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LETTRES SCIENCES
ÉCOLE NORMALE SUPÉRIEURE

Structure formation, turbulence and feedback

Patrick Hennebelle

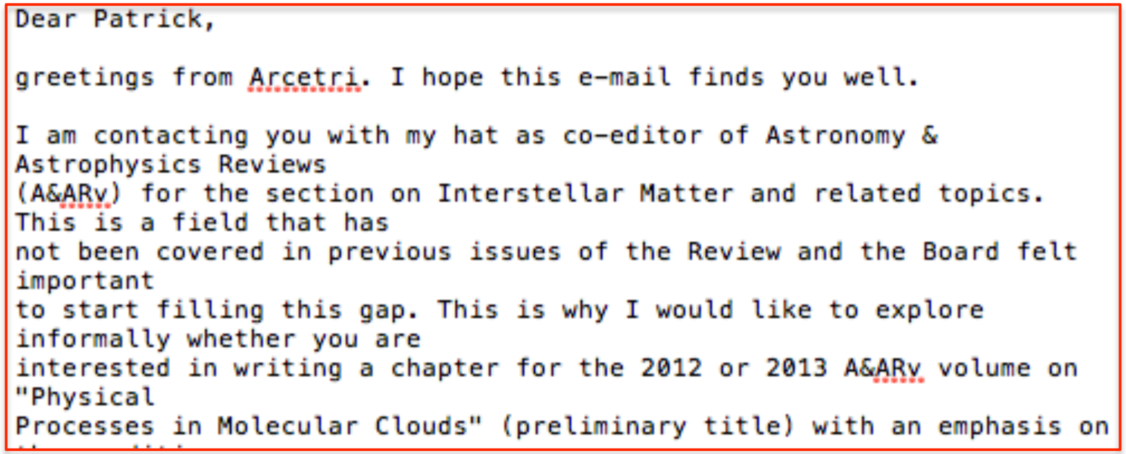
Thanks to

Sam Geen, Olivier Iffrig, Yueh-Ning Lee, Eva Ntormousi, Juan Soler, Valeska Valdivia
Edouard Audit, Gilles Chabrier, Ralf Klessen, Romain Teyssier, Philippe André

One of the Constellation network meetings

Turbulent molecular clouds

Patrick Hennebelle · Edith Falgarone



Dear Patrick,

greetings from Arcetri. I hope this e-mail finds you well.

I am contacting you with my hat as co-editor of Astronomy &
Astrophysics Reviews
(A&ARv) for the section on Interstellar Matter and related topics.
This is a field that has
not been covered in previous issues of the Review and the Board felt
important
to start filling this gap. This is why I would like to explore
informally whether you are
interested in writing a chapter for the 2012 or 2013 A&ARv volume on
"Physical
Processes in Molecular Clouds" (preliminary title) with an emphasis on

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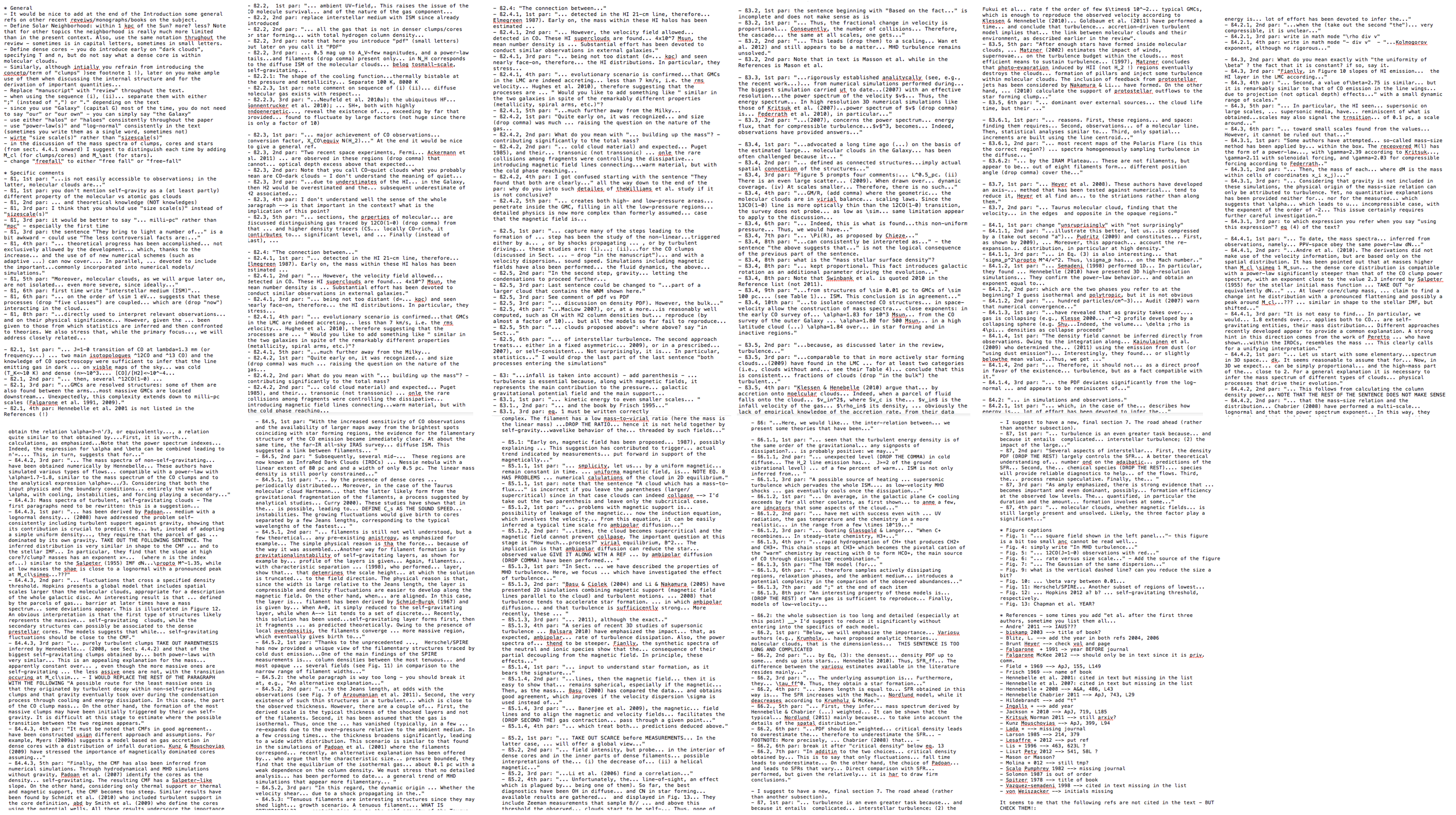
Abstract Stars form within molecular clouds but our understanding of this fundamental process remains hampered by the complexity of the physics that drives their evolution. We review our observational and theoretical knowledge of molecular clouds trying to confront the two approaches wherever possible. After a broad presentation of the cold interstellar medium and molecular clouds, we emphasize the dynamical processes with special focus to turbulence and its impact on cloud evolution. We then review our knowledge of the velocity, density and magnetic fields. We end by openings towards new chemistry models and the links between molecular cloud structure and star–formation rates.

Keywords Instabilities · Interstellar medium: kinematics and dynamics – structure – clouds · Star: formation

1 Introduction: bridging theory and observations

In the Galaxy and all spiral galaxies, molecular clouds are the sites of star–formation. The roots of star–formation are therefore to be sought in the physics

I've now completed the reading of the whole chapter... Below, follow some general and specific comments. I don't know whether you have already received comments from other people and have changed the text. In the following, I refer to the version you sent me on Sept 21. In the specific comments, I follow the text as paragraphs within sections/ subsections, mixing relevant things to typos/minor points. Finally, note that although I offer some change in the style, I do not ask you to follow them exactly since my english is imperfect...



* General

- It would be nice to add at the end of the Introduction some general refs on other recent reveiws/monographs/books on the subject.
- Define Solar Neighborhood: within 1 kpc of the Sun? more? less? Note that for other topics the neighborhood is really much more limited than in the present context. Also, use the same notation thrughout the review - sometimes is in capital letters, sometimes in small letters.
- Define dense cores - you do introduce early on "dark clouds", specifying T and n, but do not say what a dense core is within molecular clouds.
- Similarly, although intially you refrain from introducing the concetp/term of "clumps")see footnote 1 !), later on you make ample use of them when discussing the internal structure and for the derivation of important quantities...
- Replace "manuscript" with "review" throughout the text.
- when using the sequence (i), (ii)... separate them with either ";" (instead of ",") or "." depending on the text
- since you use "Galaxy" (capital G) most of the time, you do not need to say "our" or "our own" - you can simply say "the Galaxy"
- use either "halos" or "haloes" consistently throughout the paper
- use "power-law(s)" and "log-normal" consistently in the text (sometimes you write them as a single word, sometimes not)
- wirte "size scale(s)" rather than "sizescale(s)"
- in the discussion of the mass spectra of clumps, cores and stars (from sect. 4.4.1 onward) I suggest to distinguish each time by adding M_cl (for clumps/cores) and M_\ast (for stars).
- change "freefall" to either "free fall" or "free-fall"

* Specific comments

- ß1, 1st par: "...is not easily accessible to observations; in the latter, molecular clouds are..."
- ß1, 1st par: you don't mention self-gravity as a (at least partly) different property of the molecular vs atomic gas clouds
- ß1, 2nd par: ... and theoretical knowledge (NOT knowledges)
- ß1, 3rd par: I think that you should use "size scale(s)" instead of "sizescale(s)"
- ß1, 3rd par: it would be better to say "... milli-pc" rather than "mpc" - especially the first time
- ß1, 3rd par: the sentence "They bring to light a number of..." is a bit awkward - could use "The less controversial facts are:..."
- ß1, 4th par: "... theoretical progress has been accomplished... not exclusively allowed by the development... which, thanks to the increase... and the use of of new numerical schemes (such as adaptive ...) can now cover.... In parallel, ... devoted to include the important...commonly incorporated into numerical models/ simulations."
- ß1, 5th par: "Moreover, molecular clouds, as we will argue later on, are not isolated... even more severe, since ideally..."
- ß1, 6th par: first time write "interstellar medium (ISM)"...
- ß1, 6th par: "... on the order of \sim 1 eV... suggests that these processes (drop "five classes") are coupled... which are (drop "now") interacting in the cloud...
- ß1, 8th par: "...directly used to interpret relevant observations... and on their physical significance... However, given the ... been given to those from which statistics are inferred and then confronted to theories. We also stress that, while the primary focus..., we will address closely related...

- ß2.1, 1st par: "... J=1-0 transition of CO at lambda=1.3 mm (or frequency...) ... two main isotopologues ^12CO and ^13 CO) and the knowledge of CO spectroscopy were sufficient to infer that the line emitting gas in dark ... on visble maps of the sky... was cold (T_K<~10 K) and dense (n>~10^3.... [CO]/[H2]<~10^-4...
- ß2.1, 2nd par: "... then, several ^12CO(1-0) ...
- ß2.1, 3rd par: "...GMCs are resolved structures: some of them are also found between the arms...most massive GMCs are located downstream... Unexpectedly, this complexity extends down to milli-pc scales (Falgarone et al. 1991, 2009)."
- ß2.1, 4th par: Hennebelle et al. 2001 is not listed in the References (!)

- ß2.2, 1st par: "... ambient UV-field,. This raises the issue of the CO molecule survival... and of the nature of the gas component...
- ß2.2, 2nd par: replace interstellar medium with ISM since already introduced
- ß2.2, 2nd par: "... all the gas that is not in denser clumps/cores or star forming... with total hydrogen column density...
- ß2.2, 3rd par: note that here you introduce "pdf" (small letters) but later on you call it "PDF"
- ß2.2, 3rd par: ... 0.5 mag up to A_V~few magnitudes, and a power-law tails...and filaments (drop comma) present only... in N_H corresponds to the diffuse ISM of the molecular clouds... belog tosmall-scale, self-gravitating...
- ß2.2.1: The shape of the cooling function...thermally bistable at the pressure and metallicity... Separate 100 K, 8000 K
- ß2.2.3, 1st par: note comment on sequence of (i) (ii)... diffuse molecular gas exists with respect...
- ß2.2.3, 3rd par: "...Neufeld et al. 2010a); the ubiquitous HF... Sonnentrucker et al. 2010); ... SH+, both with highly endoenergetic..., reveal the existence of..., exceeding by far that provided... found to fluctuate by large factors (not huge since there is only a factor of 10)

- ß2.3, 1st par: "... major achievement of CO observations... conversion factor, X_CO\equiv N(H_2)..." At the end it would be nice to give a general ref.
- ß2.3, 2nd par: "Two recent space experiments, Fermi... Ackermann et al. 2011) ... are observed in these regions (drop comma) that cannot... optical depth excess above that expected...
- ß2.3, 2nd par: Note that you call CO-quiet clouds what you probably mean are CO-dark clouds - I don't understand the meaning of quiet...
- ß2.3, 3rd par: "...due to understimates of the HI... in the Galaxy, then H2 would be overestimated and the... subsequent underestimate of H2 associated...
- ß2.3, 4th par: I don't understand well the sense of the whole paragraph --> is that important in the context? what is the implication of this point?
- ß2.3, 5th par: "... sections, the prprerties of molecular... are discussed distinguishing gas traced by 12CO(1-0) (drop comma) from that ... and higher density tracers (CS... locally CO-rich, it contirbutes to... significant level, and ... Finally (instead of Last), ...

- ß2.4: "The connection between..."
- ß2.4.1, 1st par: "... detected in the HI 21-cm line, therefore... Elmegreen 1987). Early on, the mass within these HI halos has been estimated ...
- ß2.4.1, 2nd par: "... However, the velocity field allowed... detected in CO. These HI superclouds are found... 4x10^7 Msun, the mean number density is ... Substantial effort has been devoted to conduct similar observations in external galaxies."
- ß2.4.1, 3rd par: "... being not too distant (d=... kpc) and seen nearly face-on, therefore... the HI distributions. In particular, they stress...
- ß2.4.1, 4th par: "... evolutionary scenario is confirmed...that GMCs in the LMC are indeed accreting... less than 7 km/s, i.e. the rms velocity... Hughes et al. 2010), therefore suggesting that the processes are ... " Would you like to add something like " similar in the two galaxies in spite of the remarkably different properties (metallicity, spiral arms, etc.)"?
- ß2.4.1, 5th par: "...much further away from the Milky...
- ß2.4.2, 1st par: "Quite early on, it was recognized... and size (drop comma) was much ... raising the question on the nature of the gas...
- ß2.4.2, 2nd par: What do you mean with "... building up the mass"? - contributing significantly to the total mass?
- ß2.4.2, 2nd par: "... cold cloud material) and expected... Puget 1985), and their... transonic (not transsonic) ... onle the rare collisions among fragments were controlling the dissipative... introducing magnetic field lines connecting...warm material, but with the cold phase reaching...

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- ß2.4.2, 4th par: I got confused starting with the sentence "They found that both are clearly..." all the way down to the end of the par: why do you into such detailes of theWilliams et al. study if it is not conclusive?
- ß2.4.2, 5th par: "... creates both high- and low-pressure areas... penetrate inside the GMC, filling in all the low-pressure regions... detailed physics is now more complex than formerly assumed... case that the magnetic field is...

- ß2.5, 1st par: "... capture many of the steps leading to the formation of ... step has been the study of the non-linear...triggered either by a... , or by shocks propagating ... , or by turbulent driving... these studies are: (i)...; (ii)...for the CO clumps (discussed in Sect. ... - drop "in the manuscript")... and with a velocity dispersion.. sound speed. Simulations including magnetic fields have also been performed... the fluid dynamics, the above...
- ß2.5, 2nd par: "In the second step, gravity... letting the condensations to proceed further...
- ß2.5, 3rd par: Last sentence could be changed to "...part of a larger cloud that contains the WNM shown here."
- ß2.5, 3rd par: See comment of pdf vs PDF
- ß2.5, 3rd par: "... discussion on density PDF). However, the bulk..."
- ß2.5, 4th par: "...MacLow 2007), or, at a more...is reasonably well computed, such as CH with H2 column densities but... reproduce (by almost a factor of 10)... but all the models so far fail to reproduce...
- ß2.5, 5th par: "... clouds proposed above": where above? say "in Sect..."
- ß2.5, 6th par: "... of interstellar turbulence. The second approach treats... either in a fixed asymmetric... 2009), or in a prescribed... 2007), or self-consistent... Not surprisingly, it is... In particular, statistics..." I would drop the last part of the last sentence "both processes entering the simulations"

- ß3: "...infall is taken into account) - add parenthesis - ... turbulence is essential because, along with magnetic fields, it represents the main contribution to the pressure... galactic gravitational potential field and the main support...
- ß3.1, 1st par: "... kinetic energy to even smaller scales... "
- ß3.1., 2nd par: "... and the book by Frisch 1995..."
- ß3.1, 3rd par: eq. 1 must be written correctly

- ß3.2, 1st par: the sentence beginning with "Based on the fact..." is incomplete and does not make sense as is
- ß3.2, 1st par: "... Thus, the fractional change in velocity is proportional... Conseuently, the number of collisions... Therefore, the cascade... the same at all scales, one gets..."
- ß3.2, 2nd par: "... This leads (drop them) to a scaling... Wan et al. 2012) and still appears to be a matter... MHD turbulence remains unsolved."
- ß3.2, 2nd par: Note that in text is Masson et al. while in the References is Mason et al.

- ß3.3, 1st par: "...rigorously established analitycally (see, e.g., the recent work...)... from numerical simulations performed during... The biggest simulation carried ut to date...(2007) with an effective resolution...the power spectrum of the velocity v... Thus, the energy spectrum... In high resolution 3D numerical simulations like those of Kritsuk et al. (2007)...power spectrum of v (drop comma) is... Federrath et al. 2010), in particular..."
- ß3.3, 2nd par: "...(2007), concerns the power spectrum... energy flux, that for compressible turbulence...v^3, becomes... Indeed, observations have provided answers..."

