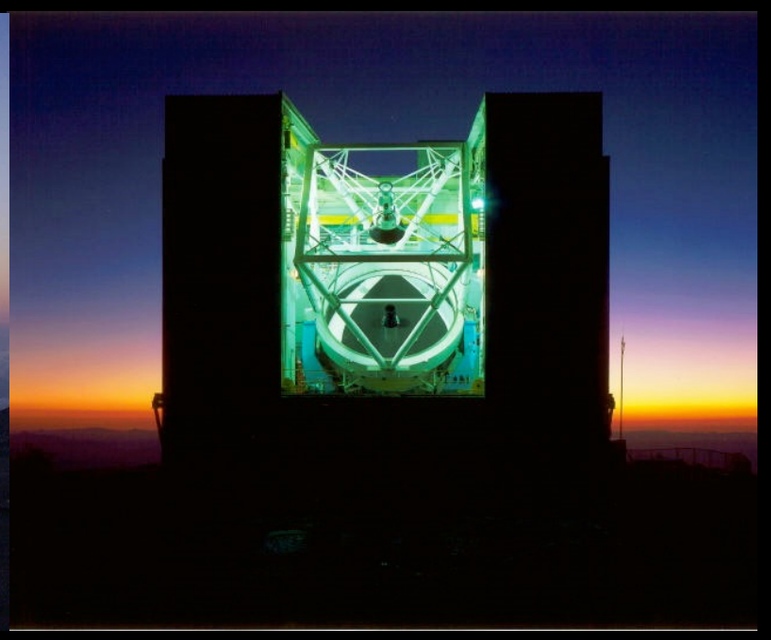
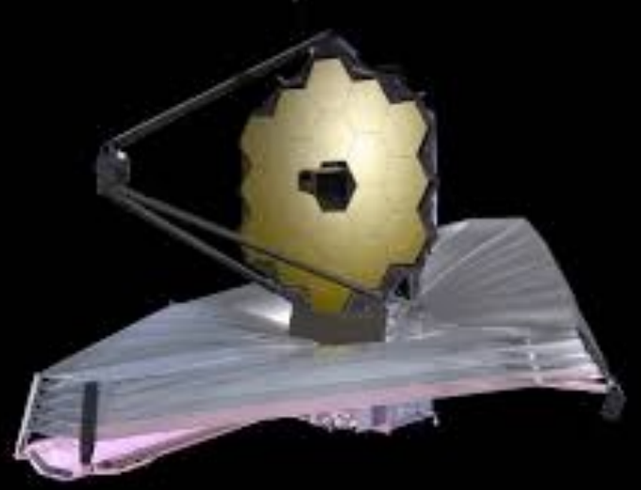
OU Astronomy Program





Sean Matt
Talk 4 REU Students
2024 June 25

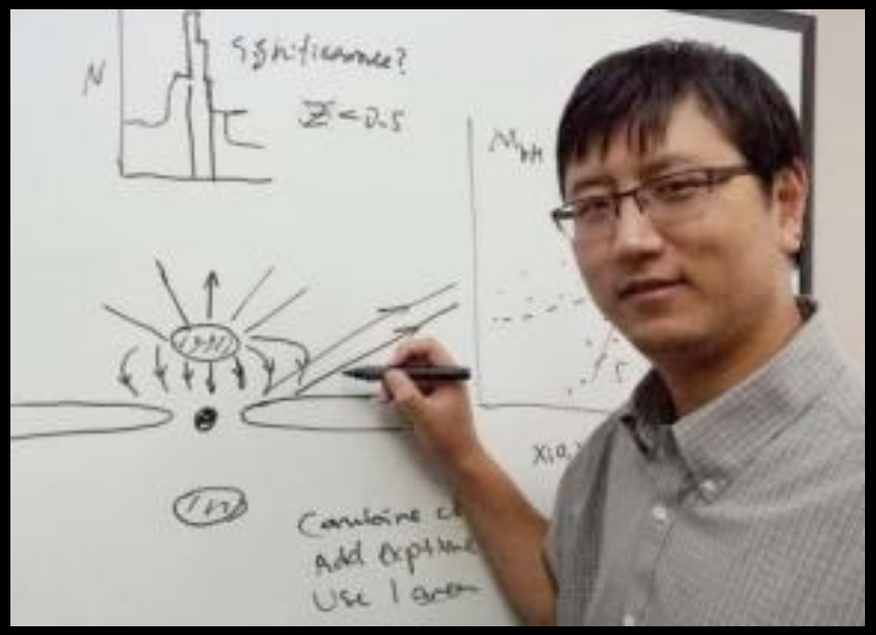
APO 3.5m telescope in NM
10% share, 70 half/nights, remotely operated

OU Supercomputing Center for Education & Research (OSCER)

- Free use for OU community
- Can purchase dedicated nodes

- + can apply for time on national facilities

OU Astro Group Faculty



Xinyu Dai

Mukremin Kilic

Nikole Nielsen

Karen Leighly

Sean Matt

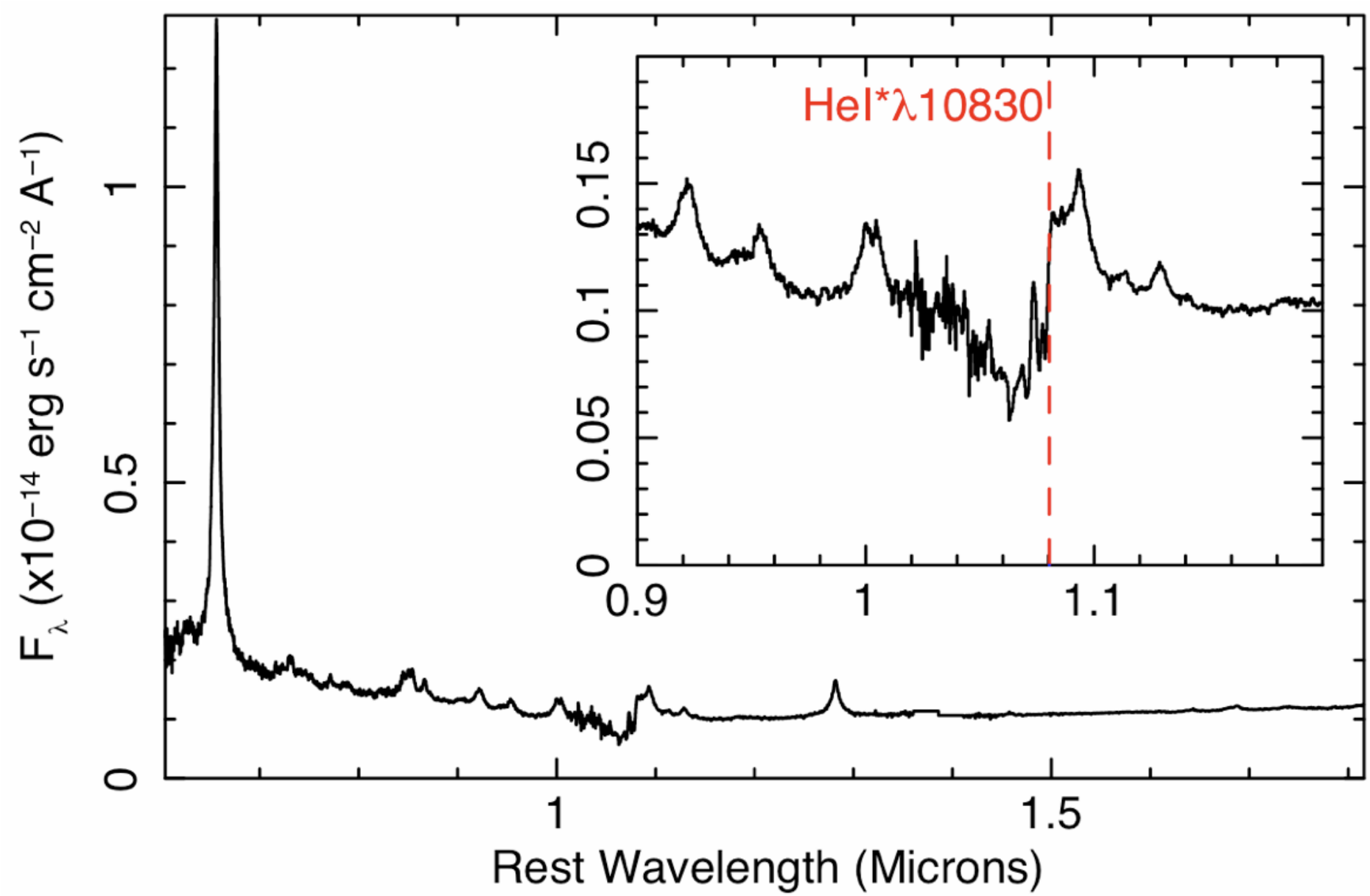
Michael Hayden

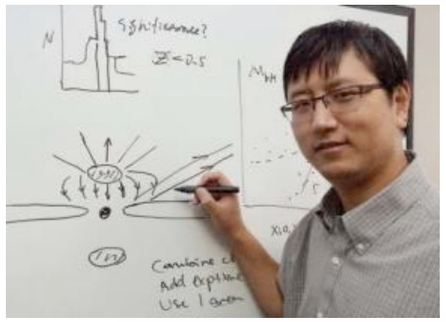
+new searches in fall 2025

Karen Leighly: Active Galactic Nuclei, Black hole mass and accretion

Leighly et al. 2011: The Discovery of the First He Iλ10830 Broad Absorption Line Quasar:

log (N_H/(g/cm^2)) = 21.7-22.9, mass outflow rate = 11 - 56 Msol/year, mass outflow rate / accretion rate = 1.2 - 5.8

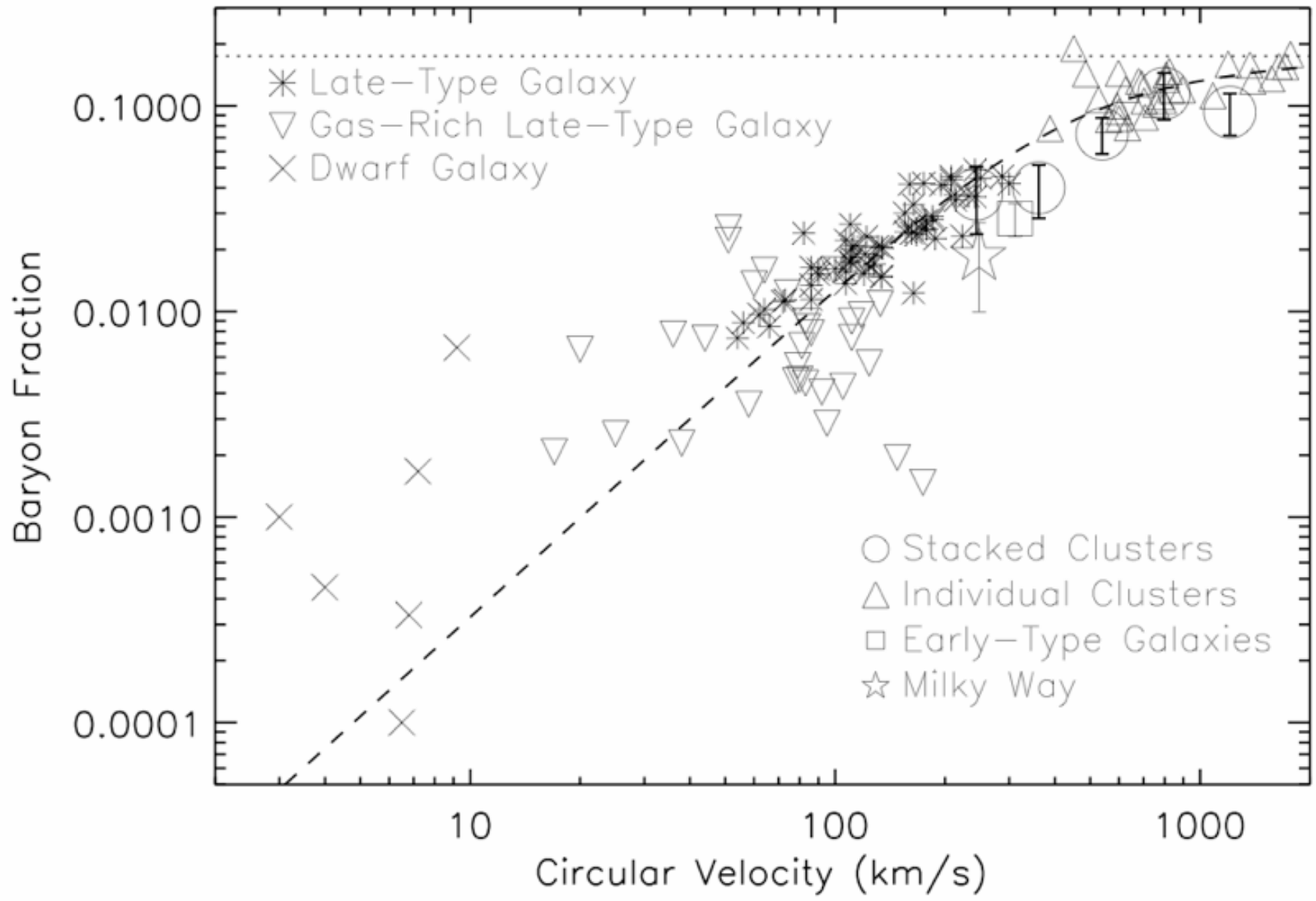


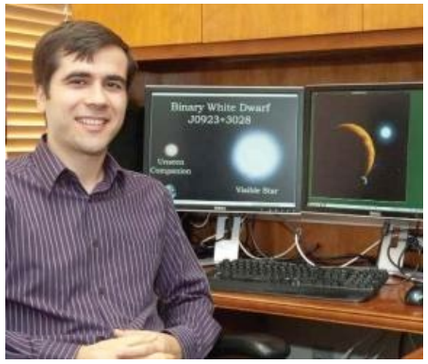


Xinyu Dai: Gravitational lenses, galaxy clusters, active galactic nuclei, and gamma-ray bursts

Dai et al. 2010: On the Baryon Fractions in Clusters and Groups of Galaxies::

For deep potential wells (rich clusters) baryon loss is not significant.

