Magnetic Fields in Protostellar Disks

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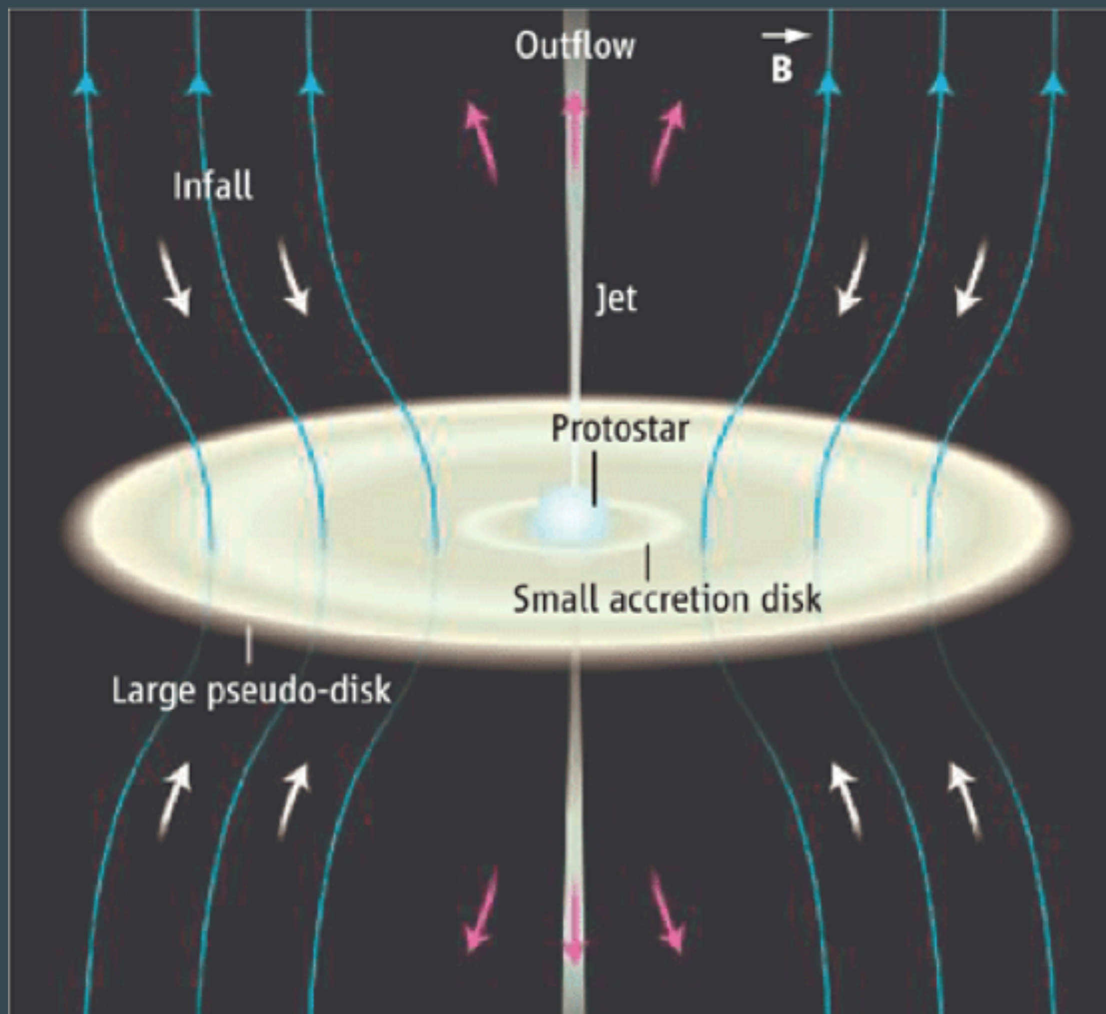
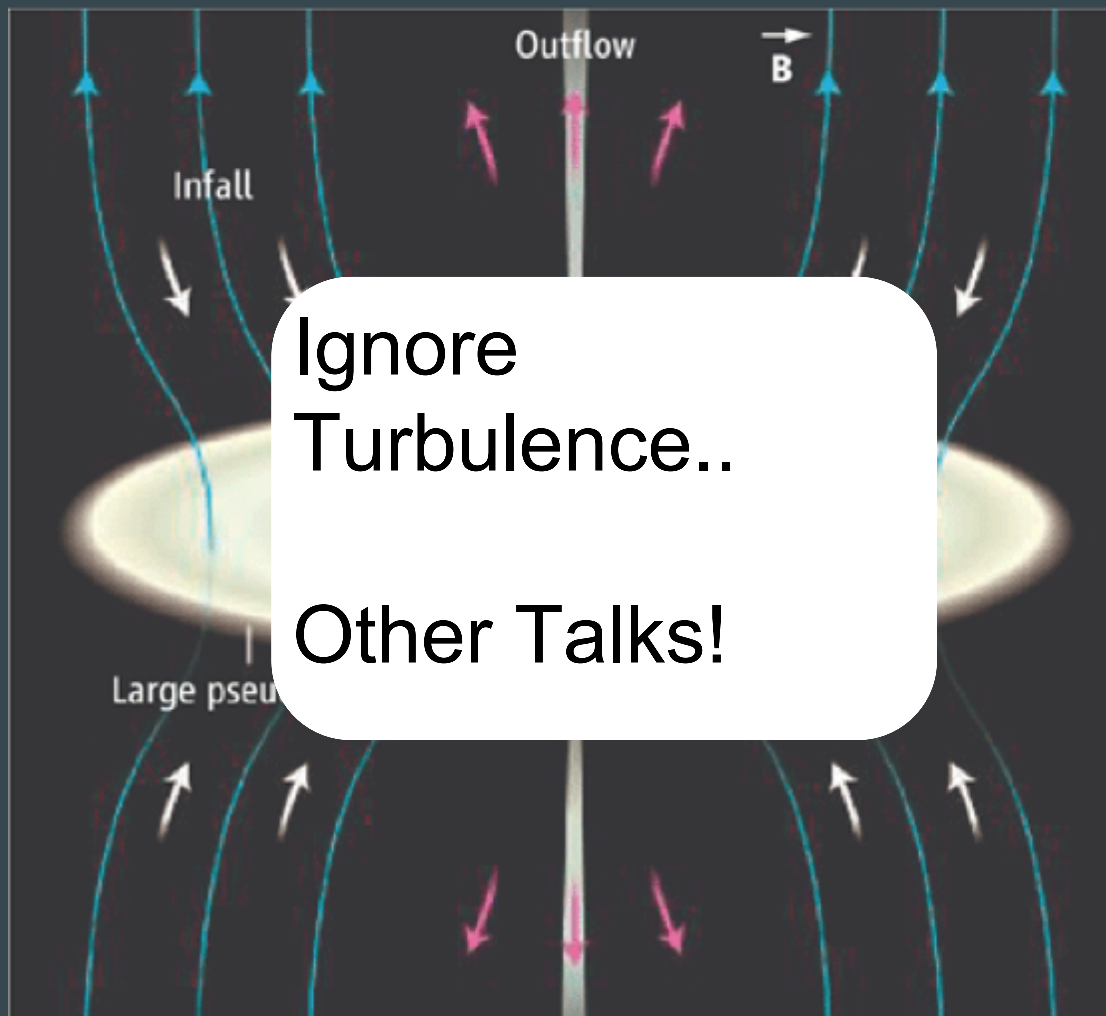
Standard Paradigm of Magnetically Regulated Star Formation



Crutcher 06

Standard Paradigm of Magnetically Regulated Star Formation



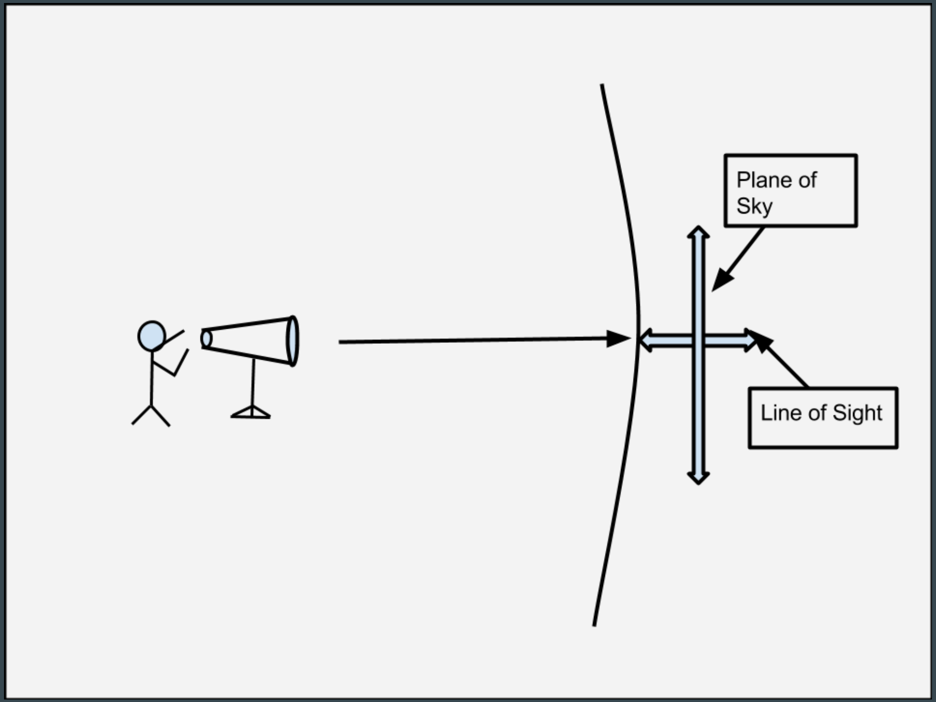
Ignore Turbulence..

