LYRA observations and seismology of two oscillation modes in a single flare

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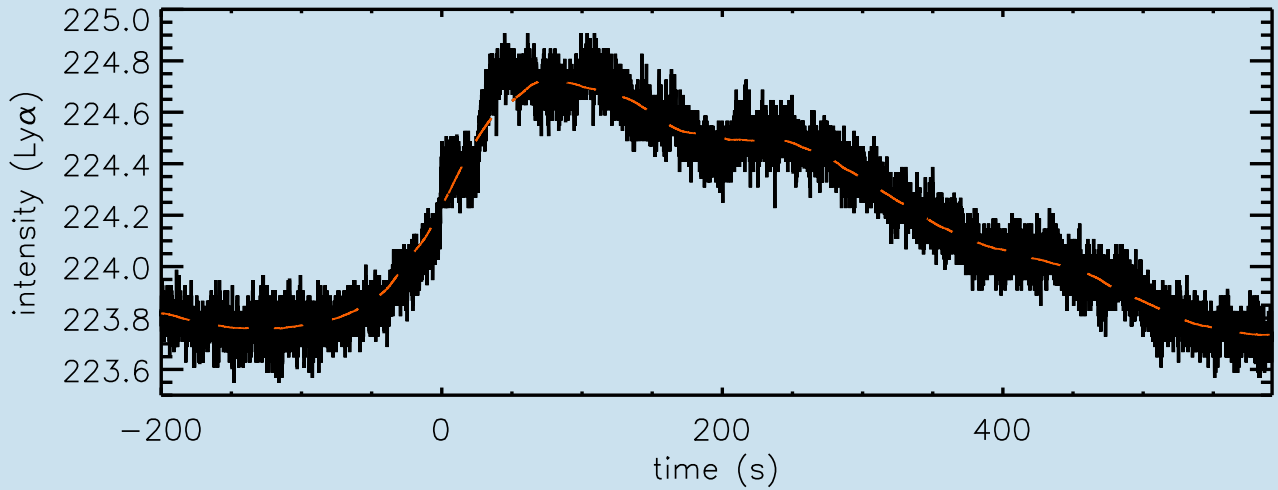
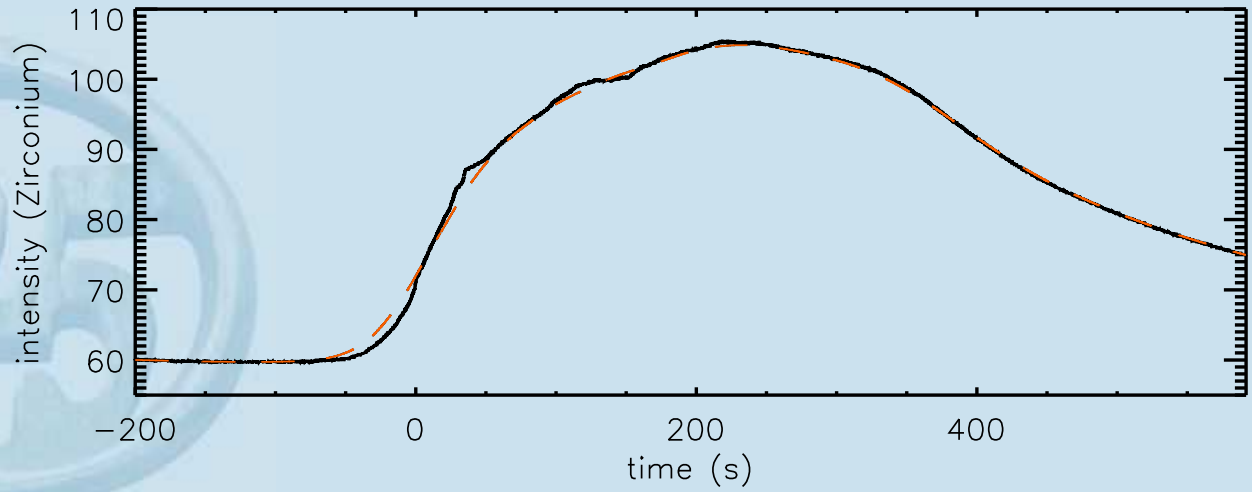
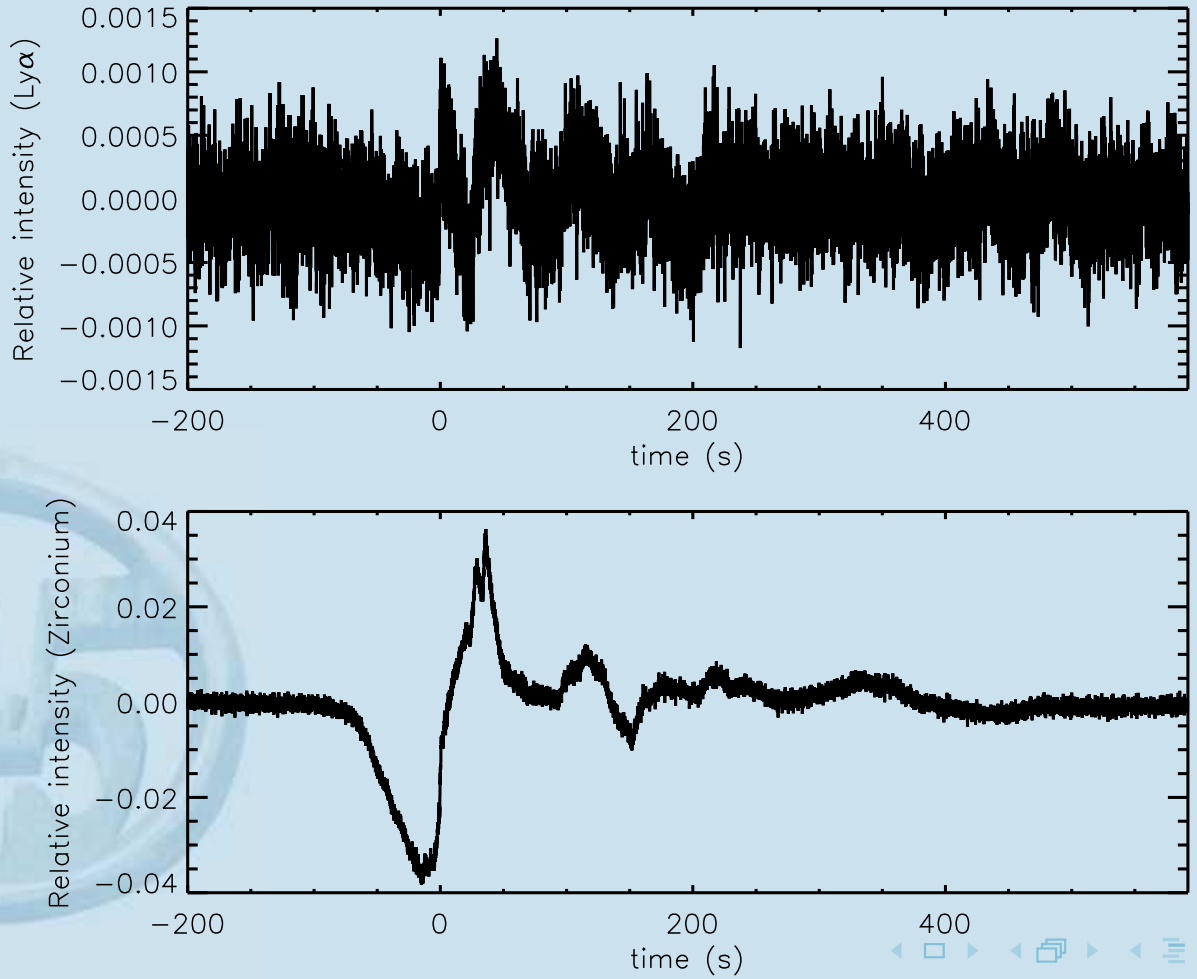
LYRA intensity data from 08 Feb 2010





