Origin of Molecular Outflow Determined from Thermal Dust Polarization

K. Tomisaka (NAOJ) (*Publ. Astron. Soc. Japan* **63**, 147-158)

1.INTRODUCTION

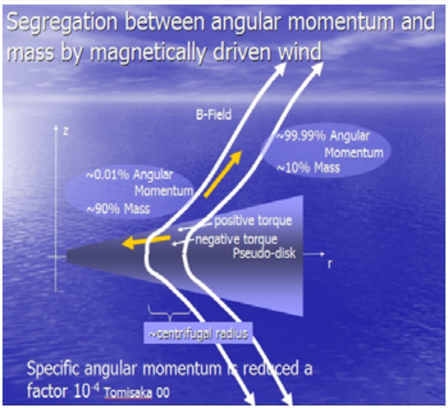
Origin of Molecular Outflow is open question.

(a) Entrainment Model → Linear momentum of a jet is transferred to ambient molecular material

(b) Magnetically Driven Model → Molecular gas is directly driven by the magnetic Lorentz force

Magnetic drive model has an advantage to solve "the angular momentum problem of new born stars."

Angular momentum of the parent cloud core (~1M$_\odot$) is much larger than that of the protostar / star.



If we look for observational evidence of magnetic drive of molecular outflow. → B_φ Toroidal B-Field

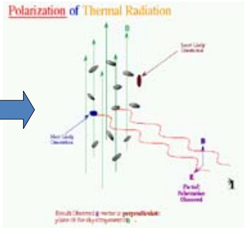
Because the torque is induced by $F_\varphi \propto J_{pol} B_{pol} \propto \nabla B_\varphi B_{pol}$

If we find the toroidal magnetic field B_φ this indicates magnetic drive.

Polarization observation of dust thermal emissions can explore the existence of toroidal magnetic field B_φ.

2. METHOD

Oblate/prolate dust is aligned in the B-field direction, this emits polarized light. EM wave's E vector // B field.



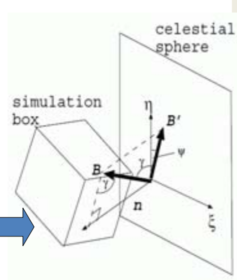
Stokes parameter *I*, *Q*, and *U*

$$Q=\int C\cdot R\cdot F\cdot c\cdot B_\nu(T)\rho\cos 2\psi\cos^2\gamma ds$$

$$U=\int C\cdot R\cdot F\cdot c\cdot B_\nu(T)\rho\sin 2\psi\cos^2\gamma ds$$

C: difference of cross sections perp and parallel to B
R: reduction factor due to imperfect grain alignment
F: reduction factor due to turbulent B-field
$c=\rho/n_d$

(Draine & Lee 85, Fiege & Pudritz 2000)



γ: angle b/w B and plane of the sky.

ψ: angle b/w projection of B and η-axis

Calculate following q, u, Σ, & Σ_2, using simulation data.

Relative Stokes parameter

(Wardle & Konigl 90)

$$q=\int\rho\cos 2\psi\cos^2\gamma ds$$

$$u=\int\rho\sin 2\psi\cos^2\gamma ds$$

$$\Sigma=\int\rho ds$$

$$\Sigma_2=\int\rho\left(\frac{\cos^2\gamma}{2}-\frac{1}{3}\right)ds$$

Observed quantities

Polarization direction

$$\cos 2\chi=\frac{q}{\left(q^2+u^2\right)^{1/2}}$$

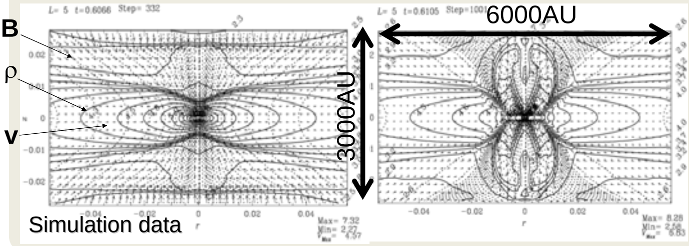
$$\sin 2\chi=\frac{u}{\left(q^2+u^2\right)^{1/2}}$$

