Space Weather in Planetary Systems

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(NASA)

OVERVIEW

This talk will review the rationale for, the methods used and the results from exoplanetary space weather research, and the implications for our Solar System and planet Earth.

(NASA)

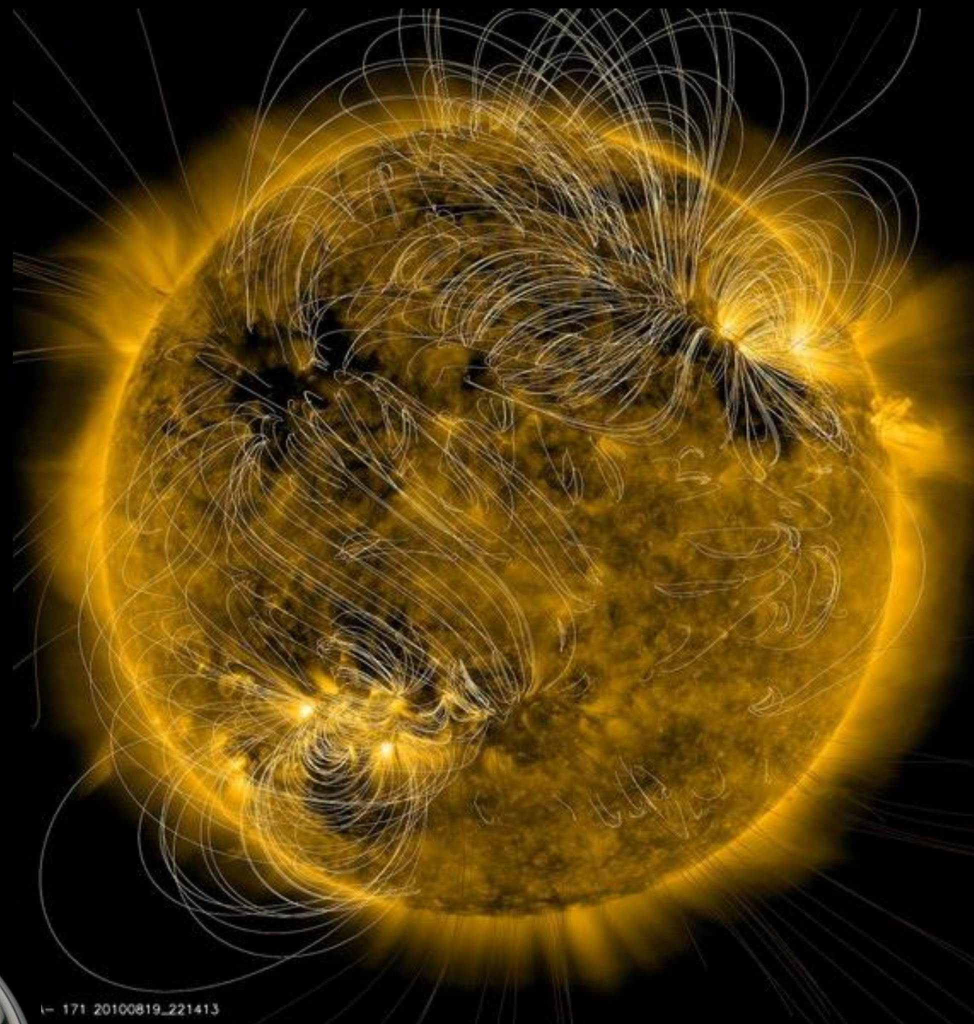
INTRODUCTION

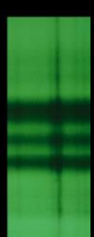
Our Solar System's space weather is familiar to us

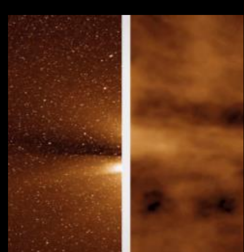
Its origins lie in our local star's dynamo magnetic fields that power the solar wind and activity

