

The Torsional Oscillation and the Timing of the Solar Cycle

R. Howe¹, R. Komm², F. Hill², T.P. Larson³, J. Schou⁴, M.J. Thompson⁵

1 University of Birmingham 2 National Solar Observatory 3 Stanford University

4 Max Planck Institute 5 High Altitude Observatory, NCAR

Introduction

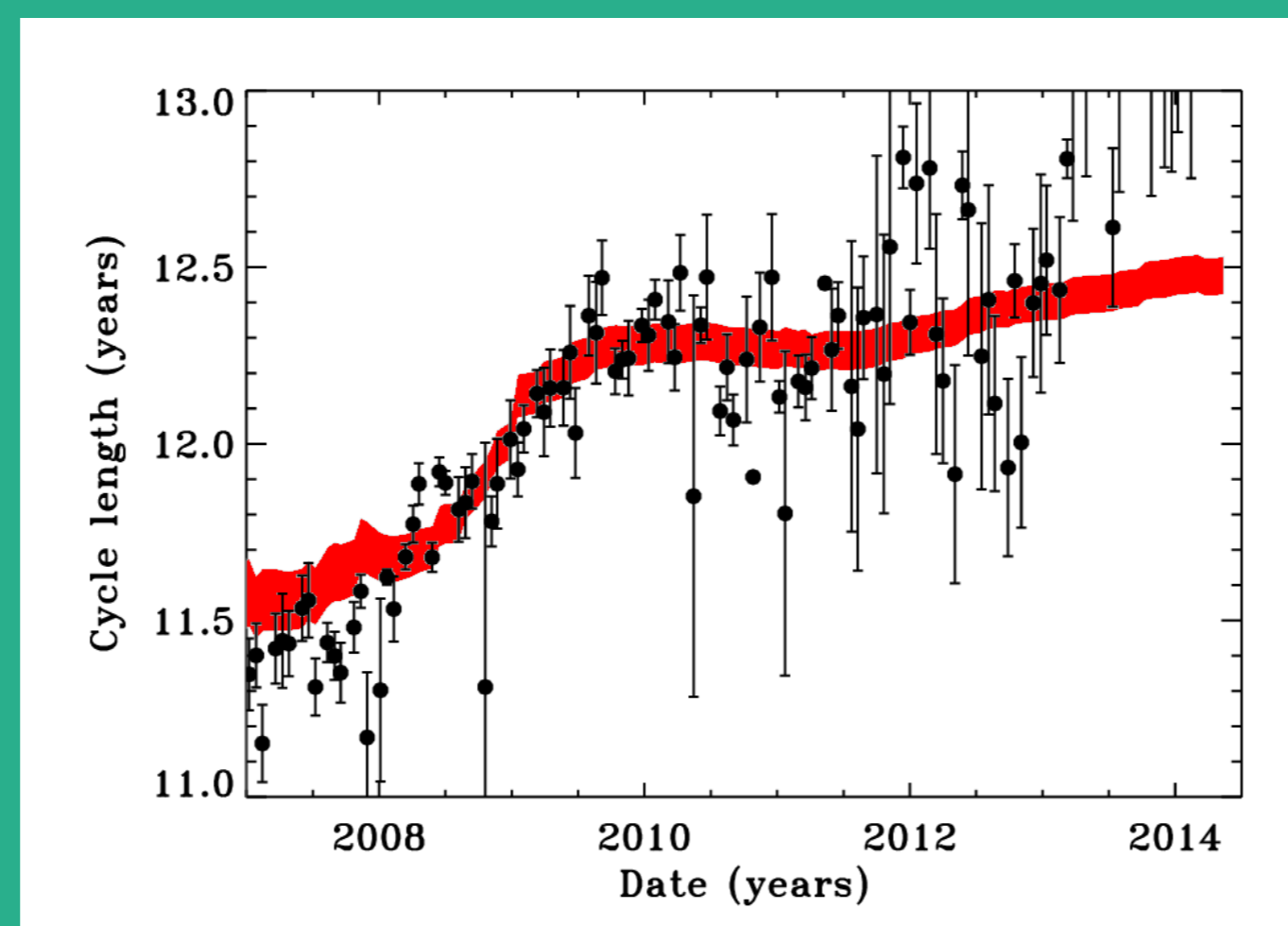
The pattern of migrating zonal flows known as the torsional oscillation is closely associated with the magnetic solar cycle, but can provide hints on the future evolution of the cycle before active regions appear. The flows have been monitored using global helioseismology since the Cycle 22/23 minimum. In this poster we consider the evolution of the flows and how they relate to the timing of the solar cycle, including the possible timing of Cycle 25

The Data

We have continuous medium-degree helioseismic data from the Global Oscillation Network Group (GONG) since May 1995, from the Michelson Doppler Imager (MDI) from May 1996 to April 2011, and from the Helioseismic and Magnetic Imager (HMI) from April 2010 to April 2014. For each 108-day set of rotational splitting data (GONG) or 72-day set of splitting coefficients (MDI, HMI) we perform 2D regularized least squares (RLS) rotation inversions. The zonal flow changes are then revealed by subtracting a temporal mean over the whole series.

