Brief Overview of VarSITY/SEE

Solar Evolution & Extrema

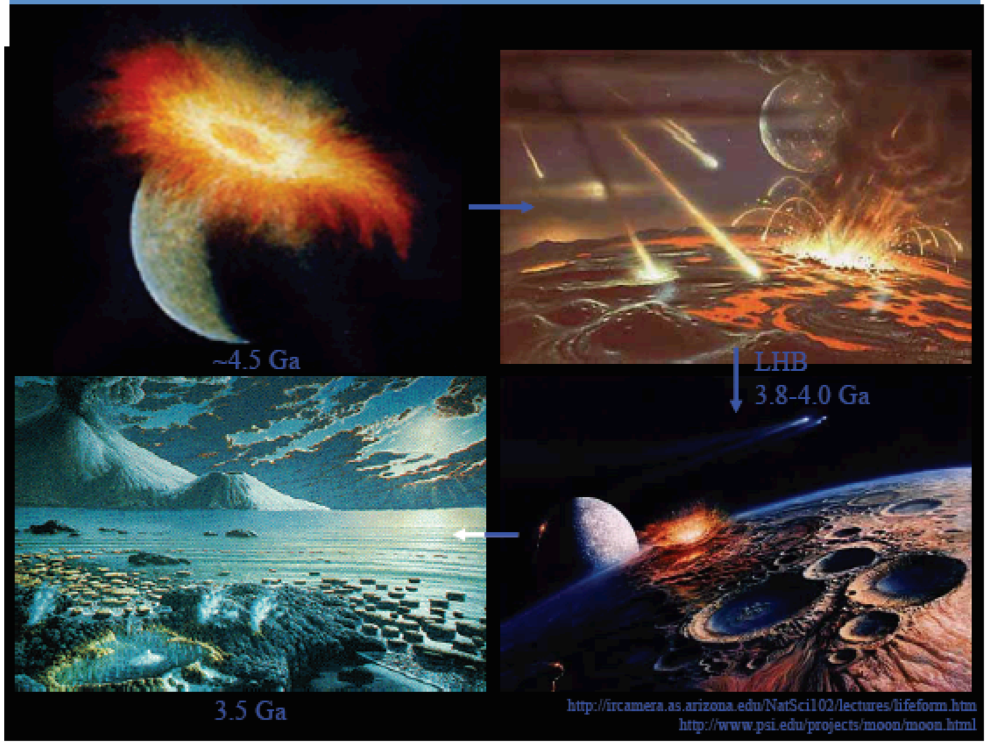
A project under the auspices of SCOSTEP's VarSITI program, Variability of the Sun and Its Terrestrial Impact

SEE Co-chairs:

Prof. Petrus C Martens, Montana State University, USA

Prof. Dibyendu Nandi, Indian Institute of Science Education and Research Kolkata, India

Prof. Vladimir N. Obridko, IZMIRAN. Moscow, Russian Federation



SEE: Science Questions

1) Are we at the verge of a new grand minimum? If not, what is the expectation for cycle 25?

2) Does our current best understanding of the evolution of solar irradiance and mass loss resolve the "Faint Young Sun" problem?

3) For the next few decades, what can we expect in terms of extreme solar flares and storms, and also absence of activity?

SEE: White Paper Team

- Sarah Gibson, High Altitude Observatory (NCAR), USA,
- Katja Matthes, GFZ German Research Centre for Geosciences, Germany,
- Manuel Gudel, University of Vienna, Austria,
- Laurene Jouve, University of Toulouse, France, Email: ljouve@irap.omp.eu
- Steve Saar, Harvard Smithsonian Center for Astrophysics, USA,
- Aline Vidotto, University of St Andrews, UK,
- Andrés Muñoz-Jaramillo, Montana State University, USA,
- Ilya Usoskin: University of Oulu, Finland,
- Kanya Kusano, Nahoya University, Japan,
- Jeremy Drake, Smithsonian Astrophysical Observatory,
- Frederic Clette, Royal Observatory of Belgium, Belgium,
- Vladimir Obridko, IZMIRAN, Russia,
- Dibyendu Nandi, IISER Kolkata, India,
- Piet Martens, Montana State Univversity, USA
- Please join our group!

Extreme Events: Obridko

Much progress is being made by other scientists already on this issue (e.g. the Shibata group in Kyoto)