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)

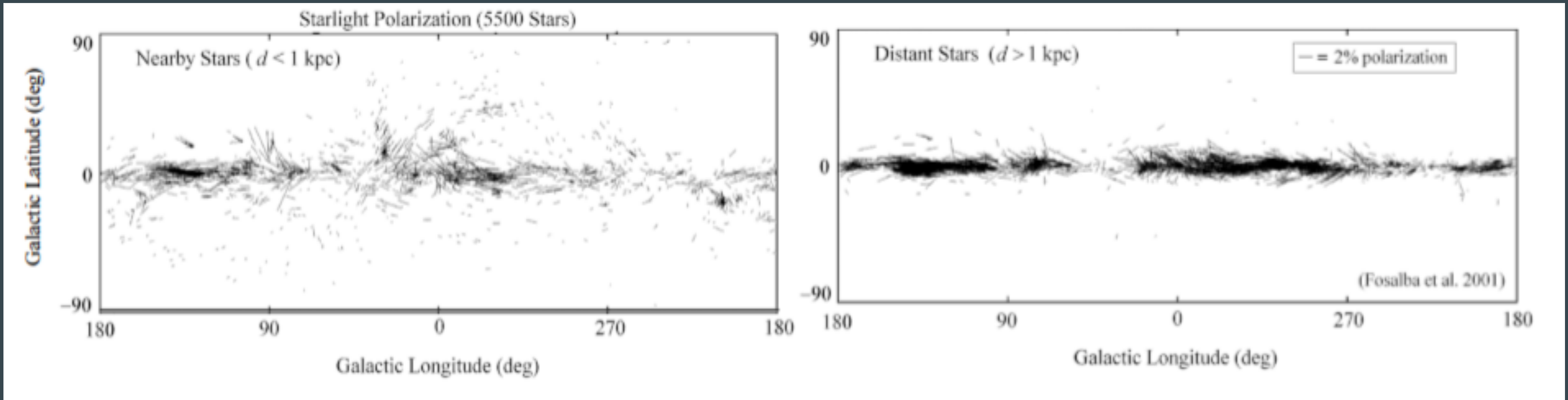


Plane of Sky component or B_perpendicular mainly via observation of polarization of spinning dust grains

CAVEAT!
Only Zeeman observations can provide B Field strengths. Polarized dust emission only gives us the direction!

Observations of Polarization from Dust

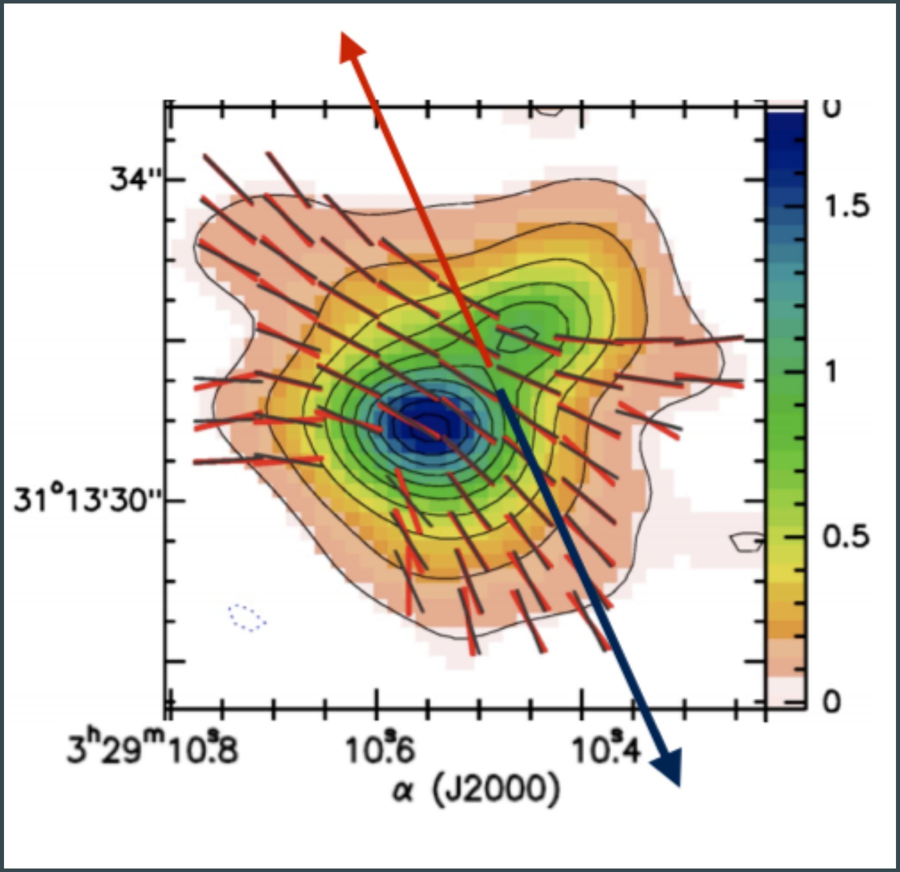
Observations of background starlight polarization in absorption → independently mapped by Hall (1949) and Hiltner (1949)



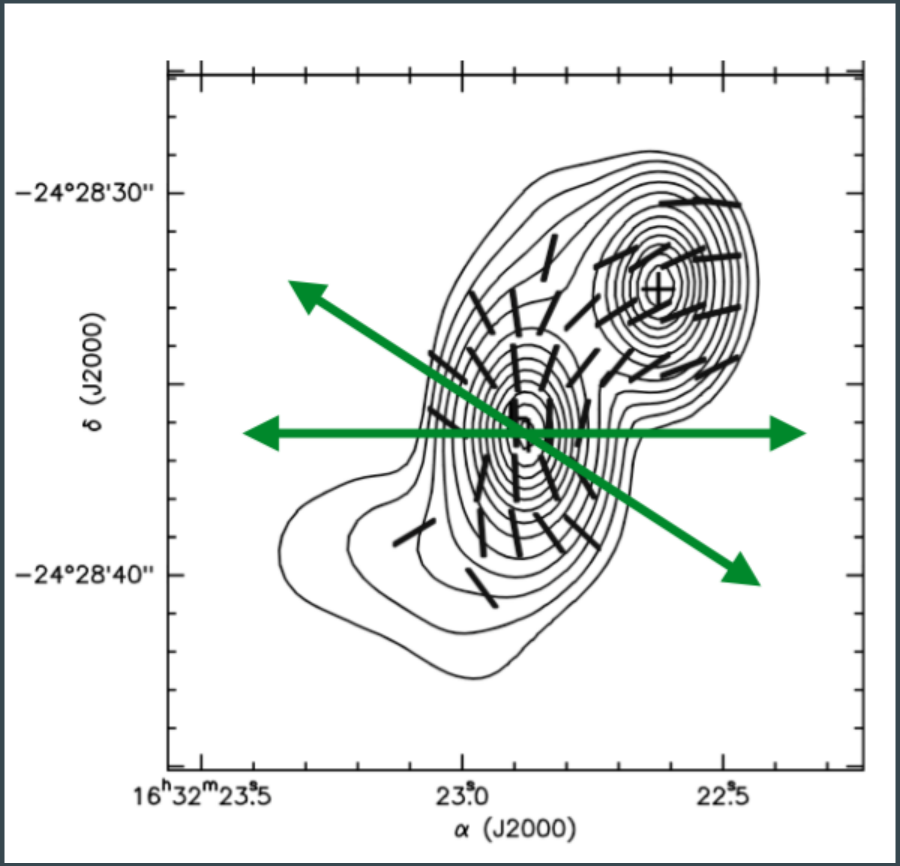
Original explanation by Davis and Greenstein (1951) → based on paramagnetic alignment of spinning dust grains

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!

