Watching brown dwarfs go round and round *

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Plus many students and collaborators

Rotation and variability from stars to planets

* Thanks to John Lennon and Scott Wolk
Brown dwarfs are extreme

Central object: $<0.08 \, M_\odot$

J-band mag $>12$ ($L<0.05 \, L_\odot$)

Disk masses: $\lesssim$ Jupiter mass

Dust masses: $\lesssim$ few Earth masses

Most disk sizes: $<25$ AU

Accretion rates: $<10^{-9} \, M_\odot/yr$

Pinilla et al. 2018
Variability is a really useful tool for faint sources.
Brown dwarf planets

Jung et al. 2018
Gaia CMD of variable stars

Eyer 2018

Brown dwarfs
20 years ago: first brown dwarf variability papers

- Martin et al. 1997
- Bailer-Jones & Mundt 1999
- Liebert et al. 1999

**Flares**

Liebert et al. 1999

**Clouds**

Bailer-Jones & Mundt 1999

**Spots**

Martin et al. 1997
Rotation period: fundamental parameter at <1% accuracy

Lamm 2003
Brown dwarf rotation: the database for 0.02-0.08 Msol

1-2 Myr: ~120 periods
Rodriguez Ledesma 2009, Scholz 2018, +

3-20 Myr: ~100 periods
Scholz 2004/05, Cody 2010, Scholz 2015,
Rebull 2018, Moore 2019, +

Field: ~20 periods, plus vsini
Many papers
K2 brown dwarf periods in Upper Scorpius

Moore et al. (2019)
Slow rotation and presence of disks

![Graphs showing slow rotation and presence of disks in Taurus and UpSco regions.](image)
Disk braking works for a few Myr. *

The planetary spin-mass relation

Snellen et al. 2014: first exoplanet spin rate

Power law relation between spin and mass from rocky planets to gas giants
Spin vs. mass

Brown dwarfs

$V \sim M^{1/2}$

Planets

Scholz et al. 2018
Cloud fragmentation and accretion

Disk fragmentation or core accretion

Ejection?
Turbulence?
Feedback?
A universal spin-mass relation - constraints on formation? *

* Scholz et al., ApJ, 2018
Inclined dipole + accretion column = complex variability

Romanova et al. 2004
AA Tau-like dippers among BDs
Spectroscopic variability in 2M1207

Scholz et al. 2005
2M1207: stable in 2005 vs. unstable in 2006

Stelzer et al. 2007

Kurosawa & Romanova 2013
V2737: unstable, face-on, like TW Hya?

Scholz & Eislöffel 2004

Scholz et al. 2009
Accretion bursts in VLM objects

Sicilia Aguilar et al. 2017

Caratti o Garatti et al. 2013
The same paradigm seems to work for low-mass stars and brown dwarfs.
Among M stars: Dippers without accretion

Scholz, Natta et al. 2019

See also:
David 2017
Stauffer 2017, 2018
Zhan et al. today
A sample of highly variable VLM objects in Sigma Ori

Strong aperiodic variability without disk
High variability without spectral changes

Hot spots, but only a few 100K above photosphere?

Filling factor 20-40%?
Bozhinova 2017

V2737 Ori Dec 2015 - Jan 2016

Magnitude + offset [mags]

MJD [d]

LCOGT i-band, 40s
LCOGT i-band, 100s
LCOGT i-band, 20s
Spitzer 4.5 μm
WT I-band
Variability tends to make things more complicated.
Still to be discovered

Accretion bursts
Long disk eclipses
Non-accretion dippers
Circumsecondary disks
Transiting exoplanets

Jon Lomberg
Needed: deep, wide, multi-filter survey with fast cadence
The first open, free, peer-reviewed arxiv-overlay journal

The Open Journal of Astrophysics

Now open for submissions