Growth of Massive Molecular Filament by Accretion Flows: Origin of Constant Width

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Observations of molecular clouds indicate that dense filaments are the sites for present-day star formation [1]. Therefore, it is crucial to understand filament formation and evolution, as these filaments provide the initial conditions for star formation. The width of filaments is a significant factor as it determines the fragmentation scale through self-gravity and affects the stellar masses to be formed [2]. Observations suggest that the width has a universal value of 0.1 pc, regardless of the filament's line mass [3]. However, theoretical predictions suggest that the width of supercritical filaments (> 17 solar masses per pc) should contract due to self-gravity [2,4,5,6]. Most simulations show a much narrower width due to strong gravity for massive filaments, and why massive filaments maintain their width of 0.1 pc has remained unexplained for more than ten years. Recent studies suggest that massive filaments (~100 solar masses per pc) are bound by slow mode shocks resulting from accretion flows onto the filaments (see [7]). The wavefront of the slow mode shock is known to be unstable, and the corrugation of the shock front grows [8]. This corrugation converts the accretion flow's ram pressure into thermal/turbulent pressure across the shock front, possibly maintaining the filament's width. In this study, we perform non-ideal MHD simulations to investigate filament evolution via slow shock instability, considering ambipolar diffusion, which is effective in dense filaments. We discovered slow shock instability including ambipolar diffusion drives anisotropic turbulence in the massive filament, named this new mechanism the "bullet mechanism". We also conducted a simulation considering self-gravity and found that the bullet mechanism can sustain a realistic filament width, even for a filament as massive as ~100 solar masses per pc [Fig. 1].

References
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Figure 1: Results of three-dimensional simulation of the evolution process of a large mass filament. Colors show density contours.