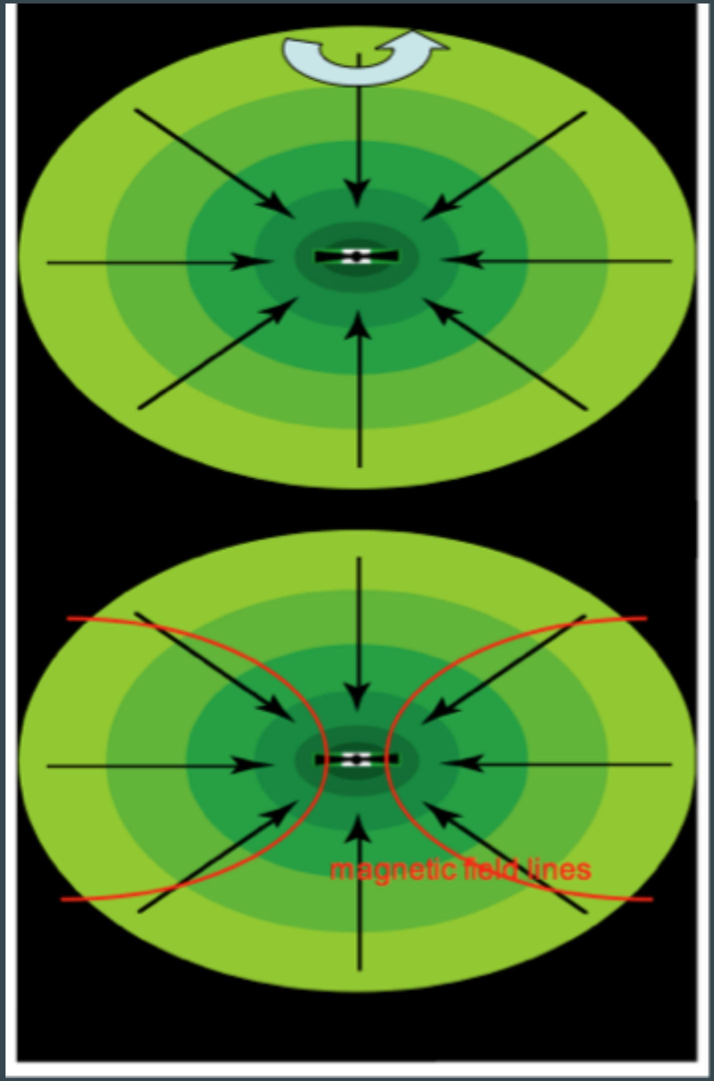
What about the Magnetic Fields in Disks?

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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rotating
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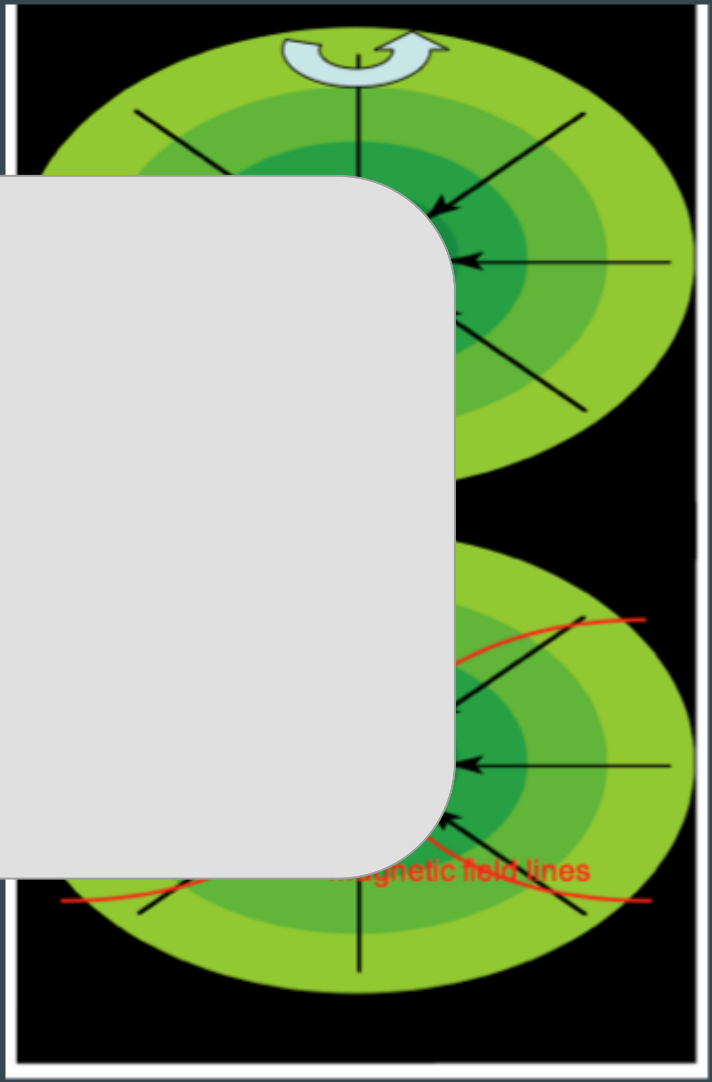
How to resolve --

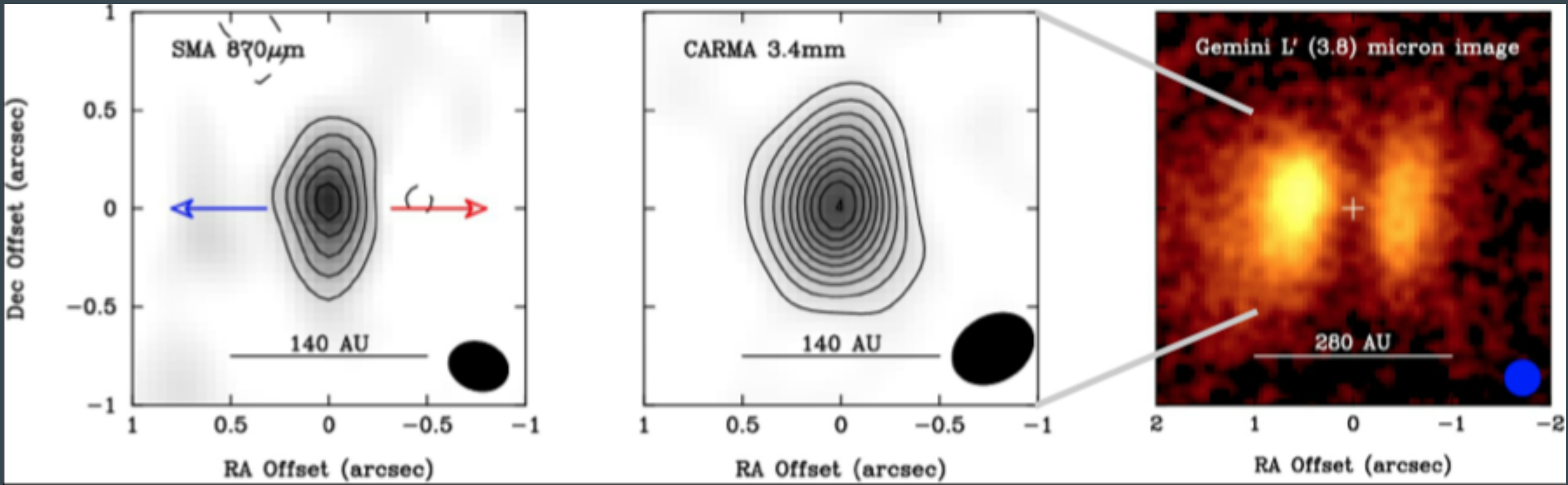
1. Turbulence
2. Non ideal MHD effects
3. Axis misalignment etc.

