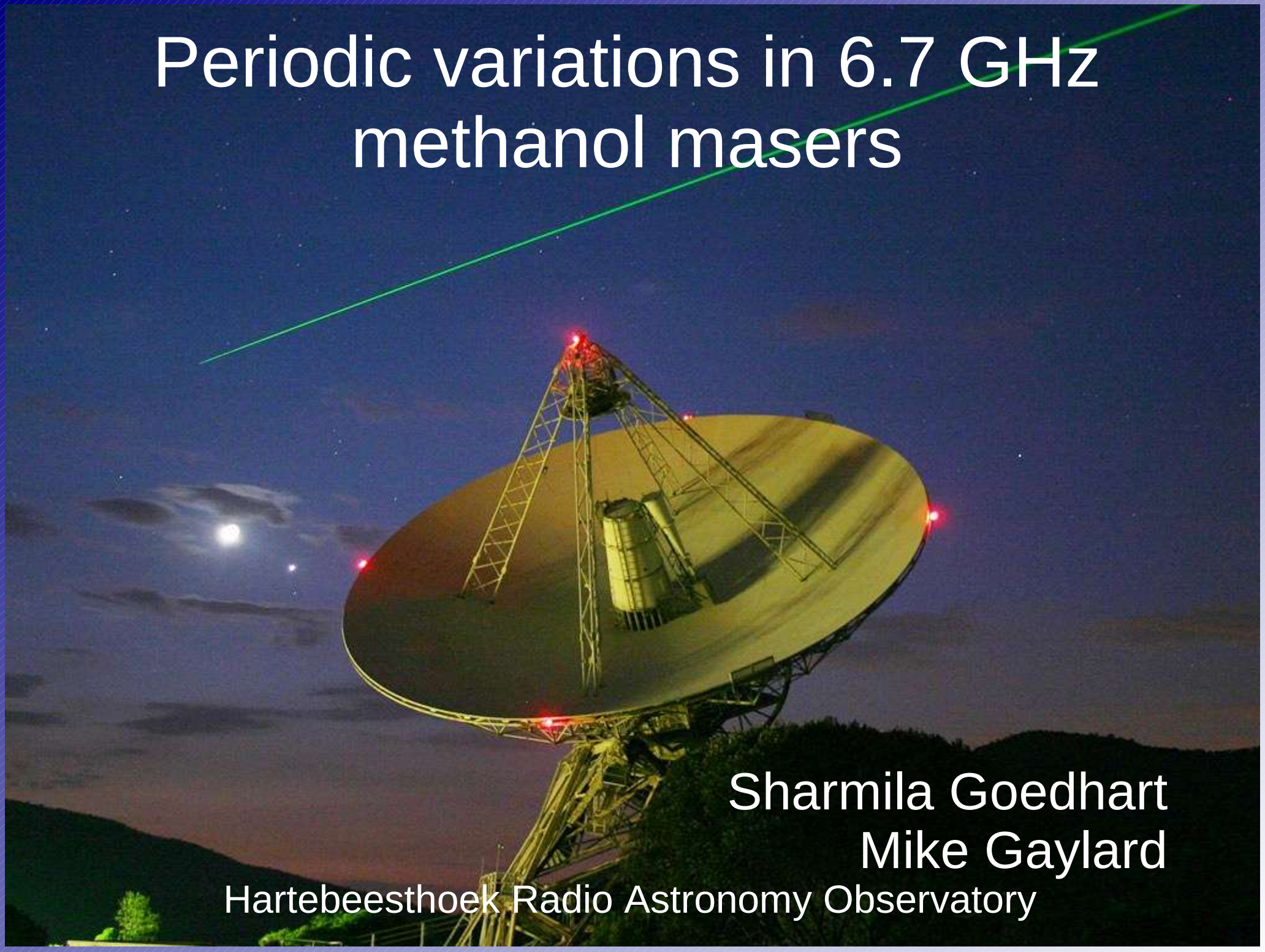
Periodic variations in 6.7 GHz methanol masers



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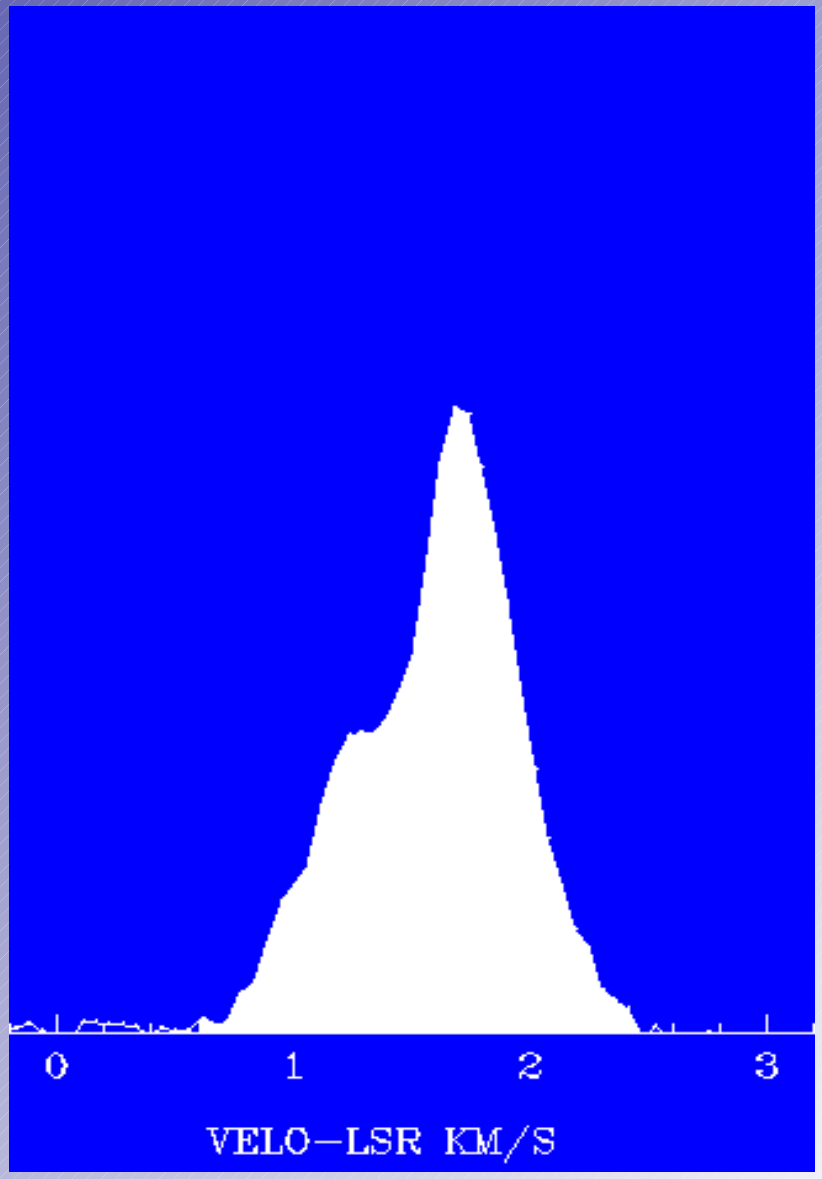
Mike Gaylard
Hartebeesthoek Radio Astronomy Observatory

6.7 GHz methanol masers can be highly variable

G351.78-0.54 – variations over one year showing three cycles.



What can maser variability tell us about the process of high mass star formation?

Observations at 6.7 GHz

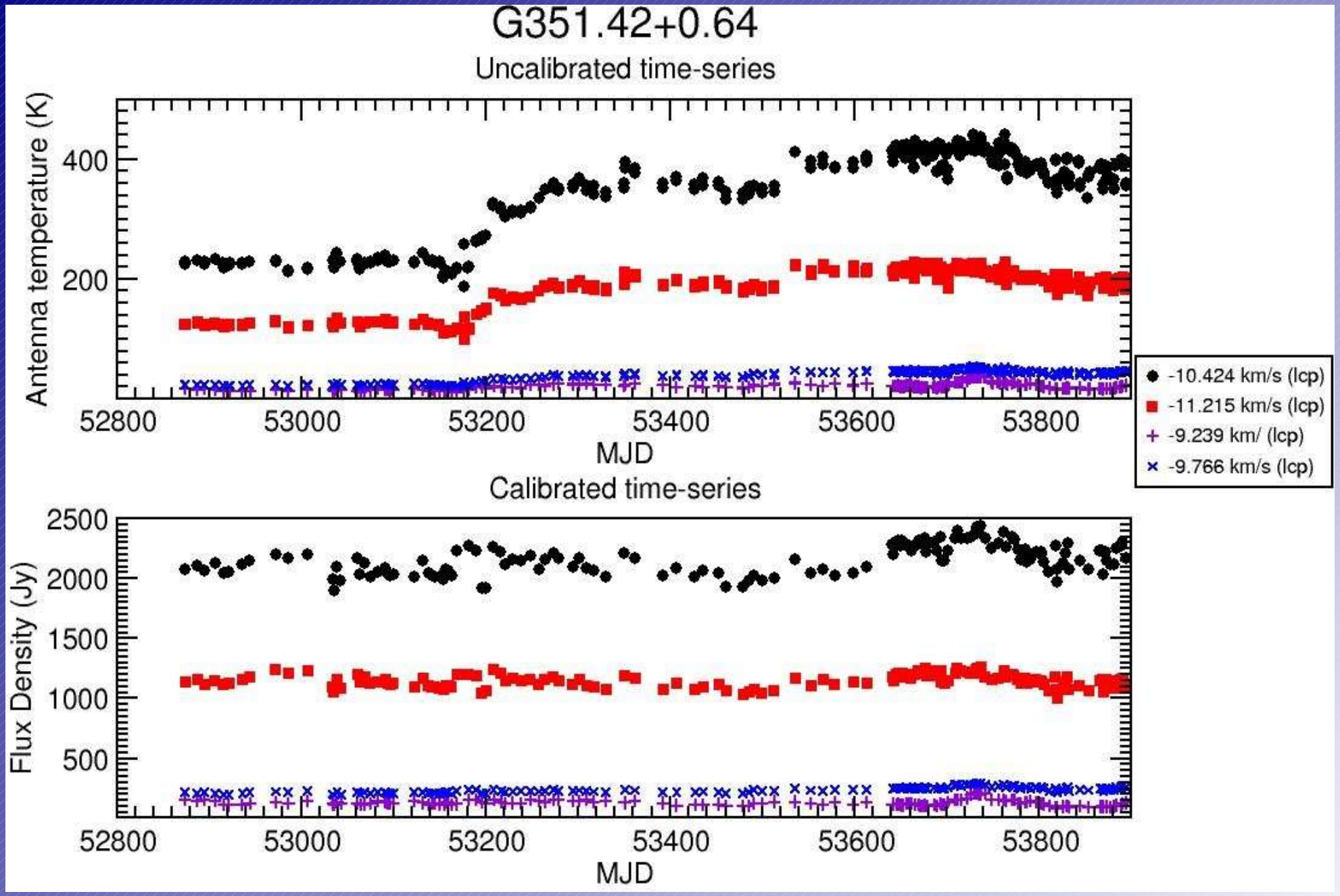
with the 26-m Hartebeesthoek Telescope

- Initial survey (Goedhart et al., 2004 MNRAS, 355,553):
  - January 1999 --> April 2003
  - 54 sources
  - single polarisation (LCP)
  - 256-channel correlator at 0.32 or 0.64 MHz bandwidth

- Ongoing monitoring
  - New main reflecting surface, ~0.5mm rms (22 GHz available!)
  - Rebuilt receiver in 2003, dual polarisation, LCP & RCP
  - new control computer & observing software
  - 1024 channels/pol correlator at 1 MHz bandwidth
  - 19 sources of interest

