VARIABILITY OF THE SOLAR ROTATION RATE

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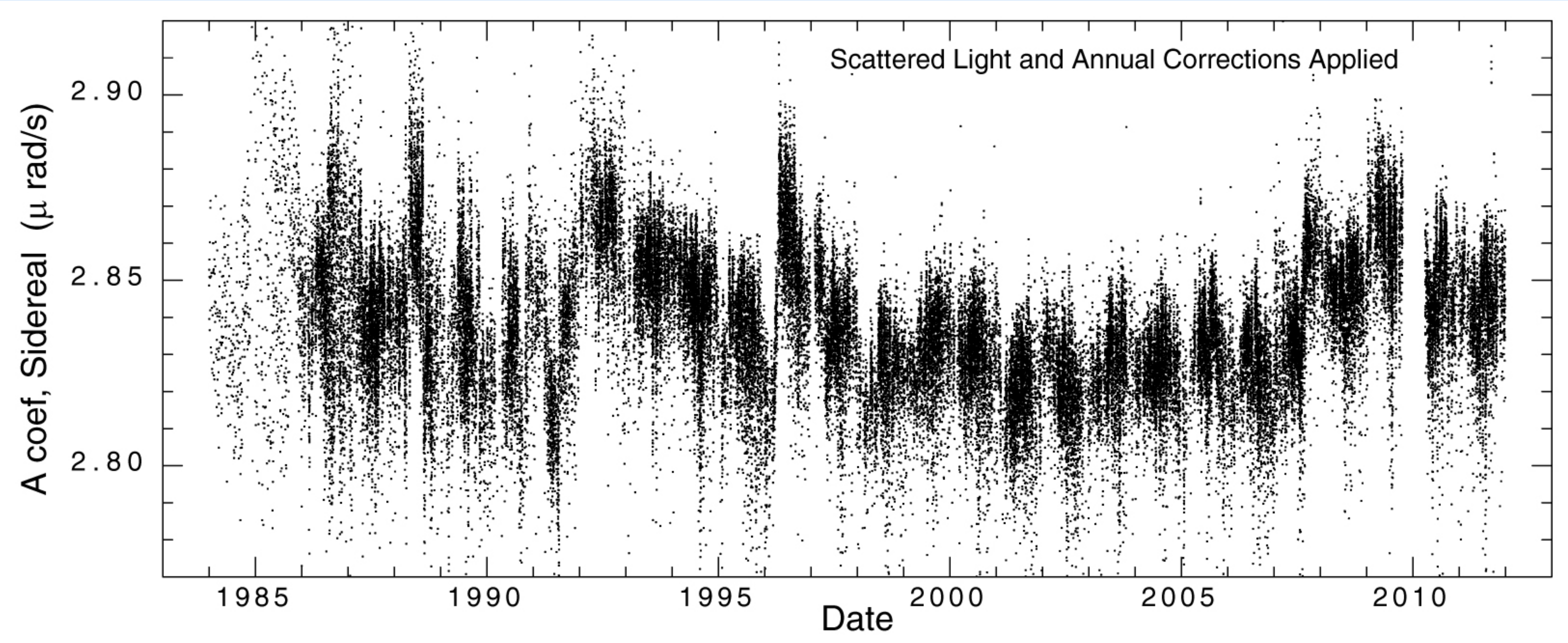
ABSTRACT

- The solar surface rotation rate can be measured by Doppler shifts of the plasma or by feature position shifts including the pattern rotation of helioseismic modes.
- We rely on surface Doppler shifts.
- The solar rotation rate depends on latitude and is normally represented by an equation of the form $\omega(\varphi) = A + B \sin^2(\varphi) + C \sin^4(\varphi)$ were φ is the latitude and ω is the rotation rate.
- We hold *B* and *C* fixed with values based on long term averages.
- We find that *A* undergoes significant changes with time.
- The 150-foot tower telescope began in 1996 to obtain simultaneous samples of ten blue/red pairs from four separate spectral lines.
- These pairs show different amplitudes of variation with times of variability being similar.
- Several non-solar mechanisms which might cause this variability have been ruled out.



25 m/s

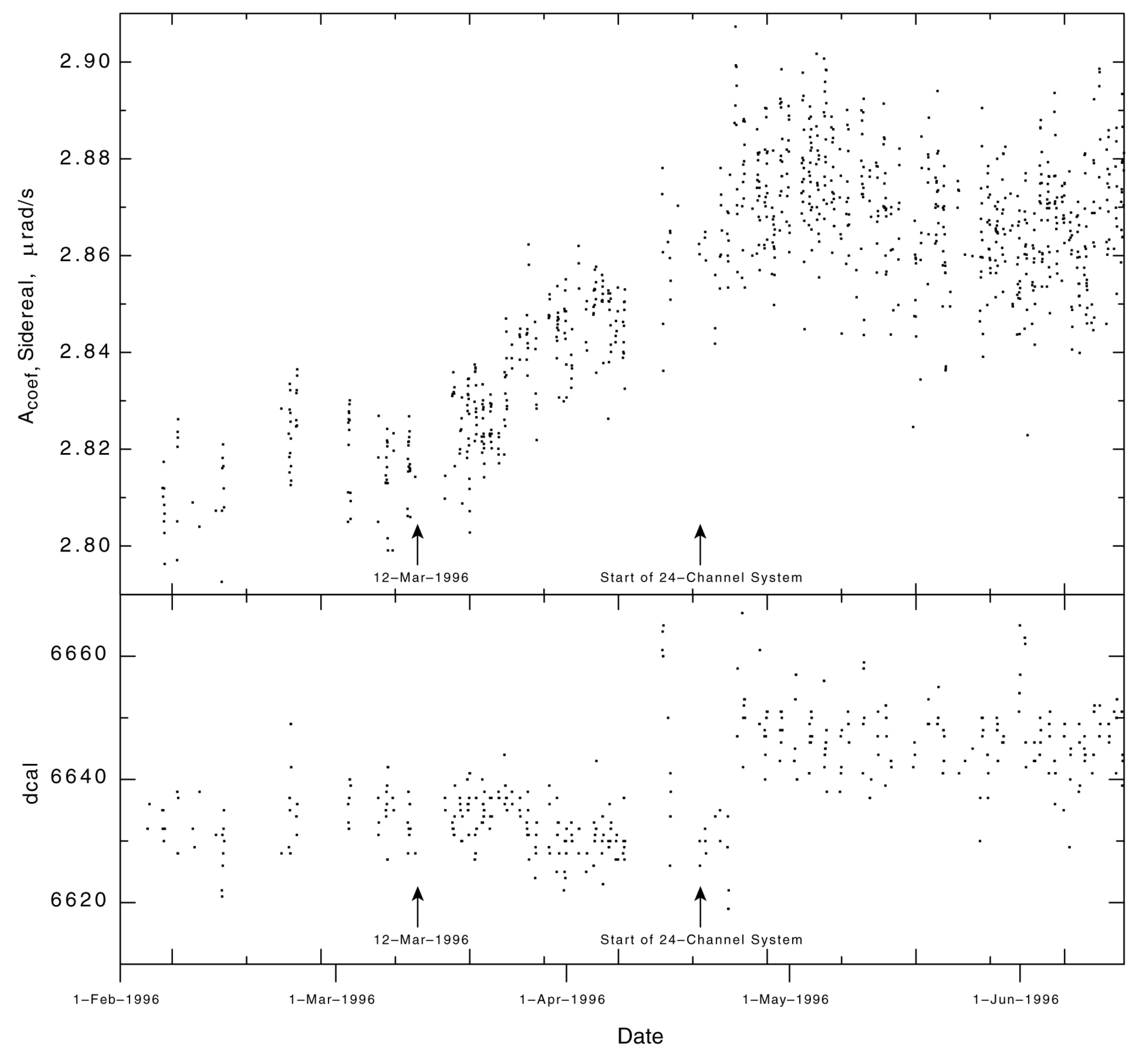
THIS FIGURE WILL BE PRESENTED AT THE AGU FALL MEETING 2020

NON-SOLAR POSSIBLE CAUSES

- 1. A changing calibration or magnetograph sensitivity.
- 2. Differential atmospheric refraction.
- 3. Terrestrial absorption lines – water vapor and other.
- 4. Fringes in the order separation filters.