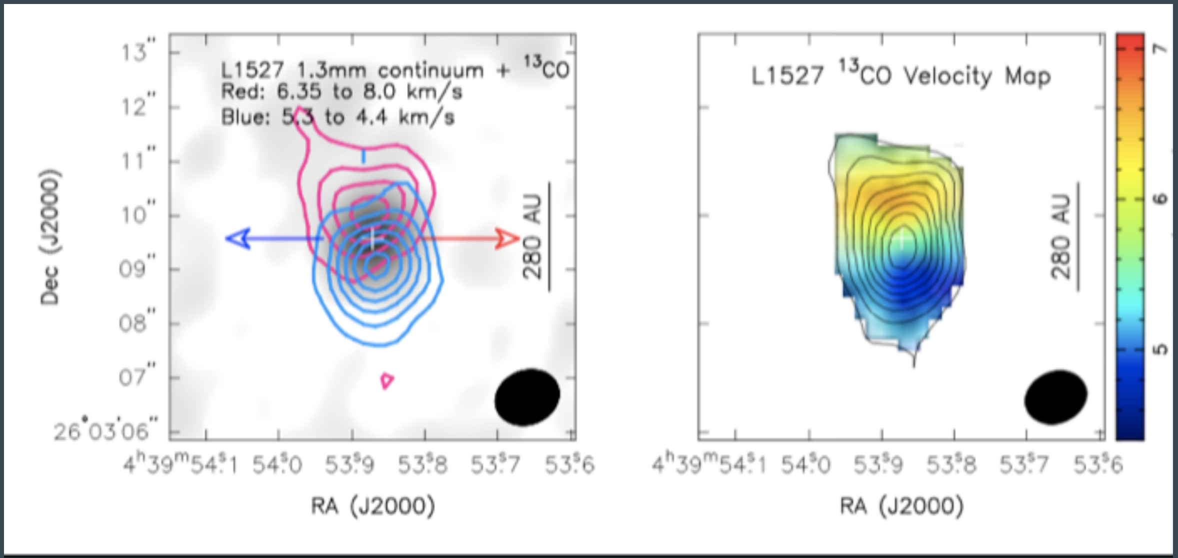


Slide courtesy Zhi-Yun Li; See Li+ 2014 PPVI

What do observations tell us about the size scales of these disks?

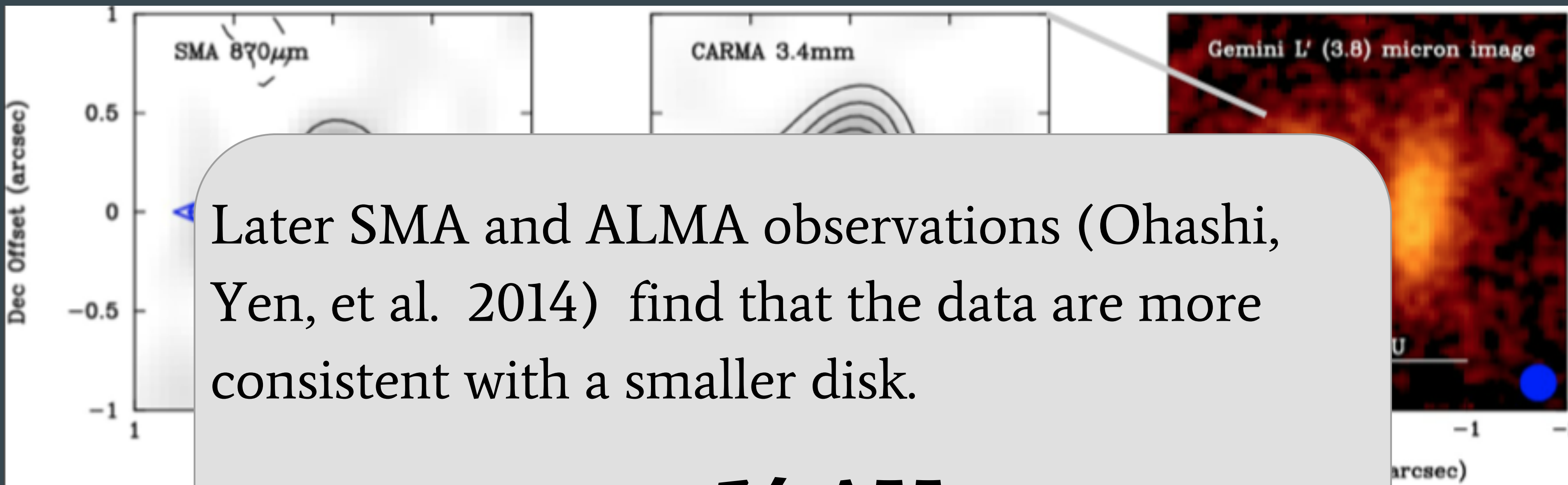
L1527: Is the Disk really this Large?





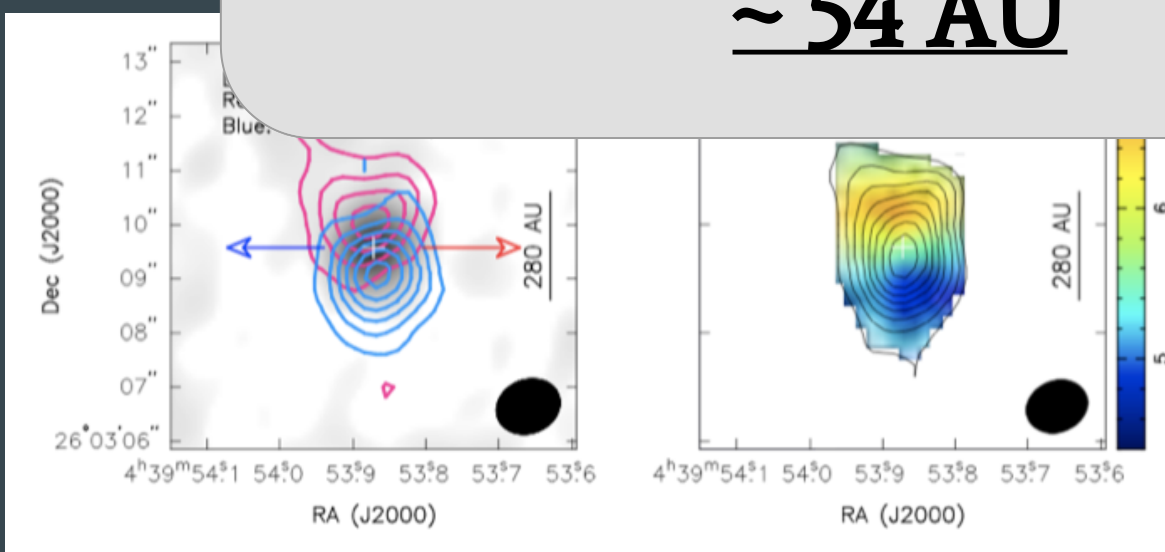
Tobin+ 12

L1527: Is the Disk really this Large?



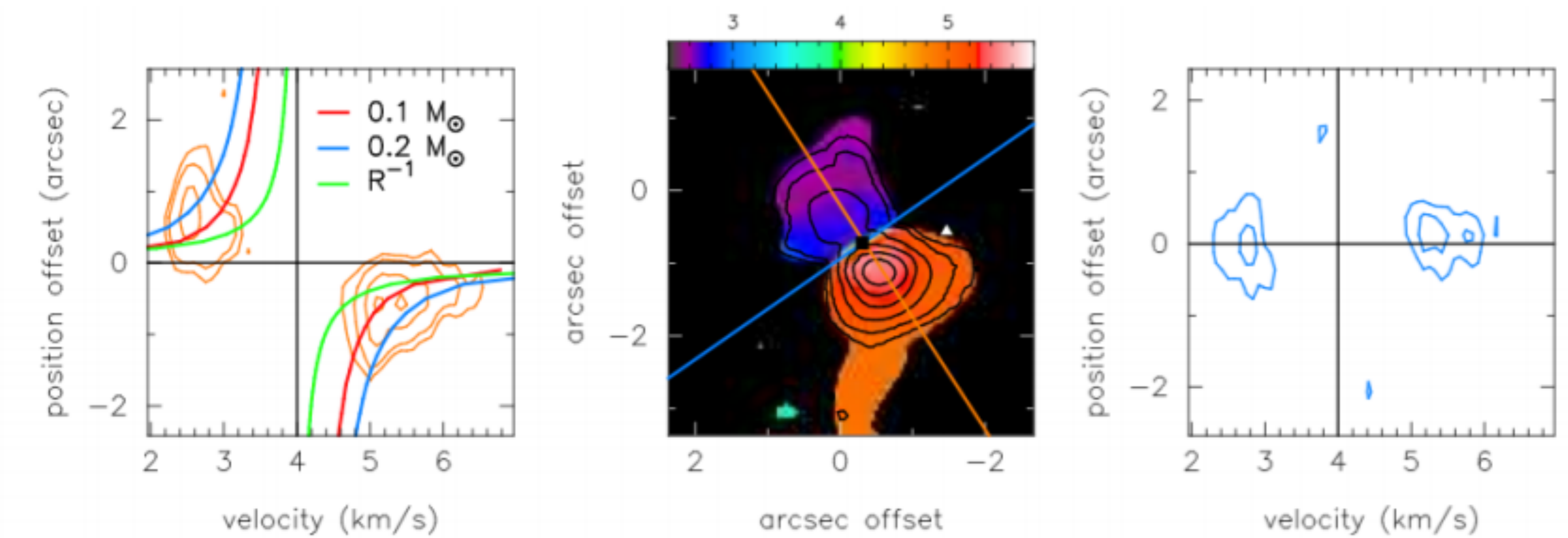
Later SMA and ALMA observations (Ohashi, Yen, et al. 2014) find that the data are more consistent with a smaller disk.