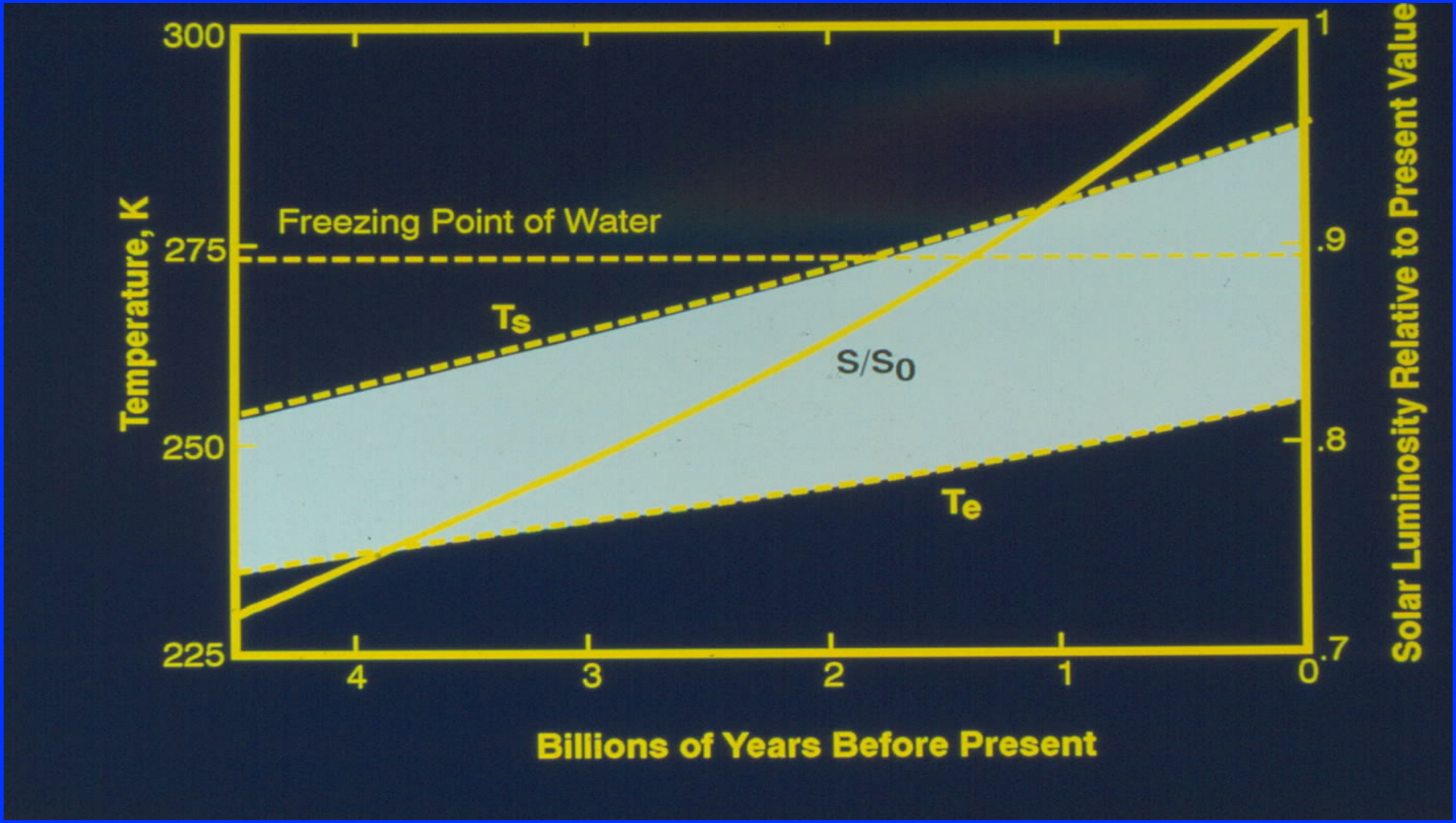
Prof. Obridko's subgroup will focus on the following:

- **Really large solar flares and storms, e.g. the Carrington event and the 1921 magnetic superstorm occur in smaller solar cycles. Can that be confirmed from larger data samples?**
- **If so, what is the expectation value for such super large storms during the upcoming era of less strong solar cycles? Are we in fact facing a larger risk?**

The Faint Young Sun Paradox: Martens

The Sun was about 30% less luminous when life developed on Earth, yet geological and biological evidence points to a warm young Earth, 60 to 70 C

A Faint Young Sun Leaves the Earth Frozen Solid



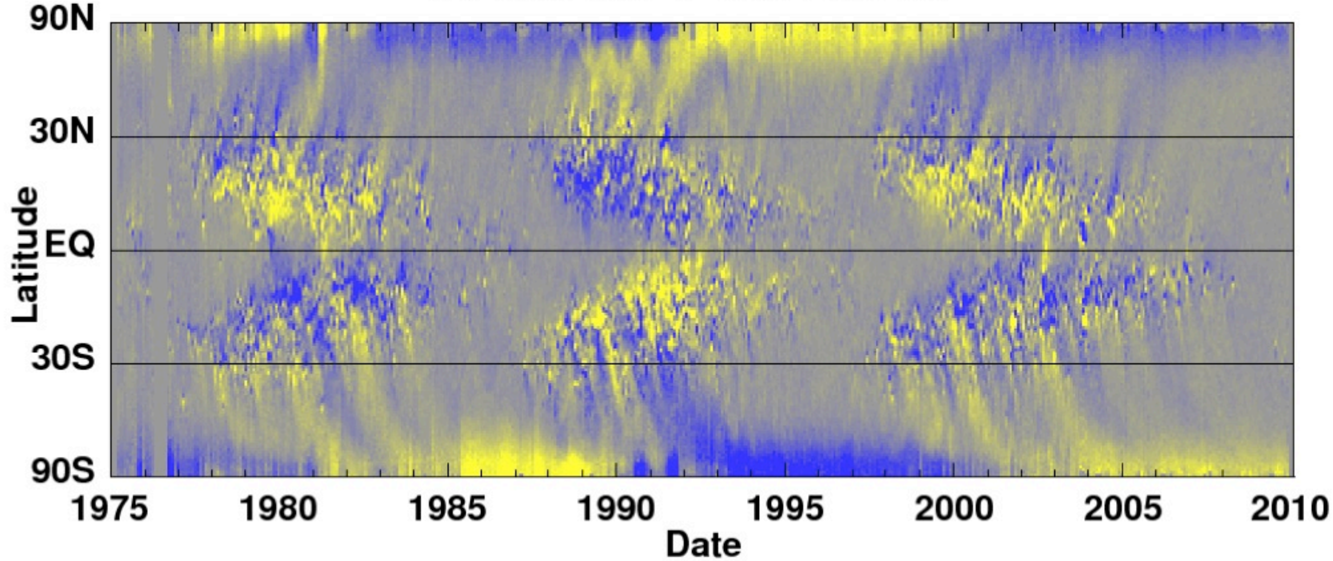
Kasting et al, Scientific American, 1988