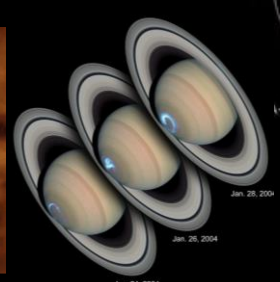
Solar magnetic fields can be readily detected in spectra using the Zeeman effect

The Solar wind can be imaged directly and aurorae produce observable planetary impacts







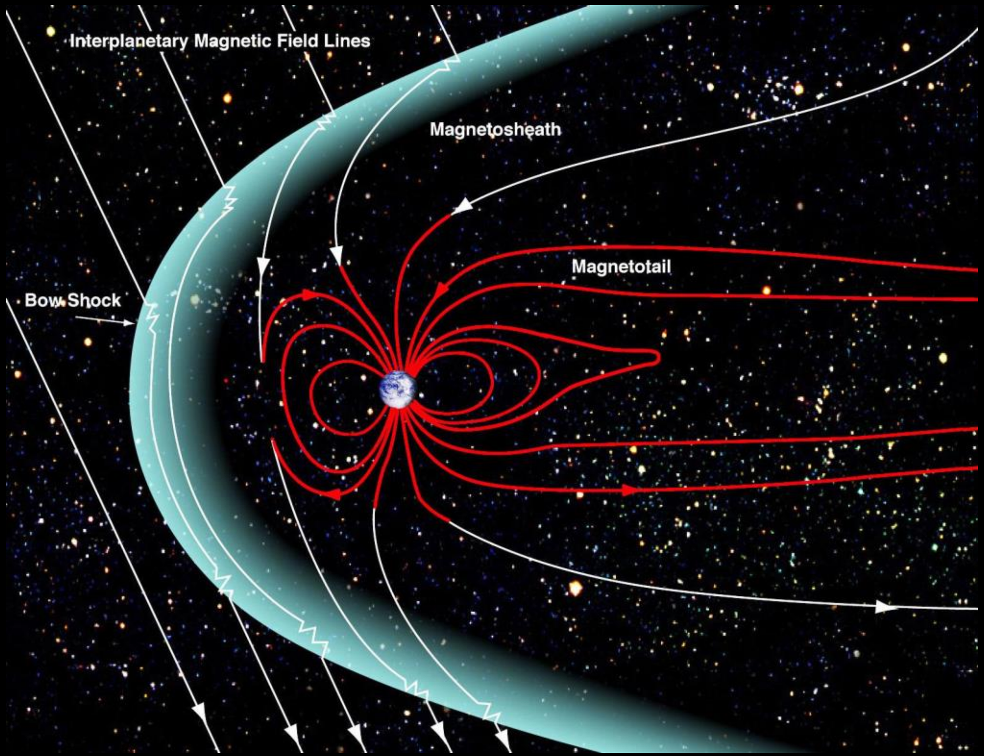


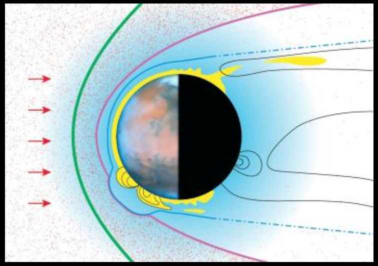
(SDO/NASA/HST/SwRI)

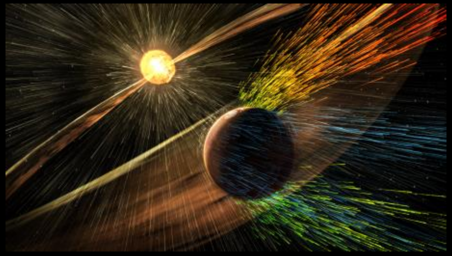
Our planetary system

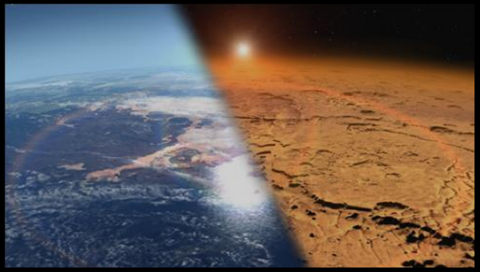
In our Solar System, Earth is protected to some extent by its own dynamo magnetic field and its atmosphere