<u>~ 54 AU</u>



Tobin+ 12

VLA 1623: Disk revealed by Kinematics

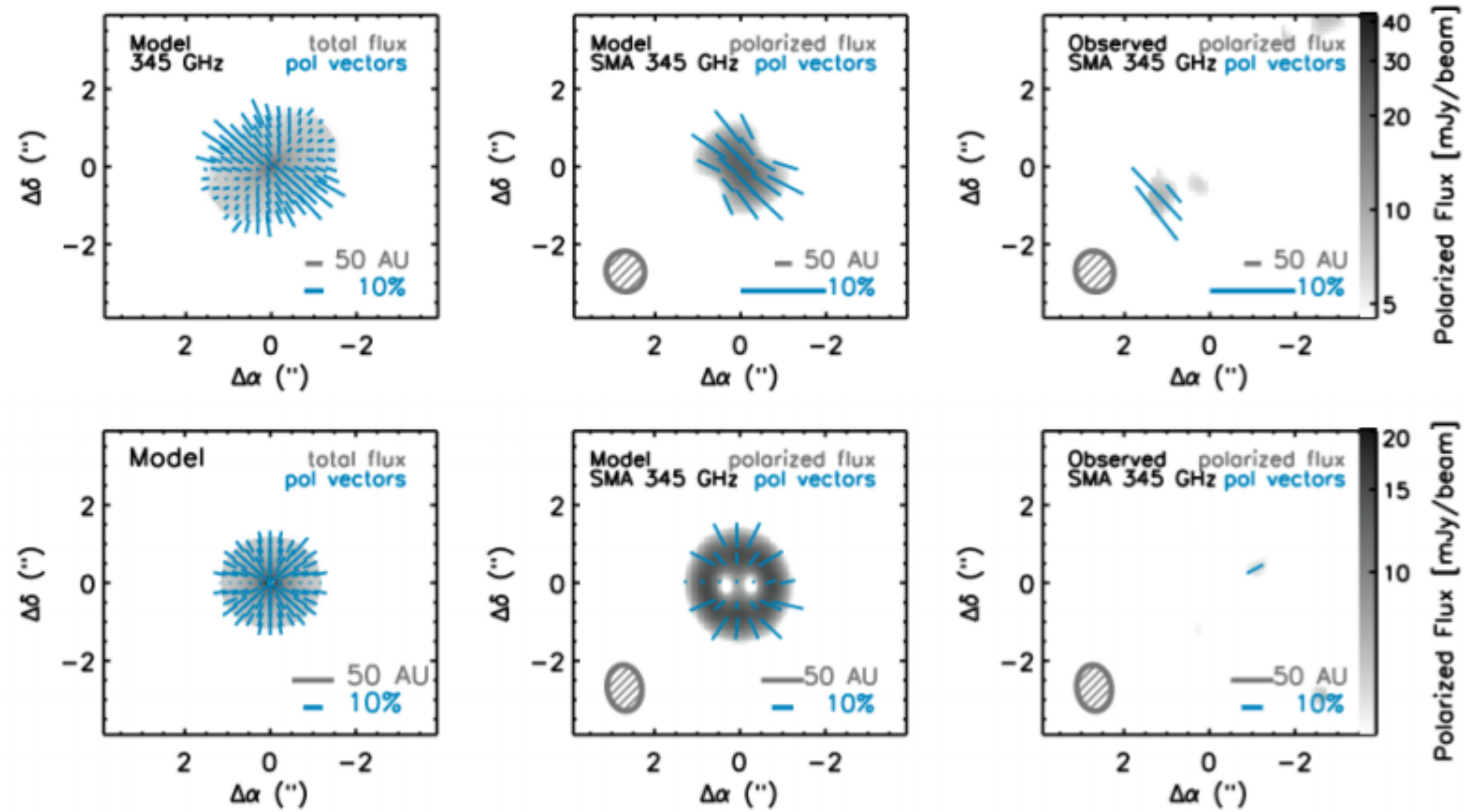


Murillo +13: ALMA C18O 2 ->1 observations of VLA1623 A and fitted models.

Disk is 50 AU in size

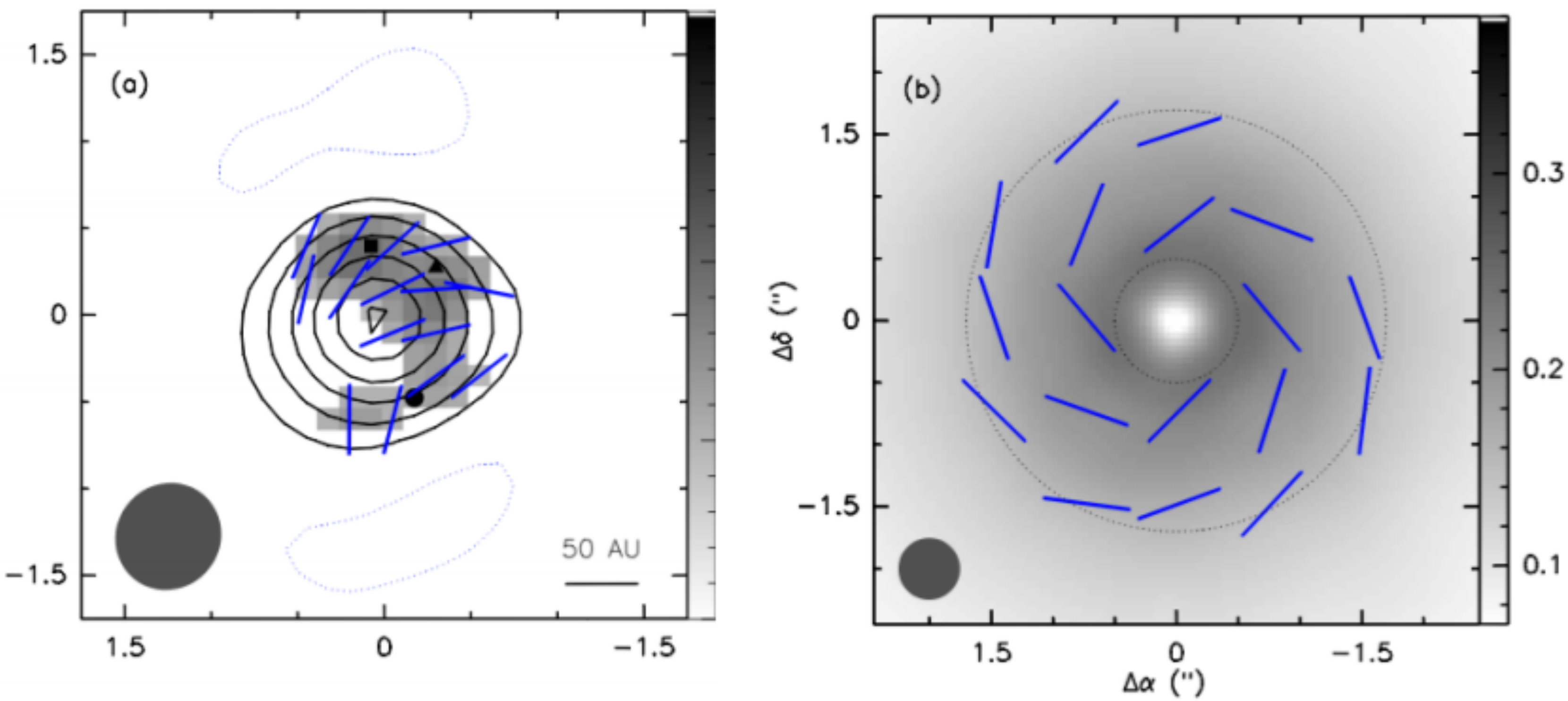
The Challenge is to Find the Magnetic Field Structure in Disks in YSOs!

