

Preparing for Kepler: Simulating Stellar Microvariability

Francisco Ramos Stierle

Gibor Basri

Ansgar Reiners

Tom Berger

Kurt Soto

Tristan Lewis

University of California, Berkeley

University of California, Berkeley

University of Hamburg

Lockheed Martin Solar Astrophysics Laboratory

University of California, Santa Barbara

University of California, Berkeley



Cool Stars XIV - TPF/Darwin workshop

November 11th, 2006

Pasadena, California

Better title for the talk: “P” Broadening

Not pressure broadening...
Nor “Pancho” Ramos Stierle

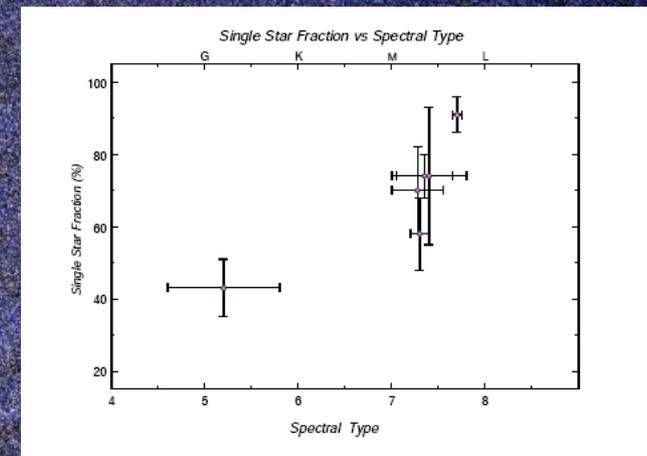
University of California, Berkeley

Rather:

Perspective

OUTLINE

- The Kepler mission in the context of stellar microvariability (active regions and the nature of faculae)
- More examples of “P” broadening:
 - 3D surfaces and lightcurve simulations
- 5 take-home ideas



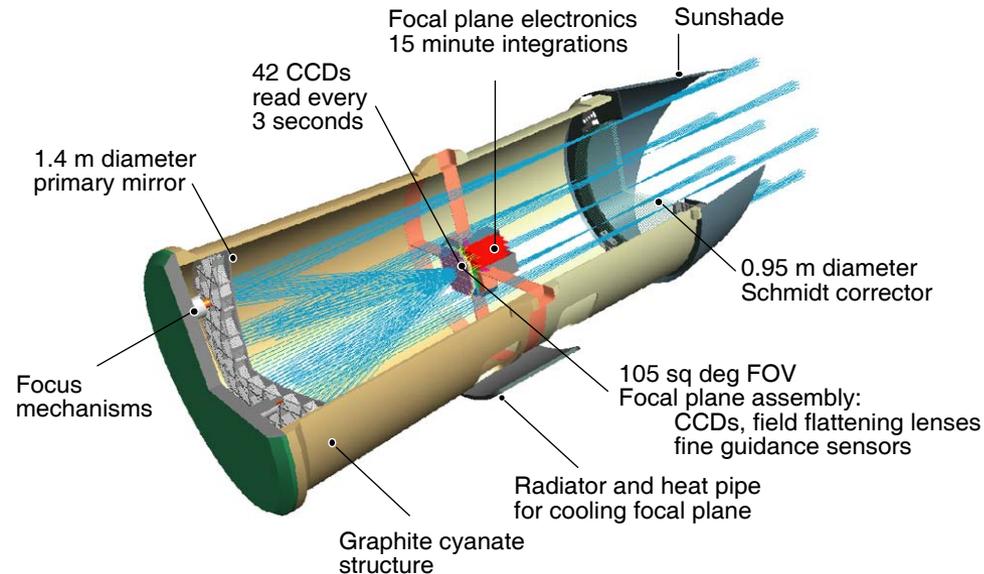
Henry & McCarthy 1990
Duquennoy & Mayor 1991
Fischer & Marcy 1992
Leinert et al. 1997
Bouy et al. 2003
Delfosse et al. 2004
Siegler et al. 2005
... Lada 2006



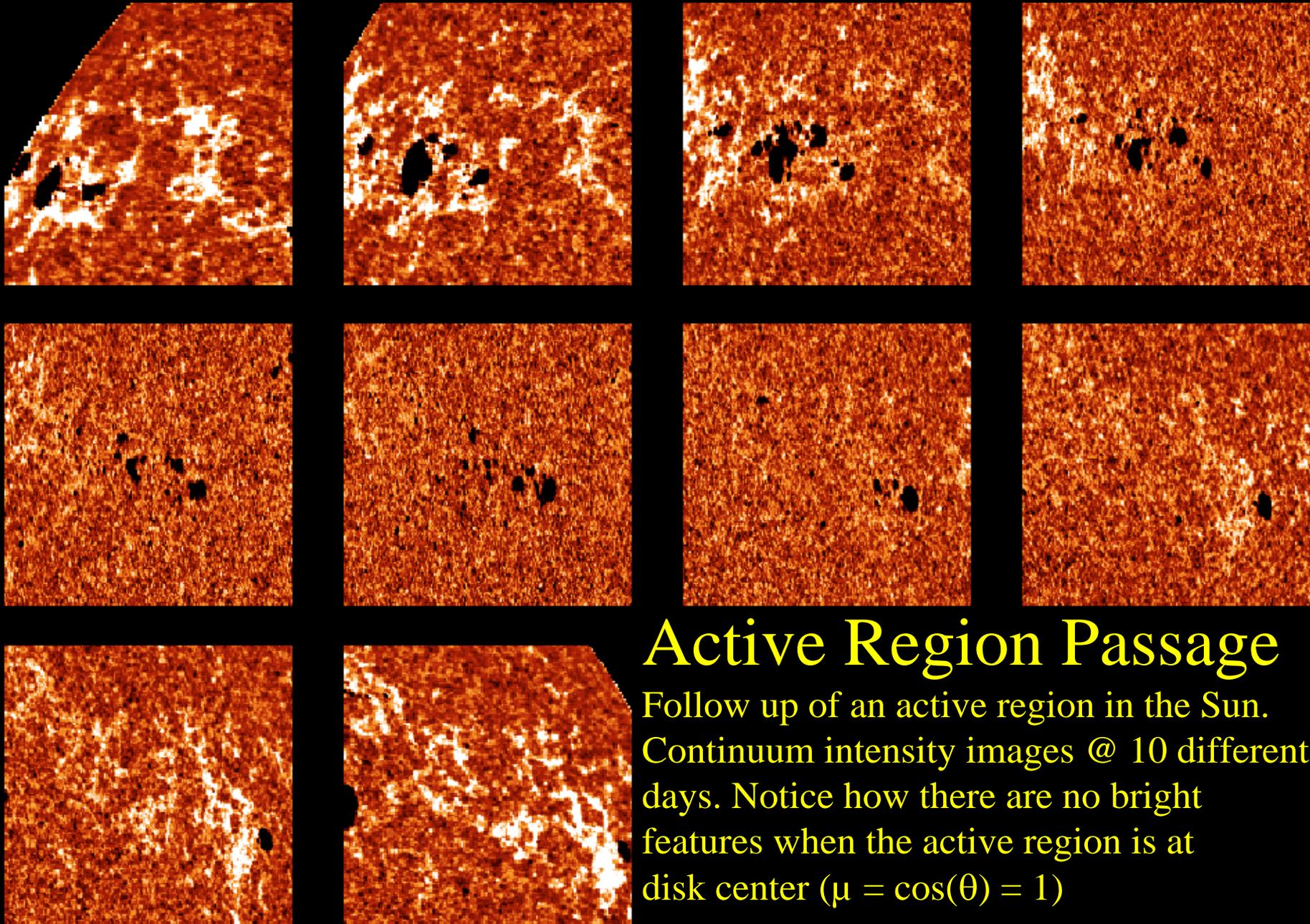
~ 75% of the total number of stars are **Mdwarfs**.
- Multiplicity of systems decreases with spectral type

Single Star fraction ~70%

- The *Kepler Mission* is optimized for finding habitable planets (0.5 to $10 M_{\oplus}$) in the HZ (near 1 AU) of solar-like stars
- Continuously and simultaneously monitor $100,000$ dwarf stars using a 1 -meter Schmidt telescope: FOV >100 deg² with 42 CCDs
- Photometric precision of < 20 ppm in 6.5 hours on $V_{\text{mag}} = 12$ solar-like star $\rightarrow 4\sigma$ detection for one Earth-sized transit



JD 51989.50 – 51999.50



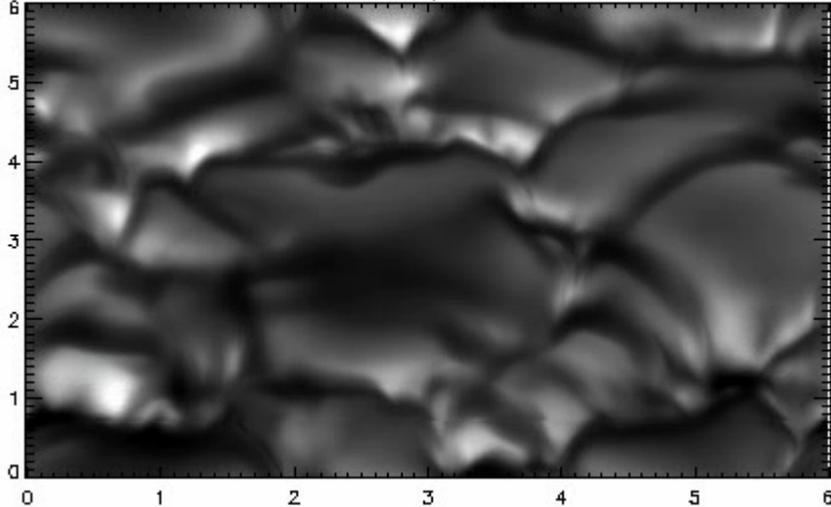
Active Region Passage

Follow up of an active region in the Sun.
Continuum intensity images @ 10 different
days. Notice how there are no bright
features when the active region is at
disk center ($\mu = \cos(\theta) = 1$)

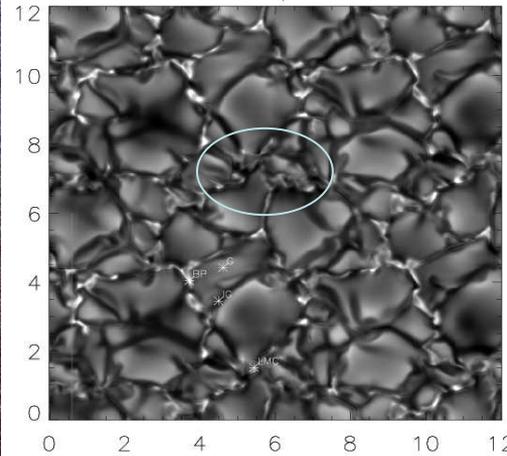
Granules: THINK 3D!

Reality is not always as it seems...

