An Alternative Approach to Measuring Solar Velocities on the Solar Dynamics Observatory (SDO) using the Helioseismic and Magnetic Imager (HMI)

Brittany Cavin | Dr. Valentin Martinez Pillet

The Sun

From the Earth's line of Sight the Sun rotates on an axis in the approaching and receding motion

This dopplergram shows the velocity of the sun's rotation in a two-dimensional representation.

The Sun spins faster around the equator and slower around it's poles

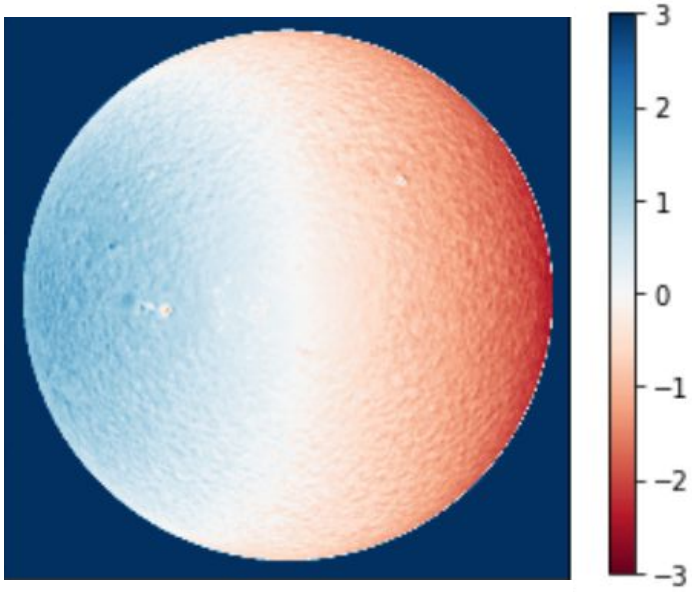
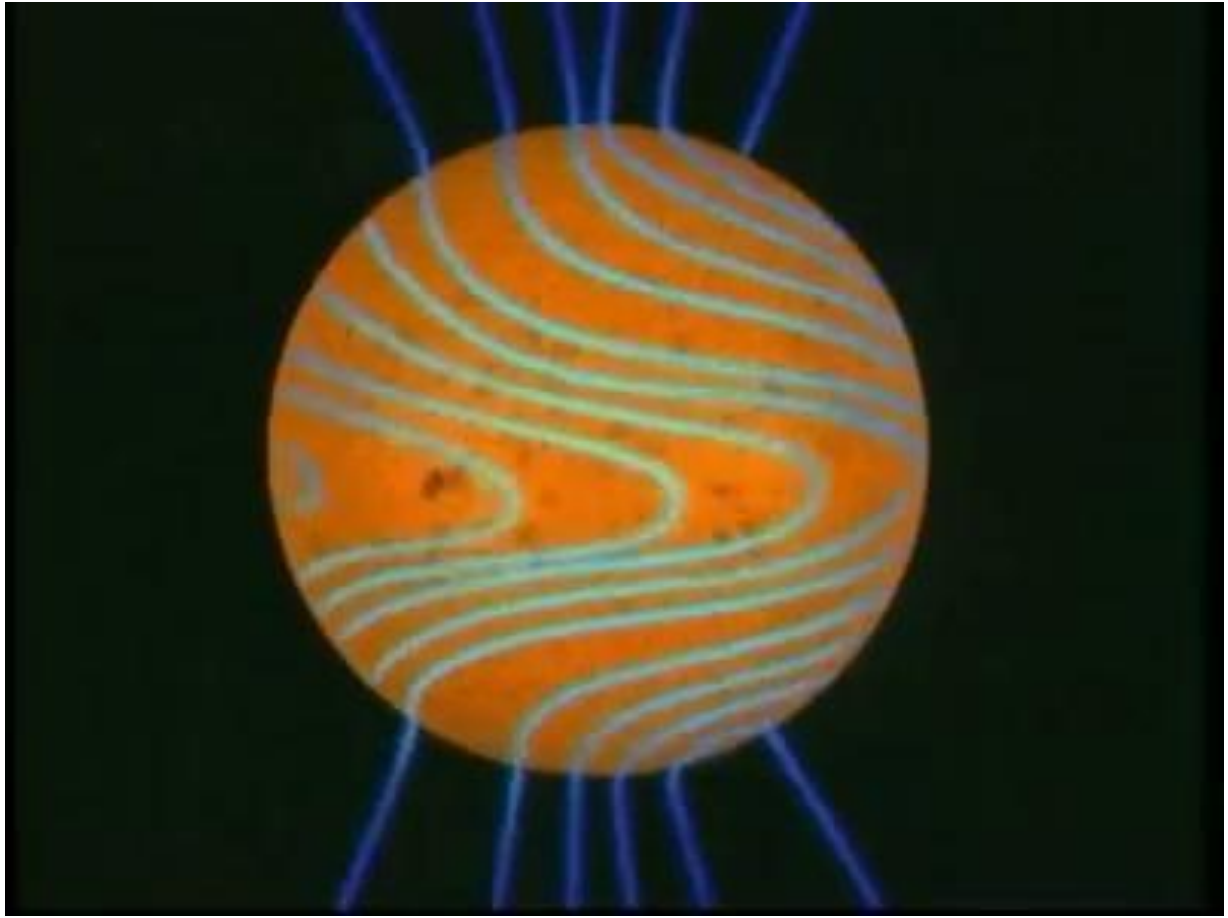
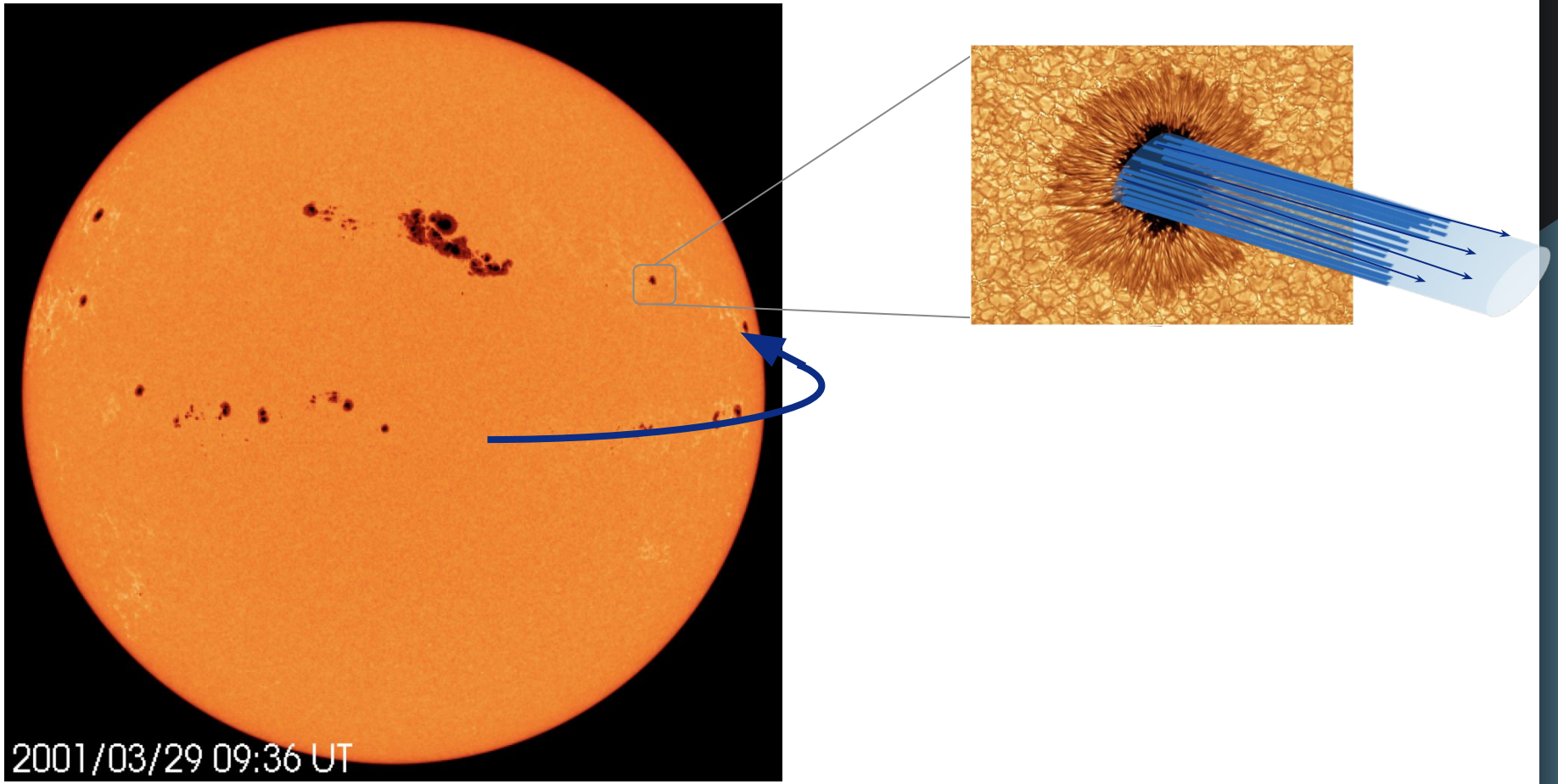


