OMOSHI Effect: A New Mechanism for Mass Accretion under Radiation Pressure in Massive Star Formation

Tokyo Institute of Technology
Tanaka, K.E.I. and Nakamoto, T.
kt503i@geo.titech.ac.jp

1. Radiation Pressure Problem

Accretion

Radiation

Dust-free region
→ Radiation Pressure does not force.

Dust region
→ Radiation Pressure forces!!

1.1 What is Radiation Pressure Problem?

In massive star formation, radiation pressure exceeds gravity force!!!

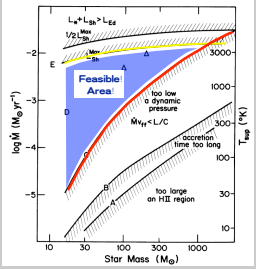
Especially,

Radiation Pressure >> Gravity Force @Dust Sublimation Front (DSF)

This is because direct stellar radiatoin is absorbed in a thin layer near DSF.

1.2 Condition for Large Ram Pressure

:Review of Wolfire&Cassinelli 1987



Large Ram Pressure is needed to pass DSF. $\frac{L_*}{4\pi r^2 c} < \frac{\dot{M}}{4\pi r^2} u_{ff}$

To make a large ram pressure, accretion rate must > $10^{-3} M_{sun} yr^{-1}$

The Large Ram Pressure is regarded as the only mechanism to overcome the direct stellar radiation @DSF.

2. OMOSHI Effect

2.1 General Condition

We investigate more general condition to overcome the radiation pressure@DSF. and, we find a new mechanism!!!

Equation of General Condition

$$\Delta p_{gas} + \frac{\dot{M}}{4\pi r^2}|\Delta u| + \frac{GM_*}{r^2}\Sigma = \frac{L_*}{4\pi r^2 c}$$

Previous Works | This Work

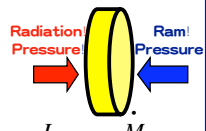
We call this new mechanism!! "OMOSHI effect" .

OMOSHI is an acronym for "One Mechanism for Overcoming Stellar High radiaition pressure by welght."

Additionally, in Japanese, OMOSHI is a noun meaning "a heavy weight that is put on something to prevent it from moving."

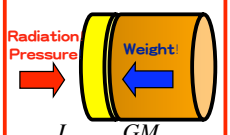
2.2 Advantage of OMOSHI Effect

Previous Works : Ram Pressure



$$\frac{L_*}{4\pi r^2 c} \sim \frac{\dot{M}}{4\pi r^2}|\Delta u|$$

This Work : OMOSHI Effect



$$\frac{L_*}{4\pi r^2 c} \sim \frac{GM_*}{r^2}\Sigma$$

Large accretion rate is Not needed for OMOSHI effect.

Thus, OMOSHI effect relaxes accretion condition!!!

Why has Not OMOSHI been discovered?
The resolution of recent simulations is not enough to investigate OMOHSI effect.
e.d., Krumholz et al. can resolve >10AU, although structure of OMOSHI <<10AU.

3. Structure of OMOSHI

※We present here only the result for a spherically symmetric accretion case. The result for a disk accretion case is almost the same in a basic sense.

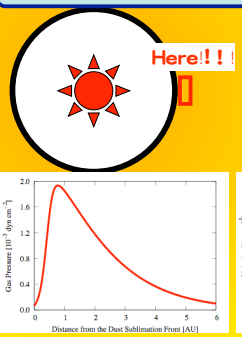
Discussion 1

We calculate structure for OMOSHI effect by steady radiation hydrodynamic simulation.

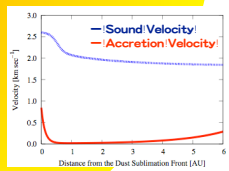
From this calculation, we learn
- OMOSHI effect works in spherically symmetric accretion and in disk accretion.
- structure can be separated to irradiated region and shadow region.
- gas presure plays a crucial role to hold up OMOSHI structure.

The resolution of our calculation is much higher than those of previous works.

To investigate OMOSHI effect, a high resolution is needed because gas structure is very steep.

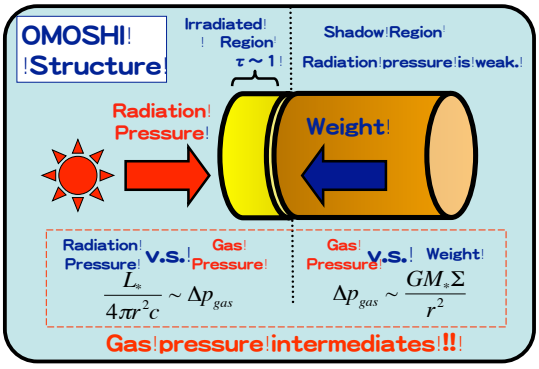


Gas pressure has a steep gradient to hold up the OMOSHI structure.



Accretion velocity is subsonic.

OMOSHI Structure



Gas pressure intermediates!!!

However, time variation is not clear...!

4. Sweep UP of Accretion Flow

※We present here only the result for a disk accretion case. In a spherically symmetric accretion case, the sweep up would not halt.

Discussion2

We calculate sweep up of accretion flow after a collapse of OMOSHI structure by some instability to examine reconstruction.

From this calculation, we learn
- in a sherically symmetric accretion case, the sweep up would not halt.
- in a disk accretion case, the sweep up would halt in time shorter than Keplerian time.

Thus, disk accretion has an advantage for reconstruction.

Time Scale of Reconstruction << Time Scale of Star Formation, OMOSHI effect would work sufficiently even though OMOSHI is unstable.

Motion of "Sweeping Ring"

Favorable setting for sweep up
- storing all angular momentum
- ignoring gas pressure term

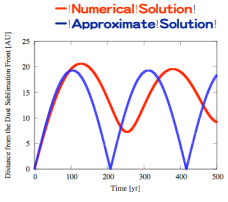
eq of continuity: $\frac{dm}{dt} = \dot{M} + 2\pi r \Sigma u$

eq of angular momentum: $\frac{dl}{dt} = \left(\dot{M} + 2\pi r \Sigma u\right) v_{Kep} r$

eq of motion: $\frac{d}{dt}(mv) = \frac{H}{r}\frac{L_*}{c} - \frac{GM_* m}{r^2} - \dot{M}(u_{acc} + u) + \frac{l^2}{mr^3}$

$M_*=100M_{sun}$
$\dot{M}=10^{-4}M_{sun}yr^{-1}$

※Only expansion stage is realistic.



Approximate Solution

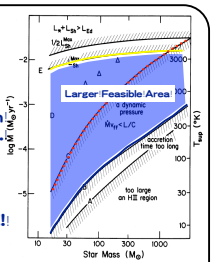
$$\Delta r = R\sqrt{1-\cos\omega t} \qquad R = \sqrt{\frac{r_d H_d L_*}{\pi c G M_* \Sigma_{acc}}} \qquad \omega = \sqrt{\frac{GM_*}{r^3}}$$

Sweep up would halt in Keplerian time, which is much shorter than time scale of star formation.

Summary

Back Ground

- Radiation pressure halts accretion flow in massive star formation.
- Ram pressure is regarded as the only overcoming mechanism.
  → Large accretion rate is needed!!



This Study

OMOSHI Effect : A new mechanism with Weight!!! → NOT need a large accretion rate!!

OMOSHI Structure : Gas pressure plays a crucial role!!!

OMOSHI Reconstruction : Disk accretion has an advantage for reconstruction.

Conclusion:

OMOSHI effect widely relaxes the accretion condition!!!