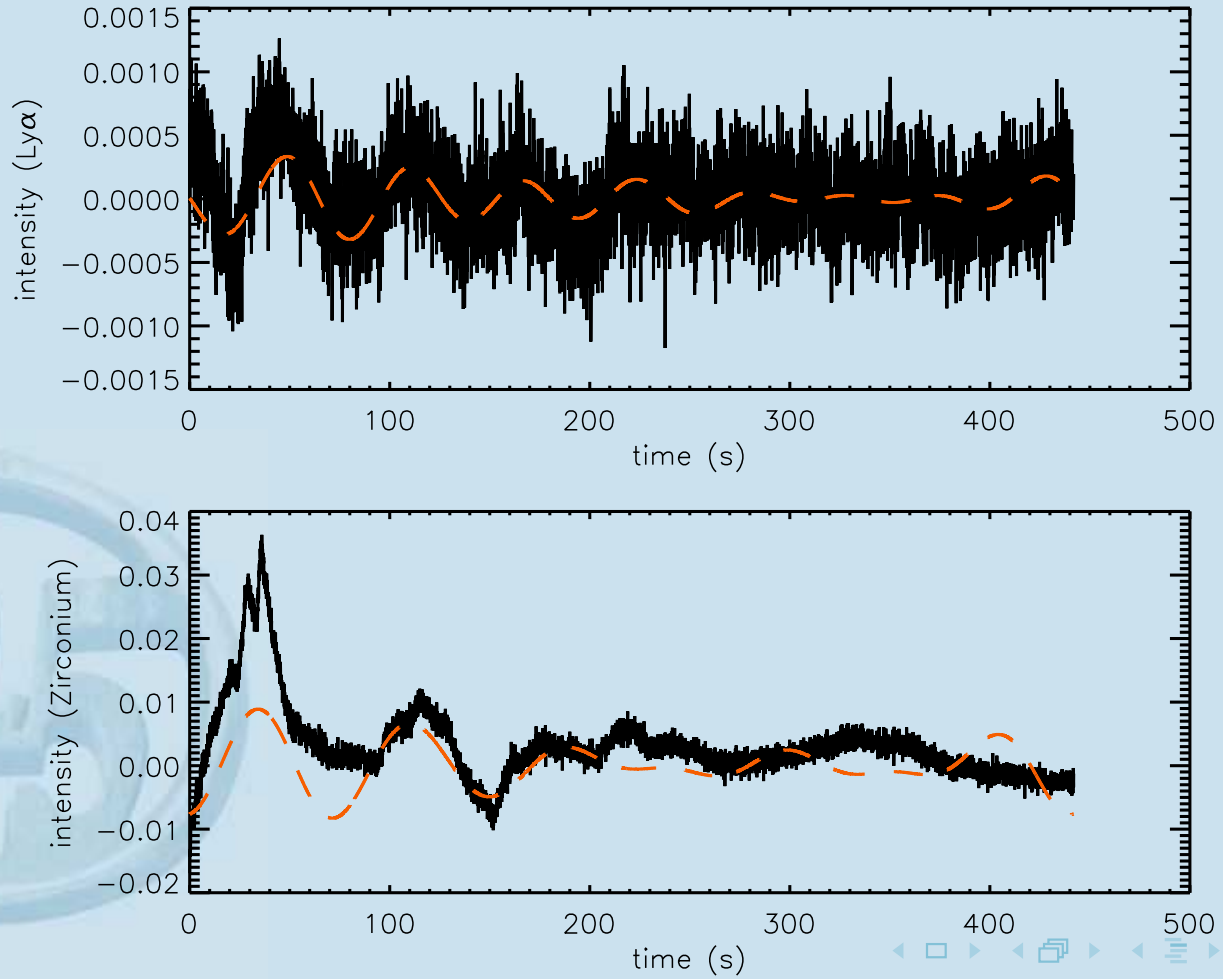
Relative intensity

After background subtraction (dashed line in previous graph), i.e. time signal smoothed by 1500 data points (75s).



