An Origin of Narrow Extended Structure in the Interstellar Medium:

An Interstellar Contrail

Created by a Fast-moving Massive Object

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- We propose an "**Interstellar Contrail Model**" that can form **Giant Filaments** as long as 100 pc.
- Our goal is to explain the origin of Giant Filaments and indirectly observe **Intermediate-Mass Black Holes**.

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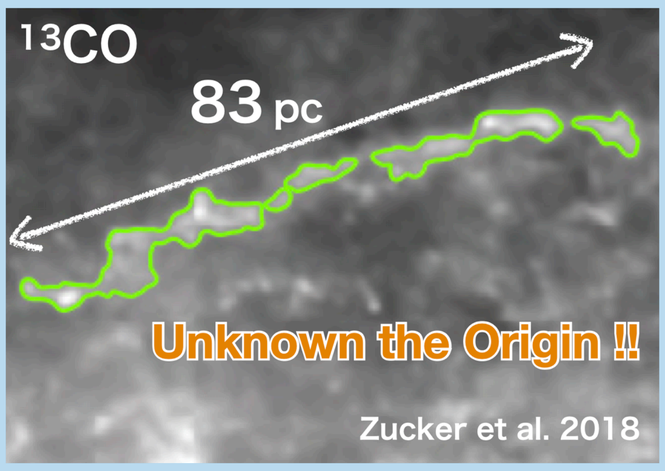
Introduction

Observations of Giant Filaments



Length~100 pc
Number of filaments~50

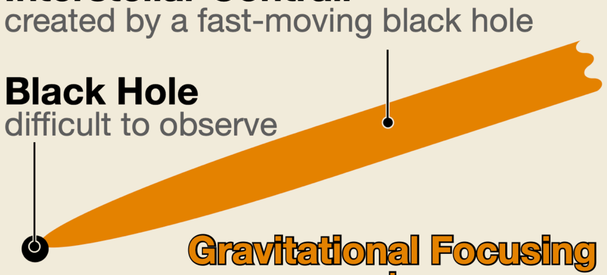
It is difficult to explain these formations by existing filament formation mechanisms (e.g. Abe et al. 2021).

A fast formation over the scale ~100 pc may overcome turbulent dispersal.
But, how?

"Interstellar Contrail Model"

Interstellar Contrail
created by a fast-moving black hole

Black Hole
difficult to observe



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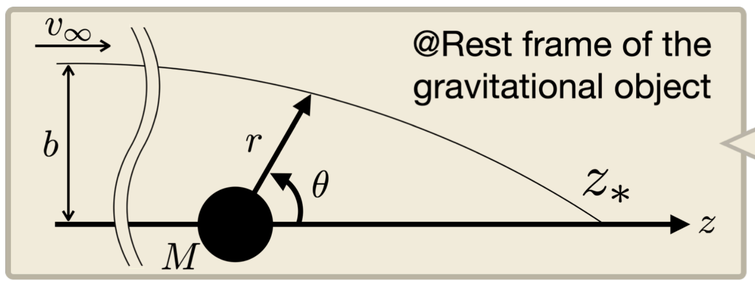
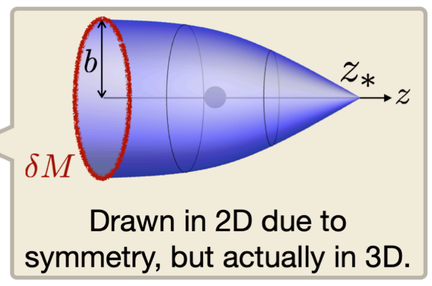
The filament could be formed by the passage of a fast-moving black hole similar to the formation of an airplane cloud.

We propose a new formation model "**Interstellar Contrail Model**".

Can our new model create Giant Filaments?

Gravitational Focusing-Induced Mass Accretion





Drawn in 2D due to symmetry, but actually in 3D.

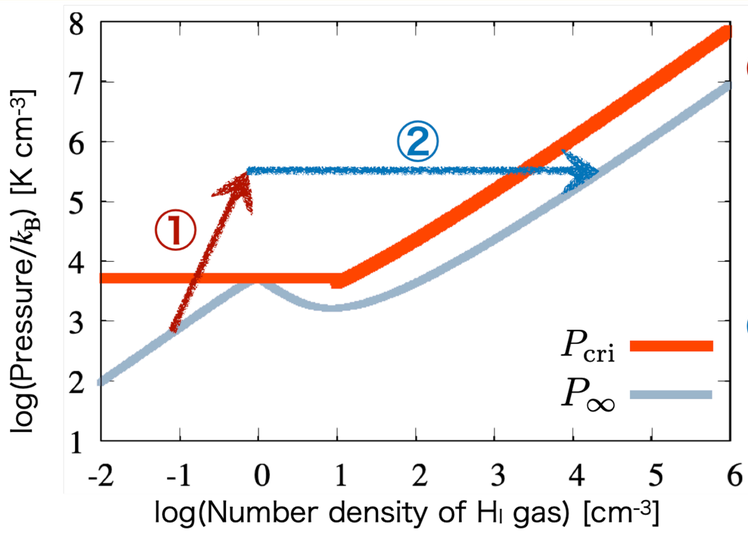
- z_* is where the gas trajectory significantly changes $\Rightarrow \frac{1}{2}v_\theta^2 \sim \frac{GM}{z_*}$
- law of conservation of angular momentum $\Rightarrow bv_\infty = z_* v_\theta$

