SIMBA in far-infrared emission with SIGAME v3

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Thomas Greve, UCL
Josh Borrow, DUR
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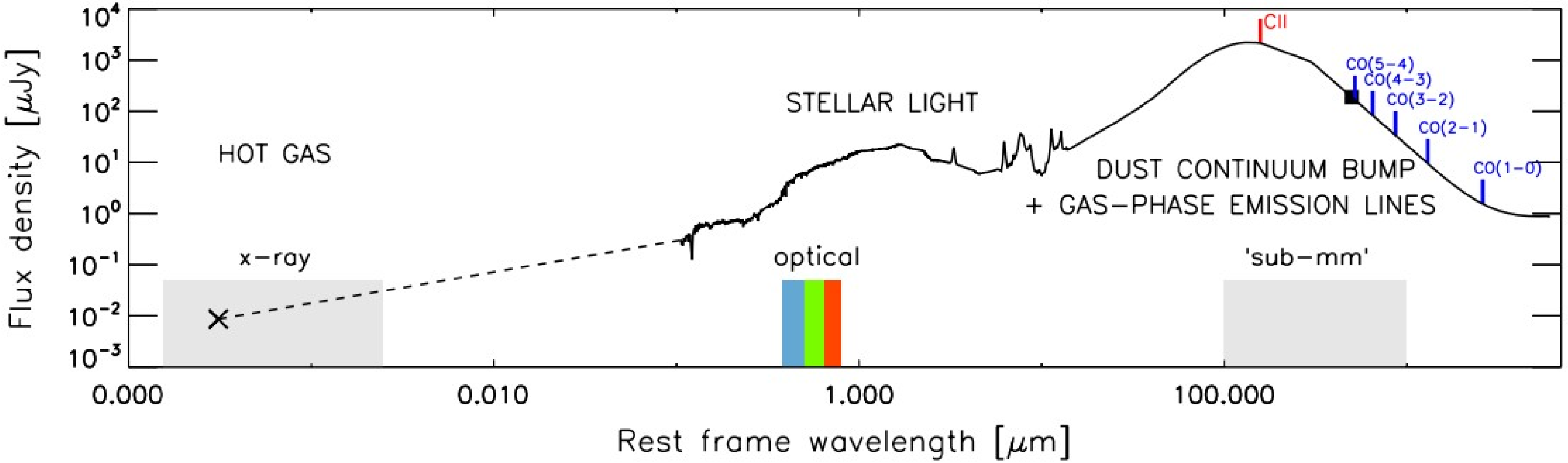
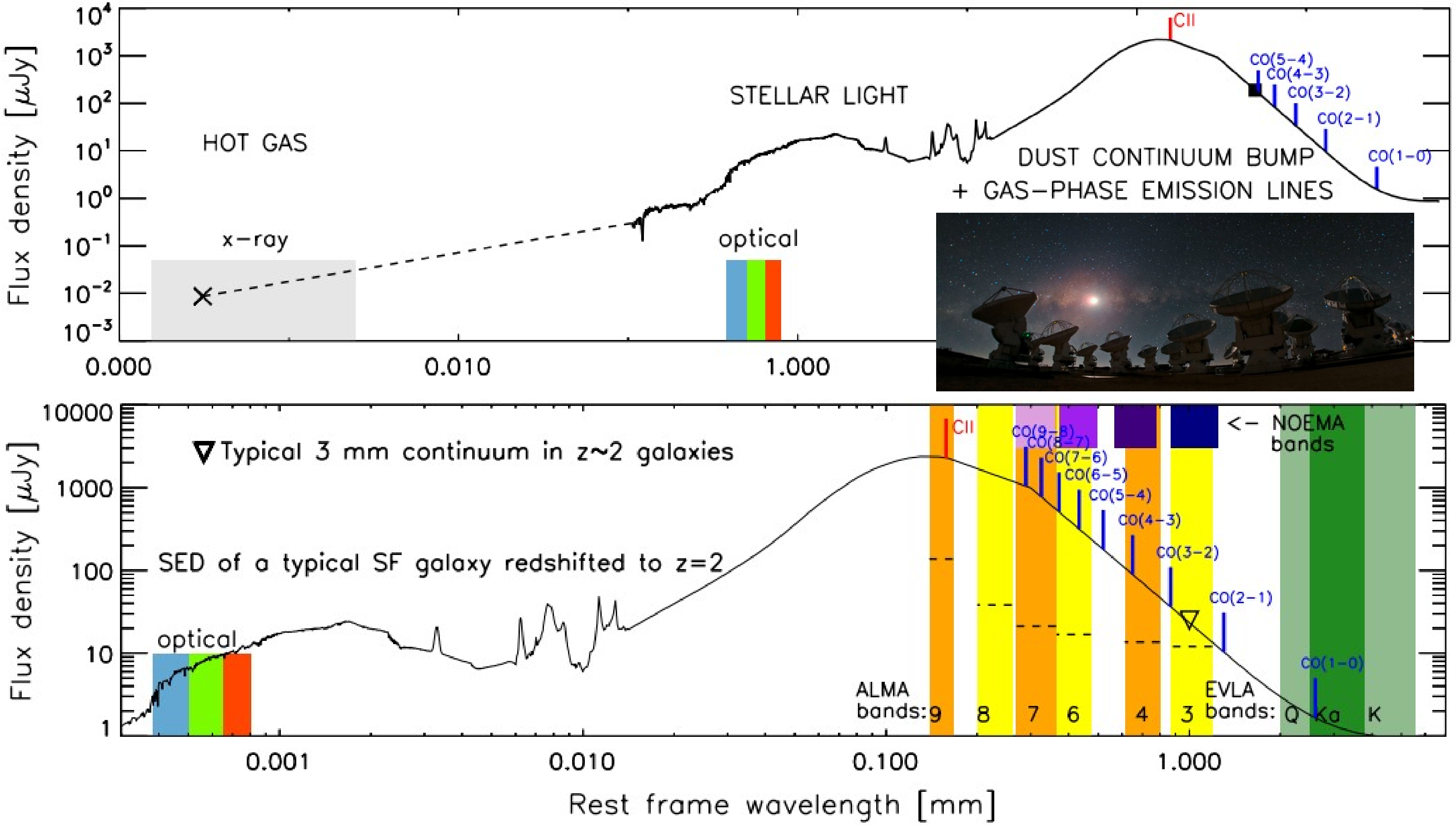
University of Arizona