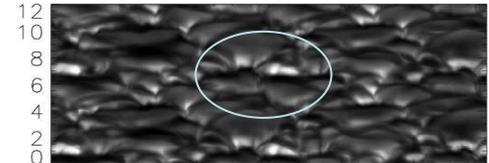
Gband $\mu=0.6$



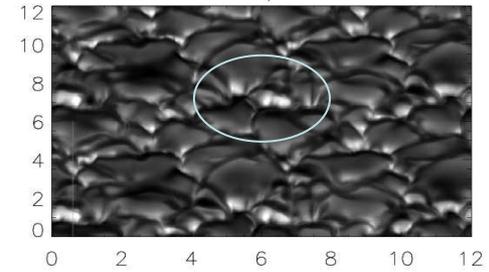
Gband $\mu=1.0$



Gband $\mu=0.4$



Gband $\mu=0.6$

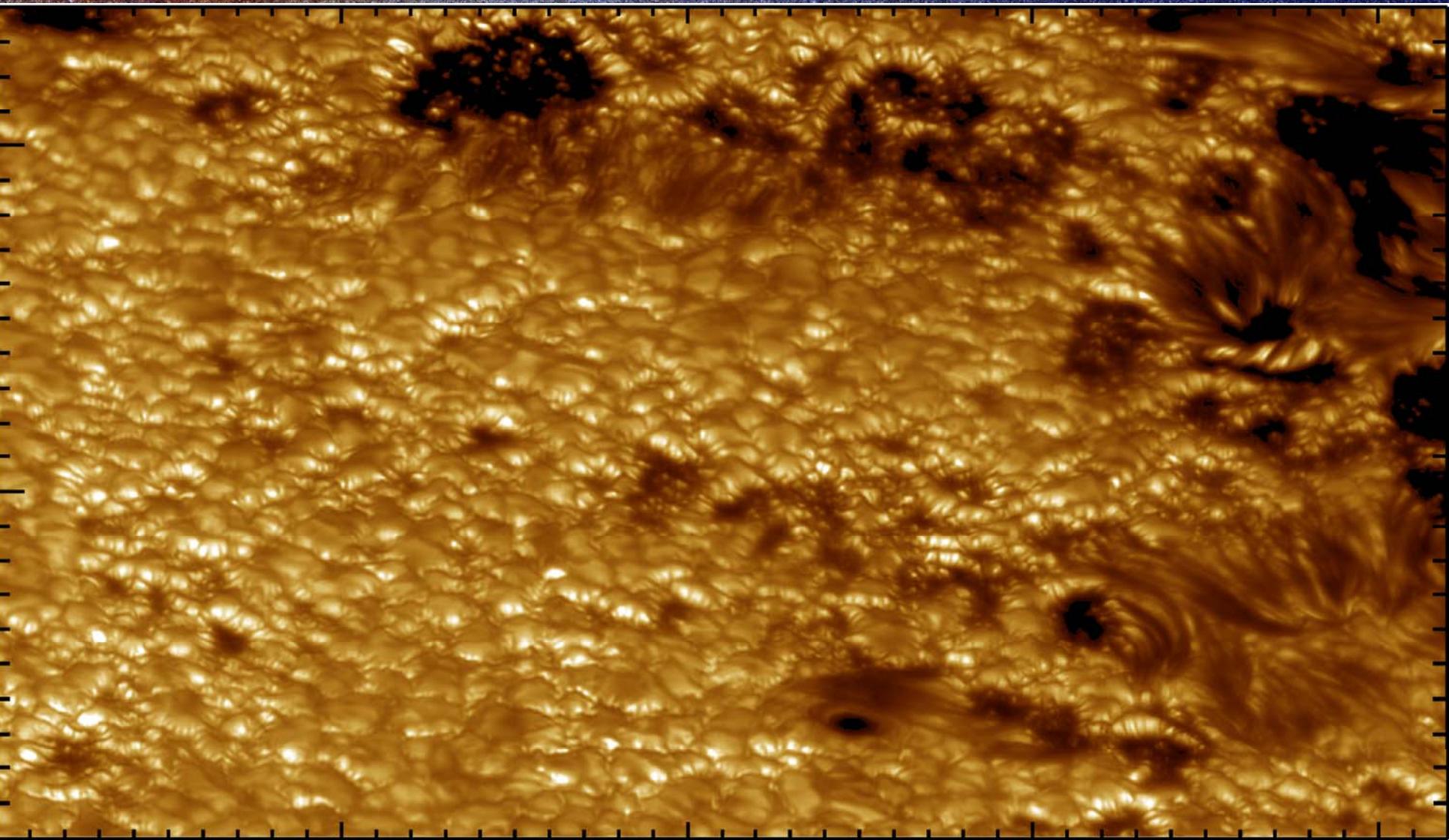


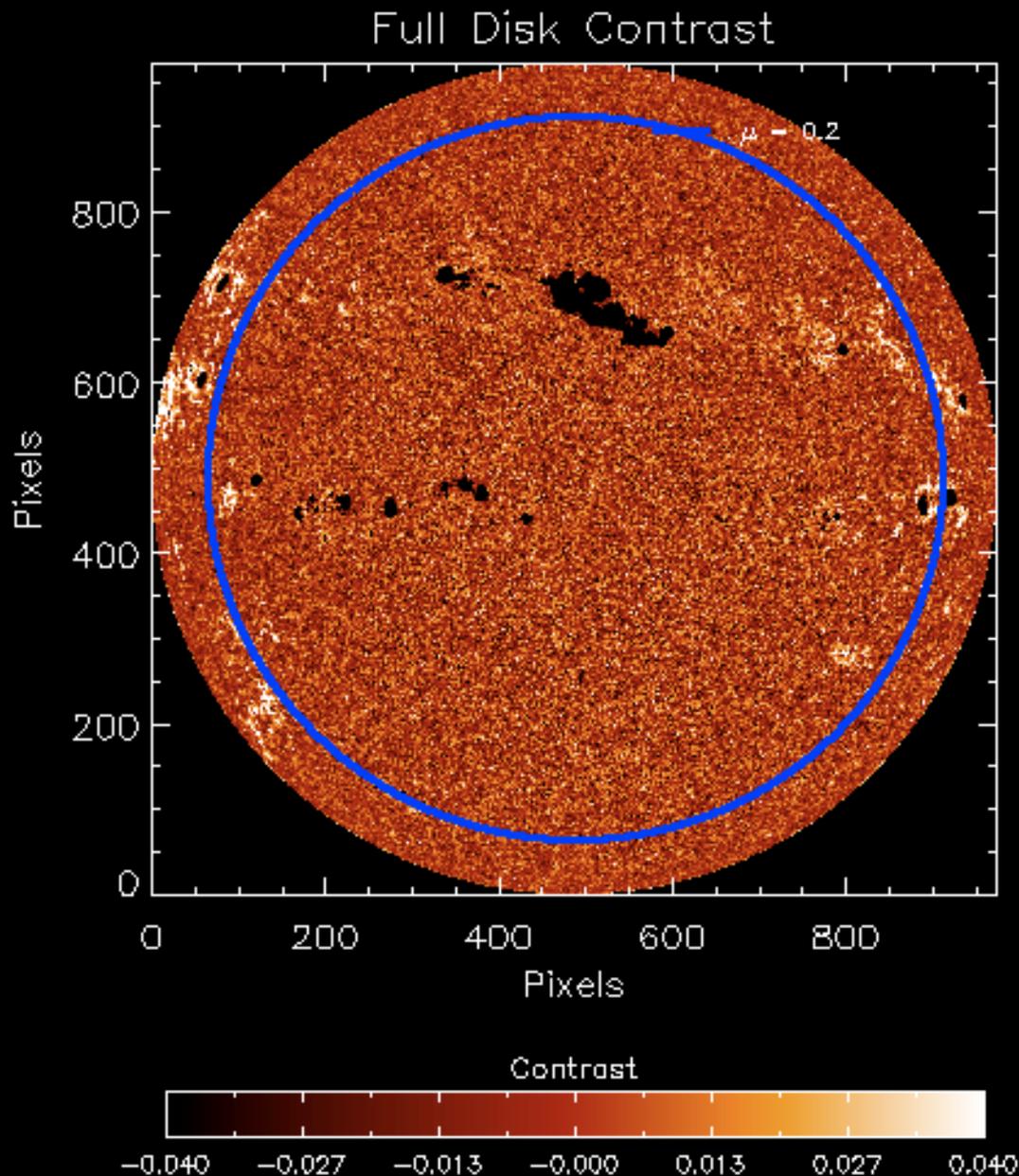
3D compressible MHD models

- Carlsson, Stein, et al., ApJL 2004 July
- Keller, Schussler, et al., ApJL 2004 May