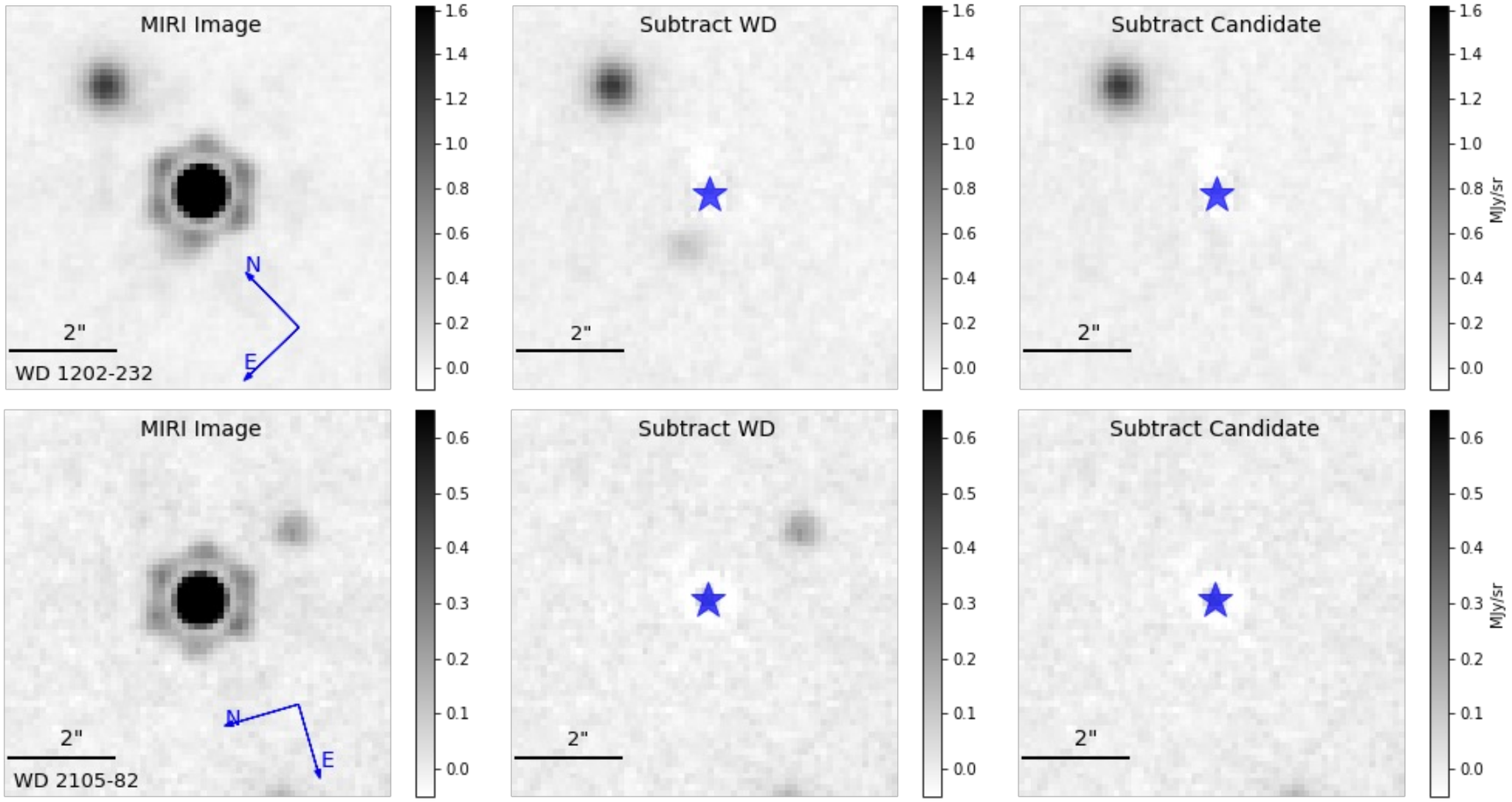




Mukremin Kilic: White dwarfs, planets and debris around white dwarfs

S. Mullally et al. 2024 (incl Poulsen & Kilic): JWST Directly Images Giant Planet Candidates Around Two Metal-polluted White Dwarf Stars:

Candidate planets separations of 11 and 35 AU, masses 1-7 MJupiter

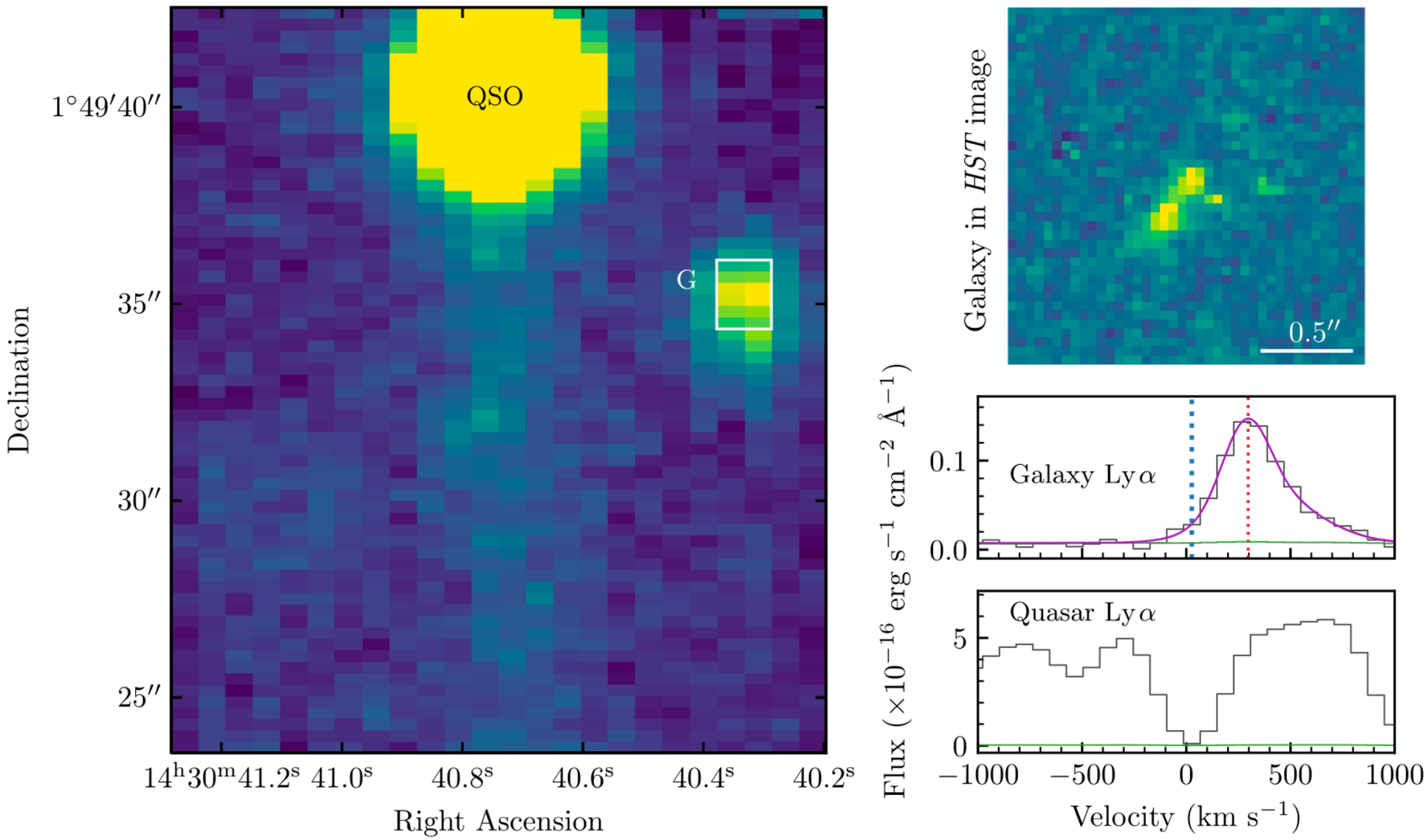


JWST Cycle 3 approved program to confirm these candidates.

Nikole Nielsen: Circumgalactic Medium and the baryon cycle in galaxies

Nielsen et al. 2020: The CGM at Cosmic Noon with KCWI: Outflows from a Star-forming Galaxy at z = 2.071

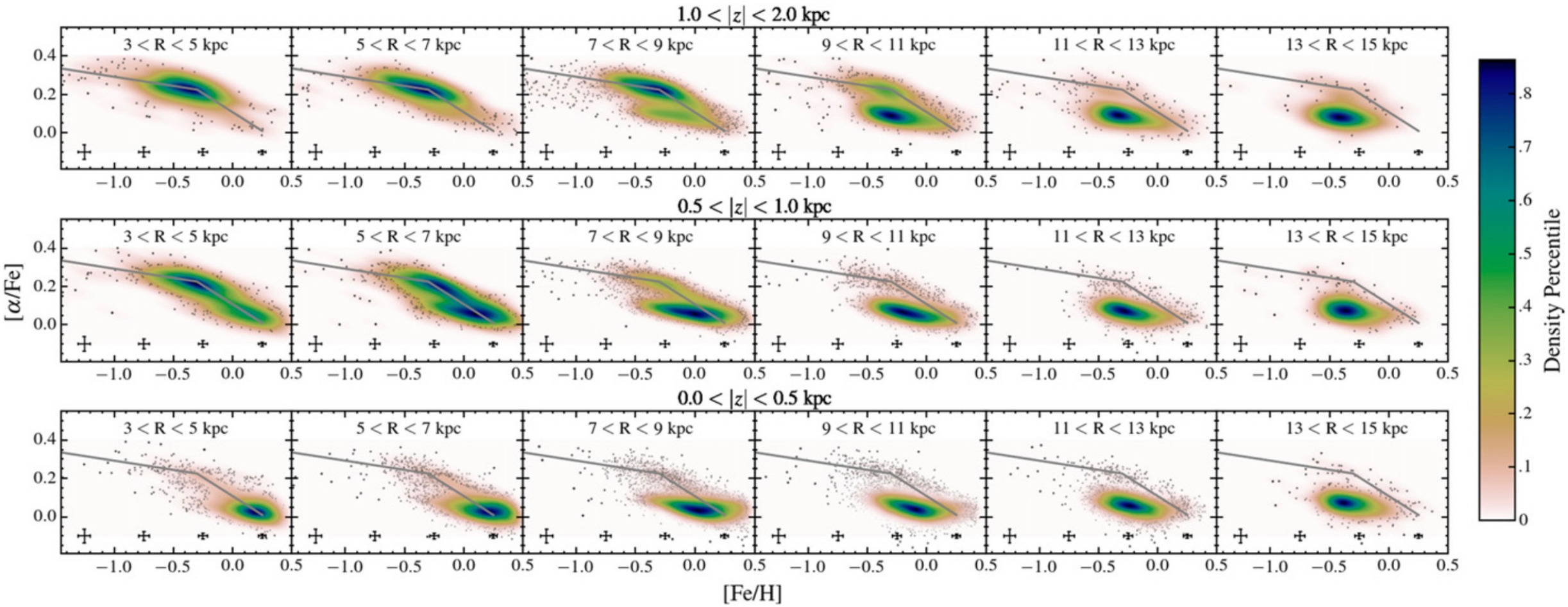
Light from distant quasar absorbed by outflow from galaxy; Mass outflow rate ~50 Msol/year, speed 100-600 km/s.



Michael Hayden: Galactic archaeology and galactic evolution

Hayden et al. 2015: Chemical Cartography With APOGEE: Metallicity Distribution Functions and the Chemical Structure of the Milky Way Disk:

Spectra for 70,000 red giants. Elemental abundances vary with position in our galaxy.