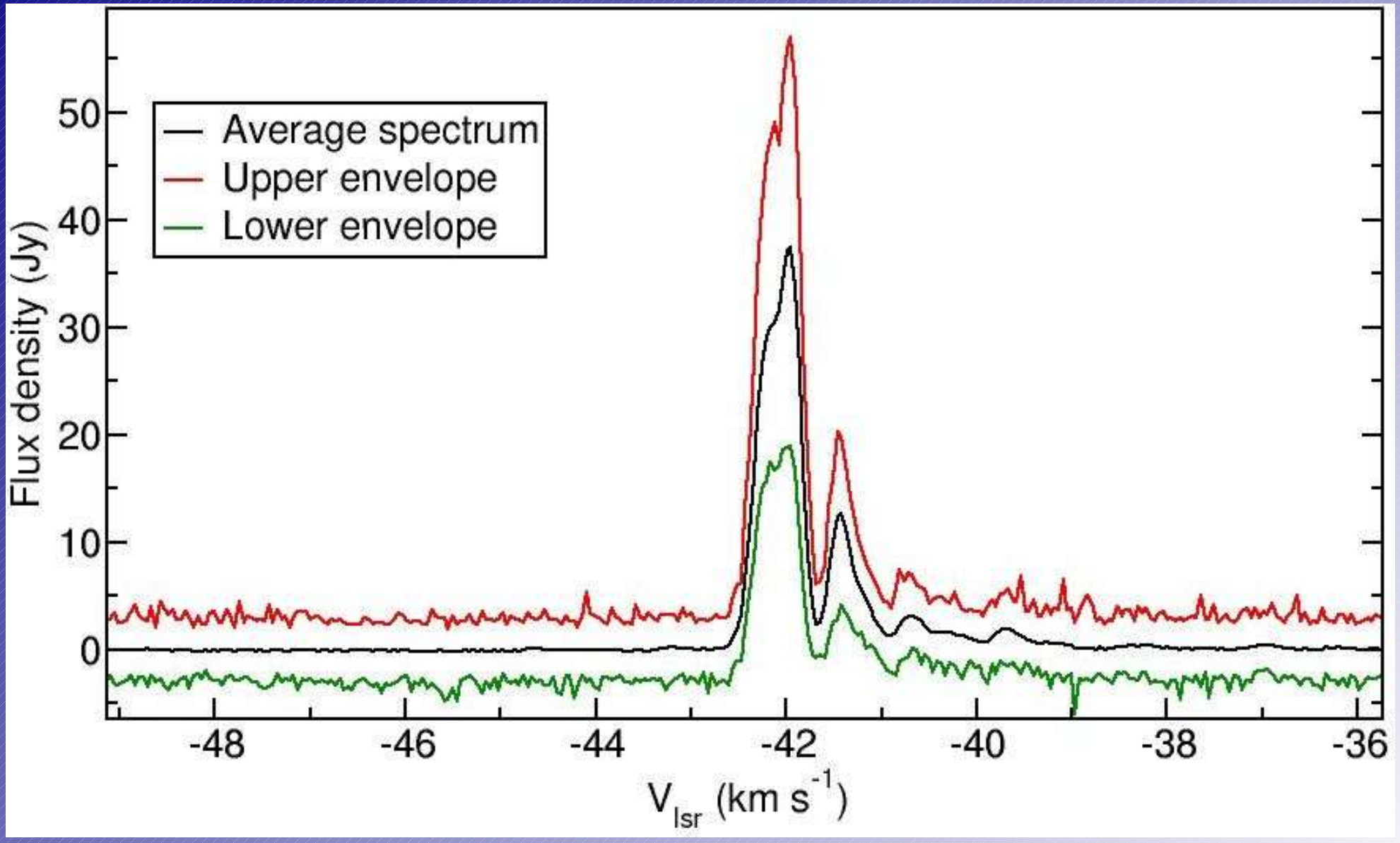
Amplitude calibration

- Continuum drift scans scheduled with each set of spectral line observations
- Hydra A, Virgo A & 3C123
- with pointing checks

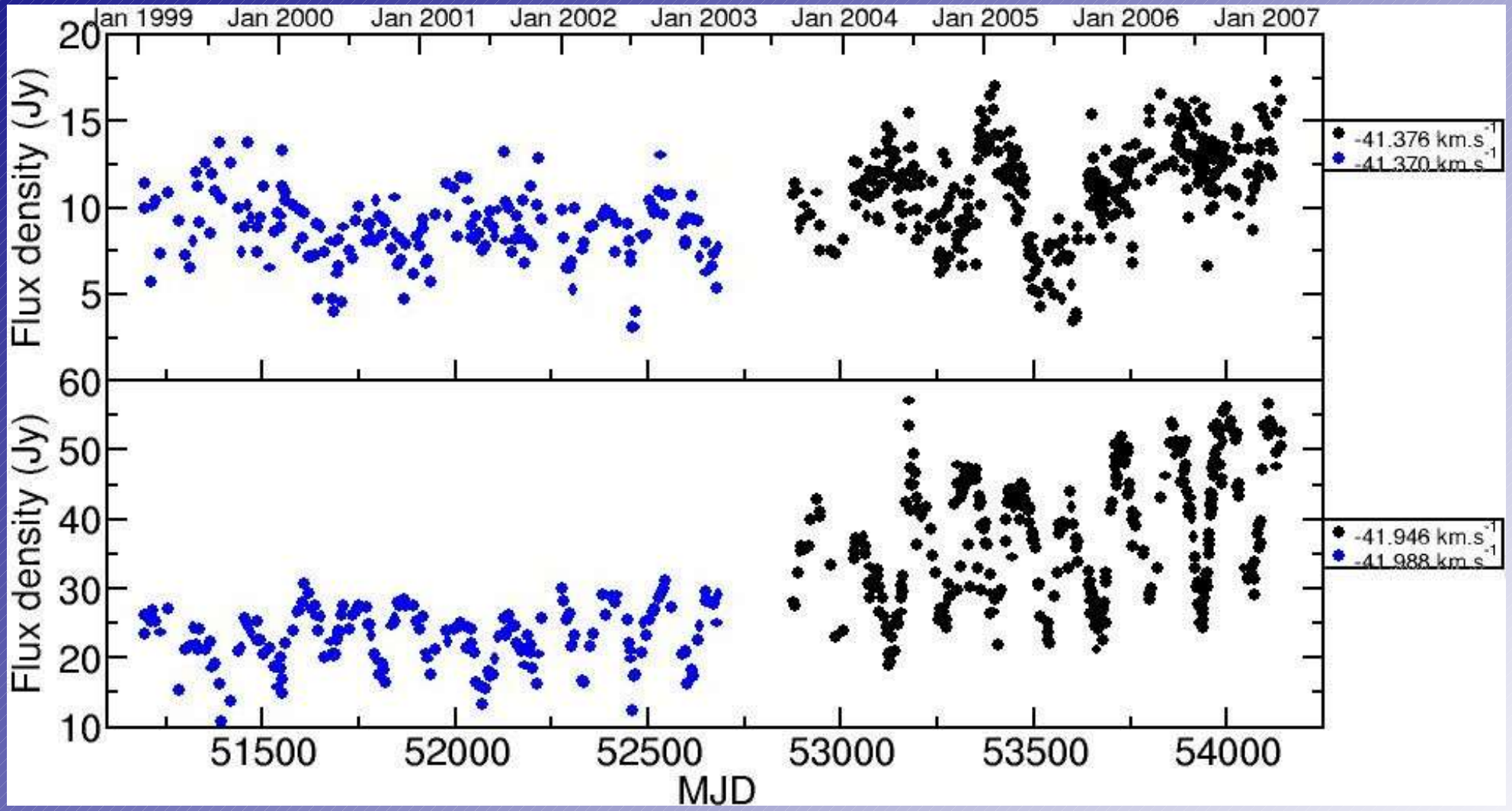

G351.42+0.64
Uncalibrated time-series
Antenna temperature (K)
400
200
52800
53000
53200
53400
53600
53800
MJD
-10.424 km/s (lcp)
-11.215 km/s (lcp)
-9.239 km/ (lcp)
-9.766 km/s (lcp)
Calibrated time-series
Flux Density (Jy)
2500
2000
1500
1000
500
52800
53000
53200
53400
53600
53800
MJD