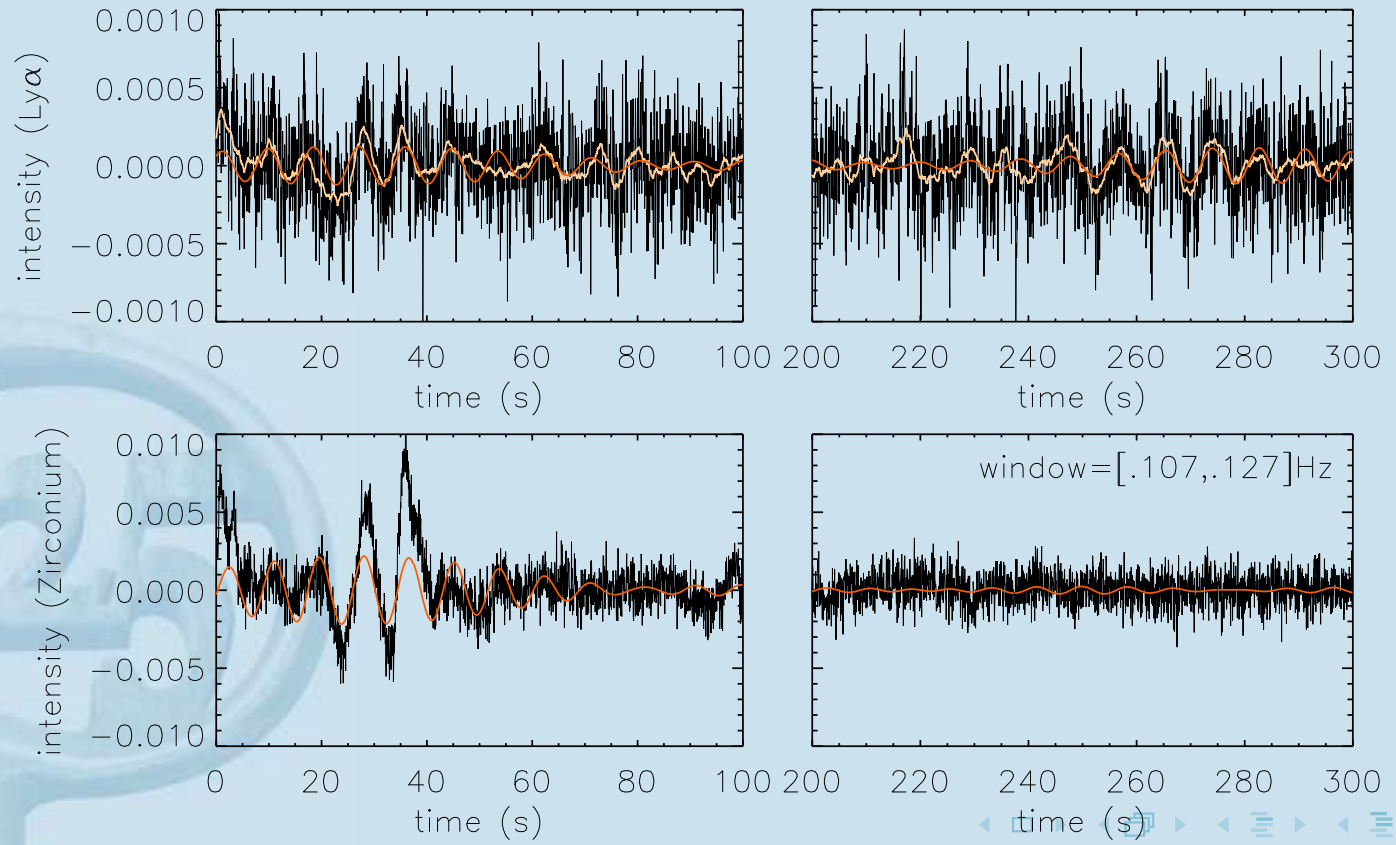
Filtered signals

Spectral peak at $P = 75\mathrm{s}$. Overplot filtered signal (top hat filter between 10 and 19mHz) in orange.



Fast(er) oscillations

Smooth with 12.5s (250 data points). Oscillations with period 8.5s are found. Filter signal (top hat filter between 107 and 127mHz). Obvious match with oscillations in Lyα, but the oscillations in Zr do not persist past the maximum of the flare.



Interpretation

Our interpretation of the observed periodicities:

- Periods are from standing oscillations in a single post-flare loop
- Short period = fast sausage mode
- Long period = slow sausage mode

Additional assumptions necessary for seismology:

- Oscillations live in *the same post-flare loop*.
- Consider a cylindrical model for the post-flare loop, where density, pressure and magnetic field are constant in the internal and external region (*Edwin & Roberts, 1983*).
- Post-flare loop is in *pressure balance*.