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

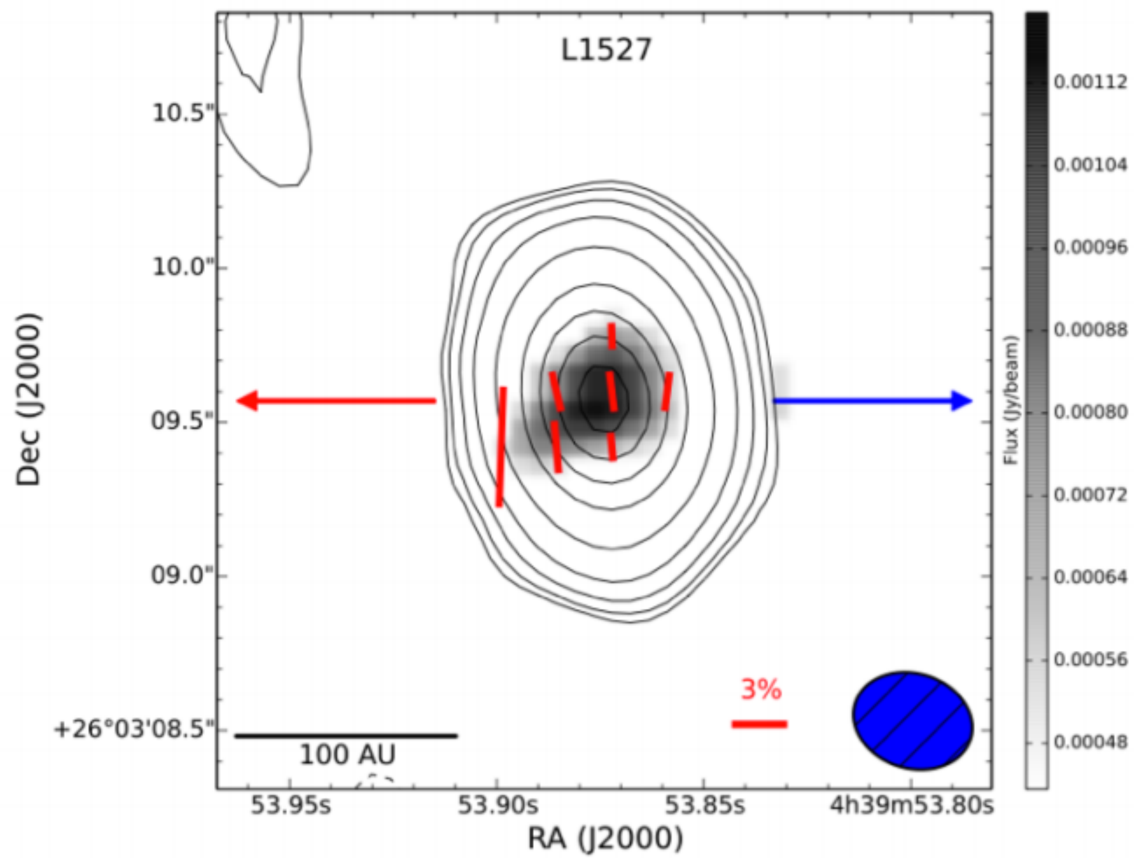


Rao+ 14; SMA Observations

Henebelle & Ciardi 09, Padovani+ 12
Simulations

Class 0 Disk

Disk B Fields in L1527

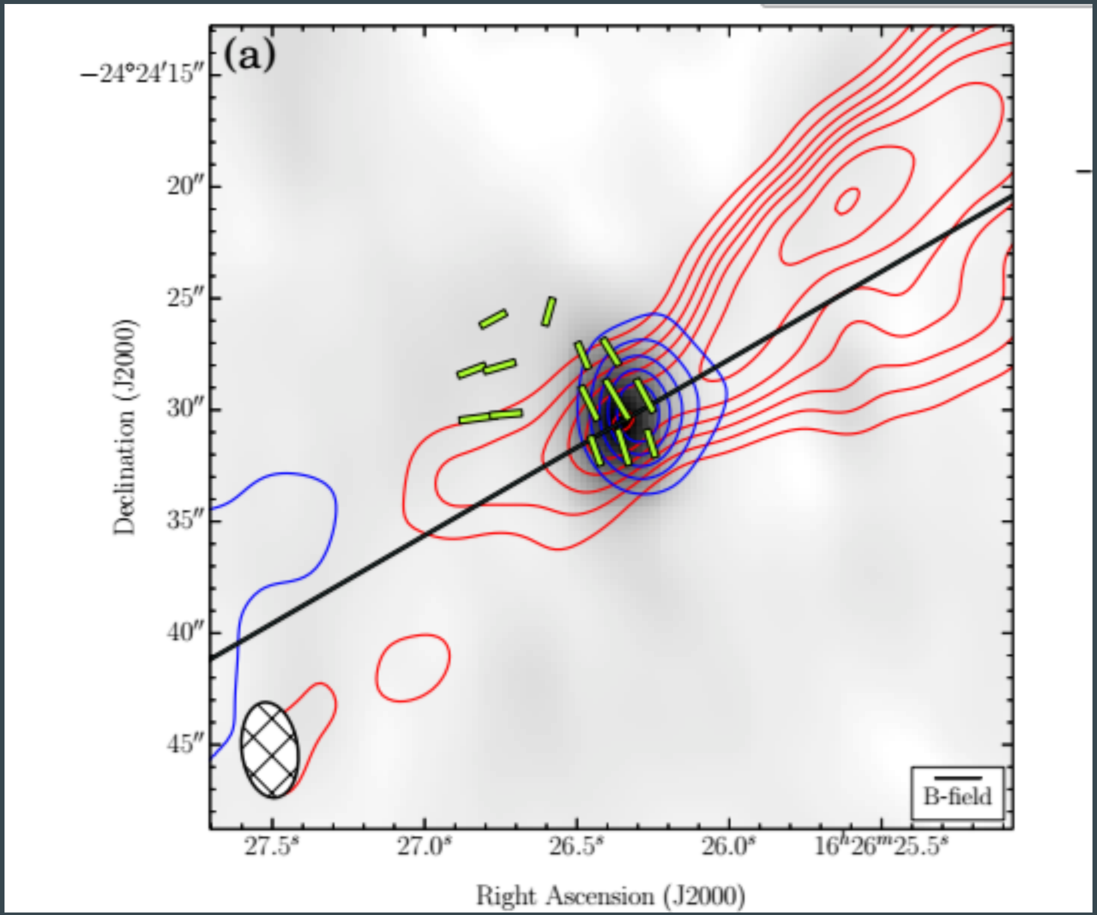


Outflows show Disk Geometry

Segura-Cox+ 15

Class 0 Disk

