Development and verification of data analysis pipeline

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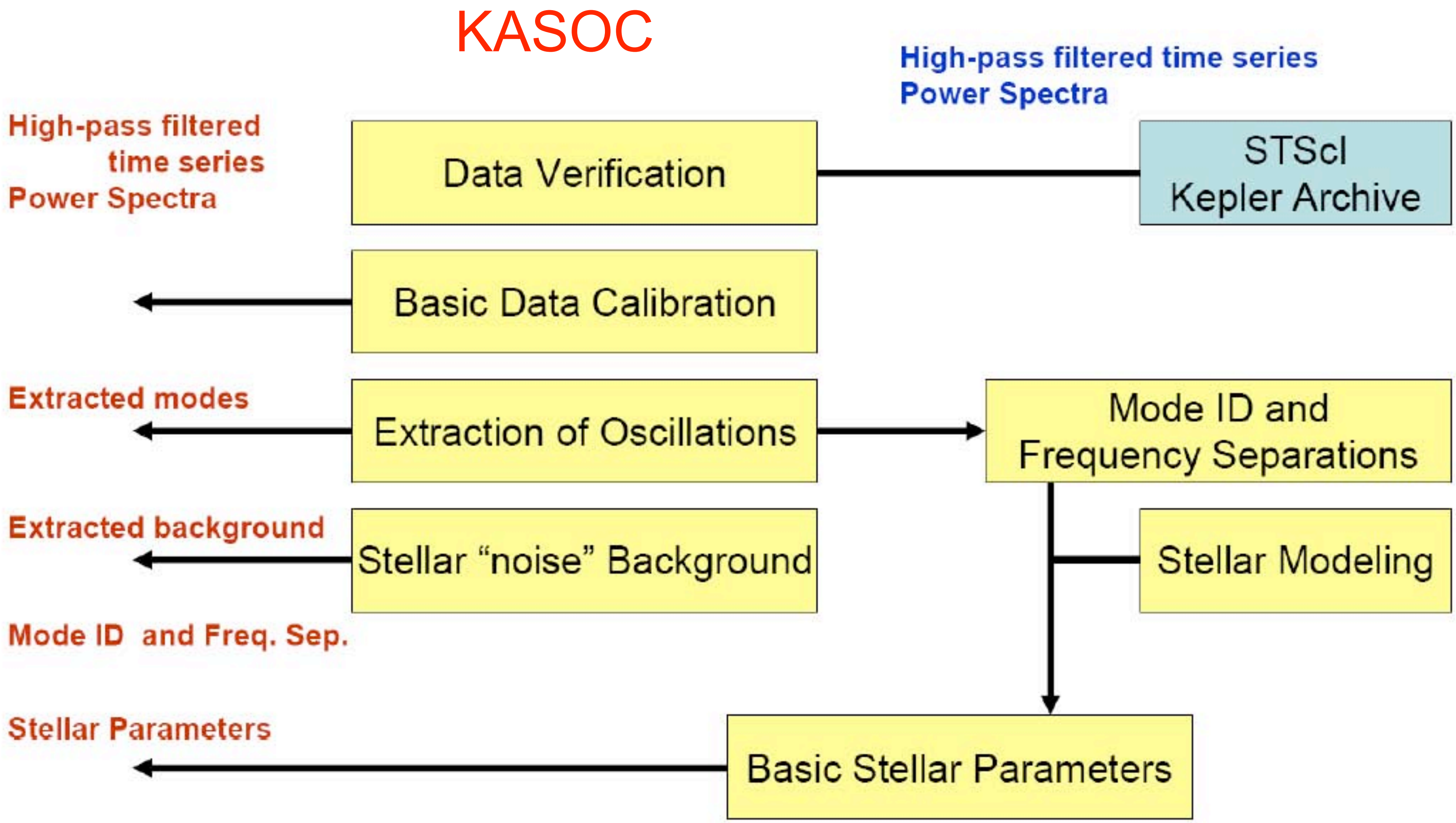
- KAI activity as described in the Letter-of-Direction:

Develop a pipeline to extract frequencies or frequency properties from observed time-series

- For solar-like stars this includes frequency spacings, mode identification, lifetimes, ...

- Asteroseismic characterization of (faint) planet host stars using solar-like oscillations:

Frequency spacings to determine radii


KASOC
High-pass filtered time series
Power Spectra
High-pass filtered
time series
Power Spectra
Data Verification
STScI
Kepler Archive
Basic Data Calibration
Extracted modes
Extraction of Oscillations
Mode ID and
Frequency Separations
Extracted background
Stellar “noise” Background
Stellar Modeling
Mode ID and Freq. Sep.
Stellar Parameters
Basic Stellar Parameters

Development of pipeline

- The basic analysis tools already exist

  Power spectra, frequency and amplitude determination, frequency spacings, mode identification, mode lifetimes

- Tools to be extended and optimized for Kepler through input from KASC

- Parallel analysis lines: Quality and robustness

- Develop robust methods for automatic analysis of low *Signal-to-Noise* data

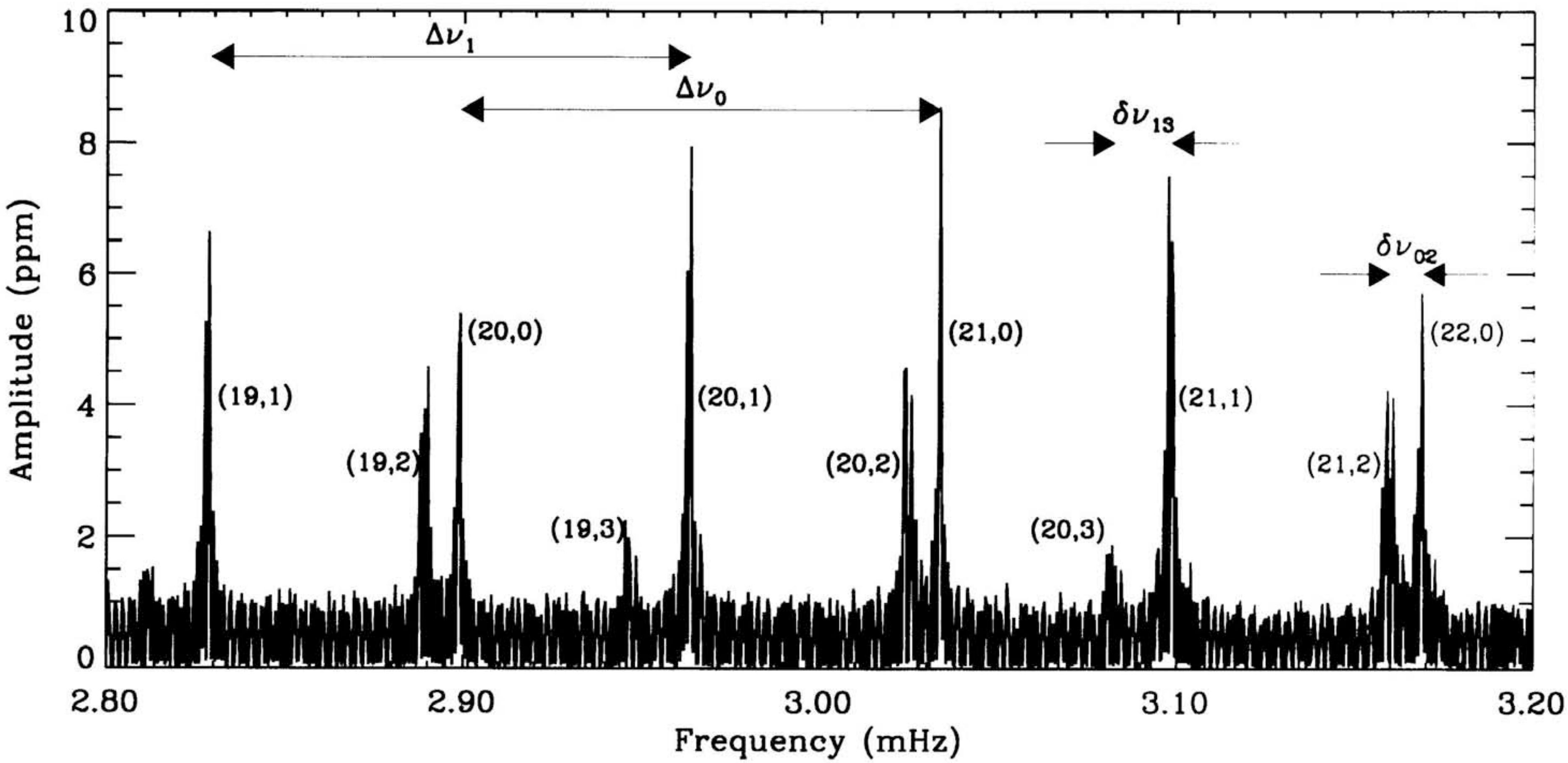
Verification of pipeline

- Simulations and Hare-and-Hound exercises
- First rounds of simulations performed at KASOC
- First asteroFLAG Hare-and-Hound (Bill Chaplin)
- Major task for KASC to verify pipeline and to test and compare different analysis methods through Hare-and-Hound exercises

Verification of pipeline – simulations

- First rounds of simulations performed at KASOC using present version of the pipeline
- The Aarhus Simulator for simulating solar-like oscillations (see also De Ridder et al. 2006)
- Limiting magnitudes for determination of the Large Frequency Separations across the HRD