However Mars lacks a substantive magnetic field and thick atmosphere, and the young Sun's powerful wind stripped Mars of much of its atmosphere









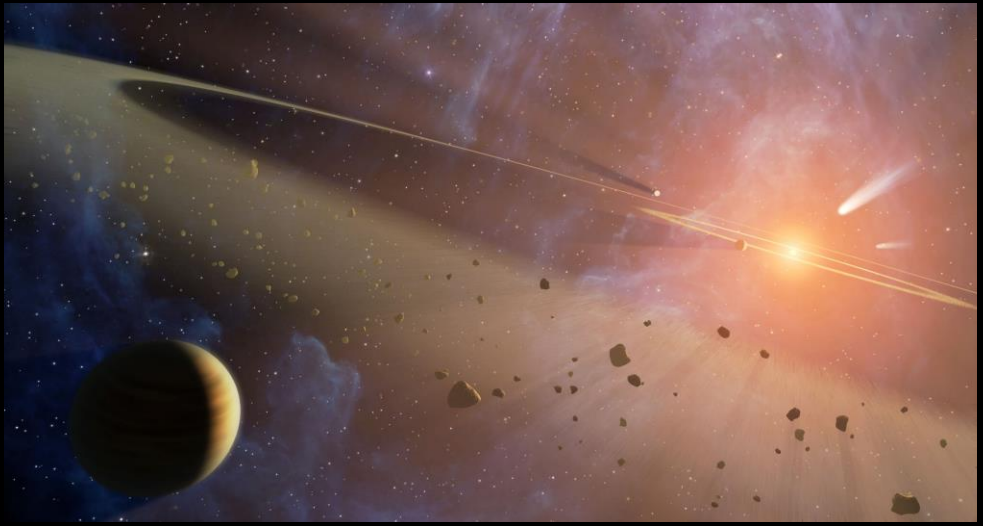
(NASA)

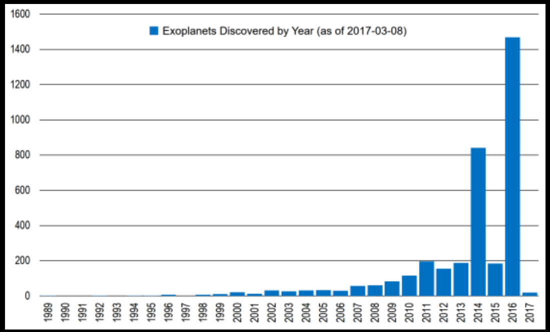
Exoplanetary systems

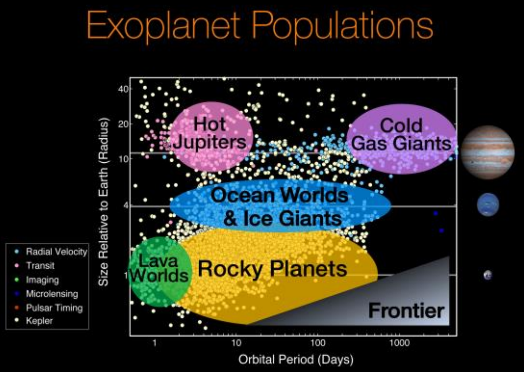
Planets orbiting other stars (exoplanets) are abundant

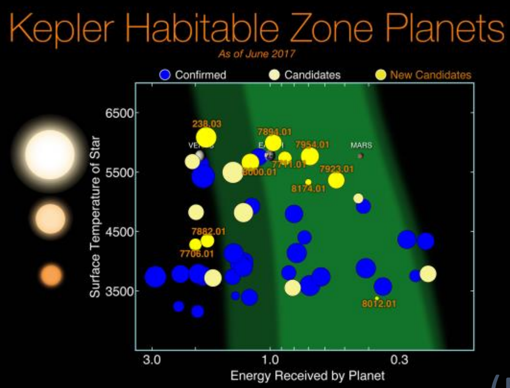
Exoplanetary systems provide a new frontier for astronomy and lessons for our Solar System.