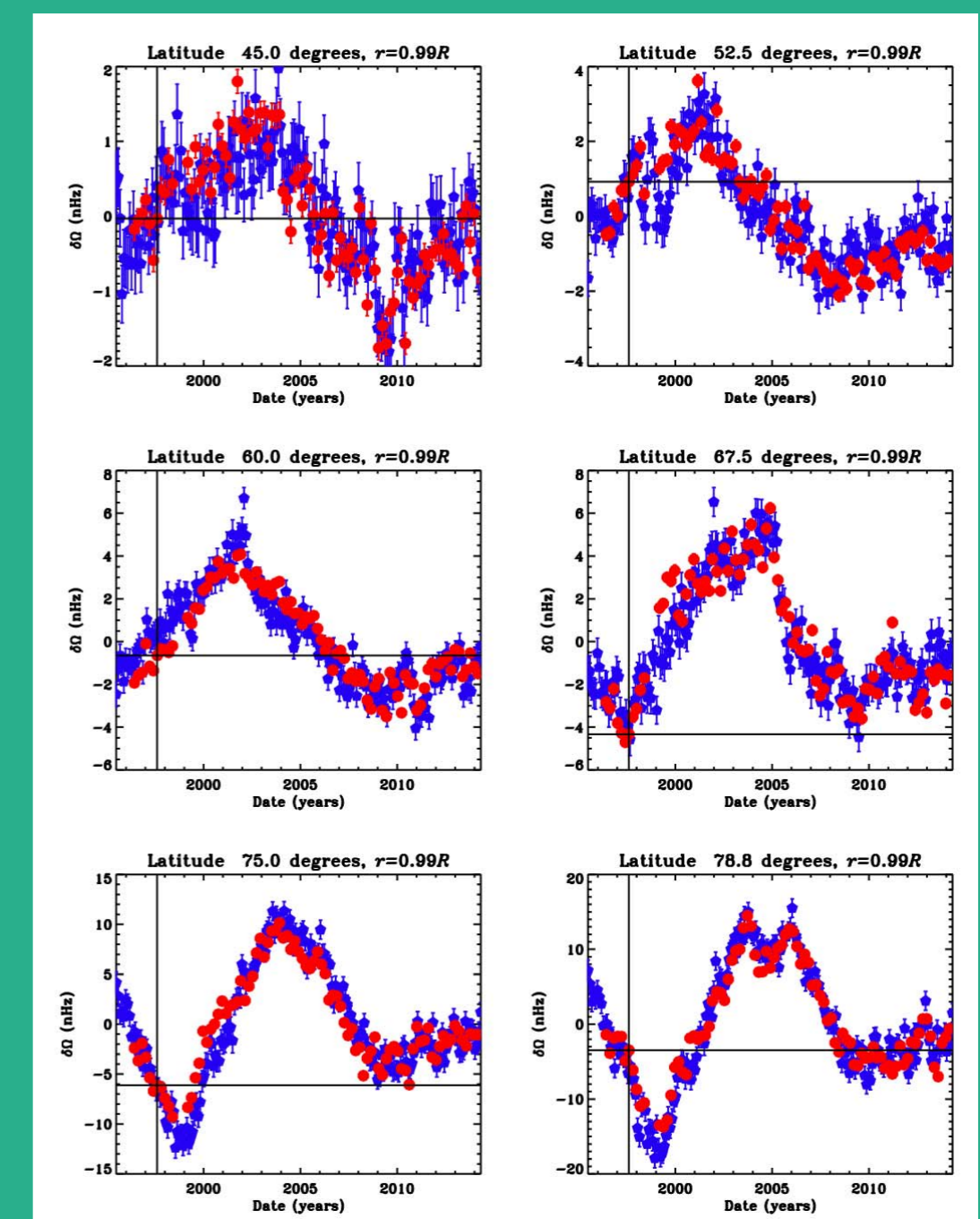
How Long is the Solar Cycle?