- ß3.4, 1st par: "...advocated a long time ago (...) on the basis of the estimated large... molecular clouds in the Galaxy... has been often challenged because it... "
- ß3.4, 2nd par: "... defined as connected structures...imply actual spatial conncetion of the structures..."
- ß3.4, 3rd par: "Figure 5 prompts four comments:... L^0.5_pc. (ii) There is an even large scatter... (2009). When drawn over... dynamic coverage. (iv) At scales smaller... Therefore, there is no such..."
- ß3.4, 4th par: "...GM/R, (add comma) where the geometric... the molecular clouds are in virial balance... scaling laws. Since the 13CO(1-0) line is more optically thin than the 12CO(1-0) transition, the survey does not probe... as low as \sim... same limitation appear to apply to the discussion...
- ß3.4, 6th par: "... Indeed, this is what is found...this non-uniform pressure... Thus, we would have..."
- ß3.4, 7th par: "... \Pi(R), as proposed by Chieze..."
- ß3.4, 8th par: "...can consistently be interpreted as..." - the sentence "the above suggests that..." is not the logical consequence of the previous part of the sentence.
- ß3.4, 8th par: what is the "mass stellar surface density"?
- ß3.4, 8th par: "... kept proportional. This fact introduces galactic rotation as an additional parameter driving the evolution..."
- ß3.4, 8th par: Note that Swinbank et al. is quoted 2010 in the Reference list (not 2011).
- ß3.4, 9th par: "...from structures of \sim 0.01 pc to GMCs of \sim 100 pc.... (see Table 1)... ISM. This conclusion is in agreement..."
- ß3.4, 10th par: "...to isolate connected CO structures... in space-velocity allow the construction of mass spectra... close exponents: in the early CO survey of... \alpha=1.83 for 10^3 Msun... from the CO survey of the outer Galaxy ... \alpha=1.80 for 500 Msun... in a high latitude cloud (...) \alpha=1.84 over... in star forming and in inactive regions."

- ß3.5, 2nd par: "...because, as discussed later in the review, turbulence..."
- ß3.5, 3rd par: "...comparable to that in more actively star forming clouds...(2009) have found in the LMC ... for at least two categories (i.e., clouds without and... see their Table 4)... conclude that this is consistent... fractions of clouds (drop "in the bulk") the turbulent..."
- ß3.5, 4th par: "Klessen & Henebelle (2010) argue that... by accretion onto moelcular clouds... Indeed, when a parcel of fluid falls onto the cloud... v_in^2, where Sv_c is the... v_in is the infall velocity of the gas... ρ_in its density, ... obviously the lack of empirical knowledge of the accretion rate. From their data Fukui et al... rate f the order of few $\times$ 10^-2... typical GMCs, which is enough to reproduce the observed velocity according to Klessen & Hennebelle (2010)... Goldbaum et al. (2011) have performed a time... and conclude that turbulence... accretion-driven turbulent model implies that... the link between molecular clouds and their environment, as described earlier in the review".
- ß3.5, 5th par: "After enough stars have formed inside molecular clouds, ... Matzner (2002) estimates the impact of winds, supernovae... on the turbulence budget within the clouds... most efficient means to sustain turbulence... (1997), Matzner concludes that photo-evaoration induced by HII (not H_2 !) regions eventually destroys the clouds... formation of pillars and inject some turbulence within molecular clouds. The inclusion of feedback from protostellar jets has been considered by Nakamura & Li... have formed. On the other hand, ... (2010) calculate the support of protostellar outflows to the star forming clump..."
- ß3.5, 6th par: "... dominant over external sources... the cloud life time, but their ..."

- ß3.6.1, 1st par: "... reasons. First, these regions... and space: finding them requires... Second, observations... of a molecular line. Then, statistical analyses similar to... Third, only spatial... increments are built using the line centroid..."
- ß3.6.1, 2nd par: "... most recent maps of the Polaris Flare (is this the correct region?) ... spectra homogeneously sampling turbulence in the diffuse... "
- ß3.6.2: "... by the IRAM Plateau... These are not filaments, but appear to be... out of eight filaments form... different position angle (drop comma) cover the..."

- ß3.7, 1st par: "... Heyer et al. 2008). These authors have developed an axis-... method that has been tested against numerical... tend to reduce it, Heyer et al find an... to the striations rather than along them."
- ß3.7, 2nd par: "... Taurus molecular cloud, finding that the velocity... in the edges and opposite in the opaque regions."

- ß4.1, 1st par: change "unsruprisingly" with "not surprisingly"
- ß4.1.1, 2nd par: "...illustrate this better, let us...is compressed by a (take out second "a")... Pudritz (2009) and constitutes... First, as shown by 2009), ... Moreover, this approach... account the re-expansion... distribution, in particular at high density."
- ß4.1.1, 3rd par: "... in Eq. (3) is also interesting... that 'sigma_p^2\propto M^4/<^2. Thus, \sigma_p has... on the Mach number.."
- ß4.1.2, 1st par: "... Semadeni (1998) performed 1D... In particular, they found ... Hennebelle (2010) have presented 3D high-resolution simulations... They confirm the power-law behavior... and obtain an exponent equal to...
- ß4.1.2, 2nd par: which are the two phases you refer to at the beginning? I guess isothermal and polytropic, but it is not obvious
- ß4.1.2, 2nd par: "... hundred particles/cm^-3)... Audit (2007) warn that numerical convergence..."
- ß4.1.3, 1st par: "...have revealed that as gravity takes over.... gas is collapsing (e.g., Klesse 2000... r^-2 profile developed by a collapsing sphere (e.g. Shu...Indeed, the volume... \delta ;rho is 4\pi... densities as collapse proceeds"
- ß4.1.4, 1st par: "The density field cannot be inferred directly from observations. Owing to the integration along... Kainulainen et al. (2009) who determined the... (2011) using the emission from dust (or "using dust emission")... Interestingly, they found... or slightly belowthe mean value...Thus, we get ..."
- ß4.1.4, 2nd par: "... Therefore, it should not... as a direct proof in favor of the existence... turbulence, but as a fact compatible with it."
- ß4.1.4, 3rd par: "... the PDF deviates significantly from the log-normal ... and appears to be reminiscent of..."

- ß4.2: "... in simulations and observations."
- ß4.2.1, 1st par: "... which, in the case of the... describes how energy is... lot of effort has been devoted to infer the..."
- ß4.2.1, 2nd par: "...when the (take out the second "the")... very compressible, it is unclear..."
- ß4.2.1, 3rd par: write in math mode "\rho div v"
- ß4.2.1, 4th par: write in math mode "- div v" - "...Kolmogorov exponent, although no rigorous..."

- ß4.3, 2nd par: What do you mean exactly with "the uniformity of \beta" ? the fact that it is constant? if so, say it.
- ß4.3, 3rd par: "Fianlly, in Figure 10 slopes of HI emission... the HI layer in the LMC according..."
- ß4.3, 4th par: "... Second, a value of\beta=2.75 is similar... but it is remarkably similar to that of CO emission in the line wings... due to projection (not optical depth) effects..." with a small dynamic range of scales."
- ß4.3, 5th par: "... In particular, the HI seen... supersonic on large scales, ... supersonic media, have... reminiscent of what is obtained...scales may also signal the trnsition... of 0.1 pc, a scale around..."
- ß4.3, 6th par: "... toward small scales found from the values... However, it cannot be ruled out that..."
- ß4.3.1, 1st par: "Some authors have attempted... so-called mass-size method has been applied by... within the box. The receovered M(l) has the form of a power-law..., with \gamma=2.39 according to Kritsuk..., \gamma=2.11 with solenoidal forcing, and \gamma=2.03 for compressible forcing according to Federrath.."
- ß4.3.1, 2nd par: "... Then, the mass of each... where dM is the mass within cells of coordinates x_i x_j)..."
- ß4.3.1, 3rd par: "... Considering that gravity is not included in these simulations, the physical origin of the mass-size relation can only be attributed to turbulence. Yet, no quantitative explanations has been provided neither for... nor for the measured... which suggests that \alpha... which leads to u... incompressible case, with the exponent of the order of -2... This issue certainly requires further careful investigation."
- ß4.3.1, 3rd par: to which expression you refer when you say "using this expression"? eq (4) of the text?

- ß4.4.1, 1st par: "... To date, the mass spectra... inferred from observations, namely... PPV-space obey the same power-law dN..."
- ß4.4.1, 2nd par: "...Andre et al. (2010). The derivations did not make use of the velocity information, but are based only on the spatial distribution. It has been pointed out that at masses higher than M_cl \simeq 1 M_sun... the dense core distribution is compatible with a power-law significantly steeper than that of the CO clump power spectrum, with an exponent close to the value 2.3 inferred by Salpeter (1955) for the stellar initial mass function ... TAKE OUT "or equivalently dN..." ... At lower core/clump mass, ... claim to find a change int he distribution with a pronounced flattening and possibly a peak around M_cl...??? ... similar in shape to the stellar IMF, but shifted..."
- ß4.4.1, 3rd par: "It is not easy to find... In particular, we would... 1.8 extends over... applies both to CO... are self-gravitating entities, their mass distribution... Different approaches recently developed appear to provide a common explanation. A strong hint in this direction comes from the work of Peretto ... who have shown...within the IRDCs, resembles the mass ... This clearly calls for a unifying interpretation."
- ß4.4.2, 1st par: "... Let us start with some elementary...spectrum in 3D space... dk. It seems reasonable to assume that for... Now, in 3D we expect... can be simply proportional... and the high-mass part of the... close to 2. For a general explanation it is necessary to infer the mass spectrum of different types of clouds... physical processes that drive their evolution."
- ß4.4.2, 2nd par: "... This follows from calculating the column density power... NOTE THAT THE REST OF THE SENTENCE DOES NOT MAKE SENSE
- ß4.4.2, 2nd par: "... that the mass-size relation and the distribution... Chabrier (2008) have performed a multi-scale... lognormal and that the power spectrum exponent.. In this way, they

obtain the relation \alpha=3-n'/3, or equivalently..., a relation quite similar to that obtained by....First, it is worth... calculations, as emphasized...Note that the power spectrum indexes... Indeed, the expression for \alpha and \beta can be combined leading to n'=.... This, in turn, suggests that for..."
- ß4.4.2, 3rd par: "... The mass spectra of non-self-gravitating... have been obtained numerically by Hennebelle... These authors have simulated various types of flows... compatible with a power-law with \alpha=1.7-1.8, similar to the mass spectrum of the CO clumps and to the analytical expression \alpha=.../3. Considering that both the input physics and the boundary conditions... entirely the value of \alpha, with cooling, instabilities, and forcing playing a secondary..."
- ß4.4.3: Mass spectra of turbulent, self-gravitating clouds - The first paragraphs need to be rewritten: this is a suggestion...
- ß4.4.3, 1st par: "... has been derived by Padoan... medium with a lognormal density... (2008) have addressed the problem self-consistently including turbulent support against gravity, showing that its contribution is crucial to predict the... but, instead of adopting a simple uniform density..., they require that the parcel of gas ... dominated by its own gravity. TAKE OUT THE FOLLOWING SENTENCE. The inferred distribution is very similar in shape to the CMF ... and to the stellar IMF... In particular, they find that the slope at high core?/clump? masses has an exponent x=... (where n is the index of...) similar to the Salpeter (1955) IMF dN...\propto M^-1.35, while at low masses the shae is close to a lognormal with a pronounced peak at M_cl\simeq...???"
- ß4.4.3, 2nd par: "... fluctuations that cross a specified density threshold. Hopkins presents a global model that includes spatial scales larger than the molecular clouds, appropriate for a description of the whole galactic disc. An interesting result is that ... defined by the parcels of gas... barrier at later times have a mass spectrum... some deviations appear. This is illustrated in Figure 12. An obvious interpretation is that the first type of structures likely represents the massive... self-gravitating clouds, while the secondary structures can possibly be associated to the dense prestellar cores. The models suggests that while... self-gravitating fluctuations should be close to the CMF."
- ß4.4.3, 3rd par: "... purely turbulent clumps TAKE OUT PARENTHESIS inferred by Hennebelle... (2008, see Sect. 4.4.2) and that of the biggest self-gravitating clumps obtained by... both power-laws with very similar... This is an appealing explanation for the mass... apparently constant over... , even though the more massive ones are self-gravitating ... the less assive ones are not, with the transition occuring at M_cl\sim... - I WOULD REPLACE THE REST OF THE PARAGRAPH WITH THE FOLLOWING "A possible route for the least massive ones is that they originated by turbulent decay within non-self-gravitating clumps and that gravity eventually took over during the condensation process through cooling and energy dissipation. In this case, the part of the CO clump mass... On the other hand, the formation of the most massive clumps may have been initially triggered by their own self-gravity. It is difficult at this stage to estimate where the possible transition between the two regimes appears."
- ß4.4.3, 4th par: "It must be noted that CMFs in good agreement.. have been constructed usign different approach and assumptions. For example, Myers (2009a) suggests a model based on gas accretion in dense cores with a distribution of infall duration. Kunz & Mouschovias (2009) have stressed the importance of magnetically dominated cores assuming..."
- ß4.4.3, 5th par: "Finally, the CMF has also been inferred from numerical simulations. Through hydrodynamical and MHD simulations without gravity, Padoan et al. (2007) identify the cores as the density... self-gravitating. The resulting CMF has a Salpeter-like slope. On the other hand, considering only thermal support or thermal and magnetic support, the CMF becomes too steep. Similar results have been found by Schmidt et al. (2010) who included turbulent support in the core definition, abd by Smith et al. (2009) who define the cores using the potential wells. All these results underscore the importance

- ß4.5, 1st par: "With the increased sensitivity of CO observations and the availability of larger maps away from the brightest spots coinciding with star forming regions, the evidence for the filamentary structure of the CO emission became immediately clear. At about the same time, the far-IR all-sky IRAS survey... diffuse ISM. This suggested a link between filaments... "
- ß4.5, 2nd par: " Subsequently, several mid-... These regions are now known as InfraRed Dark Clouds (IRDCs) ... Nessie nebula with a linear extent of 80 pc and and a width of only 0.5 pc. The linear mass density is still poorly constrained..."
- ß4.5.1, 1st par: "... by the presence of dense cores ... periodically distributed... Moreover, in the case of the Taurus molecular cloud Hartmann... that the latter likely form from the gravitational fragmentation of the filaments, a process suggested by analytical studies... Curry 2000). These studies have shown that in the... is possible, leading to... DEFINE C_s AS THE SOUND SPEED... instabilities. The growing fluctuations would give birth to cores separated by a few Jeans lengths, corresponding to the typical wavelengths of the fastest... "
- ß4.5.1, 2nd par: "... filaments is still not well understood, but a few theoretical... any pre-existing anistropy, as emphasized for example... The simple physical reason is tha the force... because of the way it was assembled...Another way for filament formation is by gravitationalinstability of self-gravitating layers, as shown for example by... profile of the layers is given... Again, filaments... with characteristic separation ... (1998), who performed... layer, show that... that detemrines the scale height... at which the solution is truncated... to the field direction. The physical reason is that, since the width is large relative to the Jeans length, the layer is compressible and density fluctuations are easier to develop along the magnetic field. On the other hand, when... are aligned. In this case, the layer is... filament has been derived by Schmid-Burgk (1967) and is given by... When A=0, it simply reduced to the self-gravitating layer, while when A--> 1it tends to a set of discrete... Recently, this solution has been used...self-gravitating layer forms first, then it fragments ... as predicted theoretically. Owing to the presence of local overdensitis, the filaments converge ... more massive region, which eventually gives birth to..."
- ß4.5.2, 1st par: "Thanks to the unprecedented ..., Herschel/SPIRE has now provided a unique view of the filamentary structures traced by cold dust emission...One of the main findings of the SPIRE measurements is... column densities between the most tenuous... and most opaque ... several fields (see Fig. 11) in comparison to the narrow range of filament widths..."
- ß4.5.2: the whole paragraph is way too long - you should break it at, e.g., "An alternative explanation..."
- ß4.5.2, 2nd par: "...to the Jeans length, at odds with the observations (see Fig. 7 of Arzoumanian et al. 2011). Second, the very existence of such thin structures in a turbulent... which is close to the observed thickness. However, there are a couple of... First, the derived scale is the typical thickness of the shocked layers and not of the filaments. Second, it has been assumed that the gas is isothermal. Thus, once the ... has vanished (typically, in a few ... re-expands due to the over-pressure relative to the ambient medium. In a few crossing times... the thickness broadens significantly, leading to a wide width distribution. This scenario is similar to that found in the simulations of Padoan et al. (2001) where the filaments correspond... recently, an alternative explanation has been offered by... who argue that the characteristic size... pressure bounded, they find that the equilibrium of the isothermal gas... about 0.1 pc with a weak dependence on the column density. We must stress that no detailed analysis... has been performed to date... a general trend of MHD simulations that appear more filamentary... "
- ß4.5.2, 3rd par: "In this regard, the dynamic origin ... Whether the velocity shear... due to a shock propagating in the.."
- ß4.5.3: "Tenuous filaments are interesting structures since they may shed light... growth scenario. A tenuous filament... WHAT IS

complex. The filament has a low mass-to-virial ratio (here the mass is the linear mass) ...DROP THE RATIO... hence it is not held together by self-gravity...wavelike behavior of the... threaded by such fields..."

- ß5.1: "Early on, magnetic field has been proposed... 1987), possibly explaining ... This suggestion has contributed to trigger... actual trend indicated by measurements... put forward in support of the magnetically..."
- ß5.1.1, 1st par: "... smplicity, let us... by a uniform magnetic... remain constant in time. ... uniforma magnetic field, is... NOTE EQ. 8 HAS PROBLEMS ... numerical calulations of the cloud in 2D equilibrium."
- ß5.1.1, 1st par: note that the sentence "A cloud which has a mass-to-flux..." is incorrect if you leave the parentheses (larger/ supercritical) since in that case clouds can indeed collpase --> I'd take out the two parenthesis and leave only the subcritical case.
- ß5.1.2, 1st par: "... problems with magnetic support is... possibility of leakage of the magnetic... now the induction equation, which involves the velocity... From this equation, it can be easily inferred a typical time scale fro ambipolar diffusion..."
- ß5.1.2, 2nd par: "...times, the cloud becomes supercritical and the magnetic field cannot prevent collpase. The important question at this stage is "How much...process?" virial equilibrium, B^2... The implication is that ambipolar diffusion can reduce the star... observed value GIVE IT ALONG WITH A REF ... by ambipolar diffusion (DROP COMMA) have been performed... "
- ß5.1.3, 1st par: "In Sect. ... we have described the properties of MHD turbulence. Here, we focus ... which have investigated the effect of turbulence..."
- ß5.1.3, 2nd par: "Basu & Ciolek (2004) and Li & Nakamura (2005) have presented 2D simulations combining magnetic support (magnetic field lines parallel to the cloud) and turbulent motions. ... 2008) that turbulence tends to accelerate star formation. ... in which ambipolar diffusion... and that turbulence is sufficicently strong... More recently, these ... "
- ß5.1.3, 3rd par: "... 2011), although the exact.."
- ß5.1.3, 4th par: "A series of recent 3D studies of supersonic turbulence ... Balsara 2010) have emphasized the impact... that, as expected, ambipolar... rate of turbulence dissipation. Also, the power spectra of... thend to be steeper. Fianlly, the synthetic spectra of the neutral and ionic species show that the... consequence of their partial decoupling from the magnetic field. In principle, these effects..."
- ß5.1.4, 1st par: "... input to understand star formation, as it bears the signature..."
- ß5.1.4, 2nd par: "...lines, then the magnetic field... then it is easy to show that... remains spherical, especially if the magnetic... Then, as the mass... Basu (2000) has compared the data... and obtains good agreement, which improves if the velocity dispersion \sigma is used instead of..."
- ß5.1.4, 3rd par: "... Banerjee et al. 2009), the magnetic... field lines and to align the magnetic and velocity fields... facilitates the (DROP SECOND THE) gas contraction... pass through a given point..."
- ß5.1.4, 4th par: "... which treat both... predictions deduced above."

