Magnetic Fields in Protostellar Disks

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Standard Paradigm of Magnetically Regulated Star Formation
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Ignore Turbulence..

Other Talks!

Crutcher 06
Detection of Magnetic Fields in Star Forming Regions

Line of Sight component of B or B\_parallel is usually observed via Zeeman Measurements (Talk by Dick Crutcher)

Plane of Sky component or B\_perpendicular mainly via observation of polarization of spinning dust grains

CAVEAT! Only Zeeman observations can provide B Field strengths. Polarized dust emission only gives us the direction!
Observations of Polarization from Dust

Observations of background starlight polarization in absorption → independently mapped by Hall (1949) and Hiltner (1949)

Original explanation by Davis and Greenstein (1951) → based on paramagnetic alignment of spinning dust grains

Current theories from the group of Lazarian + → based on Radiative Alignment Torques (RATs) (later talks)
Pinched Hour Glass Fields in Class 0 YSOs

NGC 1333 IRAS 4A (Girart+ 06)  IRAS 16293 A and B (Rao+ 09)

The fields probed here are primarily the envelope fields!
What about the Magnetic Fields in Disks?
Magnetic Fields can Impede Disk Formation

Disks form from the collapse of rotating cores due to conservation of angular momentum

But envelope and disk must be connected THRU magnetic braking

Therefore, disk formation is not guaranteed ⇒ Or only SMALL disks can be formed

Slide courtesy Zhi-Yun Li; See Li+ 2014 PPVI
Magnetic Fields can Impede Disk Formation

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But envelope and disk must be connected through magnetic braking.

Therefore, disk formation is not guaranteed ⇒ Or only small disks can be formed.

How to resolve --

1. Turbulence
2. Non ideal MHD effects
3. Axis misalignment etc.
What do observations tell us about the size scales of these disks?
L1527: Is the Disk really this Large?
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Later SMA and ALMA observations (Ohashi, Yen, et al. 2014) find that the data are more consistent with a smaller disk.

\[ \sim 54 \text{ AU} \]
VLA 1623: Disk revealed by Kinematics

Murillo +13: ALMA C18O 2 ->1 observations of VLA1623 A and fitted models.

Disk is 50 AU in size
The Challenge is to Find the Magnetic Field Structure in Disks in YSOs!
Early SMA Sensitive Non Detections in more evolved YSOs

No detections in HD 163296 and TW Hya
Hughes+ 09
A Toroidal Field: Face On Disk in IRAS 16293B

Class 0 Disk
Disk B Fields in L1527

Outflows show Disk Geometry

Class 0 Disk
The Disk B Fields in VLA 1623

Class 0 Disk

Hull+ 14
The (mostly) Edge-On Disk of HL Tau

>Class 1 Disk
Theoretical Models of the 3-D Structure

Kataoka+ 12 show both toroidal and poloidal structures
The Story So Far ...

Observations show that the fields appear to be mostly **toroidal**

But ....

We need *poloidal component* of the field in order to drive jets and outflows.

As for the Future...
The Era of ALMA: HL Tau Stokes I

Credit: ALMA (NRAO/ESO/NAOJ); C. Brogan, B. Saxton (NRAO/AUI/NSF)
The Era of ALMA

Thank You!
The Era of ALMA

Thank You!