Faculea: Latin for *Small Torches*

with the Swedish 1-meter Solar Telescope

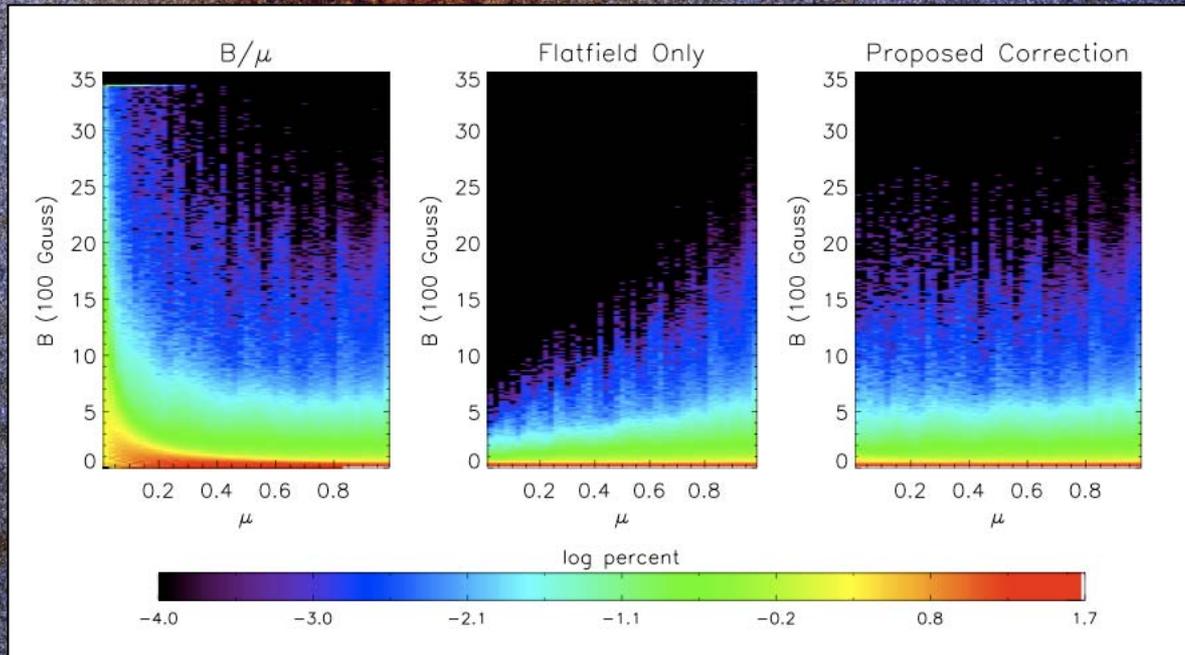
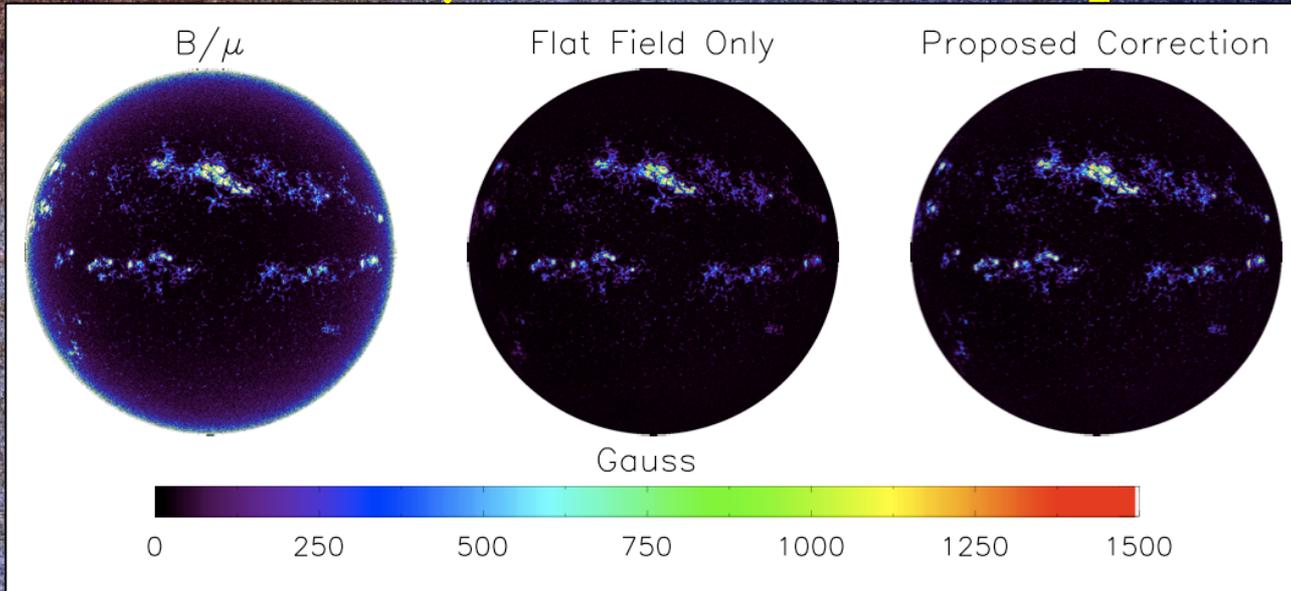




**Think out of
the... circle**

Detailed study of the magnetic field-intensity relationship of faculae requires close look towards the edge of the disk.

The B/μ Correction vs Empirical Correction



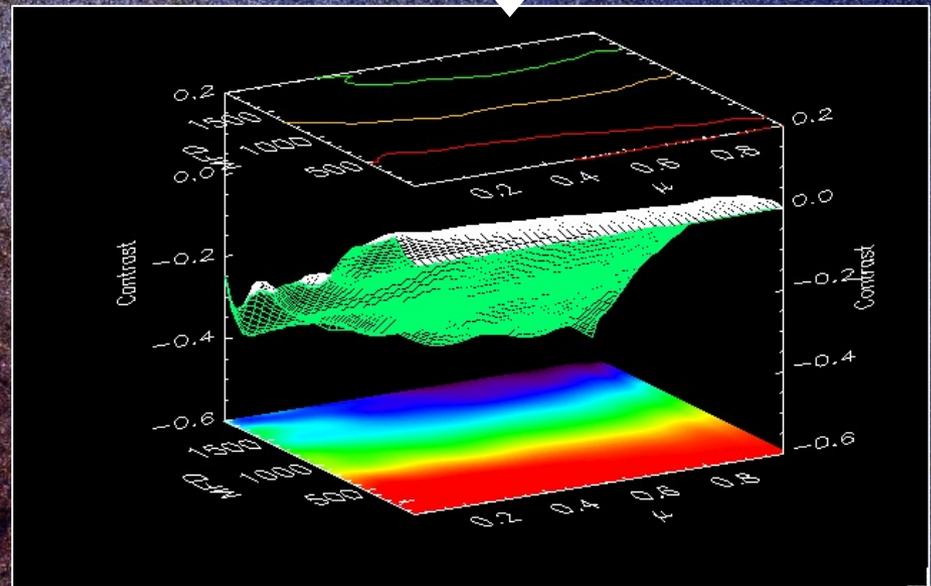
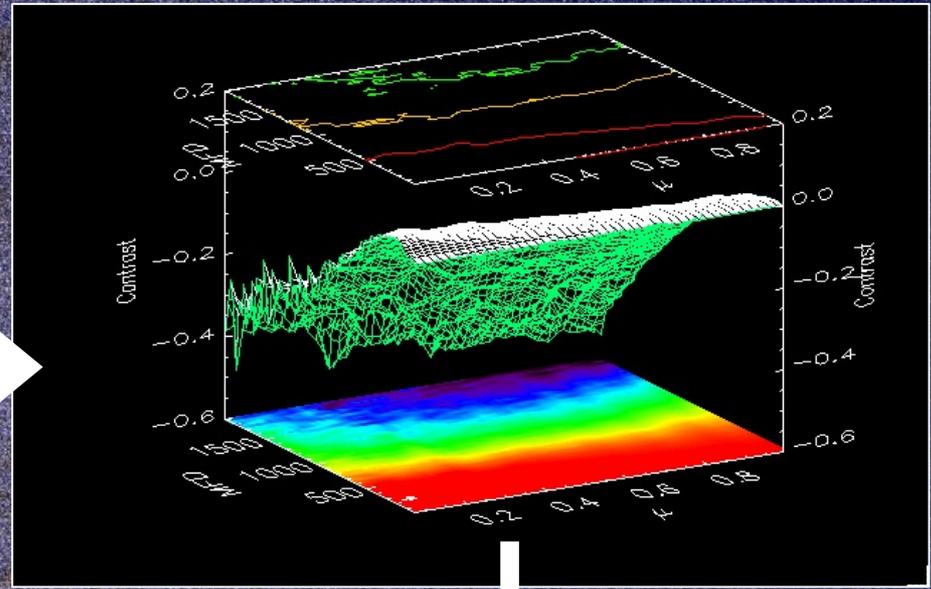
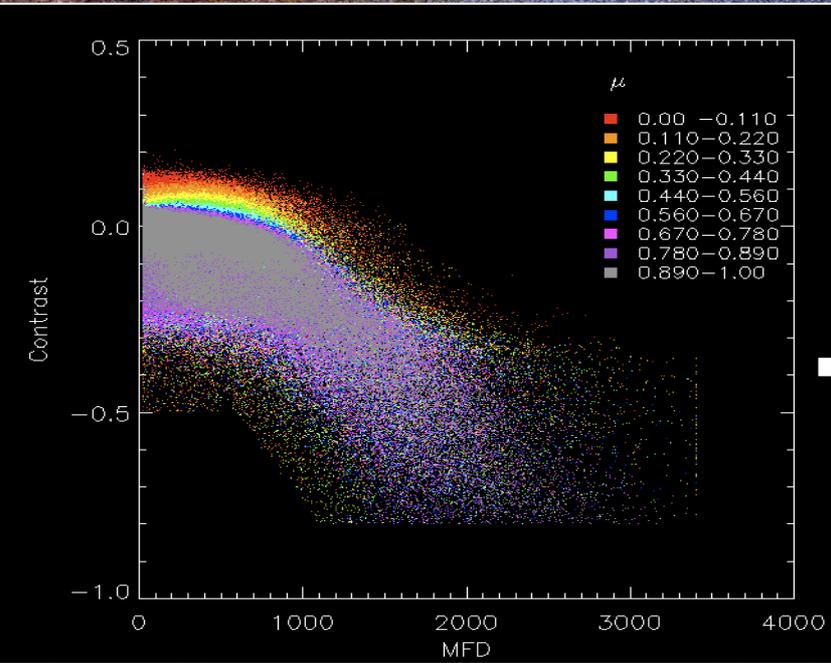
Top : The magnetogram of one day.

Bottom: the standard correction for B field divides by μ . While the proposed empirical correction does not modify the intrinsic values of active regions at the limb or at disk center.

$$B = \begin{cases} B_{Obs} \text{ No correction} & B_{Obs} < 15 \text{ G} \\ \frac{B_{Obs}}{0.9+0.1\mu} & 15 \text{ G} > B_{Obs} > 30 \text{ G} \\ \frac{B_{Obs}-30\text{G}}{0.25+0.75\mu} + 30 \text{ G} & B_{Obs} > 30 \text{ G} \end{cases}$$

Soto et al. in preparation

Fit Intensity Surface



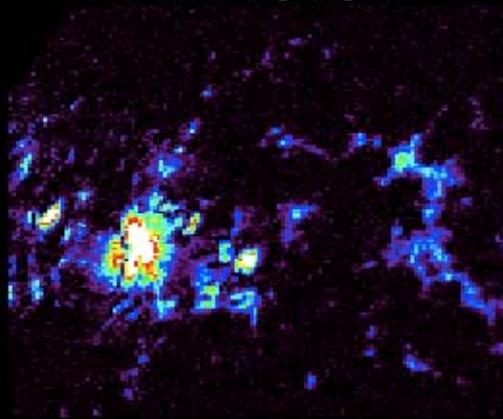
25 million points were binned and then we fit the Intensity surface as a function of B and μ

Soto et al. in preparation

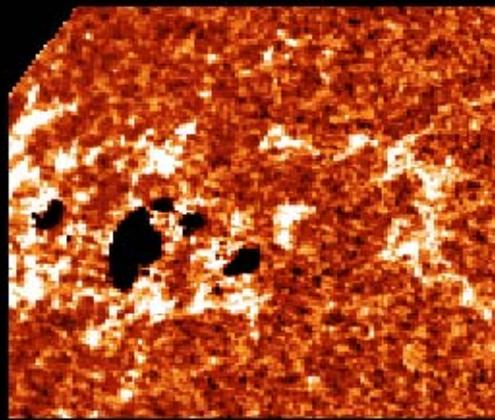
Triplets: Magnetogram/Real Image/ Prediction