- ß5.2, 1st par: "... TAKE OUT SCARCE before MEASUREMENTS... In the latter case, ... will offer a global view..."
- ß5.2, 2nd par: "... field intensity, but probe... in the interior of dense cores and in the inner parts of dense filaments... possible interpretations of the... (i) the decrease of... (ii) a helical magnetic..."
- ß5.2, 3rd par: "...Li et al. (2006) find a correlation..."
- ß5.2, 4th par: "... Unfortunately, the... line-of-sight, an effect which is plagued by... being one of them). So far, the best diagnostics have been OH in diffuse... and CN in star forming... available results are gathered... and displayed in Fig. 13... They include Zeeman measurements that sample B// ... and above this threshold the observed... clouds start to be self-... Thus, none of

- ß6: "...Here, we would like... the inter-relation between... we present some theories that have been..."

- ß6.1.1, 1st par: "... seen that the turbulent energy density is of the same order of the gravitational... any signposts of dissipation?... is probably positive: we may..."
- ß6.1.1, 2nd par: "... unexpected level (DROP THE COMMA) in cold diffuse... The H_2 line emission has... J>=2 of the ground vibrational level) ... of a few percent of warm... ISM is not only inferred from... "
- ß6.1.1, 3rd par: "A possible source of heating ... supersonic turbulence which pervades the whole ISM.... as low-velocity MHD shocks ... gas eventually cools once the dissipation..."
- ß6.1.2, 1st par: "... On average, in the galactic plane C+ cooling exceeds by far all other coolants, as first shown... to anme a few, are idncators that some aspects of the cloud..."
- ß6.1.2, 2nd par: "... have met with success even with ... UV radiation, the gas temperature and the chemistry in a more realistic... in the range from a few \times 10^19..."
- ß6.1.2, 3rd par: "... Quoting Glassgold & Langer... "When C+ recombines... In steady-state chemistry, H3+..."
- ß6.1.3, 4th par: "...rapid hydrogenation of CH+ that produces CH2+ and CH3+. This chain stops at CH3+ which becomes the pivotal cation of the "warm" chemistry by reacting with O to form HCO+, the main source of CO through dissociative recombination."
- ß6.1.3, 5th par: "The TDR model (for... "
- ß6.1.3, 6th par: "... therefore samples actively dissipating regions, relaxation phases, and the ambient medium... introduces a potential complexity in the comparison of the observed abundances..."
- ß6.1.3, 7th par: add ";" at the end of each item
- ß6.1.3, 8th par: "An interesting property of these models is... (DROP THE REST) of warm gas is sufficient to reproduce... Finally, models of low-velocity...

- ß6.2: the whole subsection is too long and detailed (especially at this point) __> I'd suggest to reduce it significantly without entering into the specifics of each model.
- ß6.2, 1st par: "Below, we will emphasize the importance... Variosu authors (e.g., Krumholx... have proposed analytic theories... molecular clouds, that is the dimensionless... THIS SENTENCE IS TOO LONG AND COMPLICATED
- ß6.2, 2nd par: "... by Eq, (3): the densest... density PDF up to some... ends up into stars... Hennebelle 2010). Thus, SFR_ff... The difference between the variosu estimates available in the literature resides mainly..."
- ß6.2, 3rd par: "... The underlying assumption is... Furthermore, they... \tau_ff^0. Thus, they obtain a star formation..."
- ß6.2, 4th par: "... Jeans length is equal to... SFR obtained in this way is... The SFR increases with the Mach... Nordlund model, while it deacreases according to Krumholz & McKee."
- ß6.2., 5th par: "... First, they infer... mass spectrum derived by Hennebelle & Chabrier (...) weighted... It can be shown that the typical... Nordlund (2011) mainly because... to take into account the details of the spatal distribution."
- ß6.2, 6th par: "...PDF should be weighted... critical density leads to overestimate the... therefore to underestimate the SFR... - FOOTNOTE: More precisely, ... Chabrier (2008) that... -
- ß6.2, 6th par: break it after "critical density" below eq. 13
- ß6.2, 7th par: "In additin to the two choices... critical density obtained by... This is to say that only fluctuations... fall time leads to underestimate... On the other hand, the choice of Padoan... and leads to SFRs that vary... Direct comparison with SFR... performed, but given the relatively... it is har to draw firm conclusions."

- I suggest to have a new, final section 7. The road ahead (rather than another subsection).
- ß7, 1st par: "... turbulence is an even greater task because... and because it entails complicated... interstellar turbulence; (2) the

- I suggest to have a new, final section 7. The road ahead (rather than another subsection).
- ß7, 1st par: "... turbulence is an even greater task because... and because it entails complicated... interstellar turbulence; (2) the impact of the large..."
- ß7, 2nd par: "Several aspects of interstellar... First, the density PDF (DROP THE REST) largely controls the SFR... A better theoretical understanding of... number ond on the adaibatic... predictions of the SFR... Second, the... chemical species (DROP THE REST).... species will provide reliable diagnostics to help... of the flows. Third, the... process remain speculative. Finally, the... "
- ß7, 3rd par: "As amply emphasized, there is strong evidence that ... becomes important and even dominant, possibly... formation efficiency at the observed low levels. The... quantified, in particular the duration and the amount... formation involves at some..."
- ß7, 4th par: "... molecular clouds, whether magnetic fields... is still largely present and unsolved. Likely, the three factor play a significant..."

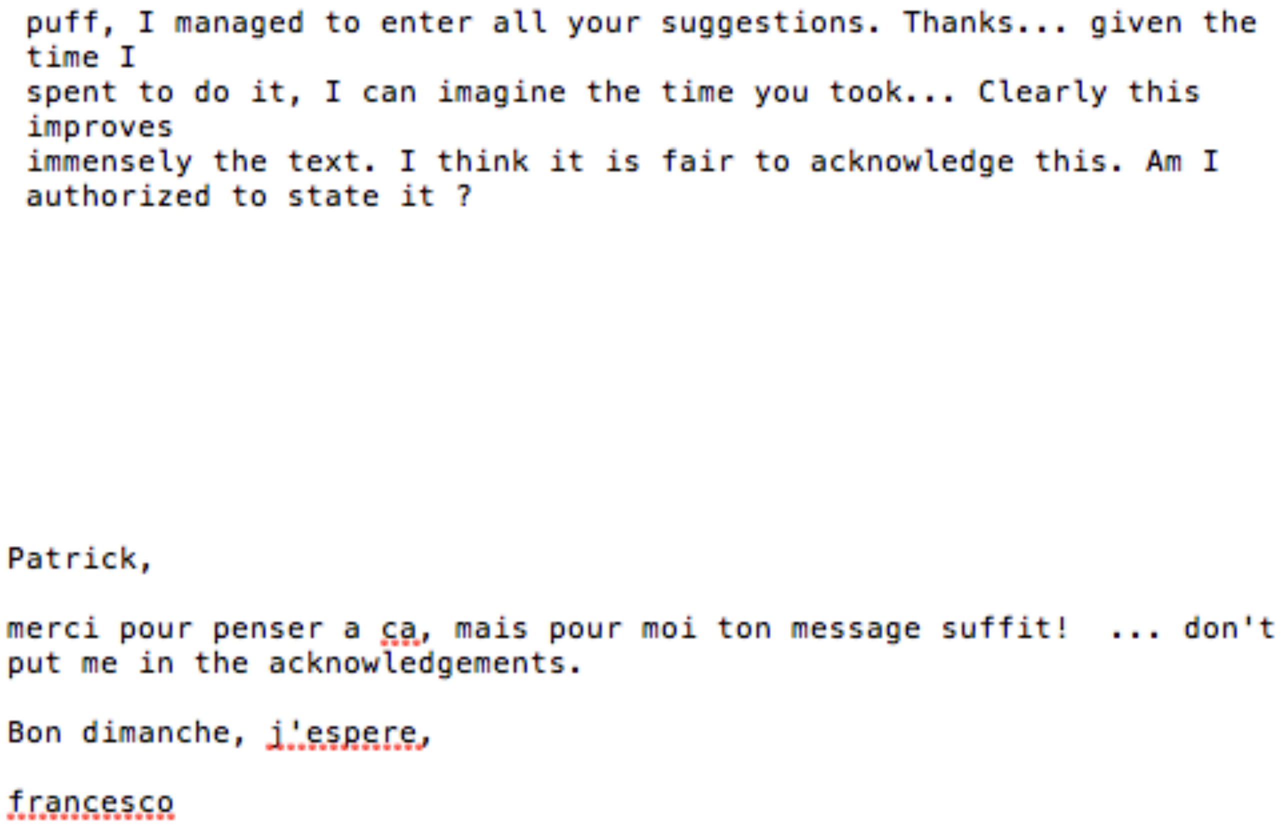
* Figure captions

- Fig. 1: "... square field shown in the left panel..."- this figure is a bit too small anc cannot be read well...
- Fig. 4: simply write "In MHD turbulence..."
- Fig. 5: "... 12CO(J=1-0) observations with red..."
- Fig. 6: "... rate versus size scale..." - Add the source of the figure
- Fig. 7: "... The Gaussian of the same dispersion..."
- Fig. 9: what is the vertical dashed line? can you reduce the size a bit?
- Fig. 10: ... \beta vary between 0.01...
- Fig. 11: Herschel/SPIRE... Another subset of regions of lowest...
- Fig. 12: ... Hopkins 2012 a? b? ... self-gravitating threshold, respectively.
- Fig. 13: Chapman et al. YEAR?

* References - some times you add "et al. after the first three authors, sometime you list them all...

- Andre' 2011 --> IAUS???
- biskamp 2003 --> title of book?
- Blitz, L. --> add the year in both refs 2004, 2006
- Brunt Heyer --> check vol and page
- Falgarone + 1991 -> year BEFORE journal
- Falgarone McKee 2012 --> should only be in text since it is priv. comm.
- Field + 1969 --> ApJ, 155, L149
- Frisch 1969 --> name of book
- Hennebelle et al. 2001: cited in text but missing in the list
- Hennebelle et al. 2007: cited in text but missing in the list
- Hennebelle + 2008 --> A&A, 486, L43
- Hennebelle Chabrier 2011 --> ApJ, 743, L29
- Hildebrandt --> add "t"
- Ingalls + --> add year
- Jackson + 2010 --> ApJ, 719, L185
- Kritsuk Norman 2011 --> still arxiv?
- Kunz Mouschovias --> ApJ, 399, L94
- Lada + --> missing journal
- Larson 1985 --> 214, 379
- Lesaffre + 2012 --> put ref
- Lis + 1996 --> 463, 623L ?
- Liszt Pety 2012 --> 541, 58L ?
- Mason or Masson?
- Molina + 012 --> still tmp?
- Scalo Pumphrey 1982 --> missing journal
- Solomon 1987 is out of order
- Spitzer 1978 --> title of book
- Vazquez-semadeni 1998 --> cited in text missing in the list
- von Weiszacker --> initials missing

It seems to me that the following refs are not cited in the text - BUT CHECK THEM!:



puff, I managed to enter all your suggestions. Thanks... given the time I spent to do it, I can imagine the time you took... Clearly this improves immensely the text. I think it is fair to acknowledge this. Am I authorized to state it ?

Patrick,

merci pour penser a ca, mais pour moi ton message suffit! ... don't put me in the acknowledgements.

Bon dimanche, j'espere,

francesco

Molecular clouds:

Galactic box and colliding flows
Turbulence and clumps

~10-100 pc

Proto-clusters:

Formation and size
Feedback and SFR

~1-10 pc

Filaments and Cores:

Formation of filaments
Fragmentation of filaments into cores
Cores from zooming-in simulations

~0.1-1 pc

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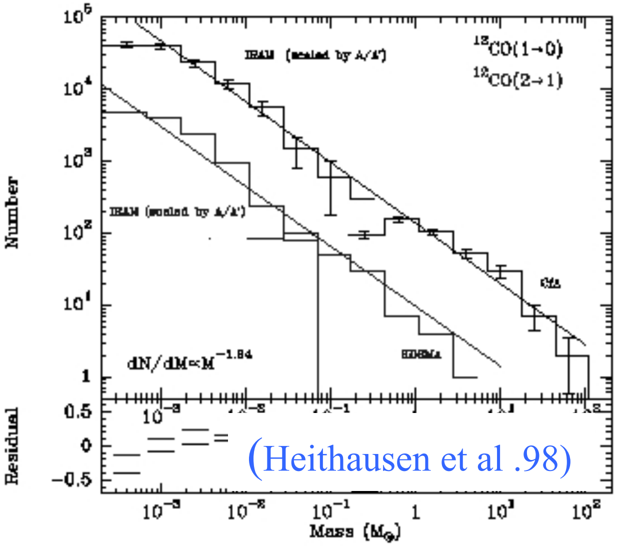
Motivations

Molecular clouds properties not obviously dependent on the presence of stars

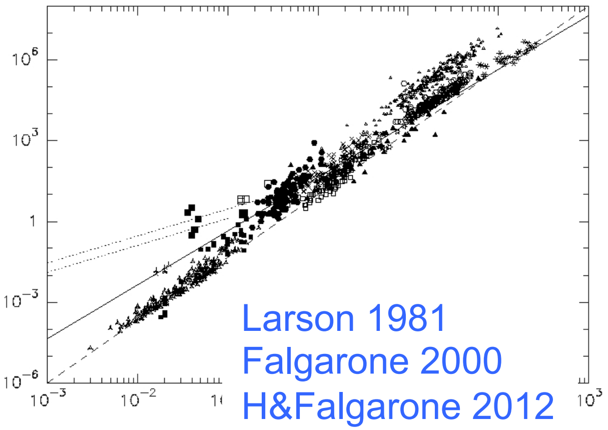
What is the origin of their internal turbulence ? Can we understand their statistics ?

Universal Mass Spectrum dN/dM α $M^{-1.6-1.8}$



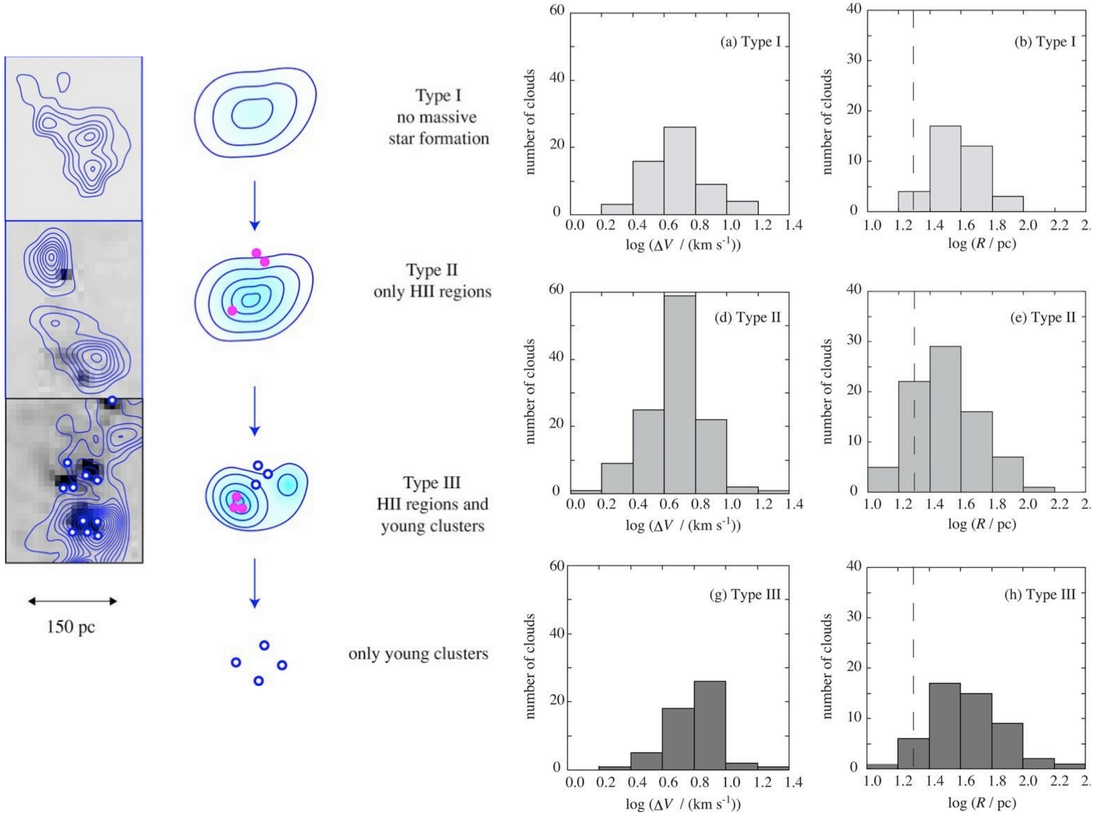
(Heithausen et al .98)

Mass versus size of CO clumps M α $R^{2-2.3}$



Larson 1981
Falgarone 2000
H&Falgarone 2012

Molecular clouds in the LMC
An evolutionary sequence ?