Figure show the computed Dopplergram of the Gaussian Fit method over a single hour




2001/03/29 09:36 UT

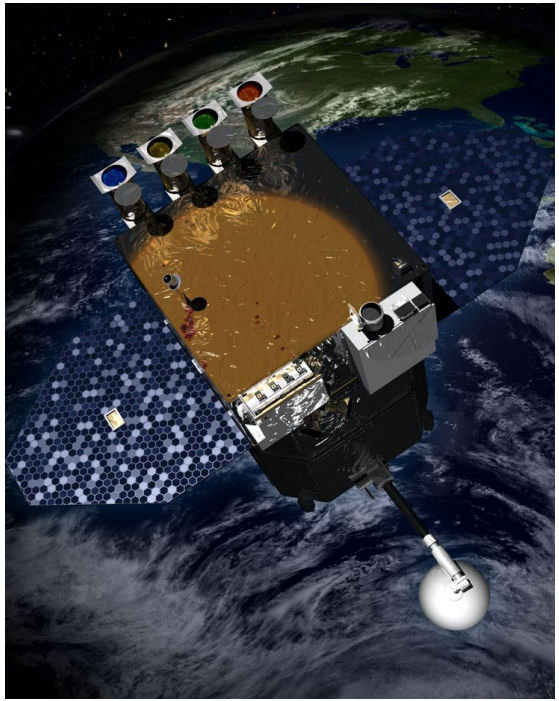
Background information

The Solar Dynamics Observatory (SDO) launched February 11, 2010.

The Helioseismic and Magnetic Imager (HMI) produces line-of-sight observables (Couvidat, 2012).

- Doppler velocity
- Magnetic- field strength
- Fe I line width
- Continuum intensity

HMI Instrument produces images with a resolution of 4096x4096 pixels.



Meaney et al., NASA/Goddard Space Flight Center Conceptual Image Lab, 2007

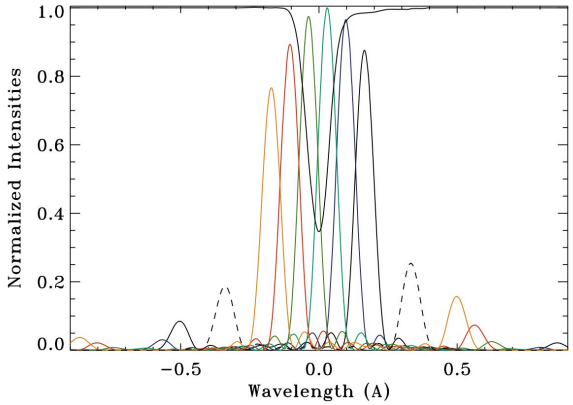
HMI Current Method

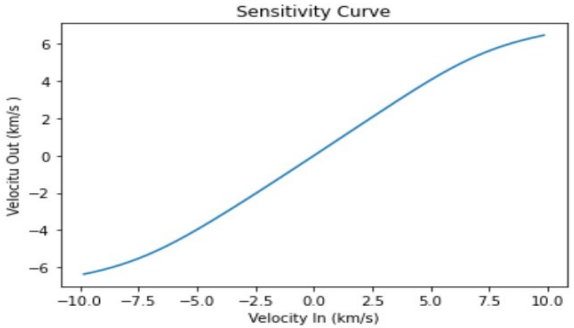
HMI Instrument uses two steps to measure solar velocity:

1. Uses ratios of 6 wavelengths to find a weighted velocity at each pixel, making the velocity estimate robust against gain errors (good!)