Research into other planetary systems enables understanding of the **shared evolution of stars and their planets including space weather impacts.**









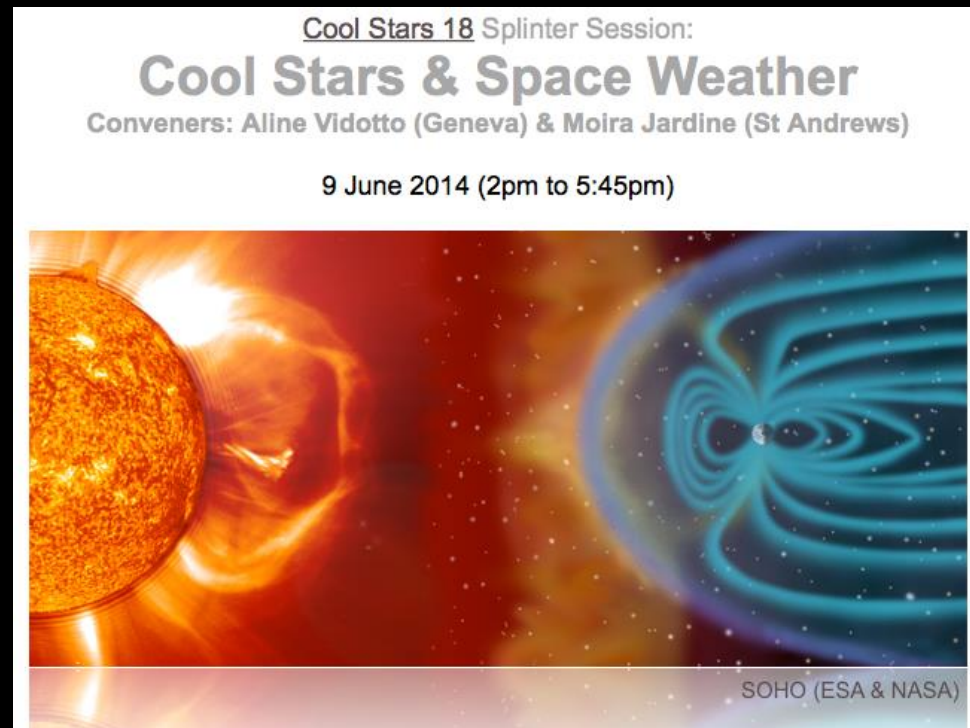
(NASA)

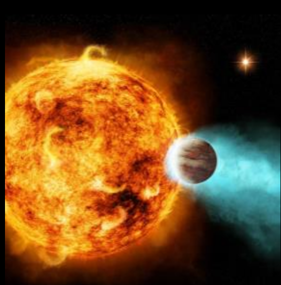
Exoplanetary space weather

The Sun and other "cool stars" generate dynamo magnetic fields, winds, activity, radiation

The resulting space weather has planetary impacts:

- For some systems atmospheric erosion is measured in spectra
- Planets around some stars are subjected to major flares





(NASA/ESA/Aline Vidotto)

Exoplanetary space weather and us

Stars and their planets show how space weather affects planets over time, and can inform our understanding of **Earth's past, present and future**

We now review some key approaches to surveying exoplanetary space weather

Stellar flares

Astronomers can survey stellar activity for long-term Solar forecasting

Astronomers observe stellar activity using photometry and spectroscopy, with surveys indicating the frequency and extremes of stellar and hence Solar activity.