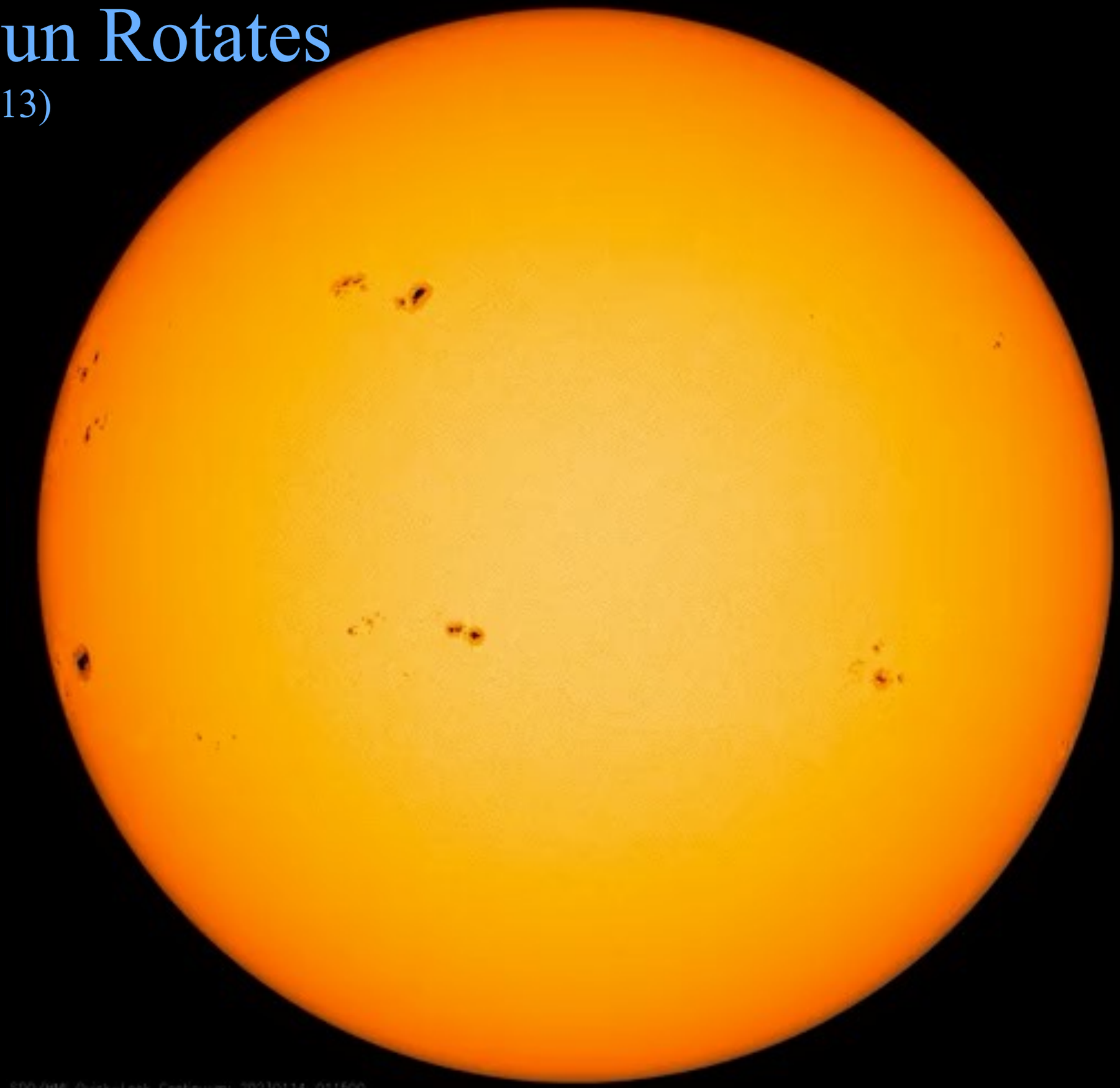


Theoretical Studies of Active Stars and their Environments

Sean Matt's
Research Interests

The Sun Rotates

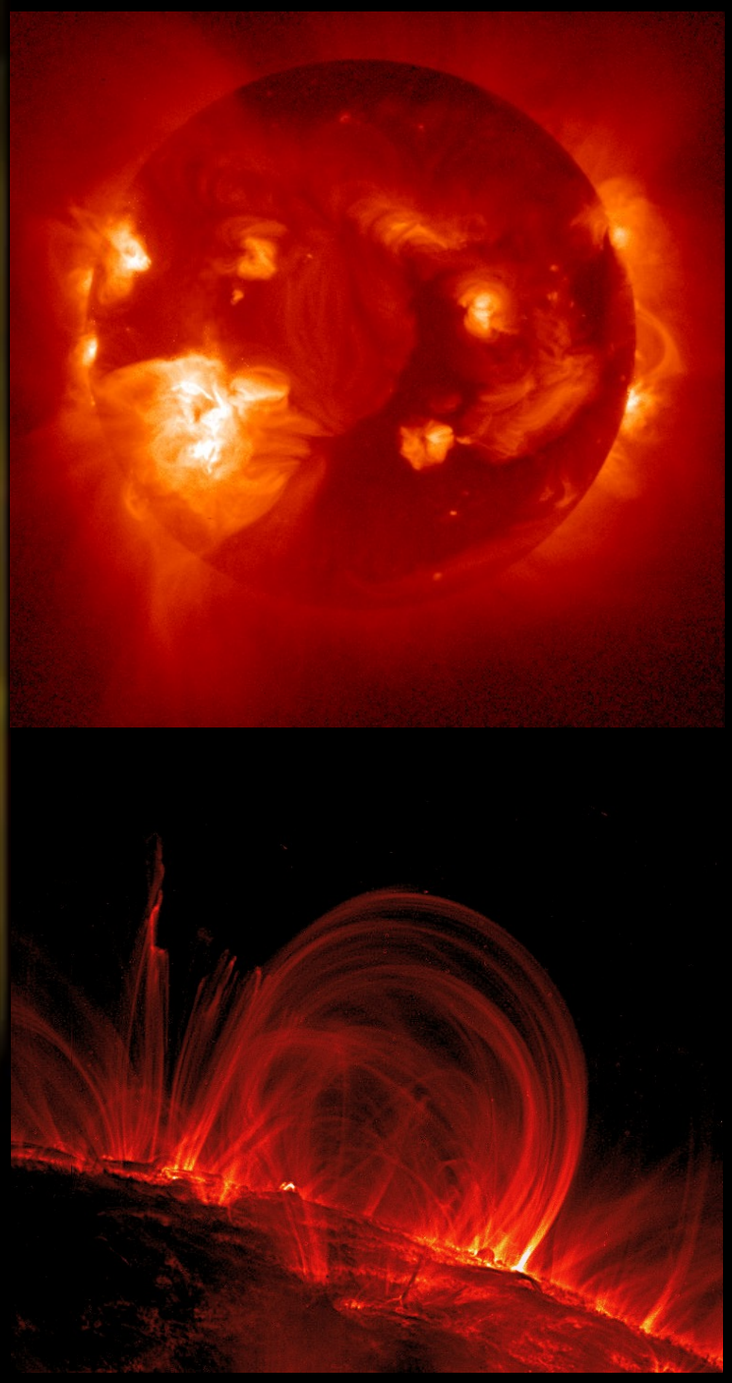
(Galileo 1613)



2023 January 14 – February 11 (sdo.gsfc.nasa.gov/)

The Sun is Magnetized

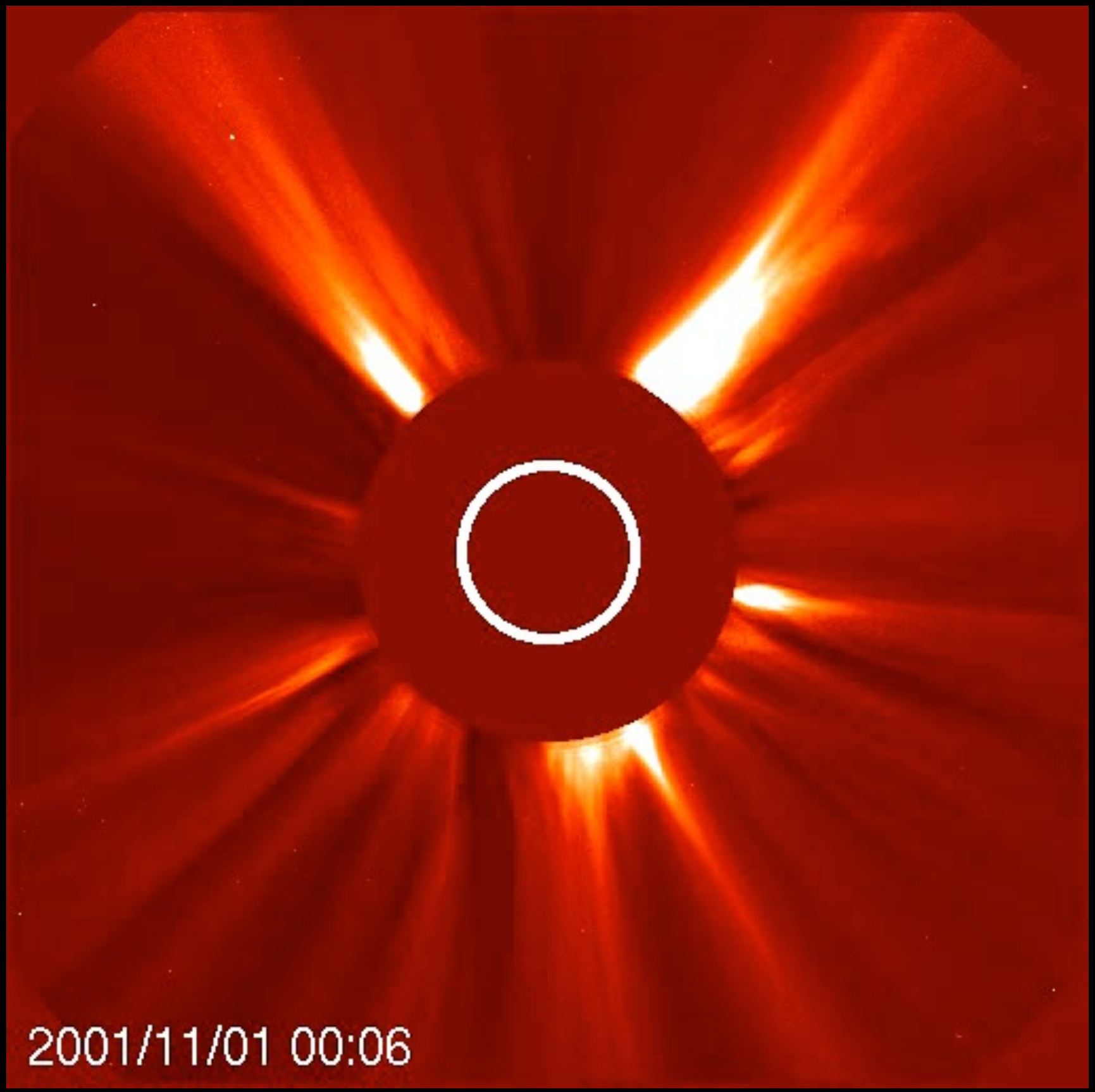
X-rays



EUV 2023 January 14 – 26 (sdo.gsfc.nasa.gov/)

SDO/AIA 171 2023-01-14 00:45:10 UT

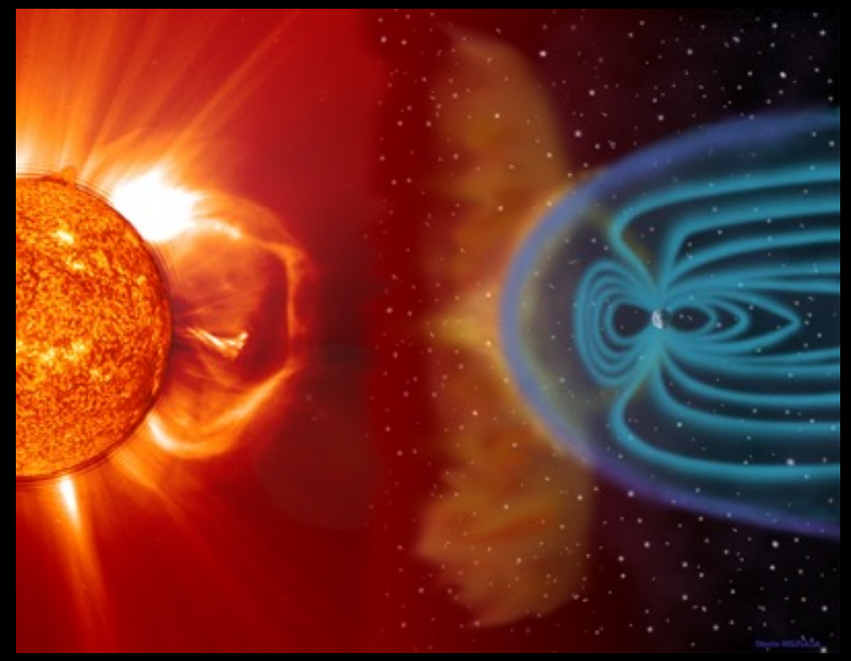
The Sun Loses Mass (Solar Wind)