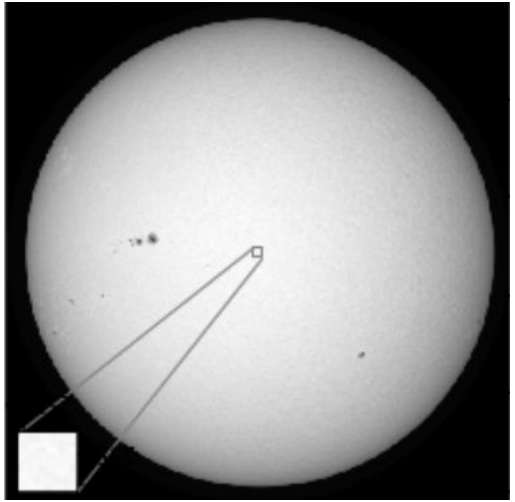
2. Needs of additional calibration via a sensitivity curve that assumes how the spectral line looks like at each pixel (bad!)

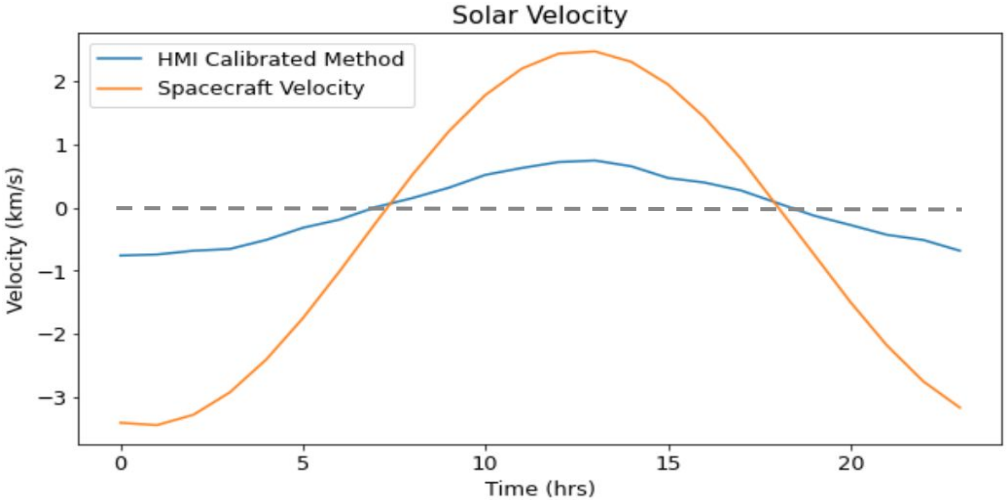
This HMI method is causing a leak of the spacecraft velocity (a known quantity) on the solar data. <u>Spacecraft has a 24h period that is seen in the data.</u>





The Problem (24h leak)



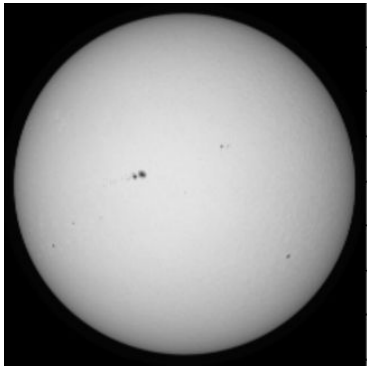


Research Goals

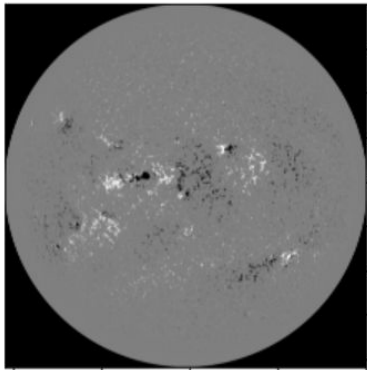
The goal is to find an alternative approach to measuring Solar velocities upon the SDO spacecraft and avoid the current 24h leak.

Compare the current HMI Method results (explained in Couvidat et al., 2016) with an alternative Gaussian Fit Method.

The Gaussian requires no calibration and hope it avoids the leak of the spacecraft's velocity on the solar data.



