Analysis of Solar Observations and Engineering Data from the 2009 Sunrise High Altitude Balloon Observatory

Piyush Agrawal
Indian School of Mines, India
High Altitude Observatory, NCAR University of Colorado, Boulder
& M. Knölker, J. Lord, A. Lecinski and the Sunrise Team

INDIAN SCHOOL OF MINES
उत्तिष्ठत जाग्रत प्राप्य वरान्निबोधत

HAO

NCAR

UNIVERSITY OF COLORADO
LET YOUR LIGHT SHINE
1876

Sunrise Mission : Key Questions

- **What are the origins and properties of the intermittent magnetic structures?**

- **How is the magnetic flux brought to and removed from the solar surface ?**

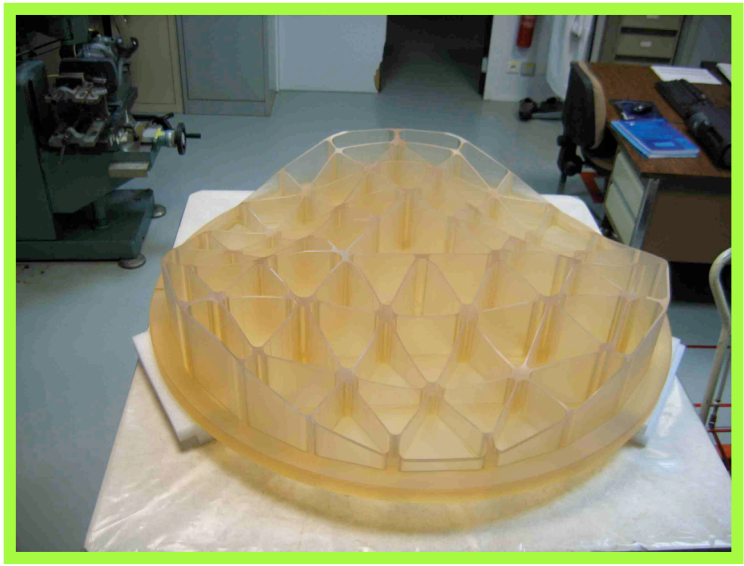
- **How does the magnetic field assimilate and provide energy to heat the upper solar atmosphere ?**

- **How does the variable magnetic field modify the solar brightness ?**

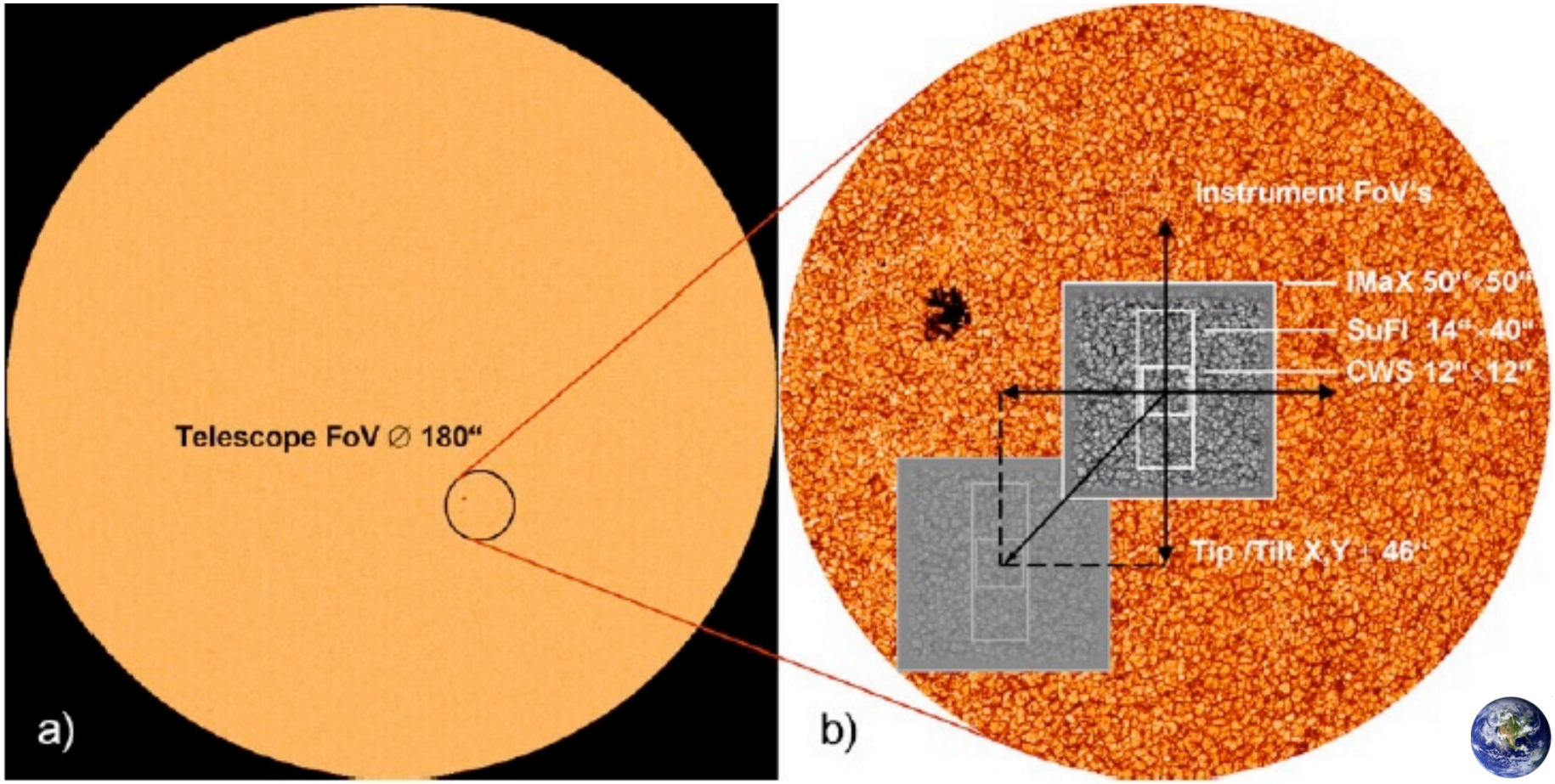
For this : Sunrise provides Intensity maps at resolution of 0.01 arcsecs in UV

Sunrise Balloon-Borne Solar Observatory

- Gregory telescope, 1-m aperture
- Protective and stabilizing Gondola
- 1.3 kW Solar Array + Li-ion batteries
- Correlating Wavefront Sensor
- Filtergraph : (SuFI)
  214nm, 300nm, 313nm, CN, Ca II H
- Magnetograph : (IMaX) Provides Dopplergrams and Vector Magnetograms in Fe I 525.02 nm