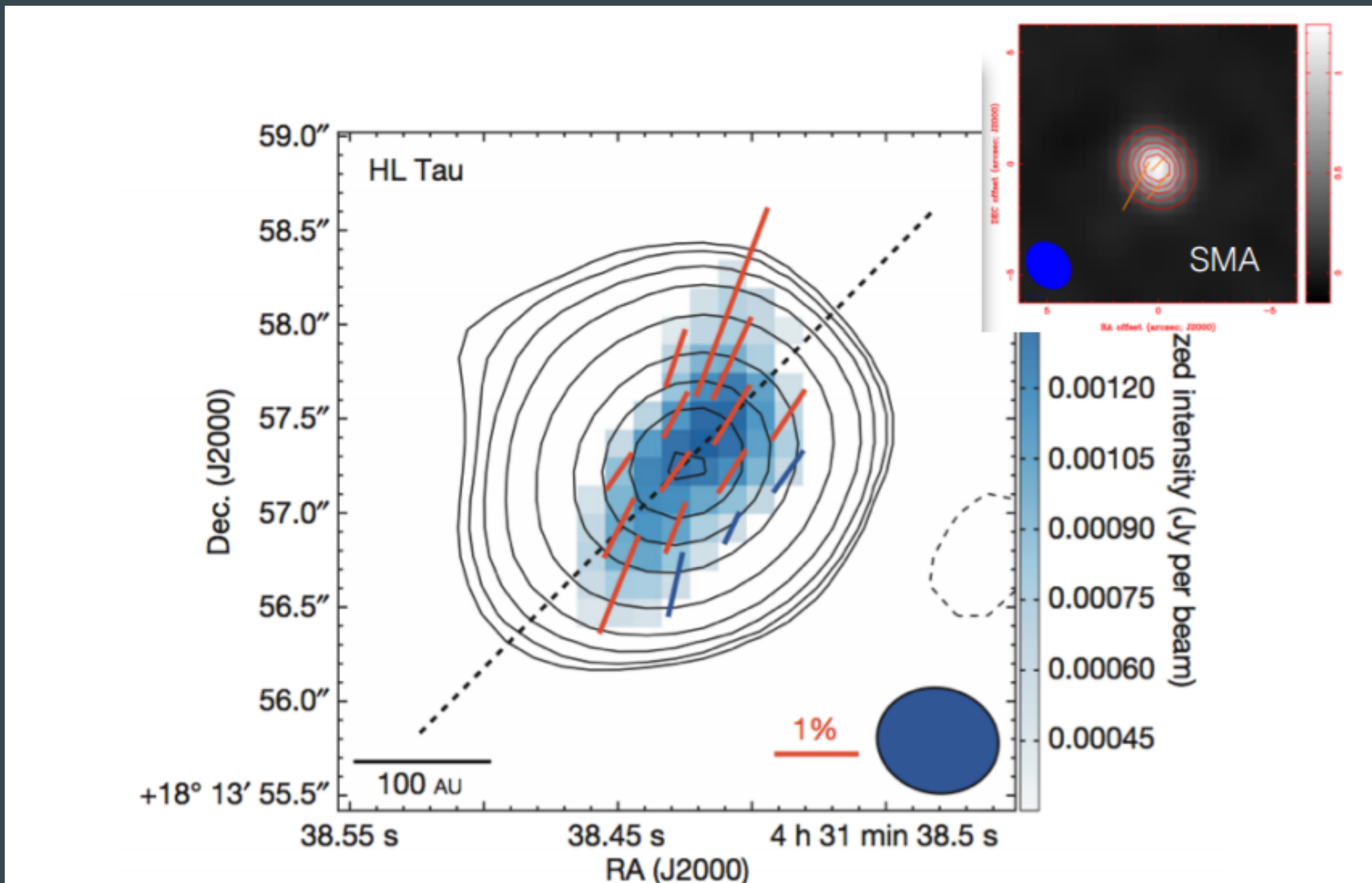
The Disk B Fields in VLA 1623



Hull+ 14

Class 0 Disk

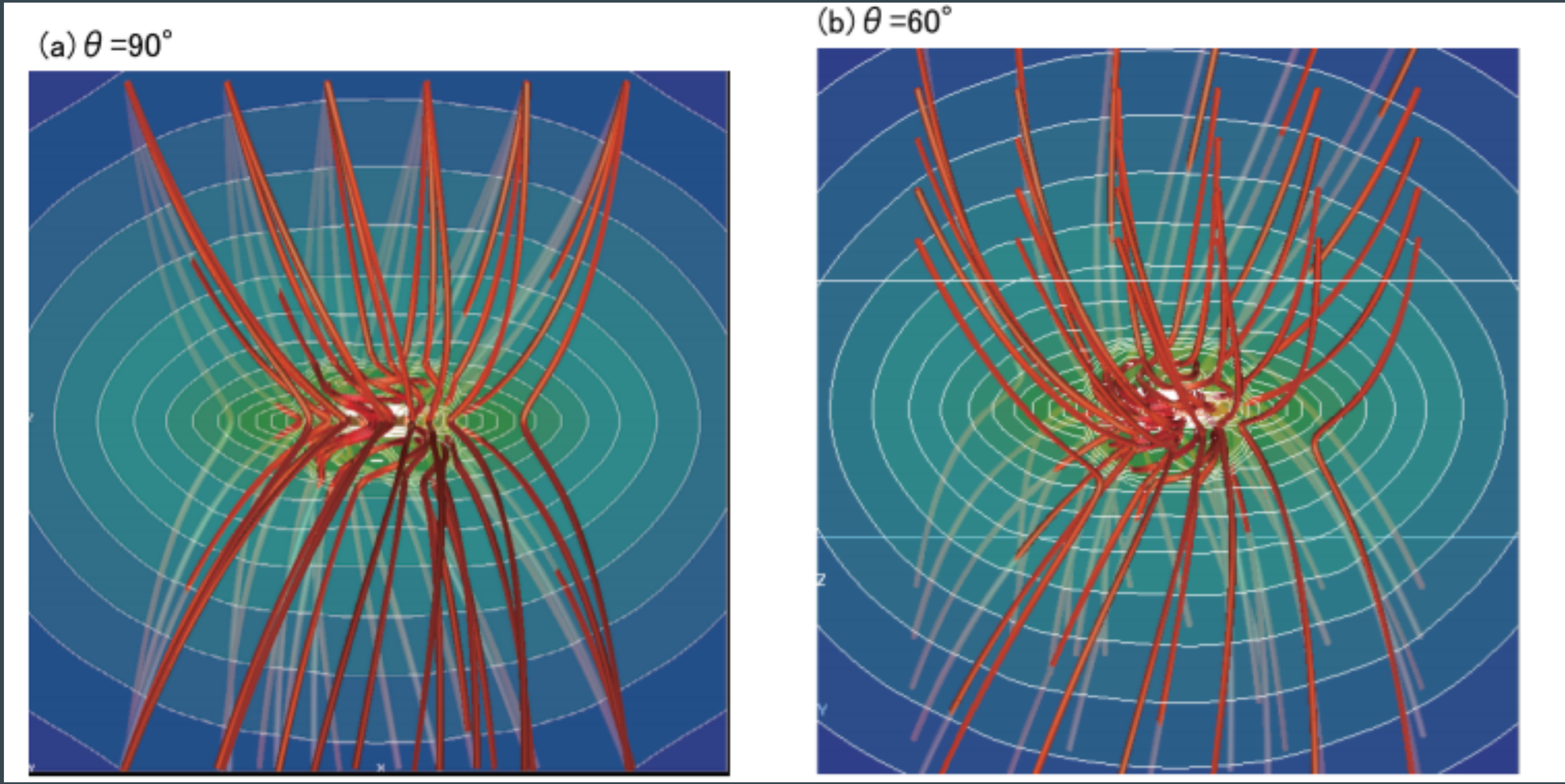
The (mostly) Edge-On Disk of HL Tau



Stephens+ 14

>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

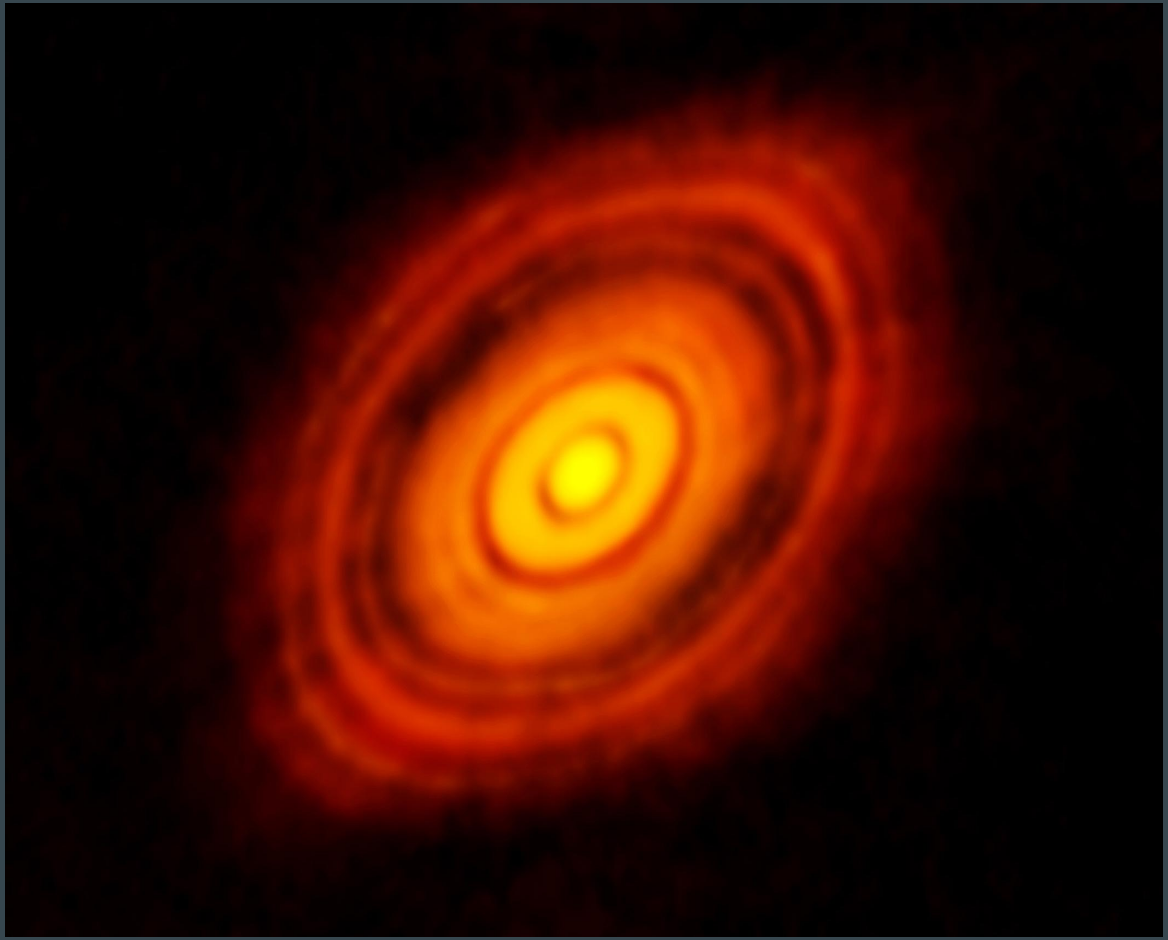
toroidal

But ....