Phase speed relation

Relate the phase speeds and periods of the waves through the equation:

$$n_{\mathrm{s}} V_{\mathrm{s}} P_{\mathrm{s}} = n_{\mathrm{f}} V_{\mathrm{f}} P_{\mathrm{f}}$$

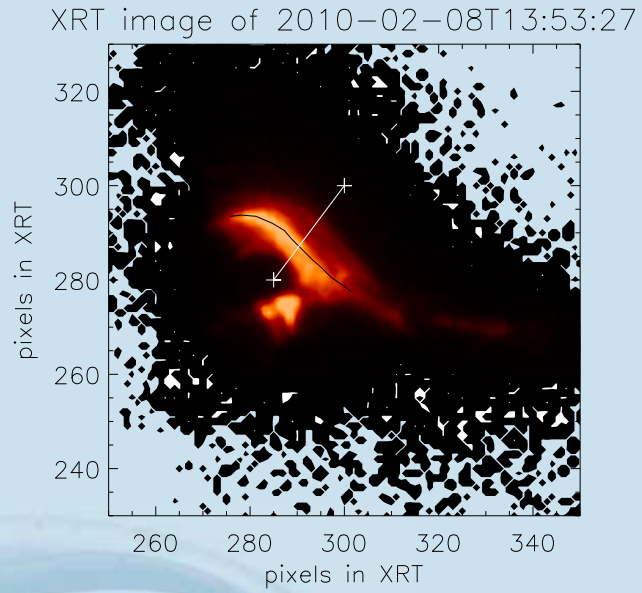
(Subscript $_{\mathrm{s}}$ ($_{\mathrm{f}}$) is for the slow (fast) mode. n is the number of nodes along the loop. V is the phase speed. P is the period.)

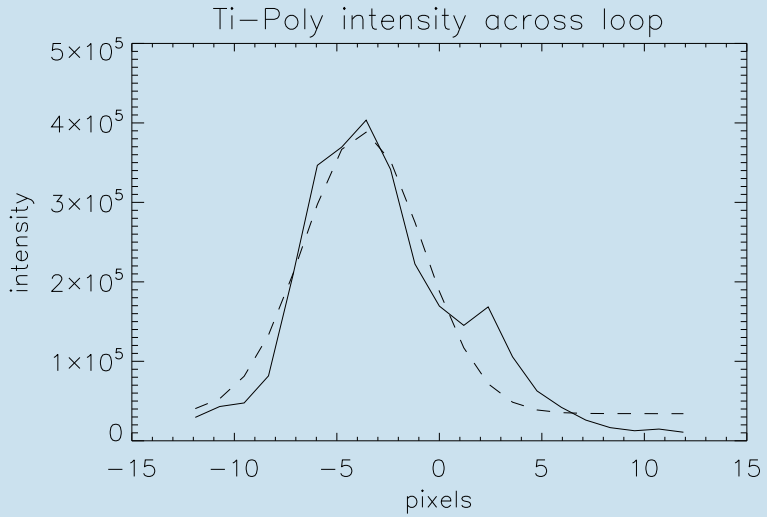
Rewrite as:

$$r = \frac{P_{\mathrm{s}}}{P_{\mathrm{f}}} = \frac{n_{\mathrm{f}} V_{\mathrm{f}}}{n_{\mathrm{s}} V_{\mathrm{s}}}$$

The observed value of $r = 8.8$.