A CHECK ON VARIABLE CALIBRATION

Instrument changes can alter the calibration.
The 24-channel system changed the fiber-optic image reformatters near the time of the 1996 variation.
The changes in *A* are not associated with the changes in the calibration coefficient, *dcal*.



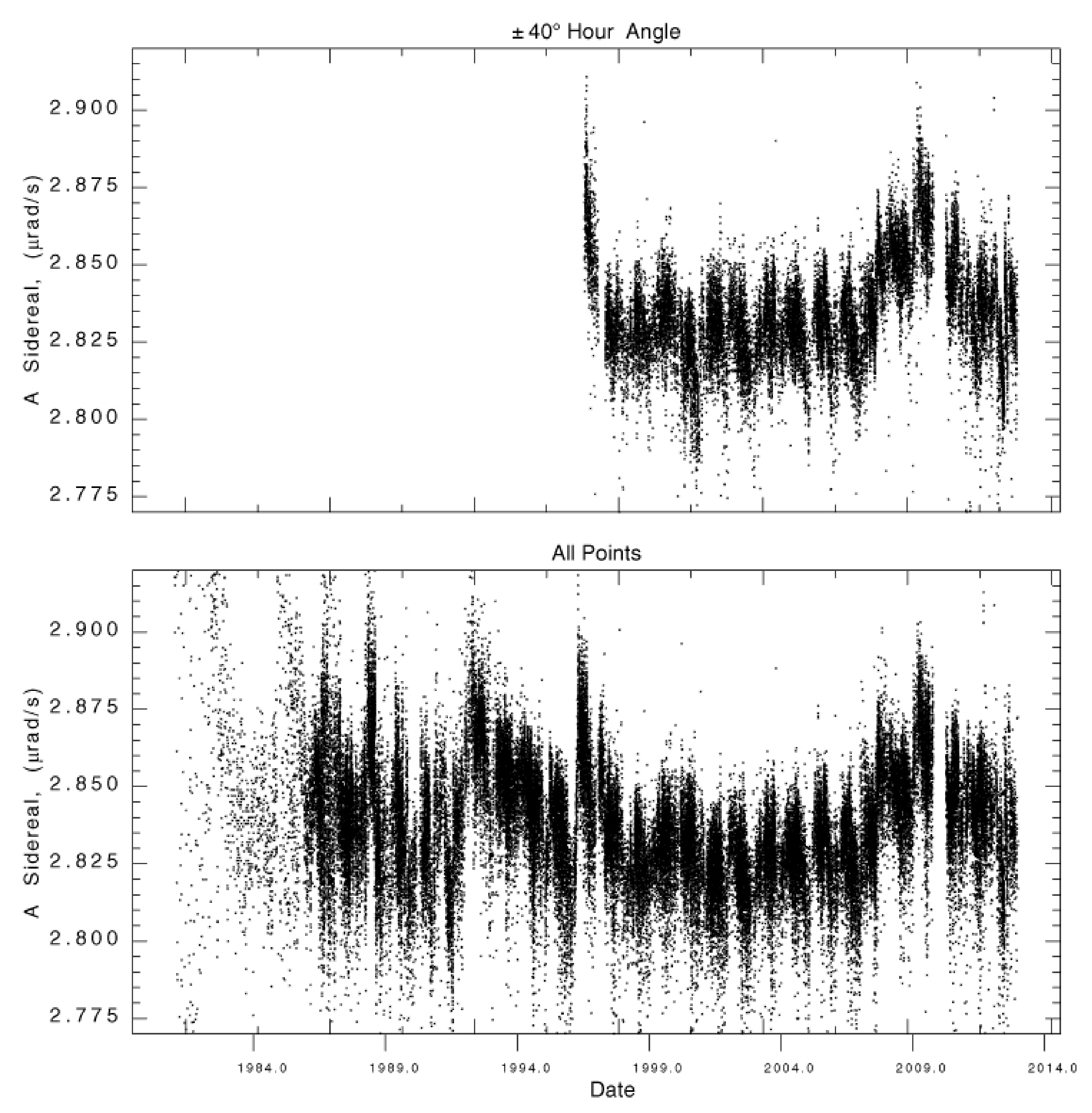
DOES THE SOLAR HOUR ANGLE MATTER?

There is less scatter.

There are a few places where the pattern is slightly different.

Basically the time of day for the observation is not a big factor.