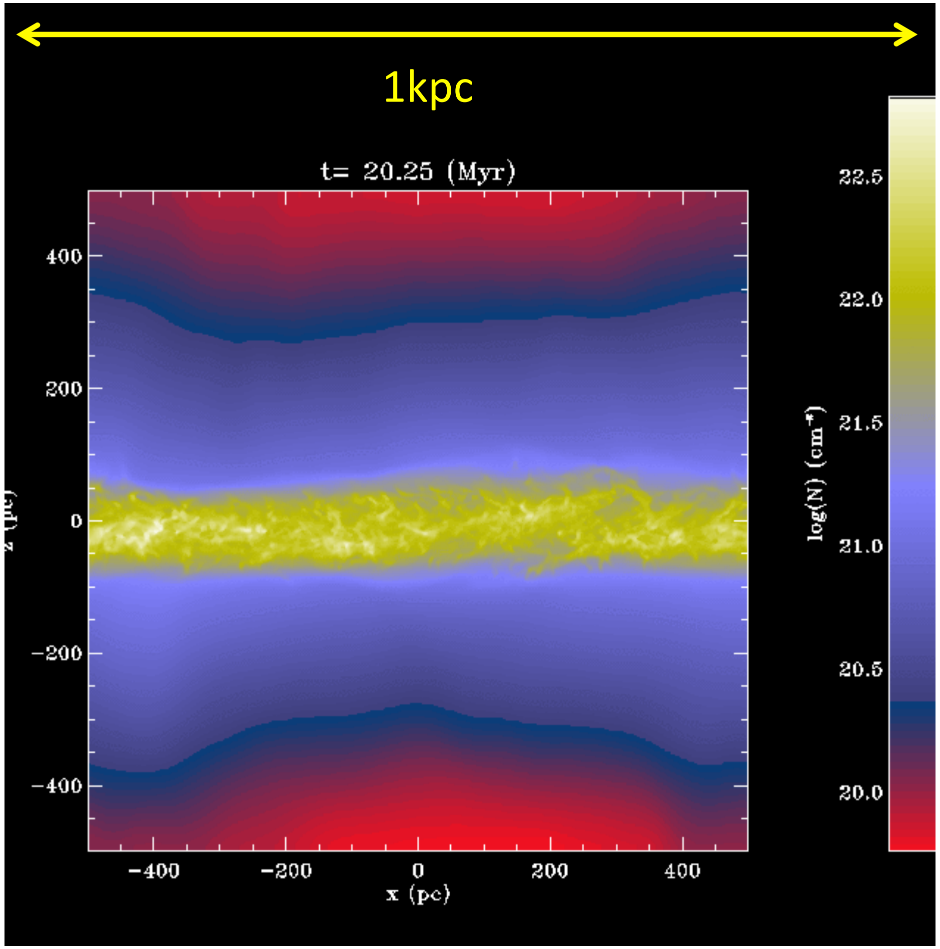
=> accretion rate onto GMC: few times $10^{-2} M_*/yr$?

(Kawamura et al. 09, Fukui & Kawamura 2010)

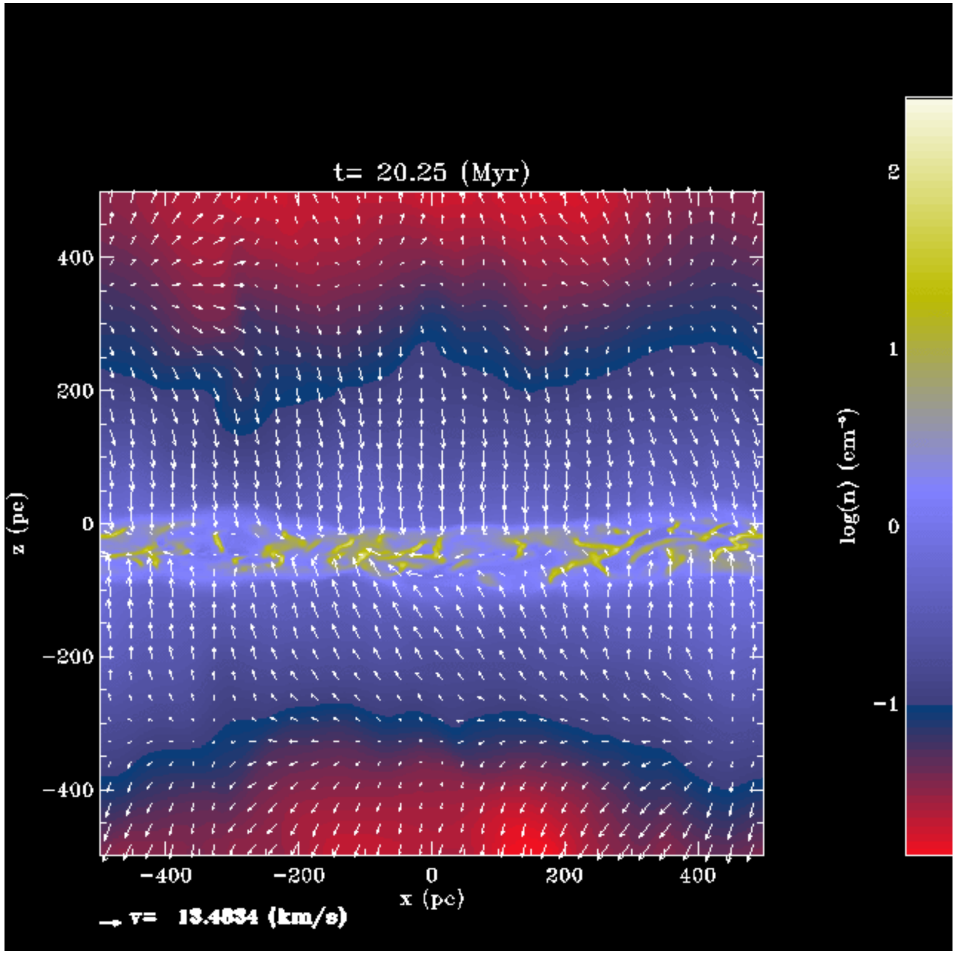
Supernovae regulated ISM (from few 100 pc to 1kpc)

(Slyz et al. 2005, de Avillez & Breitschwerdt 2005,2007, Joung & MacLow 2006, Hill et al. 2012, Ostriker+2011, Kim+2011,2015, H& Iffrig 2014, 2017, Gatto et al. 2014, Walch+2015, Ibanez-Mejia 2016, 2017, Butler+2015, 2017)

Column density



density

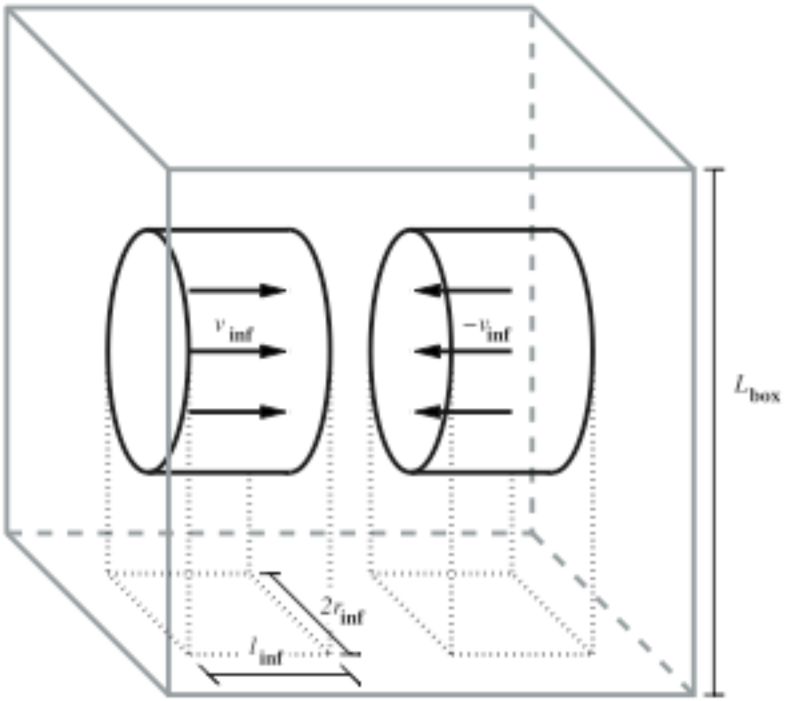


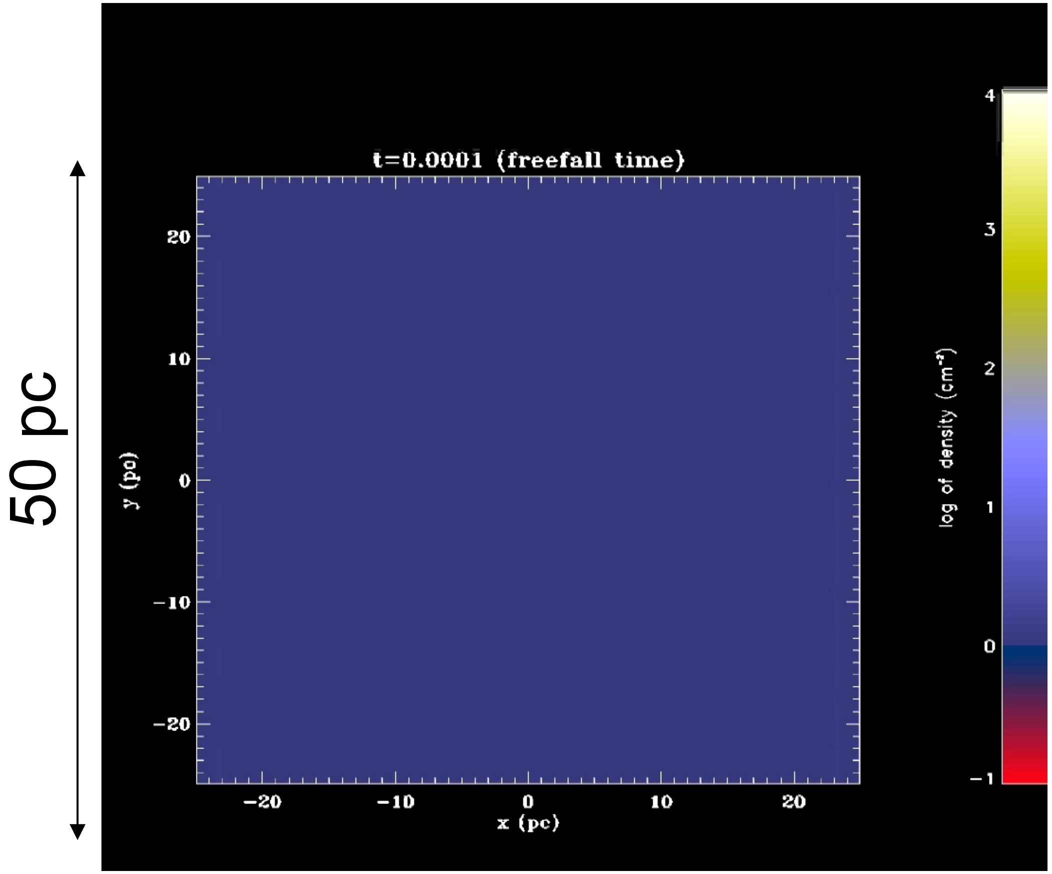
Formation of a molecular clouds from colliding flows of HI

Koyama & Inutsuka 02,04, Kritsuk & Norman 02, Gazol et al. 02, Audit & H 05, 07, 10, Heitsch et al. 05, 06, 08, Vazquez-Semadeni et al. 06, 07,11, H+08, Banerjee+09, Clark+12, Inoue & Inutsuka 12, Valdivia+16)

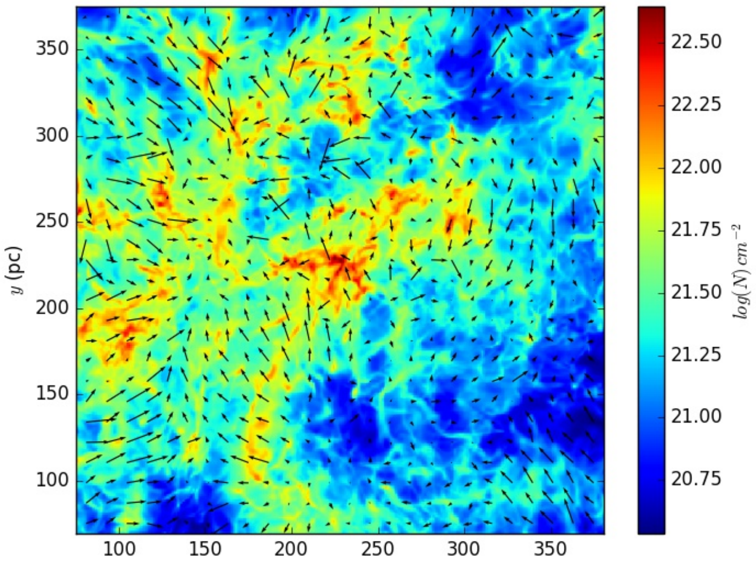
Flow of WNM (density 1cc), velocity 20km/s each side, initial magnetic field 5μG, resolution 2 10^{-2} pc

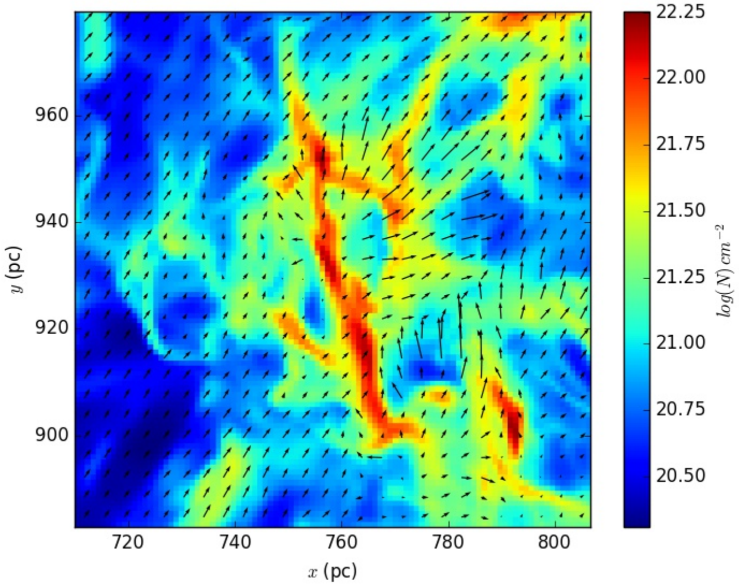
Colliding flows



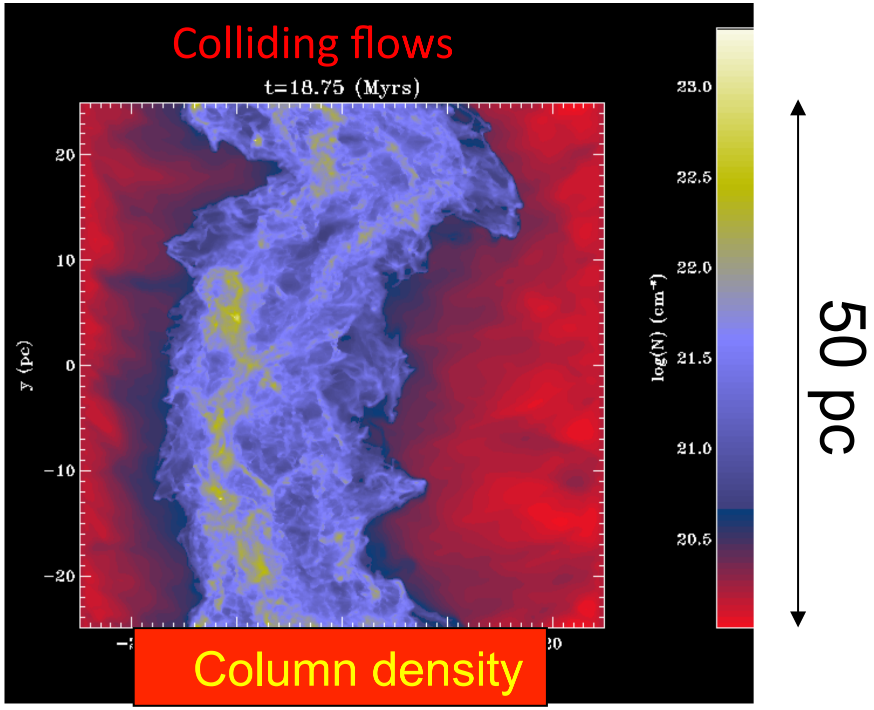


Clumps from galactic box simulations



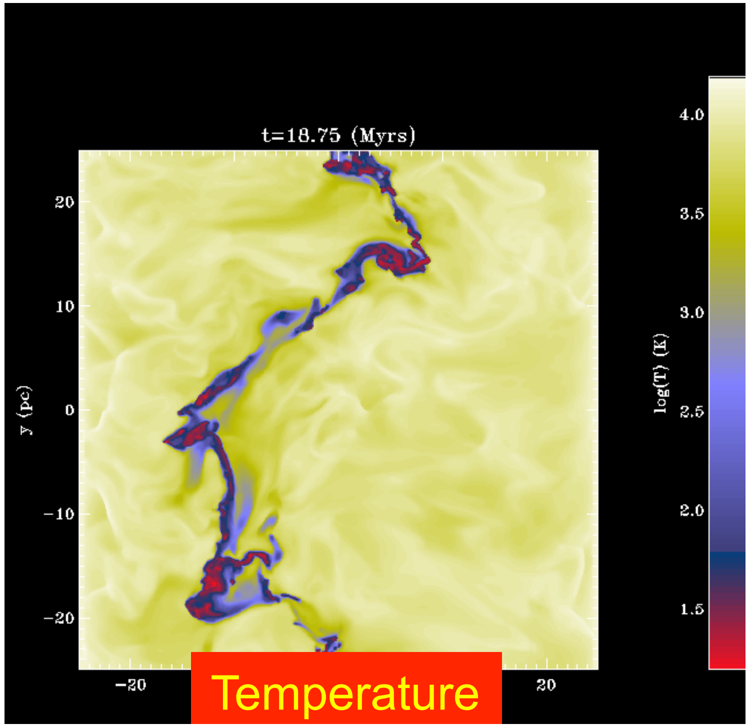


Colliding flows



Column density

50 pc



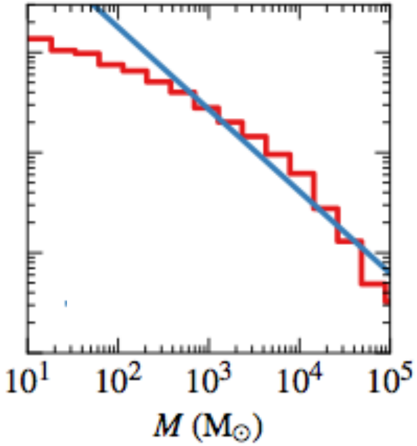
Temperature

Mass spectrum and mass size

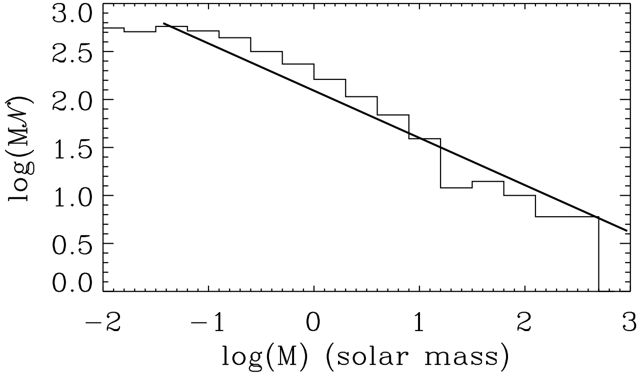
(H et al. 2008, Heitsch et al. 2009, Inoue & Inutsuka 2012, Iffrig&H2017)