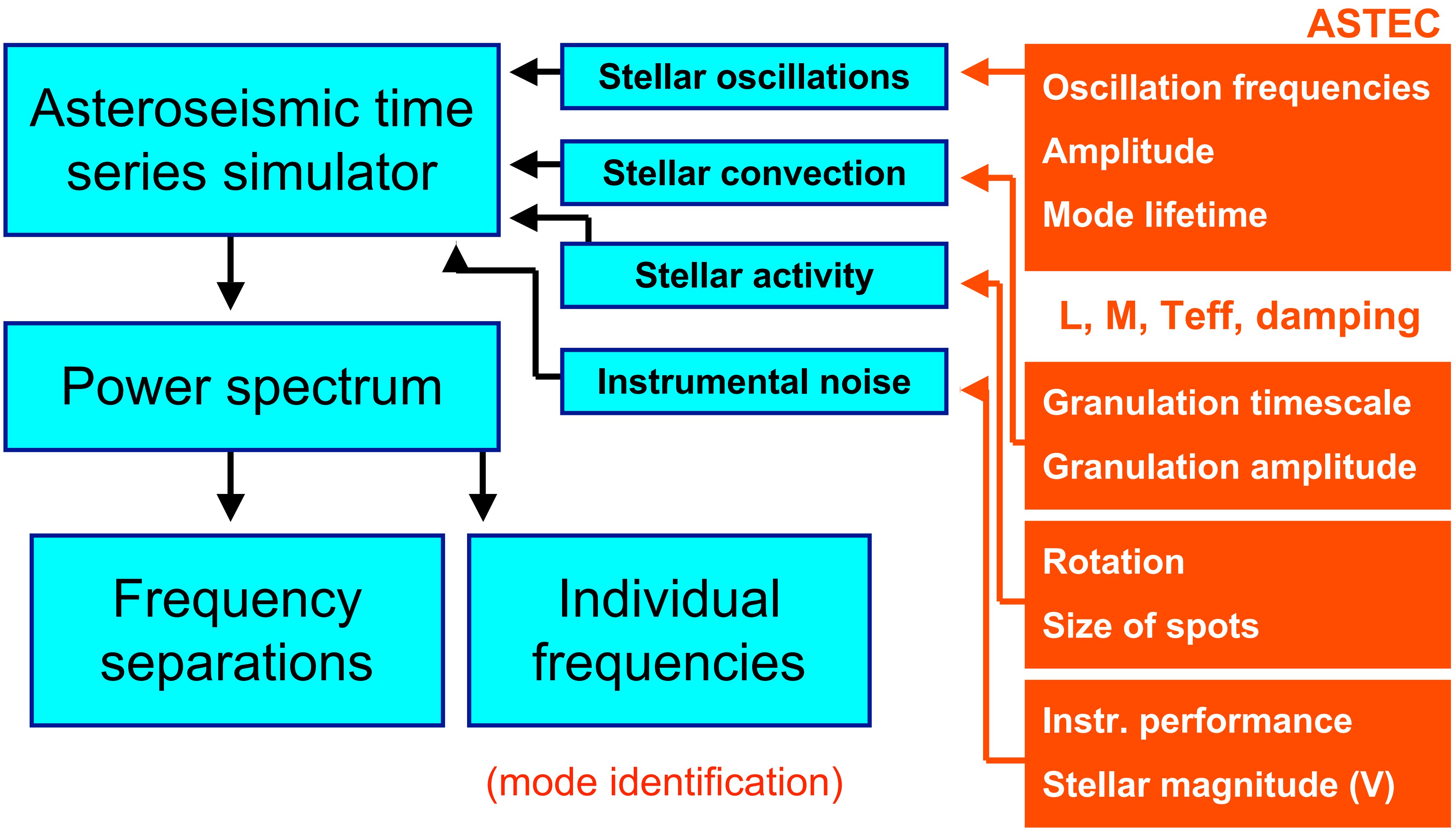
$$\nu_{n,l} = \Delta\nu\left(n + \frac{1}{2}l + \varepsilon\right) - l(l+1)D_0$$



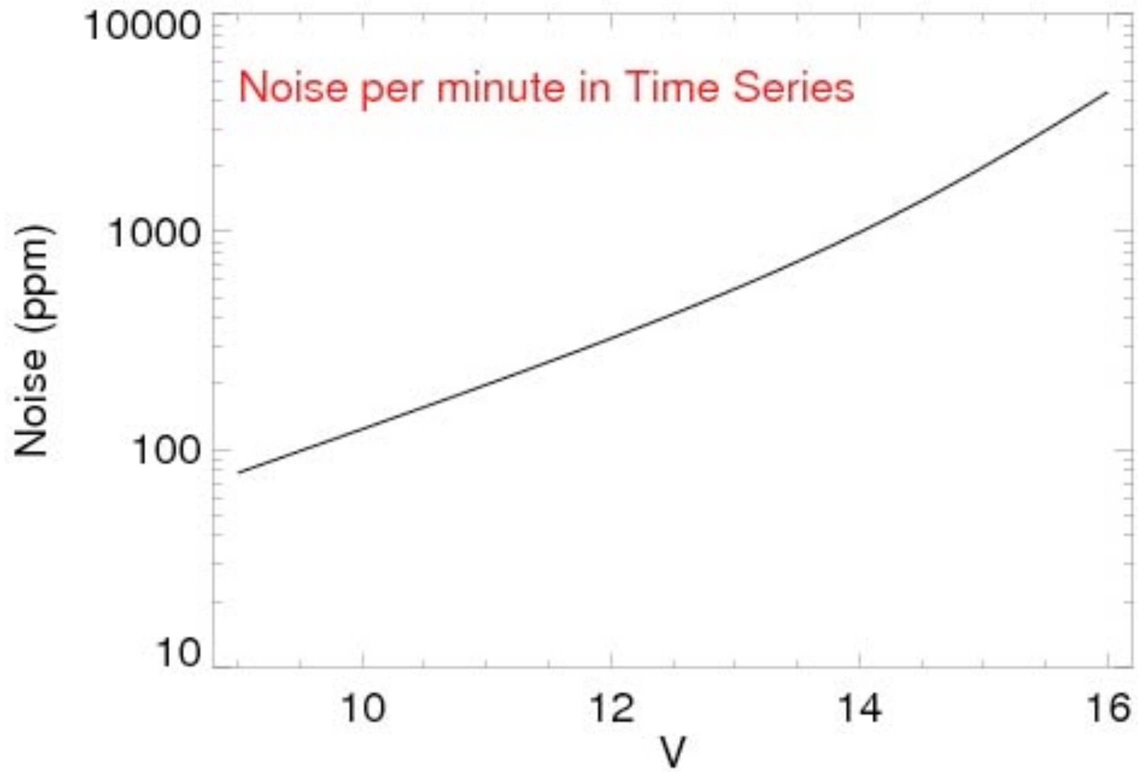
$$D_0 = \frac{1}{6}\delta\nu_{02} = \frac{1}{2}\delta\nu_{01} = \frac{1}{10}\delta\nu_{13}$$