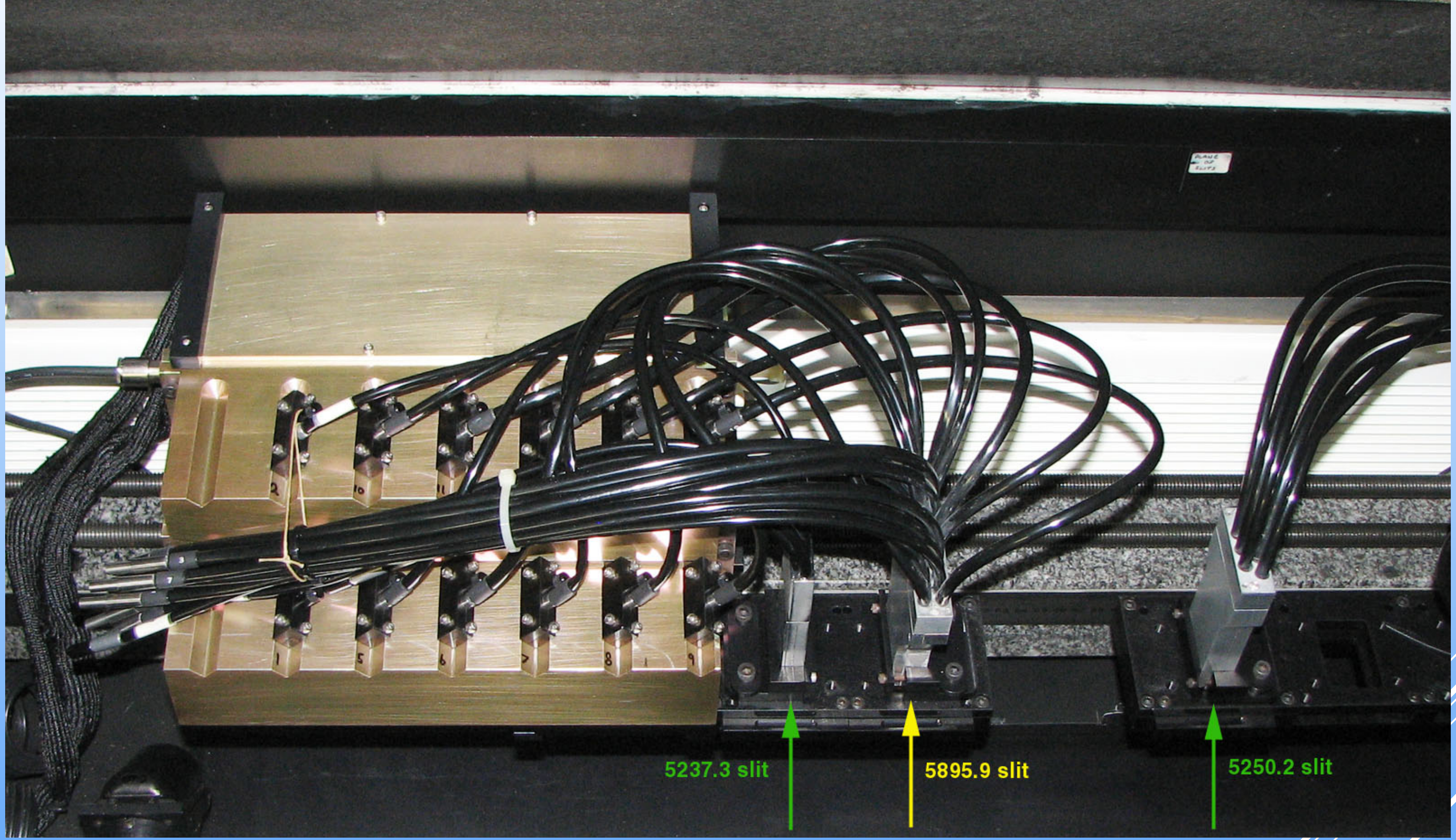
Pre 1982 data has a large scatter.



- Paired ports from four spectral lines are tracked with the Babcock magnetograph system at the 150-foot tower on Mt. Wilson.
- Fiber-optic image reformatters direct light from slices of the spectrum onto photomultiplier tubes whose output is digitized and recorded.
- Four assemblies are carried on two moveable stages which follow the movement of one of the lines while intensities on the red and blue wings of the other lines provide a measurement of the position of those wings.