JD 51990.50 $\mu = 0.24$

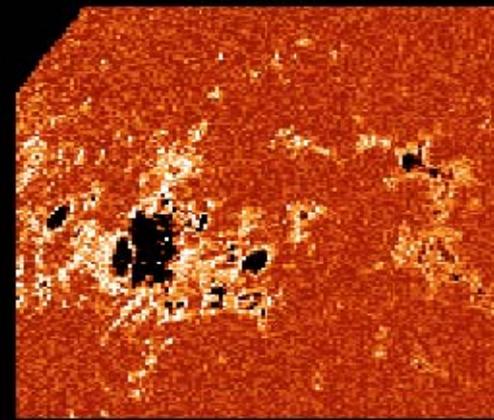
Processed Magnetogram



Continuum

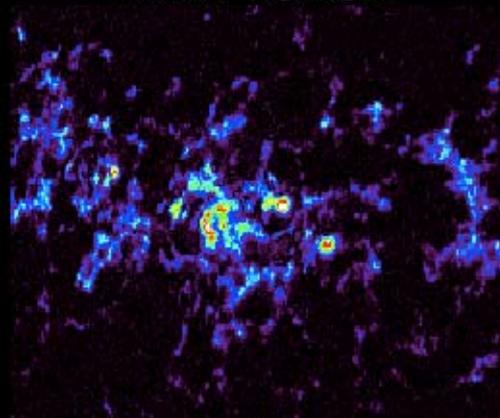


Predicted

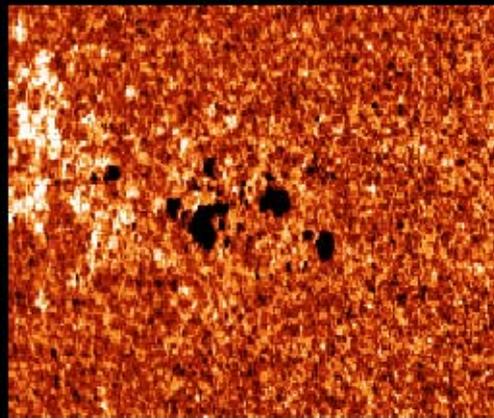


JD 51992.50 $\mu = 0.58$

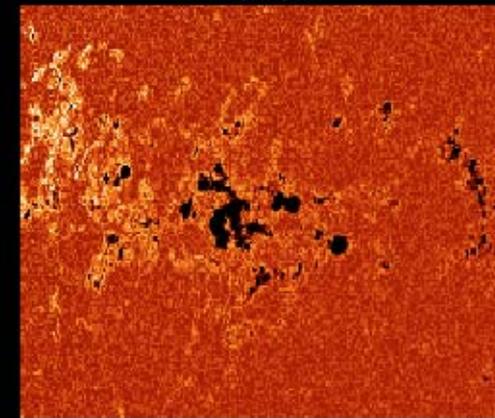
Processed Magnetogram



Continuum

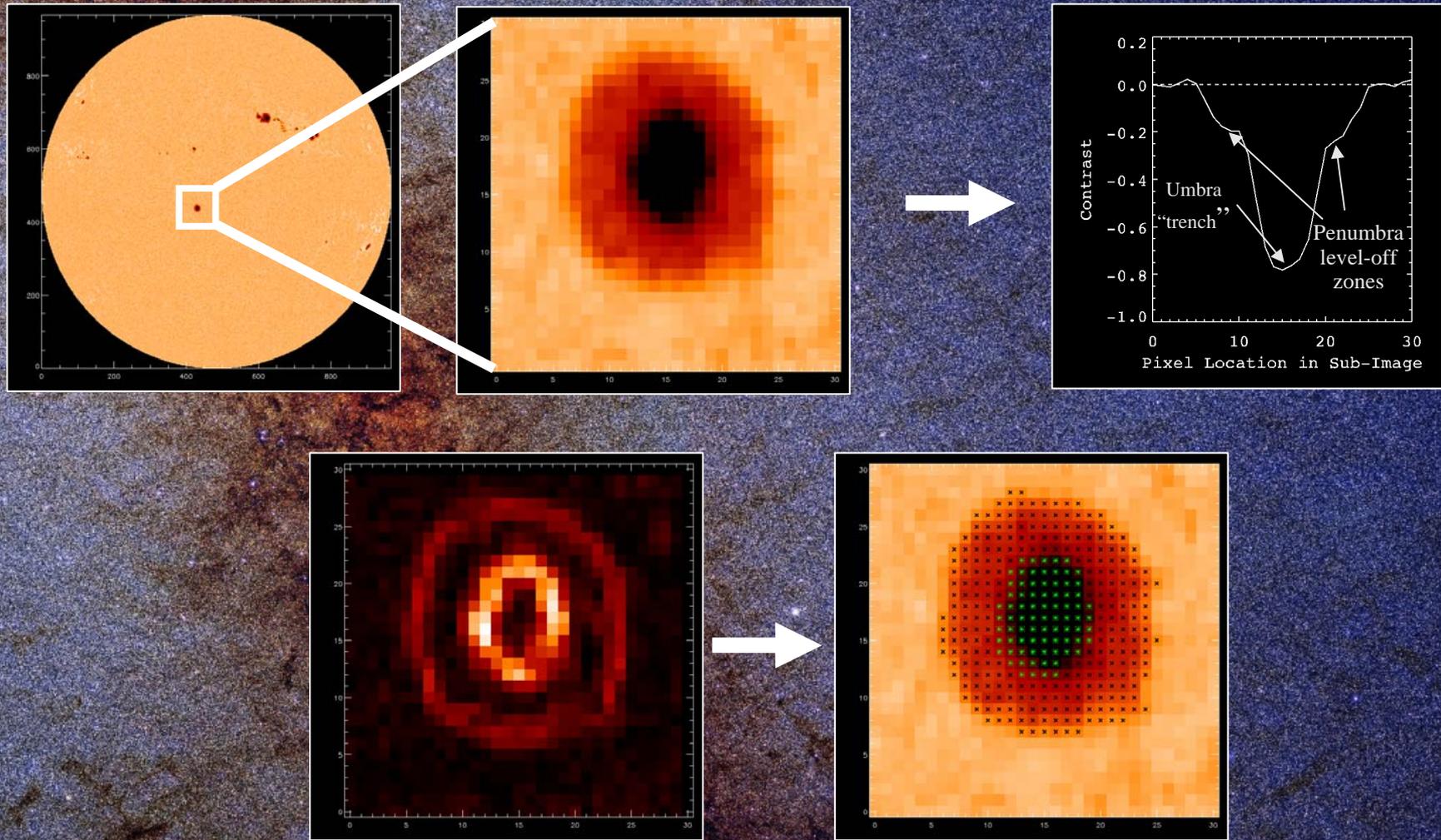


Predicted



Soto et al. in preparation

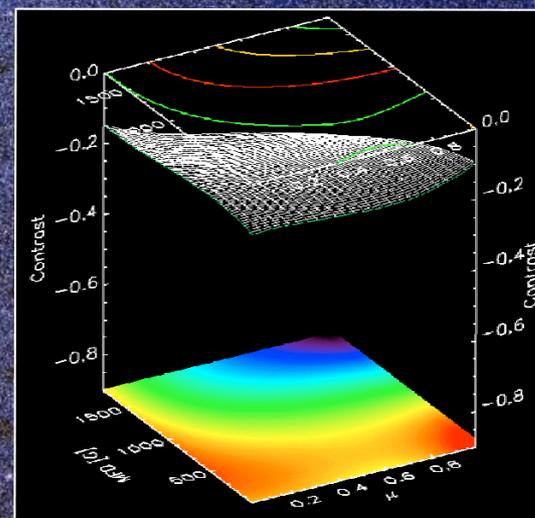
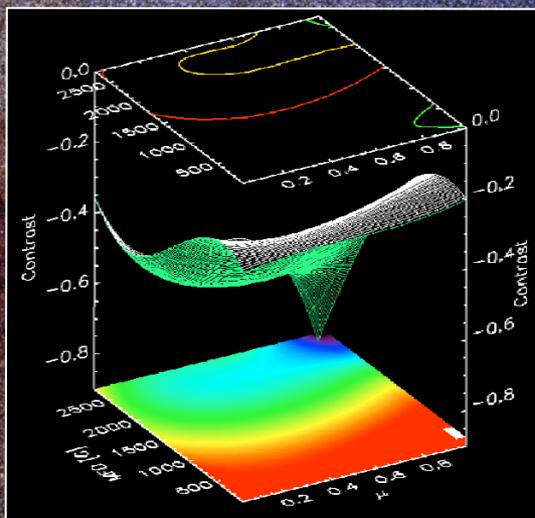
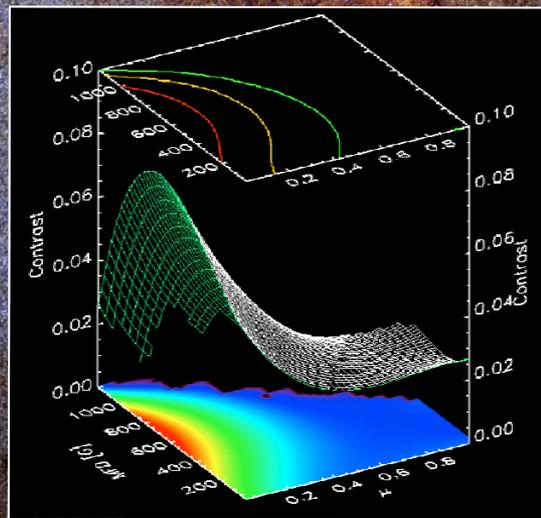
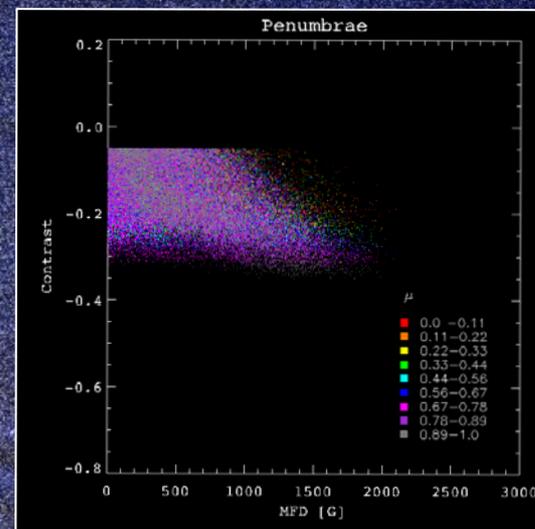
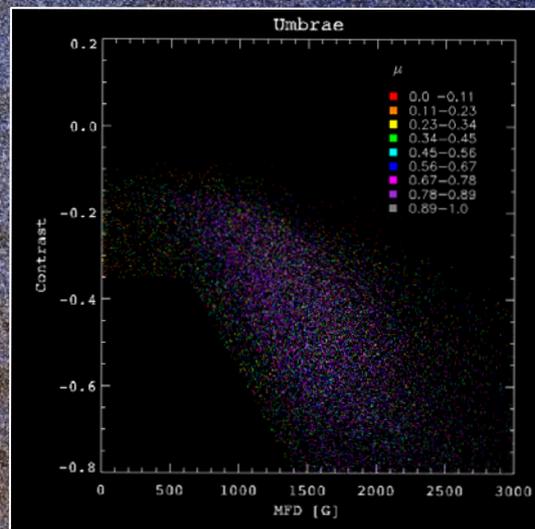
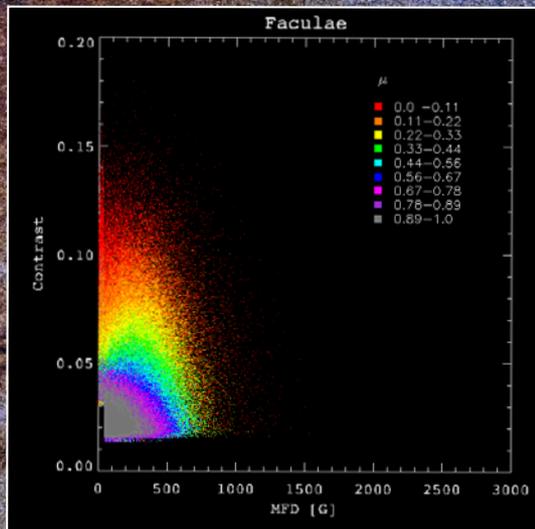
Image Segmentation: Umbra Vs Penumbra



Algorithm to identify plateau and sharp edges of a sunspot:
Roberts and Canny approaches.