Dynamo Modeling: Nandi

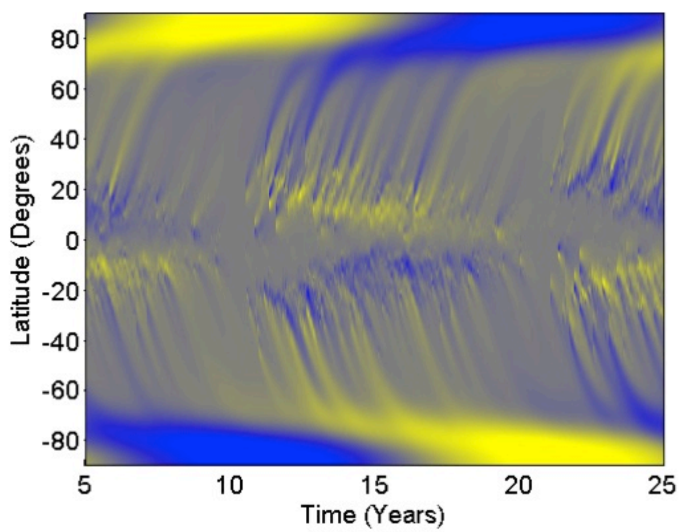
Research Projects:

- **Turbulent flux pumping: can it replace single cell meridional circulation?**
- **Full 3D kinematic simulations: Yeates & Munoz, MNRAS 2013, Jouve & Nandi, in progress**
- **The "memory" of the solar cycle: how far ahead can we predict?**
- **The physics of Grand Minima. Are we going in to a Maunder minimum?**

Observations



Double-ring



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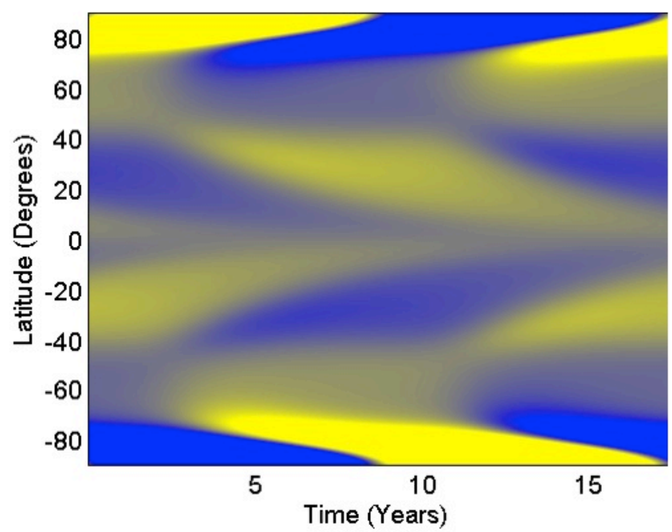
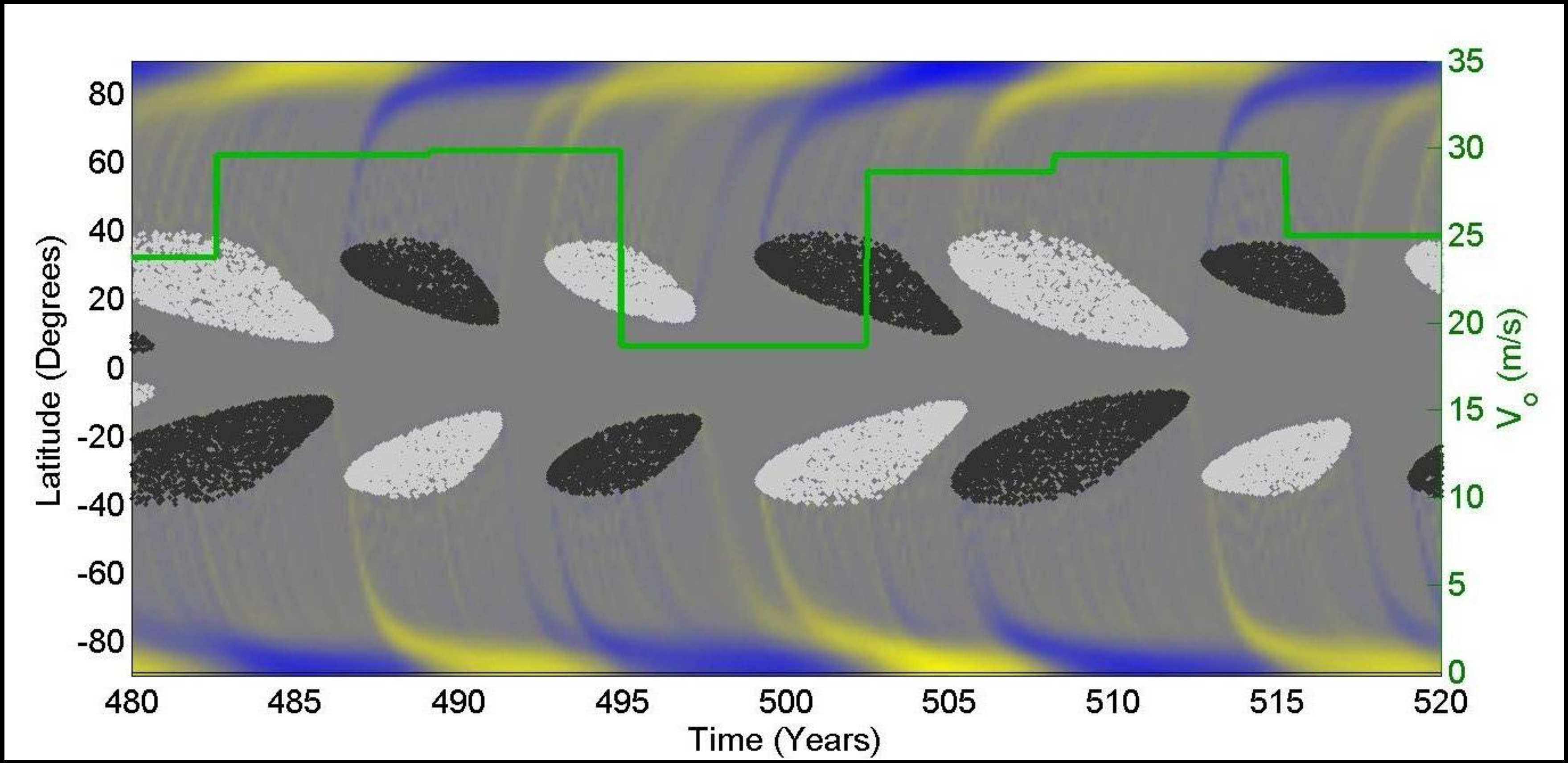