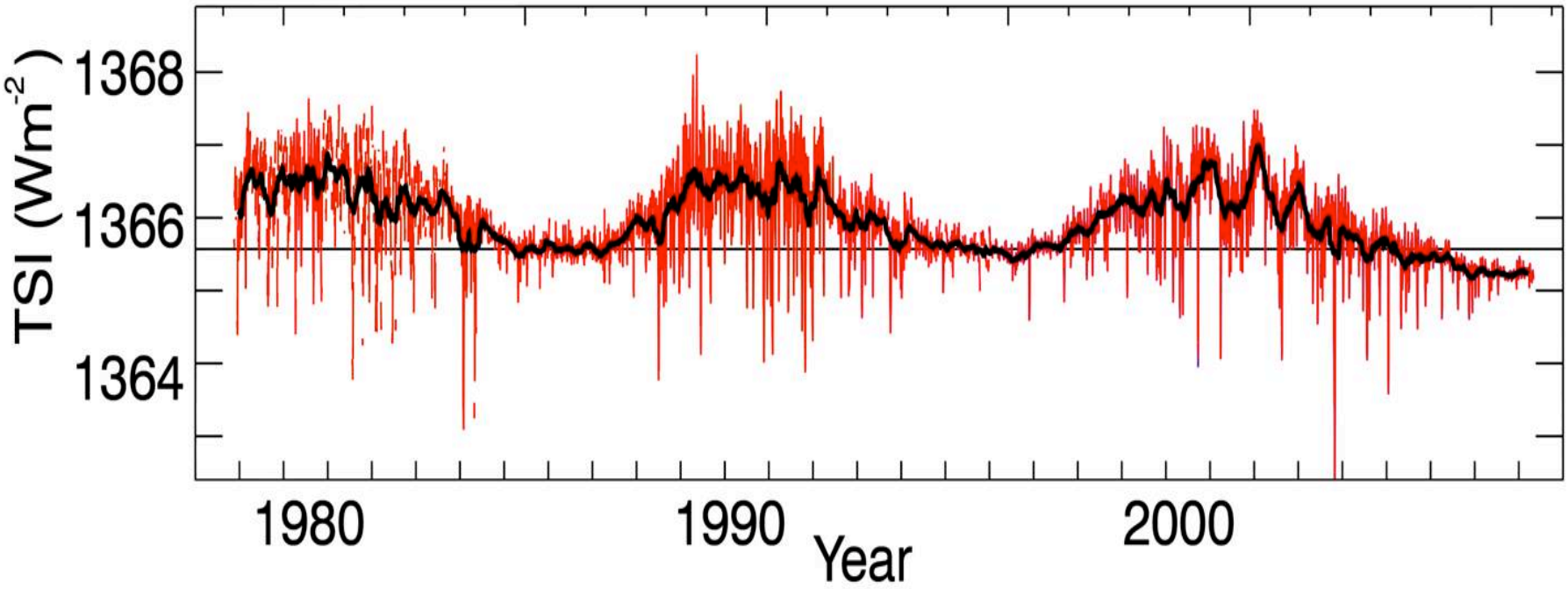
Sunrise Instruments: Fields of View



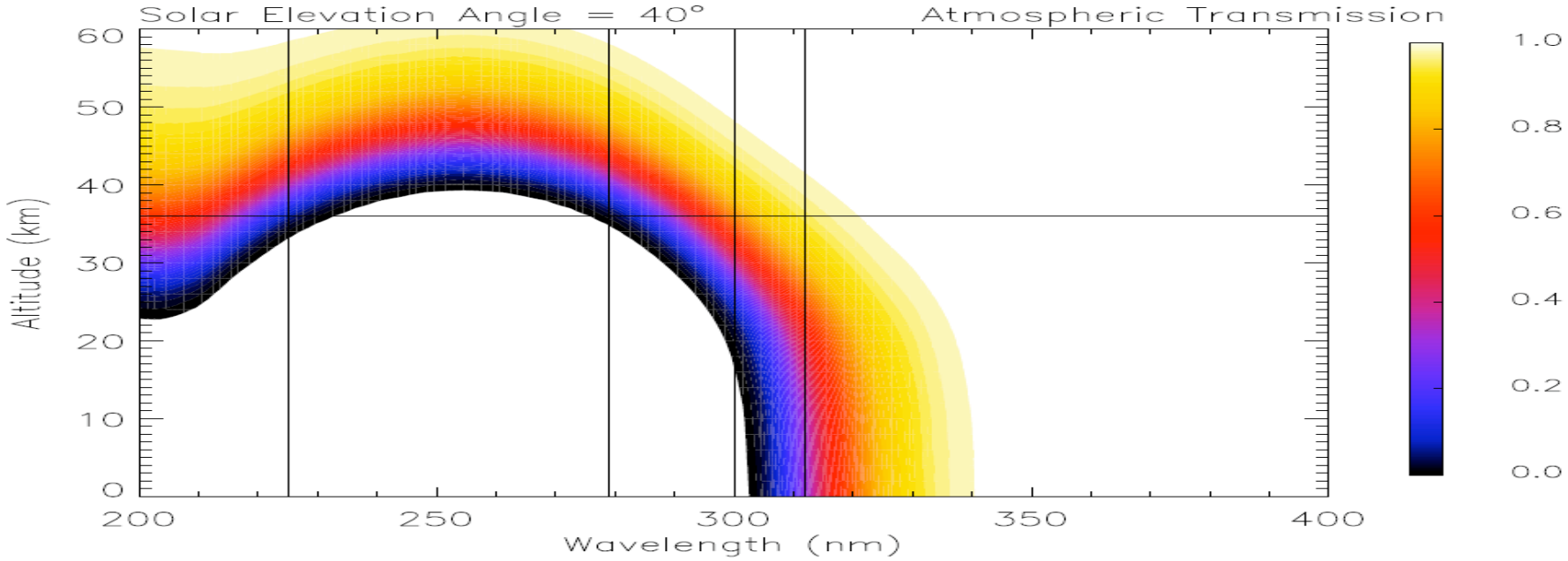
Telescope FOV = 180 arc sec (approx. 10% of solar diameter)

The REU Project :

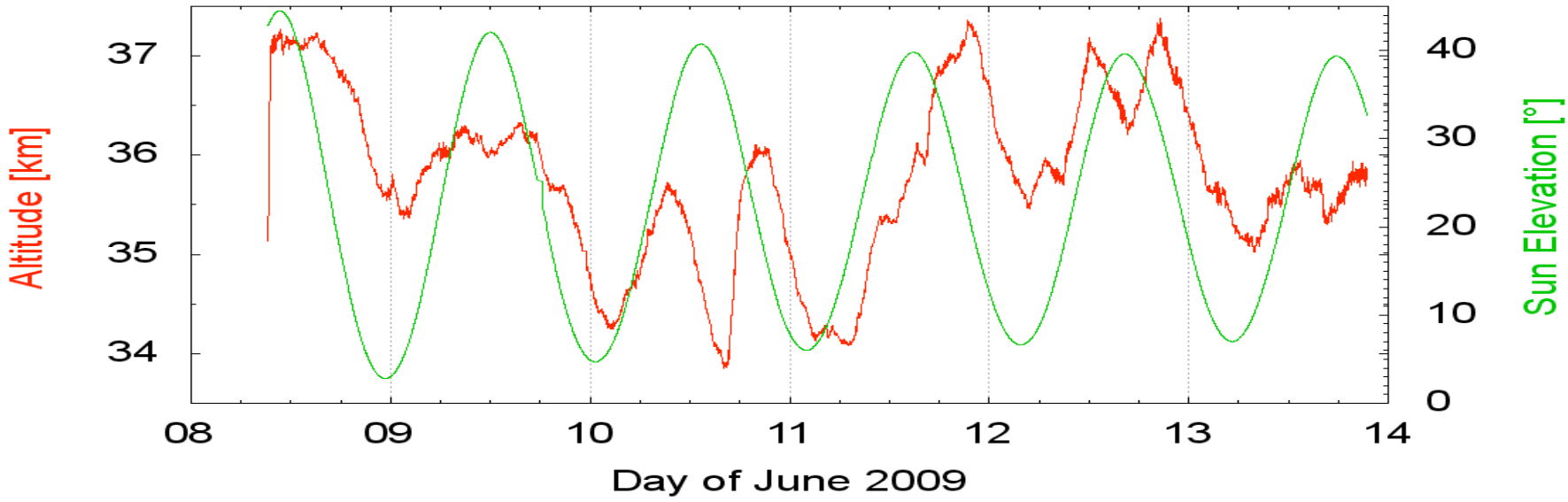
- The Solar irradiance variations with the solar cycle are very small for visible wavelengths i.e. a fraction of a percent, whereas , they are much larger for the UV and EUV . The project aims to relate this variation to the temporal variations in the number density of small bright magnetic structures