Winds interact with Earth

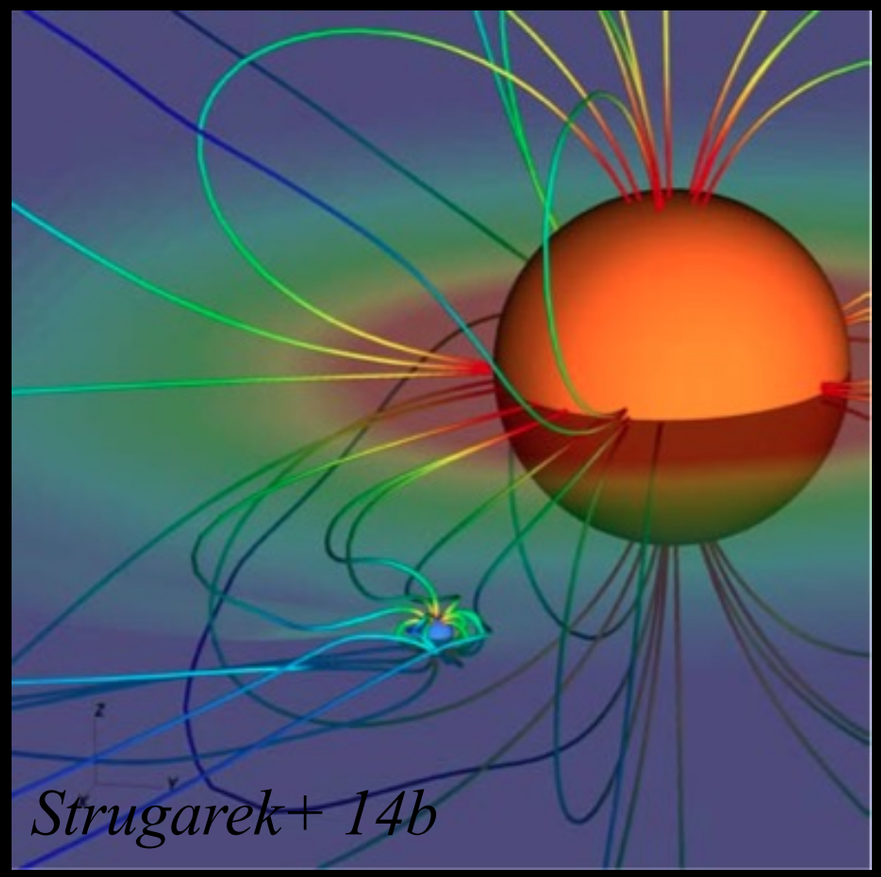
- Aurora
- Magnetic storms
- Radio communications
- Satellite interference
- "Space weather"
- Cosmic ray protection

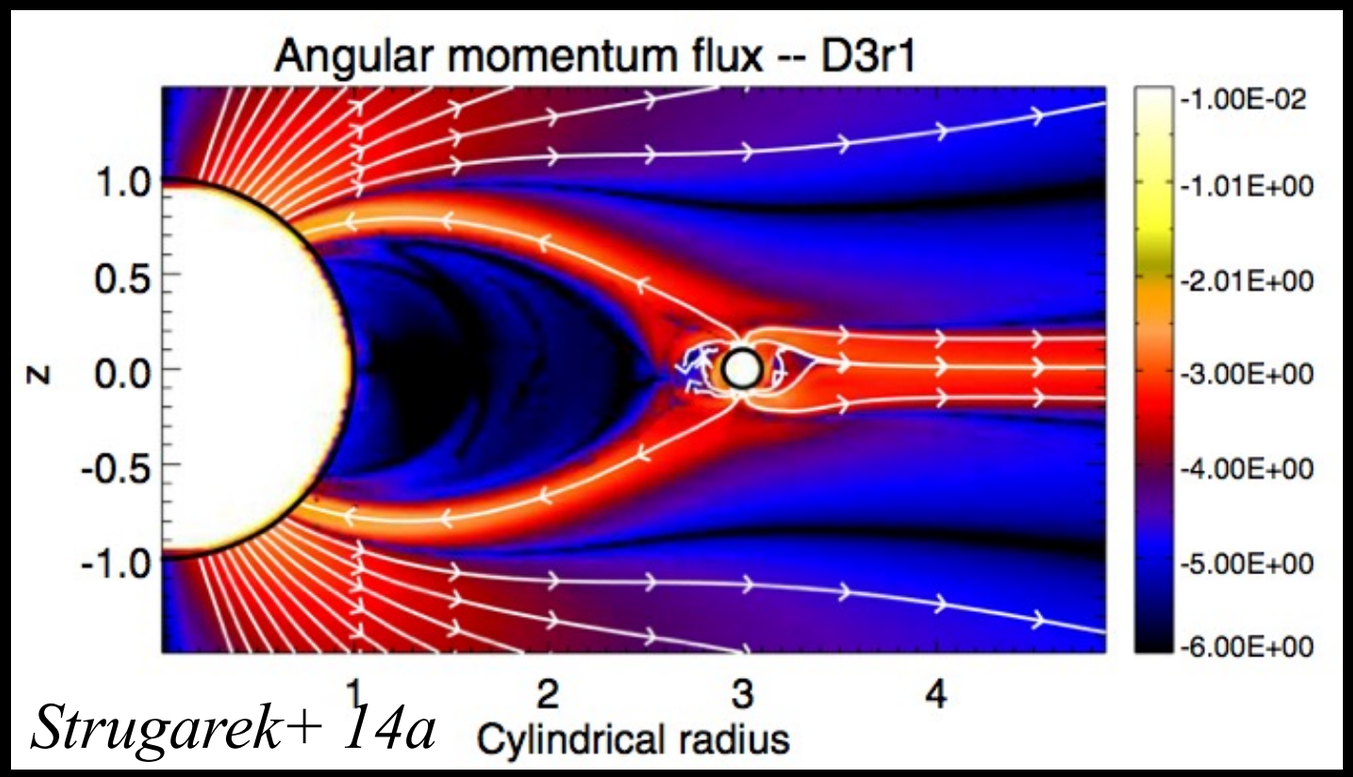
Copyright D. Hutchinson



SOHO/LASCO/EIT

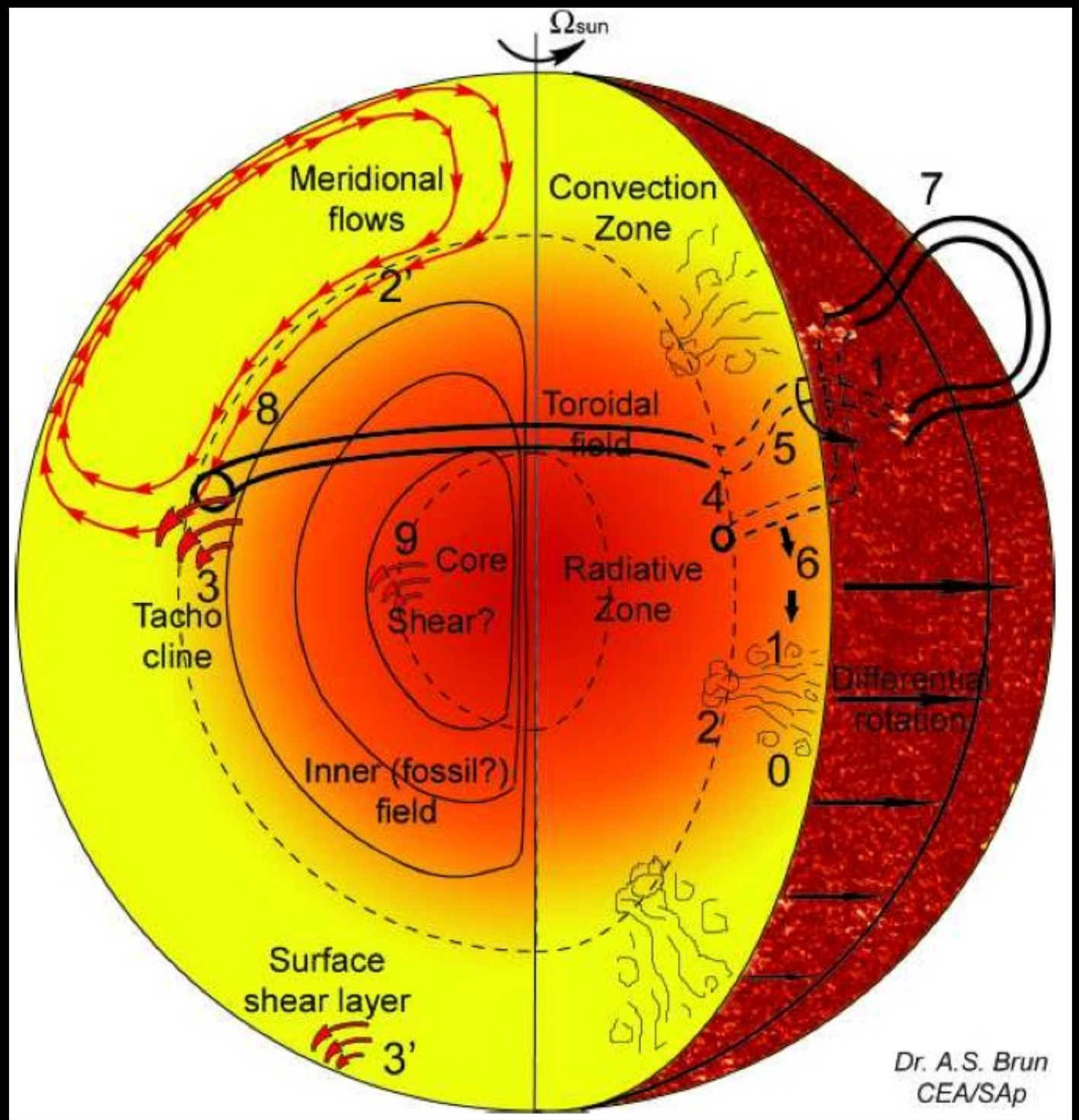
… and other planets.



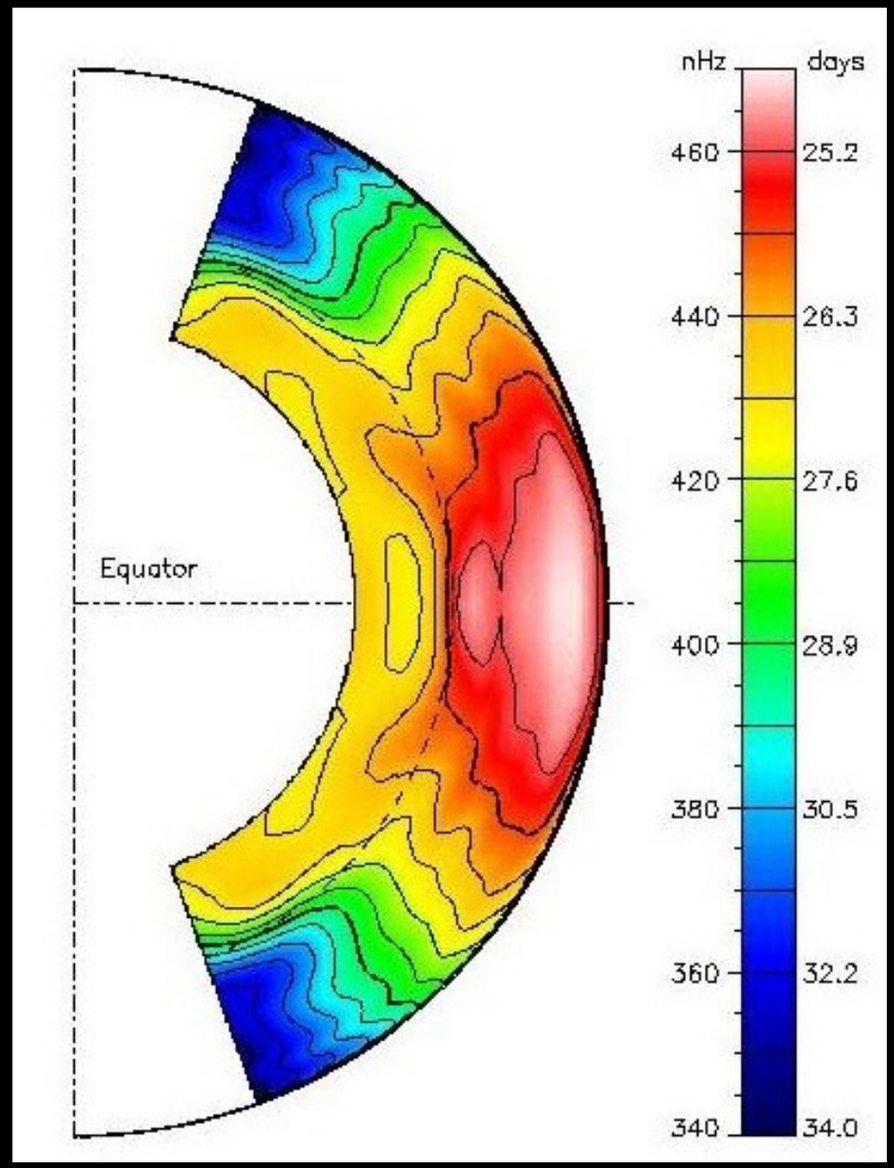


See also, e.g., Cohen+ 14, Matsakos+ 15.