Mass spectrum of clumps $dN/dM \alpha M^{-1.7}$

From galactic box

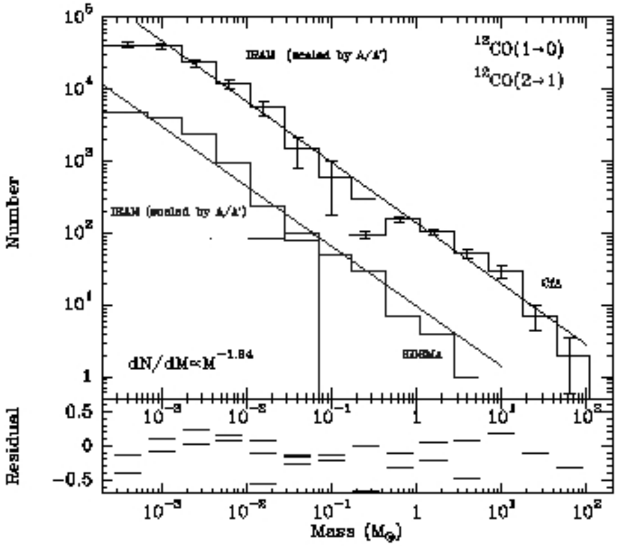


From colliding flows

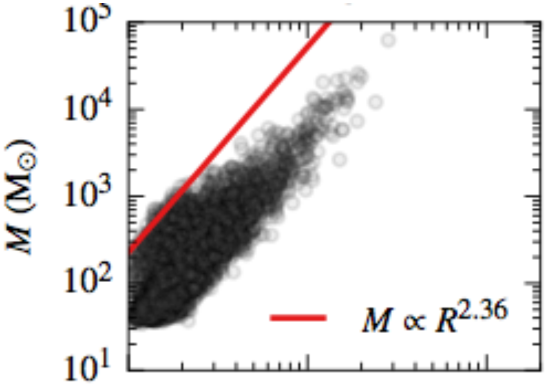


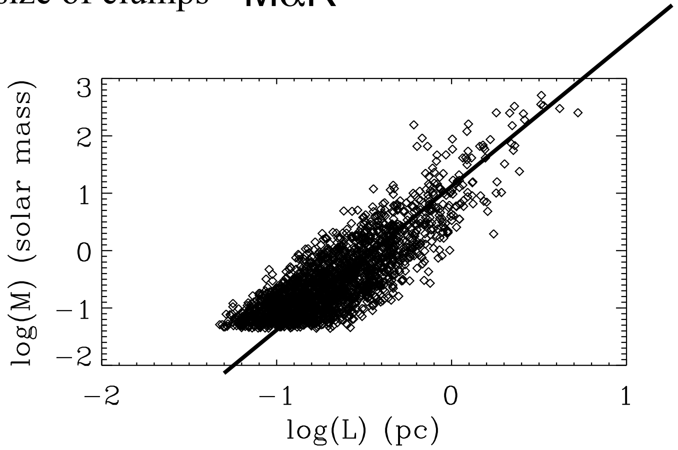
Universal Mass Spectrum

$dN/dM \ \alpha \ M^{-1.6-1.8}$ (Heithausen et al .98)



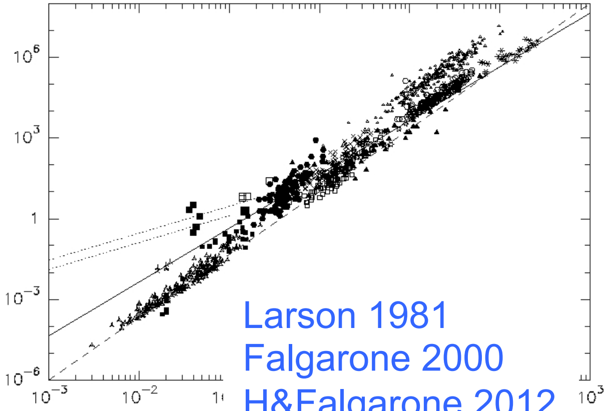
Mass versus size of clumps $M \alpha R^{2.3-2.5}$





Mass versus size of CO clumps

$M \ \alpha \ R^{2-2.3}$

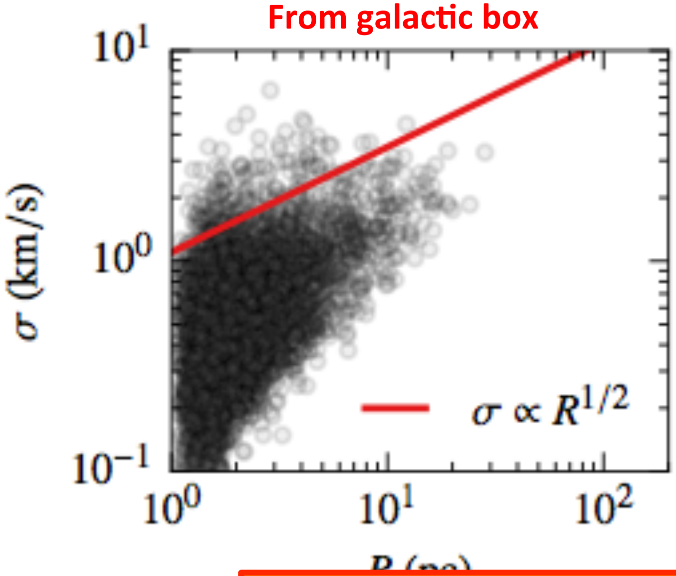


Larson 1981
Falgarone 2000
H&Falgarone 2012

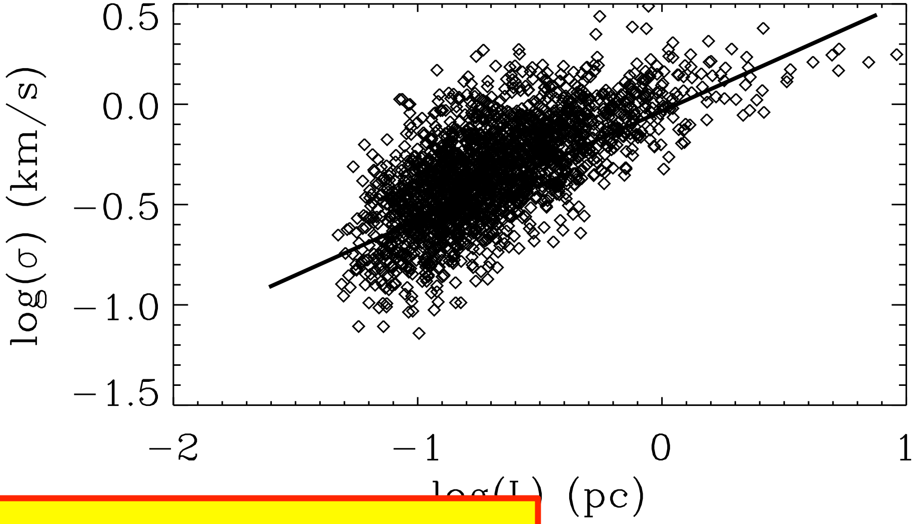
Internal clump velocity dispersion

$$\sigma(L) \approx 1\,\mathrm{kms}^{-1}\left(L/1pc\right)^{0.5}$$

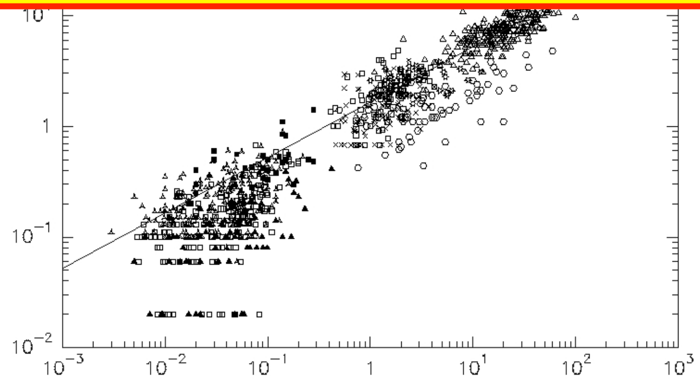
From galactic box



From colliding flows



Compatible with Larson law
=>is turbulence within GMC driven from outside ?
=>is it driven by continuous accretion of HI ?



Falgarone 2000

Velocity dispersion (Larson 1981, Kritsuk+2007, Klessen & H 2010)

$$P(v) \propto k^{-n};\ n = \frac{11}{3} \text{ or } 4 \Rightarrow \sigma(l) \propto l^{a}, a = (n-3)/2$$

$$\dot{E}_{decay} = \frac{E}{\tau_d} \quad \left(= \frac{1}{2}\frac{M\sigma^{3}}{L} \right) = \dot{E}_{inj} \quad => \quad \sigma = \left(\frac{2\dot{E}_{inj}L}{M} \right)^{1/3}$$

$$dM / dt => \dot{E}_{inj} = \frac{1}{2}\dot{M}_{in}V_{in}^{2}$$

Mass size relation (Fleck 1981, Kritsuk+2007)

$$M(l) \propto l^{2.3} \Rightarrow \rho \propto l^{-0.7} \qquad \rho v^{2} = cst \Rightarrow \rho \propto l^{-\approx 0.8-1} \text{ or } \rho v^{3} / l = cst \Rightarrow \rho \propto l^{-\approx 0.2-0.5}$$

Mass spectrum as turbulent fluctuations (H & Chabrier 2008, Hopkins 2015)

Use the statistics of supersonic turbulence (lognormal distribution, powerspectrum of logρ)

count the fluctuations above some density threshold => CO clumps

$$P(\log\rho) \propto k^{-n}, \frac{dN}{dM} = M^{-\gamma} \Rightarrow \gamma = 2 - \frac{n-3}{3}$$

$$n = \frac{11}{3} \Rightarrow \gamma \approx 1.7 - 1.8$$

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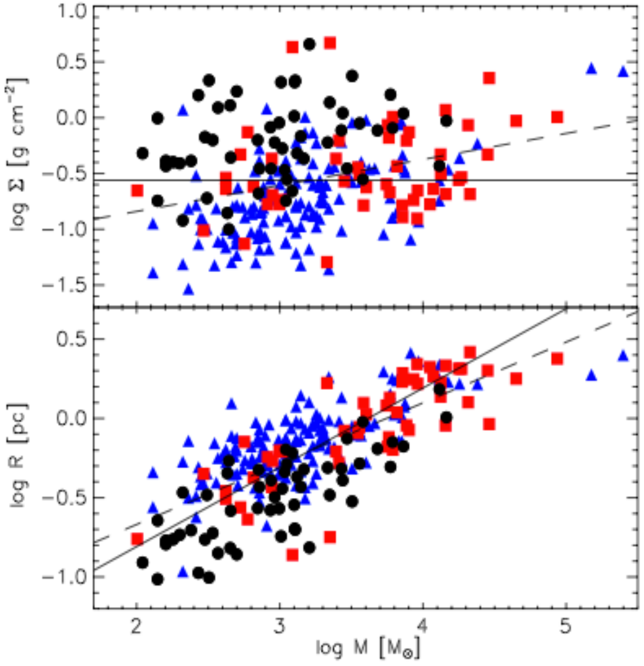
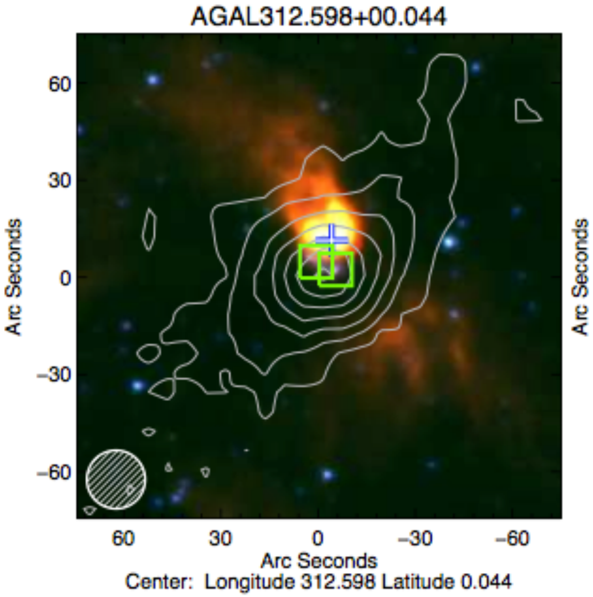
Cores from zooming-in simulations

~0.1-1 pc

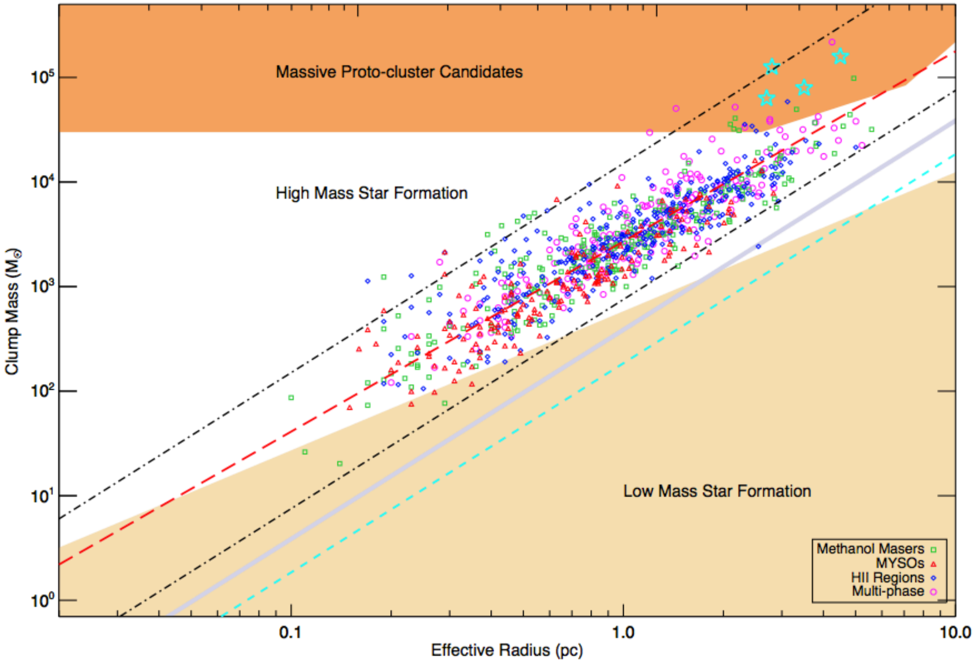
Motivations: Massive star forming clumps and clusters