The 1859 Carrington Solar flare event is dwarfed by energetic stellar flares

A Solar super-flare could cost trillions so even improbable events should be addressed

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RISKS FOR LIFE ON HABITABLE PLANETS FROM SUPERFLARES OF THEIR HOST STARS

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ABSTRACT

We explore some of the ramifications arising from superflares on the evolutionary history of Earth, other planets in the Solar system, and exoplanets. We propose that the most powerful superflares can serve as putative drivers of extinction events, and that their periodicity could correspond to certain patterns in the terrestrial fossil diversity record. On the other hand, weaker superflares may play a positive role in enabling the origin of life through the formation of key organic compounds. Superflares could also prove to be quite detrimental to the evolution of complex life on present-day Mars and exoplanets in the habitable zone of M- and K-dwarfs. We conclude that the risk posed by superflares has not been sufficiently appreciated, and that humanity might potentially witness a superflare event in the next $\sim 10^3$ years leading to devastating economic and technological losses. In light of the many uncertainties and assumptions associated with our analysis, we recommend that these results should be viewed with due caution.

Searching for Super-flares

Prior work suggests even the most powerful stellar flares are energetic versions of Solar events

Improved stellar flare statistics from NASA's forthcoming TESS mission can refine understanding of this magnetic activity

Proposal for *TESS* GI Program — **Cycle 1**

General Form

Title: TIME RESOLVED SUPERFLARES IN NORMAL STARS FROM TESS DATA

Principal Investigator: DR. JOHN F KIELKOPF

Co-Investigator(s):

Name	Institution	Country
BRADLEY CARTER	UNIVERSITY OF SOUTHERN QUEENSLAND	AUSTRALIA
STEPHEN MARSDEN	UNIVERSITY OF SOUTHERN QUEENSLAND	AUSTRALIA

Observing stellar magnetic fields

The most promising in-depth approach to exoplanetary space weather studies involves the use of spectropolarimetry to map stellar magnetic fields driving space weather

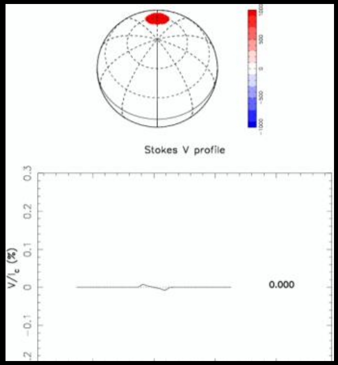
These stellar magnetic field maps can be used to model stellar winds and planetary space weather impacts in detail

Thus we can use stars as proxies to trace Solar evolution and infer Solar System space weather over longer terms than direct studies

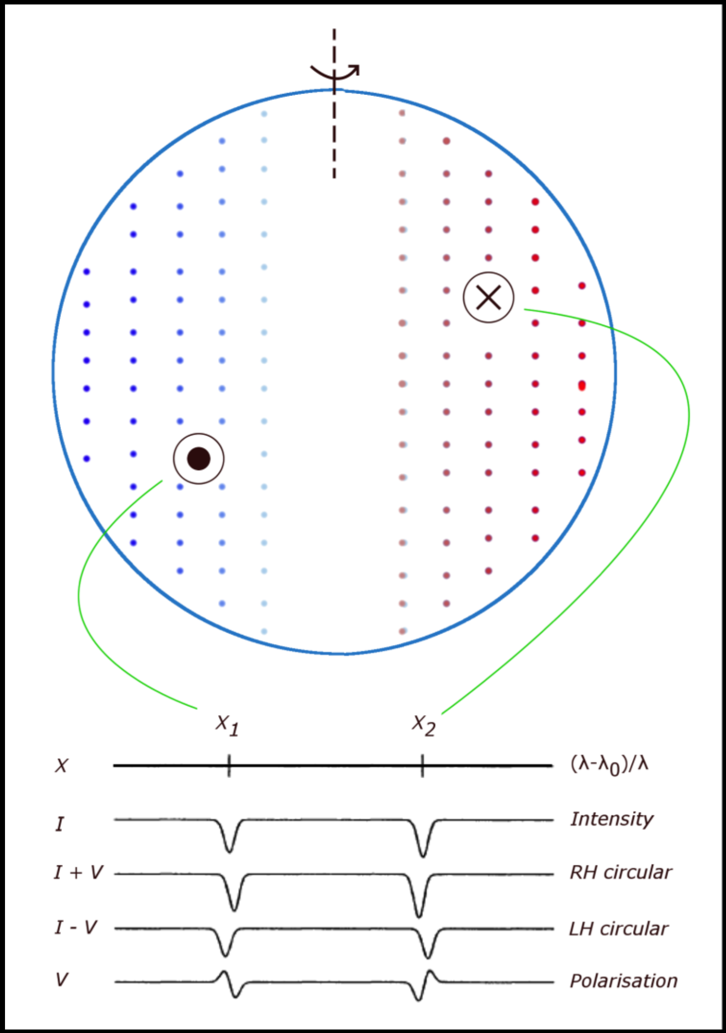
(Pascal Petit)