Interior of the Sun



Differential rotation from asteroseismology



NSF / NSO

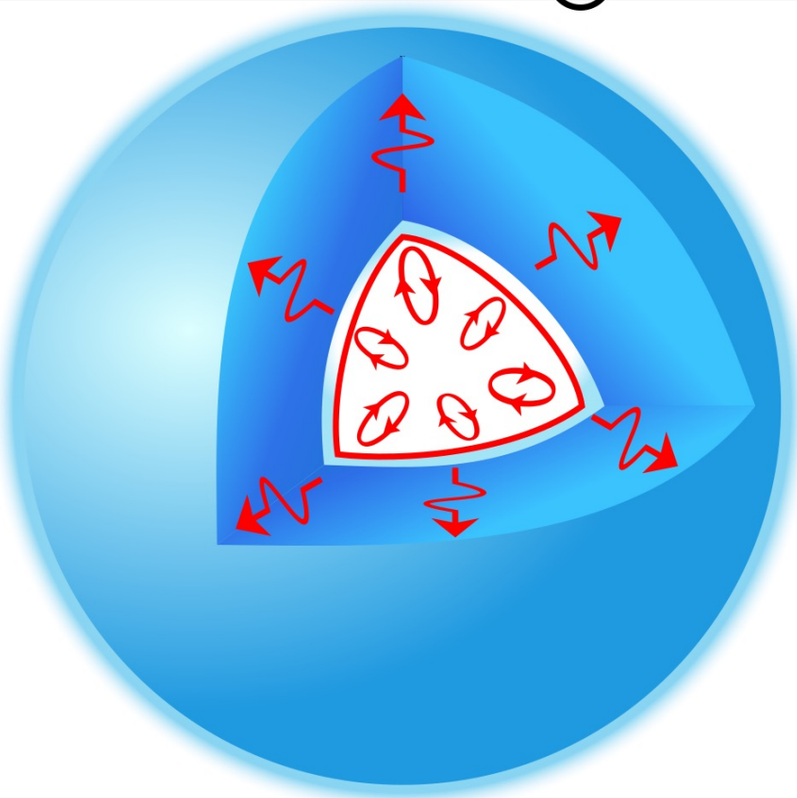
Dilemmas of Stellar Magnetism

- Angular momentum transport inside stars?
- How & where is magnetic field built?
- What explains magnetic cycles?
- Flux emergence and spot formation?
- Heating of coronae & magnetic activity?
- Driving and properties of winds?

Interiors of Sun-Like Stars

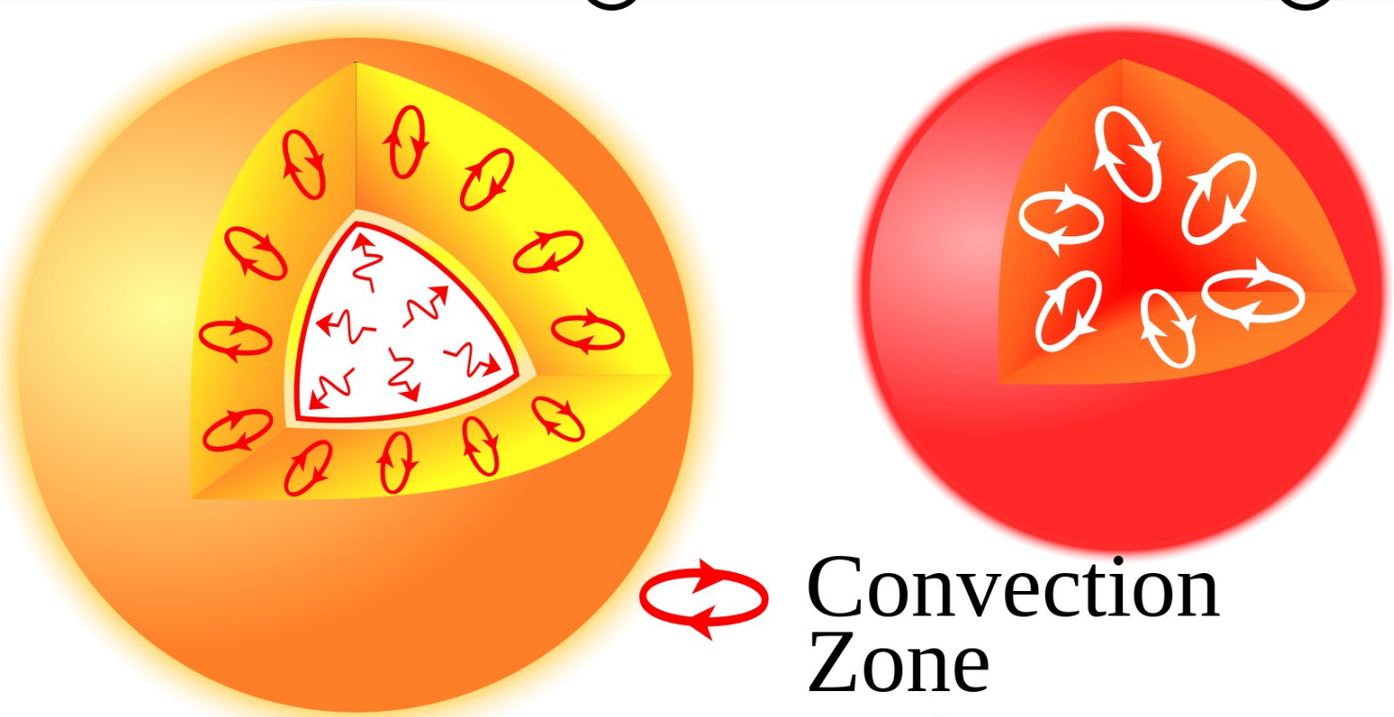
Massive stars:

~1.5 – 100+ M_{Sun}



Sun-like (and low mass) stars:

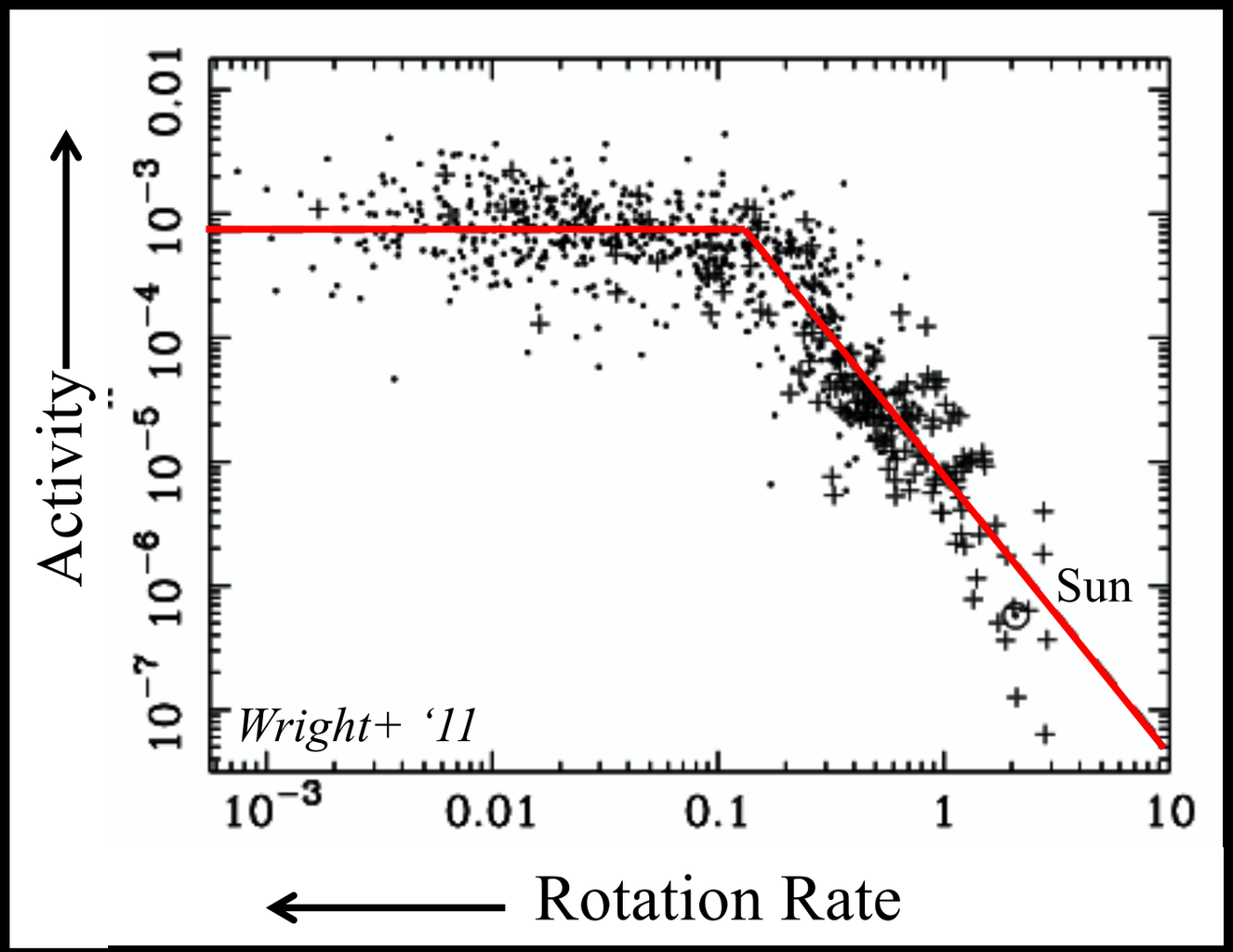
~ 0.08 – 1.4 M_{sun} (late F-M)



Have Sun-like magnetic activity

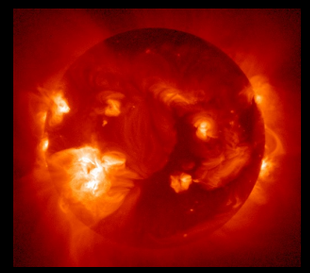
Rotation + convection produces magnetic activity

Rotation-activity relationships

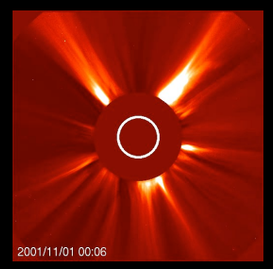


Spots & variability,

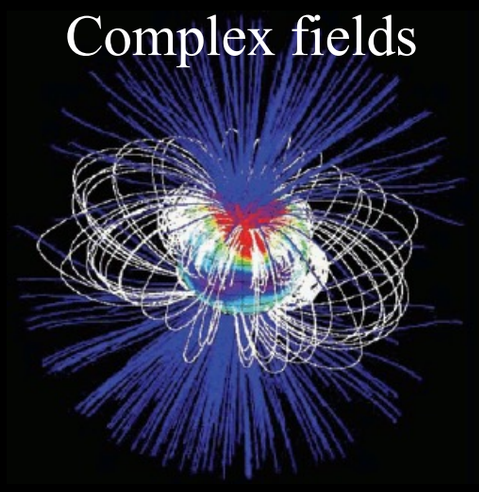
X-rays, CaH/K, Hα,



Winds & mass loss

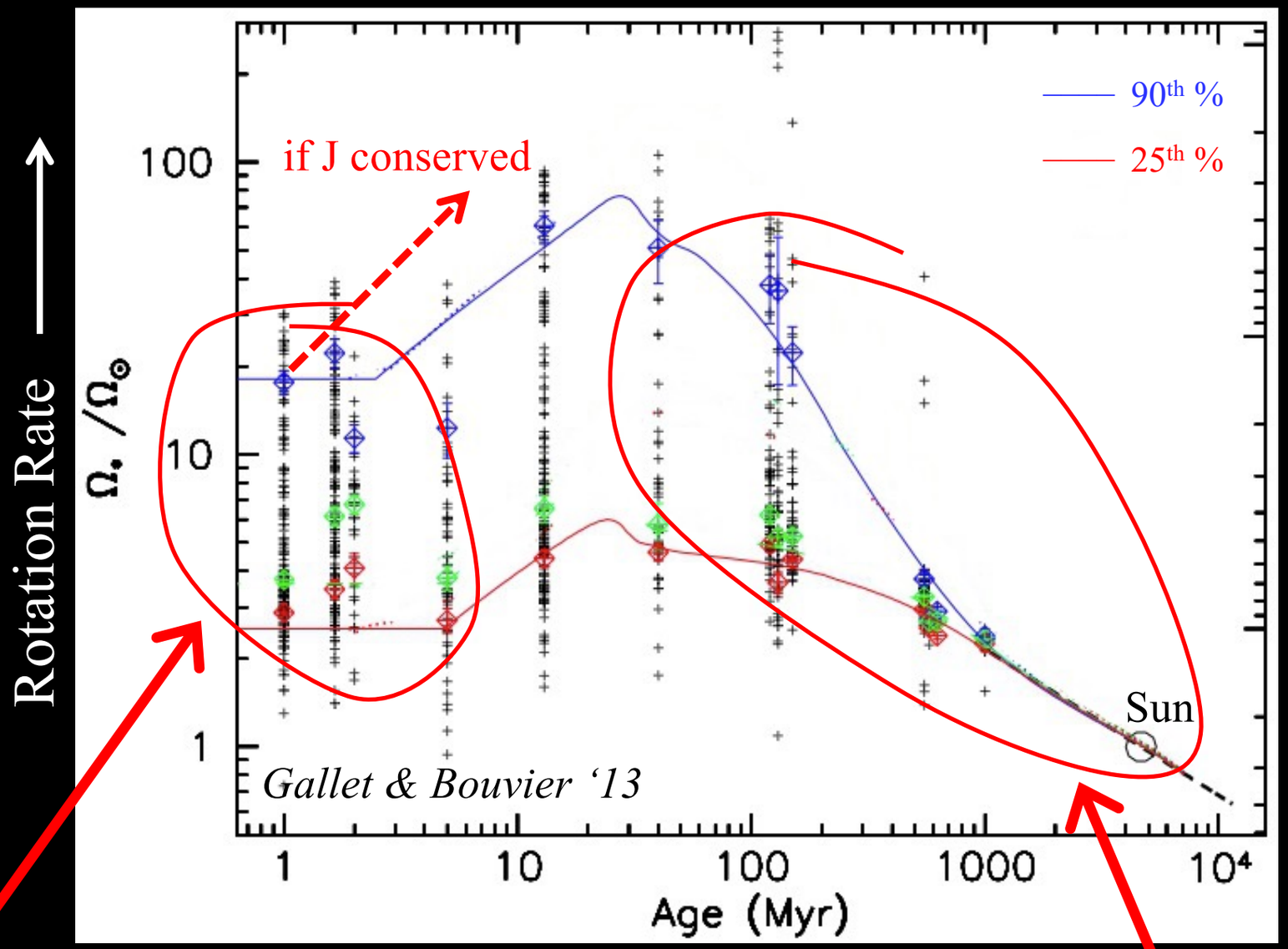


Complex fields



No predictive theory for how magnetic activity depends on rotation rate, mass, & age