Fall+2010



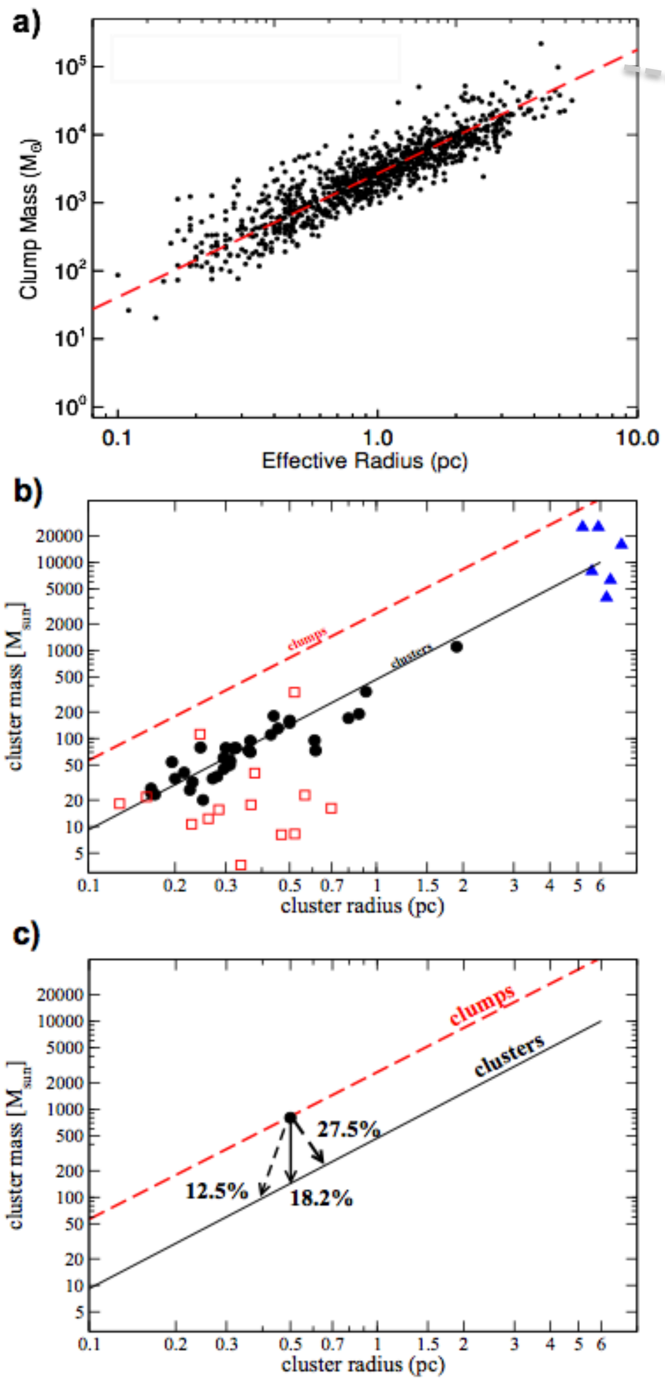
from ATLASGAL and RMS



Urquhart +2015

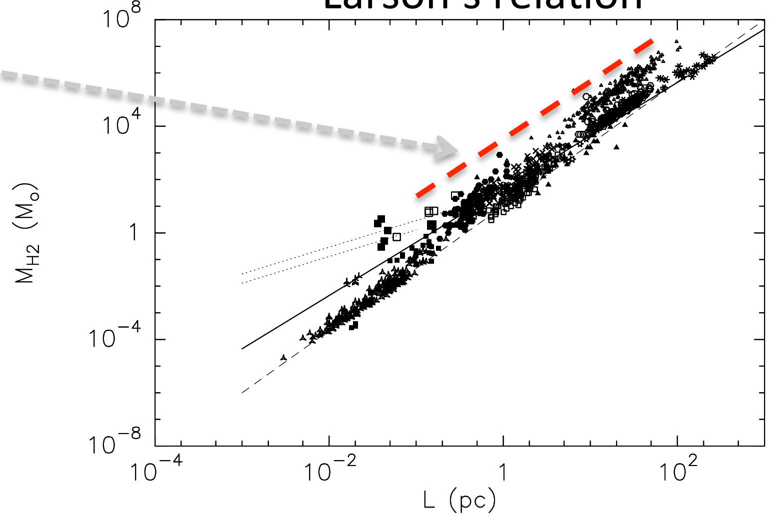
Massive star forming clump

Clusters



Pfazlner +2015

Larson's relation



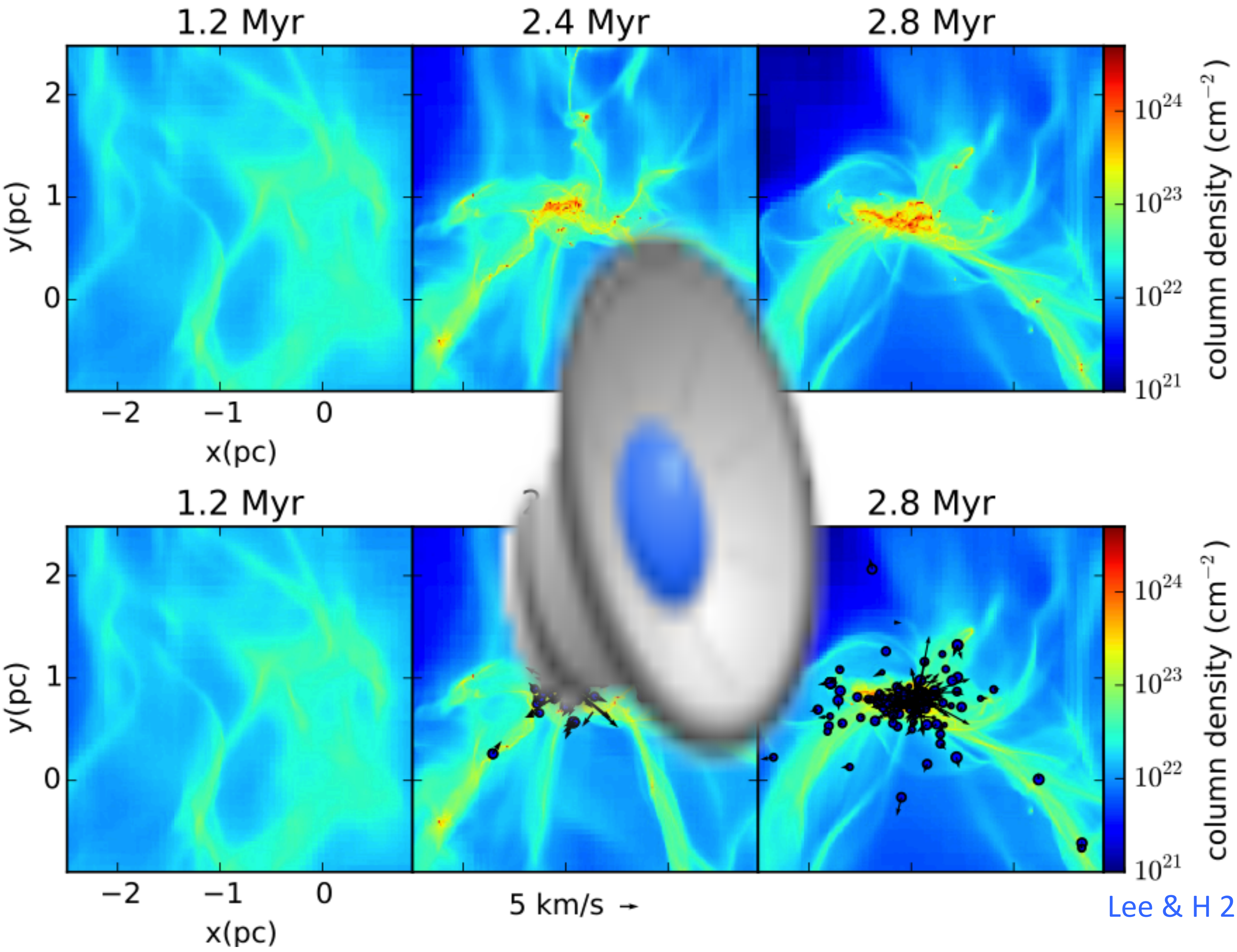
Falgarone+2009

=>Massive star forming clump are very different from typical ISM clouds
=>They are likely progenitor of clusters

How do they form ?

Forming one single cluster from gravitational collapse of a turbulent cloud

(Bate+2003,2009,2012,2015 , Bonnell+2008, Girichidis+2011,Krumholz+2012, Ballesteros-Paredes +2015,Padoan+2014,Bleuler&Teyssier2015, Lee&H2016,Vazquez-Semadeni+2016)



Lee & H 2016a

From infall to virial ? A model for protocluster

(H2012, Lee&H2016b and see Li G-X 2017 for a related model)

Mechanical equilibrium

$$\sigma \propto \sqrt{\frac{M}{R}}$$

Energy balance : dissipation=injection

$$\frac{M\sigma^3}{R} \propto \sigma^2 \dot{M} \propto \sigma^2 M^{0.75}$$

$$=> \frac{M}{R}\sqrt{\frac{M}{R}} \propto M^{0.75}$$

$$=> M \propto R^2$$

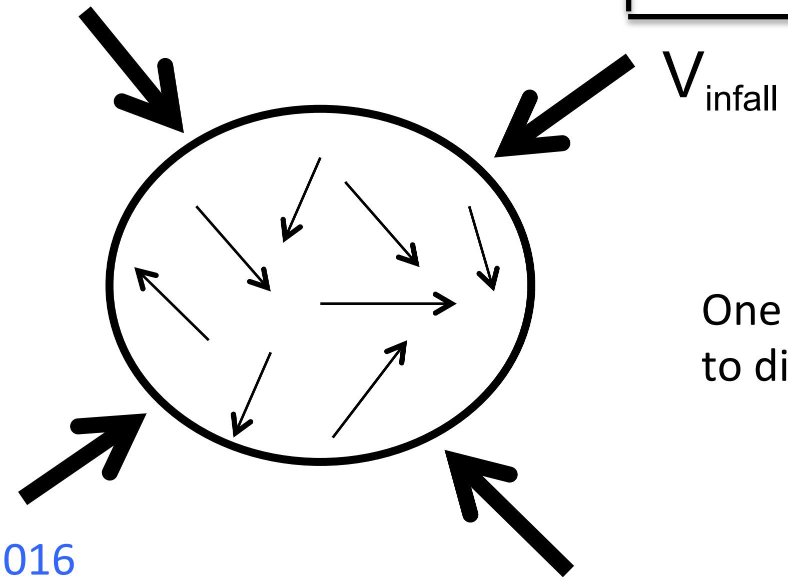
H2012, Lee&H2016

Turbulent dissipation and gravity:

$$\epsilon_{\rm vir} \approx \eta \times \frac{U^3_{{\rm vir},l}}{l} = G^{3/2}\, m^{3/2}\, l^{-5/2} \times \eta$$

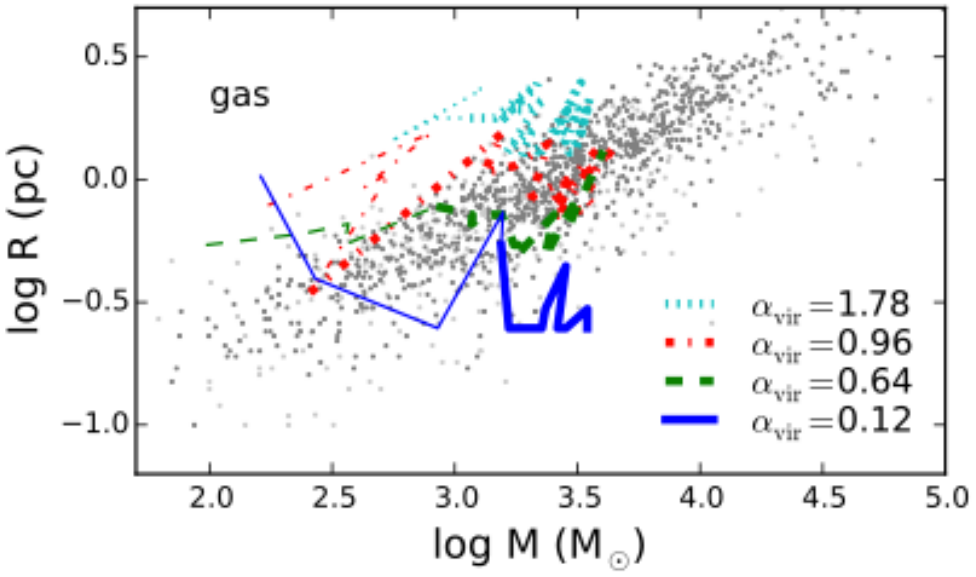
$$m_{\rm crit} \approx G^{-1} \epsilon^{2/3}_{\rm cascade} \eta^{-2/3} l^{5/3}$$

Li 2017

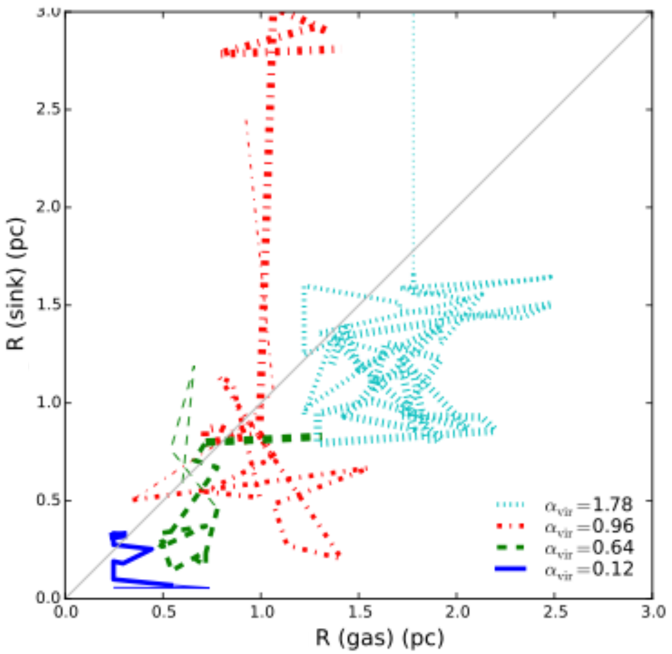


One crossing time is needed
to dissipate incoming energy

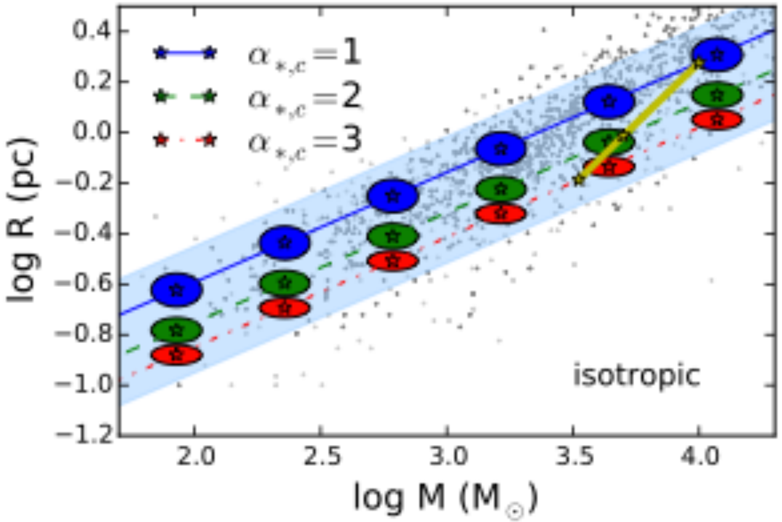
Gas distribution radius vs mass



Sink distribution radius vs gas distribution radius



Comparison between model and observations

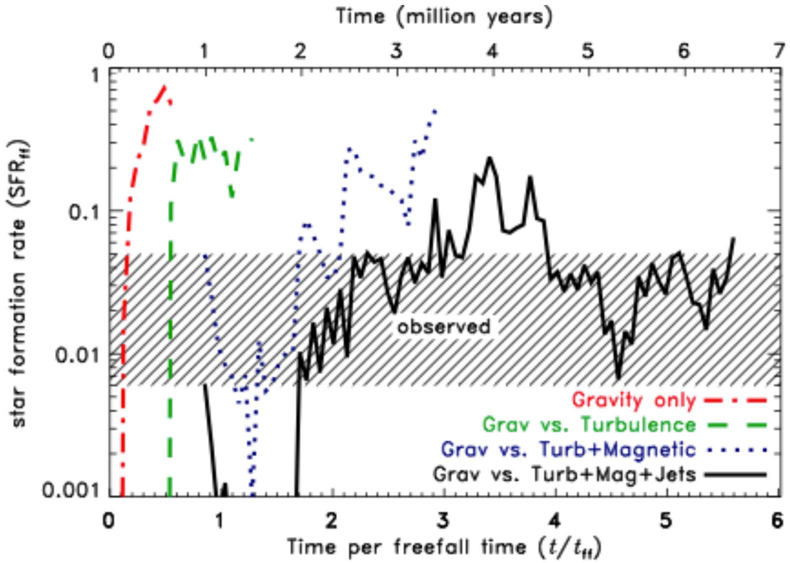


=> virial equilibrium, radius and rotation of the gas are passed to the stars

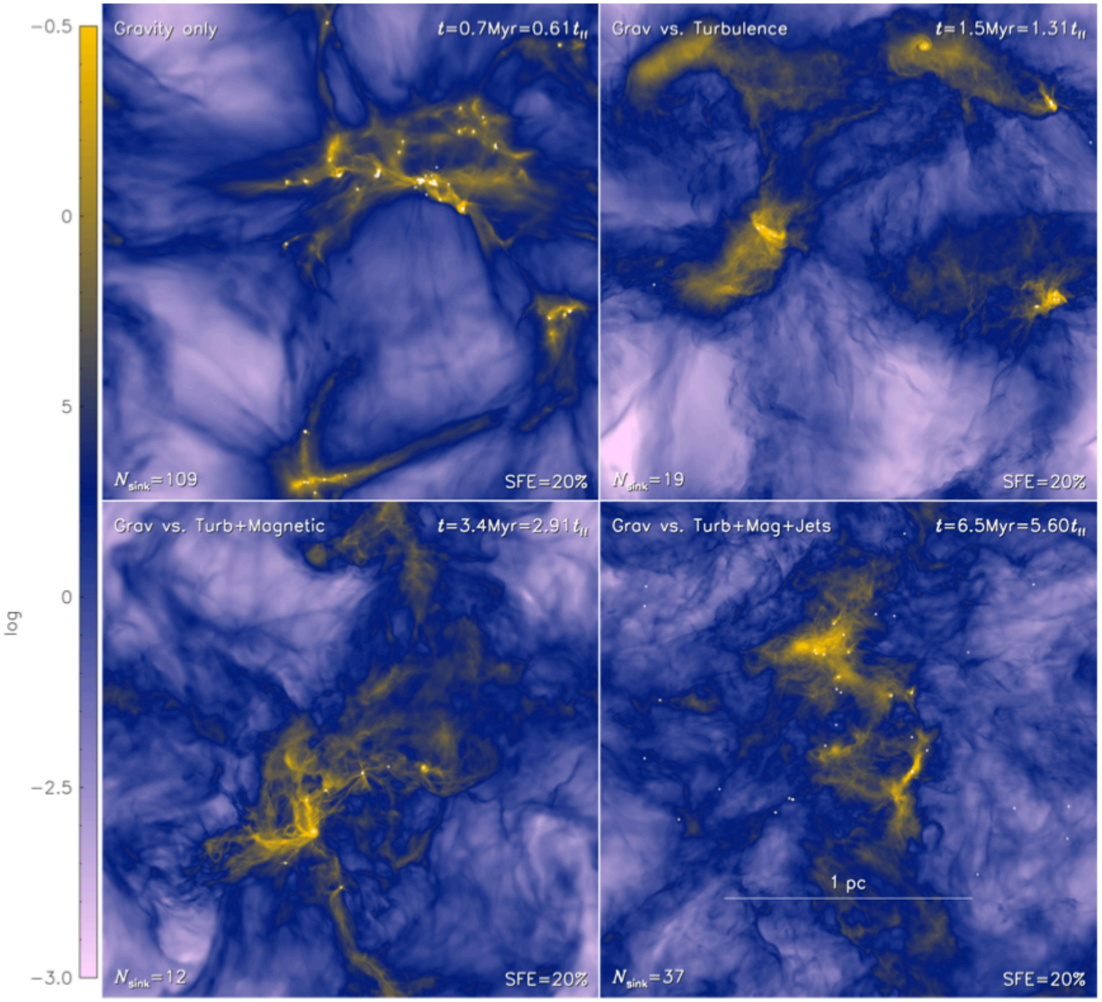
Lee & H 2016ab

Reproducing the SFR in cluster type simulations: role of jets

(Li & Nakamura 2007, Wang+2011, Federrath&Klessen 2012, Federrath 2014)



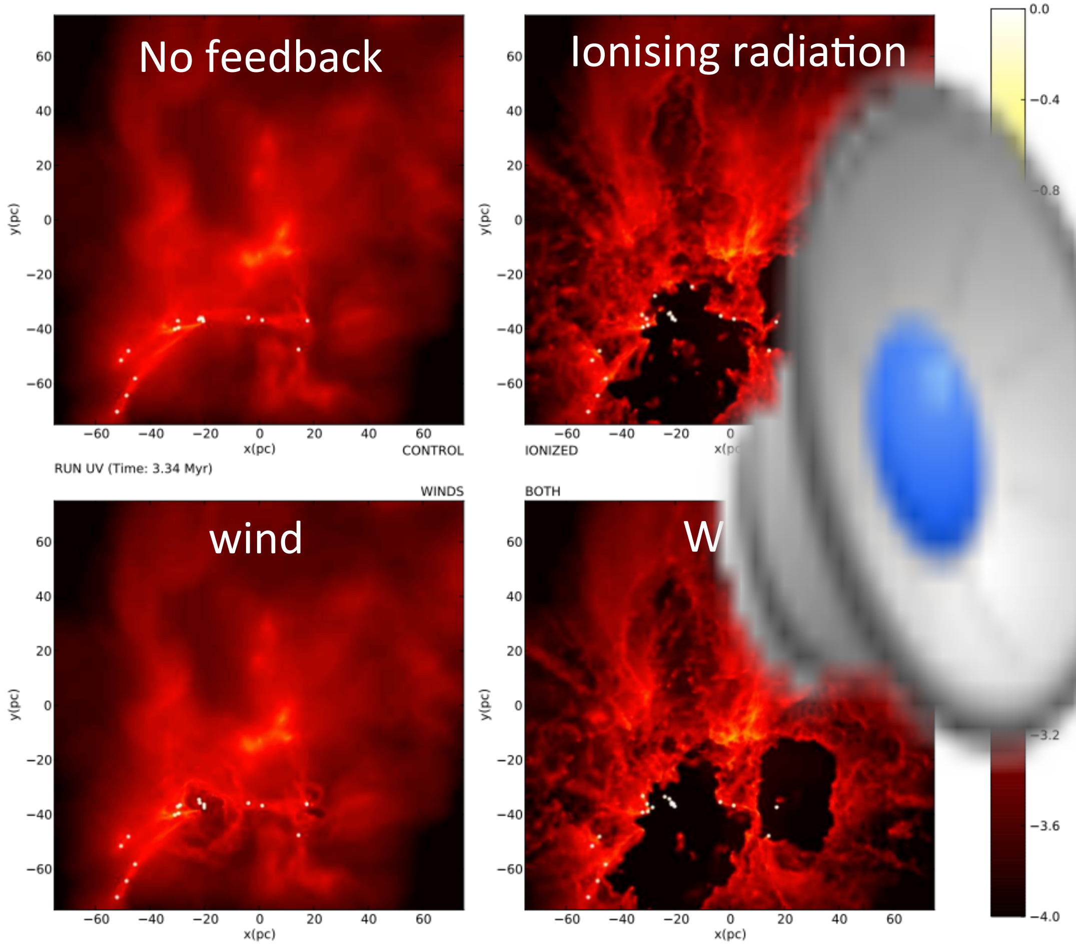
Federrath 2014



Seems that the combination of
MHD+turbulence+jet may lead to
reasonable SFR
(keeping in mind large uncertainties with outflow/jets energy injection).