Mapping stellar magnetic fields

Zeeman Doppler Imaging uses spectropolarimetry. The Zeeman effect can detect magnetic fields and the Doppler effect can recover spatial information on the star (even for a point source).



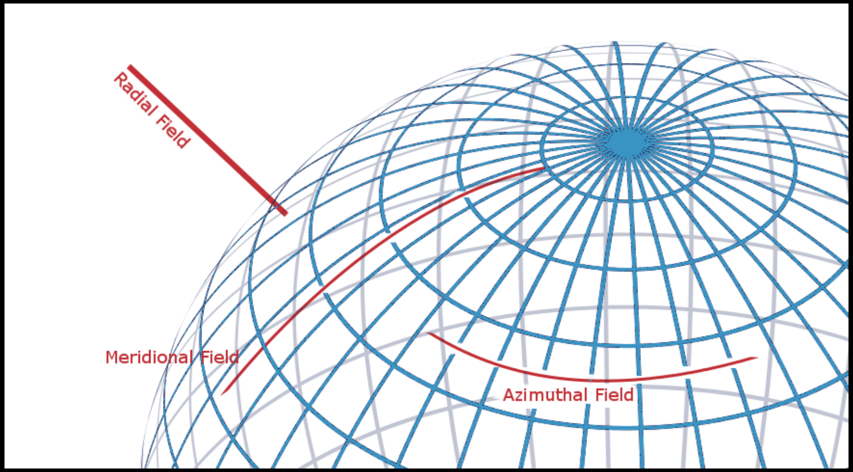
Stellar surface mapping simulation (Pascal Petit/Stephen Marsden)