Some periodic maser candidates

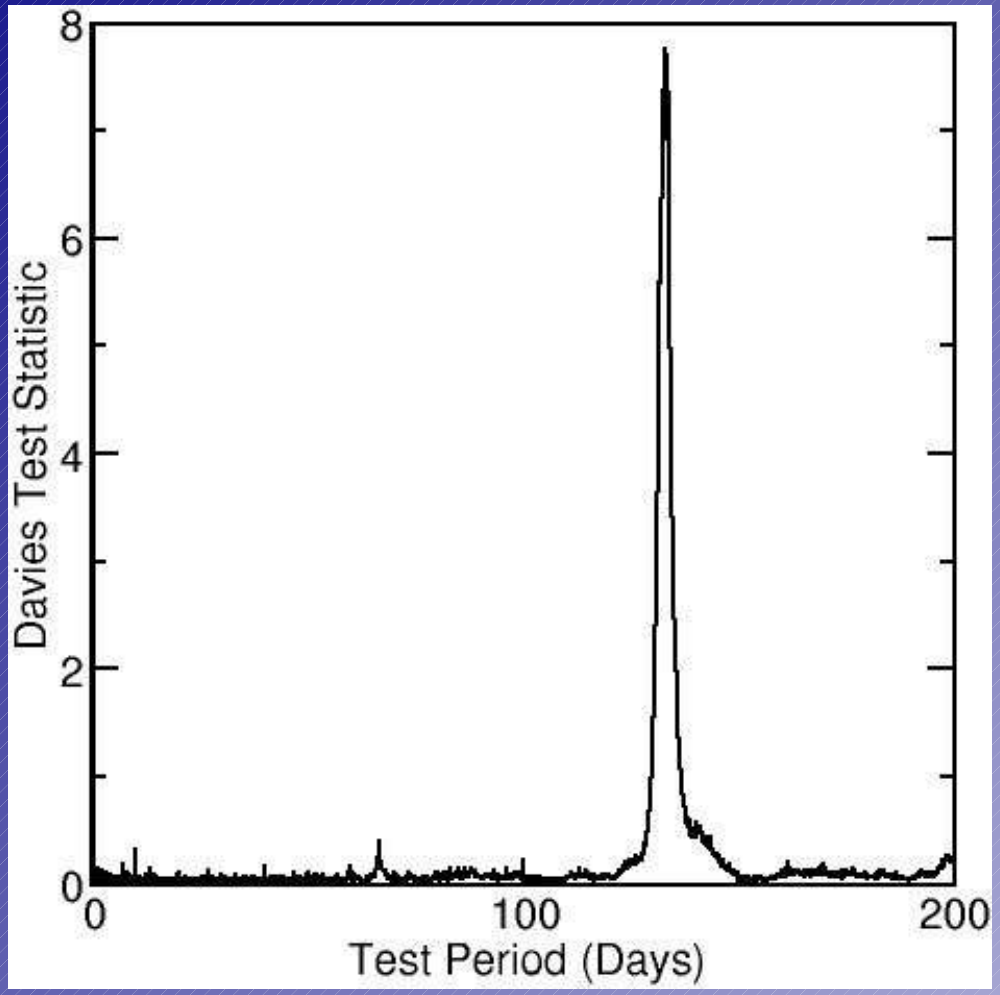
G338.93-0.06: Range of variation

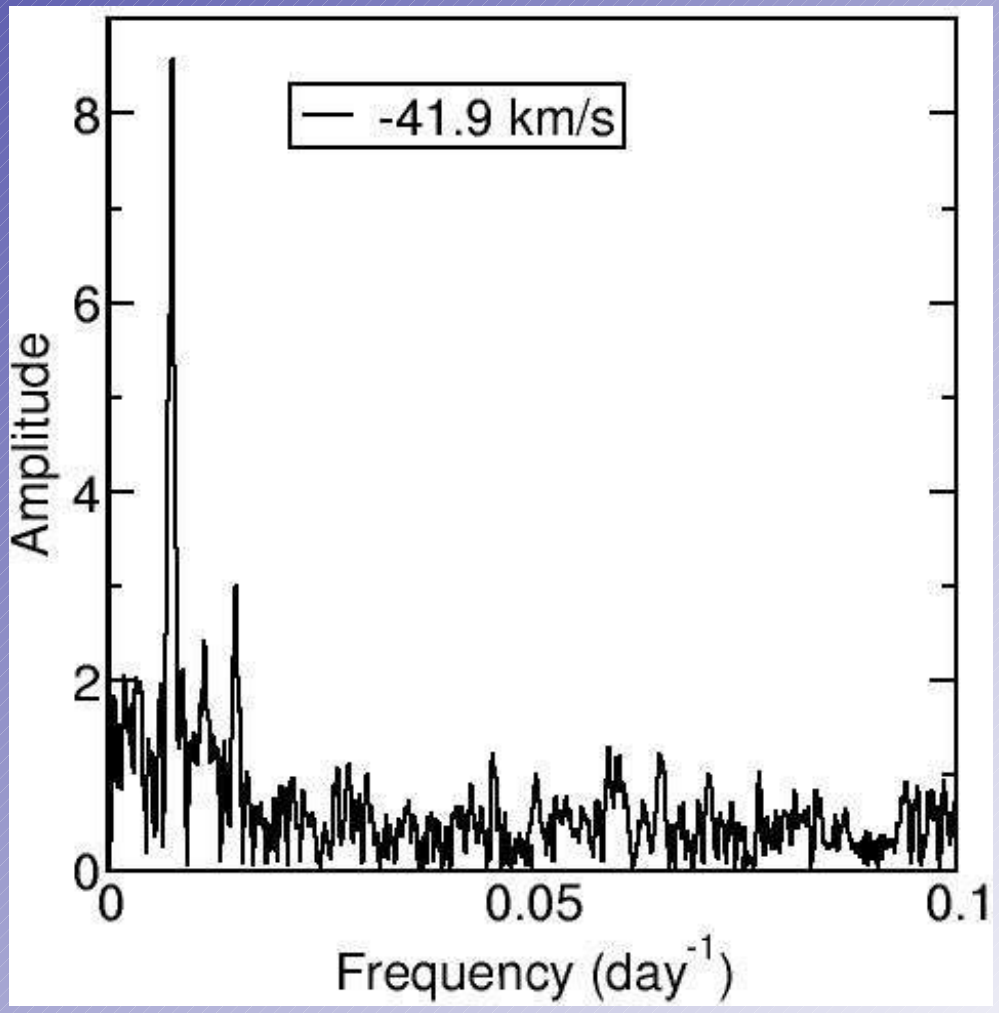


G338.93-0.06: Time-series



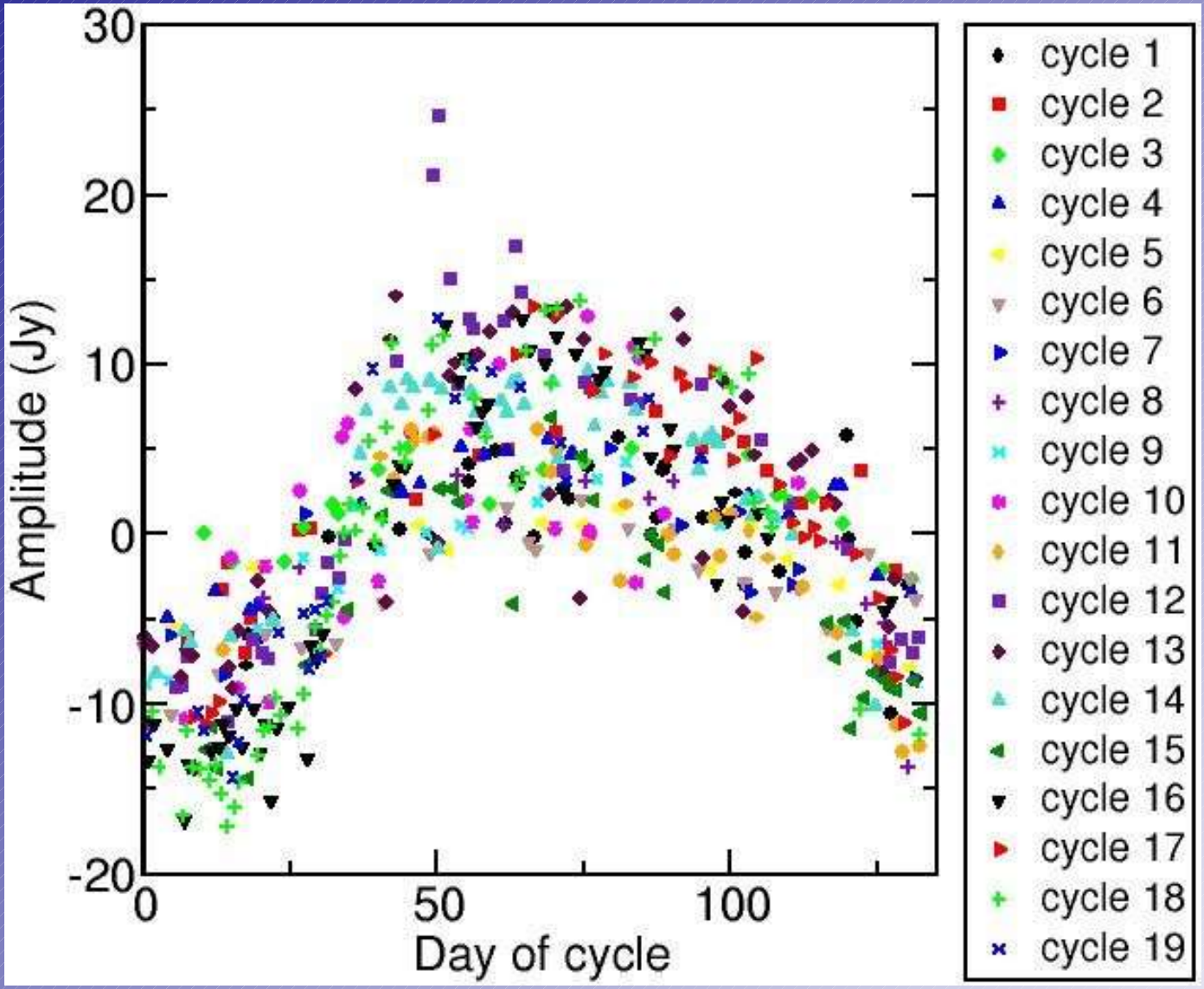
G338.93-0.06: Epoch-folding & Fourier Periodograms



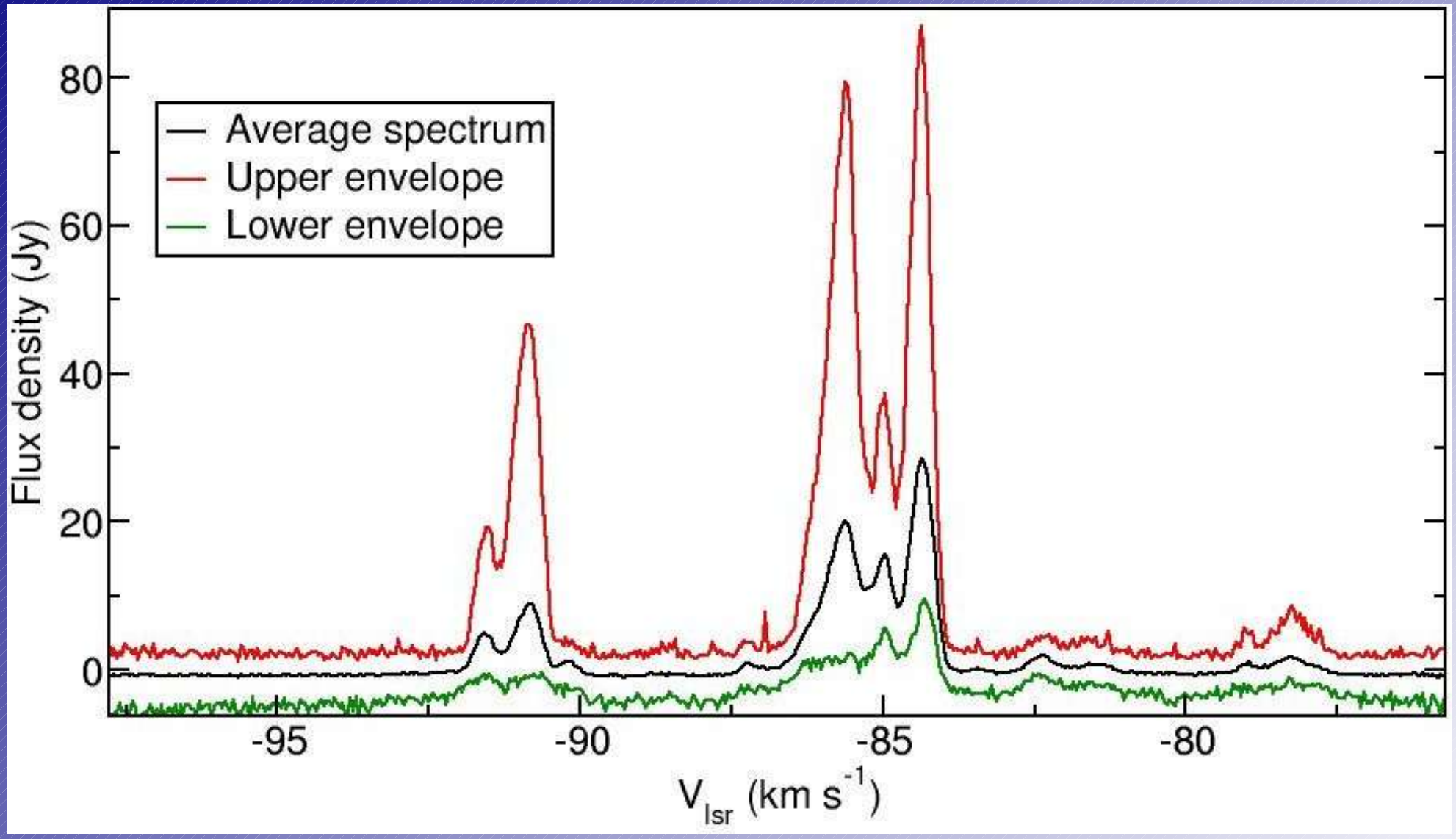


P = 133 days

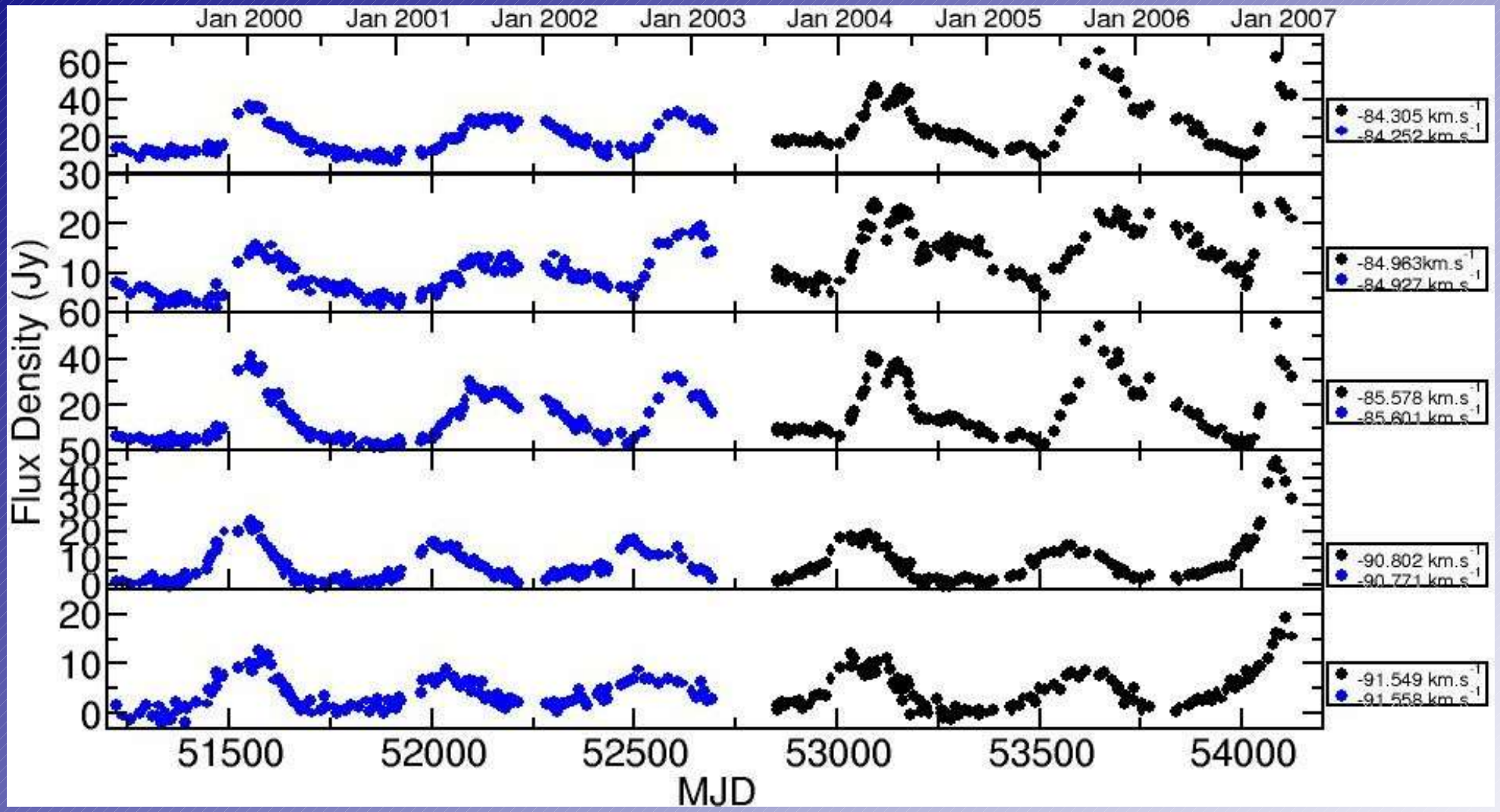
G338.93-0.06: Time-series folded modulo 133 days