- The stage on the red side carries the assemblies for λ5250Å and λ6768Å while the blue side carries the assemblies for λ5238Å and λ5896Å.
- Magnetized pixels and symmetrically placed pixels on the other side of the central meridian are dropped.

THE 24-CHANNEL SYSTEM
HOW DO OTHER SPECTRAL LINES RESPOND?

Each downward pointing assembly is an image reformatter. The face is a series of narrow rectangles that sample the dispersed light from the spectrograph. Each rectangle is converted to a circular cylinder which shines its light onto a photomultiplier tube.



ONE OF THE STAGES, BLUE SIDE

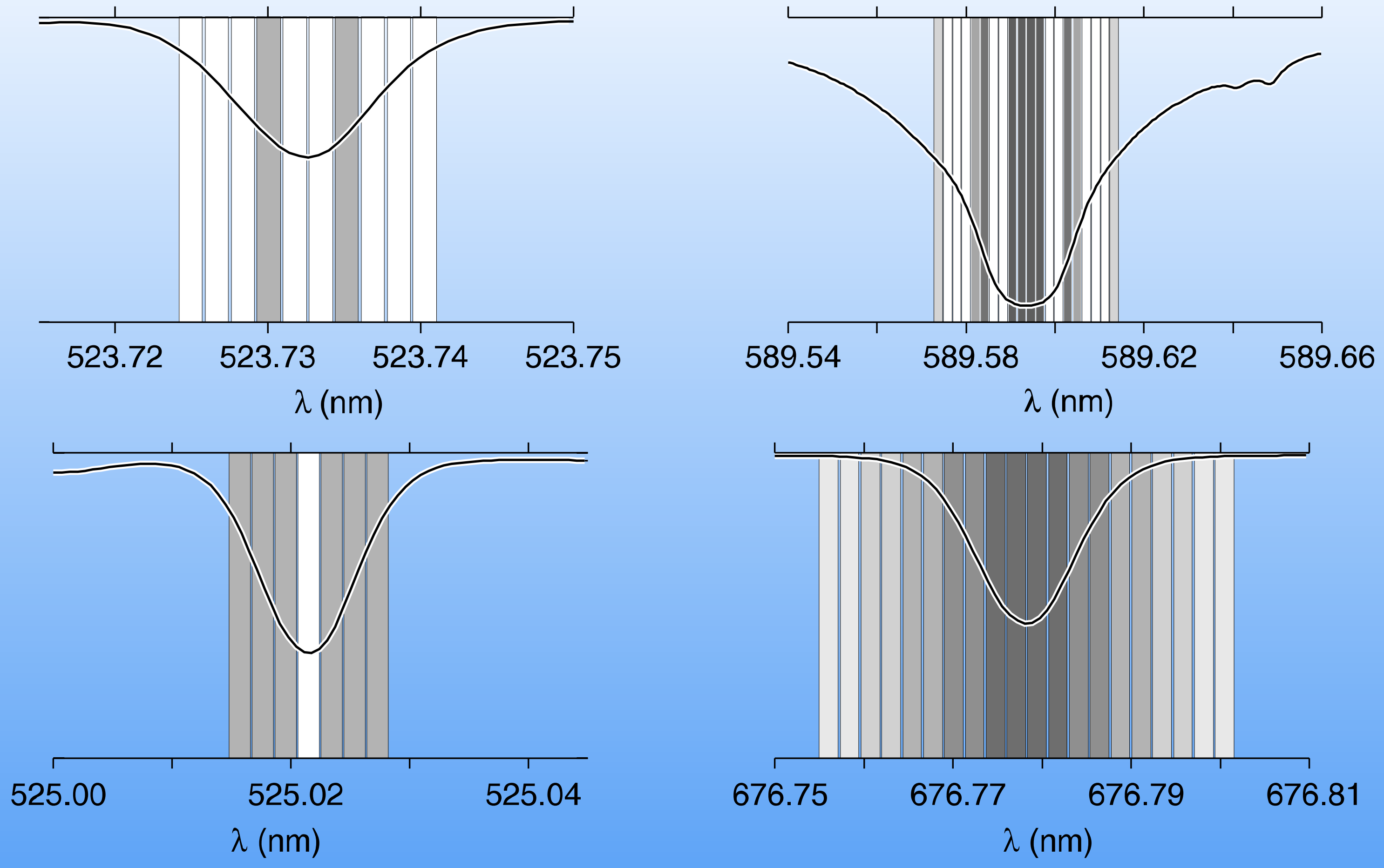
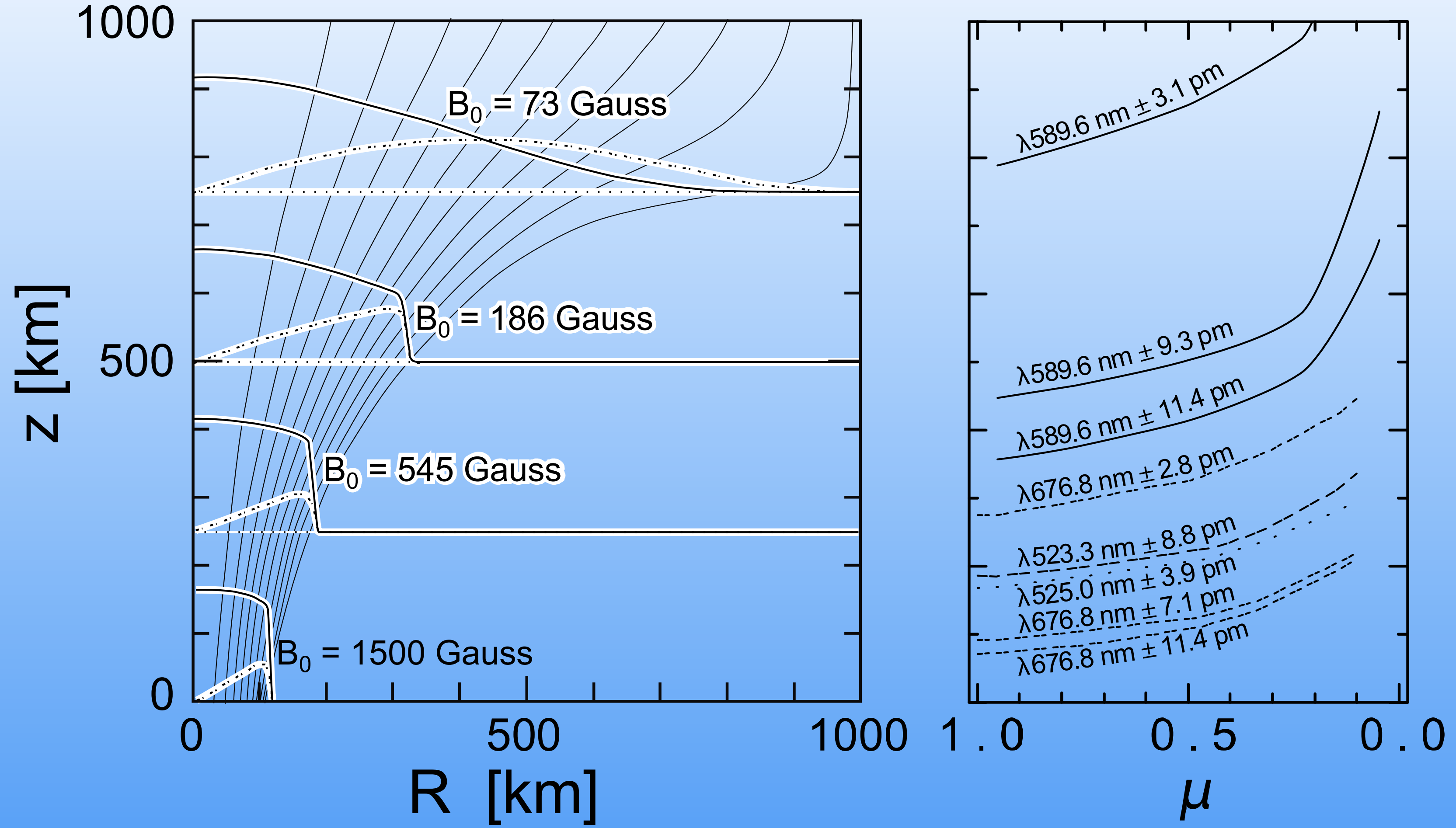