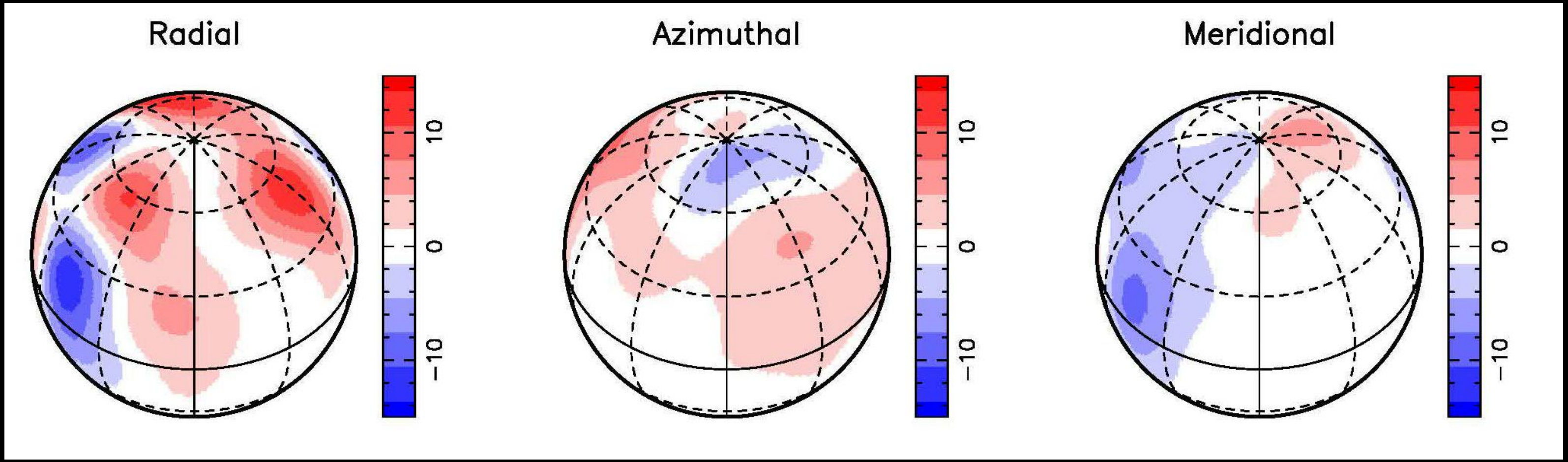


Principle of Zeeman Doppler Imaging (Matthew Mengel)

Magnetic field map results

Zeeman Doppler Imaging produces surface maps of different magnetic field components

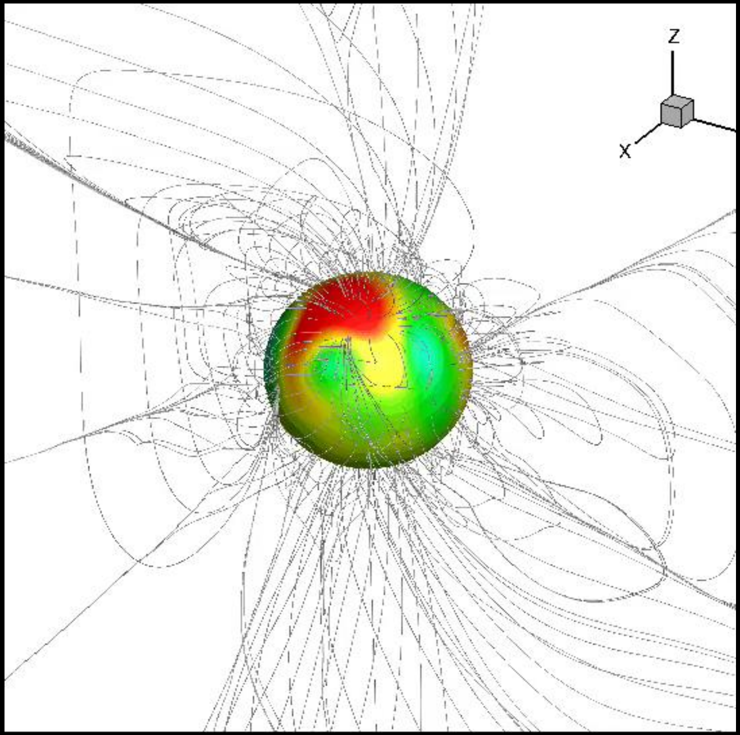




(Matthew Mengel)