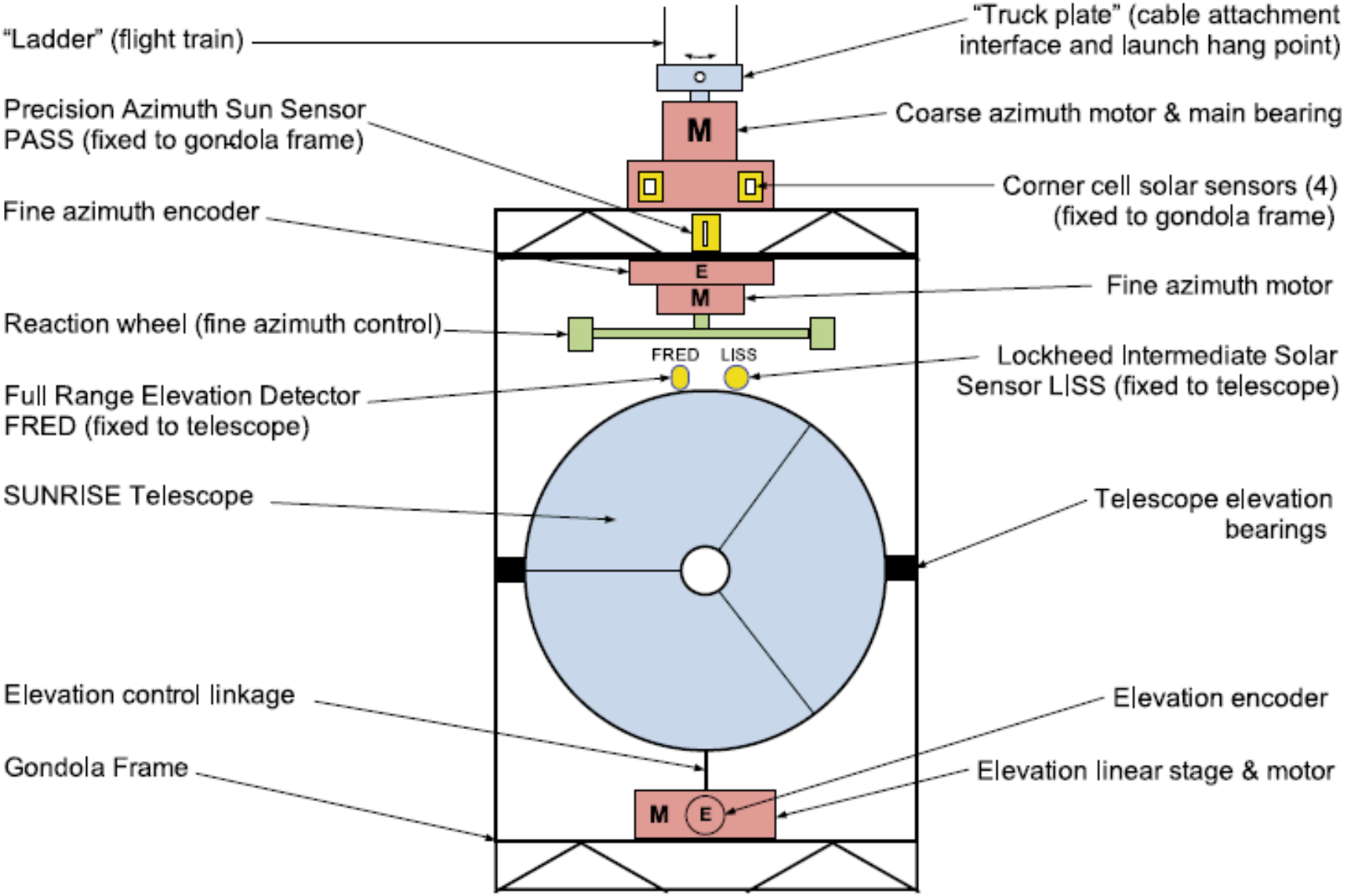
Solar UV transmission profile



Altitude Profile and calculated Sun Elevation of the 2009 SUNRISE Flight



Different Pointing Sensors:



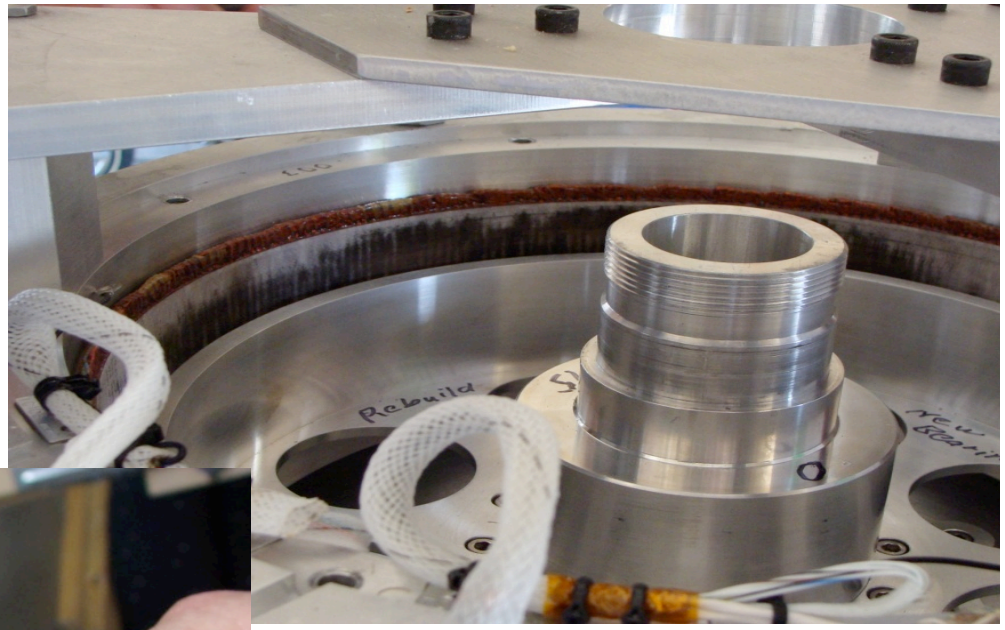
The 10 Hz Signal

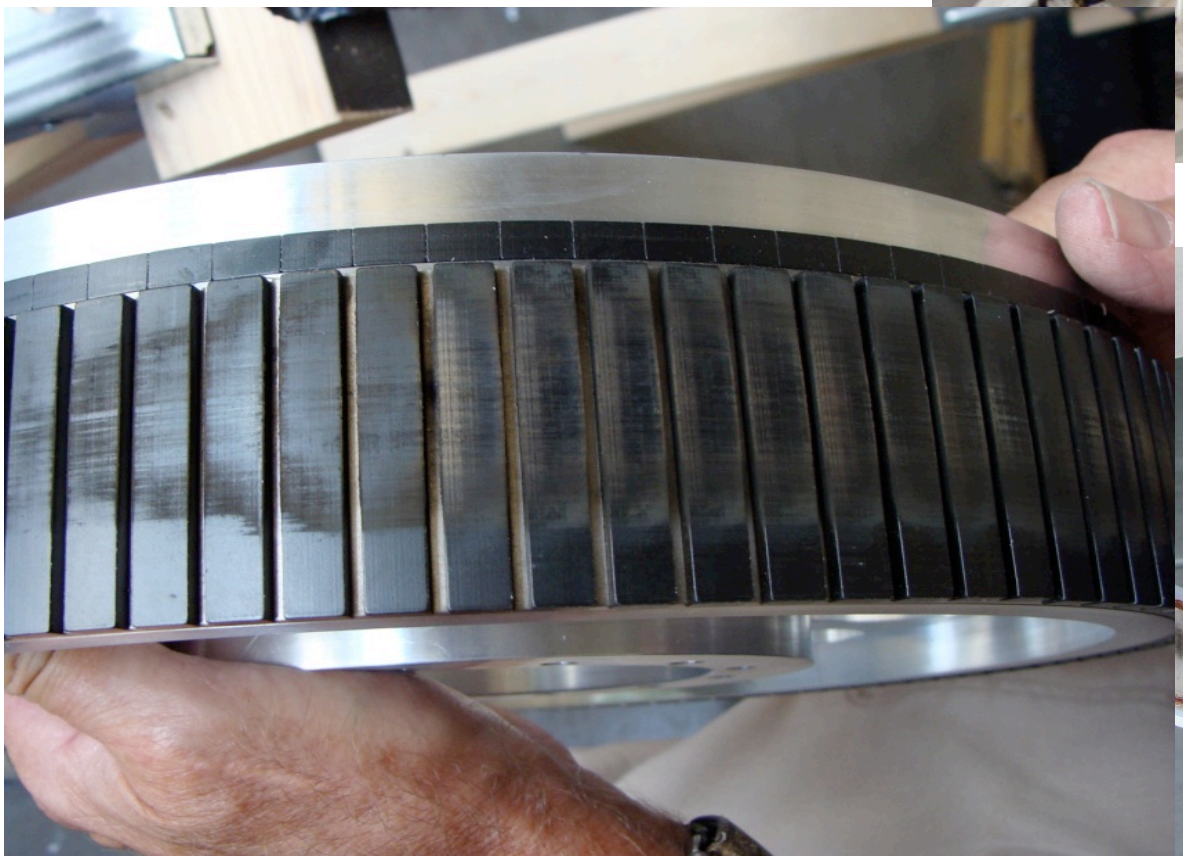
- Sunrise Data Sets are imperfect due to vibrations of various frequencies. We use a periodic 10 Hertz vibration of varying amplitude as a tracer for good data
- The inherent noise in the sensor was around 2 to 3 ADU (Analog to Digital Unit)
- The level for the 10 Hz range from .1 - 40 ADU

- It appears that the sticking azimuthal drive is one source of amplification for the 10 Hz …. but its complicated

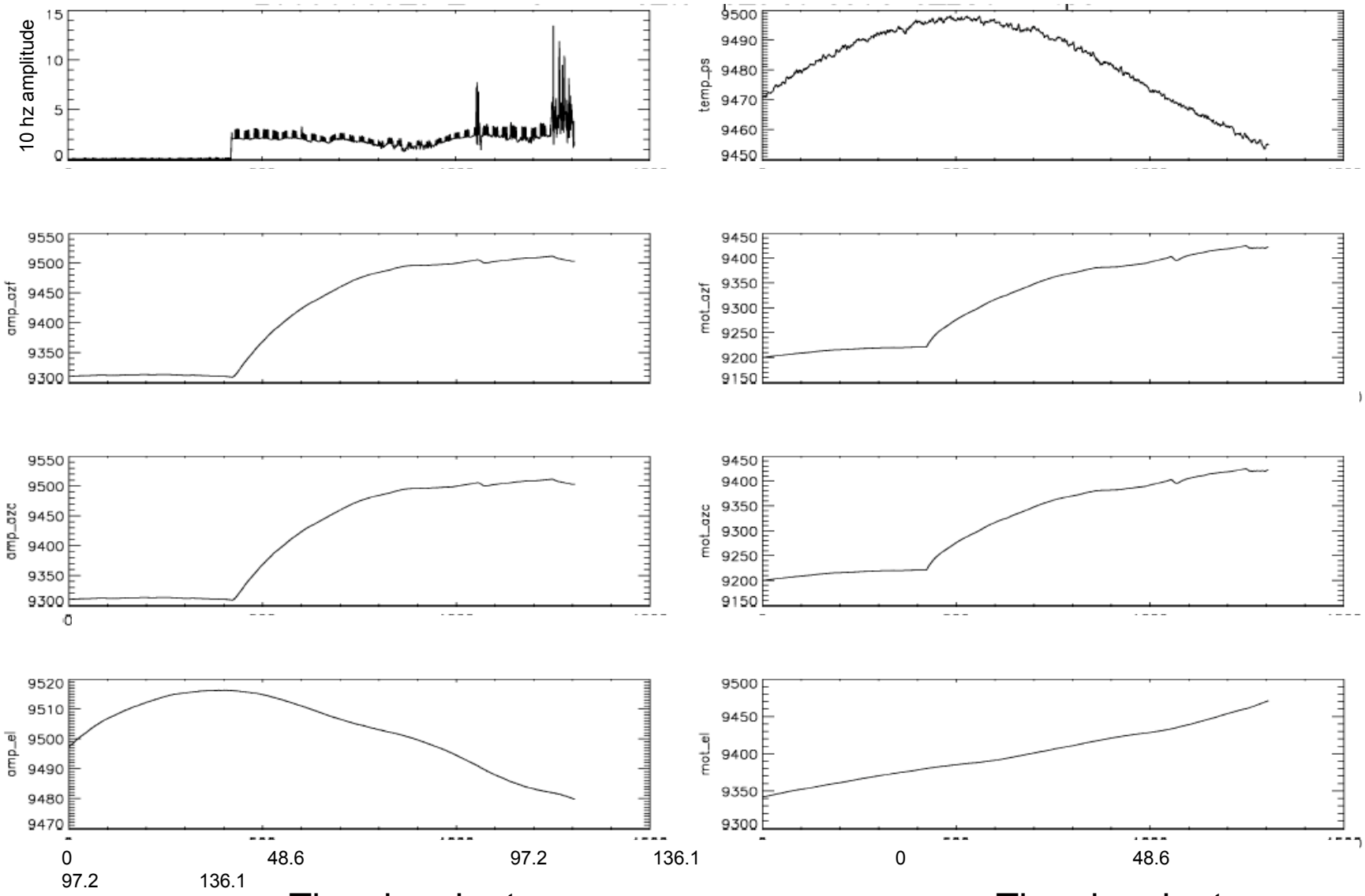
- Aim : To find the time intervals where the amplitude of the 10 Hz signal was low