Why far-infrared ?



[thesis arXiv:1509.02991]

Why far-infrared ?



[thesis arXiv:1509.02991]

Why far-infrared ?

Physical property	Lines	Ref
SFR	[CII], [OIII], [OI]	DeLooze+14_A&A568, Capak+15_Nat522, Schaerer+20_ arXiv:2002.00979, ...
Ionized to neutral gas mass ratio	[CII]/[NII]205, [OIII]88/[CII], [OIII]88/[NII]122	Croxall+17ApJ845, Arata+20_arXiv:2001.01853, ...
Molecular gas mass	CO(1-0), [CI]	Heintz+20_arXiv:2001.05770, ...
ISM pressure	[NII]122/[NII]205 (in HII regions)	Herrera-Camus+16_ApJ835

The list of ingredients to simulate line emission

Density, n_H

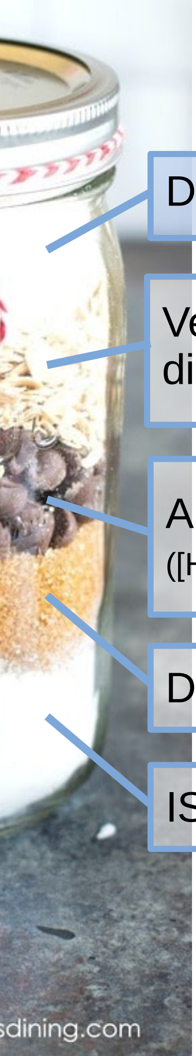
Velocity dispersion, σ_v

Abundances
([He/H], [C/H], [N/H]...)

Dust

ISRF (FUV)

Splitting H2 gas into GMCs



- Density, n_H
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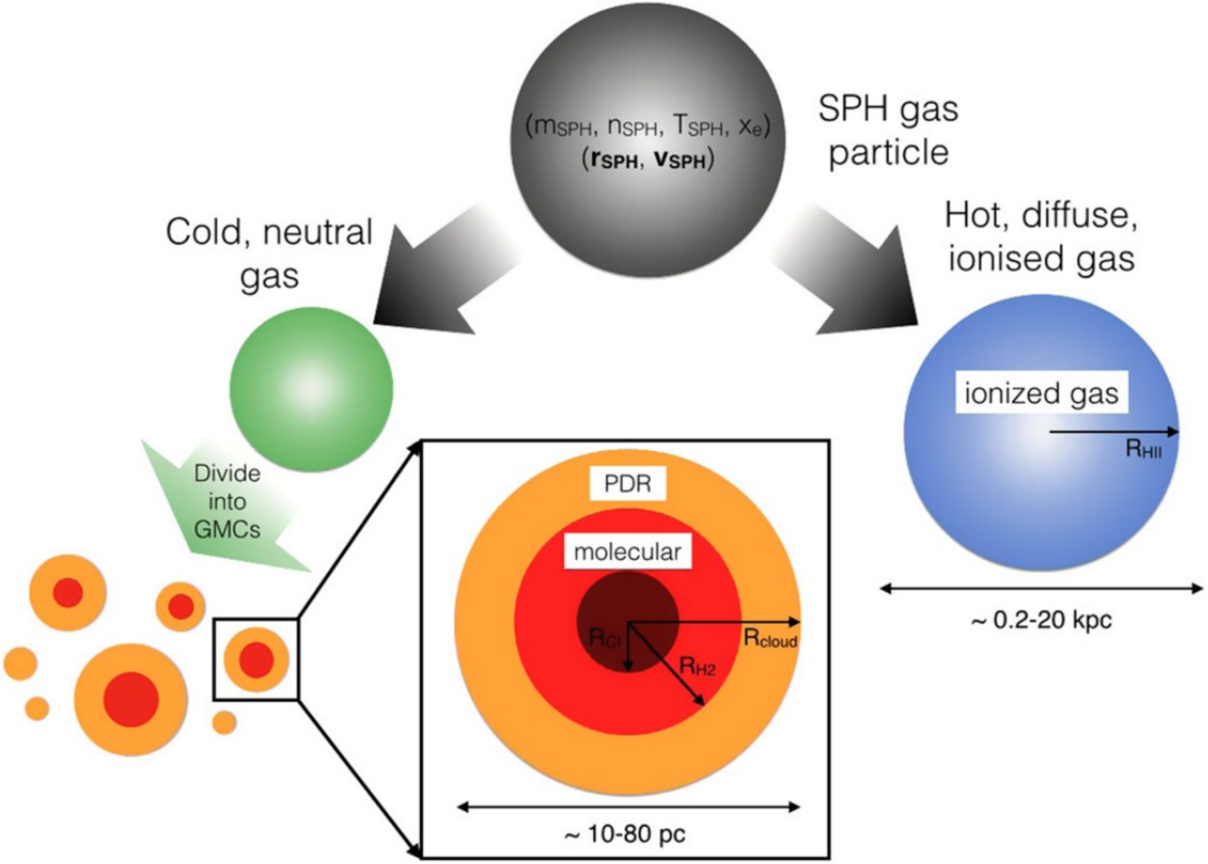
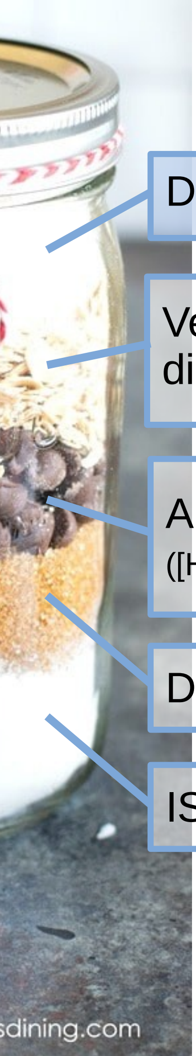