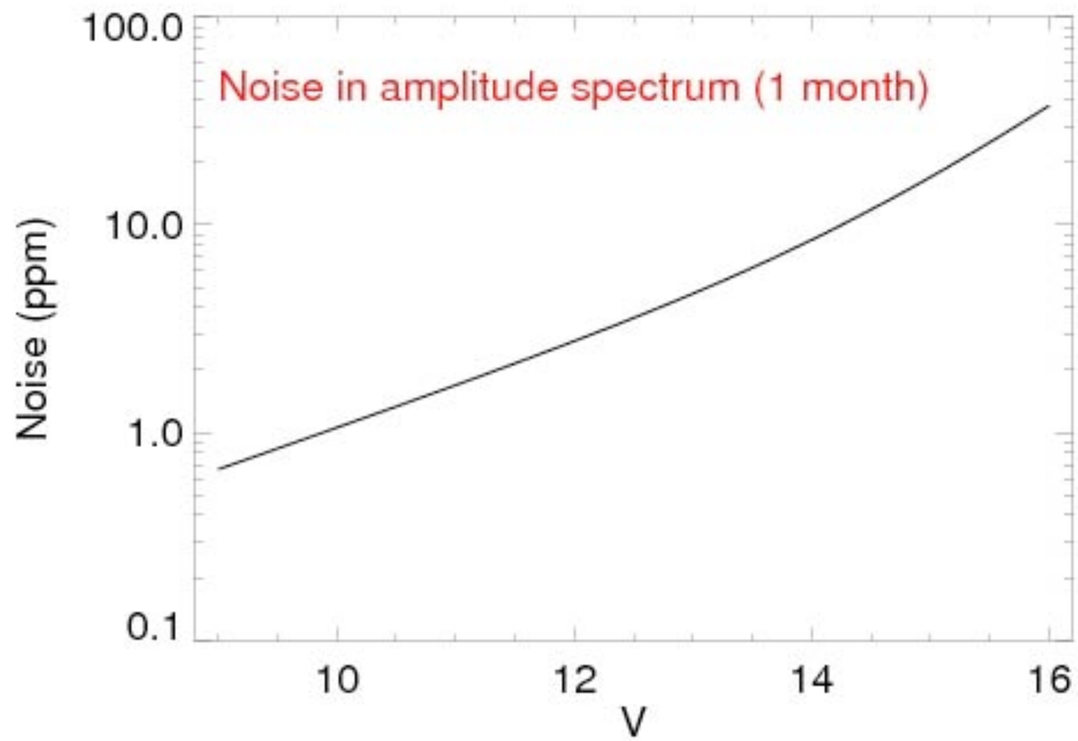
Time series simulator and pipeline SW

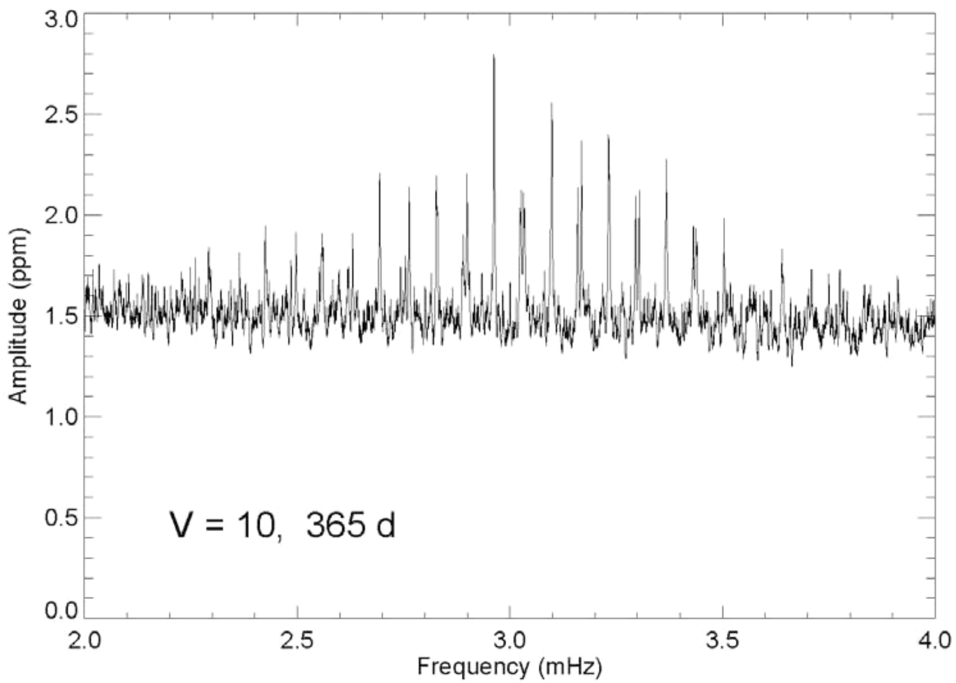
The Aarhus p-mode times series simulator (Hans Kjeldsen)

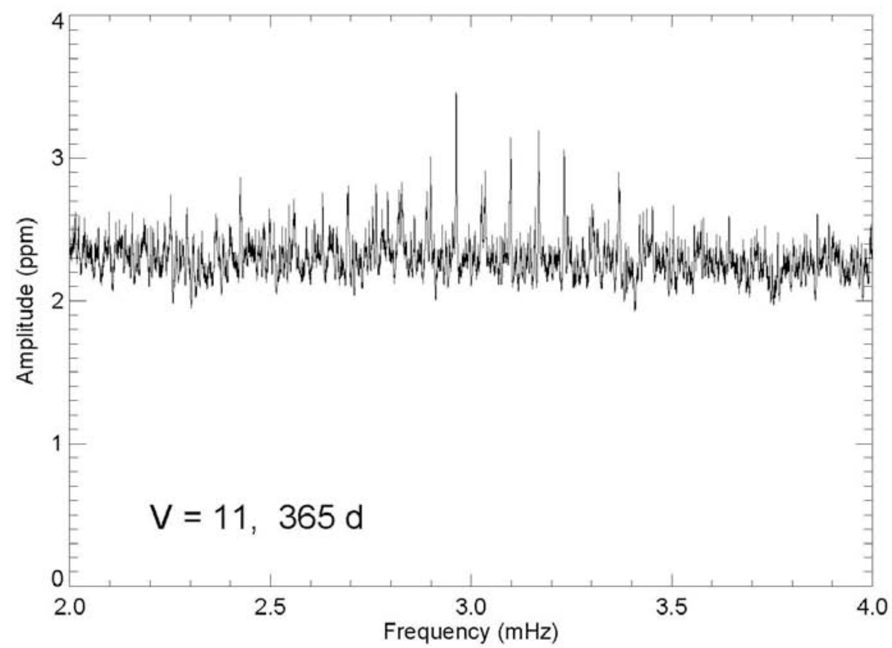


Expected noise in the Kepler data



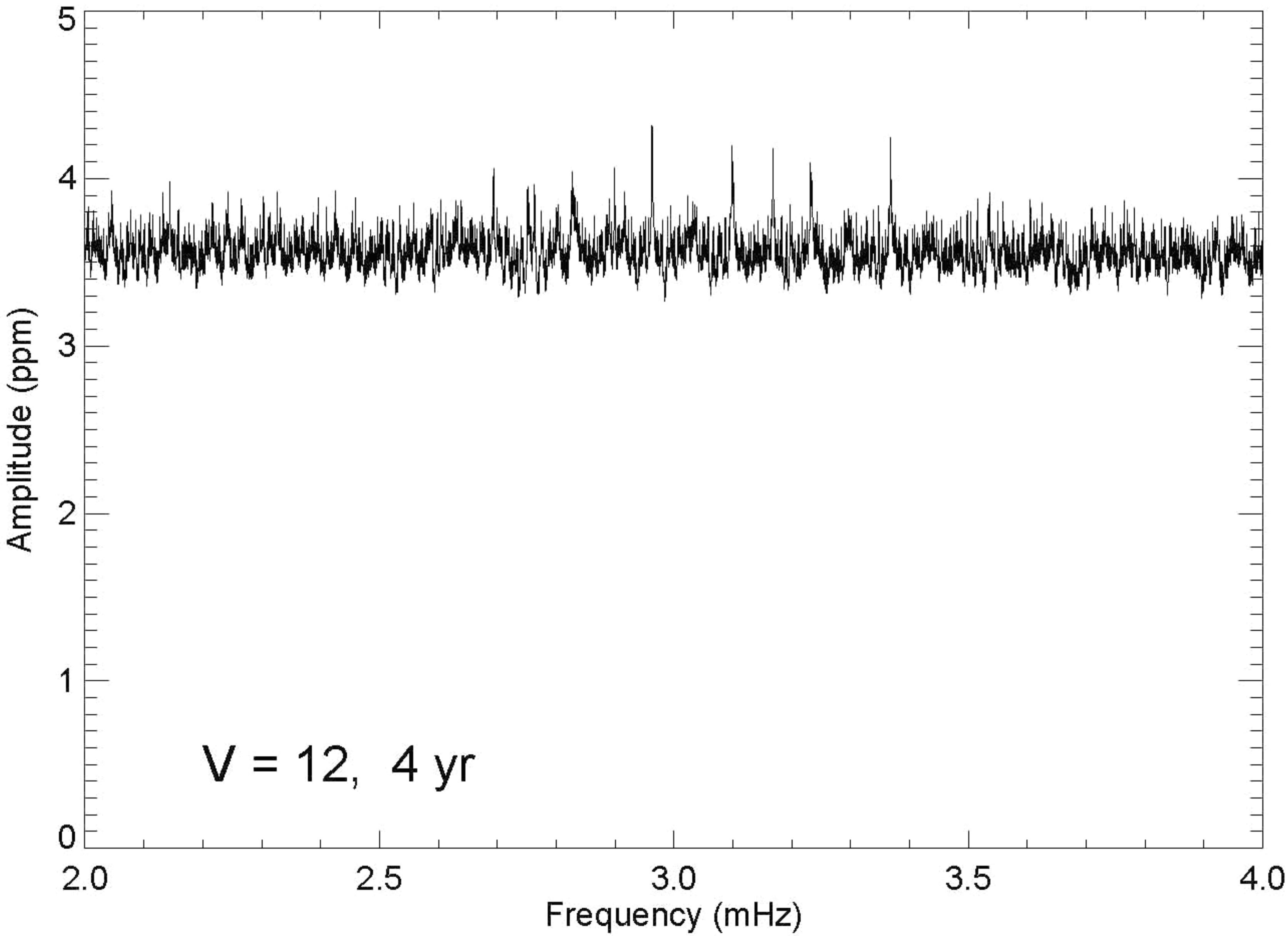






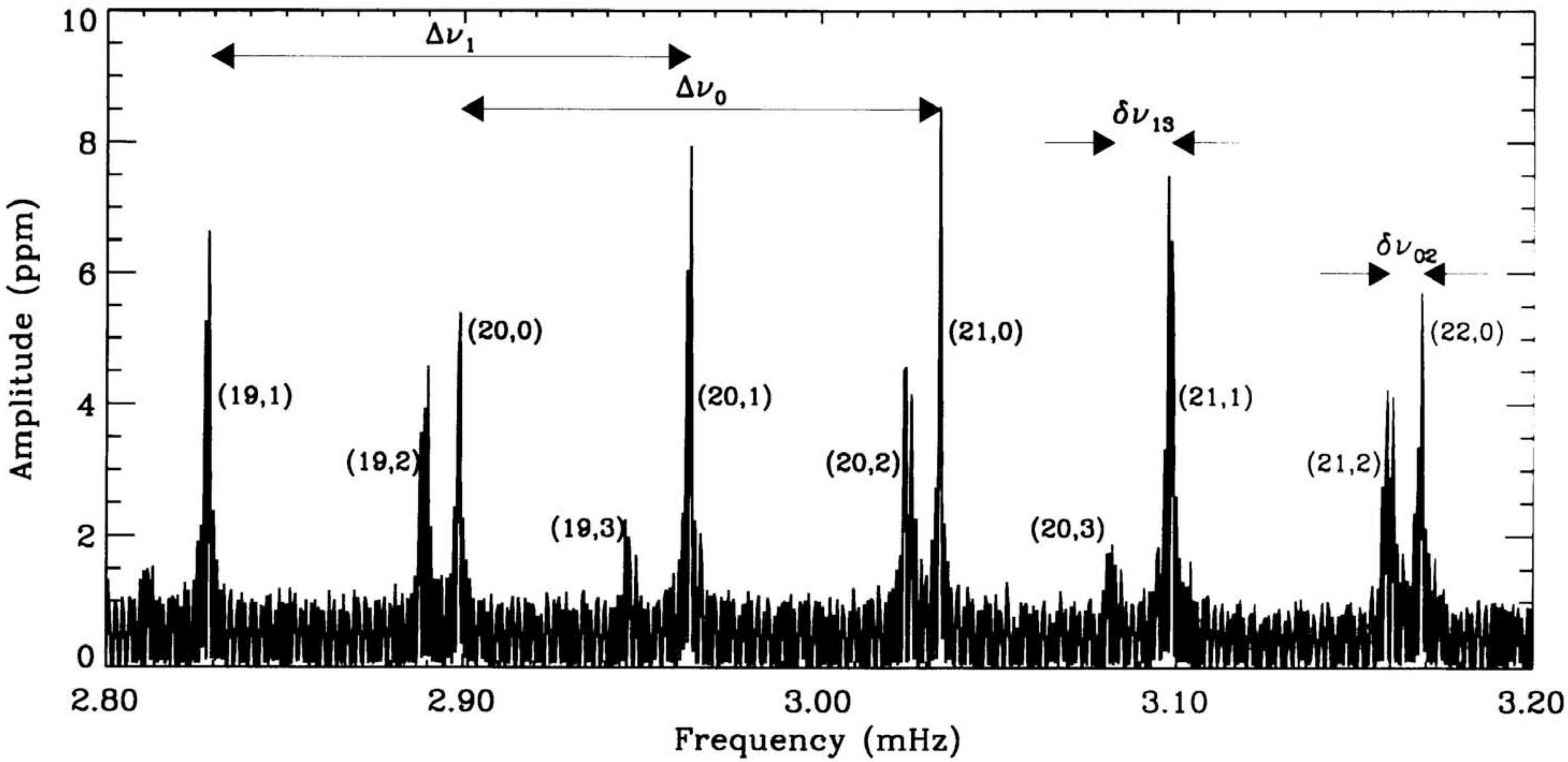
The Sun at V=10 and V=11:

Sums of 4-day power spectra



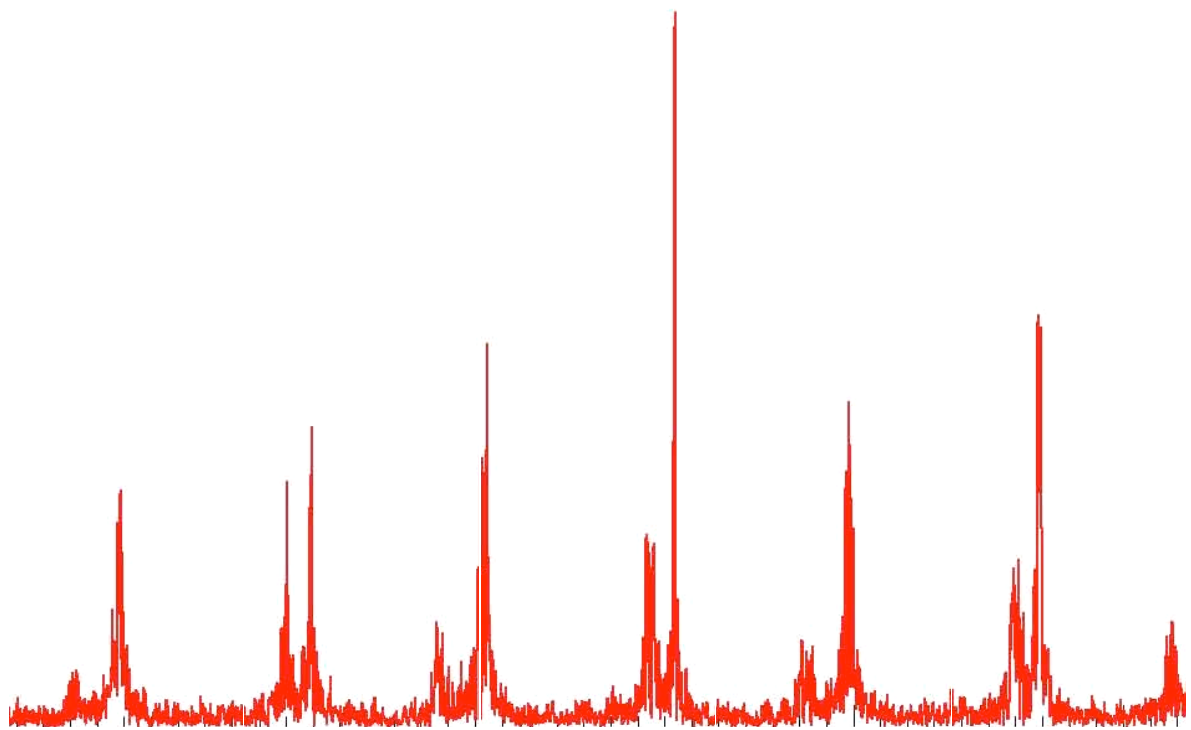
Low *Signal-to-Noise* data…

Determination of the large Separation



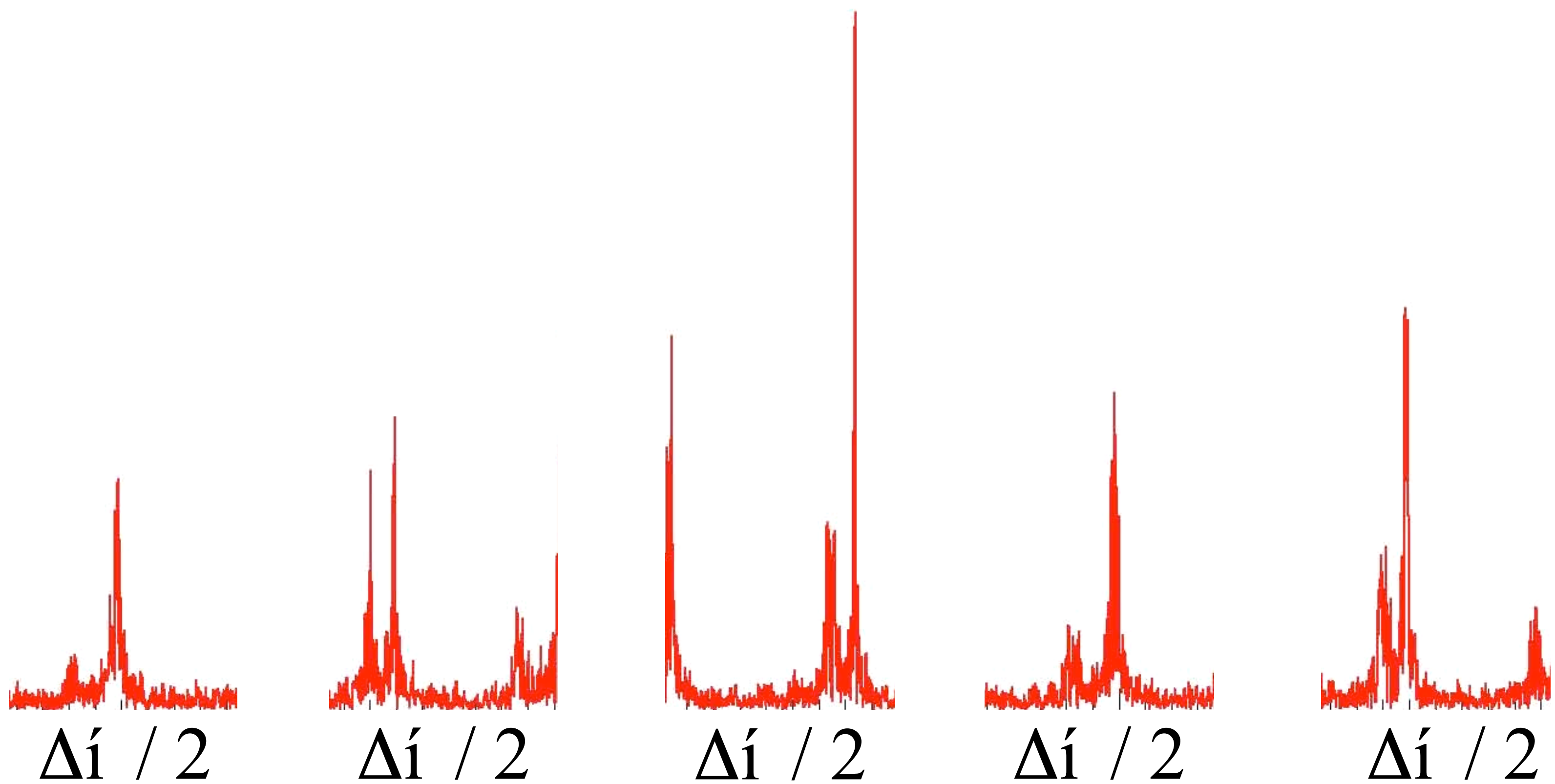
Determination of the large Separation

1. Select a range of possible Δí values



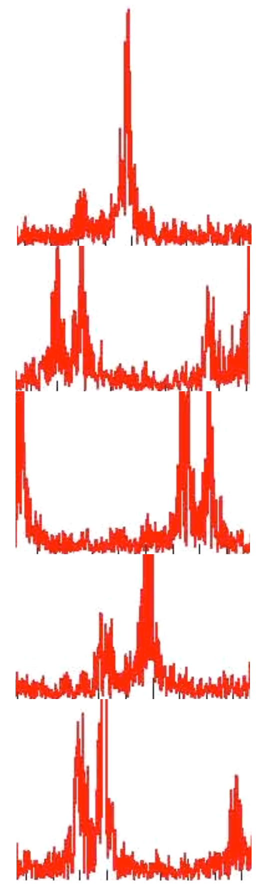
Determination of the large Separation