Solar Cycle Simulations



- Self-consistent variation in length of minimum and polar field strength
- 210 solar cycles (1860 solar years) simulated to establish a robust relationship between flow speed variations and nature of minimum

Space Climate Extremes: Dynamo-Climate Coupling

Gibson et al. NCAR/HAO

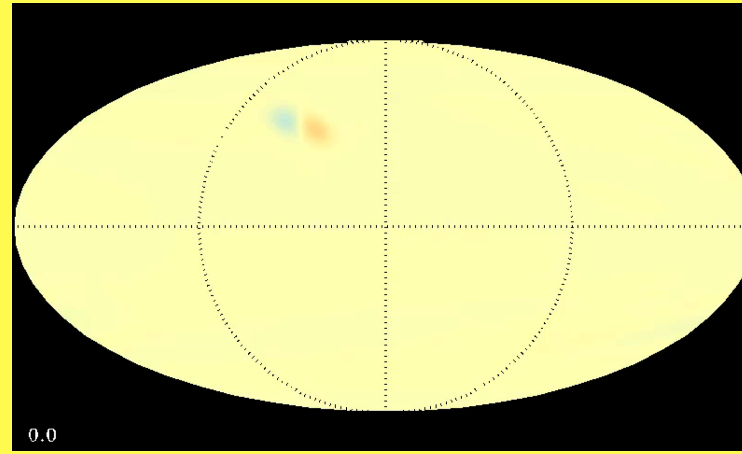
Our goals are:

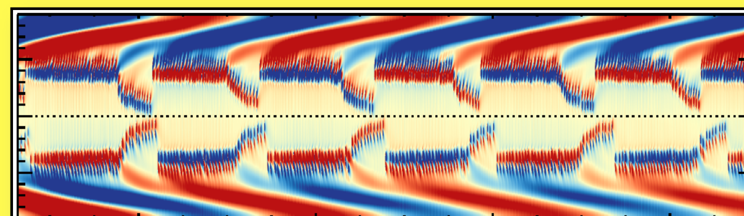
- To run controlled experiments in flux emergence within 3D dynamo simulations to characterize the variation of the Sun's surface magnetic field

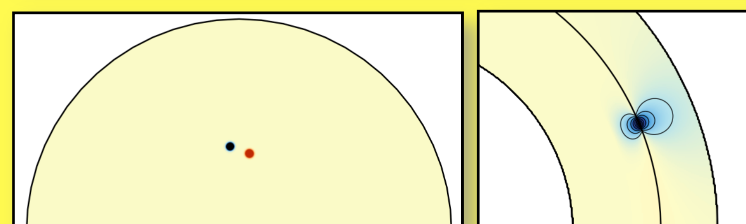
- To quantify the resulting solar radiative and particulate variations and use them as inputs to community climate and geospace models.