We estimate the length of the solar cycle from the flow pattern by fitting a sinusoid of ~ 11 years and its second harmonic (red curve) or by cross-correlation (symbols) using the data up to 45 degrees latitude. From 2007-2009 the apparent cycle length increased, before levelling off at 12.3 years after solar minimum. Recently there has been another slight increase to about 12.5 years. **This would imply a solar minimum in 2021 if the slowing stops.**



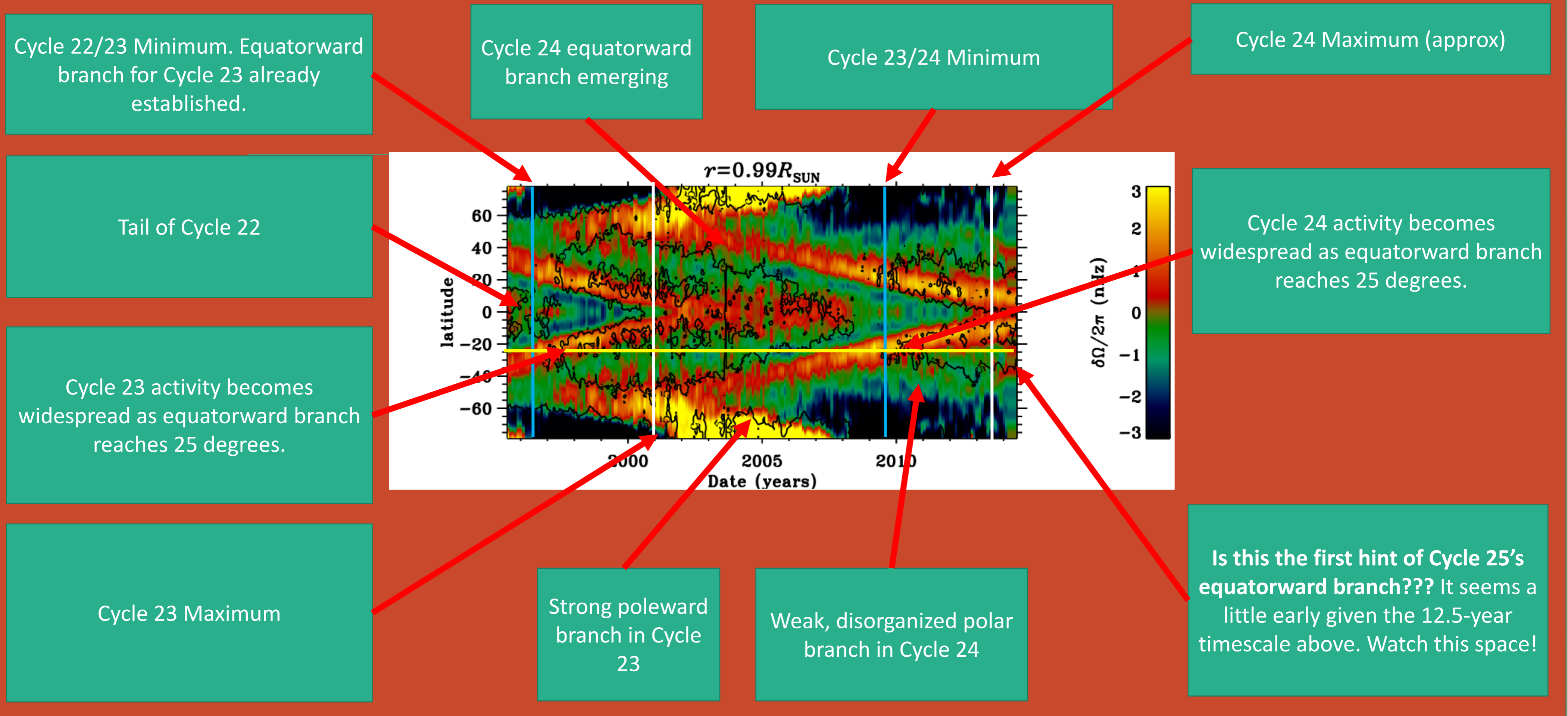
High-Latitude Variations

Rotation-rate residuals at $0.99R$ at high latitudes for GONG (blue) and MDI/HMI (red). Black lines indicate the previous solar minimum. Note **how little variation there is in Cycle 24 compared with Cycle 23.**



Nineteen Years, Four Cycles?

Below we show the zonal-flow residuals at $0.99R$ from RLS inversions of GONG, MDI, and HMI data from 1995 to 2014 and point out the major features as they relate to Cycles 22 to 25. Black contours show the 5G level of unsigned magnetic field strength from KPVT and SOLIS.



Acknowledgments

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For more details on the torsional oscillation and solar cycle timing, see: Howe *et al.* 2009, *ApJL* 701, L90
Howe *et al.* 2013, *ApJL* 767, L20