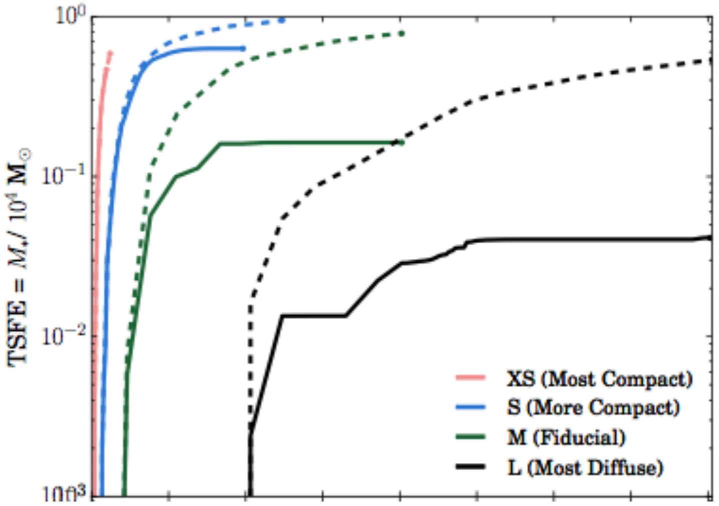
Reproducing the SFE in molecular clouds/cluster type simulations: the role of ionising radiation

(Fall+2010,Matzner2007,Dale+2011,2015, Gavagnin+2017, Geen+2017)



Dale et al. 2013

SFE for various clouds
with and without HII feedback



Geen+2017

Neighbourhood type clouds are predicted to have SFE~0.1-0.2
Too compact clouds have very high SFE.
Complete census of the feedback processes must be performed

Molecular clouds:
Galactic box and colliding flows
Turbulence and clumps

~10-100 pc

Proto-clusters:
Formation and size
Feedback and SFR

~1-10 pc

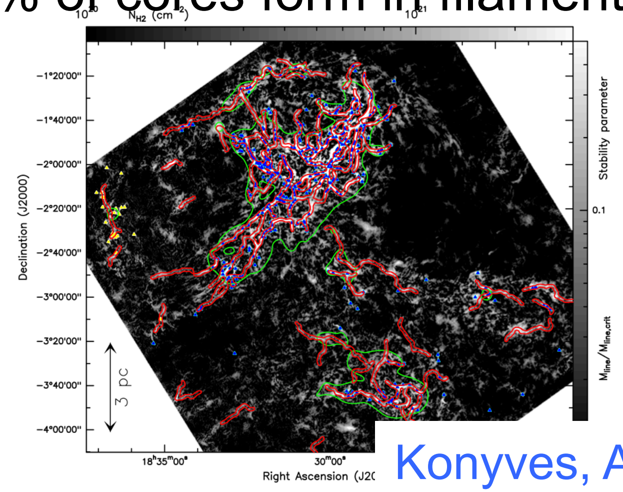
Filaments and Cores:
Formation of filaments
Fragmentation of filaments into cores
Cores from zooming-in simulations

~0.1-1 pc

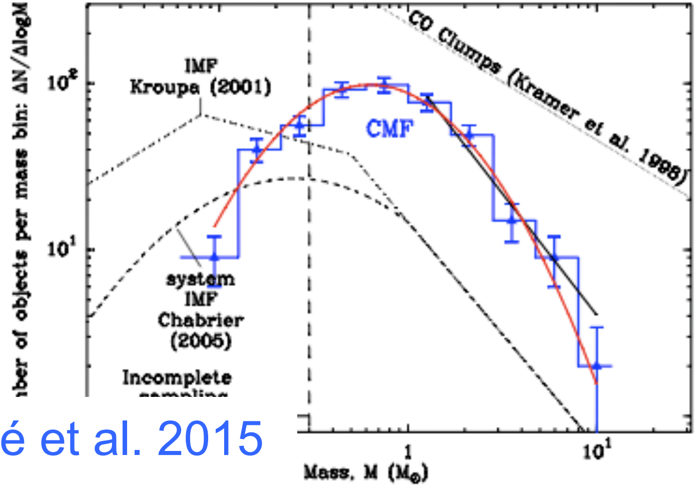
Filaments and Core Mass Function

(Motte et al. 1998, Testi & Sargent 1998, Alves et al. 2007, Johnstone et al. 2002, Enoch et al. 2008, Simpson et al. 2008, André et al. 2010, Konyves et al. 2010, 2015)

75% of cores form in filaments

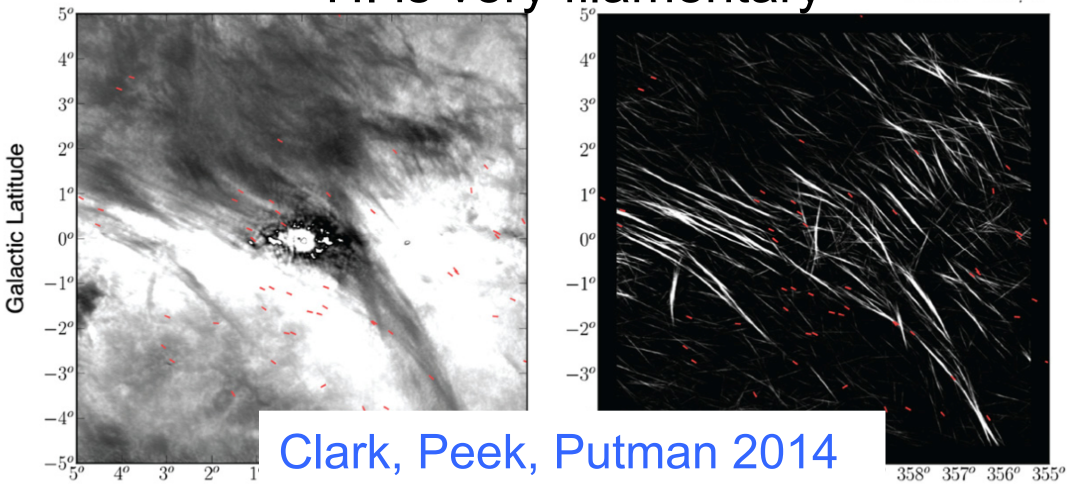


CMF in Aquila molecular cloud



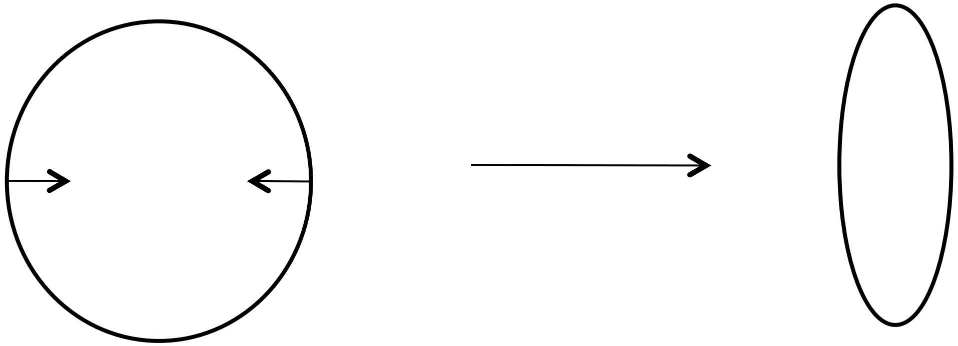
Konyves, André et al. 2015

HI is very filamentary

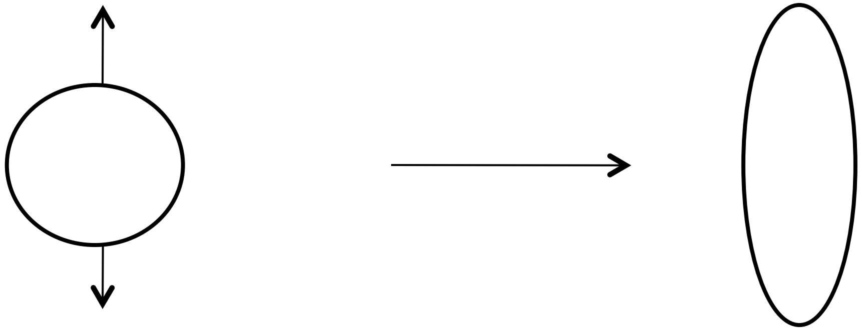


Clark, Peek, Putman 2014

How to form a filament ?



Compression of
two of the axis:
shock or gravity



Extension of
one of the axis:
Shear
(the very heart of turbulence)

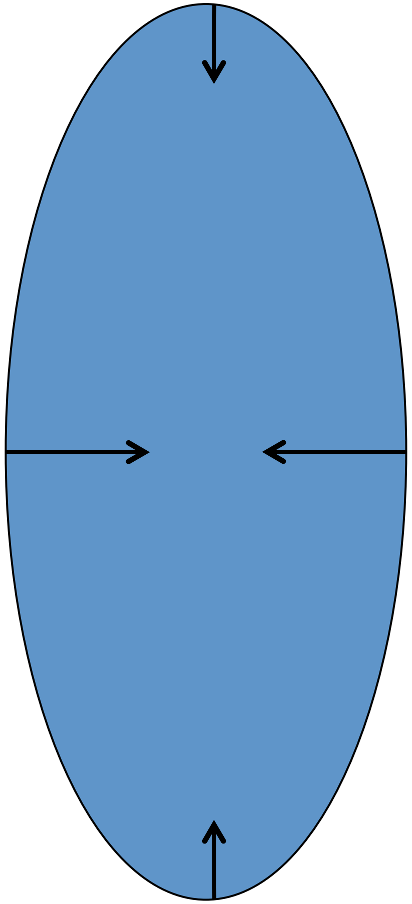
Gravitational amplification of anisotropies (seeded by turbulence ?)

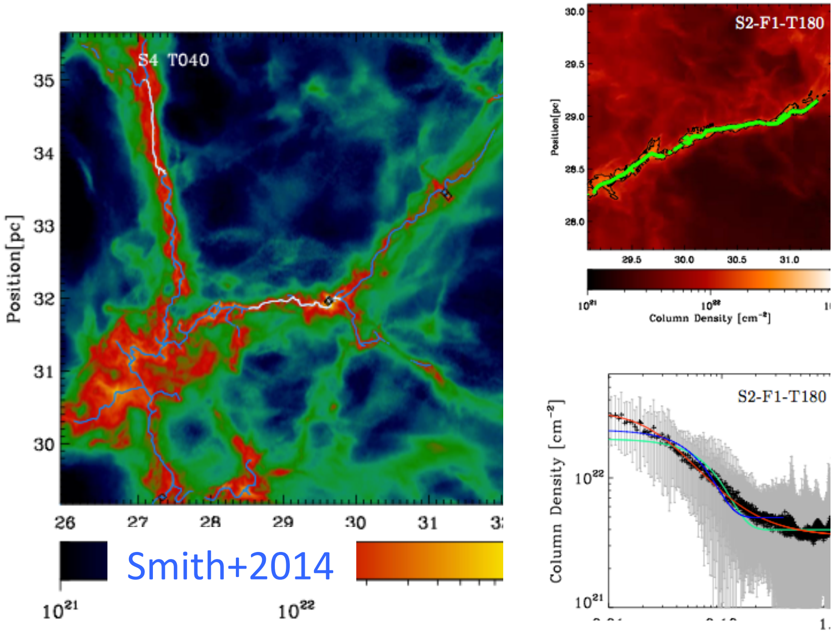
(Mestel+71)

$$F_z \propto \frac{\phi}{l}$$

$$F_r \propto \frac{\phi}{r}$$

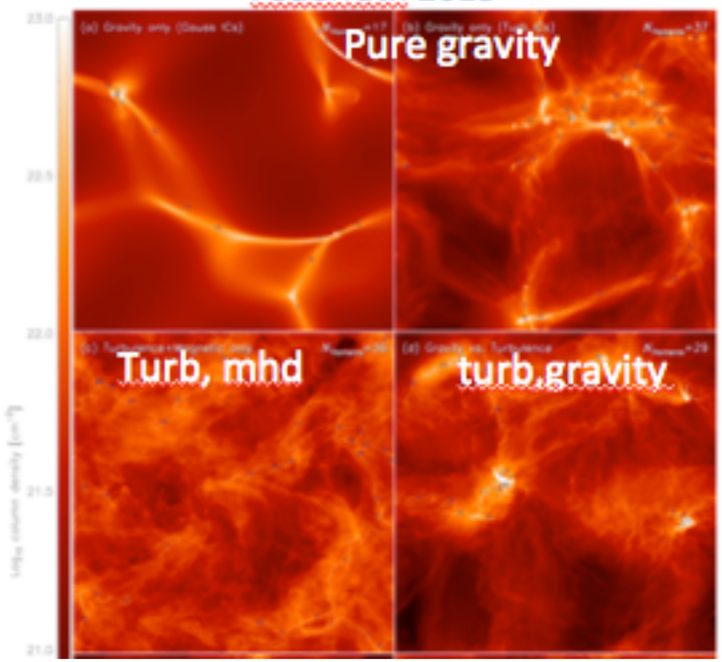
$$\Rightarrow F_z \le F_r$$





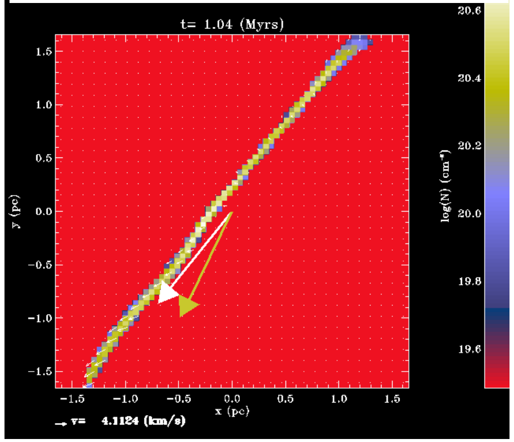
Smith+2014

Federrath 2015

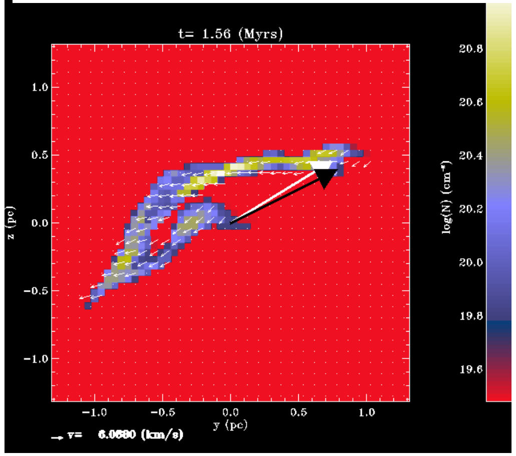


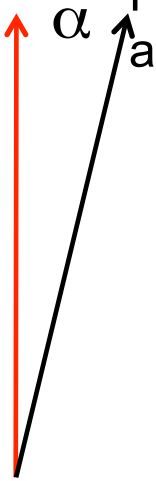
Non-self-gravitating filament:
Importance of turbulence and magnetic field