This will allow us to address questions, such as:

- What happens to the solar atmosphere and heliosphere, and, by extension, the Earth's space environment and climate, if flux emergence occurs only on scales too small to form sunspots?

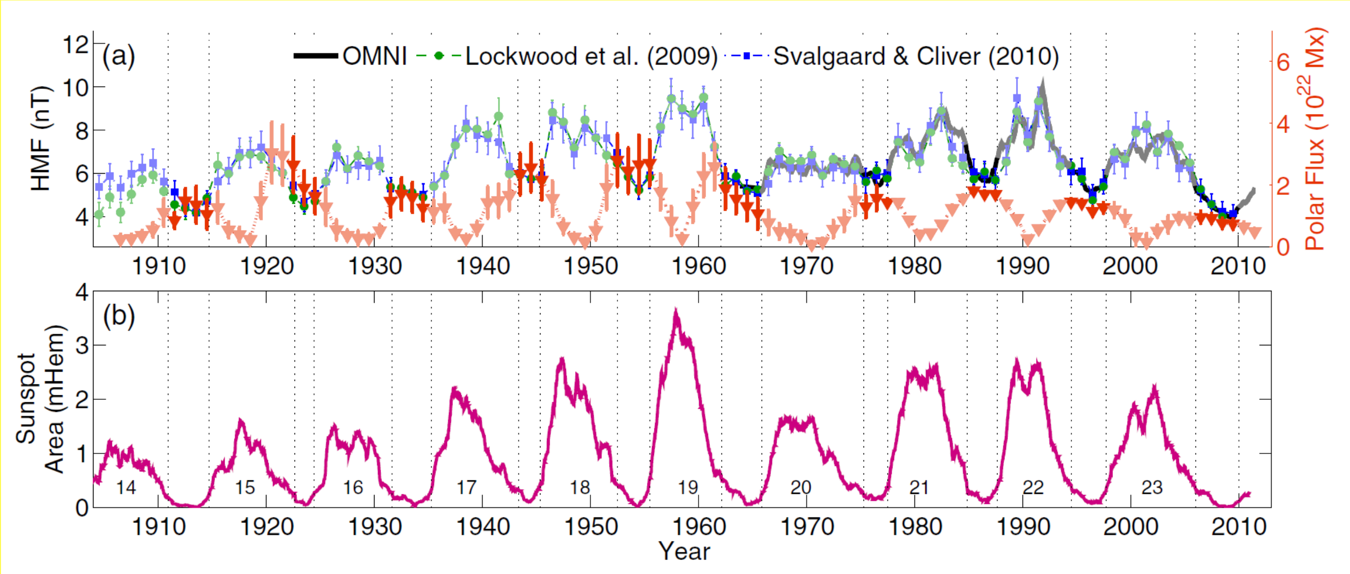






BASH: A 3D Babcock-Leighton dynamo model with explicit inclusion of sunspot pairs.

Polar Flux Measurements (*Munoz, MSU*)