Angular Momentum Problem at 1 Solar Mass

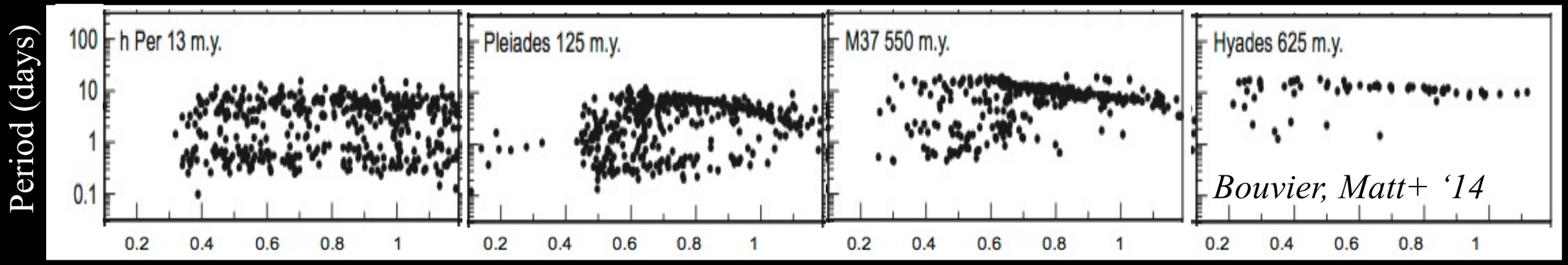


Accretion phase: How do stars lose the vast majority of their angular momentum?

How to explain this spin-down?

Opportunity: Deluge of Stellar Rotation Data

~10^4 rotation periods of cluster stars (in ~20 clusters)

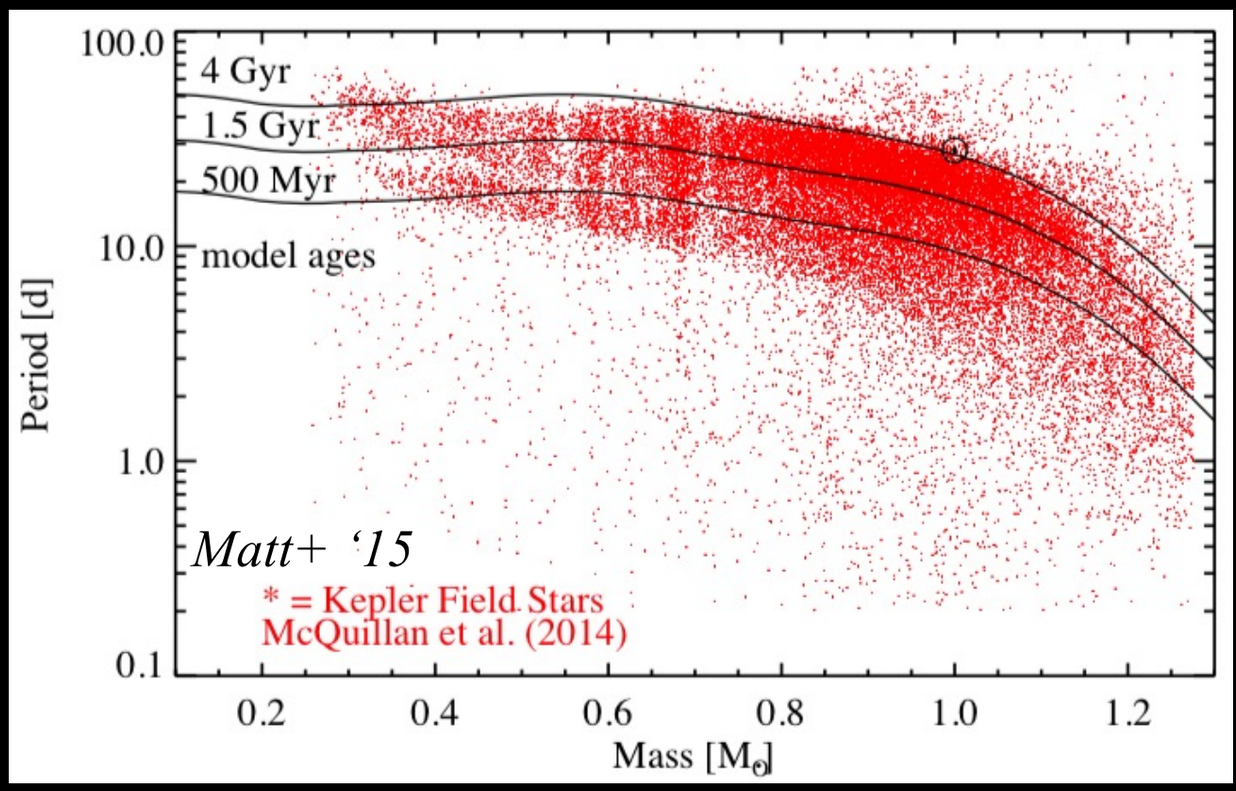


Explain period-mass distributions and cluster evolution?

Use rotation to probe ages? "Gyrochronology"

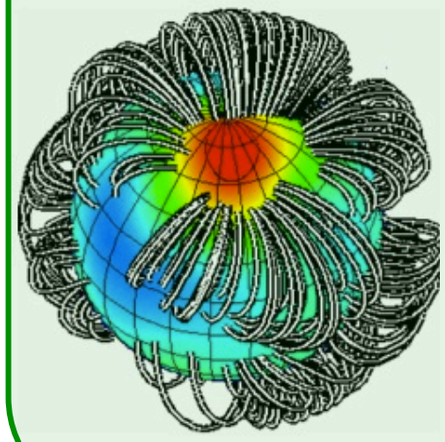
34000 rotation periods from Kepler

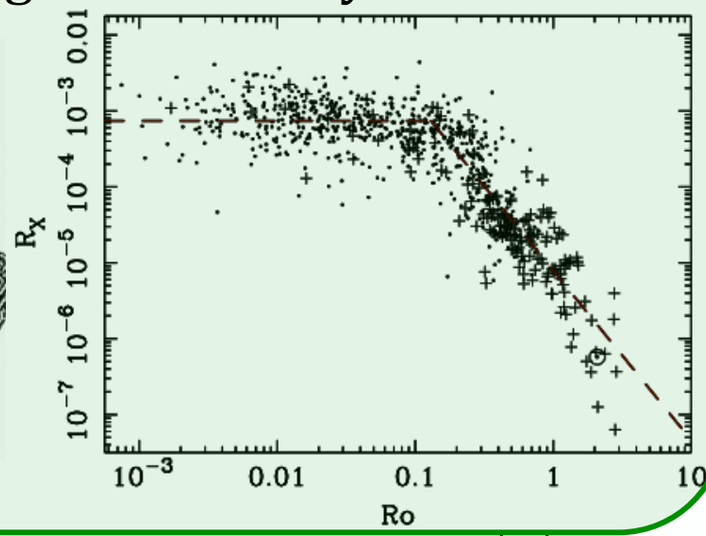
More from future surveys, TESS, LSST, PLATO, ...



Develop Comprehensive Physical Description

Magnetic Activity

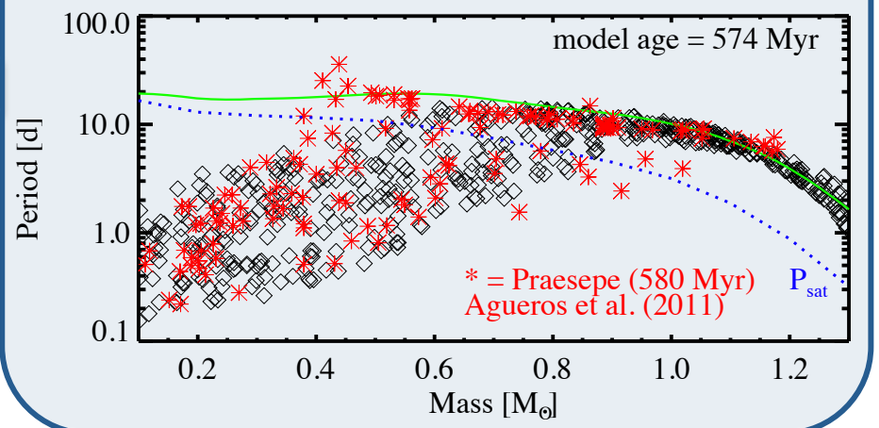




Dynamo Action

Timescales:
hours – decades

Stellar Rotation

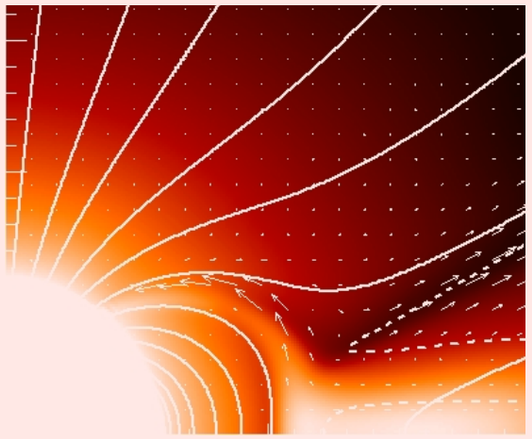


Interactions with Environment
Timescales: minutes – months

AWESoMeStars

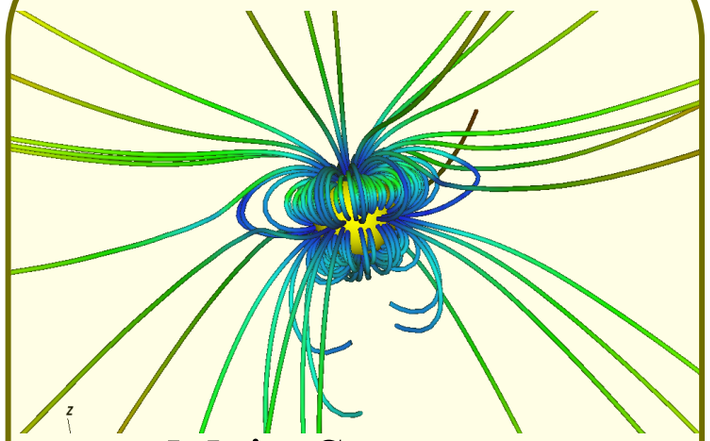
Spin Evolution

Task A:



Pre-Main-Sequence
Star-Disk Interaction

Task B:



Main-Sequence
Stellar Winds

Task C: Link *all* processes.
Timescales: 10^4 – 10^{10} yr

Torques

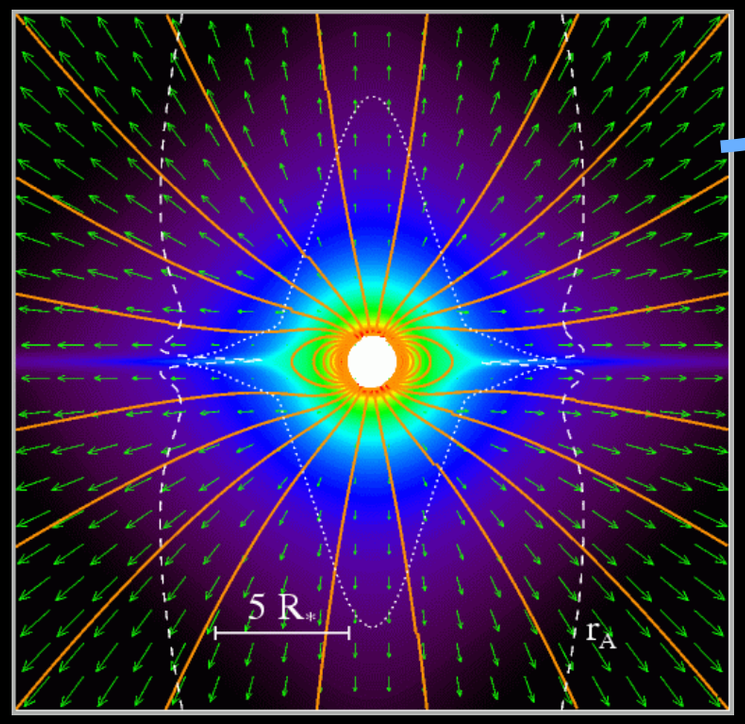
Calculating Angular Momentum Loss

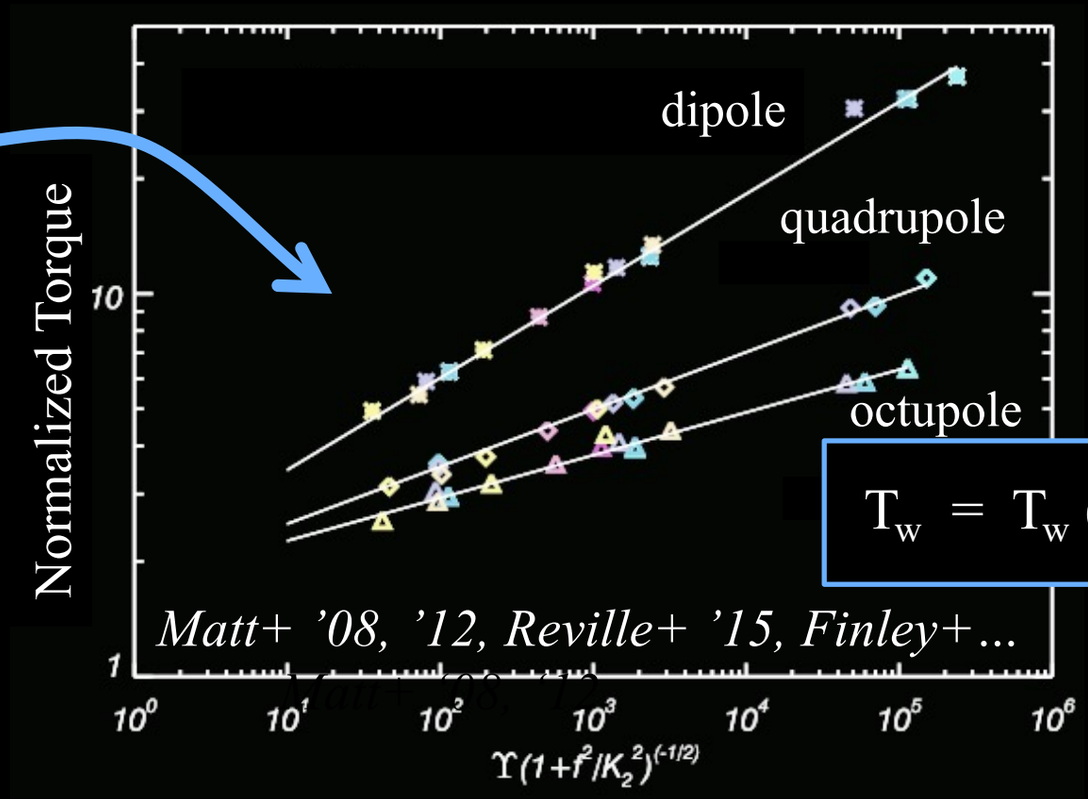
Challenge: complex physics and global problem

Strategy: MHD simulations (w PLUTO code)

Challenge: Simulation is only snapshot in time

Strategy: Novel techniques to determine torque scaling





$$T_w = T_w (M_*, R_*, \Omega_*, M_w, B_*)$$

"Magnetization" (new physical variable)

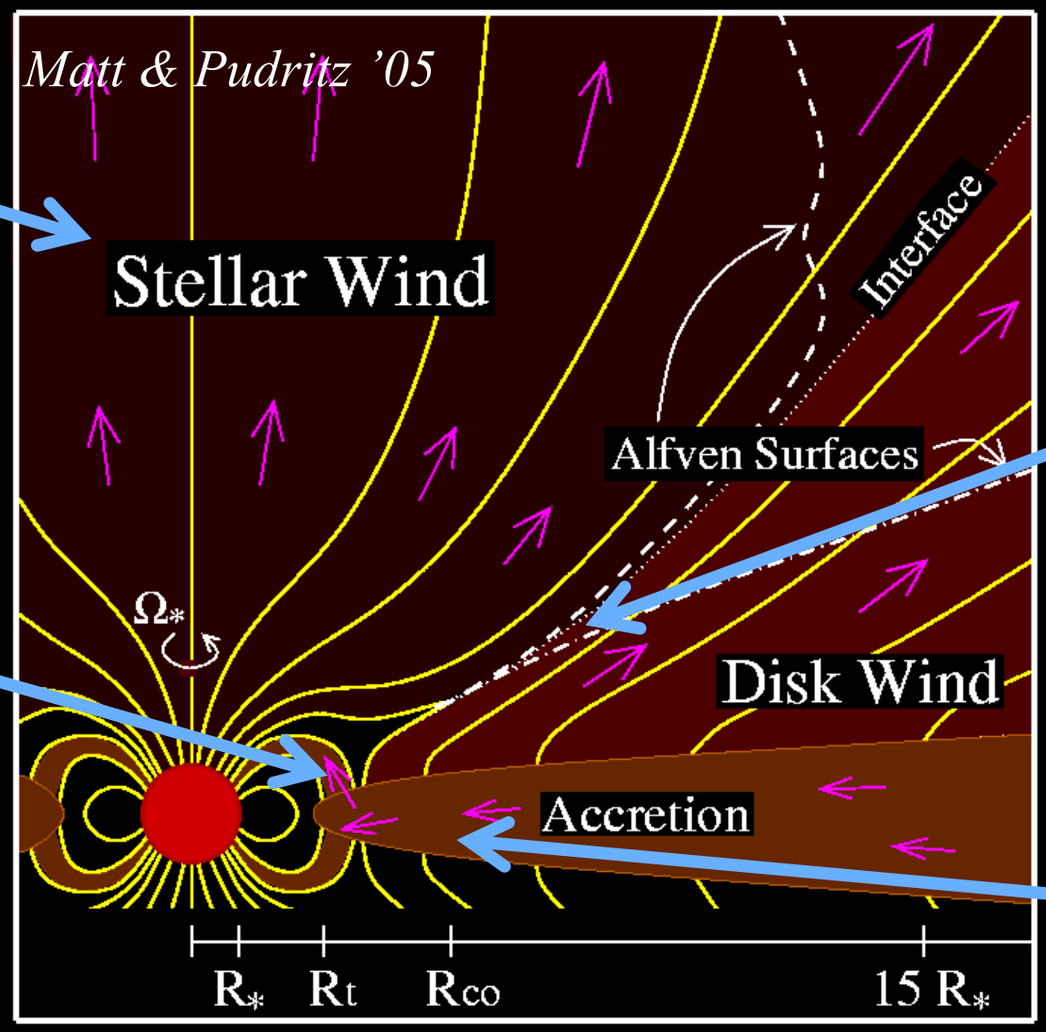
Star-Disk Interaction

Accretion-Powered Stellar Winds

Matt & Pudritz '05

Magnetic Connection

Ghosh & Lamb '78; Matt & Pudritz '05



Magnetospheric Ejections

Zanni & Ferreira 13; Romanova+ 09

Non-magnetic effects?

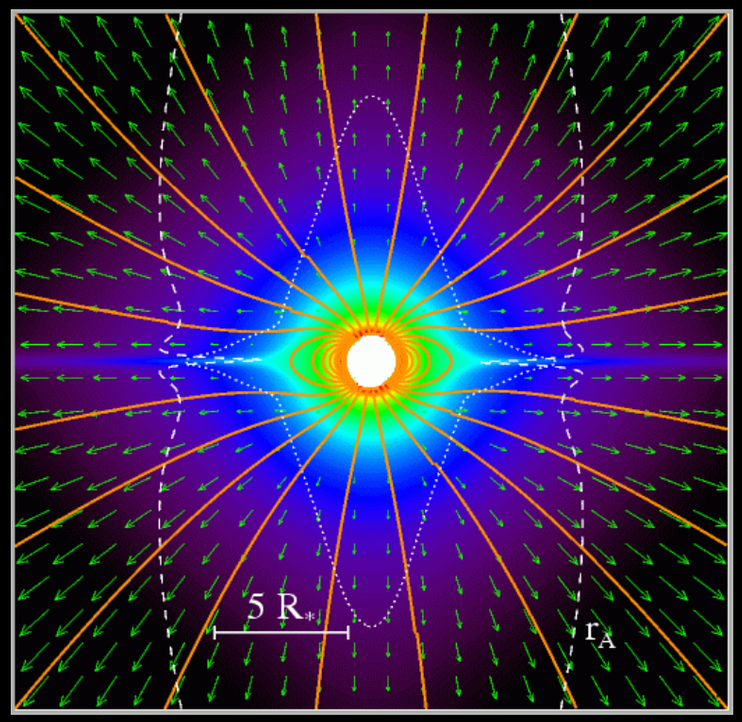
Popham & Narayan '91; Lin+ '11

1. MHD simulations of most promising mechanisms.

2. Determine the torque scaling for stars in the accretion phase.

Evolution of Spin, B, and dM/dt

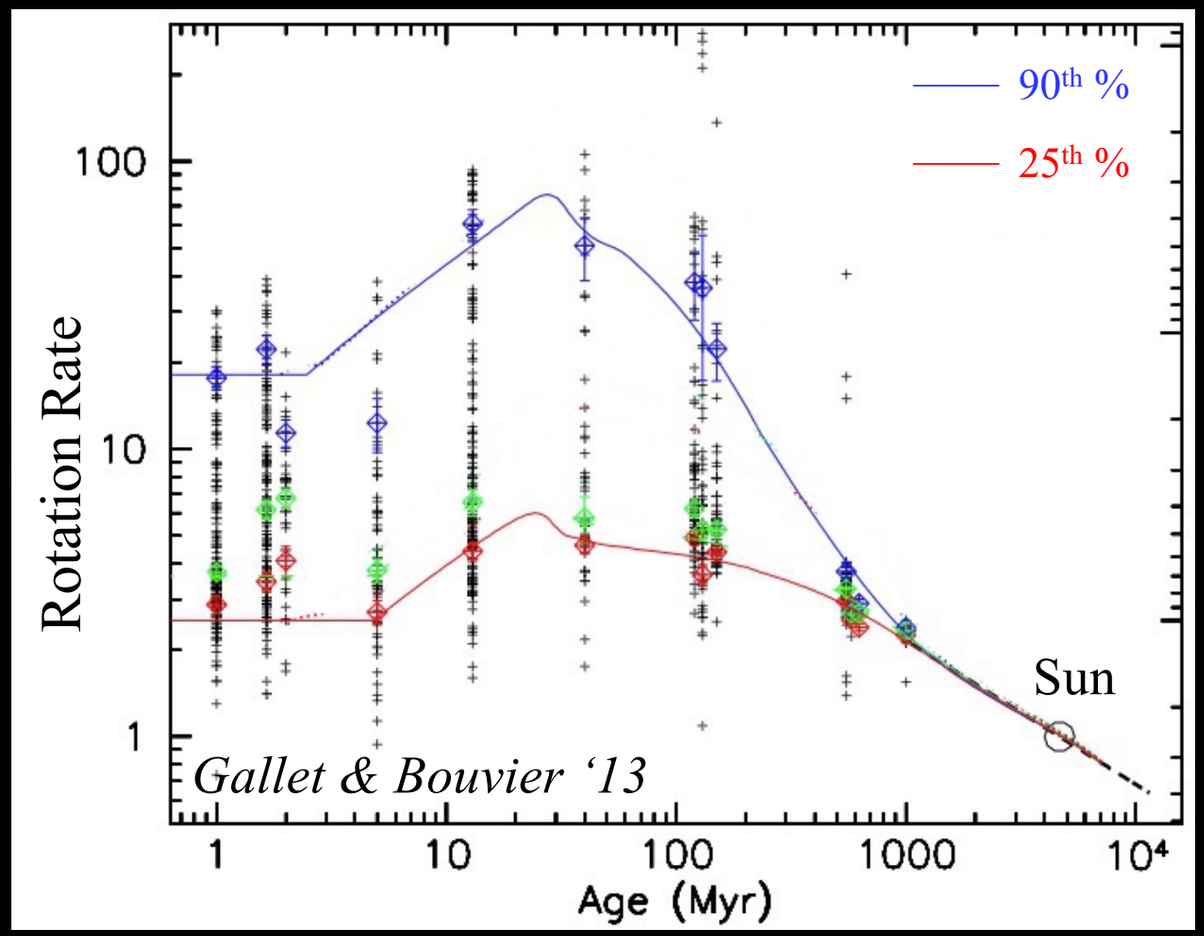
MHD Simulations



Challenge:

Timescale × 10^{10}

Stellar Evolution



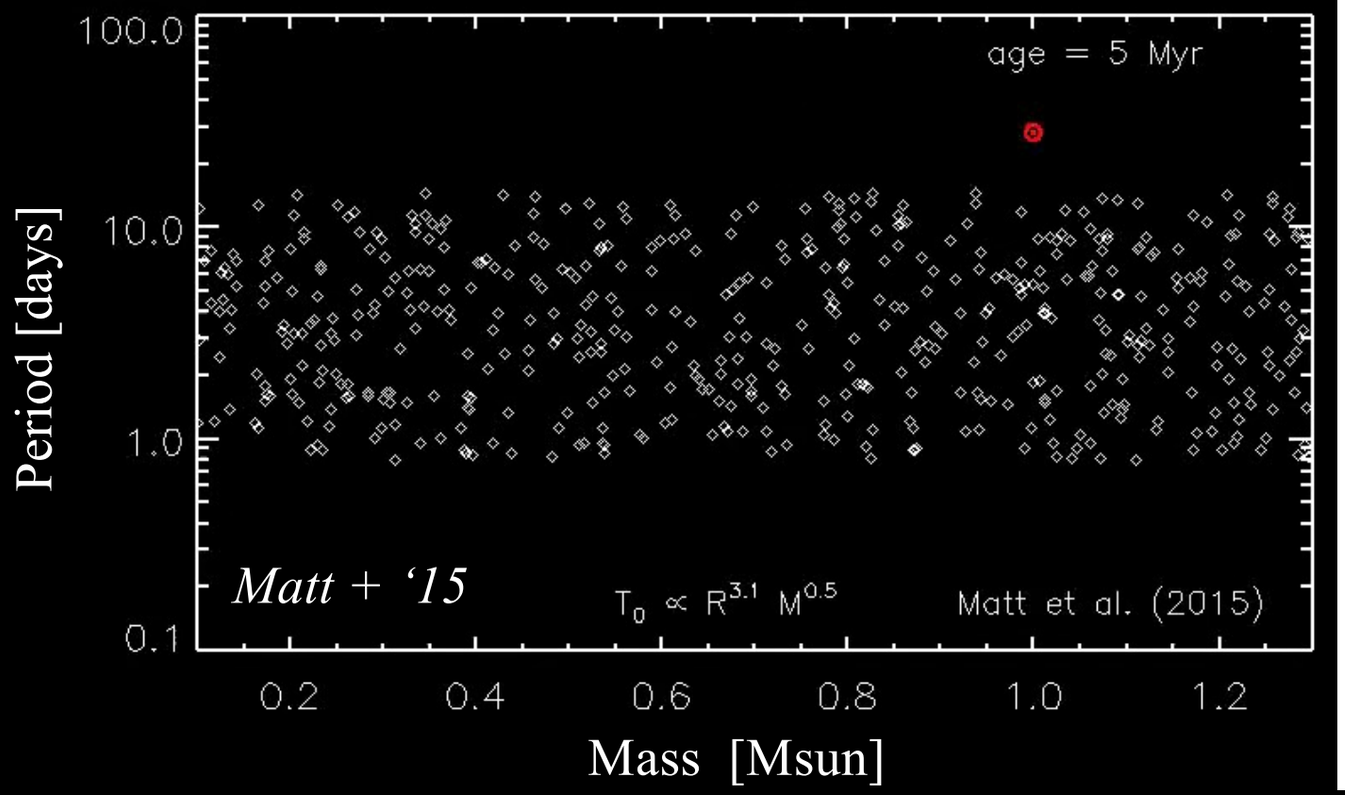
Strategy: Classical evolution models +

new torques +

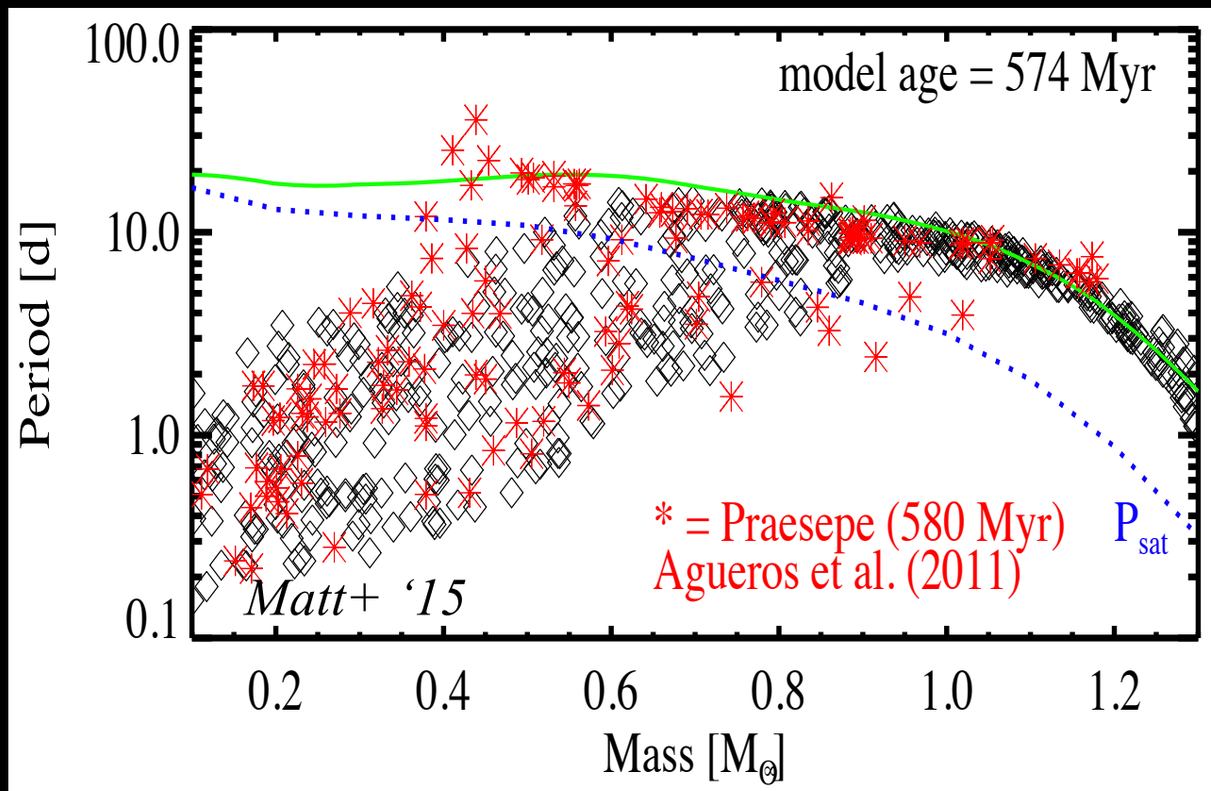
prescriptions for magnetic field + mass loss/gain

Spin-Evolution

Spin-evolution of model cluster



Snapshot compared to data



1. Evolution of clusters. Statistical comparisons with data. Probe magnetic activity across time.

2. Develop physical gyrochronology tools, decipher field star populations.

Current Research Team

- Stephanie Hall (PhD Student): Co-supervised by prof Rory Barnes (U Washington). Evolution of exo-Neptune planet atmospheres, evaporation due to star's evolving magnetic activity.

- Reshma Alexander (PhD Student): Co-supervised by prof Nate Kaib. Orbital dynamics of Jupiter-mass planets in binaries.

- David Gracia (PhD Student): Models of rotational evolution, initially exploring internal angular momentum transport.

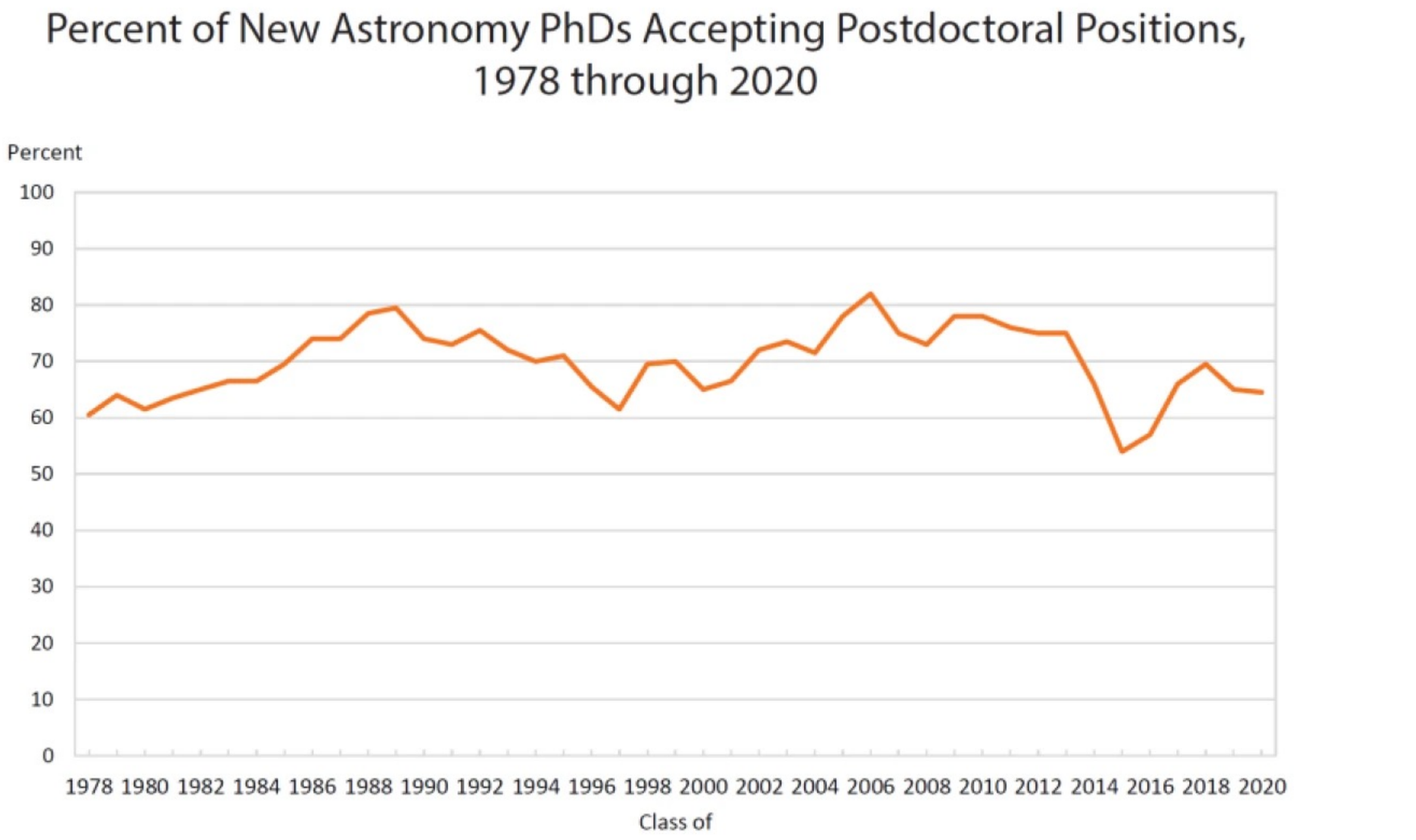
- Jordan Riley (UG Capstone + REU): Effects of stellar metallicity on rotational evolution.

- Jenna Brustad (REU student): Effects of variable accretion on rotation.

- Luke Garcia (UG Honors + Capstone): Using binary stars as "mini-clusters" to constrain understanding of rotational evolution.

- Javier Serna (Postdoc, started June): Pre-main-sequence phase evolution of accretion, rotation, and activity, observations and theory.

Grad school outcomes



Most others go to tech-skills jobs (e.g., data science, finance, software, policy, research support, …)

Grad school outcomes (e.g.)

My Students (U Exeter)

- Georgios Pantolmos (PhD 2018) -> Postdoc in France (IPAG) /Italy (Oss di Torino)
- Adam Finley (PhD 2020) -> Postdoc in France (CEA Saclay)
- Angela Breimann (PhD 2021) -> Industry (data scientist) in Scotland (Ofcom)
- Tom Wilson (PhD 2022) -> Industry (data scientist) in Oxford UK (Smith Institute)

Students of prof Kilic (from 2023)

- Sara Barber (PhD 2015) -> US House of Representatives Science Committee -> NSF
- Claudia Belardi (MS 2015) -> PhD at Leicester -> Inmarsat
- Paul Canton (PhD 2018) -> UCO/Lick Staff
- Kyra Dame (PhD 2019) -> Assistant Prof. at Grand Rapids Community College
- Alek Kosakowski (PhD 2021) -> Postdoc at Texas Tech
- Onder Catmabacak (MS 2023) -> Industry
- Renae Wall (PhD 2023) -> TBD