1. Select a range of possible Δí values
2. Cut selected parts of the spectrum into bins of Δí / 2

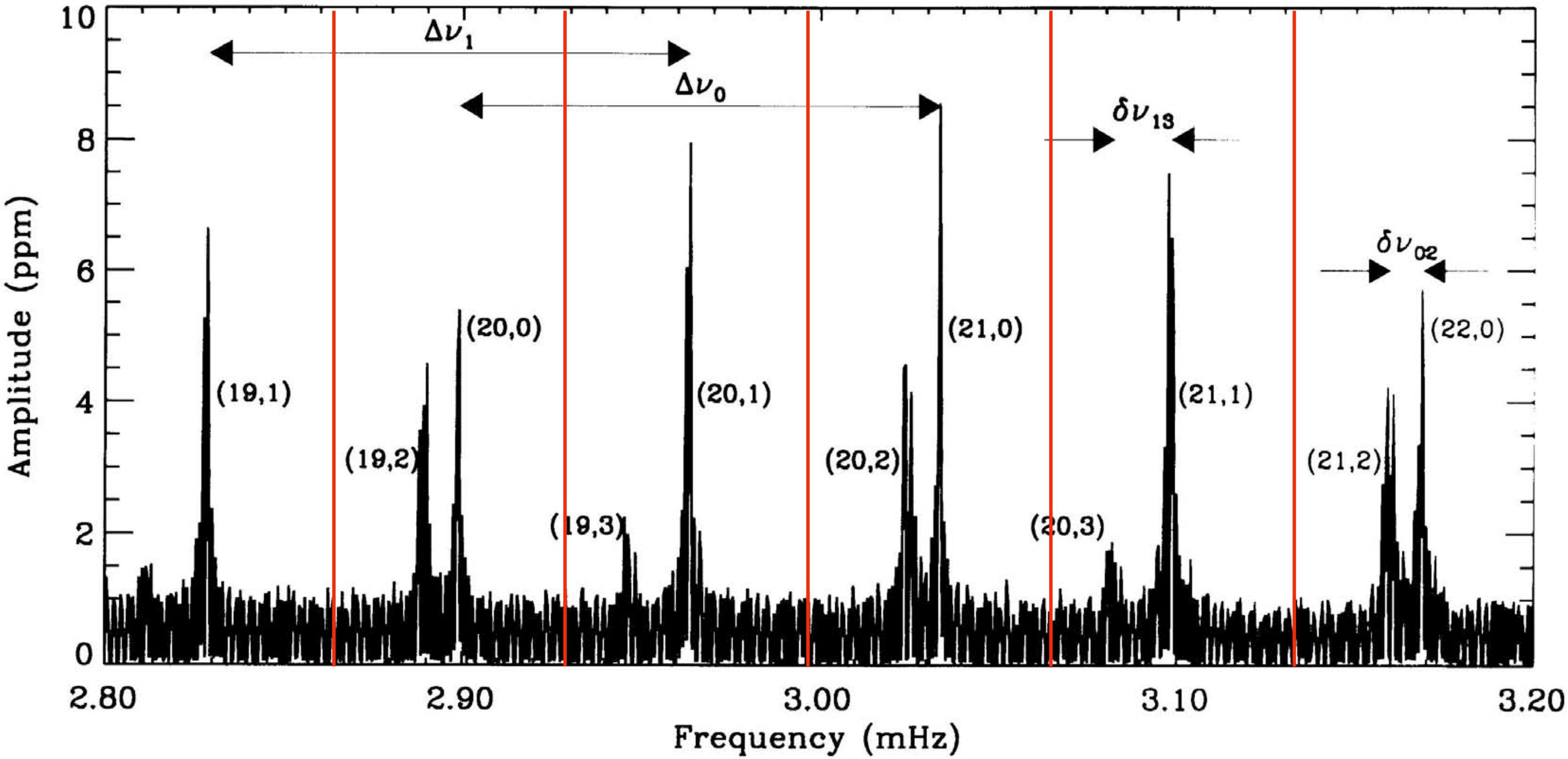


Determine the large Separation

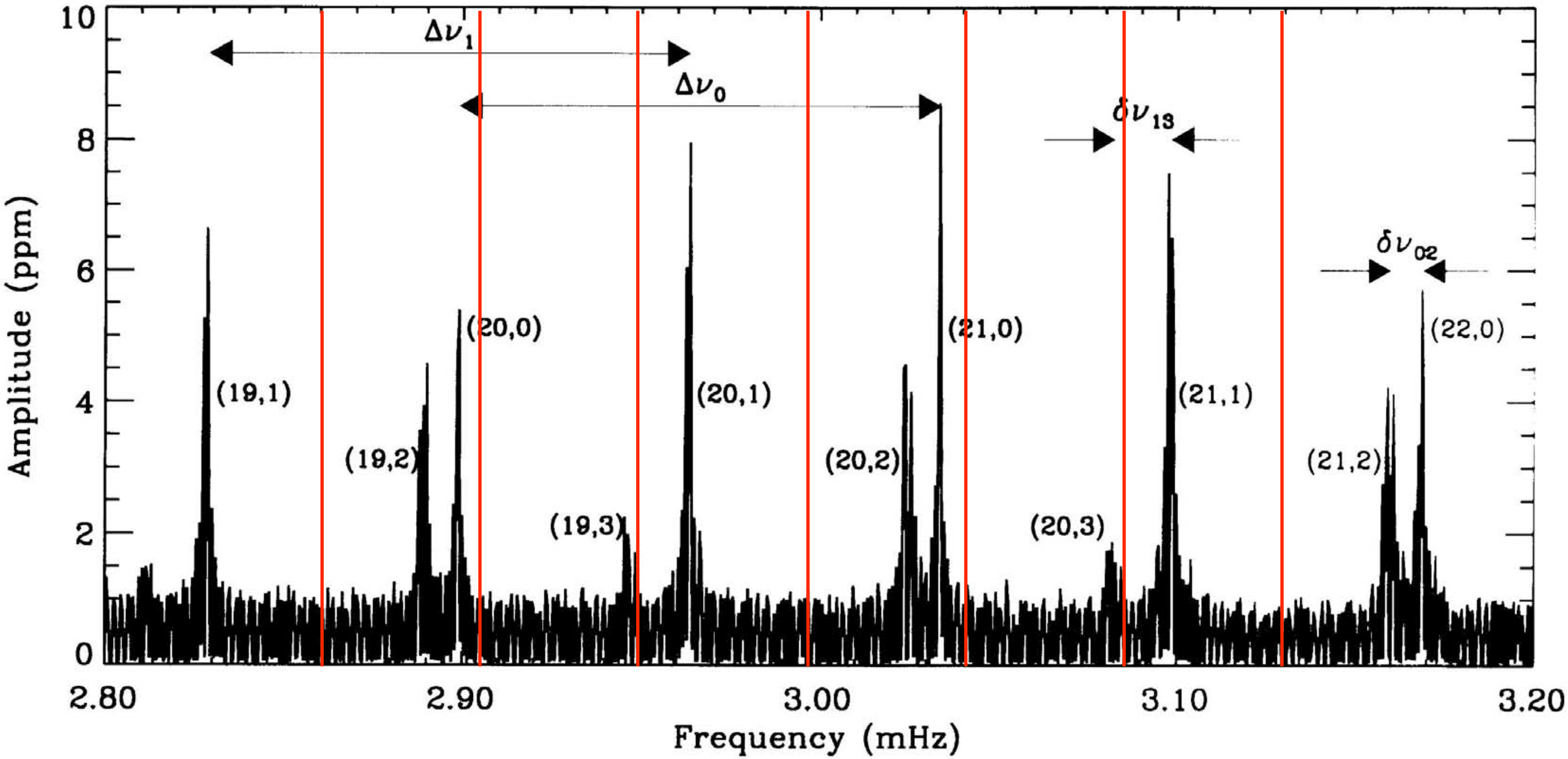
1. Select a range of possible Δí values
2. Cut selected parts of the spectrum into bins of Δí / 2
3. Sum the power of each bin
4. Find the peak of the summed power