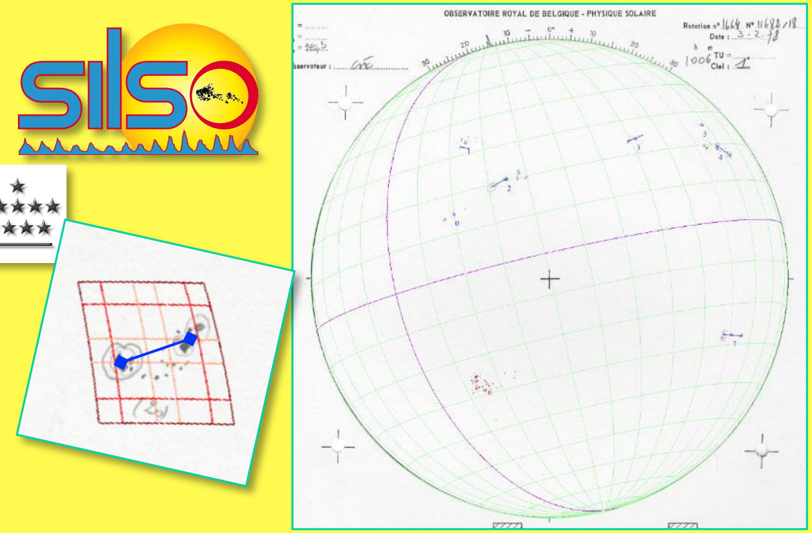


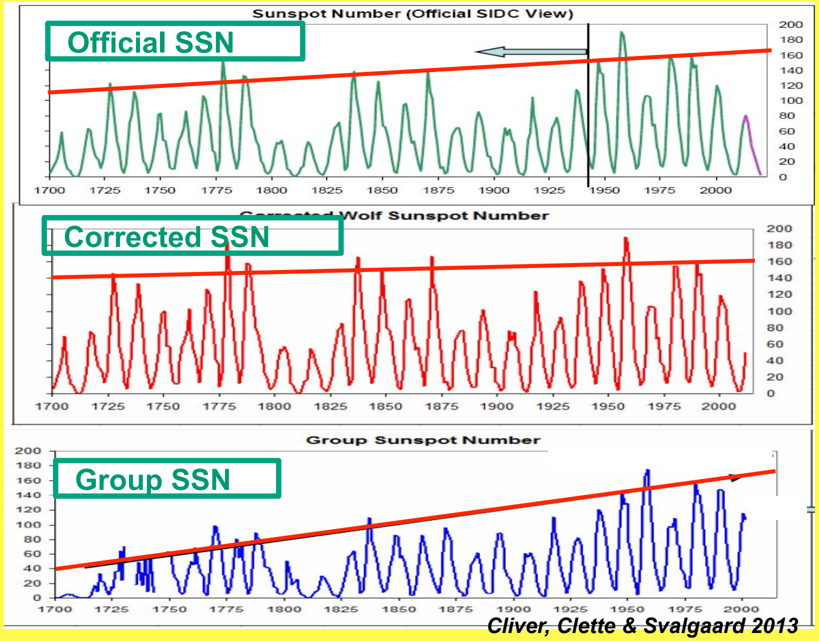
Muñoz-Jaramillo et al. 2012

- Polar flux (as an indicator of the solar axial dipole moment) is crucial for determining solar wind conditions at solar minimum. Polar flux is predictor for next cycle.
- Our dynamo and surface flux transport simulations will yield a self-consistent picture of the evolution of this baseline during long time-scales.

Contribution of the ROB *(F. Clette, Belgium)*

- Expertise in long-term solar indices of the World Data Center – SILSO *(ROB, Royal Observatory of Belgium)*
- New long-term observational constraints to solar dynamo models:
  - Exploitation and construction of digital sunspot catalogs:
    - Sources: visual and photographic observations
    - Validation of new proxies combining multiple properties of individual sunspot groups *(location, morphology, evolution, rotation, magnetic dipole, etc.)*
    - ⇨ Opens the way to sunspot-based proxy series spanning several centuries (18th to 20th): *(patterns of magnetic flux emergence, solar irradiance)*
  - Improved sunspot time series (sunspot number, group number):
    - Based on results from e.g. Sunspot Number Workshops (2011-2014)





Cliver, Clette & Svalgaard 2013

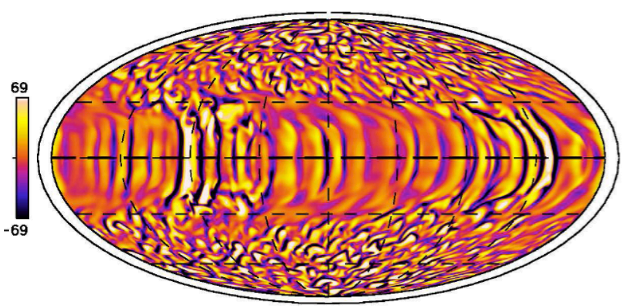
Link between multi-D models: stellar dynamo models

Stellar dynamo models: reintroducing prescriptions from 3D models to mean-field 2D dynamo models

Jouve, Toulouse

Jouve, Brown & Brun, 2010, A&A

3D simulations of solar analogs (Brown et al., 2008)

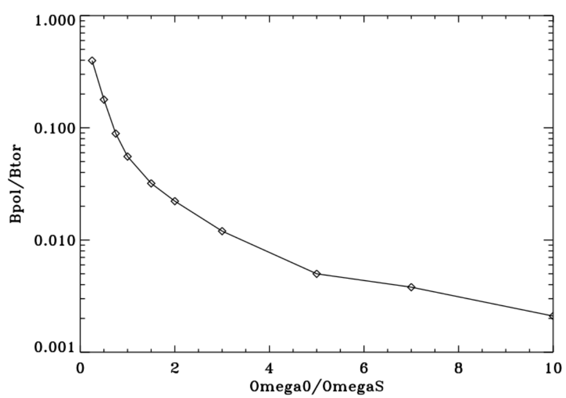


Fast rotation = low amplitude meridional flow

Reintroduction into 2D mean-field models

- Fast rotation = Strong toroidal field

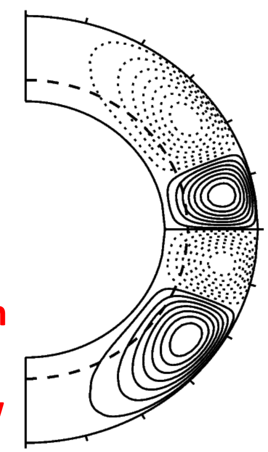
In agreement with observations (NARVAL)



- Fast rotation = longer magnetic cycle

Not in agreement with observations (Mt Wilson)

Possible solution more complex meridional flow



Pathways to Habitability: An Austrian National Key Science Program

University of Vienna, Austrian Academy of Sciences, University of Graz

~40 team members, +40 int'l co-operation partners
funding 2012-2016 ongoing, 2016-2020 after review
co-operation with other groups & networks being established, and welcome!