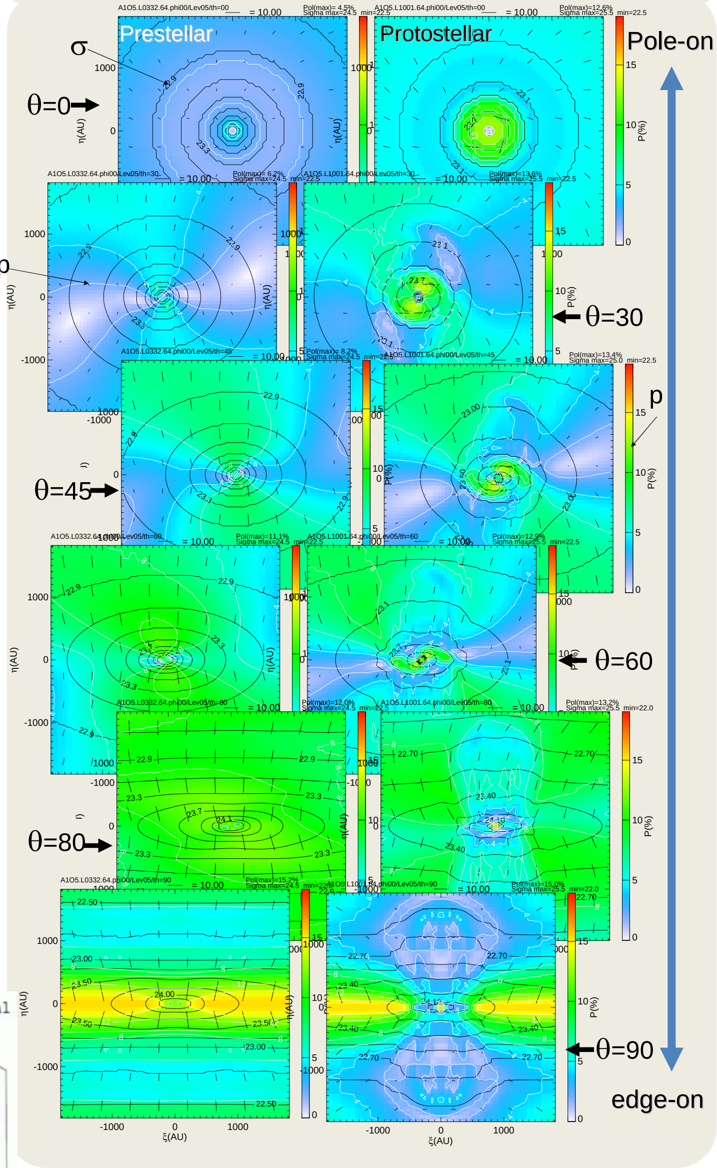
Polarization degree

$$p=\alpha\frac{\sqrt{q^2+u^2}}{\Sigma-\alpha\Sigma_2}$$

3.RESULT

Prestellar → Protostar 7000yr after FC form.





Starless phase [left]

[1] Intensity indicates a disk (this strong field model) or a spherical shape (weak field model not shown)

[2] Direction of a disk ~ low-polarization region's whose distribution is asymmetry with respect to y-axis: weakly polarized from upper-right to lower-left at θ=30~60º

Protostar phase [right]

[1] Outflow traces a low polarization region,

[2] This contains a strongly polarized region near the center (acceleration region) viewing from θ=30~60º. which contains a horizontally polarized region surrounding the η-axis.

[3] Viewing from the pole direction, azimuthal polarization pattern is emphasized.

4. CONCLUSION

Existence of B_ϕ can be found from polarization observation.