Correct value: l=0,1 same position in each bin

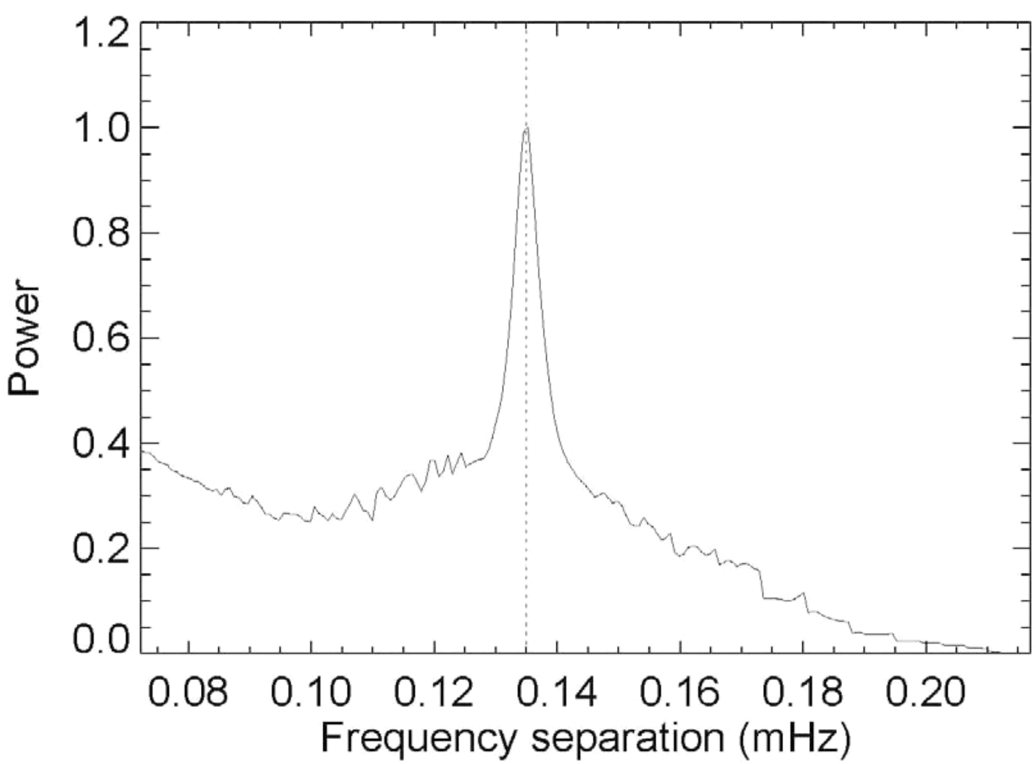


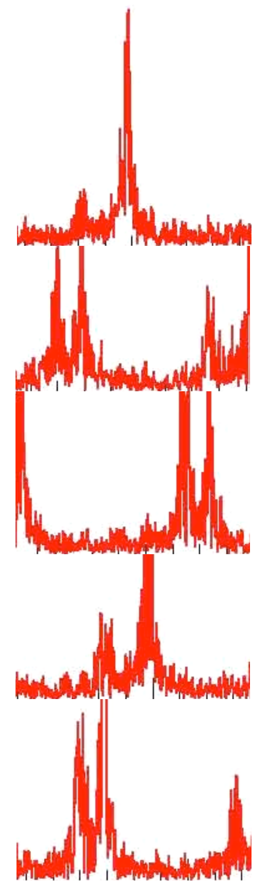
Wrong Large Separation

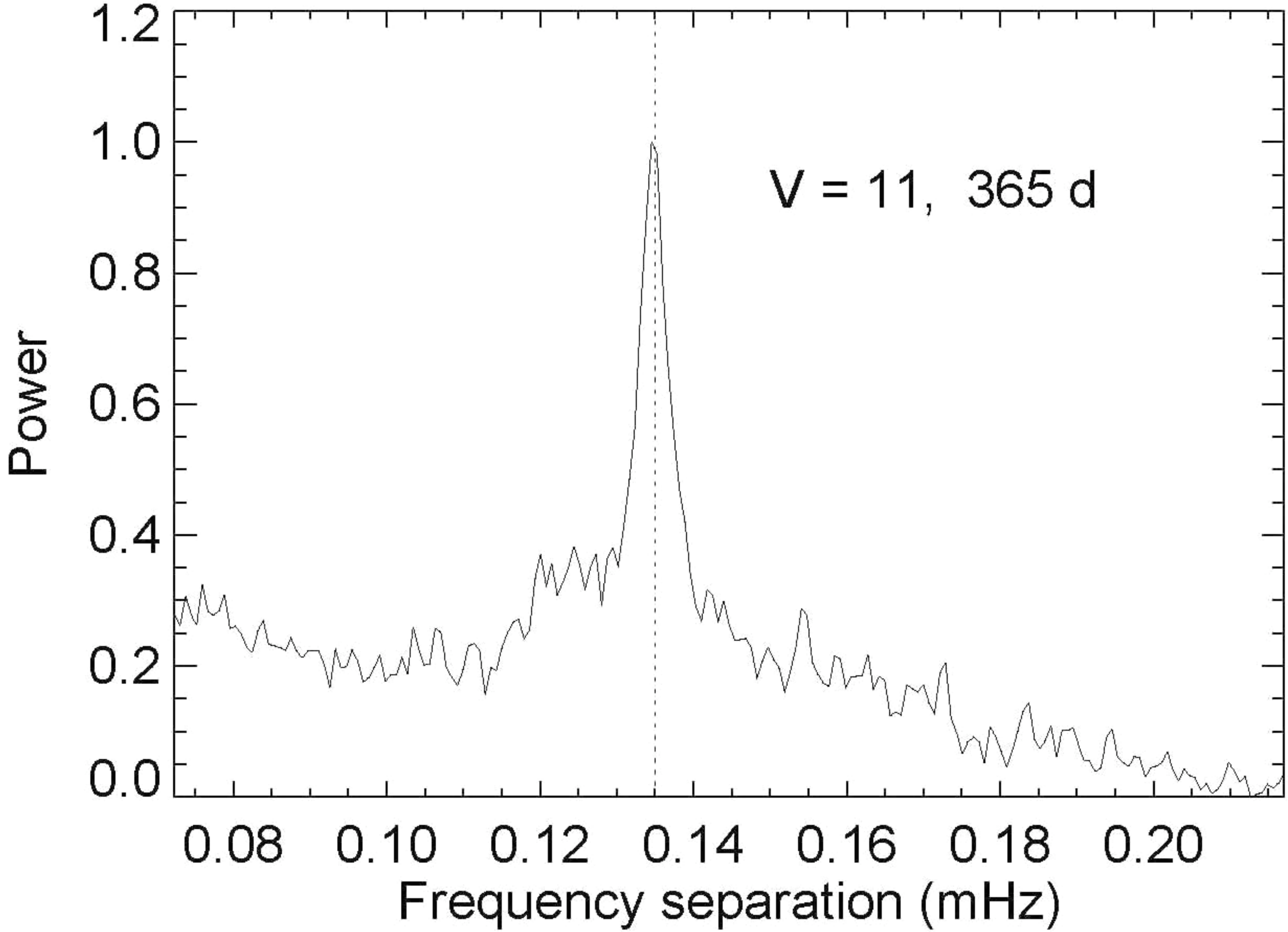


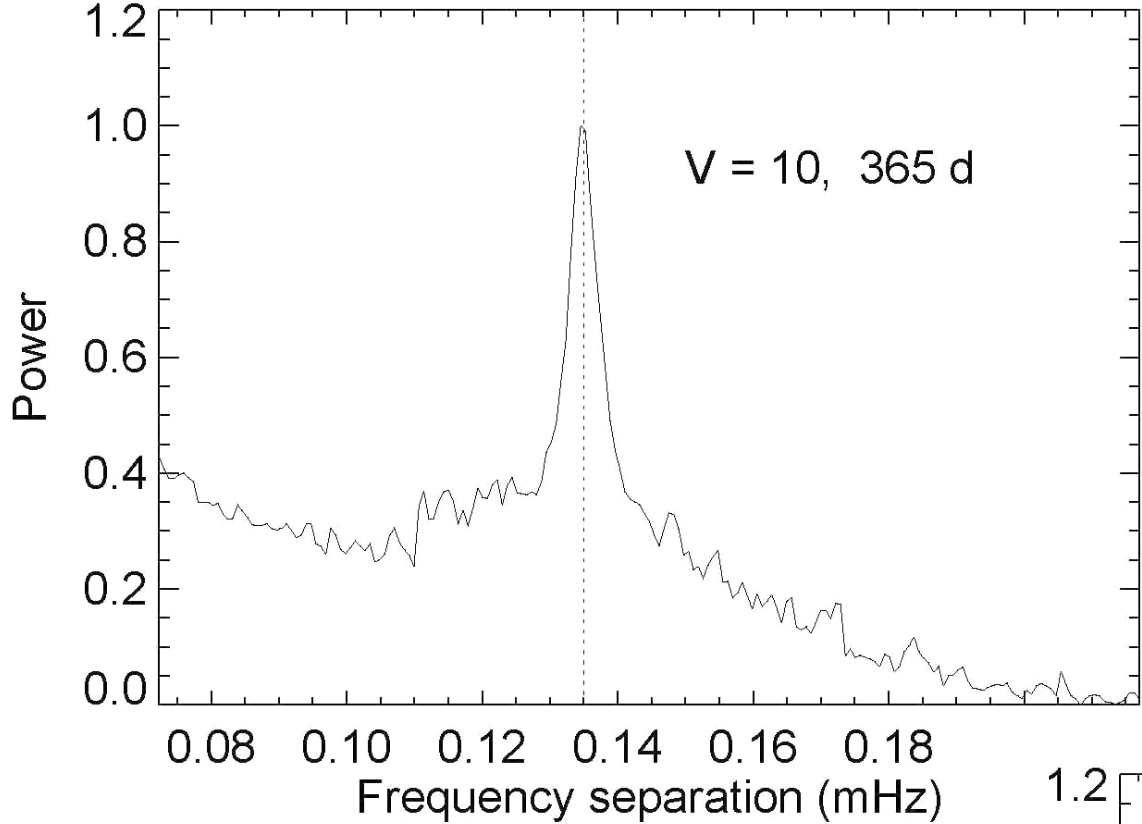
Determine the large Separation

1. Select a range of possible Δí values
2. Cut selected parts of the spectrum into bins of Δí / 2
3. Sum the power of each bin
4. Find the peak of the summed power
5. Try for all values of Δí