An extreme filament in MHD simulations



An extreme filament in hydro simulations



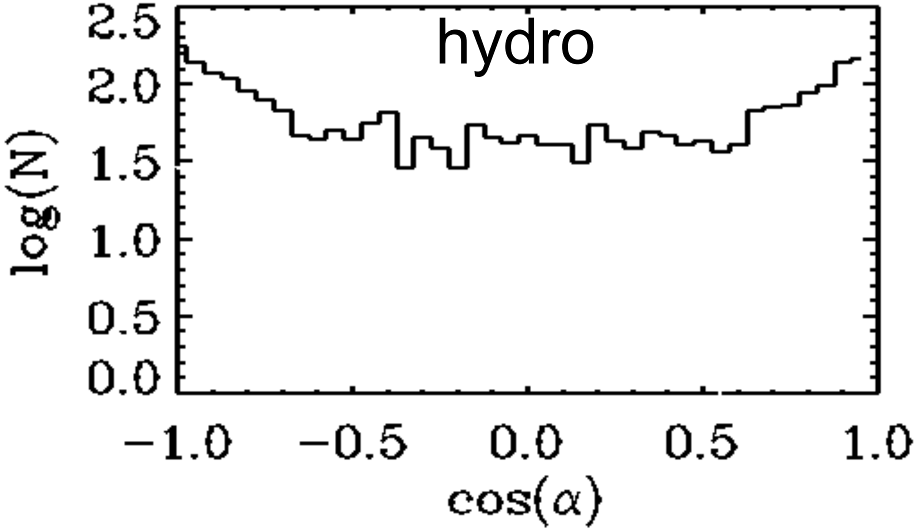


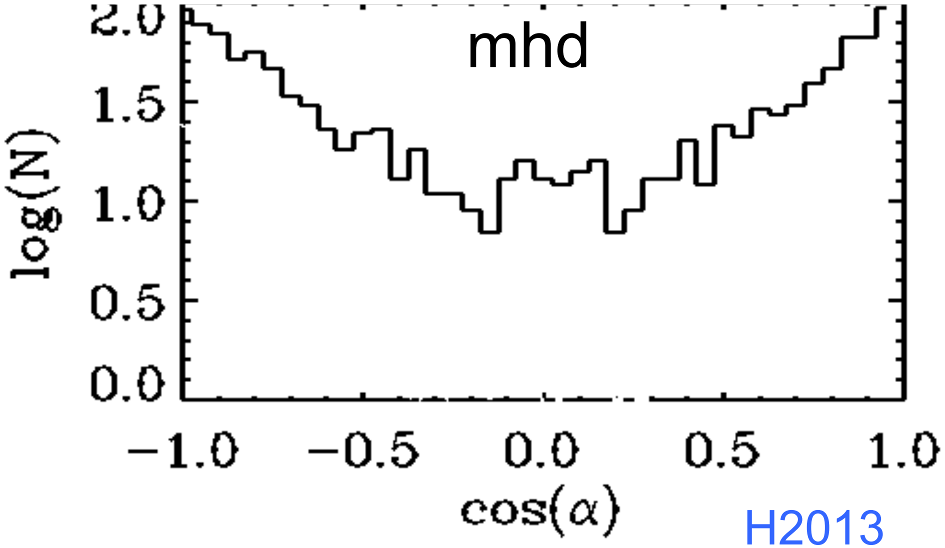
Turbulent strain axis

α

Filament axis

Correlation between strain and Filament axis

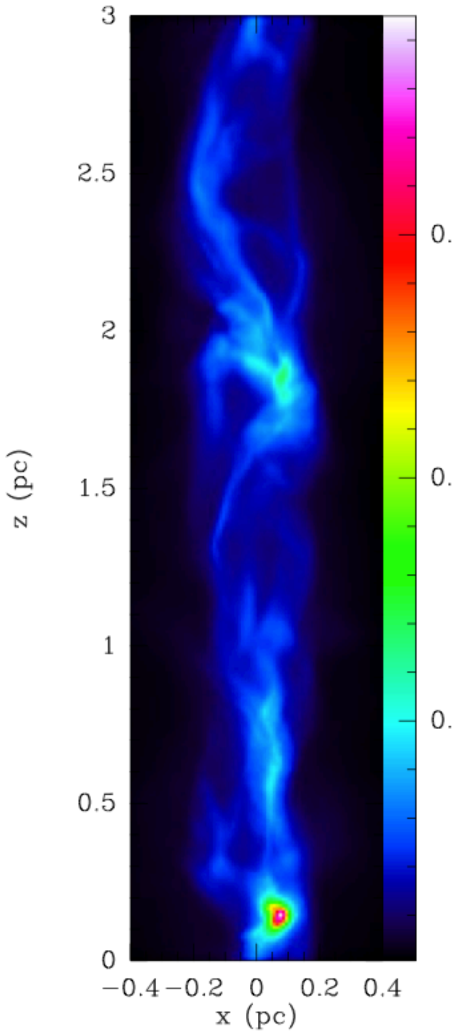




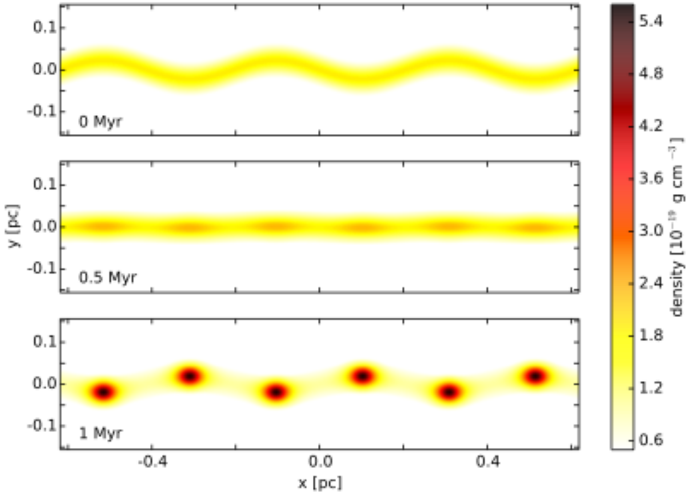
H2013

Fragmentation of filaments into cores

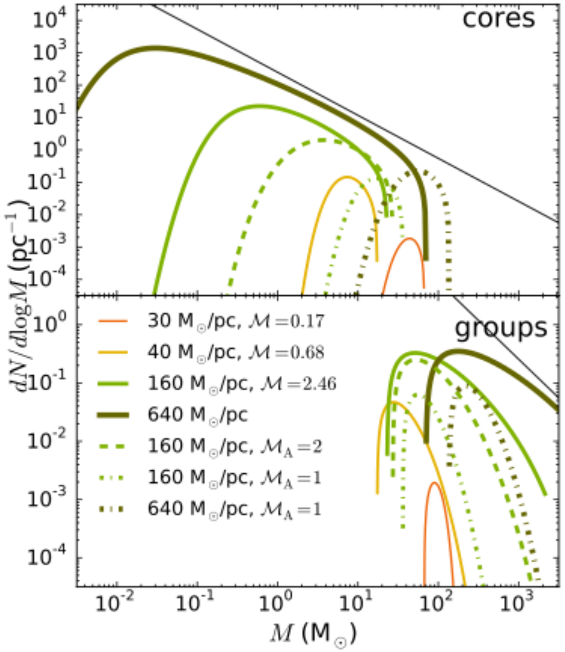
(Inutsuka+1992,1997,Inutsuka 2001,Clarke+2016,Gritschneder+2017,Lee+2017)



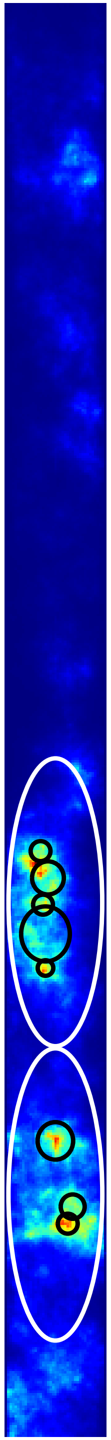
Fragmentation by turbulence
Inside filament (Clarke+2016)



Fragmentation influenced by bending modes
(Gritschneder+2017)

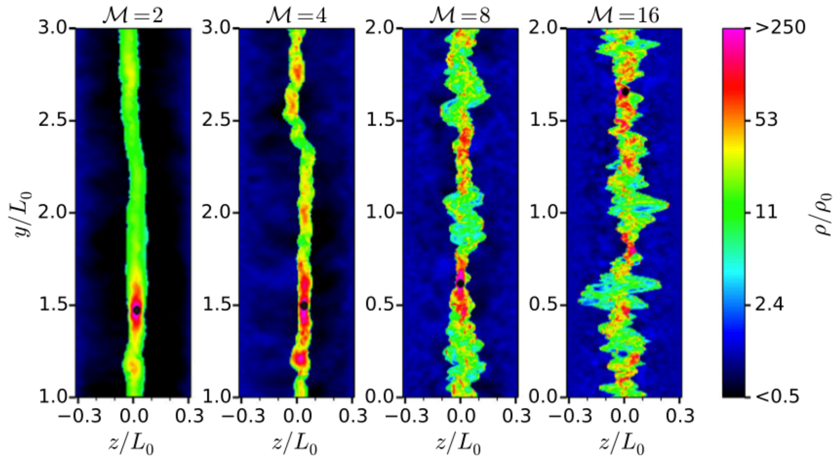


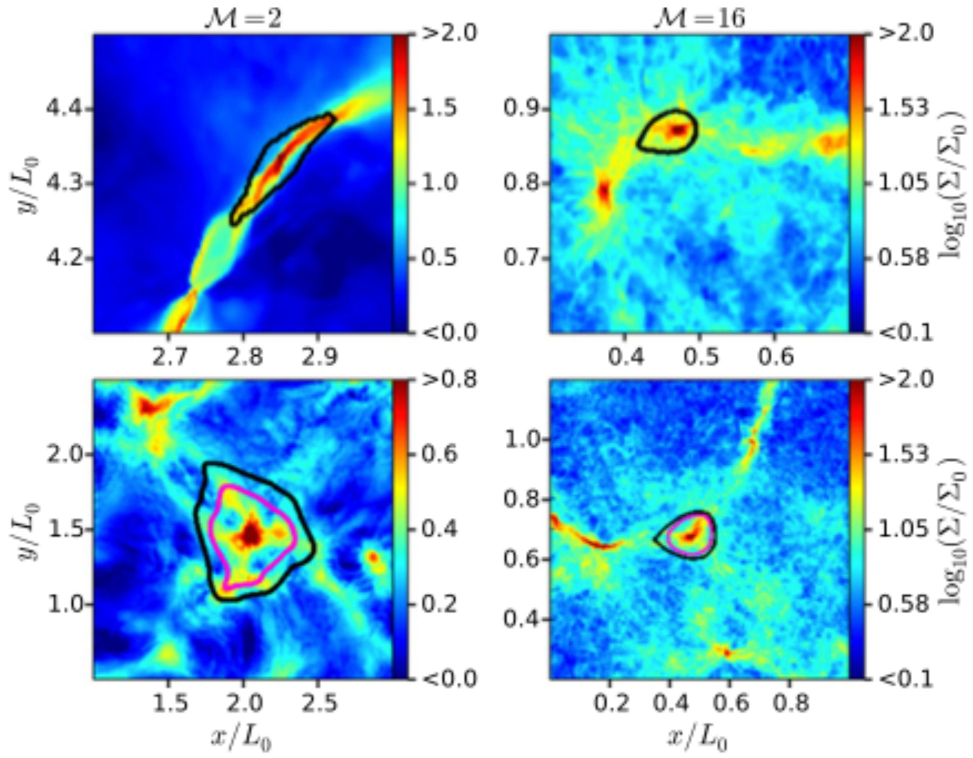
Analytical mass function for “cores” and groups of cores in filaments
(Lee+2017)

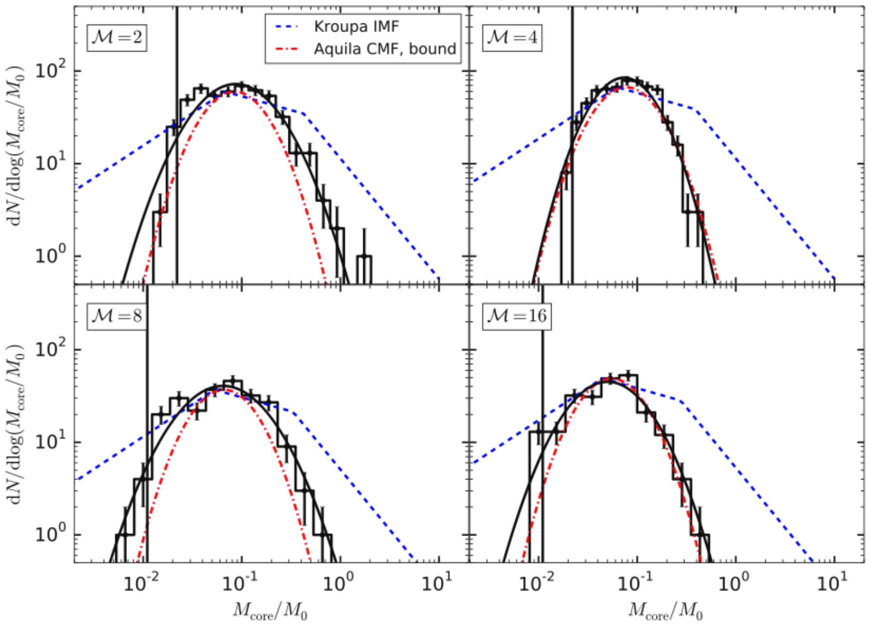


Filaments and cores from colliding flow calculations

(Gong & Ostriker 2011, 2013, 2015)



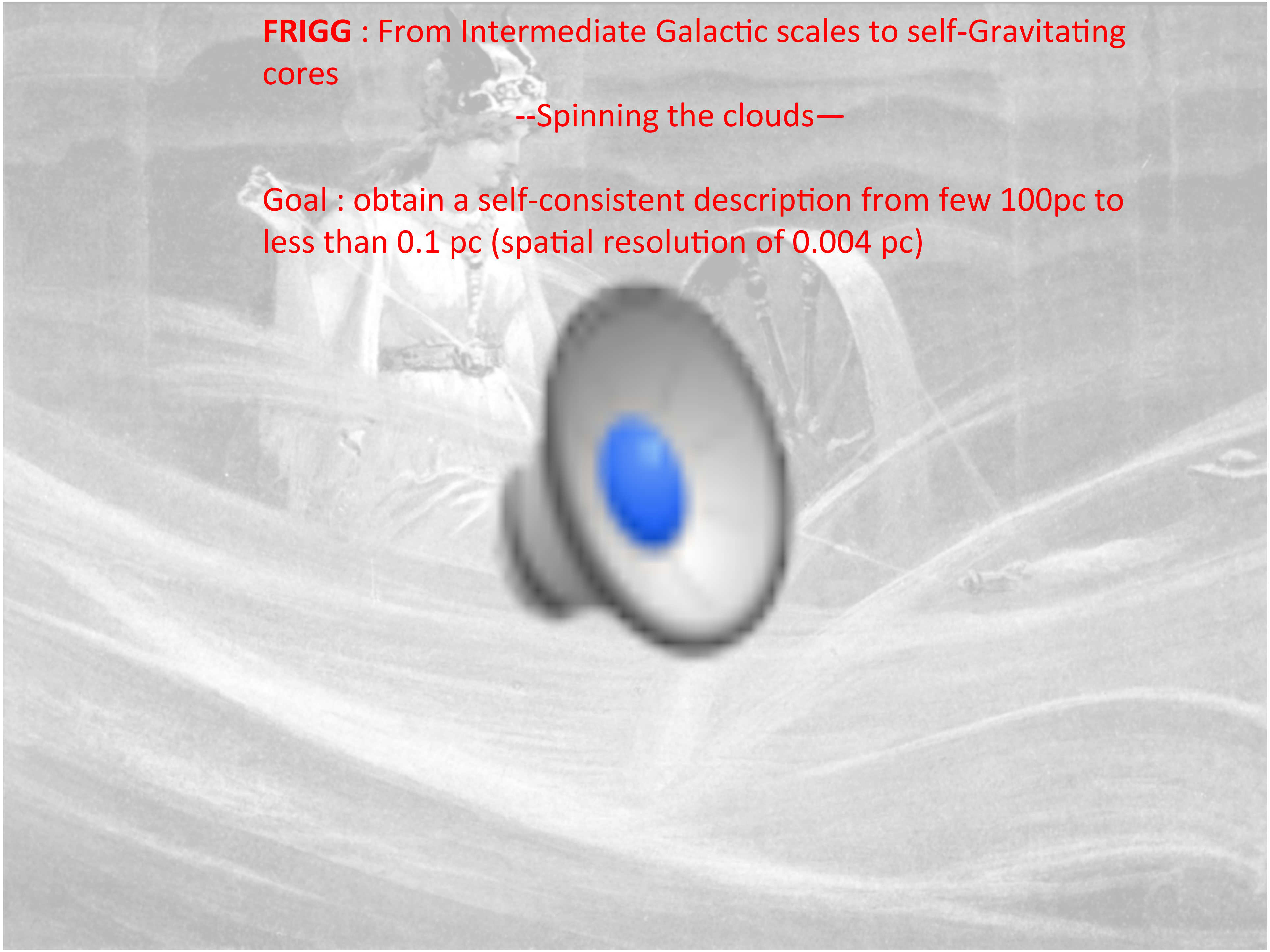




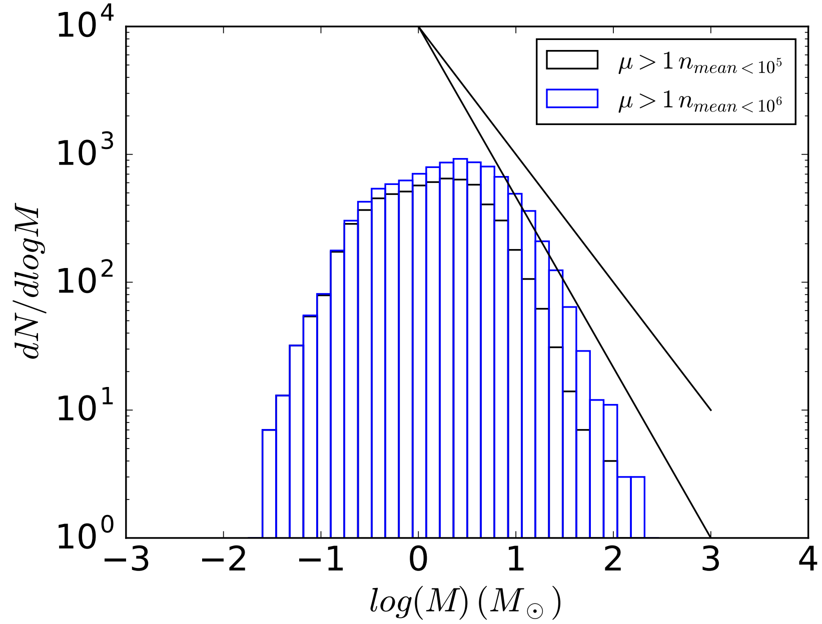
FRIGG : From Intermediate Galactic scales to self-Gravitating cores

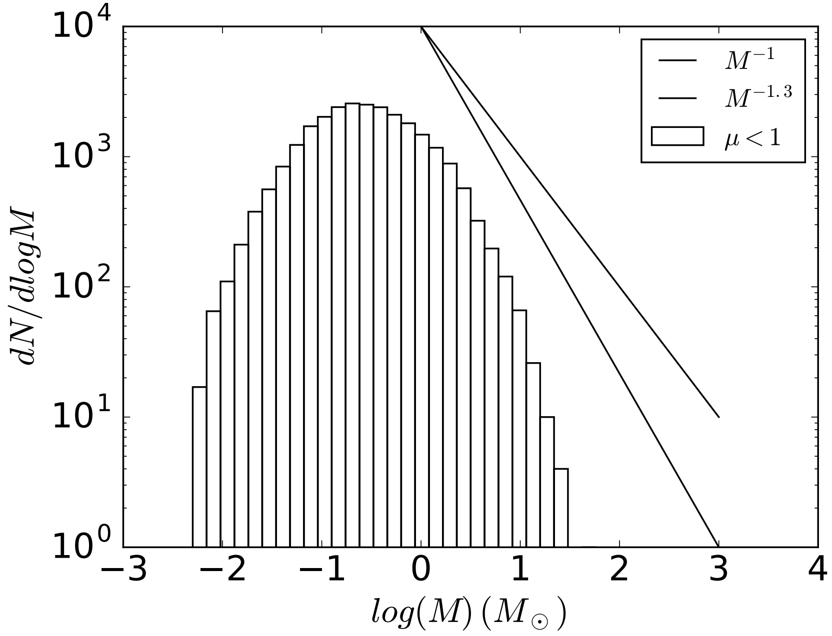
--Spinning the clouds—

Goal : obtain a self-consistent description from few 100pc to less than 0.1 pc (spatial resolution of 0.004 pc)



Getting the “core” mass function from zooming-in simulations





Encouraging results :
-CMF depends on the exact definition adopted for cores
-resolution issue with the peak

H2017

Conclusions

Accretion seems to be always playing a role
(galaxies ?, molecular clouds, clusters, discs, stars ?)

Molecular clouds: 2-phase, accreting paradigm ?
Seems to reproduce many observations in particular the velocity dispersion

Are clusters inheriting their properties from a virialised state induced by accretion driven turbulence ?

Is ionising radiation setting the SFE of the MC ?

Is the core mass function strongly influenced by the filamentary geometry ?