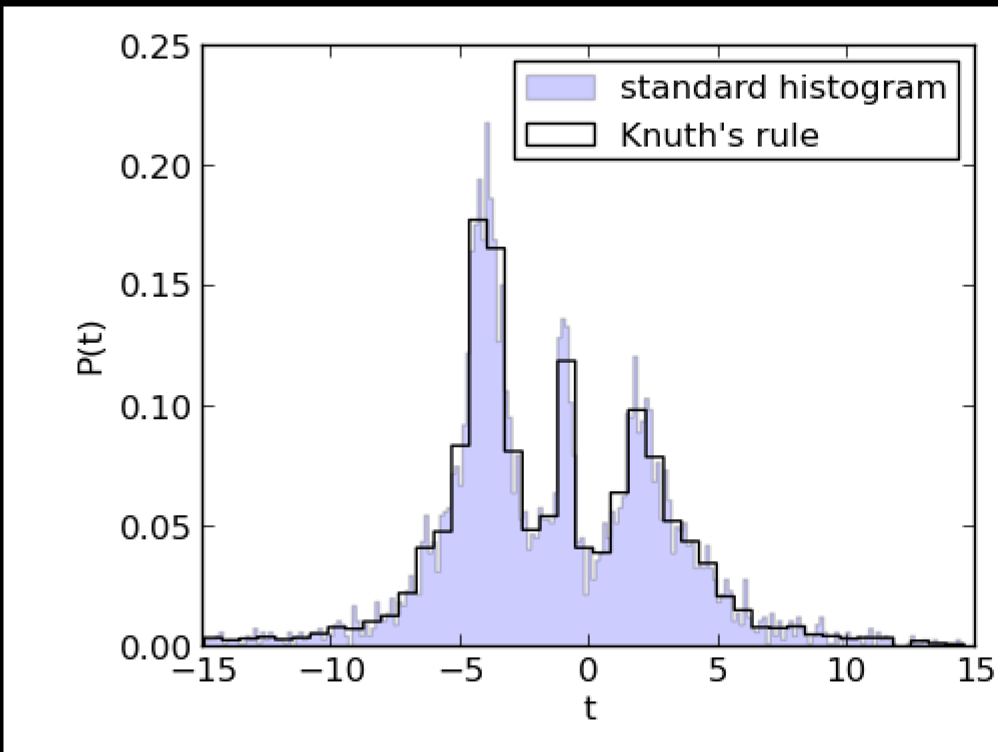
These show the same data set: how do we choose the right binning?



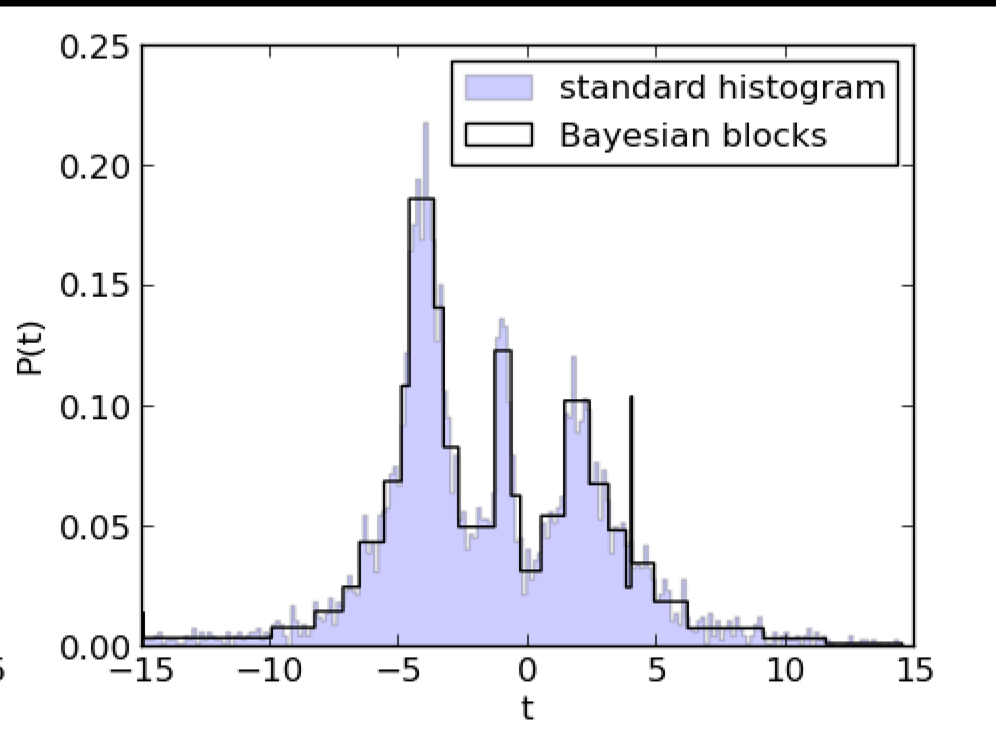
Histograms the Right Way:

Knuth's Method: optimization over fixed-width bins
Bayesian blocks: optimization over variable-width bins

Knuth's Method

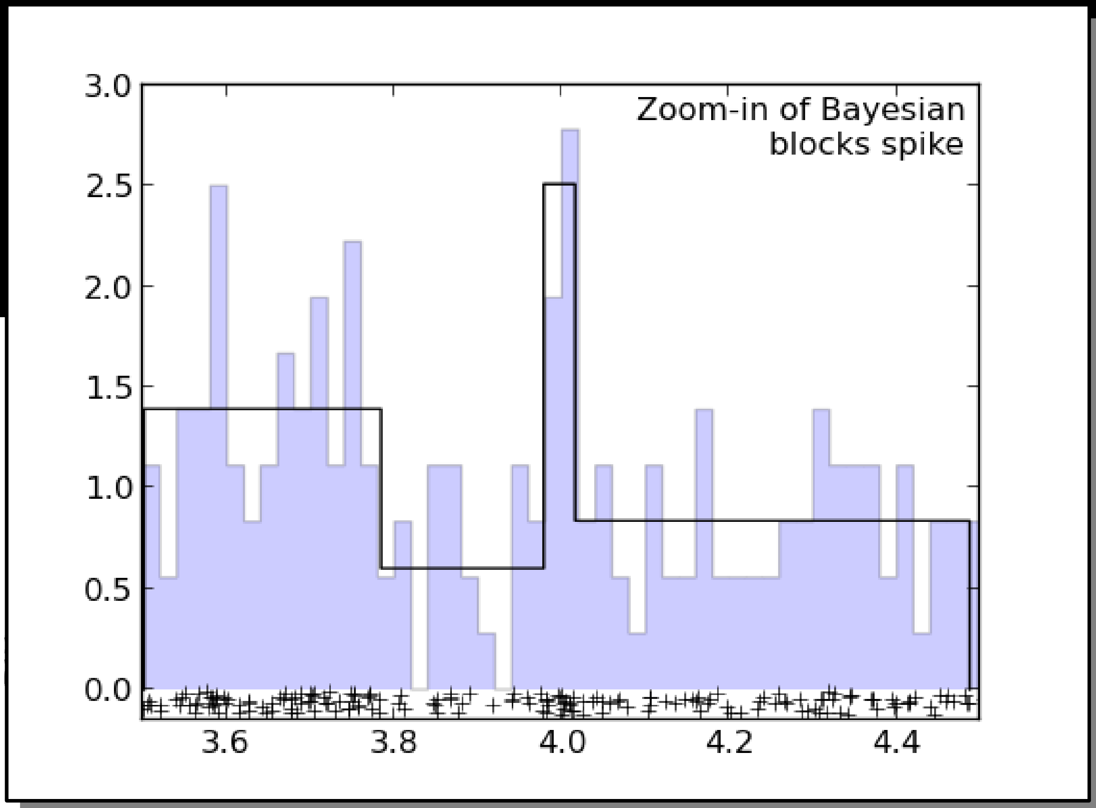


Bayesian Blocks



Histograms the Right Way:

d-width bins
riable-width bins



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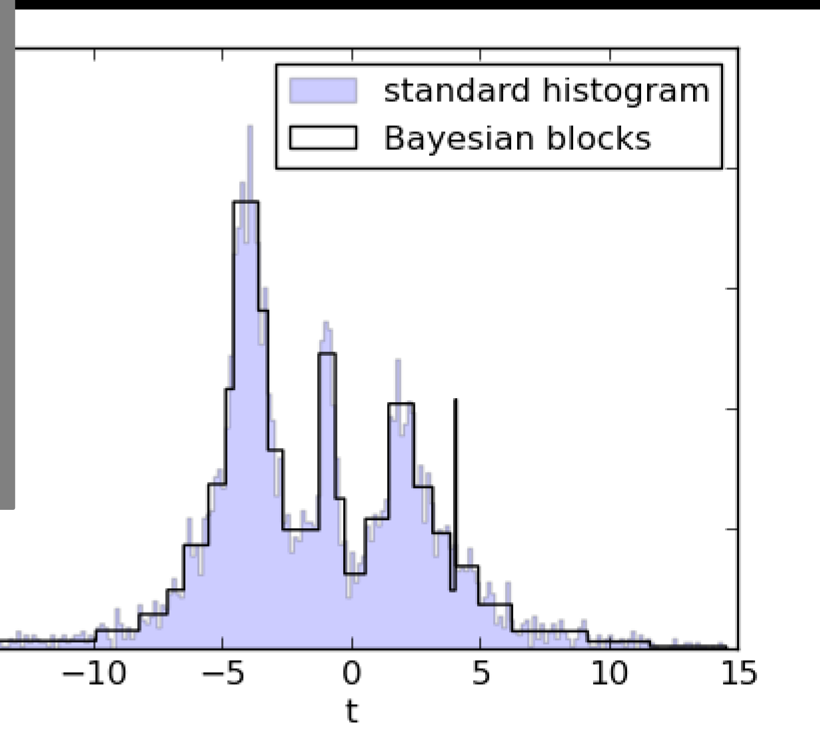