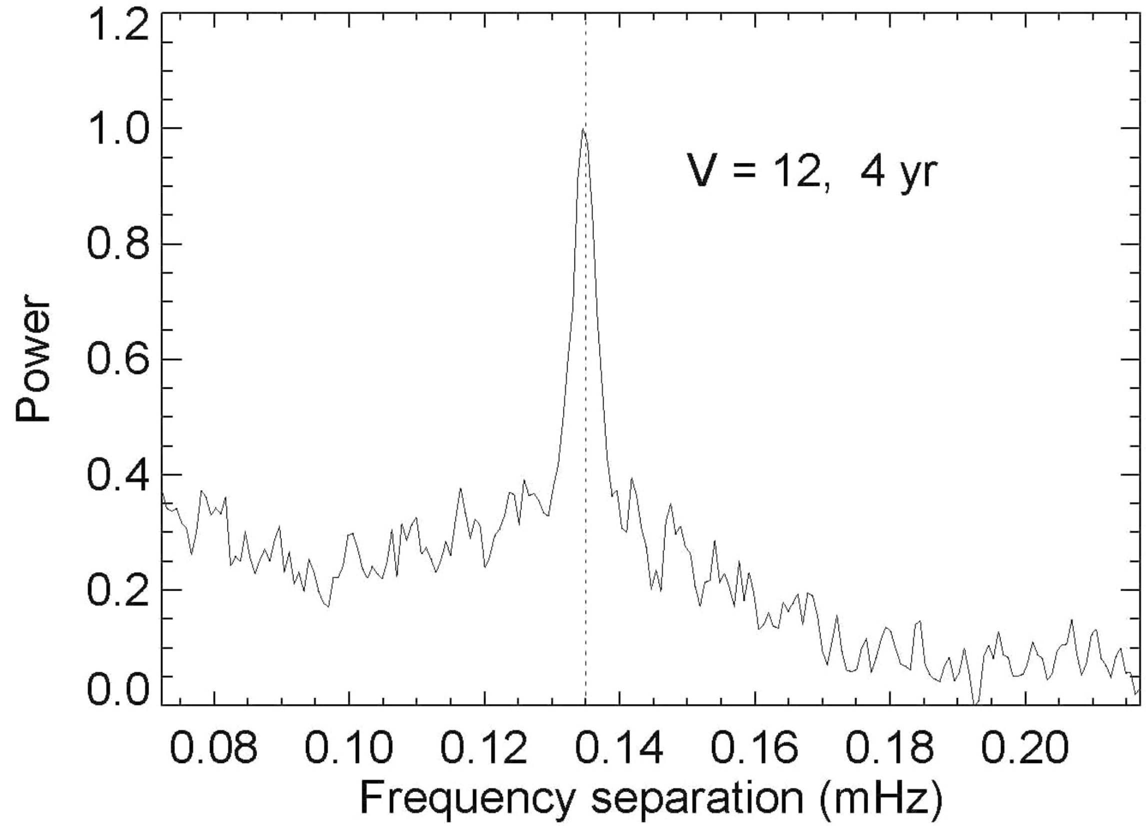




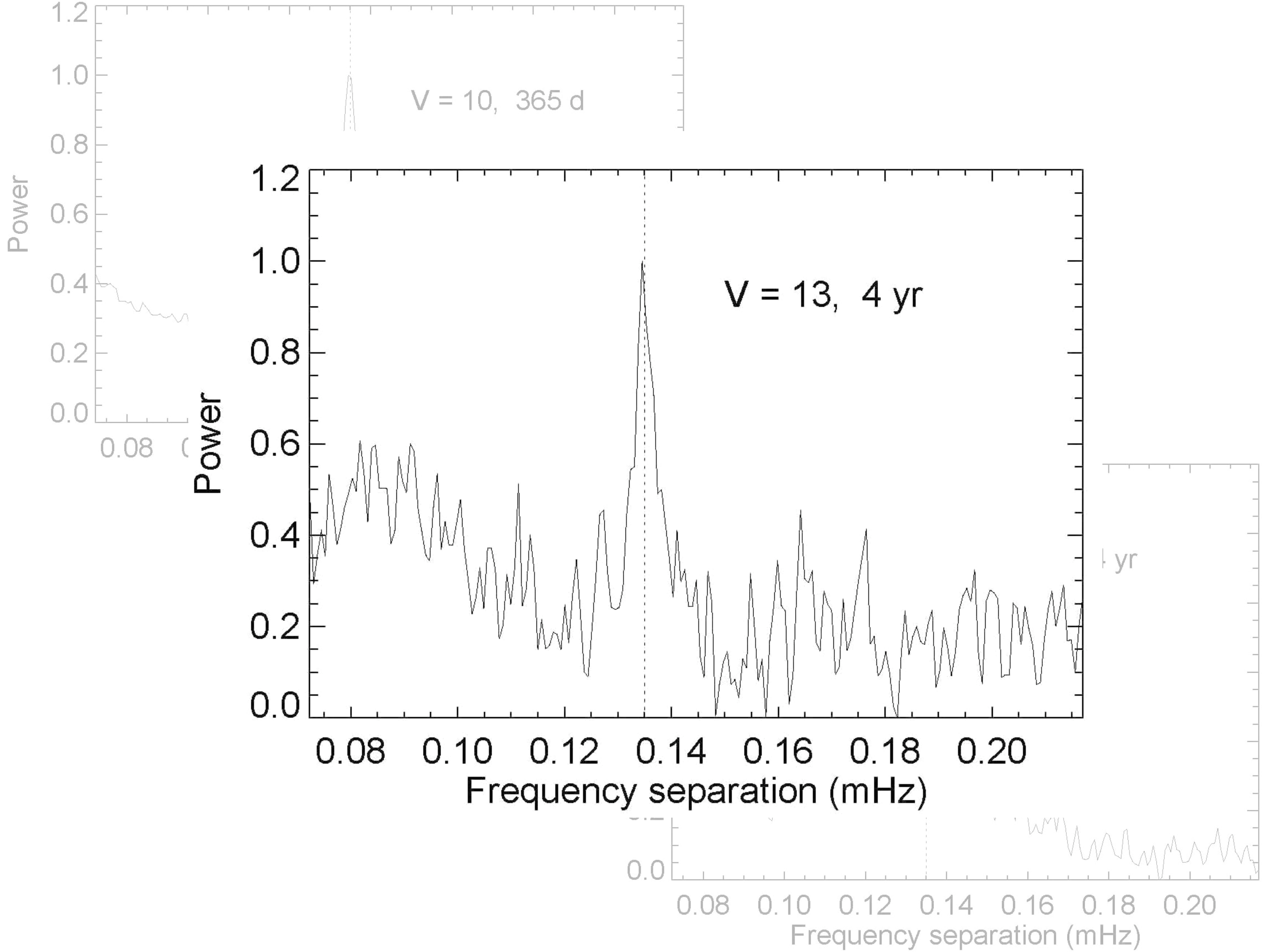

Power
Frequency separation (mHz)
V = 11, 365 d
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.08
0.10
0.12
0.14
0.16
0.18
0.20



V = 10, 365 d
Power
Frequency separation (mHz)