Fig. 3.—This figure shows the spectral line profiles as provided by the archives of the US National Solar Observatory. The sampling bandpass is shown by the sets of rectangles plotted behind the line profiles. Each rectangle represents the spectral sampling wavelength range and has a circular output that may or may not be directed into a photomultiplier tube so that the radiation intensity can be measured. Those rectangles that are white are not used. The gray rectangles are combined so that red- and blue-wing pairs with the same density of gray form a set that can be used in the standard Babcock magnetograph mode.

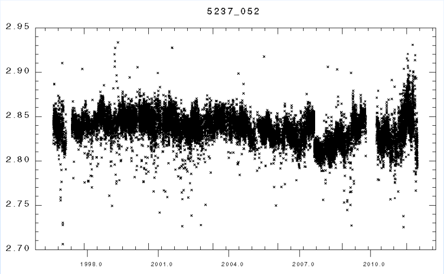
THE SPECTRAL CONFIGURATIONS

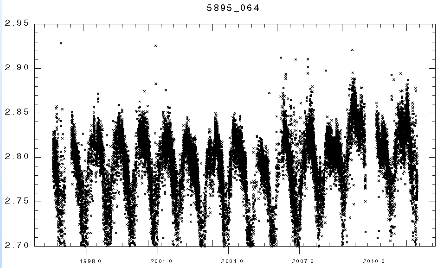


THE ATMOSPHERIC SAMPLING

THE TIME DEPENDENCES 1996 TO 2012

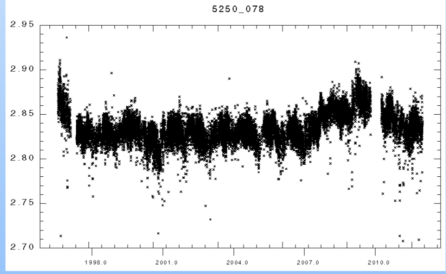
Blue

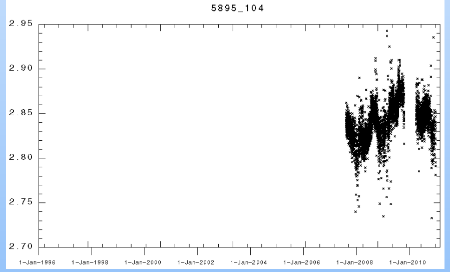




Blue

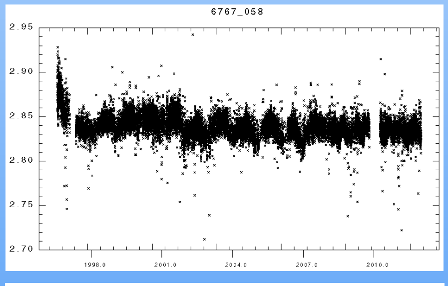
Red

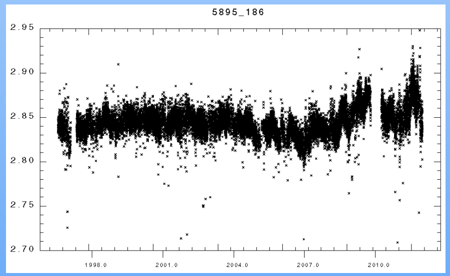




Blue

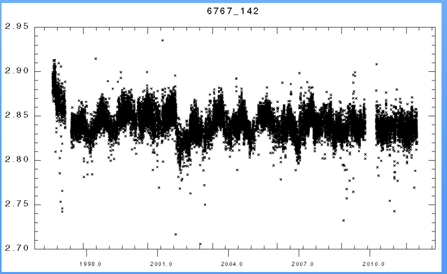
Red