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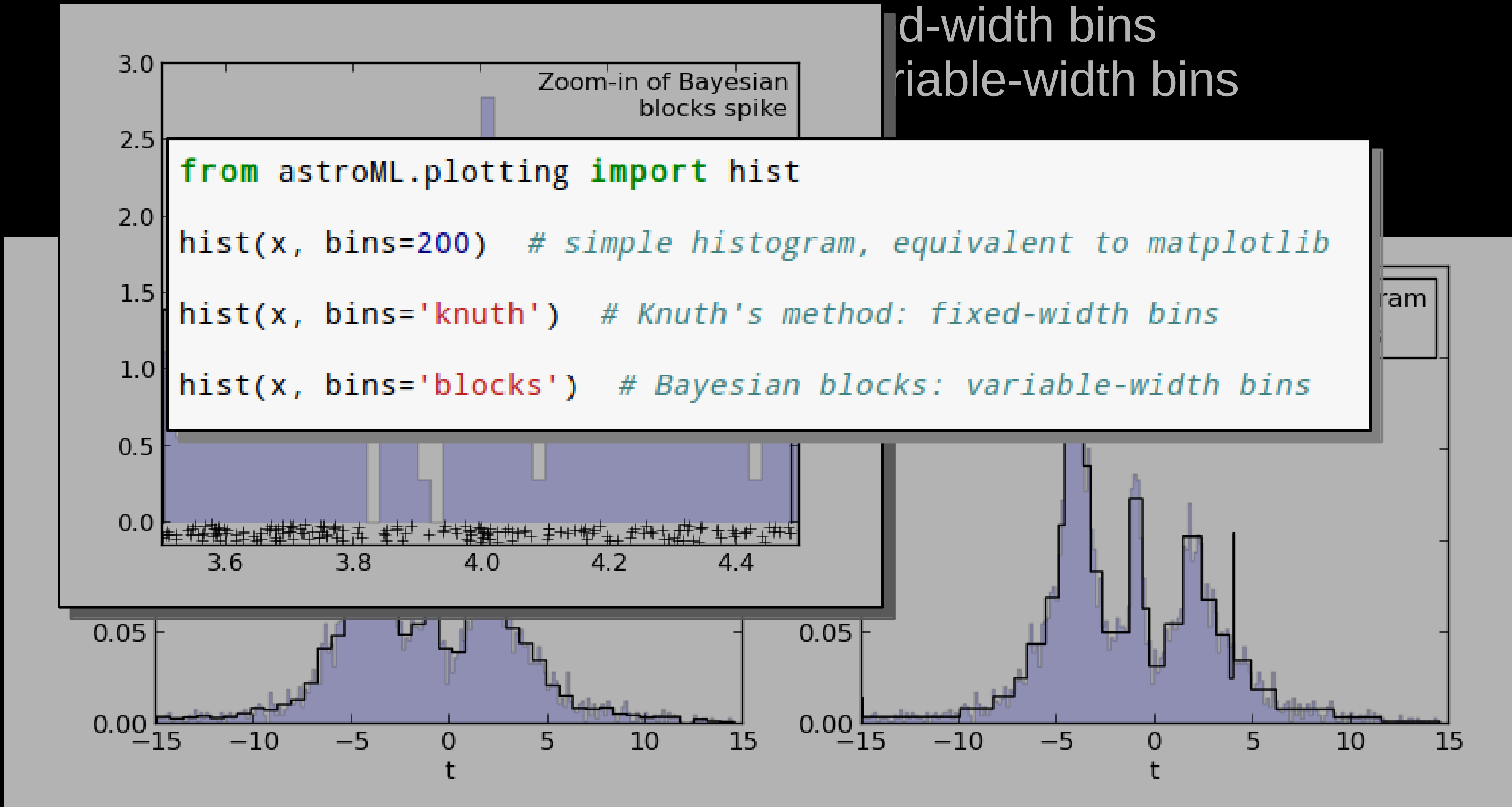


```python
from astroML.plotting import hist

hist(x, bins=200)  # simple histogram, equivalent to matplotlib

hist(x, bins='knuth')  # Knuth's method: fixed-width bins

hist(x, bins='blocks')  # Bayesian blocks: variable-width bins
```

The Vision:

- Reproducible Research: provide a standard repository for sharing well-tested algorithms

- Coherent & well-written examples *using real data*: useful for both education and research

- Speed-up data exploration: examples require a minimal amount of code (typically ~10 lines)

- Move tested, useful code upstream for use in other fields. A few examples:

    - Ball Tree & two-point statistics (scikit-learn 0.10)
    - Minimum Spanning Tree (scipy 0.11)
    - binned_statistics (scipy 0.11)
    - Bayesian blocks in matplotlib?
    - Extreme Deconvolution in scikit-learn?

Thank You

http://astroML.github.com