Blackbody Continuum
2015-03-29T16:34:33', Sample 1



Circular Polarization
2015-03-29T16:34:33, Sample 1

Methodology

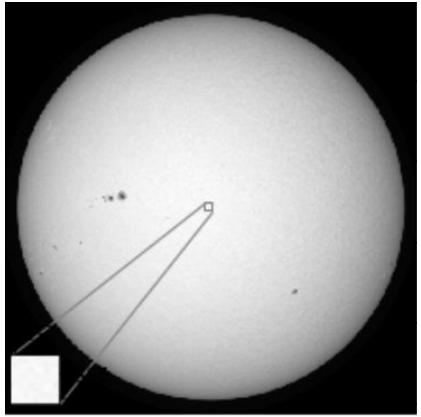
The HMI data was downsizes to 512x512 pixel image in order to increase the efficiency of the Program

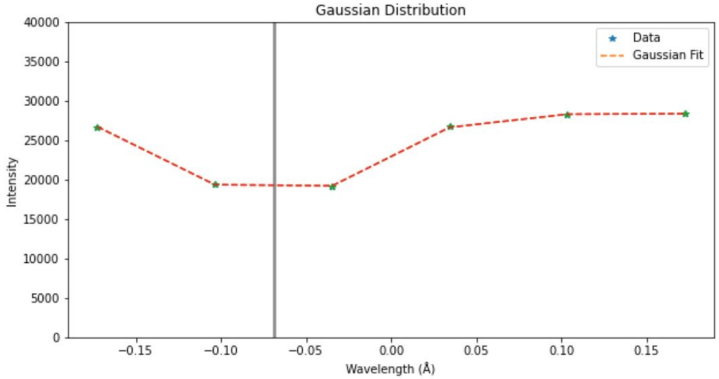
The sun was observed over 24 hours at six different wavelengths.

By plotting the Sun's spectra at six different wavelengths, I used a Gaussian fit to calculate the distribution at every pixel.

The combined spacecraft and solar velocity could be calculate using this Doppler effect equation.

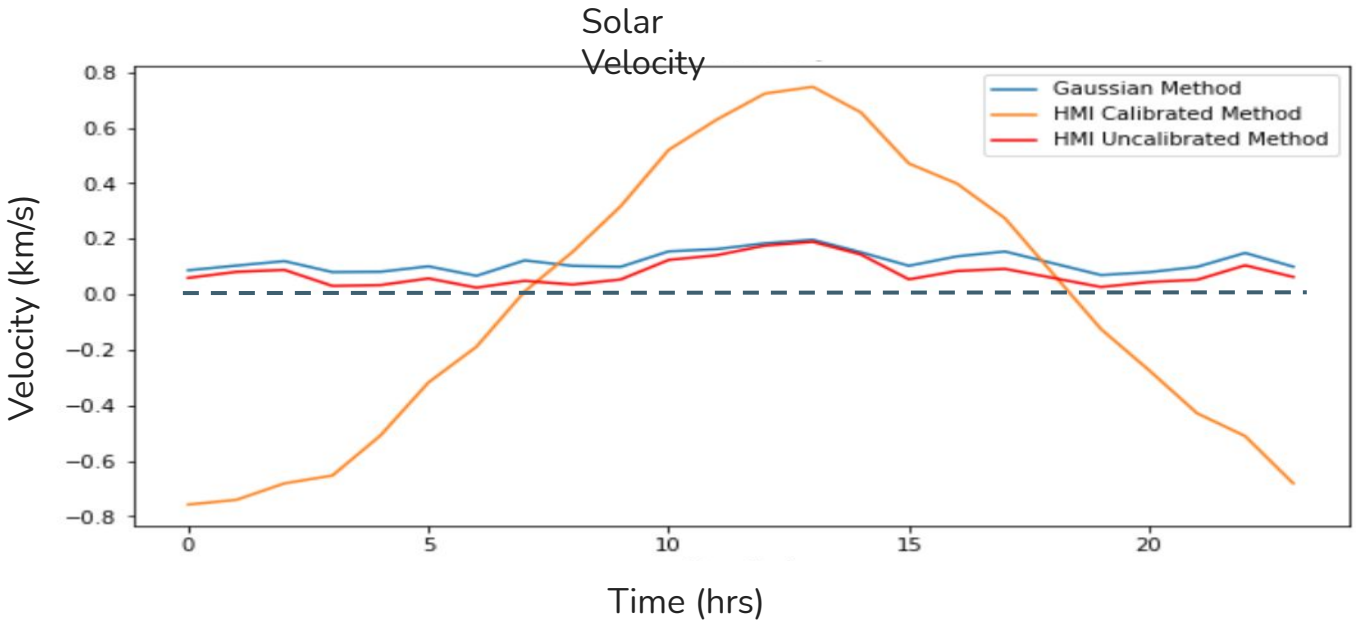
$$v = c\frac{\Delta\lambda}{\lambda_0}$$