Sticking of the flywheel





10Hz Amplitude and Temperature



Work Plan I

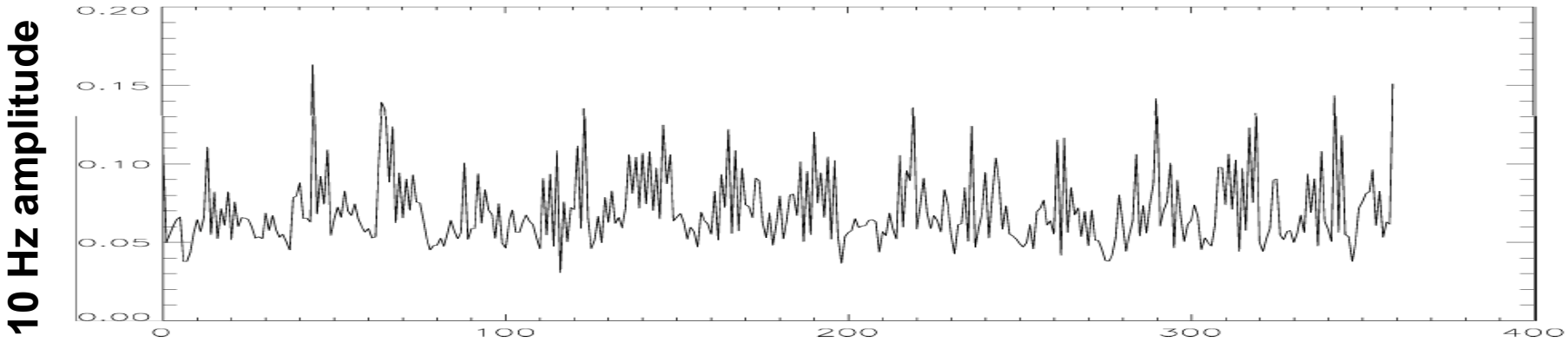
- The Engineering Data contains detailed information on pointing characteristics throughout the flight
- Data is in awkward format à develop handling and extraction tools
- Look at data following A. Lecinski's sample analysis
- Use Liss Yaw Pointing Data to sort out observing moments of amplitude within [-200,200] ADU
- Look for data therein where pointing is locked

Continued…..

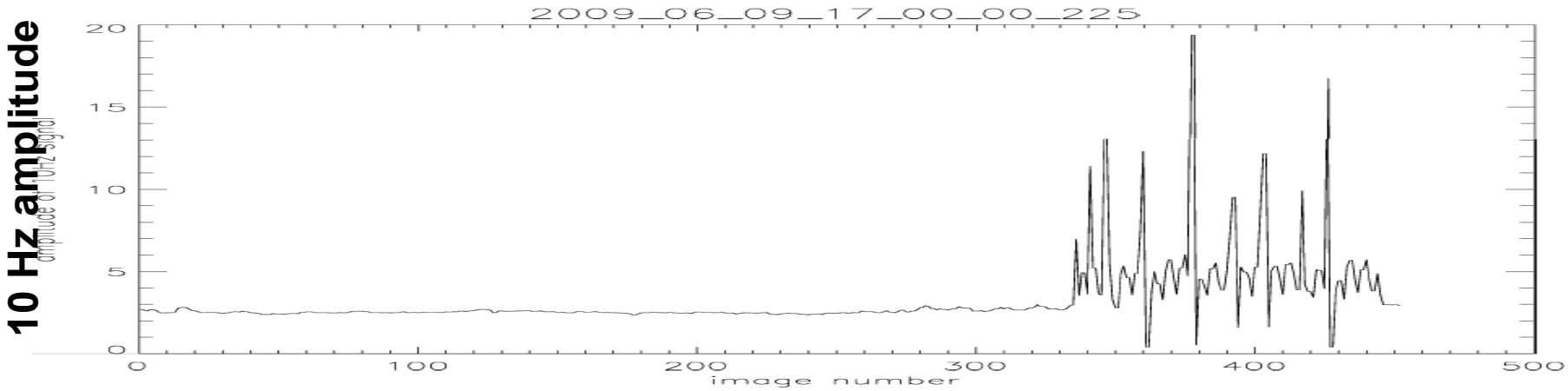
- Extraction Tools allow for looking at time series of variable length à choose appropriate time slice
- Take the FFT of the subset further obtained to get the amplitude of the 10 Hz vibration
- Analyze Observing Data to check whether those moments are indeed of better quality
- Proceed with Science Analysis with the Subset of Data
- Modify approach if necessary

10 Hz amplitude distribution

Good Data Set



14.00 14.27 14.54
14.81

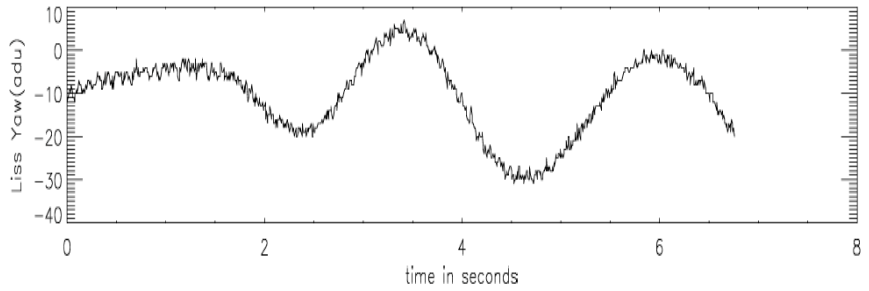


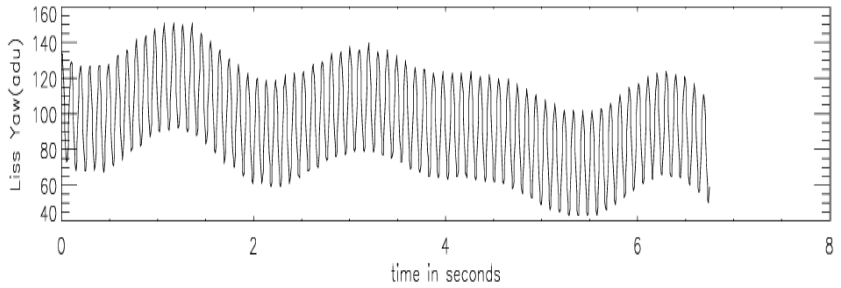
17.00 17.14 17.28 17.42 17.54

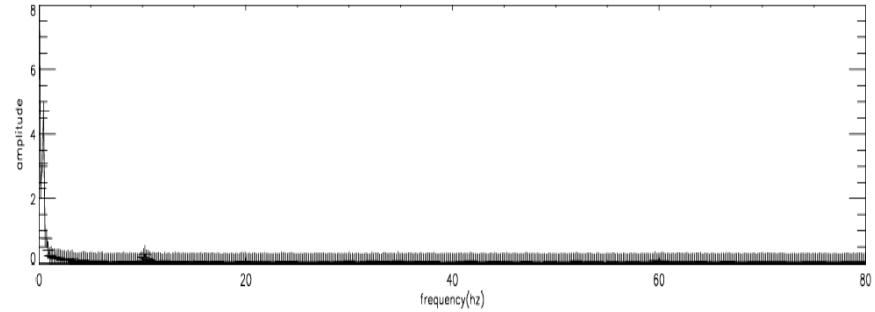
Bad Data Set

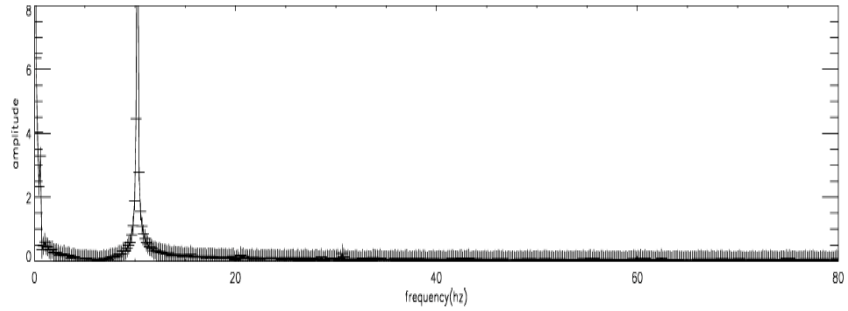
Time in hours

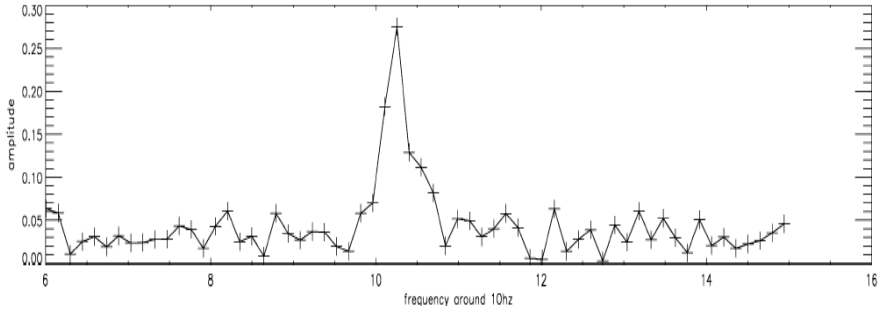
Result I : Liss Yaw plot with varying 10Hz amplitude:

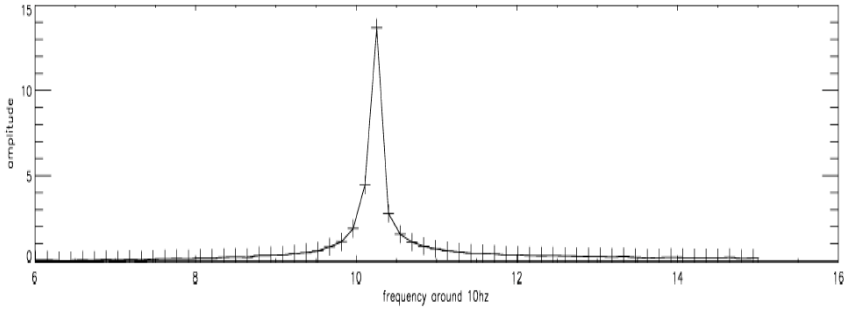








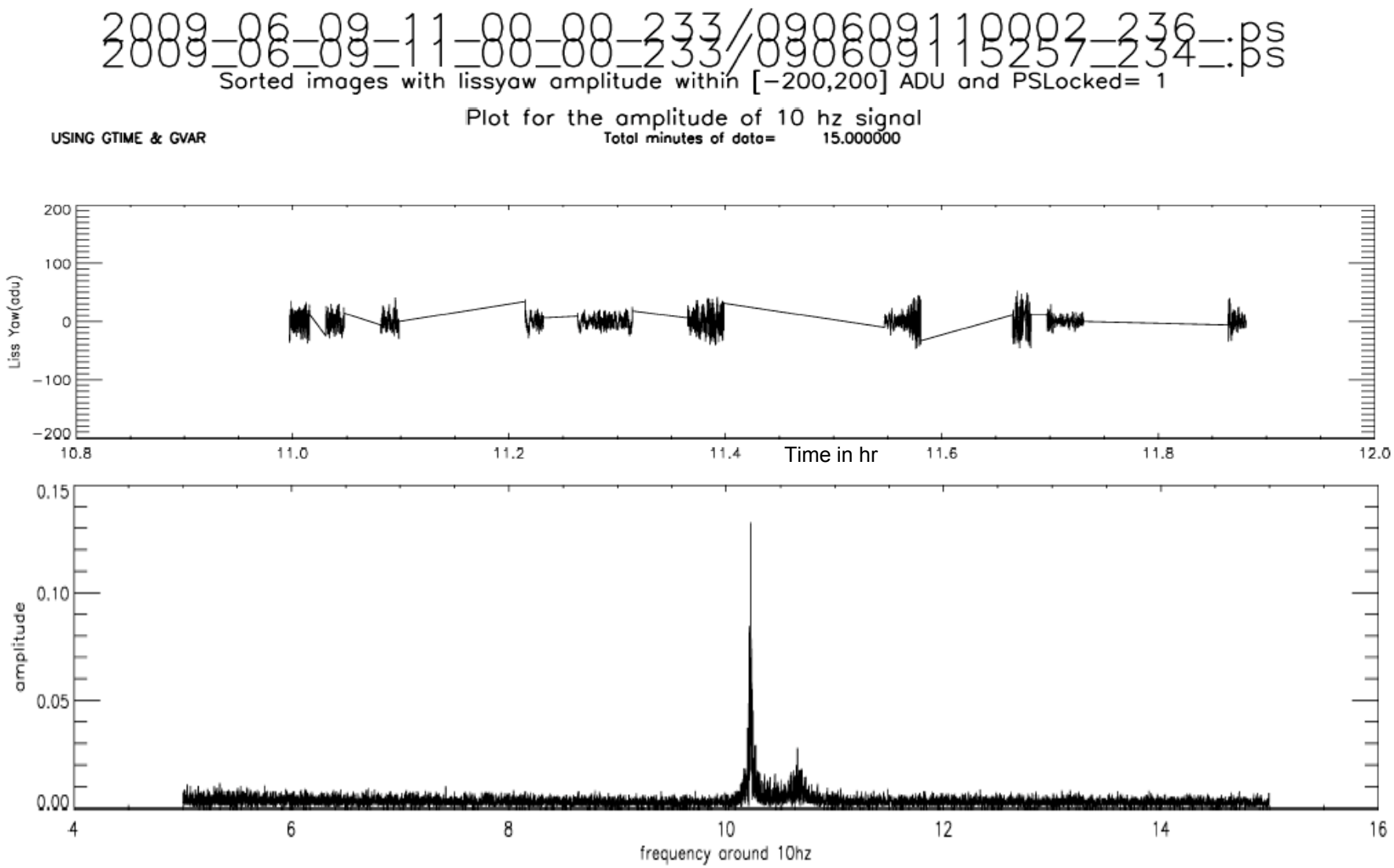




Liss Yaw with low amplitude of 10Hz signal

Liss Yaw with high amplitude

Liss Yaw plot for Sorted Data :