Principal Questions and Goals:

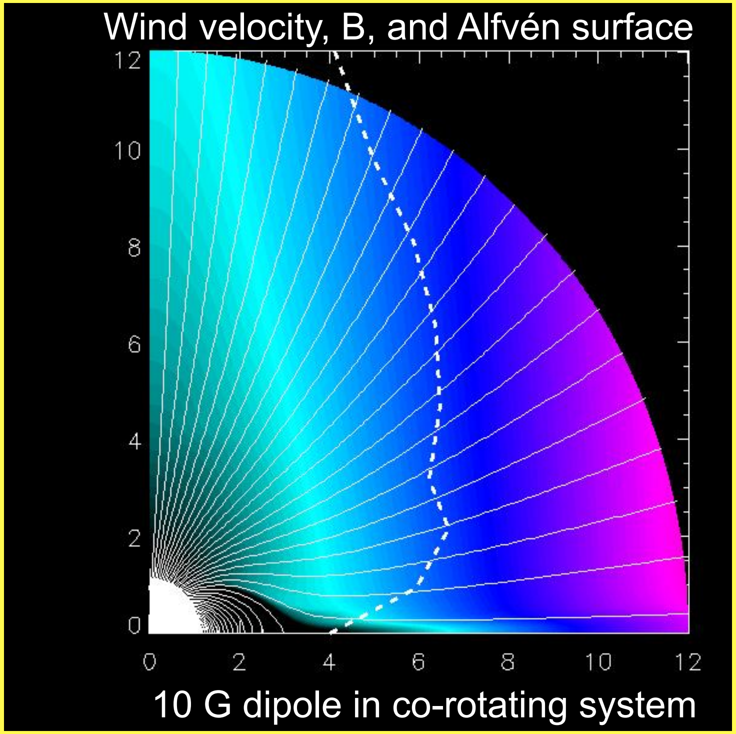
- What are the *astrophysical* conditions for planetary habitability?
- How are environments becoming habitable in forming planetary systems?
- How and when in habitability established under extreme conditions?
- What was different in the young solar system compared to the present?

ASA

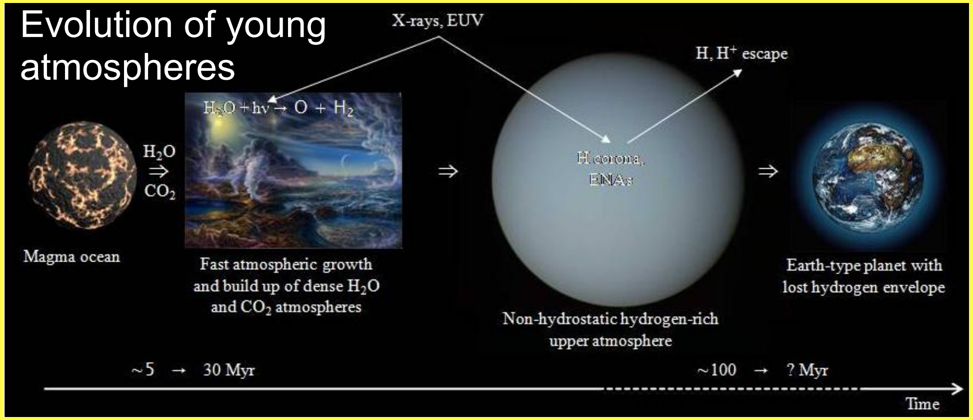
universität wien
institut für astronomie
UNIVERSITÄTSSTERNWARTE WIEN
ÖAW Österreichische Akademie der Wissenschaften
IWF Institut für Weltraumforschung
UNI GRAZ
ICAM

PatH under Extreme Conditions: From Stellar Magnetic Fields to Planetary Atmospheres

SCOSTEP
Scientific Committee on Solar-Terrestrial Physics



- Effects of high-energy radiation and winds on *atmospheric erosion and evolution* using advanced MHD, radiation-hydro and particle codes.
- Transport of *water* and evolution of water reservoirs in young planetary systems
- Focus on *young, extreme stages* including protoplanetary disks and massive proto-atmospheres.
- *Self-consistent coupling* of winds, magnetospheres, plasma disks, upper atmospheres, radiation, ENA clouds and their atmospheric energy deposition.