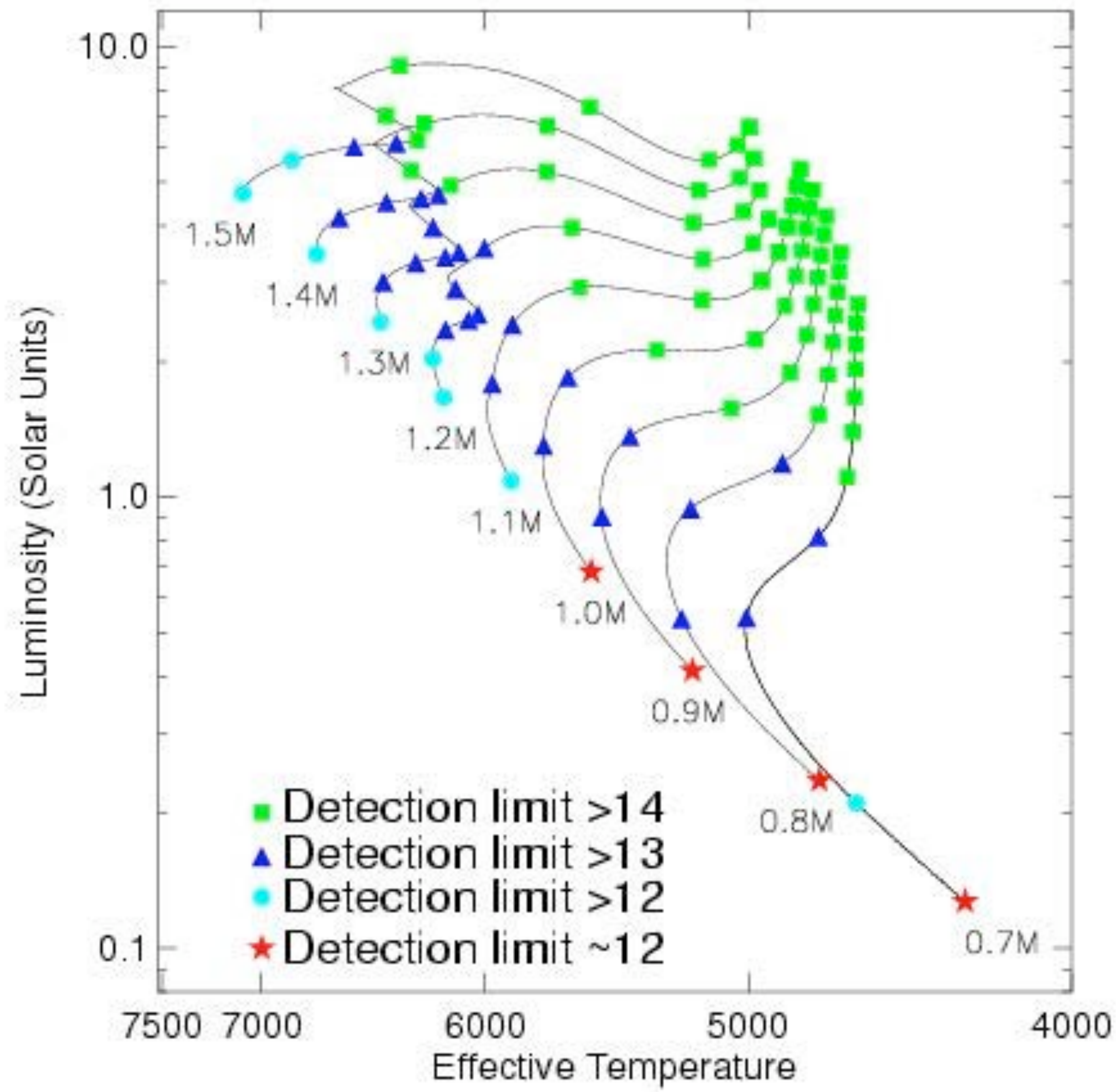


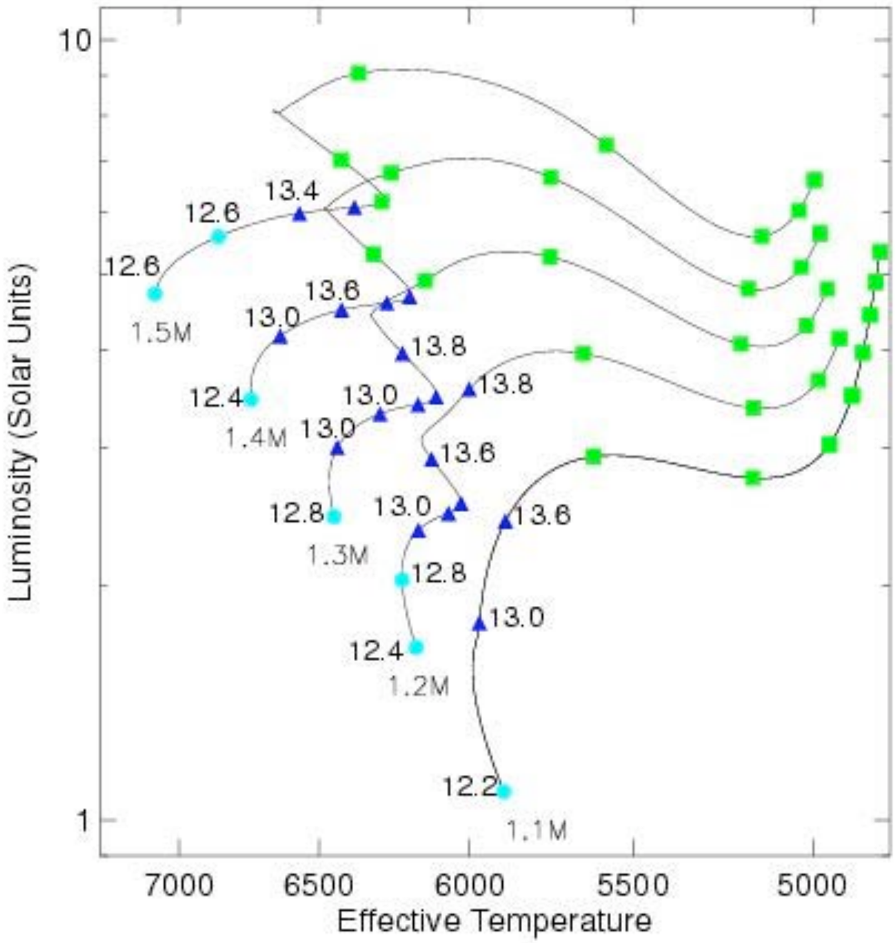
V = 12, 4 yr
Power
Frequency separation (mHz)


V = 10, 365 d
V = 13, 4 yr
Power
Frequency separation (mHz)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0.08
0.10
0.12
0.14
0.16
0.18
0.20

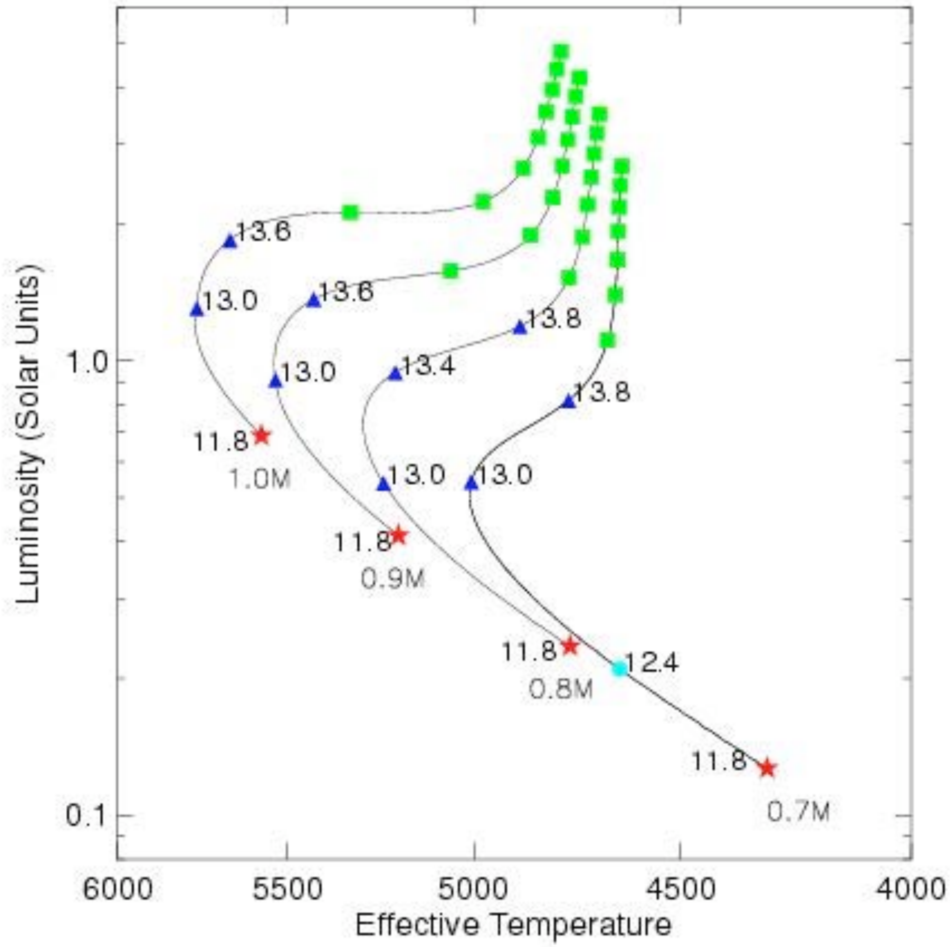
For each model:

- Run 10 realizations of the noise
- Continue to add noise until detection fails in 1 of the 10 realizations

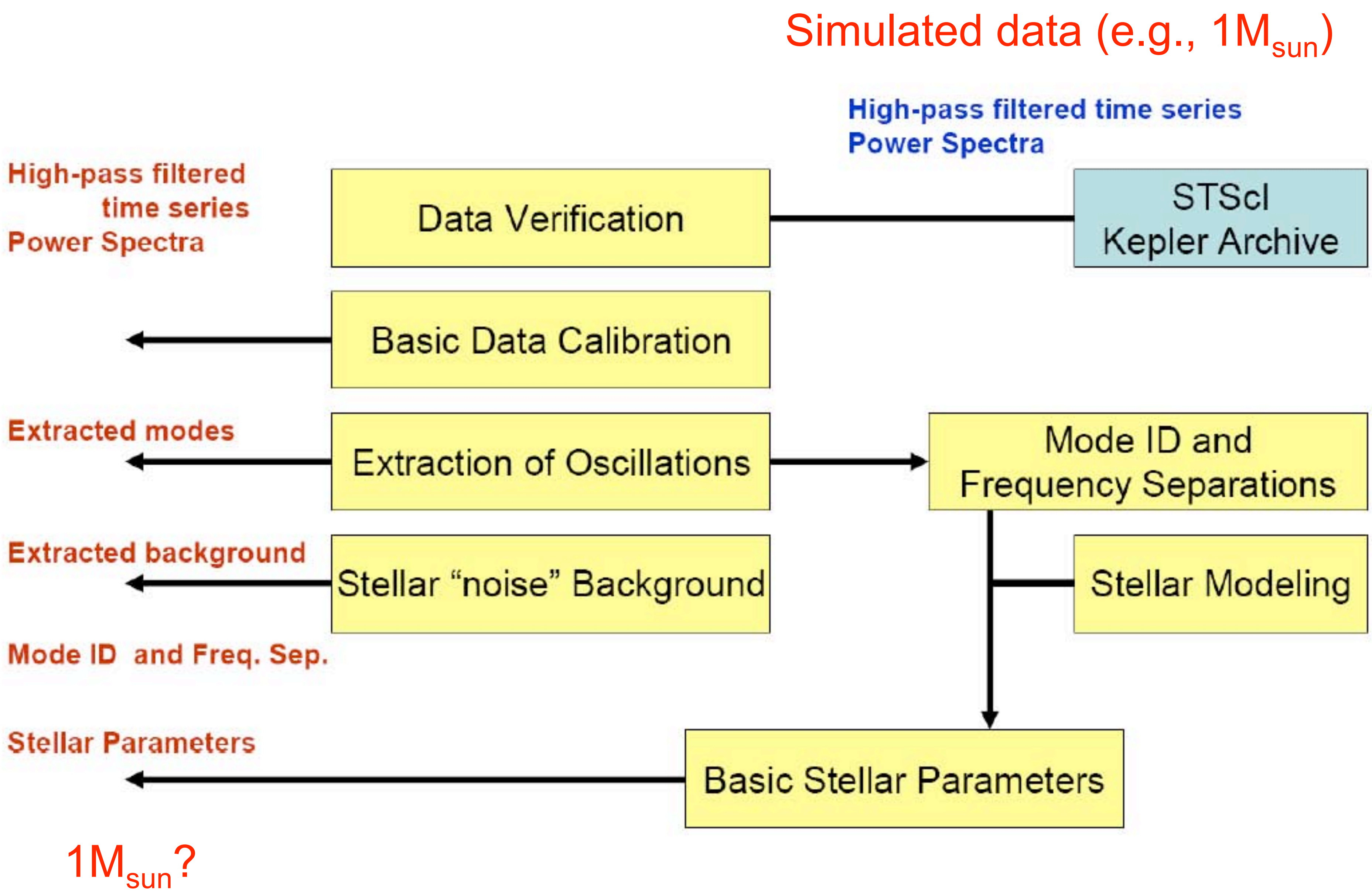




Luminosity (Solar Units)
Effective Temperature
1.5M
1.4M
1.3M
1.2M
1.1M



Luminosity (Solar Units)
Effective Temperature
1.0M
0.9M
0.8M
0.7M


Simulated data (e.g., $1M_{sun}$)
High-pass filtered time series
Power Spectra
High-pass filtered
time series
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Stellar "noise" Background
Stellar Modeling
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Basic Stellar Parameters
$1M_{sun}$?