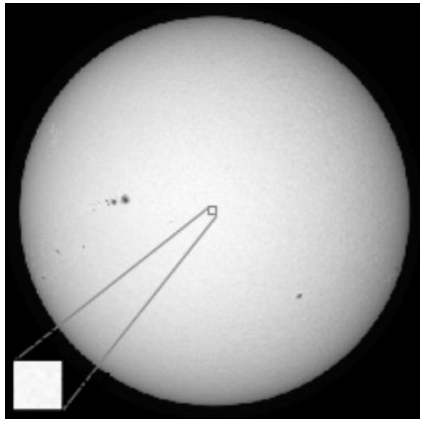




Total Velocity = -3.32 km/s

Results Center of Sun



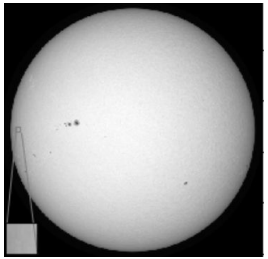


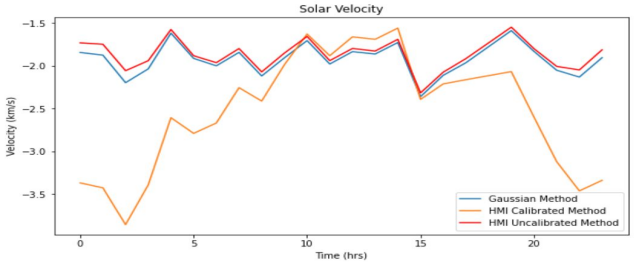
Results Inactive Region

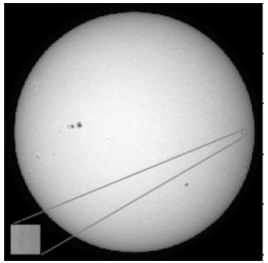
The use of calibration on the HMI data is unneeded when calculating the Sun's rotational velocity in quiet inactive regions.

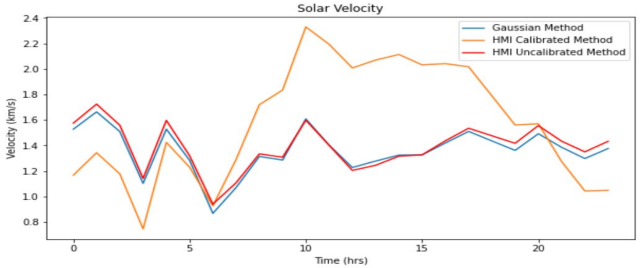
The Gaussian method produced accurate solar velocity inactive regions without the need for calibration.

<u>Note: HMI uncalibrated uses only step #1, HMI calibrated uses bot steps #1 and #2.</u>







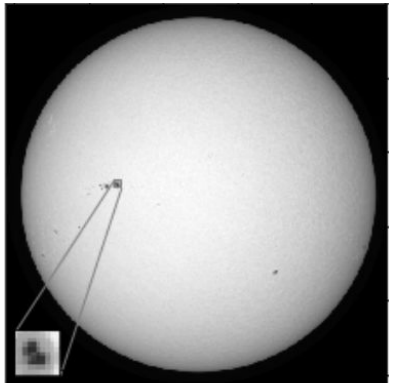


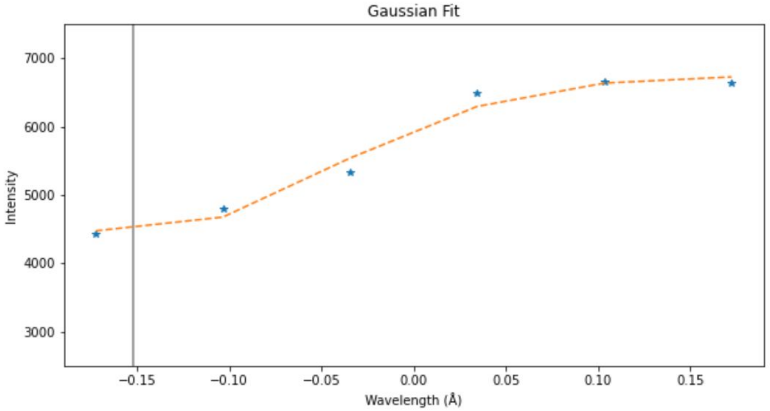
Sunspots

At the location of sunspots and active regions, determining the wavelength intensities were expected to be difficult.