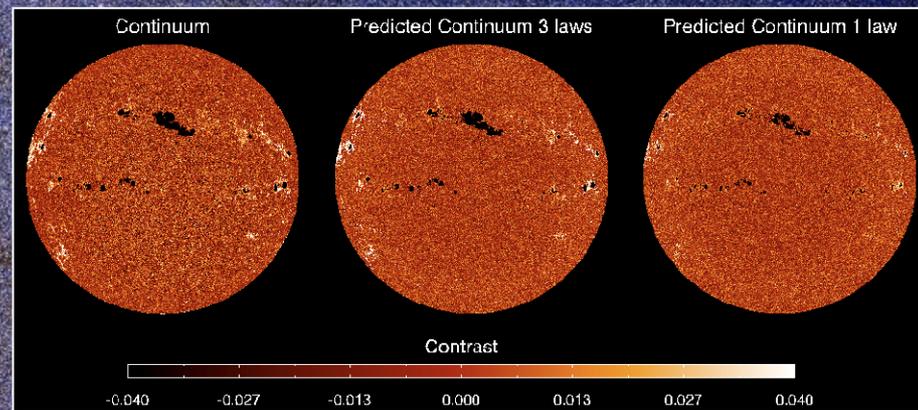
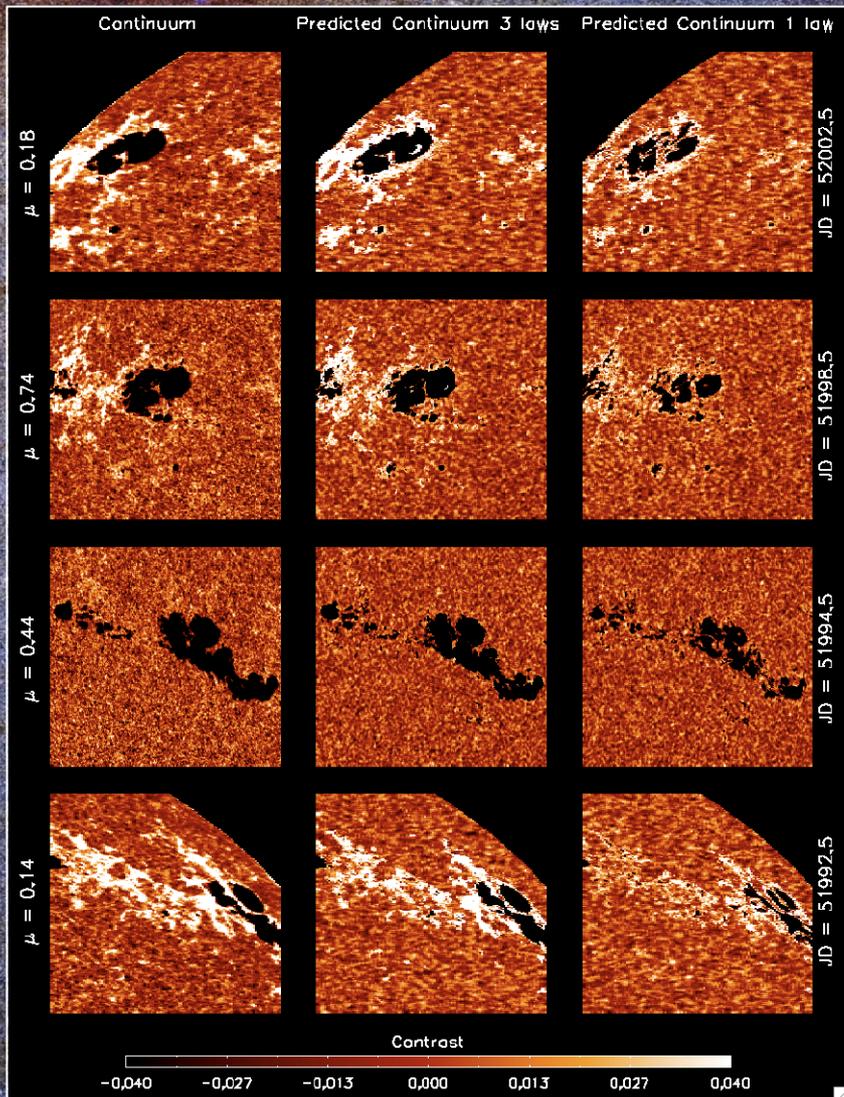
Lewis et al. in preparation

Image Segmentation: Umbra, Penumbra & Faculae



Lewis et al. in preparation

Real Sun Vs Simulated Data (1 law Vs 3 laws)

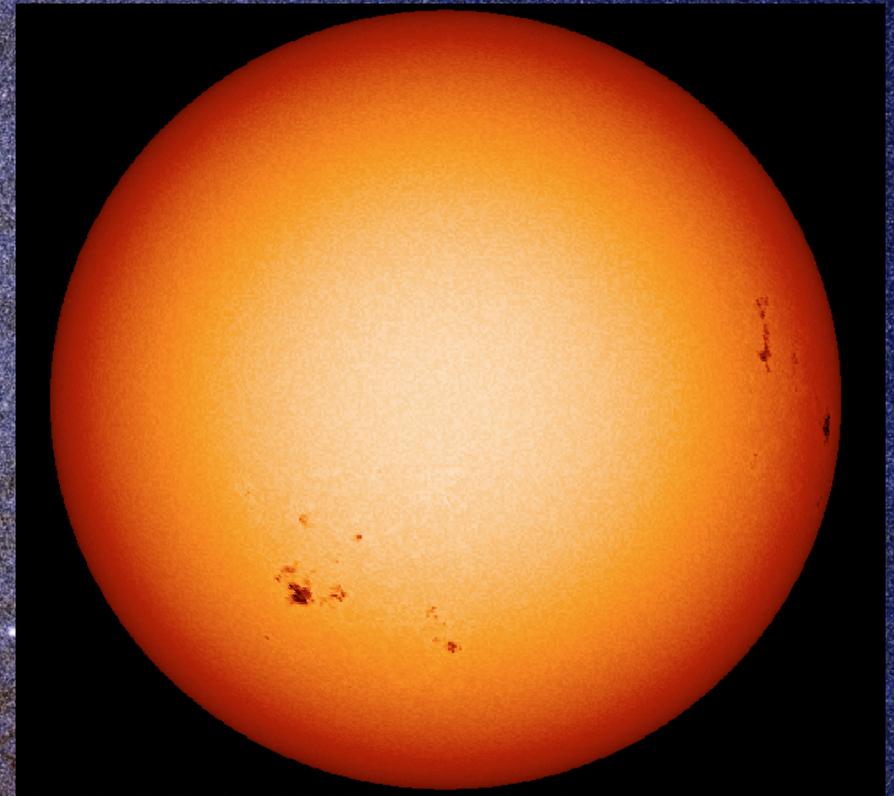
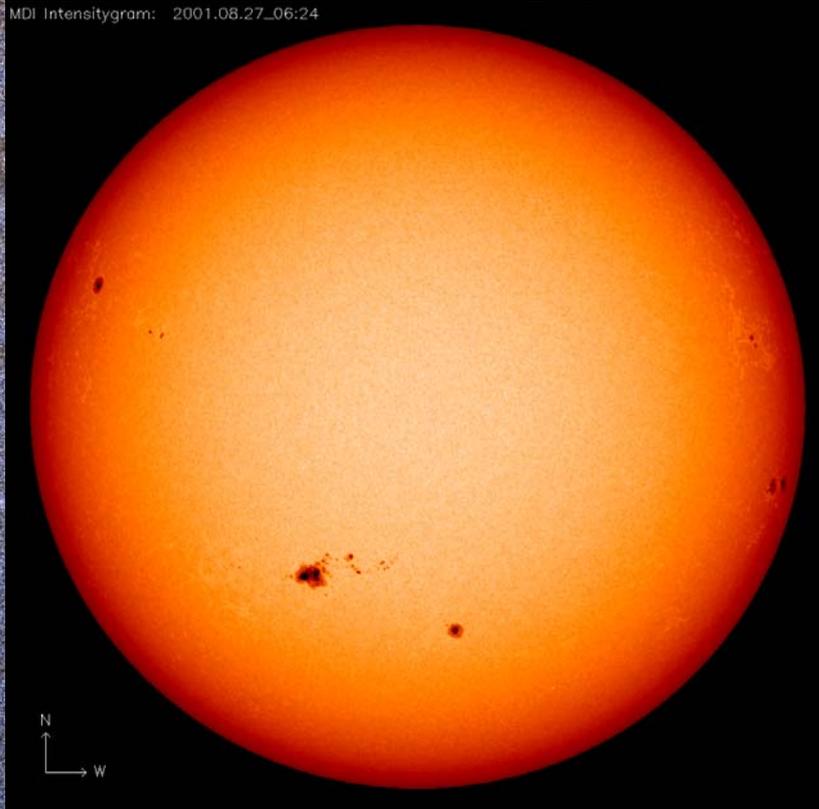