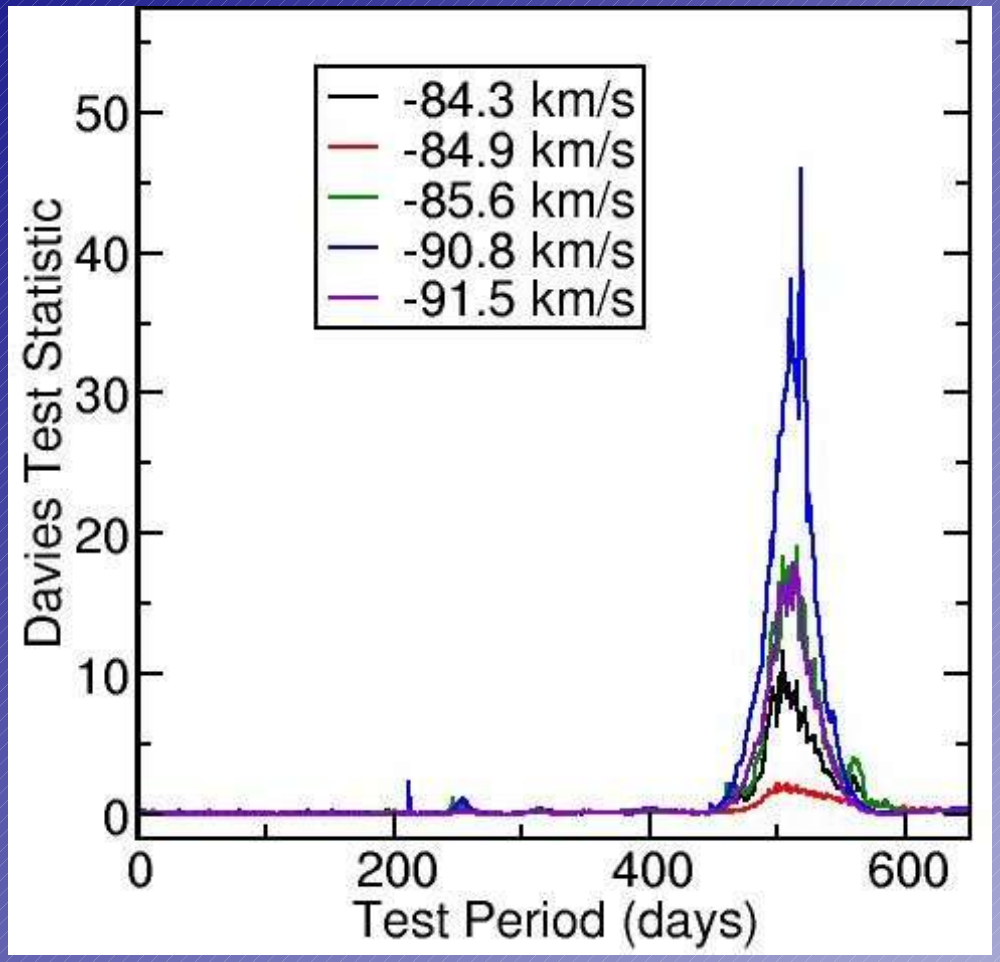
G331.13-0.24: Averaged spectrum

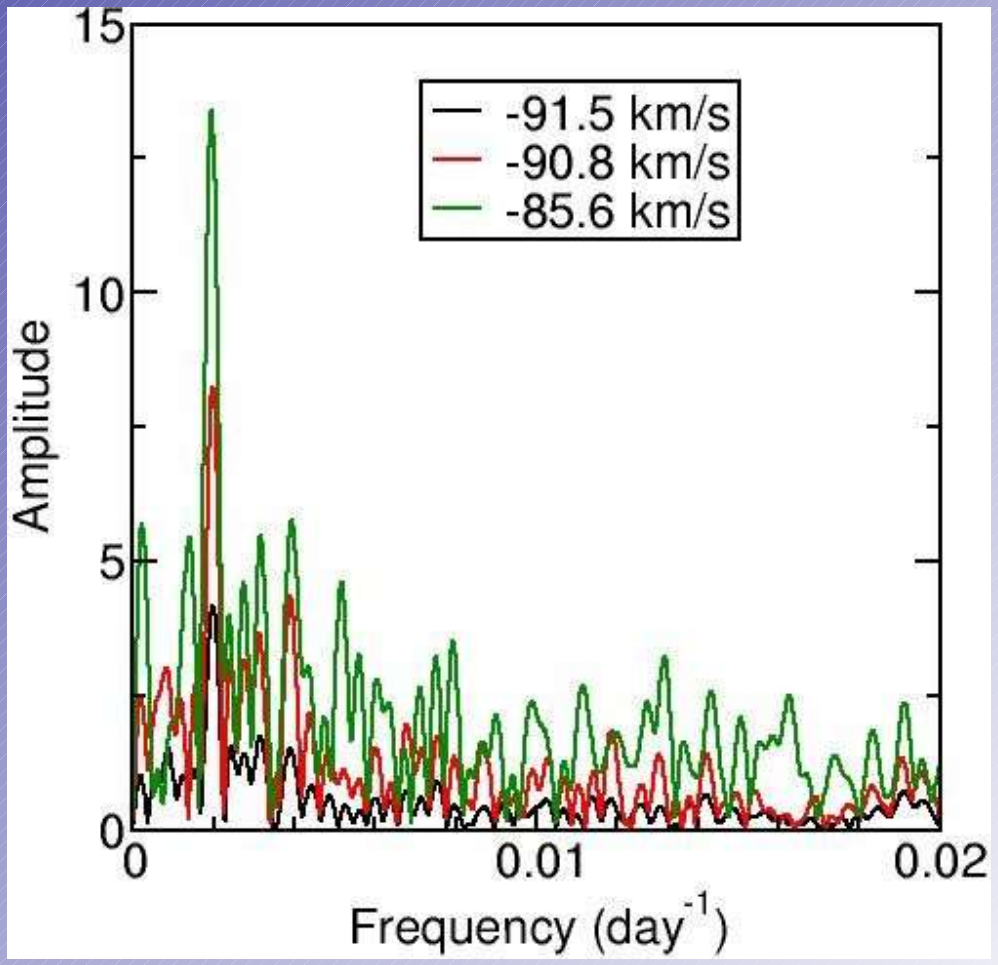


G331.13-0.24: Time-series



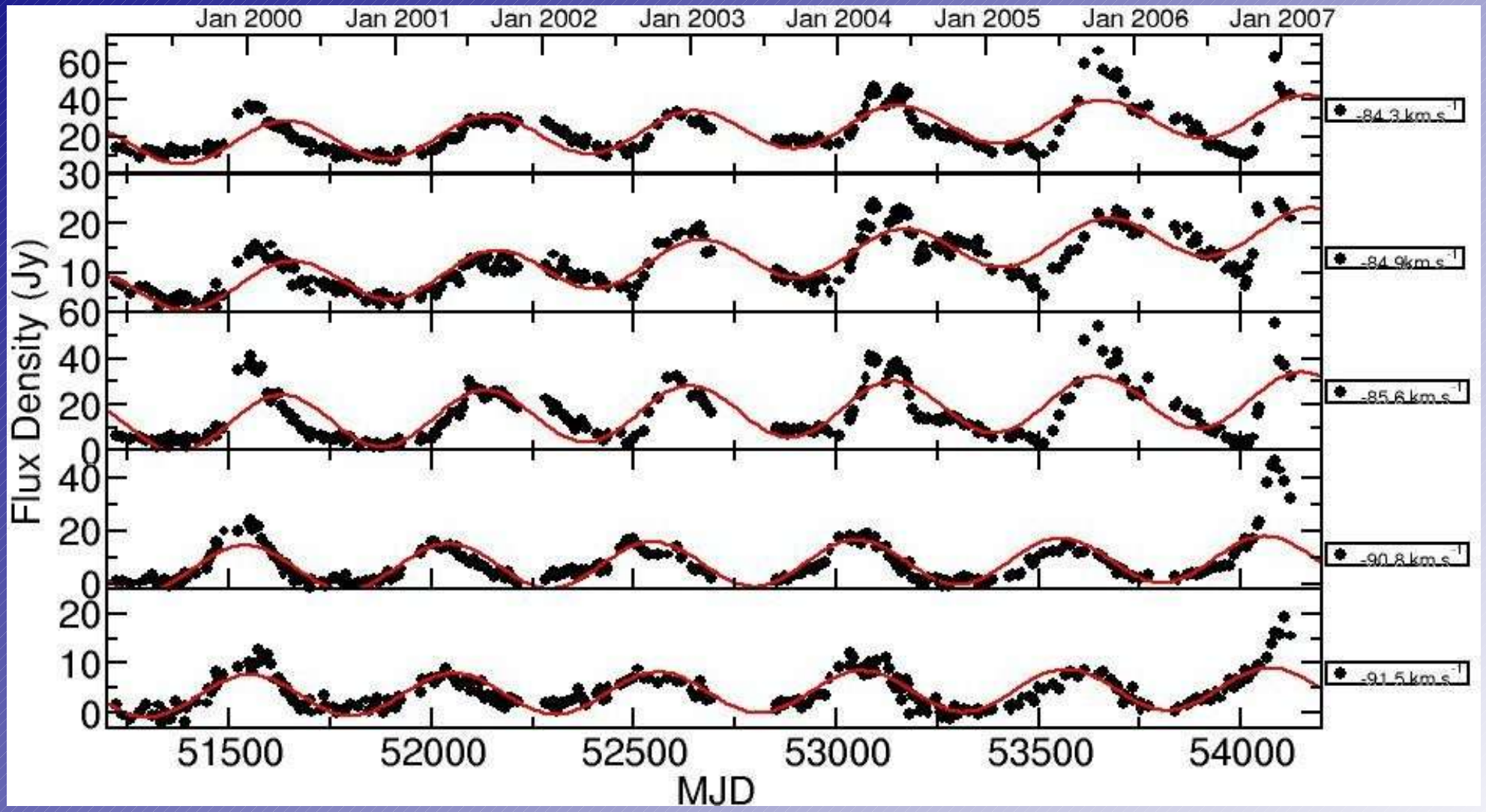
G331.13-0.24: Epoch-folding & Fourier Periodograms