Therefore, strict estimations were used to determine the center of the Gaussian curve.

Rarely an error in the 512x512 pixel image



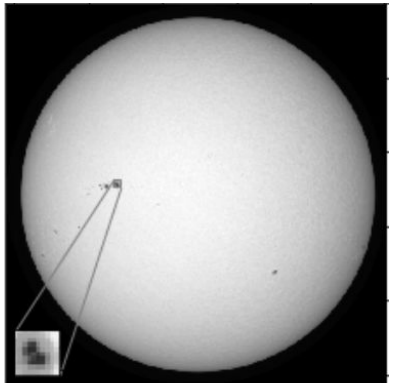


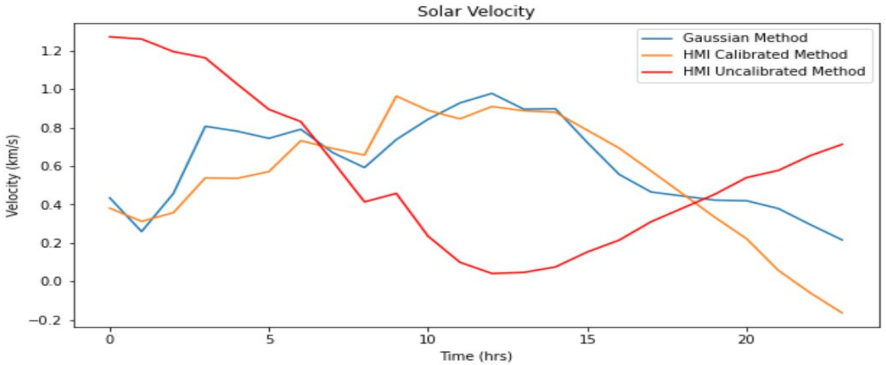
Sunspot Results

The results of the HMI Method before calibration were completely thrown off.

The HMI Method after calibration only produces accurate results in active region of the sun.

The Gaussian method produced accurate solar velocity in both active and inactive regions without the need for calibration (at least for our resolution here 512x512)





Conclusion

The Gaussian Method produces more accurate results for solar velocities among both active and inactive regions. It does not suffer from 24h leakages.

The error in the HMI's calibration of inactive regions may indicate the leak of the spacecraft velocity in active regions as well.

To produce accurate results the HMI method would need to correctly identify when calibration is need, if it is needed at all.

Future Work

These results were basic on a 24 hour study of the sun with one prominent sunspot. Further research is needed to determine consistency in each of the methods at real HMI resolutions.

The Goal is to improve line of sight observation using the HMI instrument. Future work would entail calculating the magnetic- field strength, Fe I line width, line depth, and continuum intensity using the Gaussian Method.

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References

Couvidat, Sébastien, et al. “Wavelength Dependence of the Helioseismic and Magnetic Imager (HMI) Instrument Onboard the Solar Dynamics Observatory (SDO).” The Solar Dynamics Observatory, 2011, pp. 285–325., doi:10.1007/978-1-4614-3673-7_13.

Couvidat, S., et al. “Observables Processing for the Helioseismic and Magnetic Imager Instrument on the Solar Dynamics Observatory.” Solar Physics, vol. 291, no. 7, 2016, pp. 1887–1938., doi:10.1007/s11207-016-0957-3.

Couvidat, Sébastien, et al. “Line-of-Sight Observables Algorithms for the HELIOSEISMIC and Magnetic Imager (HMI) Instrument Tested with Interferometric Bidimensional Spectrometer (IBIS) Observations.” Solar Physics, vol. 278, no. 1, 2012, pp. 217–240., doi:10.1007/s11207-011-9927-y.

Q&A