Modeling Cosmic Rays Through Time

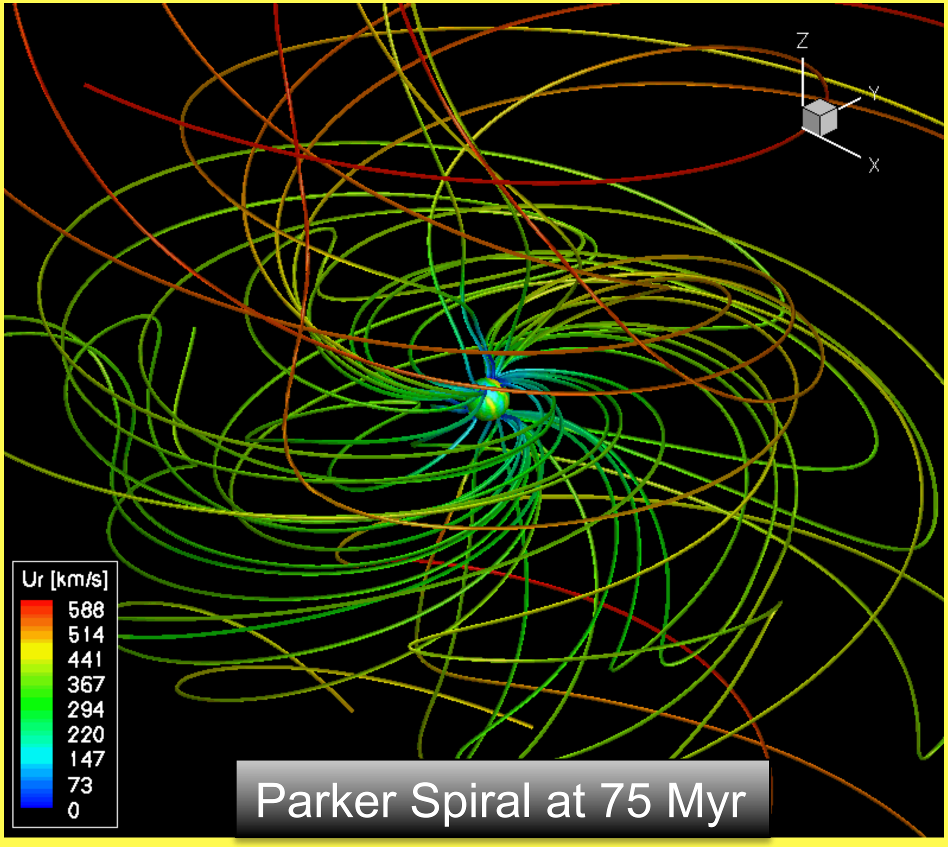
Drake, SAO

- **Cosmic ray environment depends primarily on**
  - Solar surface magnetic field and wind
  - Solar rotation rate
- **Model young solar analogs using observed B field maps**

– Observed P_{rot} vs time

– Compute CR transport

AB Doradus K0 V P=0.5d

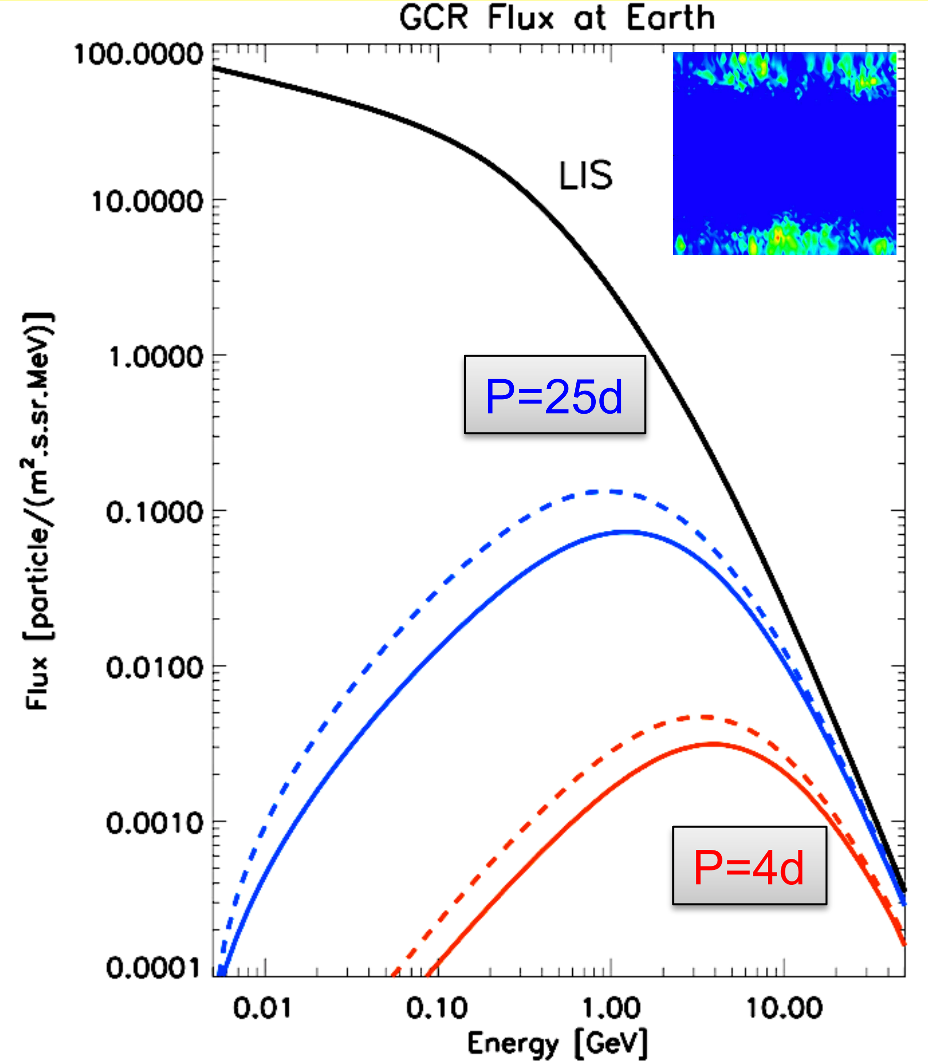


Cohen et al (2010)

Modeling Cosmic Rays Through Time

Drake, SAO

- **Cosmic ray environment depends primarily on**
  - Solar surface magnetic field and wind
  - Solar rotation rate
- **Model winds of young solar analogs using observed B field maps**
  - Observed P_{rot} vs time
  - Compute CR transport



Cohen et al (2012)