XRT observations

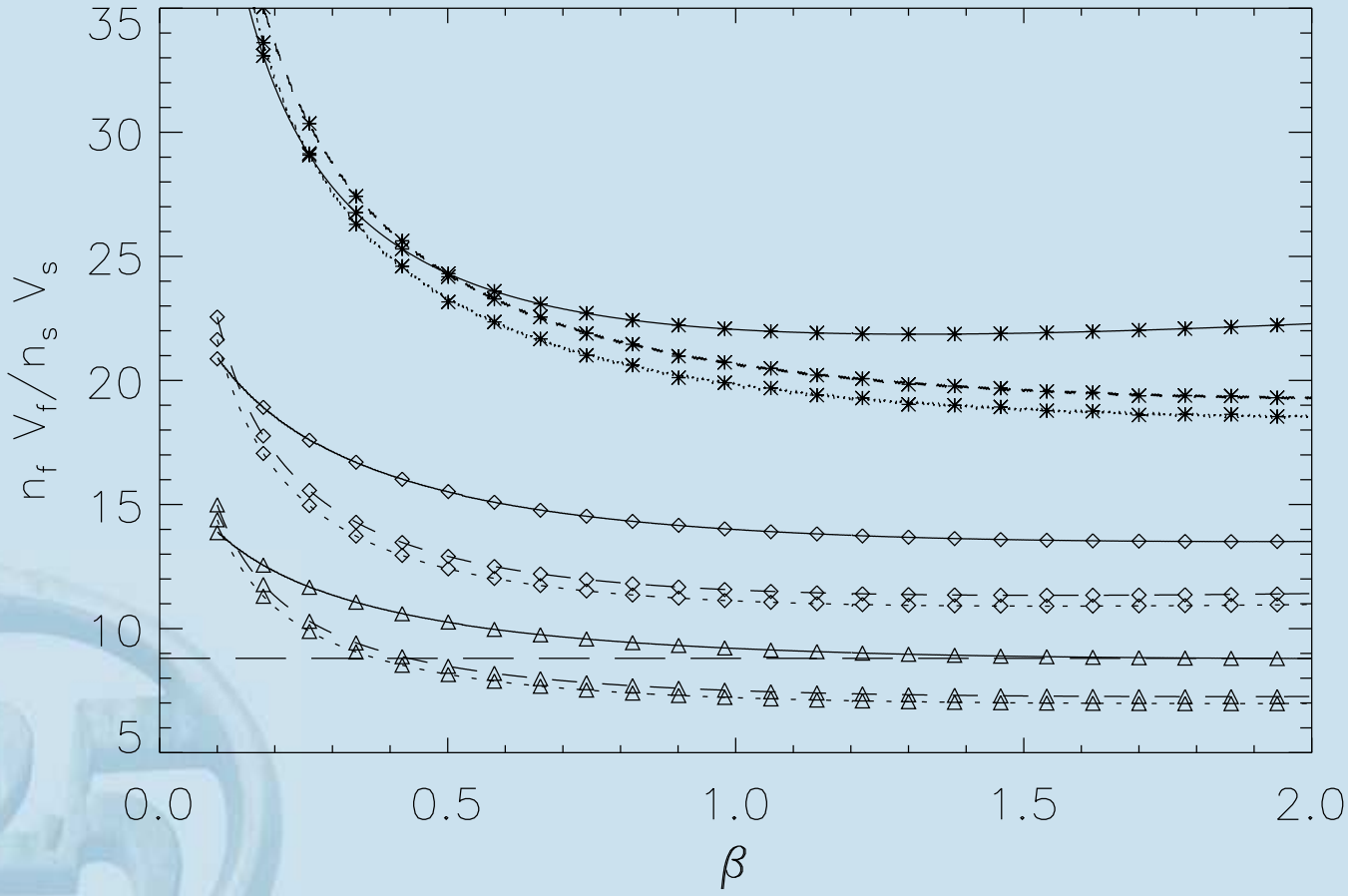




Aspect ratio: $(l/w)_{\mathrm{POS}} = 4.6$

Need to calculate the phase speed numerically!

Numerical results



Solid lines are for $n_{\rm f} = 1$, dotted for $n_{\rm f} = 2$, and dashed for $n_{\rm f} = 3$. Stars are for $n_{\rm s} = 1$, diamonds for $n_{\rm s} = 2$, and triangles for $n_{\rm s} = 3$.

Seismological results

- $n_\mathrm{f} V_\mathrm{f}$ is nearly constant.
- n_f only important for determining the minimum density contrast
  ($n_\mathrm{f} = \{1, 2, 3\} \rightarrow \{\zeta_{\mathrm{min},1} > 120, \zeta_{\mathrm{min},2} > 30, \zeta_{\mathrm{min},3} > 14\}$)
- Observed value of r only reached for $n_\mathrm{s} \geq 3$.
- In that case, $\beta = .4$ for $n_\mathrm{f} = 2, 3$.

Conclusions

- LYRA observes pronounced MHD oscillations in a flare.
- Periods of 75s (throughout the flare in both channels), and 8.5s (throughout the flare in Lyα, rising phase only for Zr).
- Interpretation as slow standing mode, and fast sausage mode.
- Seismology using a basic cylindrical model for the flaring loop.
- Need (at least) 3rd harmonic of slow standing wave to reproduce the observed period ratio.
- Indications that fundamental fast sausage mode is unrealistic.
- Plasma-$\beta = .4$.

Operations

- Fast cadence needed (selling point for LYRA!)
- Noise is undesirable (cfr. Lyα)
- Large Angle Rotations: OUCH. Can we stop these?
- Systematic study?
- Combine LYRA high cadence with EVE spectral data?