Stellar winds

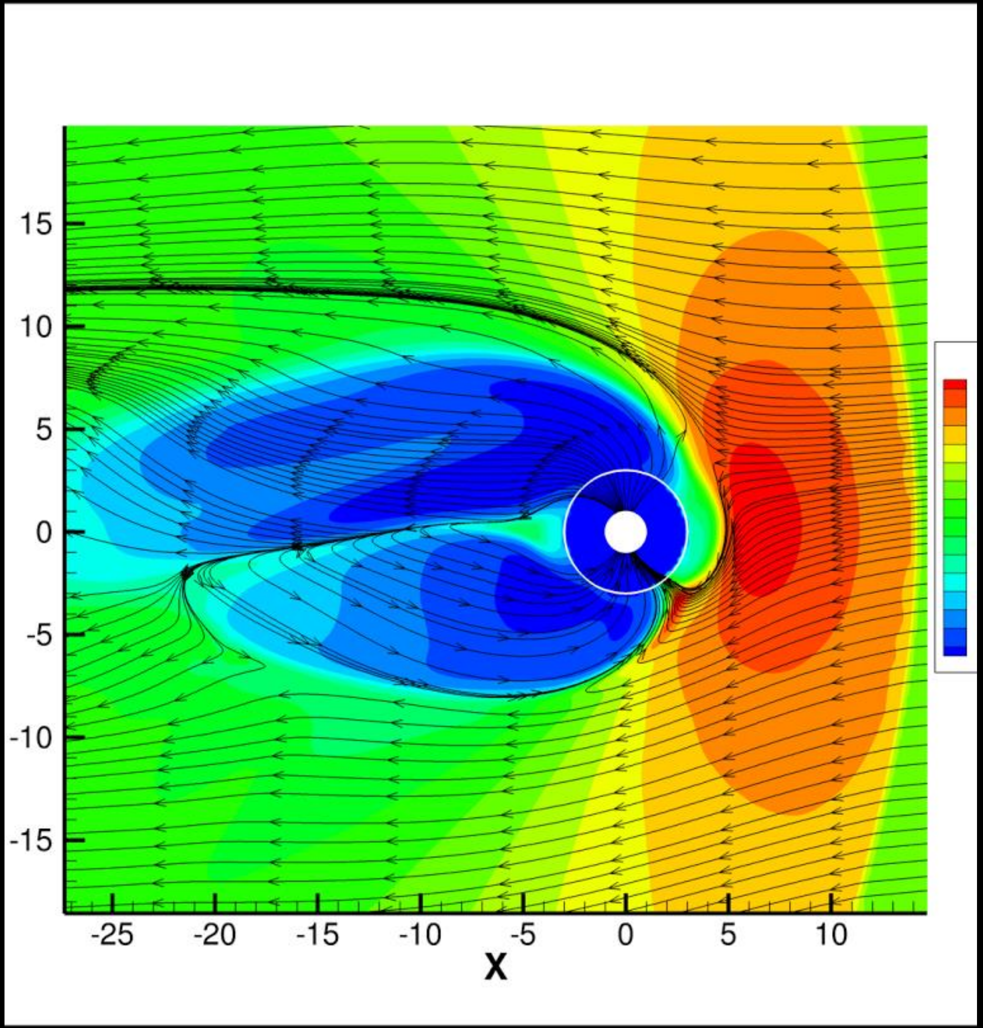
The stellar magnetic maps can be used with Solar space weather codes to model stellar outer atmospheres, magnetic fields and winds in 3 dimensions.



The surface and coronal magnetic fields for the planet-hosting star Tau Boo (Belinda Nicholson, USQ)

Stellar wind planetary impacts

The wind models can also be used to study their impacts on exoplanets (and predict whether these impacts can be observed)



Stellar wind impacting a Jupiter-like exoplanet (Leigh Brookshaw, USQ)

CONCLUSIONS & FUTURE WORK

- Observing the stars can inform our understanding of:
  - The *shared* evolution of the Sun and its planetary system
  - Long-term extremes of solar activity that *will* affect us
- Future USQ research expects to focus on:
  - Magnetic surveys of planet hosting stars to study trends
  - Detailed magnetic mapping of stars as planetary system hosts
  - Studies of stellar wind impacts on planetary systems
  - Stellar activity studies of flares and super-flares
- Outcomes:
  - Knowledge of stellar evolution including proxy Solar study
  - Knowledge of how stellar winds affect planetary evolution
  - Targeted searches for habitable worlds