Lewis et al. in preparation

Real Sun

Vs

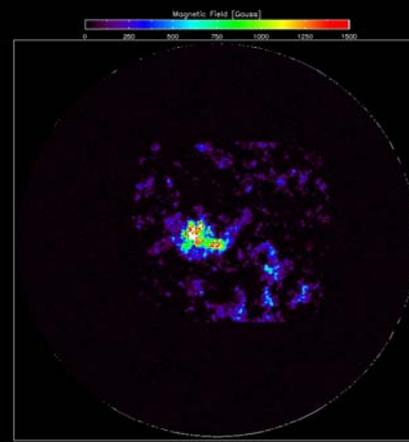
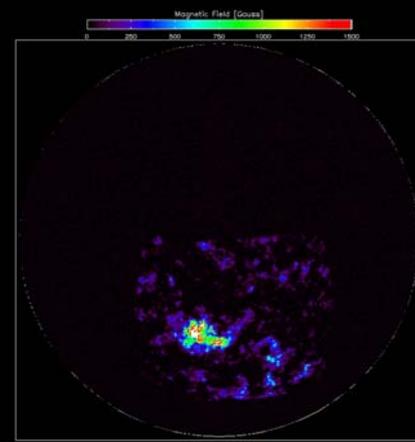
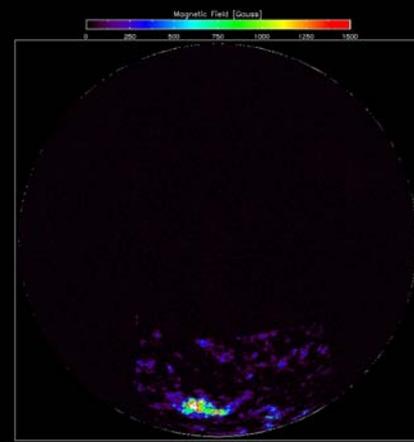
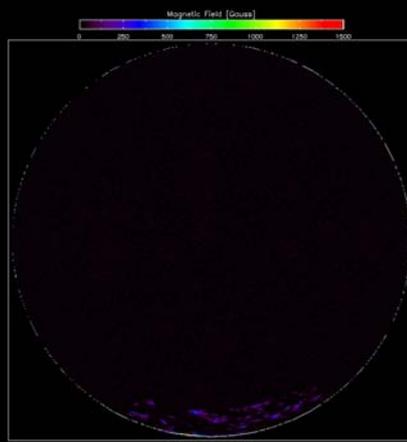
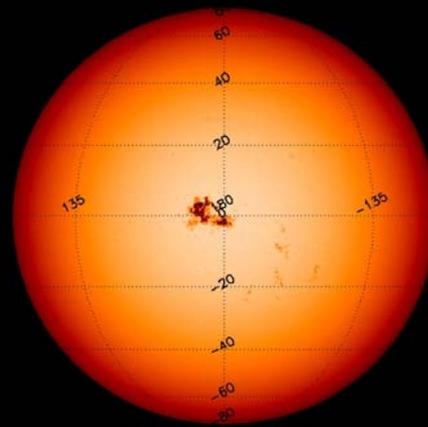
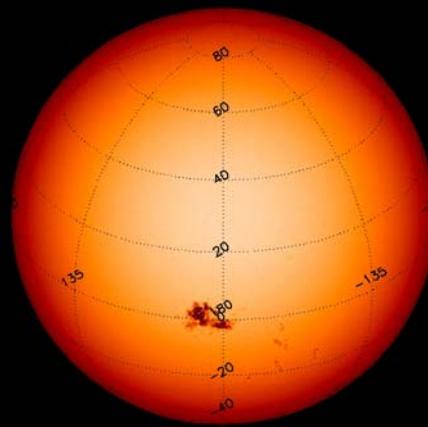
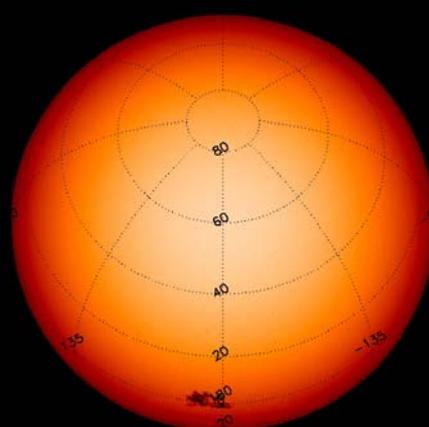
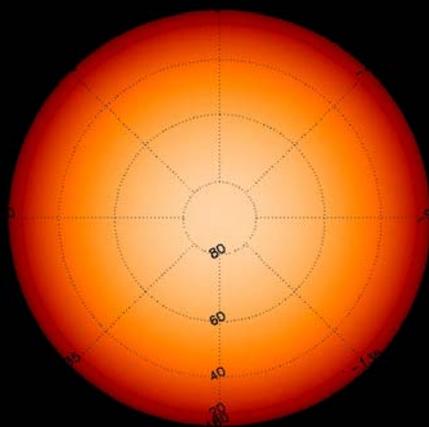
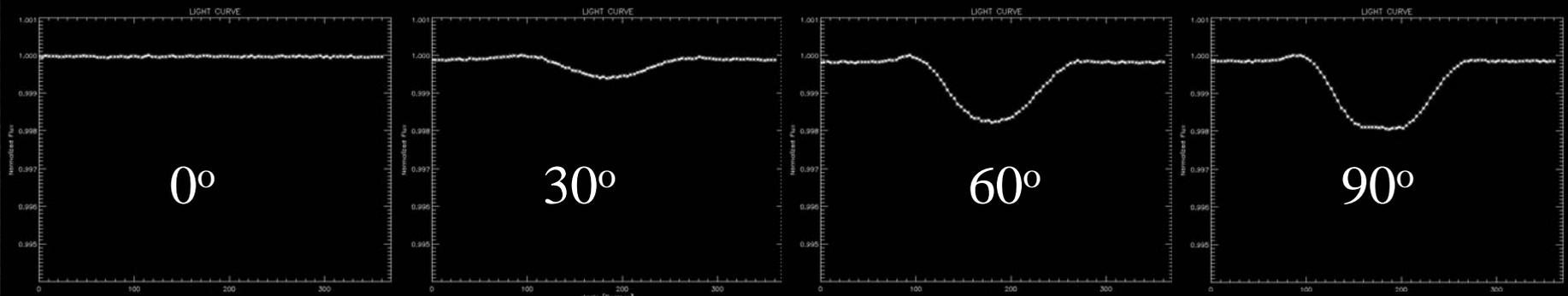
Simulated Data



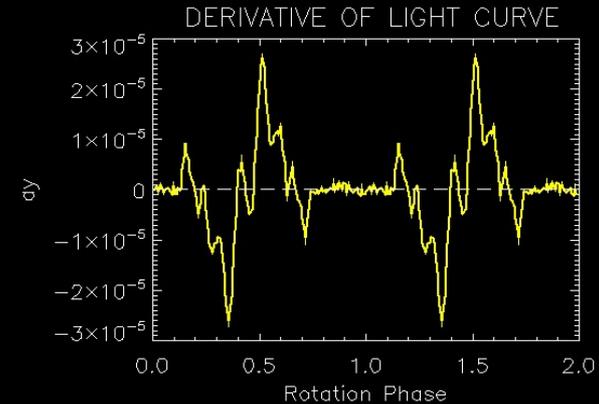
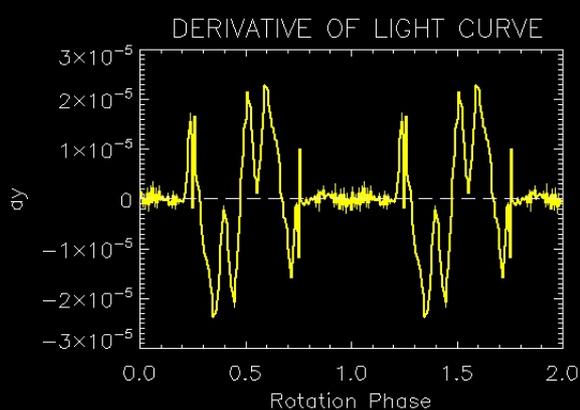
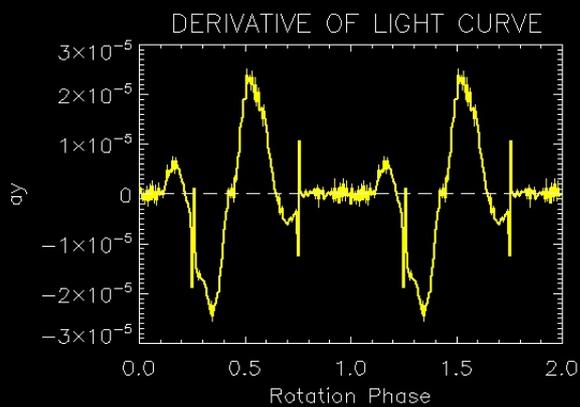
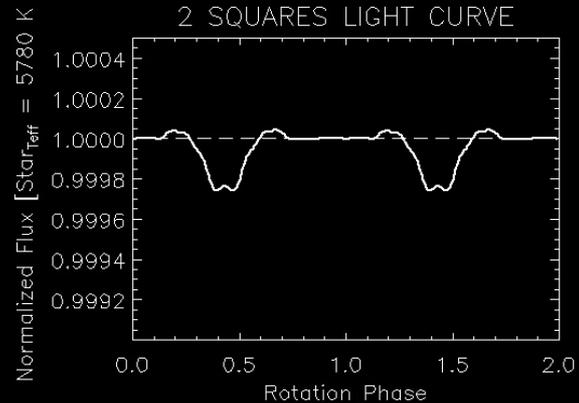
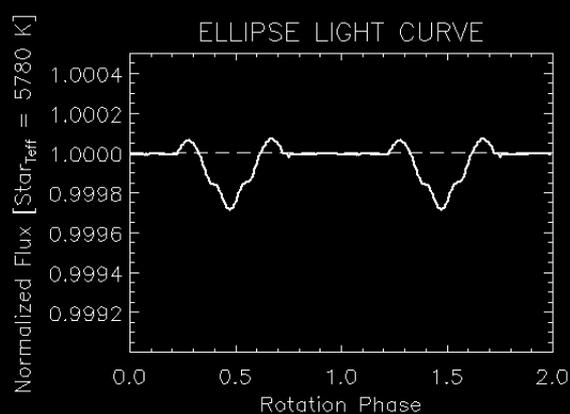
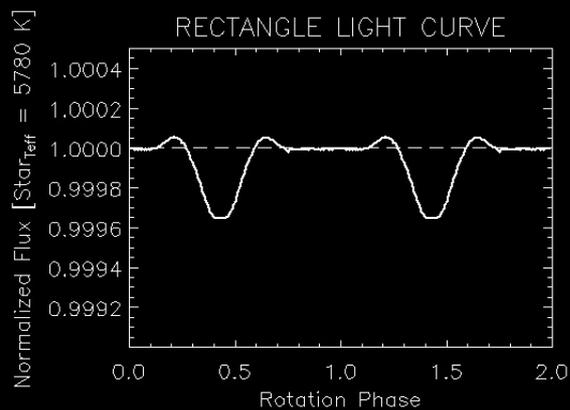
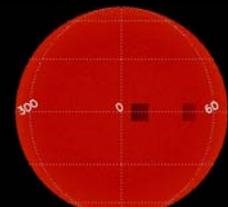
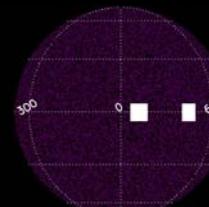
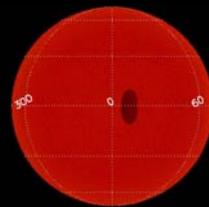
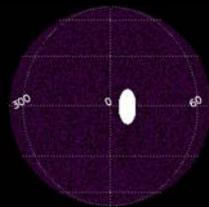
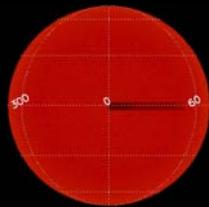
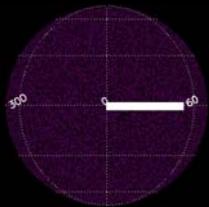
Given the fractal nature of Sunspots...
McAteer et al. 2005

We use a **fractal** method to generate a magnetic field distribution in a specified patch of stellar surface with covering and strength factors.