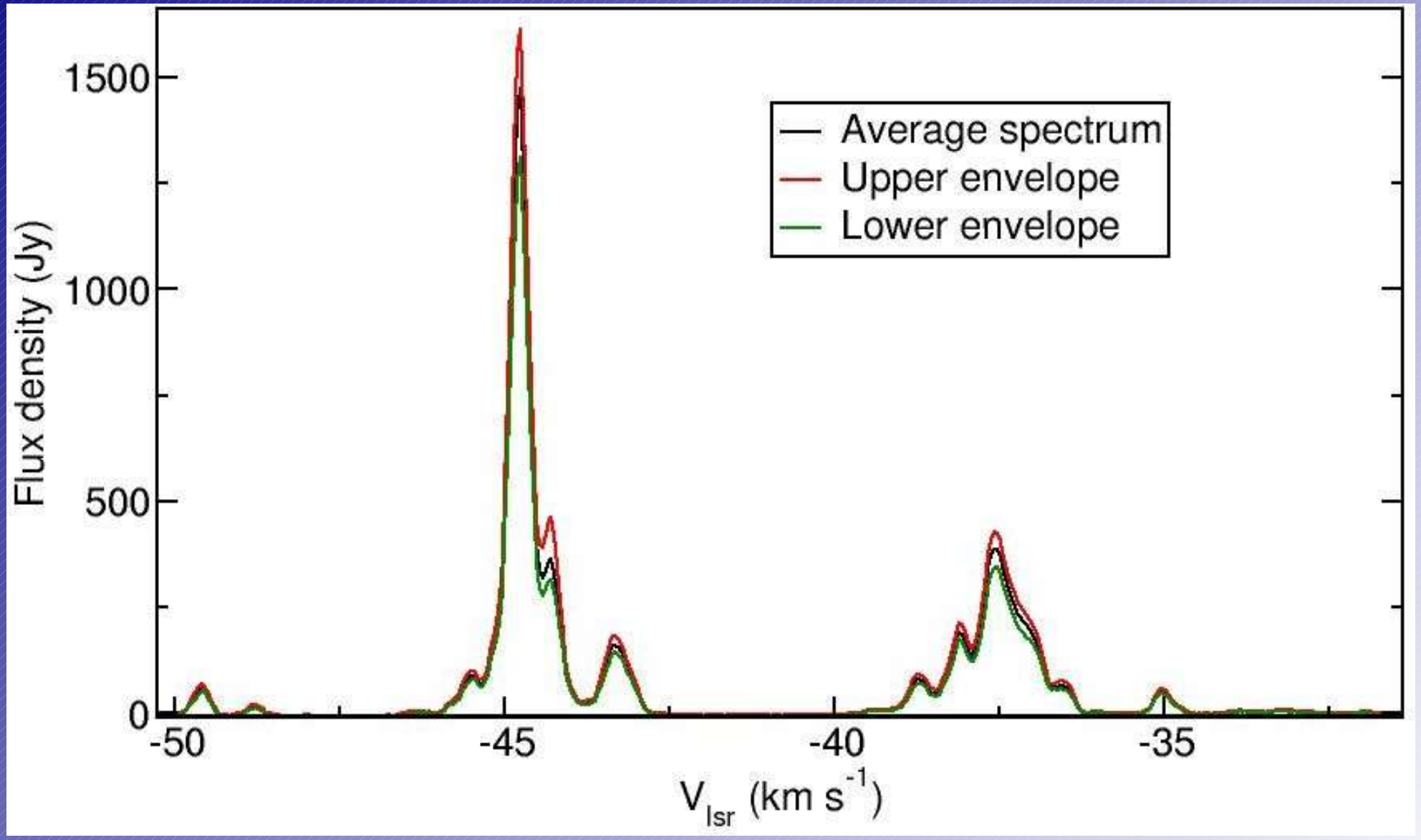


P = 504 days

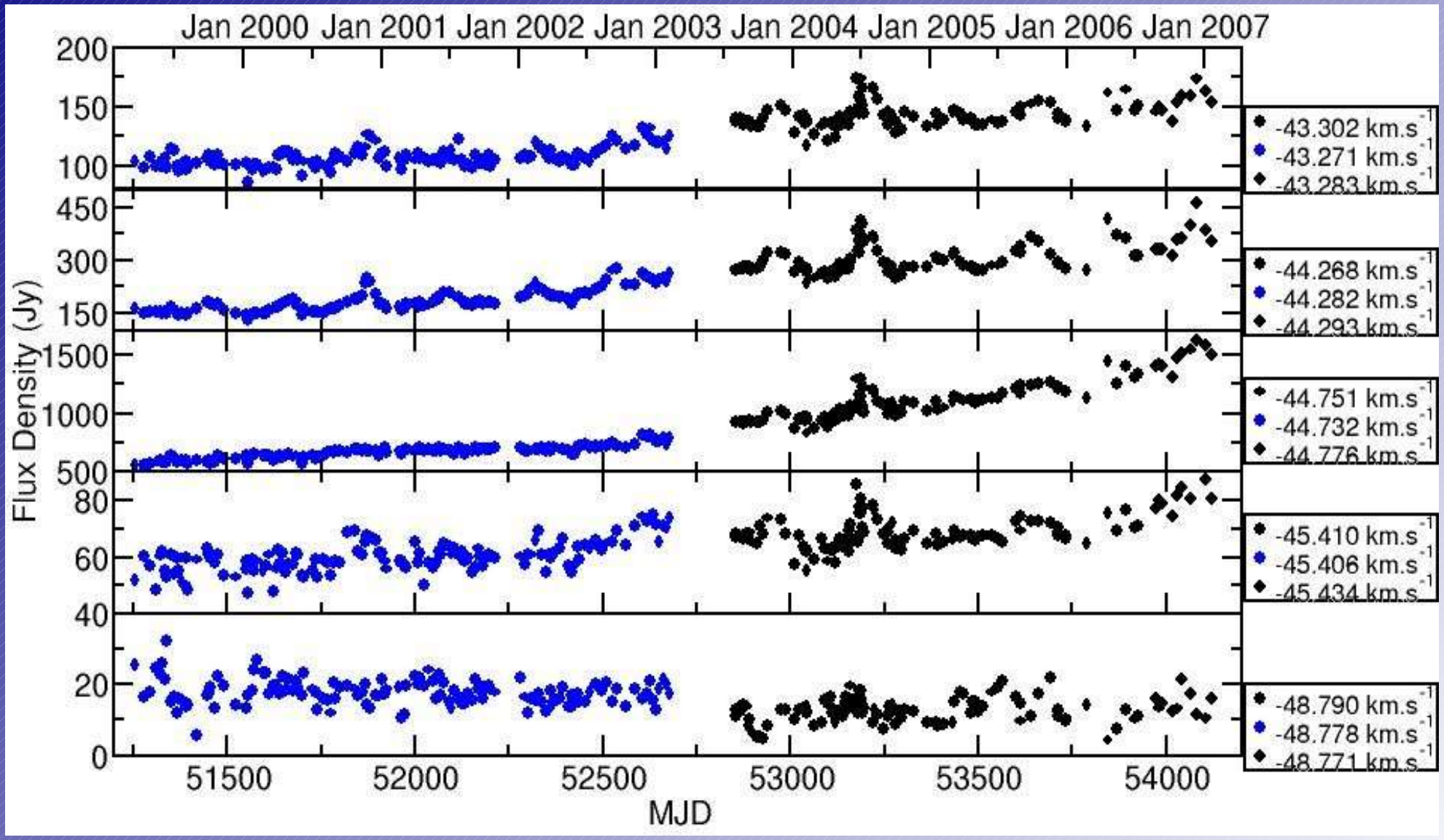
G331.13-0.24: Sinusoid fits, P=504d



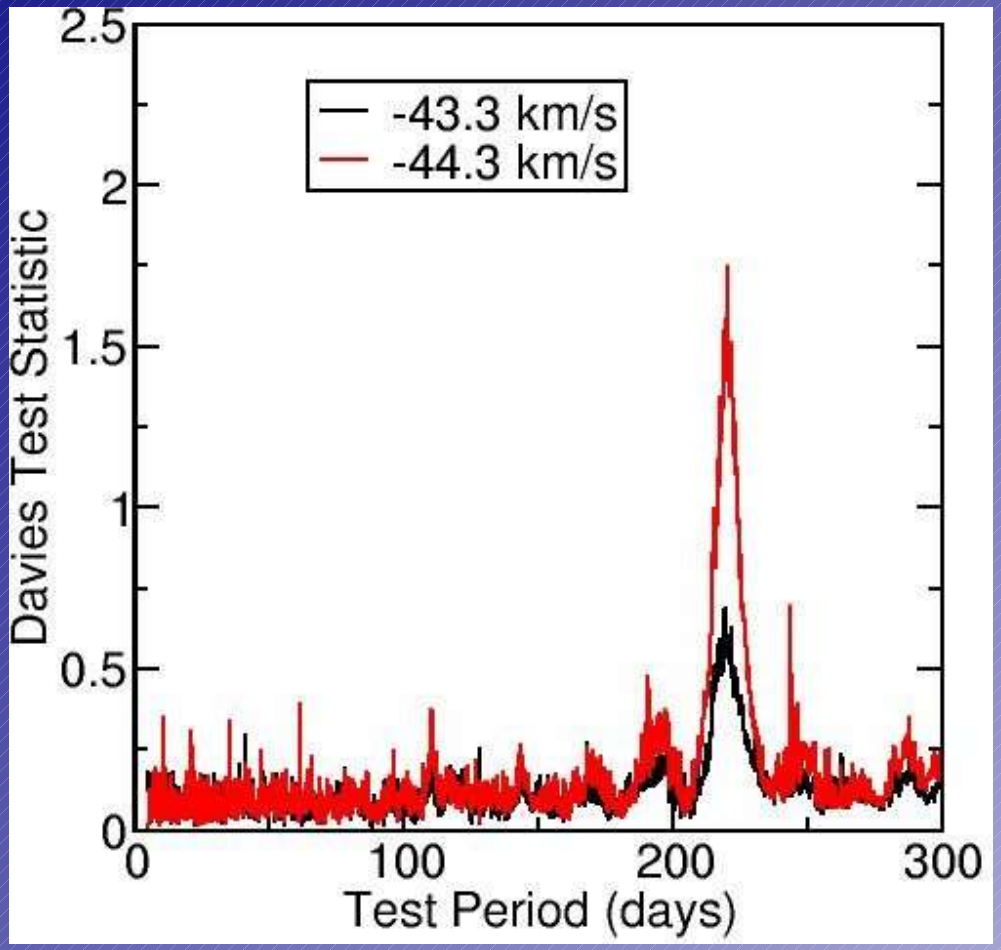
G328.24-0.55: Range of variation

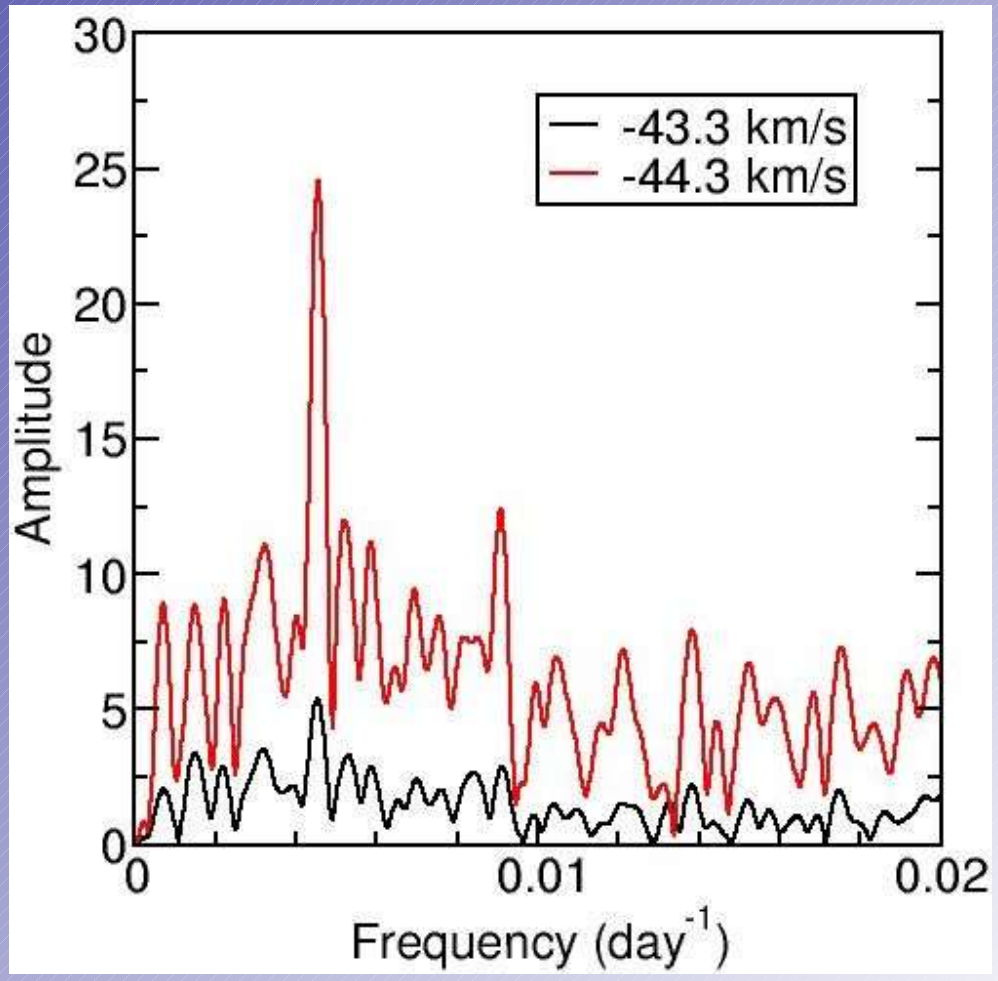


G328.24-0.55: Time-series



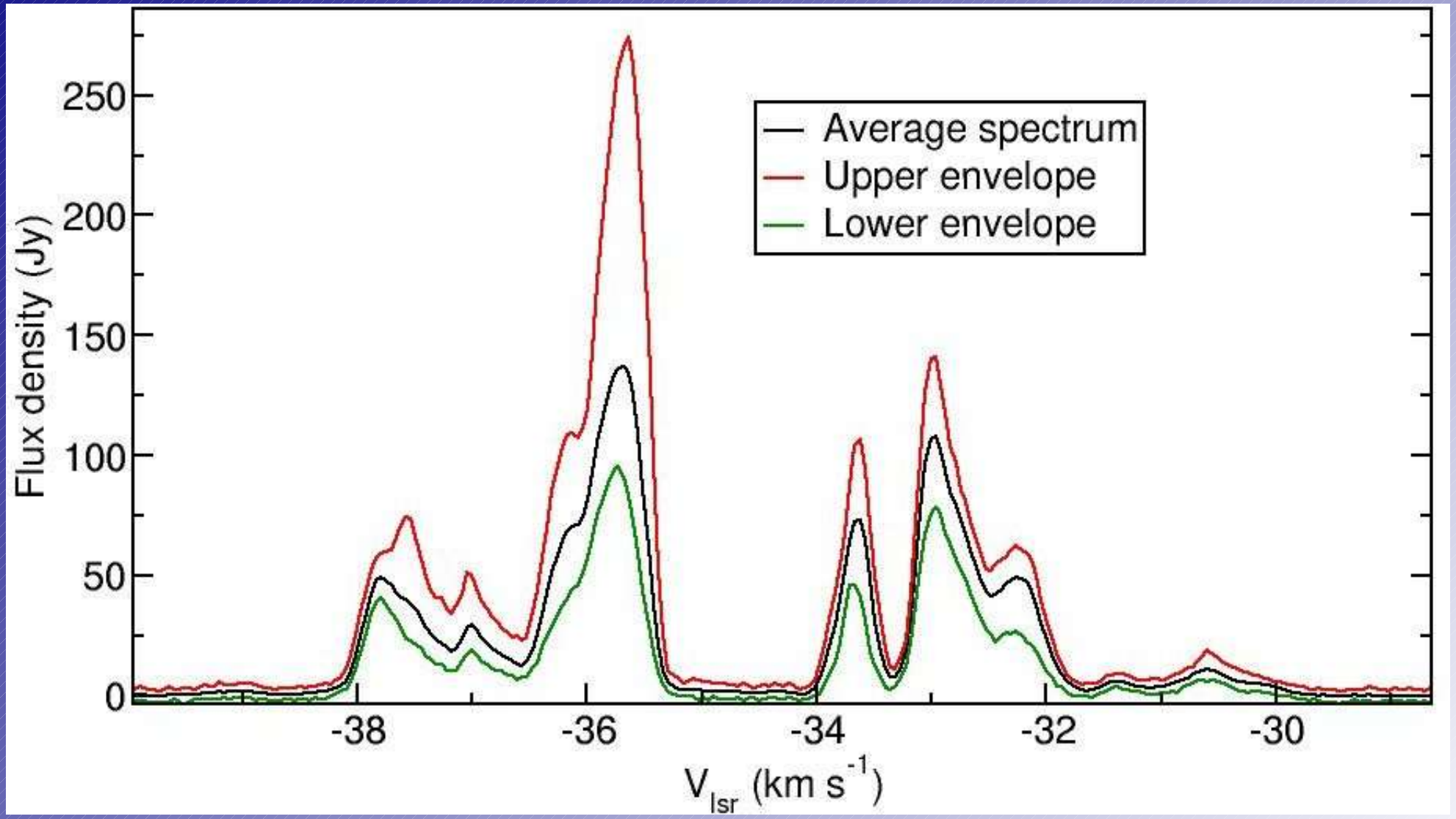
G328.24-0.55: Epoch-folding & Fourier Periodograms