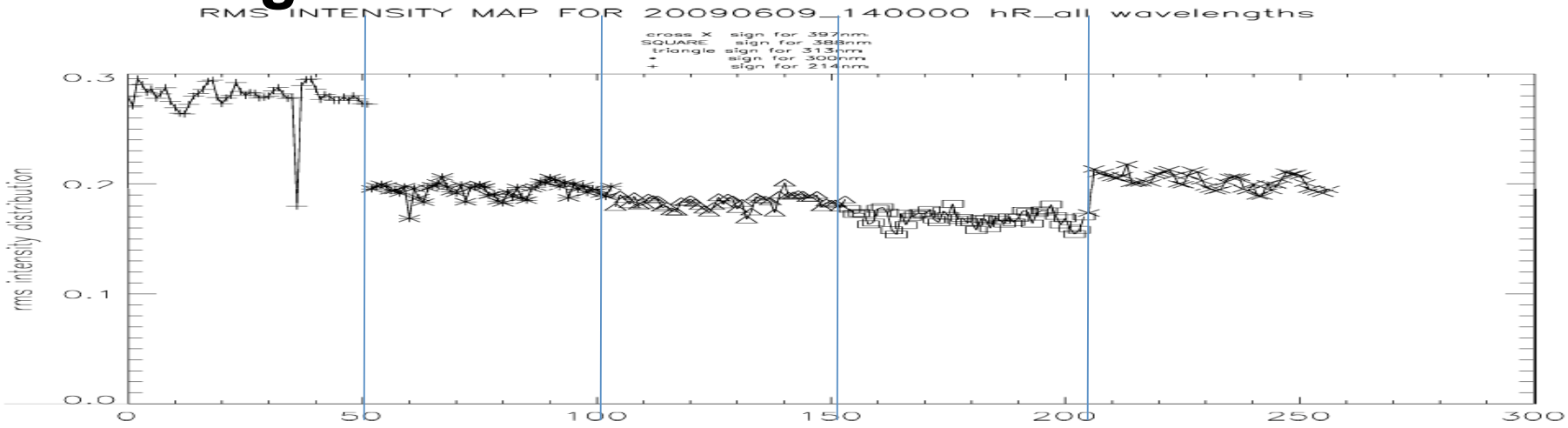


Work Plan II

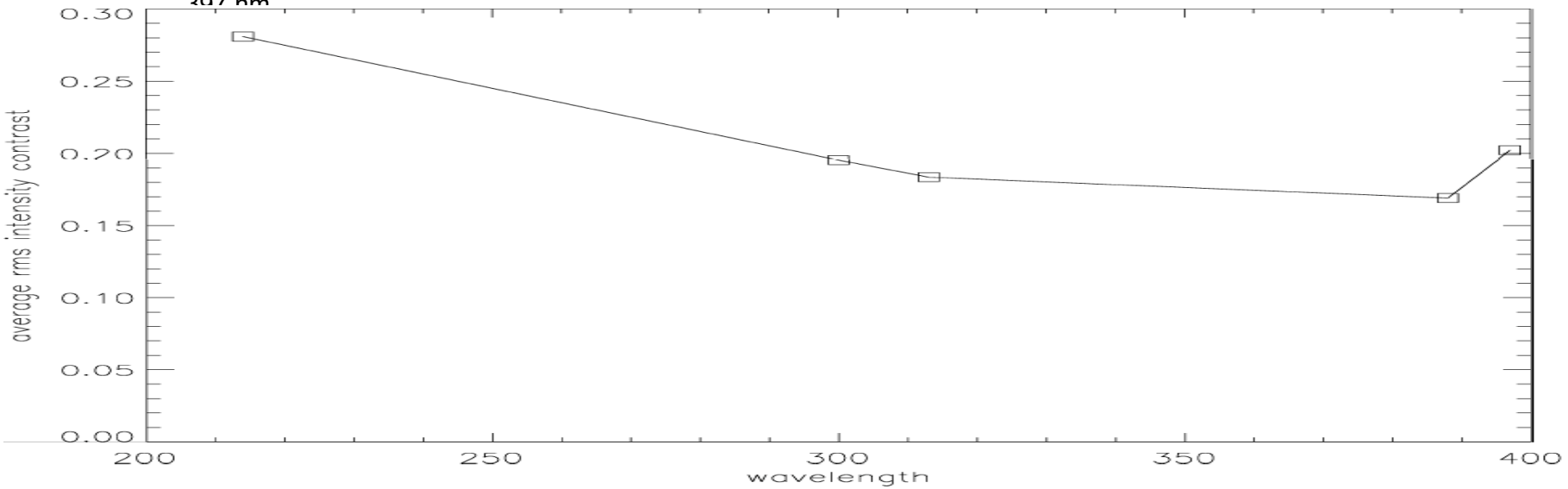
- ✓ **Determine Contrast of the Images in the 5 SUFI wavelengths**

- ✓ **Relate to Solar Irradiance variations in the wavelength range considered**

Result II : RMS Intensity Contrast for all wavelengths



Wavelength : 214 nm 300 nm 313 nm 388 nm 397 nm



Average rms intensity contrast vs Wavelength

RMS Intensity Contrast of different patches of SuFI 214 nm Intensity map :