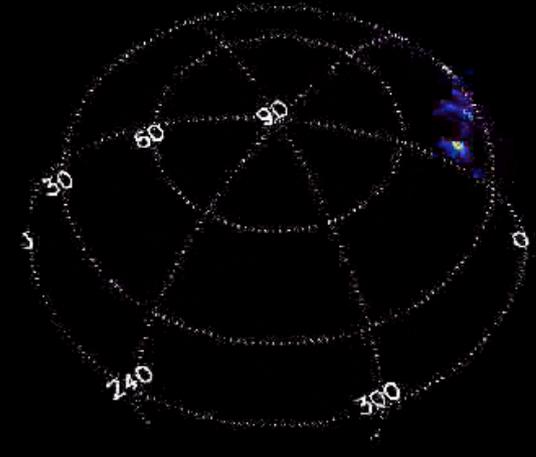
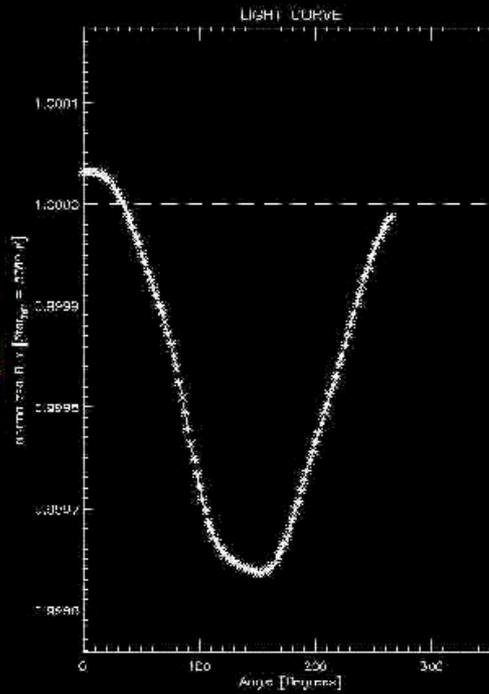
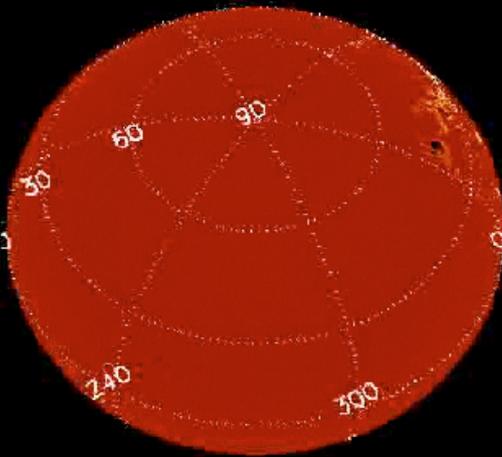
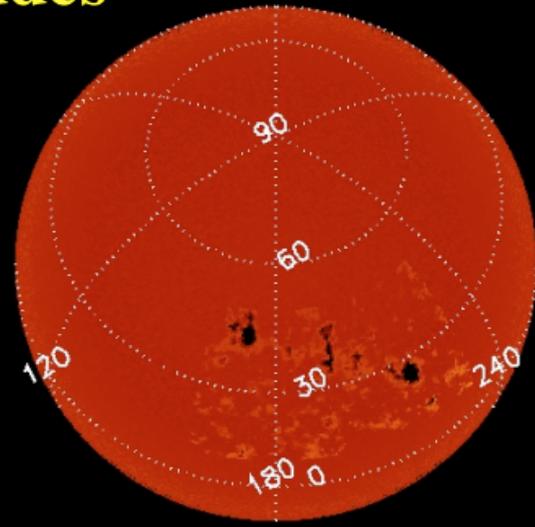
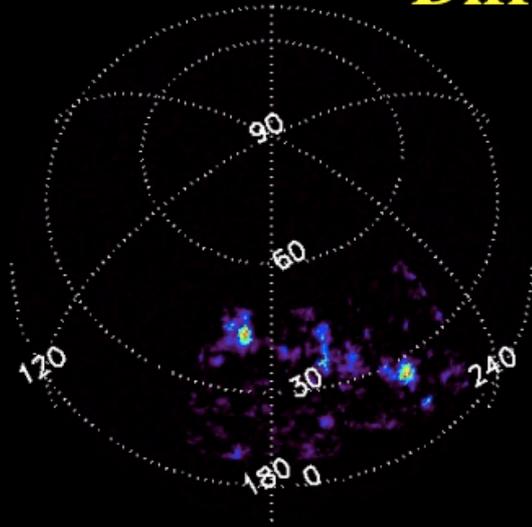
Light Curves @ Different Inclinations



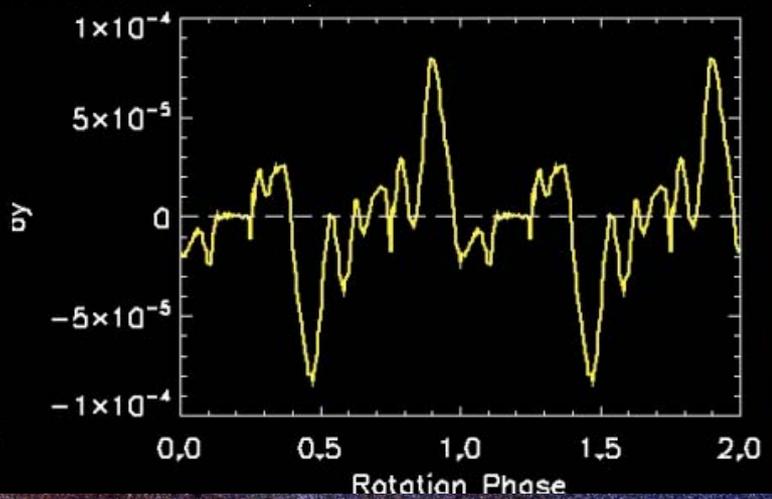
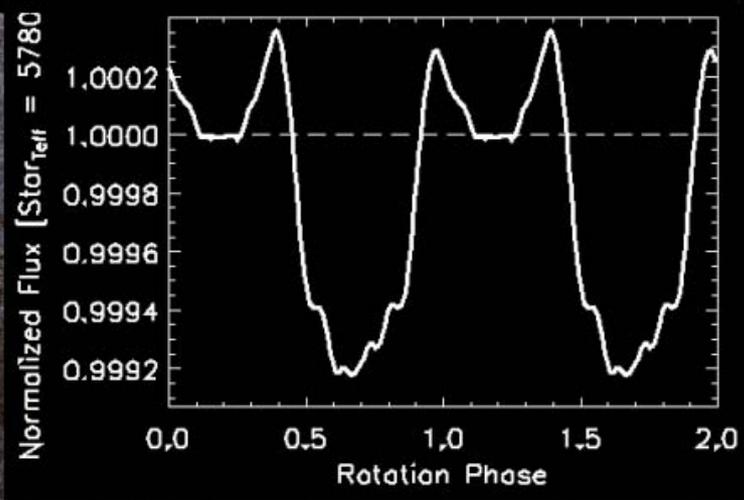
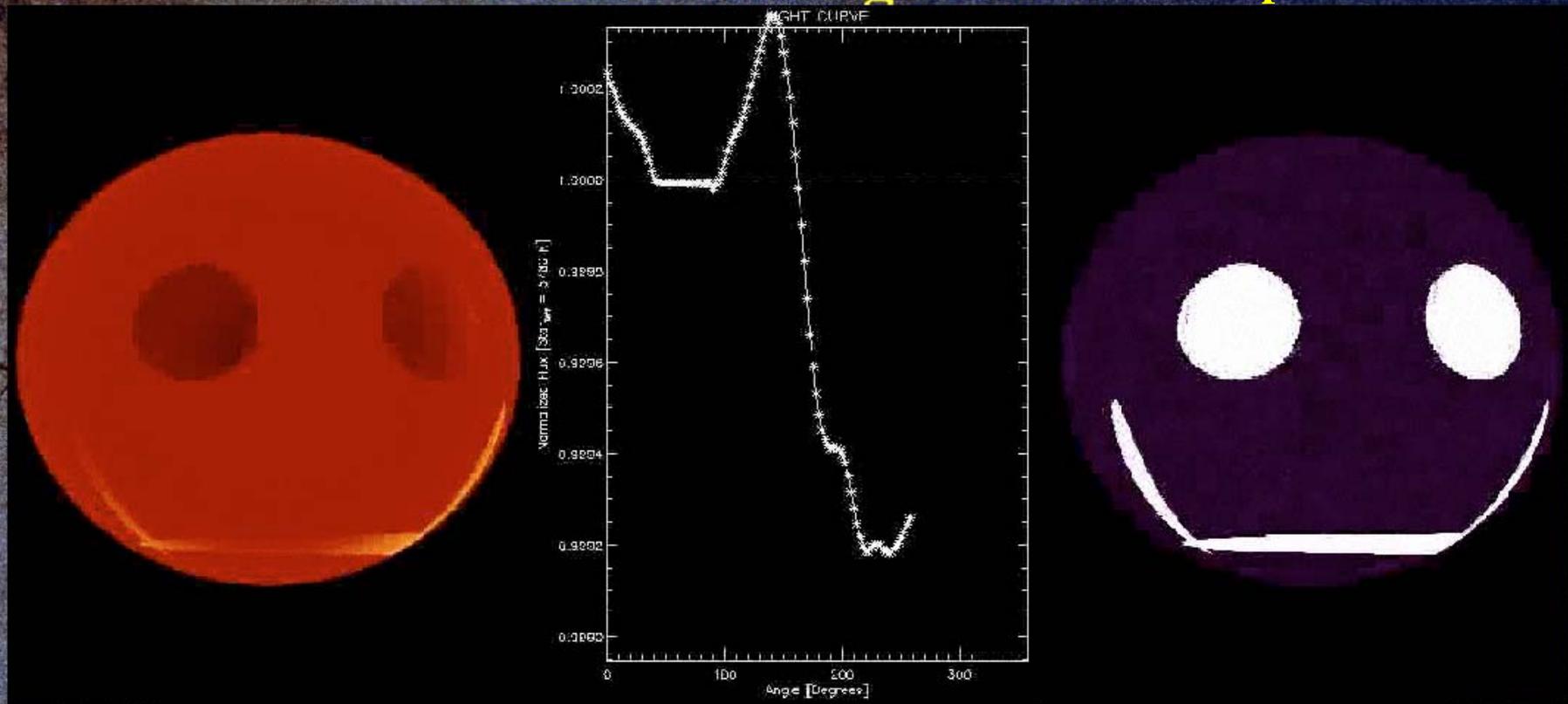
Different Shapes and Derivatives