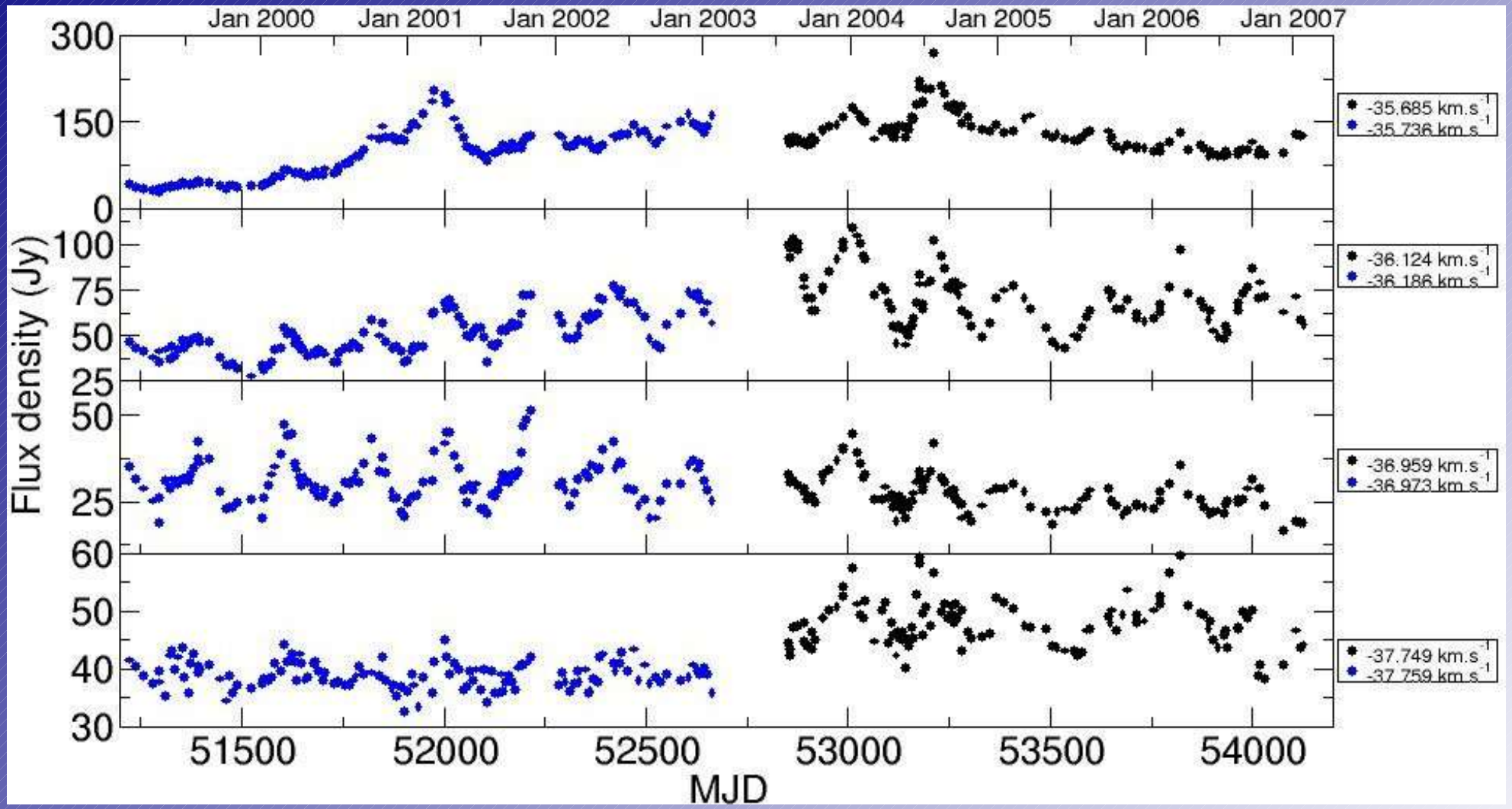


P = 220 days

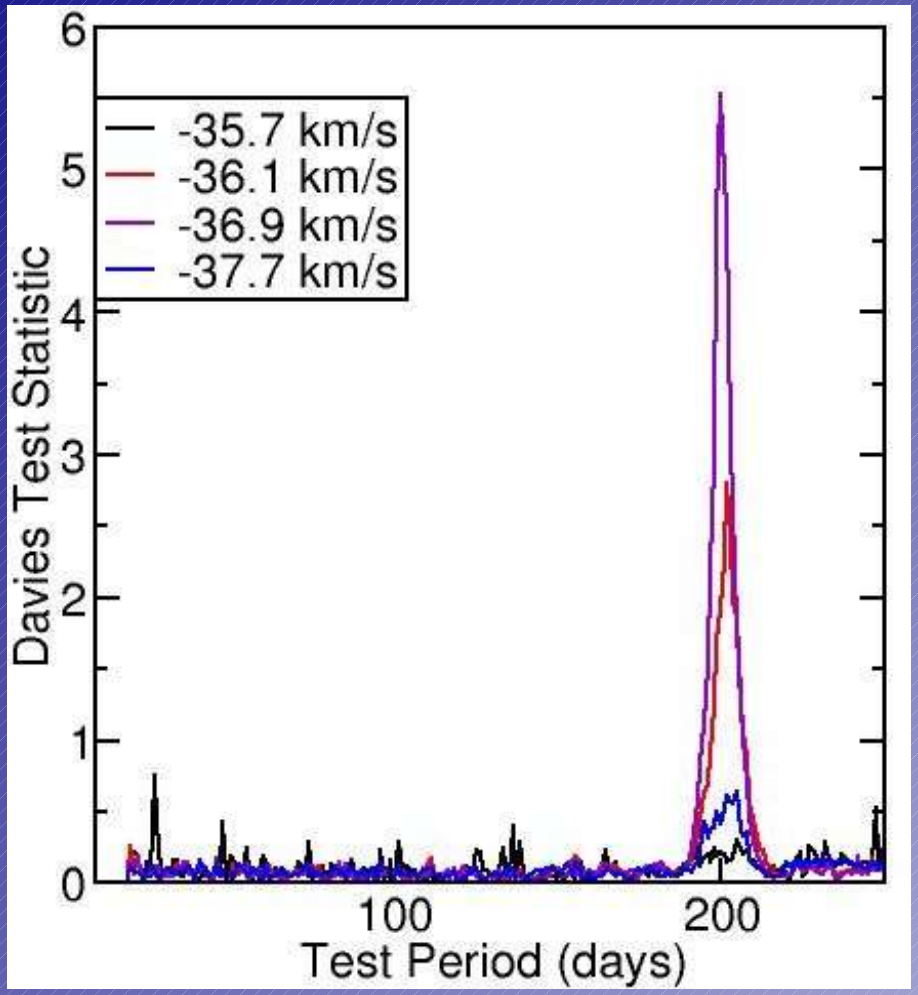
G339.62-0.12: Range of variation

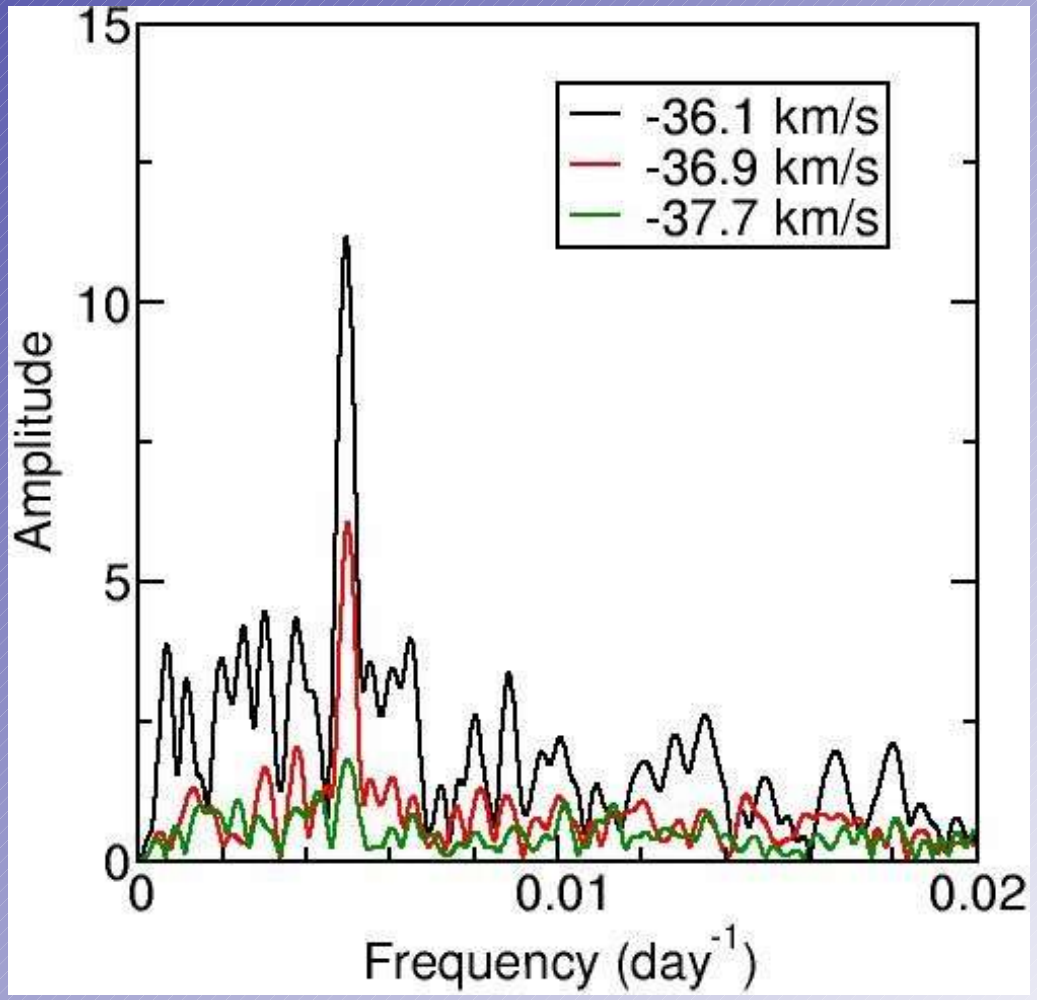


G339.62-0.12: Time-series



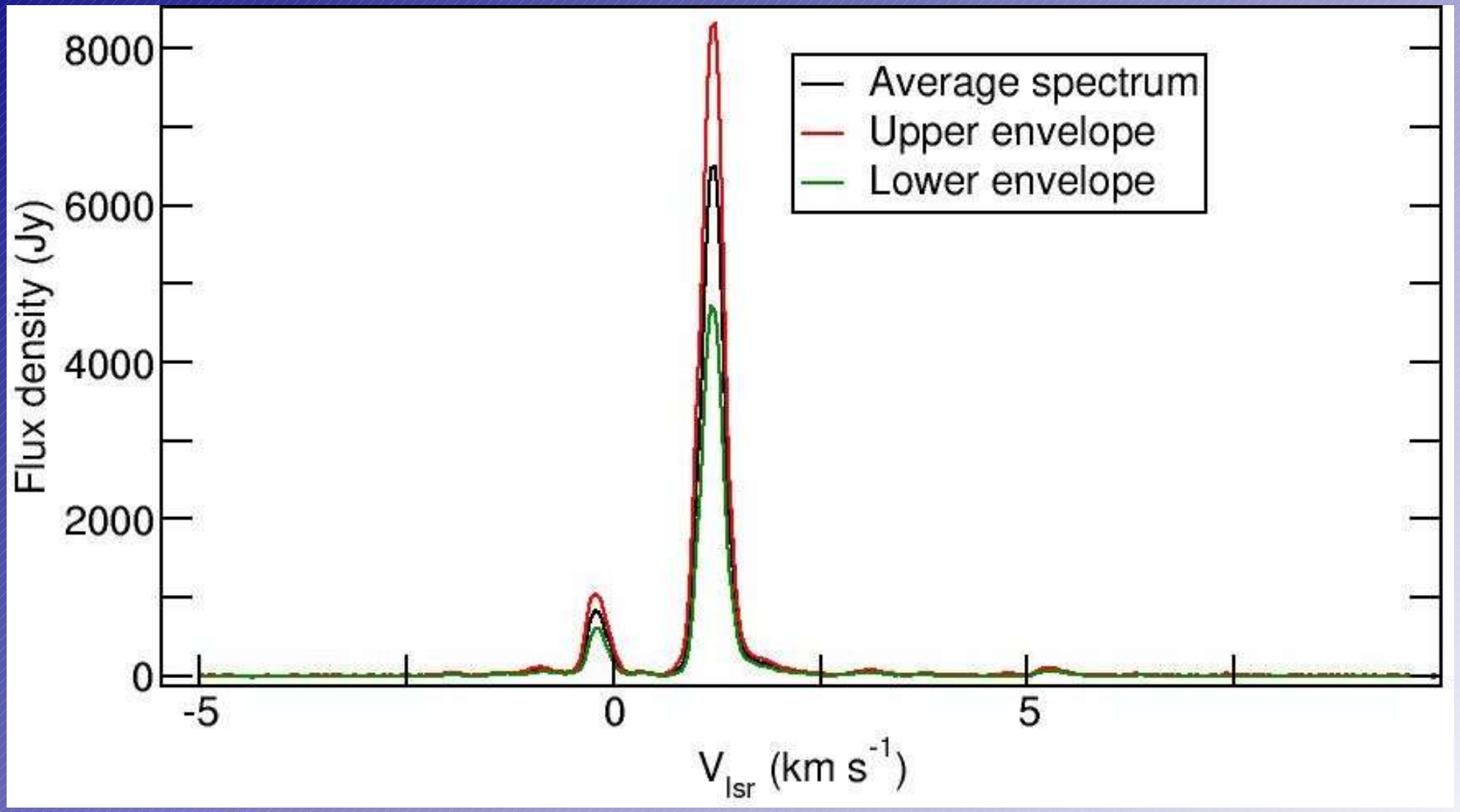
G339.62-0.12: Epoch-folding & Fourier periodograms