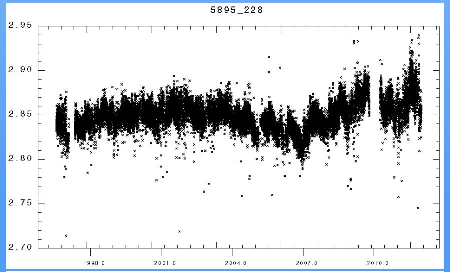




Blue

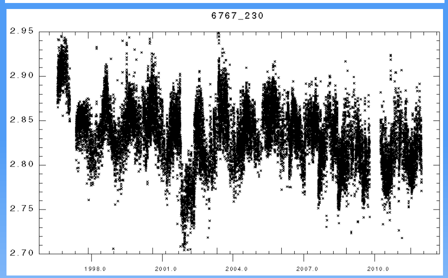
Red

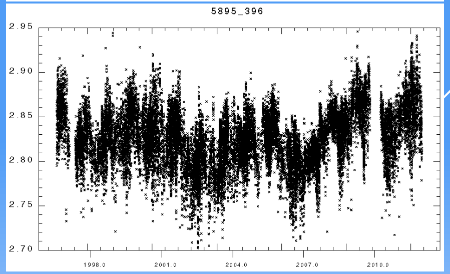




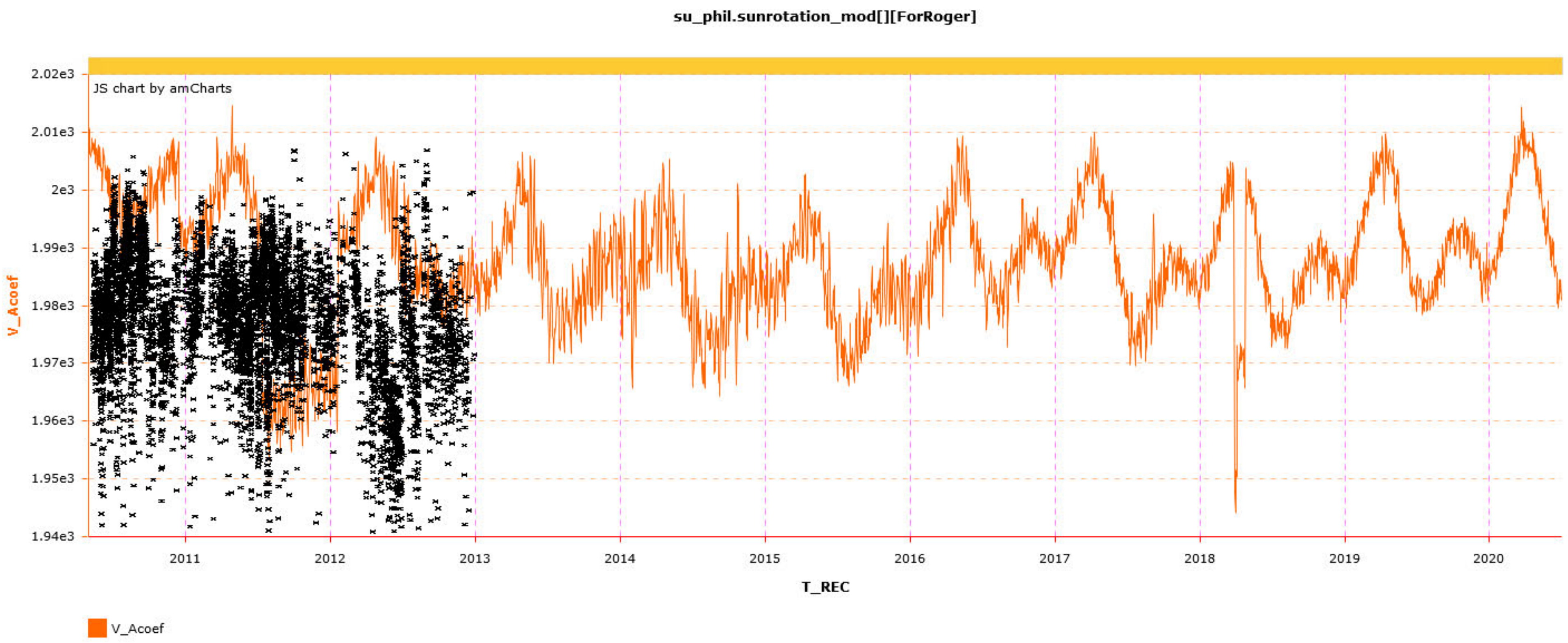
Blue

Red

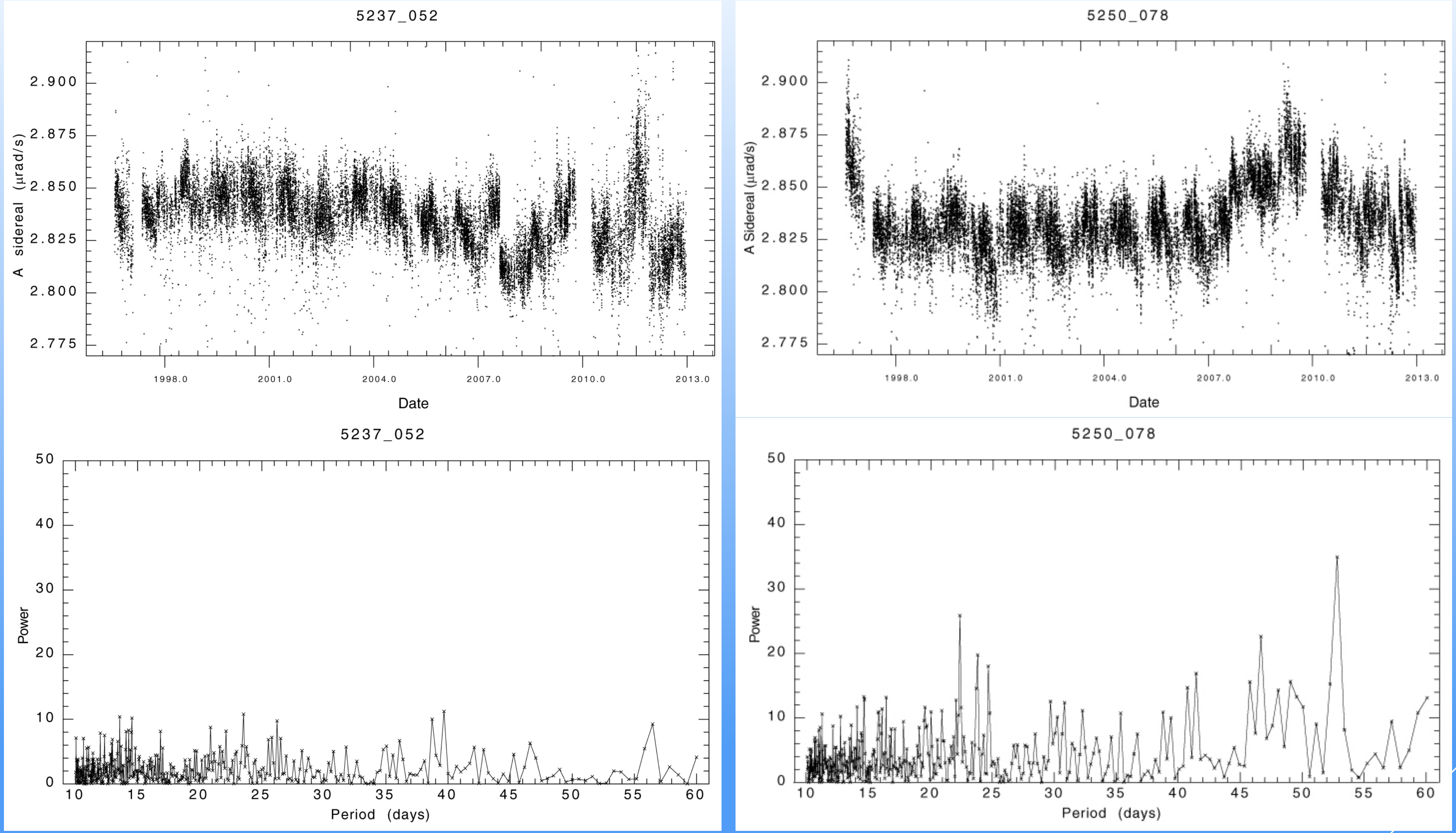




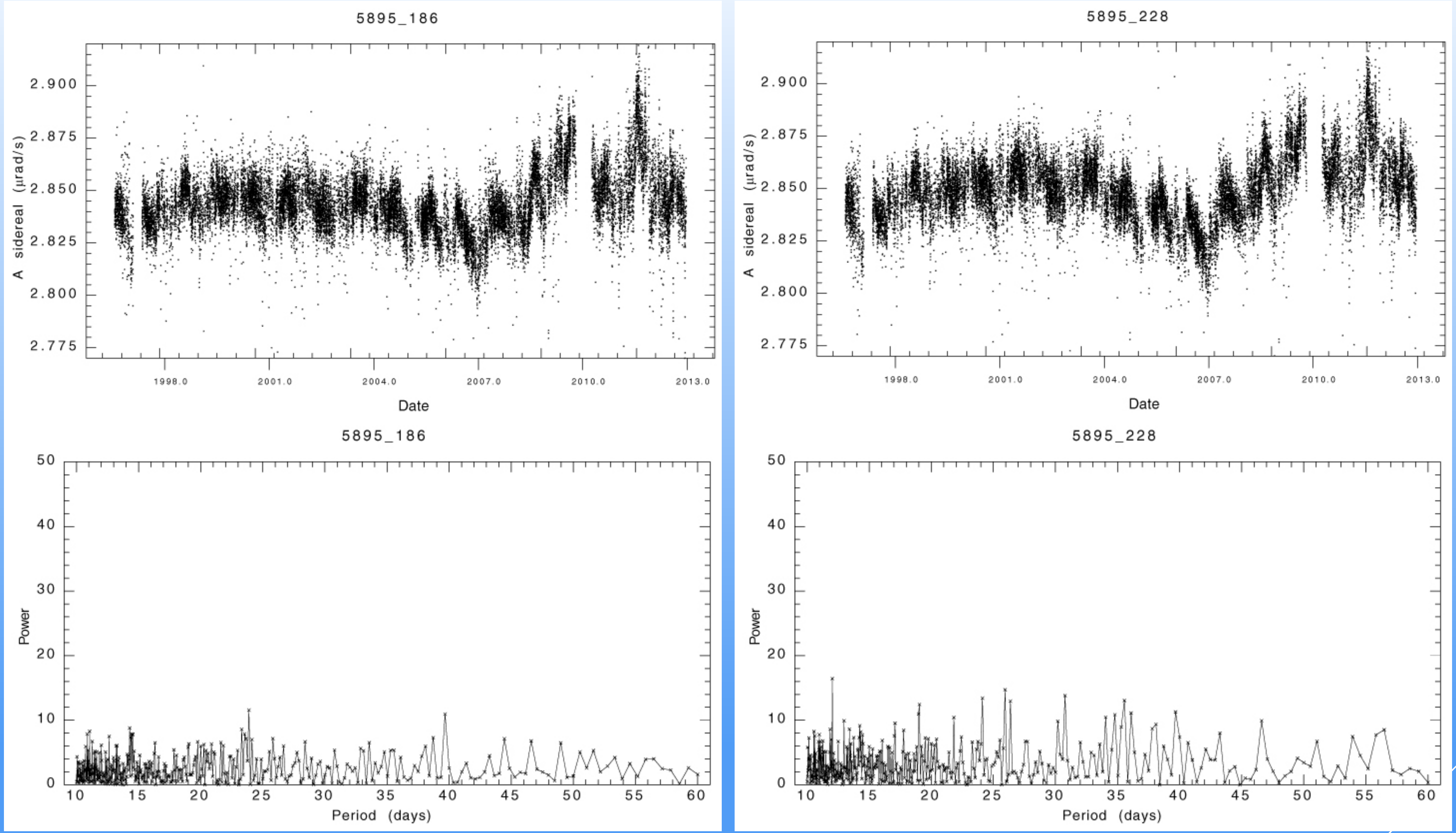
Blue



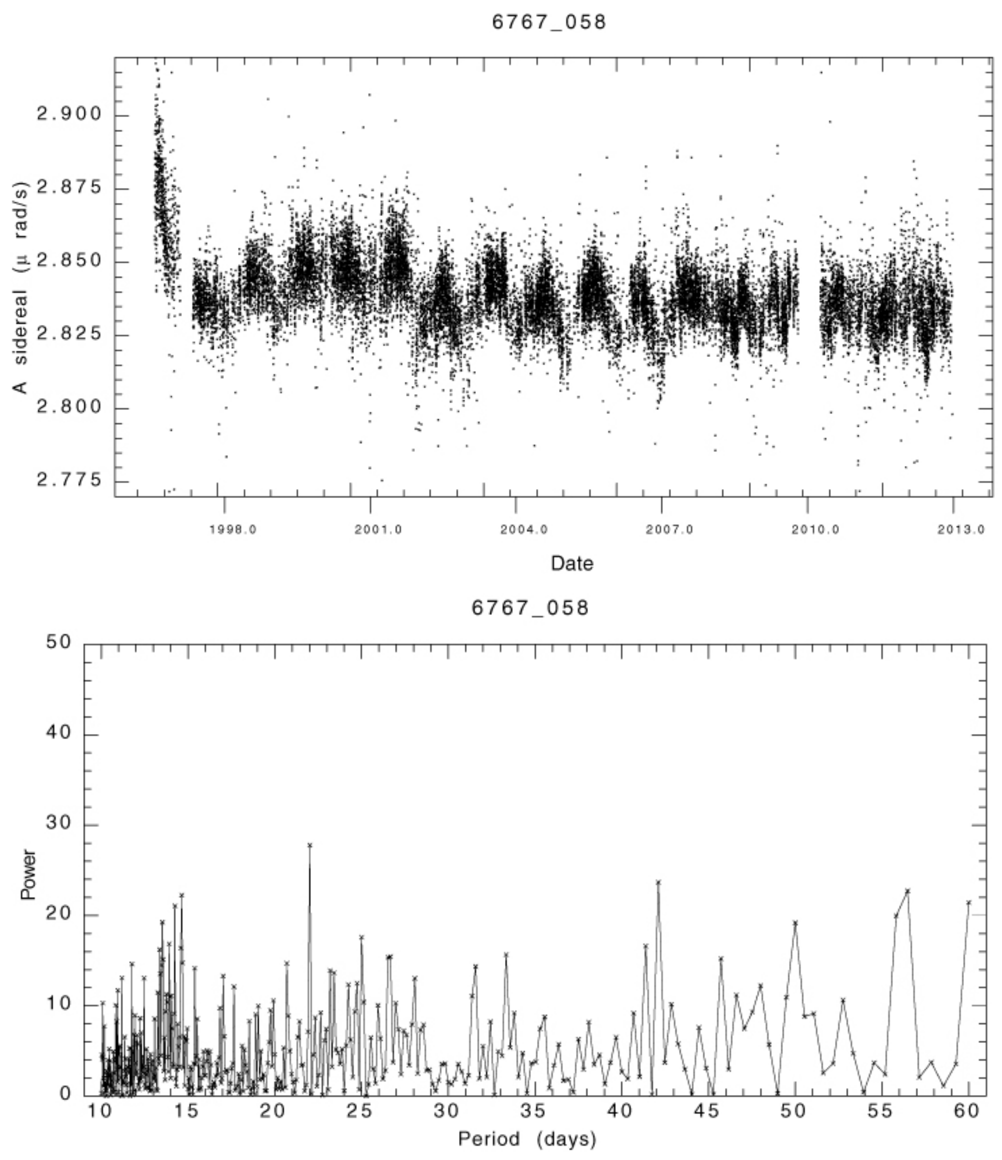
COMPARISON TO HMI

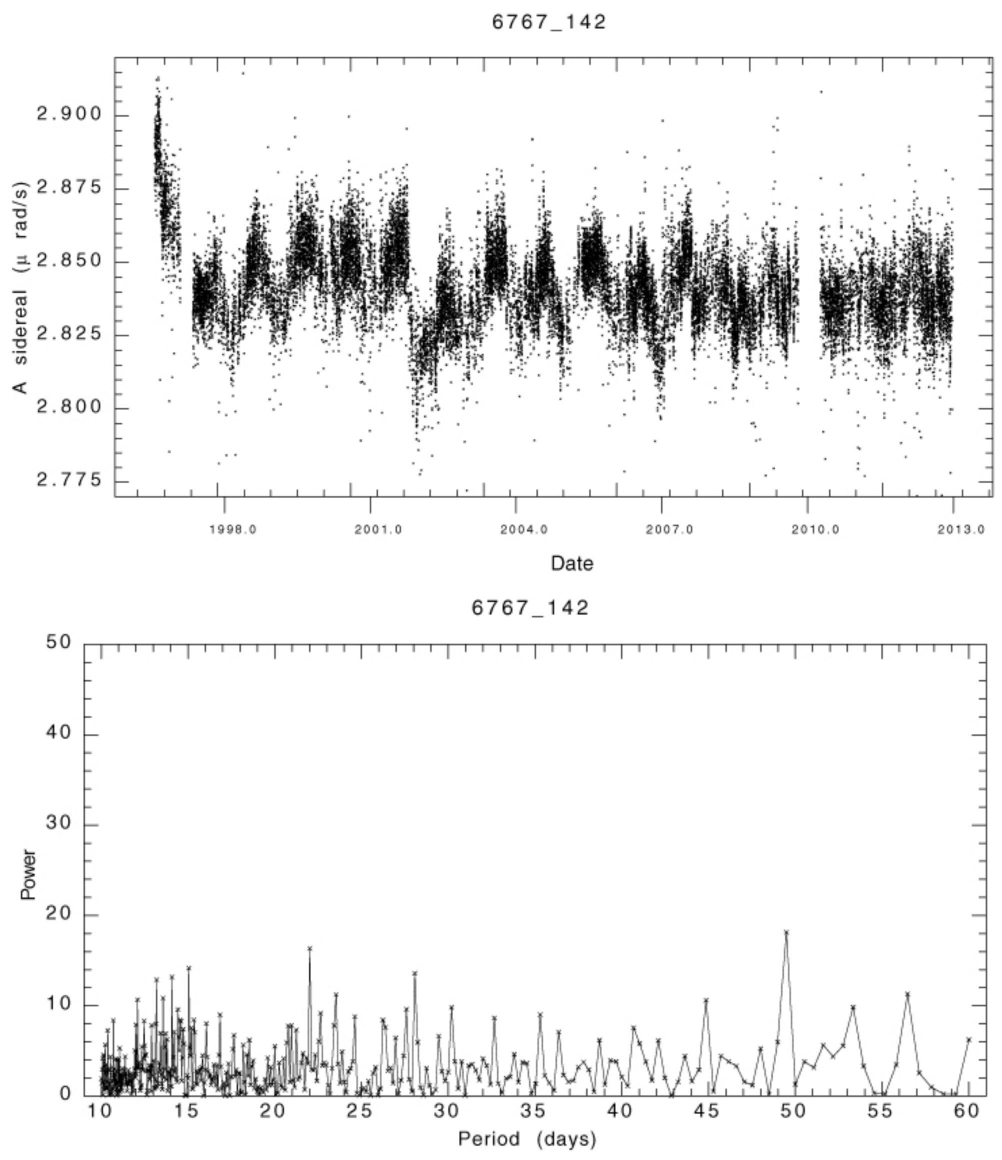


TIME DEPENDENCIES 1996 TO 2013: 5237 AND 5250



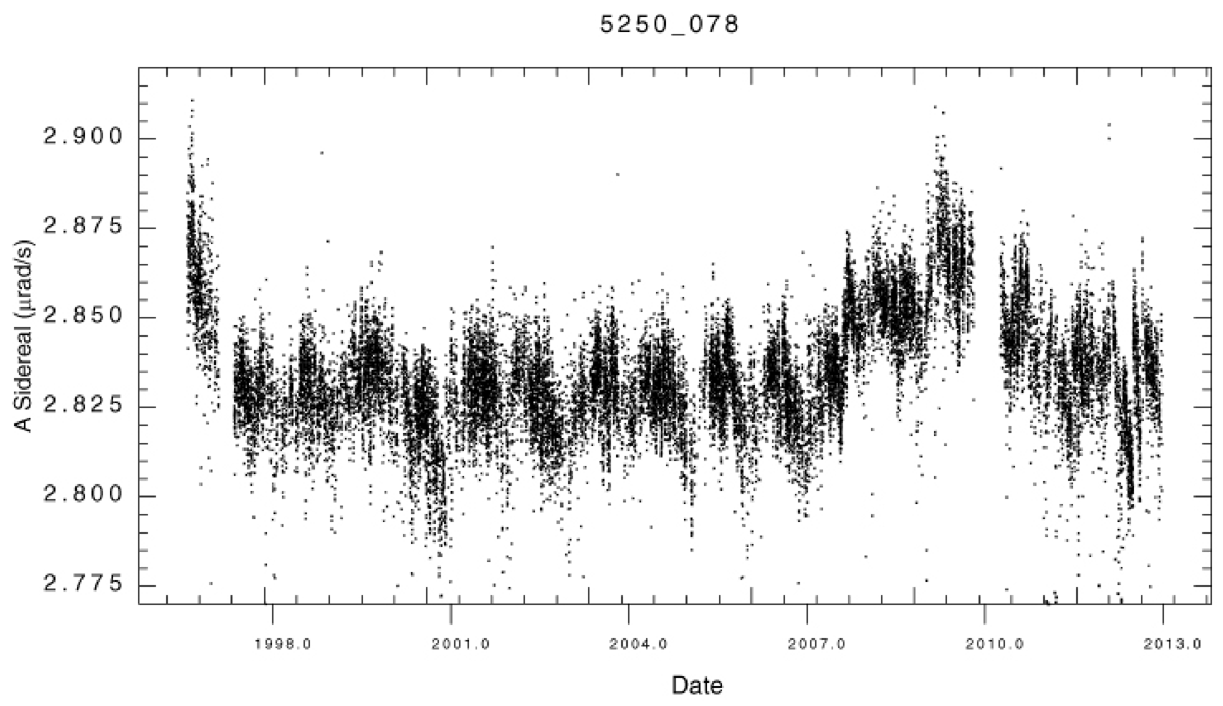
TIME DEPENDENCIES 1996 TO 2013: 5895_186 AND 5895_228