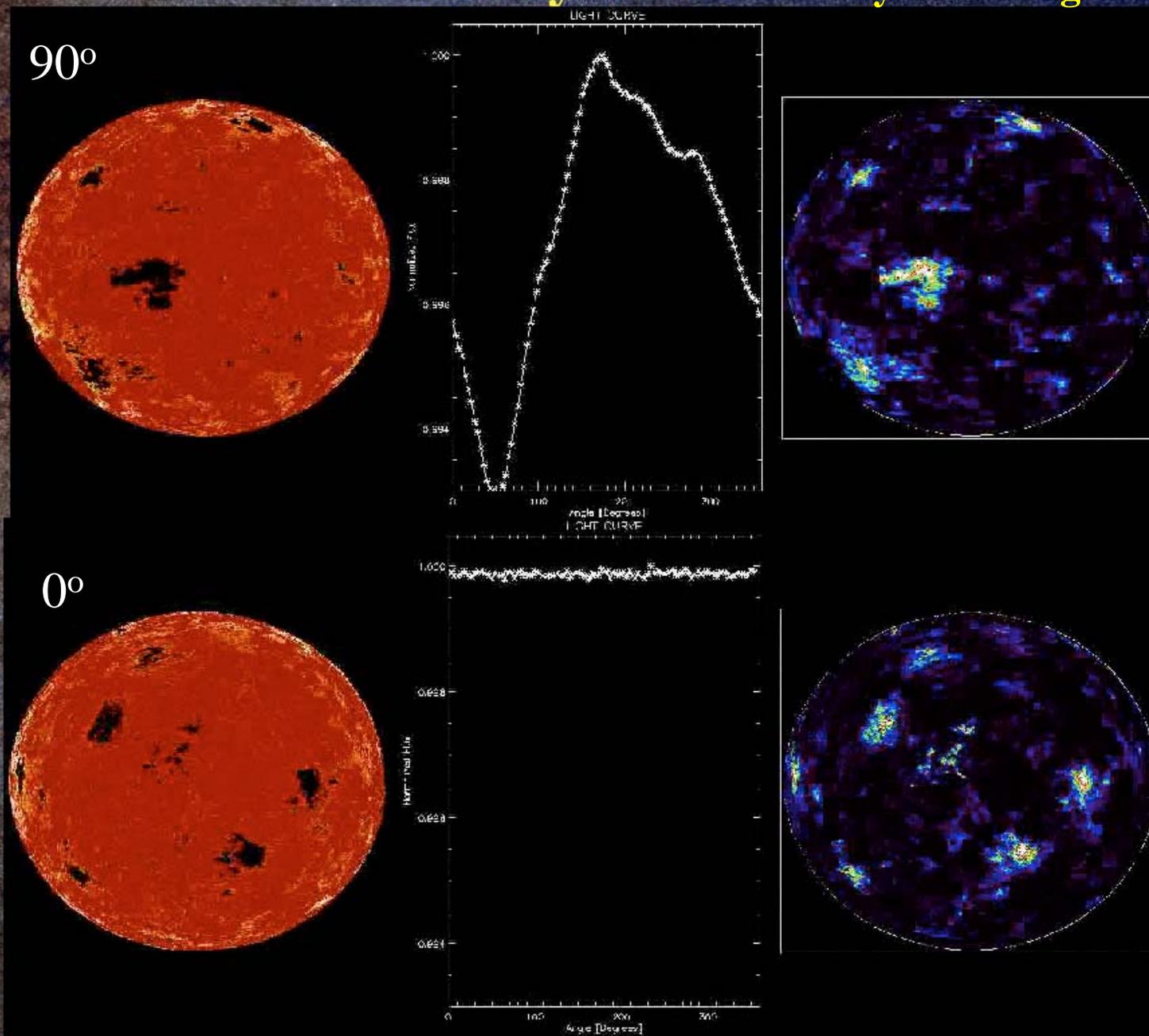
Different latitudes



The Ultimate Lightcurve ...Optical SETI



Crazy Stars ...many active regions



After all ...

Are we Preparing for Kepler ???

YES!!!

Galileo -> Changed the perspective of humanity forever with his discoveries and prepared the road for Kepler... and the **Renaissance...**

Now, WE are also preparing to change the perspective of humanity. We need to build a **catalogue of**

Super-Earths and Earth-like planets

Atmospheres, biomarkers, life, AstroBiology and here another reason...

“THE EARTH IS BUT ONE COUNTRY AND THE HUMANKIND ITS CITIZENS”



**For the 1st attempt of the Constitution of planet Earth go to:
www.EarthCharter.org**

5 Take-home ideas

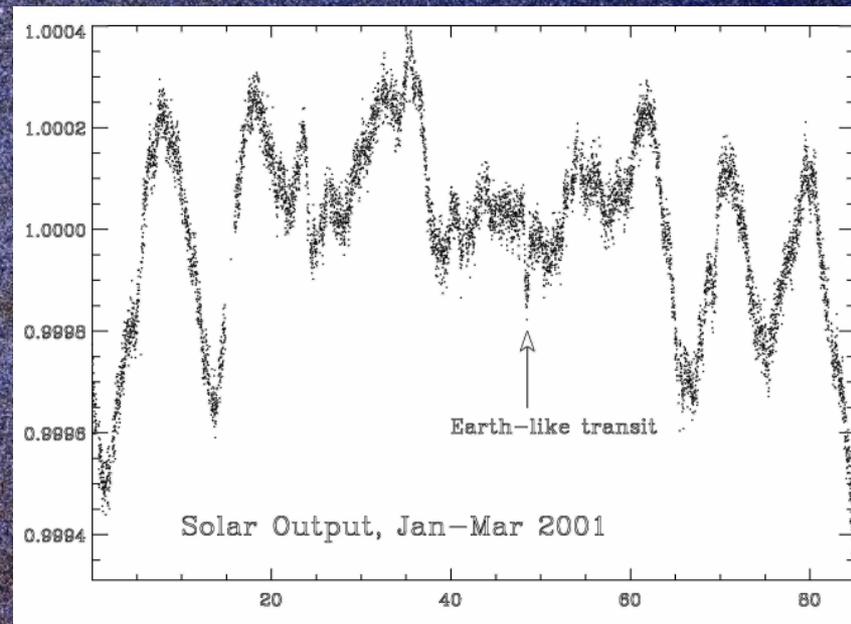
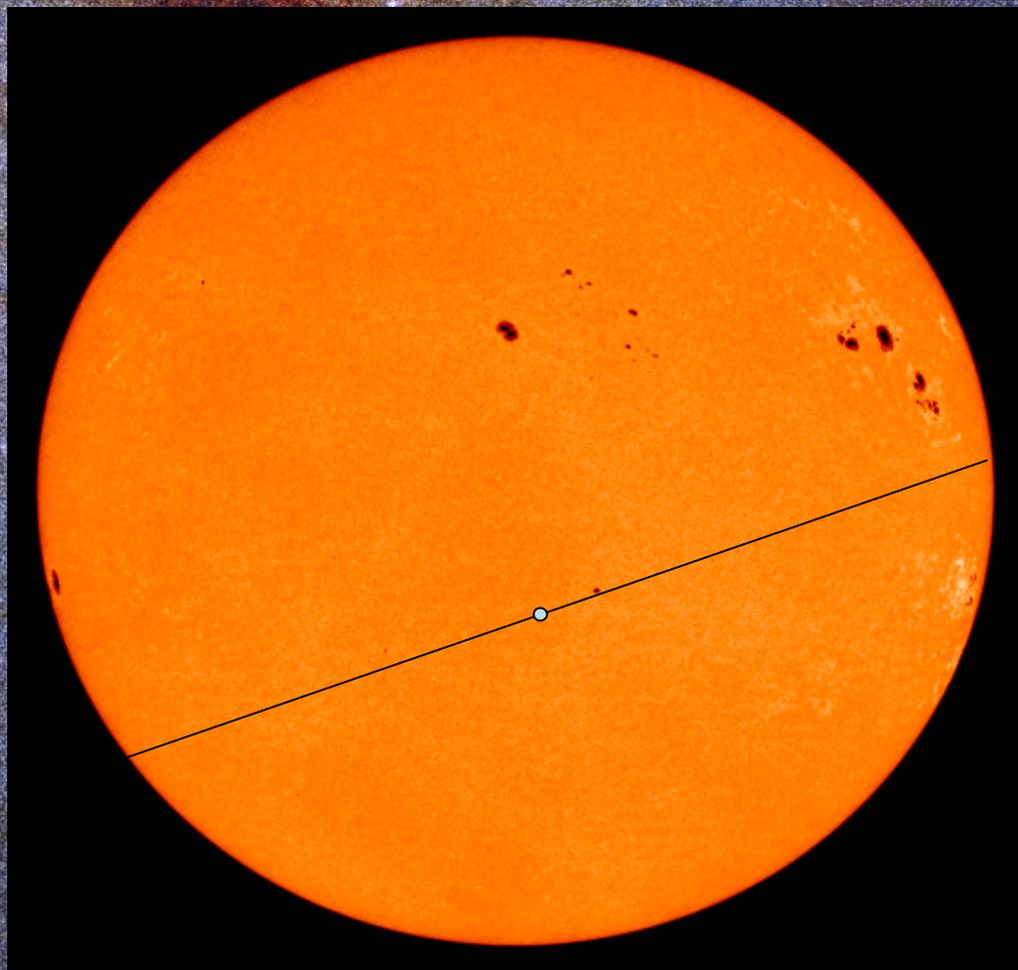
“Think out of the box and be ready for the unexpected.”

-Frank Shu 2004 at the 2nd TPF/Darwin meeting, San Diego, CA

1. **“P” broadening** : *Be a catalyst who boosts ALL perspectives. Thereafter, you will be closer to the truth.*
2. **MDwarfs rule the Galaxy**: *Don't miss those red photons, otherwise we will be missing the BIG picture.*
3. **Take lots of vitamin “P”** : **Patience, Passion**
4. **Defend Science-> Threatening the budget of a mission?**
*Let's get involved! Shakespeare in love Episode II: **TO BE more or to have more. That's the question.***
5. *Citizens of the World there is just one flag!*
If you want to be a rebel be kind. Human-kind, be both.

Francisco “Pancho” Ramos Stierle

Finding Stellar Rotation : Simulating Microvariability



Precision Solar Light Curves