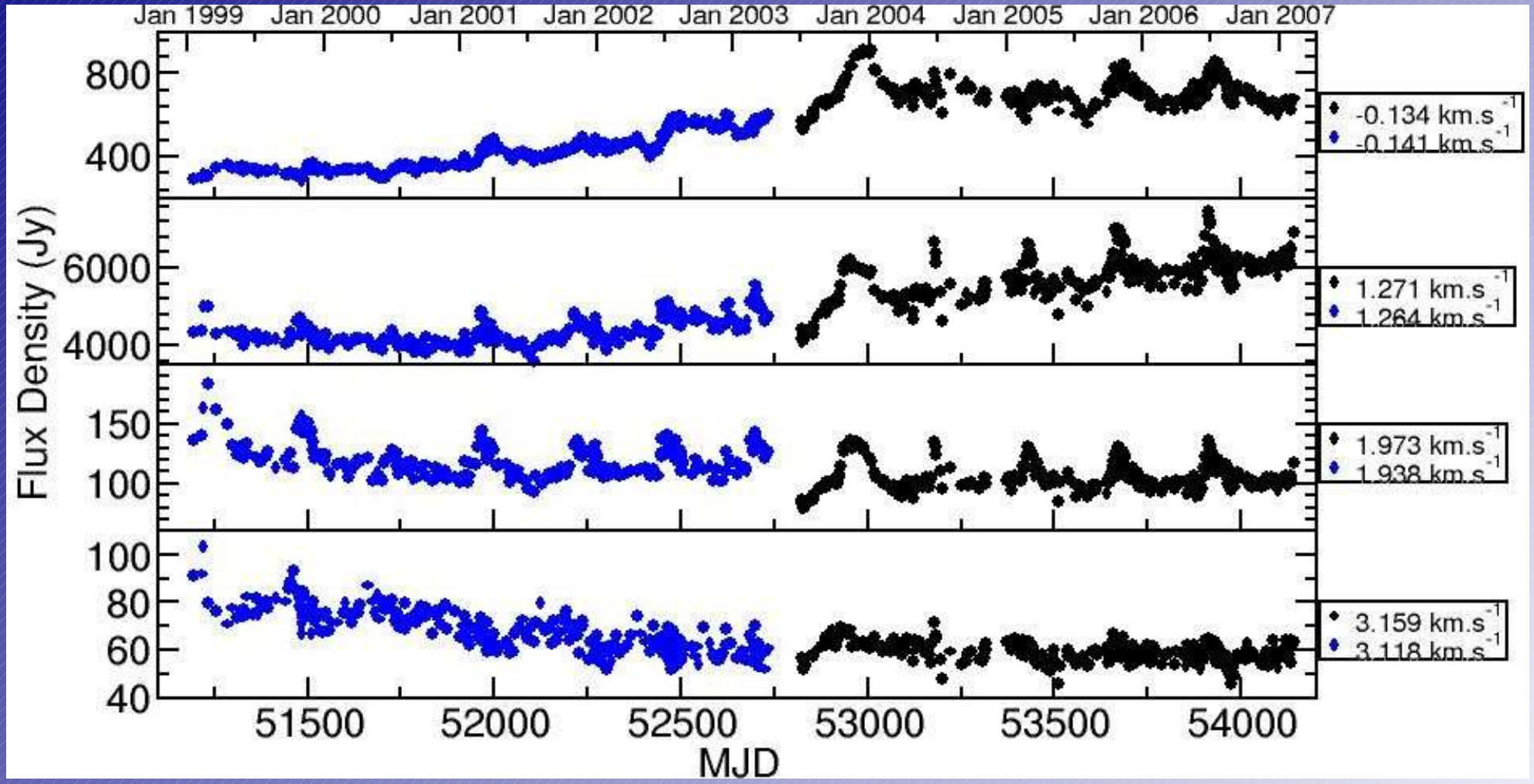


P = 201 days

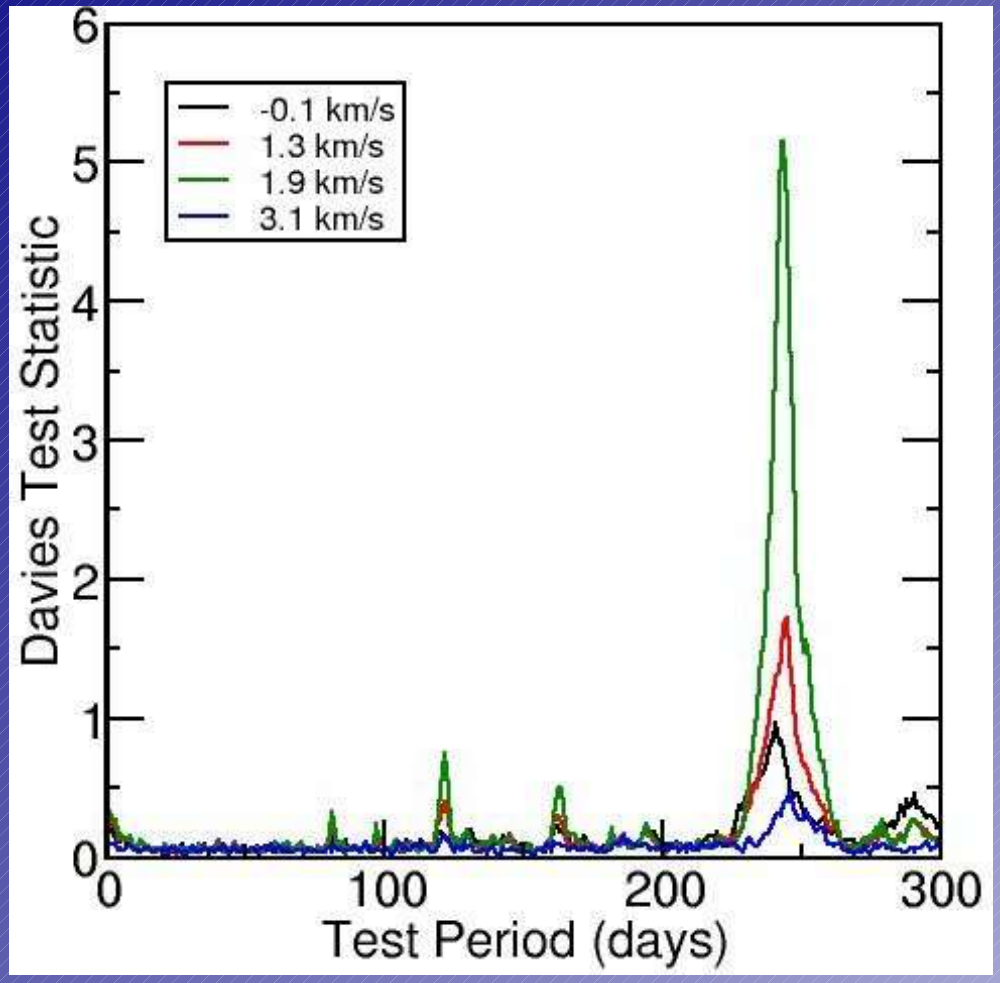
G9.62+0.20: Range of variation

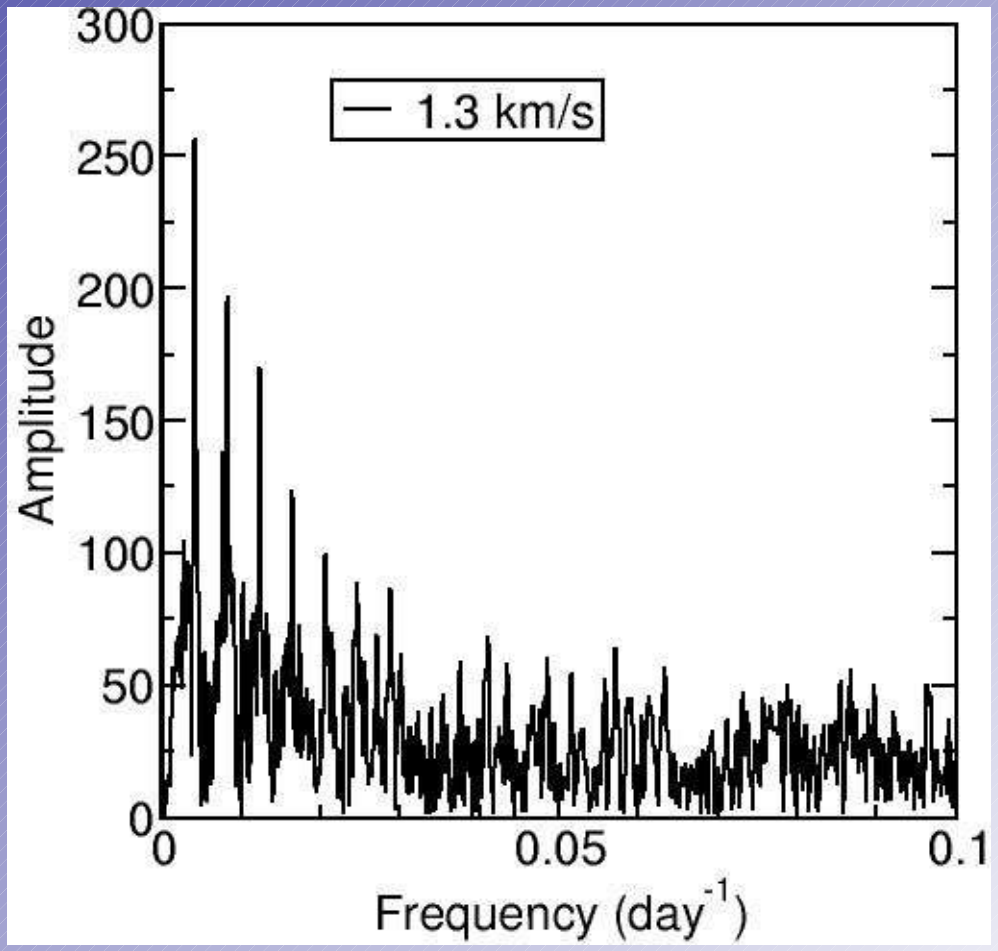


G9.62+0.20: Time-series



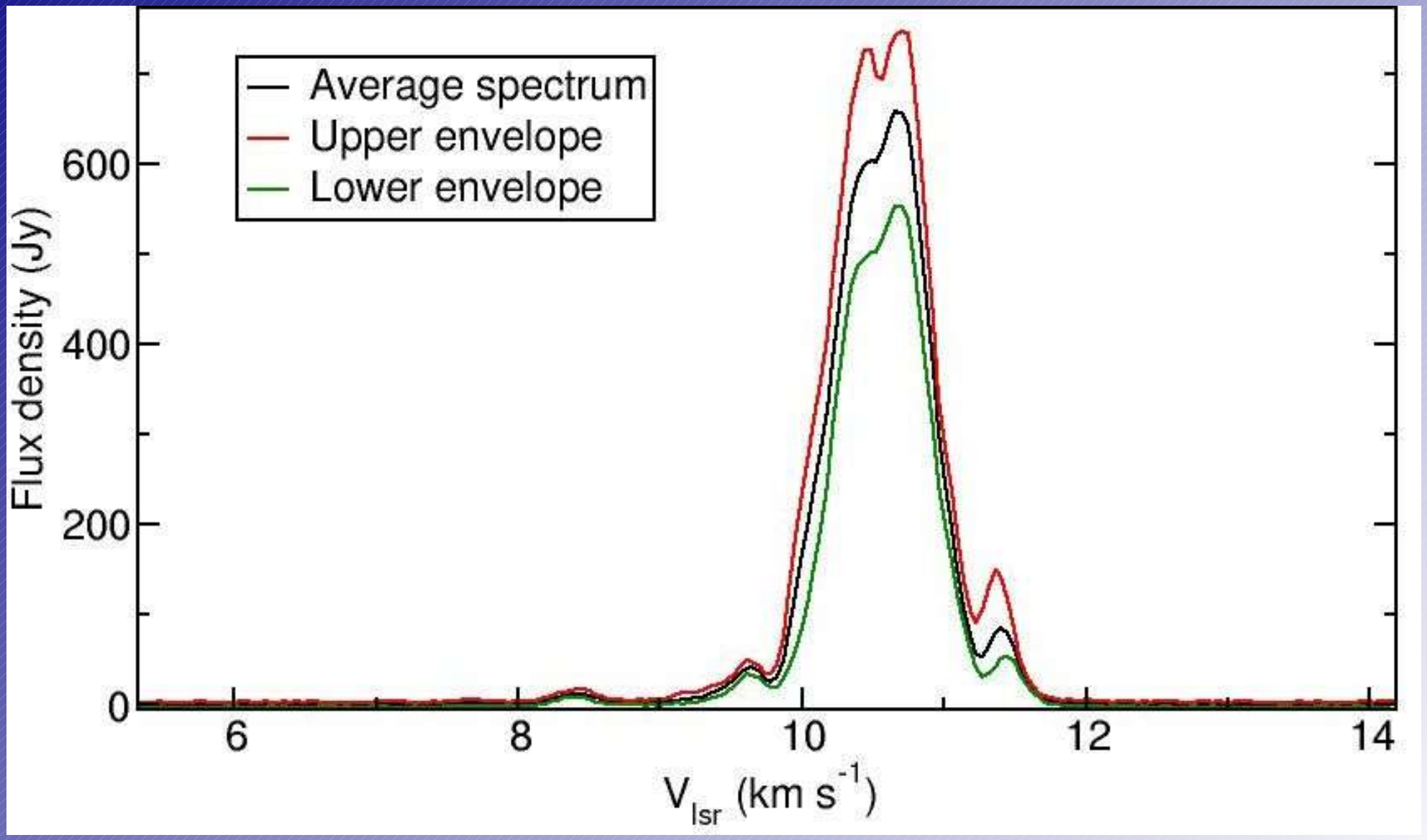
G9.62+0.20: Epoch-folding & Fourier periodograms