RMS 1/2 : 27.27 %

RMS 1/3 : 25.87 %

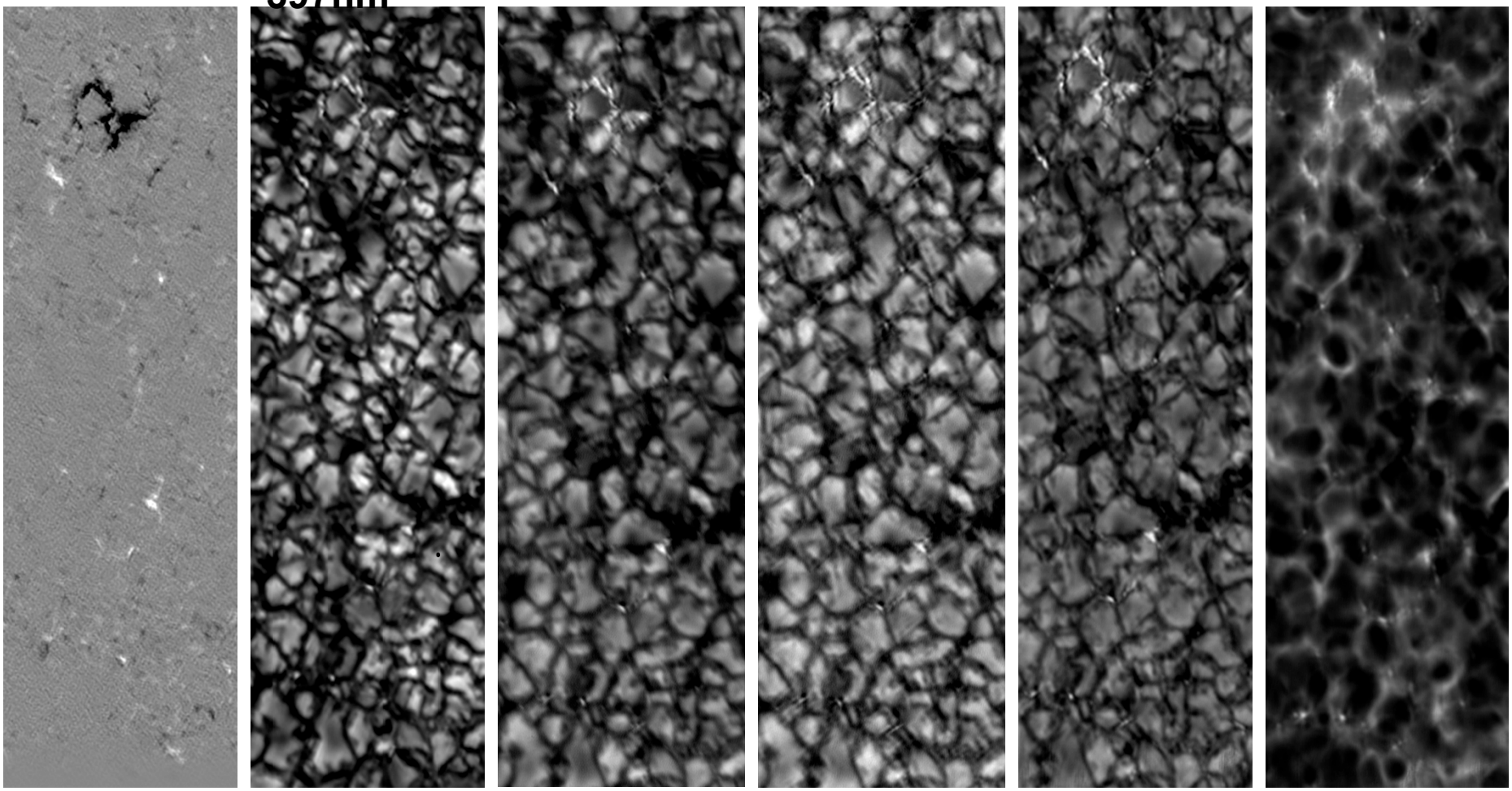
RMS 1/3 : 30.26 %

RMS 1/2 : 29.08 %

RMS 1/3 : 27.25 %

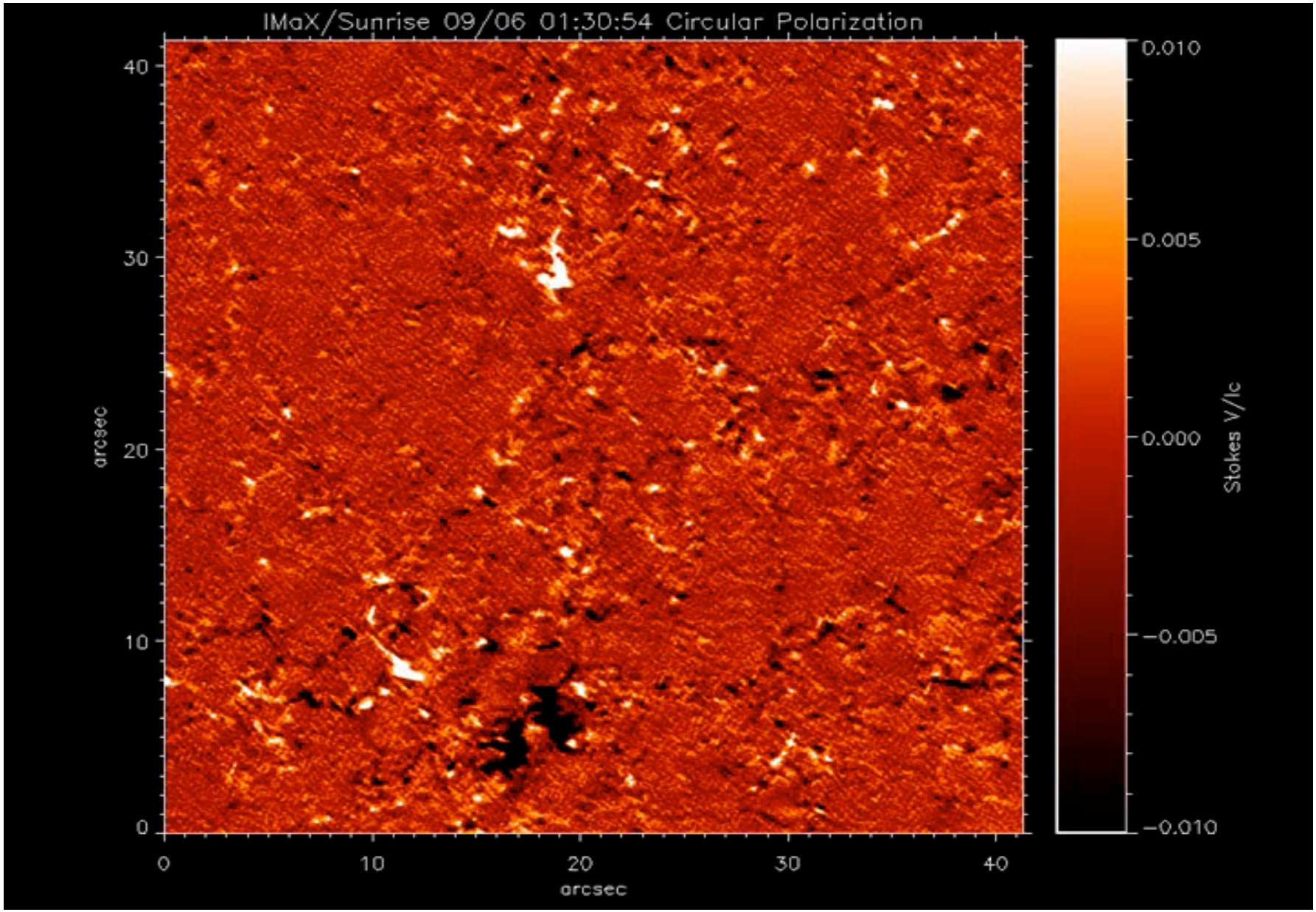
RMS total : 28.19%

RMS INTENSITY CONTRAST



RMS contrast(%) : 16.21 18.76 17.63 15.64 19.30

Stokes V Profile



Future work

- **With the tools developed, we will 'dig deeper' to find the cause of the 10Hz signal**

- **So far we concentrated on June 9 data, application of the analysis tools to the other data will follow**

- **Then the rms contrast variation with varying magnetic flux content will be studied using all data suitable**

Acknowledgments:

Michael Knölker

Jesse Lord

Alice Lecinski

Fellow REU students

Marty Snow

Erin Wood

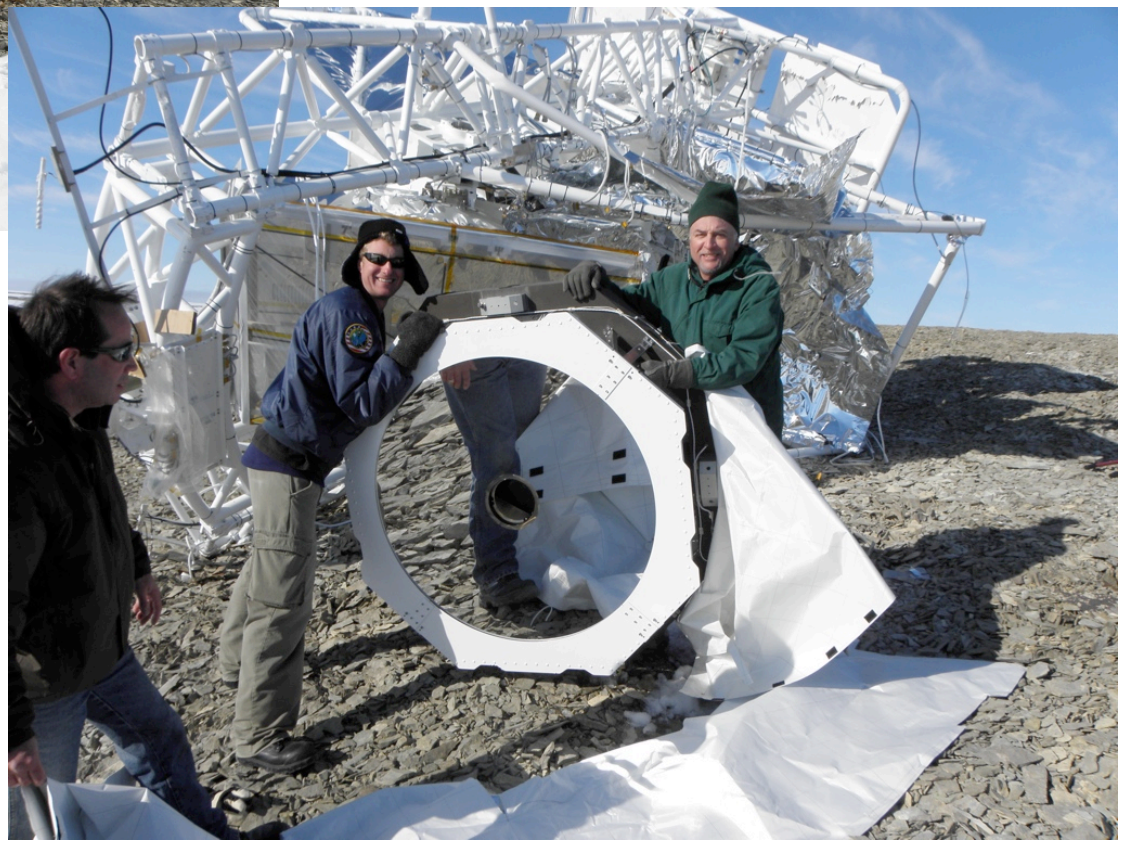
NCAR

HAO

Sunrise: Just before the flight

LAUNCH

Data disks O.K.
Primary Mirror O.K.



Questions
???

- Thank You