$\Rightarrow v_\theta \propto b^{-1}$

- Gas mass on a circle with radius b $\Rightarrow \delta M \propto 2\pi b$

Mass accretion rate at z_* : $\delta M v_\theta \sim \mathrm{const.}$
→**Constant mass accretion rate along the z-axis.**

Observability by Thermal Condensation

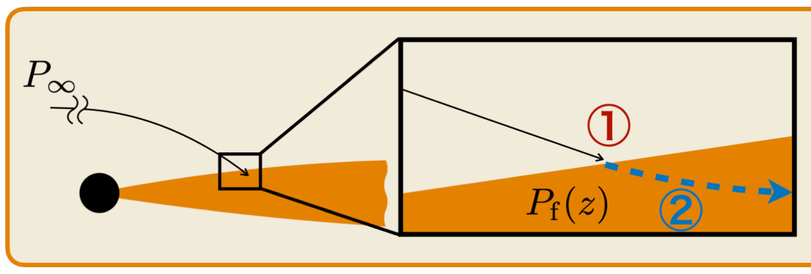


① H I gas is compressed by a shock wave at the surface of the interstellar contrail.

② H I gas reaches thermal equilibrium through repeated cycles of cooling and compression nearly **isobarically**.

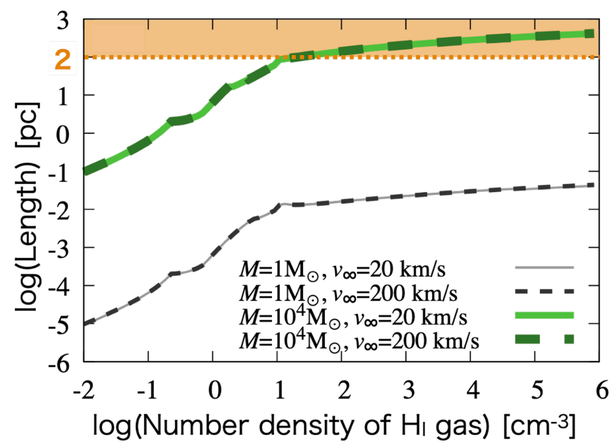
P_{cri} : Pressure in the observable condition for thermal condensation

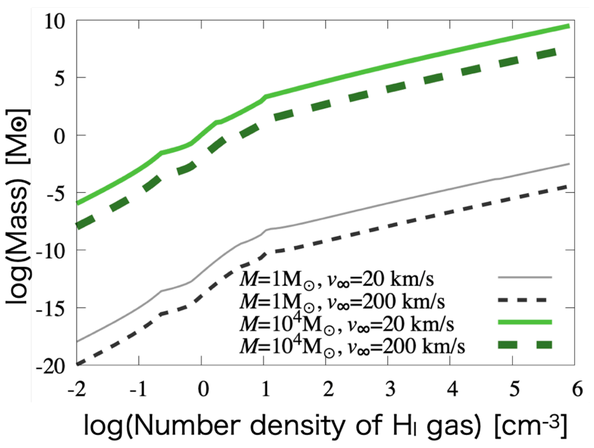
P_∞ : Pressure at thermal equilibrium



We assume that an interstellar contrail becomes dense enough to observe when
$P_f(z) > P_{cri}$.

Results





$$L \approx 78.3\ \mathrm{pc} \left(\frac{M}{10^4\ \mathrm{M}_\odot}\right) \left(\frac{n_\infty}{20\ \mathrm{cm}^{-3}}\right) \left(\frac{P_{\mathrm{crit}}/k_\mathrm{B}}{10^{3.82}\ \mathrm{K\,cm}^{-3}}\right)^{-1}$$

$$M_\mathrm{f} \approx 2.55 \times 10^3\ \mathrm{M}_\odot \left(\frac{M}{10^4\ \mathrm{M}_\odot}\right)^3 \left(\frac{v_\infty}{20\ \mathrm{km\,s}^{-1}}\right)^{-2} \left(\frac{n_\infty}{20\ \mathrm{cm}^{-3}}\right)^3 \left(\frac{P_{\mathrm{crit}}/k_\mathrm{B}}{10^{3.82}\ \mathrm{K\,cm}^{-3}}\right)^{-2}$$

A Fast-Moving Intermediate-Mass Black Hole forms a Giant Filament!

Summary

- We propose a new mechanism for filament formation, the interstellar contrail model, and show the possibility of an intermediate-mass black hole which fast-moving can form a giant filament.
- If we observationally identify such phenomena in multiple regions, we will be able to estimate the abundance of intermediate-mass black holes that are not luminous enough to be visible.