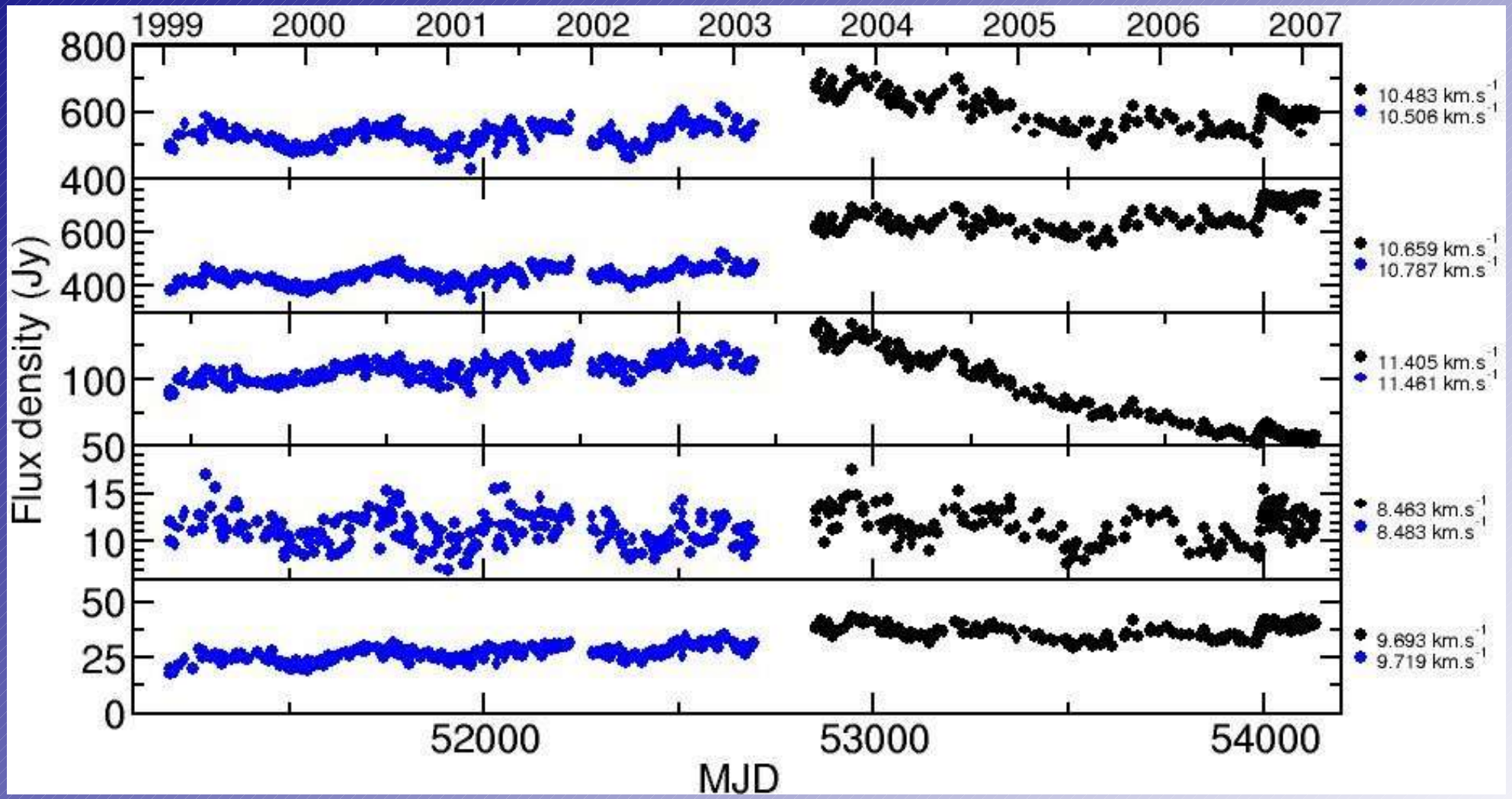


P = 244 days

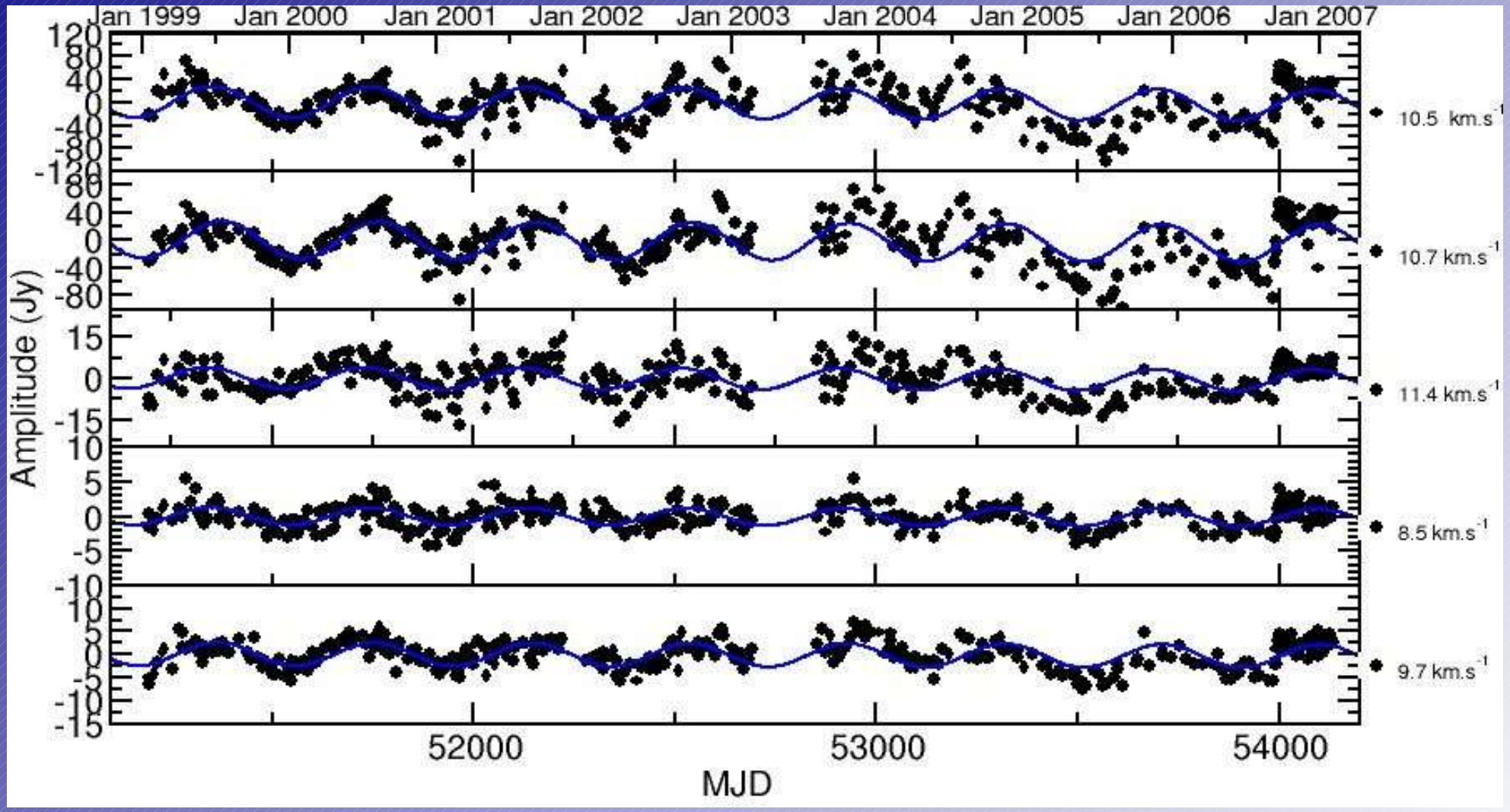
G188.95+0.89: Range of variation



G188.95+0.89: Time-series



G188.95+0.89: Sinusoidal fits with P=404 days



So, what happens during a flare?

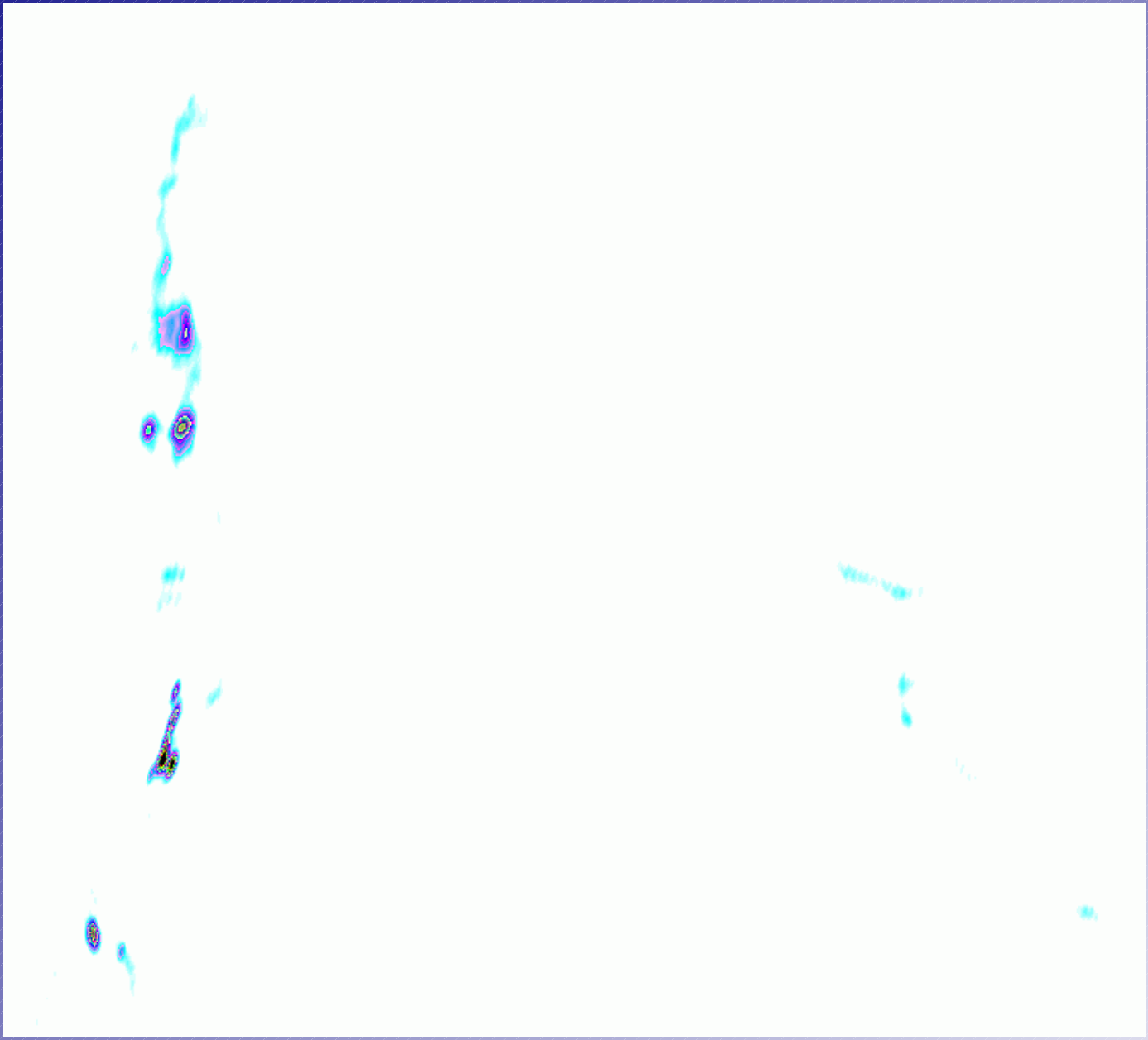
- Local effect or increase in incoming radiation?
- Do new spots appear?
- Is it a shock wave or some other disturbance passing through the masing regions?

VLBA observations of G9.62+0.20

- 7 observations during October – December 2001
- 6 hours integration time/observation
- 12.2 GHz

- Goedhart, Minier, Gaylard & van der Walt, 2005, MNRAS, 356, 839

G9.62+0.20 @ 12 GHz during a flare



Available on-line at MNRAS

Causes of periodicity

- Rotating hot spots? Rotation periods ~ days
- Stellar pulsations? Beta Cep periods < 1 day
- Binary system?
  - Periods imply orbital radii between ~ 1 – 10 AU
  - Solid angles of eclipsing binaries probably too small
  - Maybe one or both stars still have an accretion disk?
  - Accretion from companion – cataclysmic variables

Causes of periodicity, cont.

- Precessing jets?
- Accretion disks?
  - gravitational instabilities
  - condensations
  - periodic mass dumps (binary)
- ???

Summary

- 8 year time-series
- Six (five?) periodic maser candidates
- Period range: 133d – 504d
- Varying amplitudes & durations in flares but start times the same
- Behaviour may evolve over time

Outlook

- Lots of work to do!
- We need a time-dependent maser model
- Can we distinguish between possibilities of a binary system, precessing jet or accretion disk?
- Radiative transfer calculations – cause of disturbance at a few AU but masers at 100s – 1000s AU