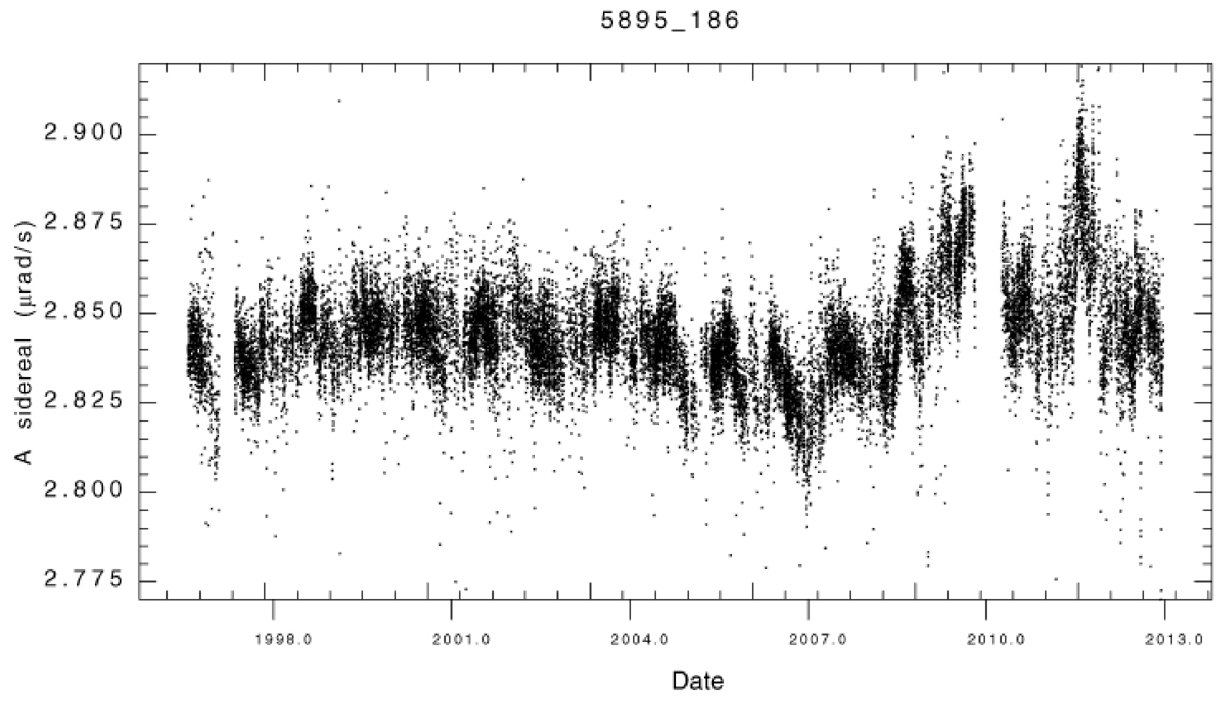




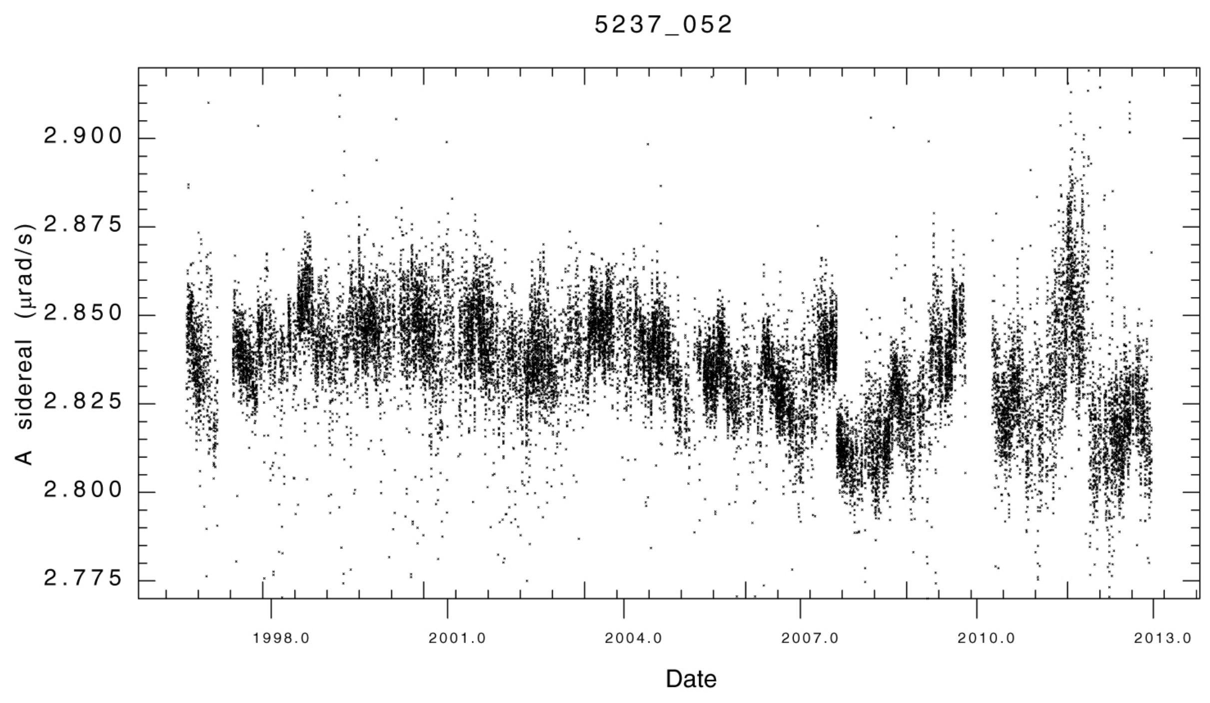
TIME DEPENDENCIES 1996 TO 2013: 6767_058 AND 6767_142

THE GROUND STATE NEUTRAL CASES





AN IONIZED STATE CASE



SUMMARY

- The drifts are different for separate port combinations.
- The drop from 1996 to 1997 is present in some combinations but not others.
- The complex increase in A during 2007 to 2013 is present for the two ground state species but not for the other two lines.
- Several combinations show strong annual variations that probably come from telluric contamination.
- The 1996-1997 decrease is shown by lines on both red and blue stage systems and not shown on the other two lines also on the red and blue stage systems.
- A solar origin for these behaviors is the simplest explanation.
- Latitude differences and/or solar atmospheric altitude differences may be the cause for the different behaviors.