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

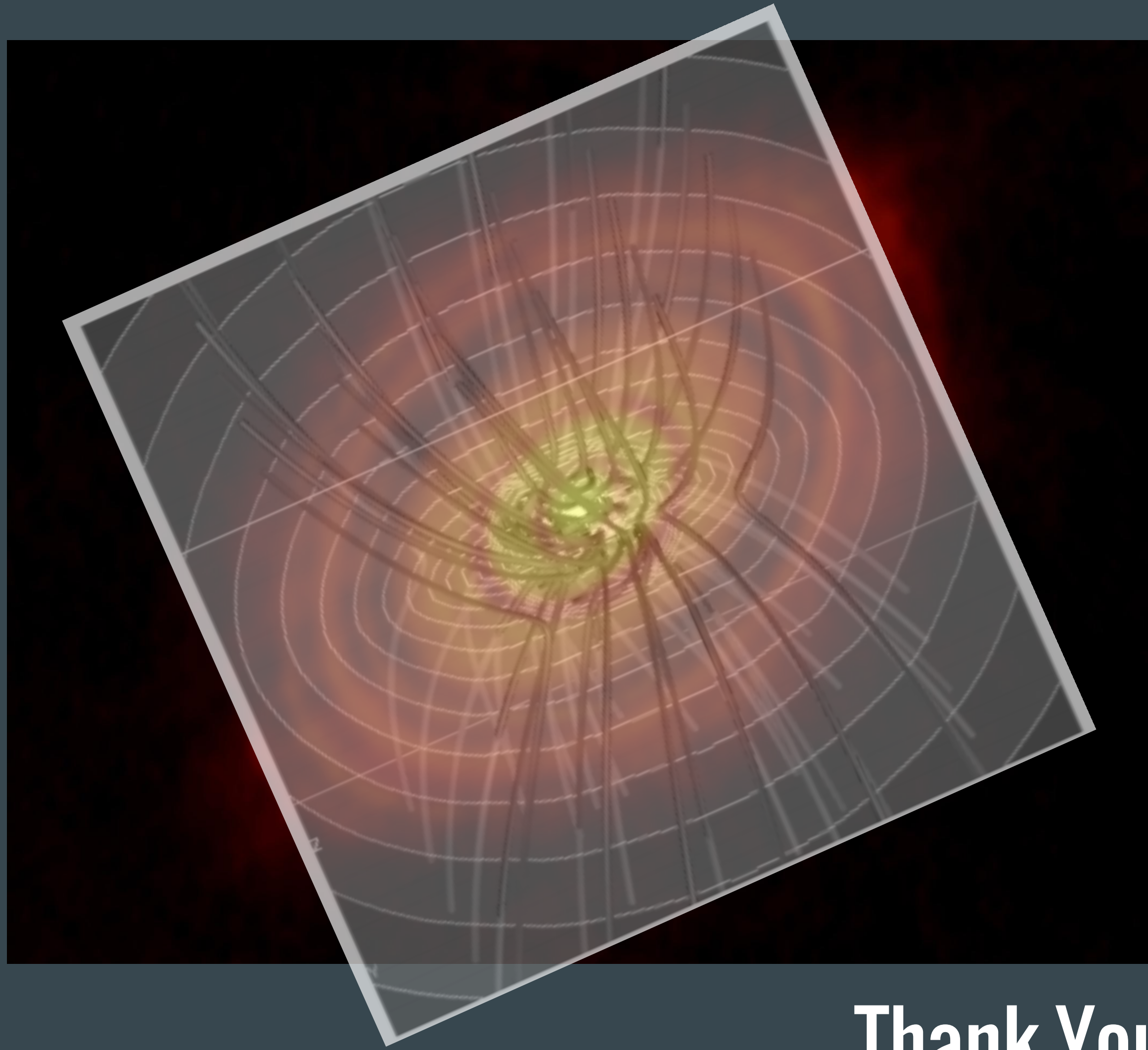
As for the Future...

The Era of ALMA: HL Tau Stokes I



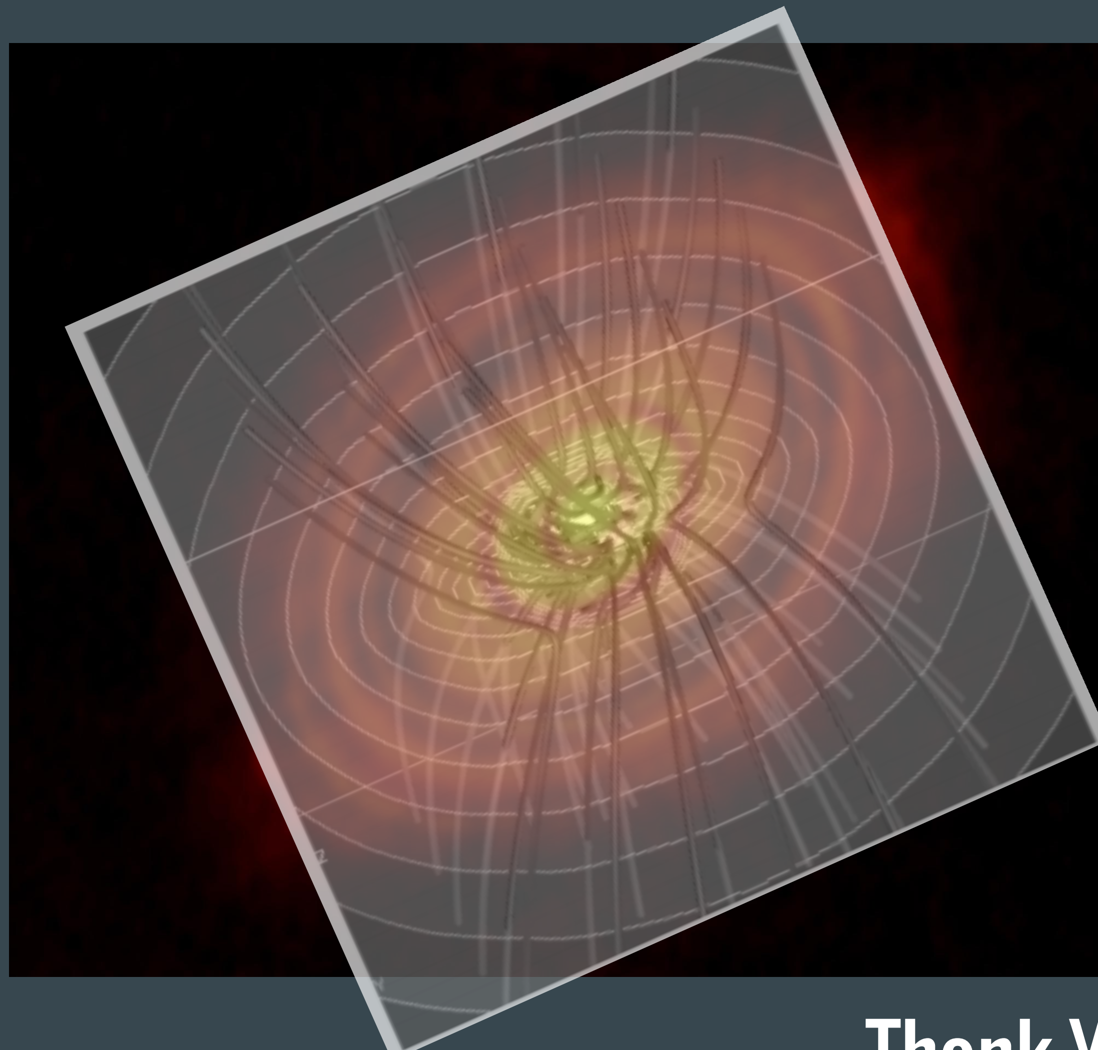
Credit: ALMA (NRAO/ESO/NAOJ); C. Brogan, B. Saxton (NRAO/AUI/NSF)

The Era of ALMA



Thank You!

The Era of ALMA



Thank You!