[Olsen+15_ApJ814]

Assuming a clumping factor



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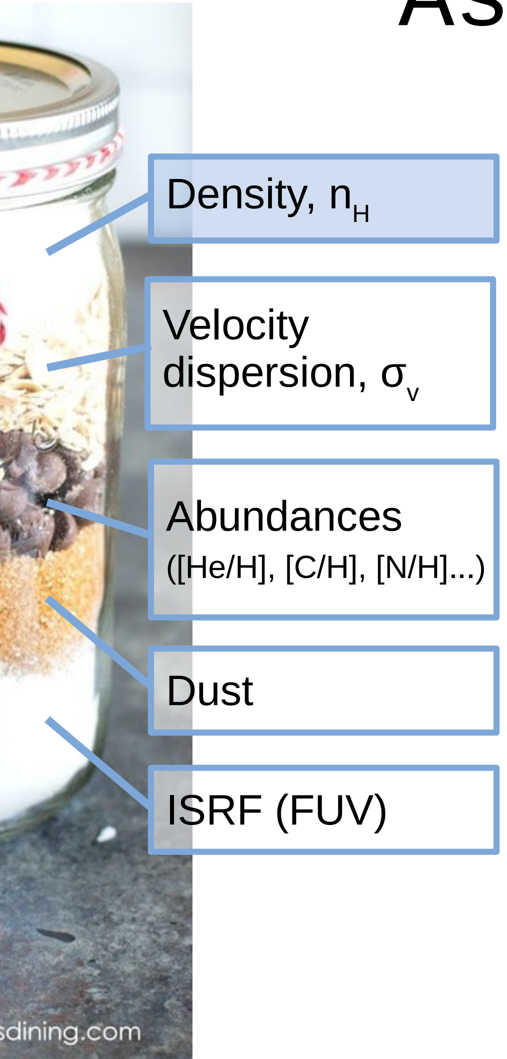


A way to account for clumping inside unresolved MCs

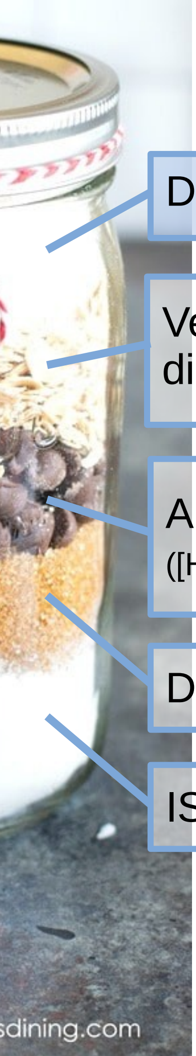
A couple of ways to do it:

- C_p : $\langle\rho^2\rangle/\langle\rho\rangle^2$ ~ 3-10 multiplied unto the effective H_2 formation rate [Gnedin+09_ApJ697, Bovino+16_A&A590]
- f_{cl} : $\langle\rho\rangle_{mw}/\langle\rho\rangle_V$ multiplied on the collision rates [Krumholz+14_MNRAS437,Popping+16_MNRAS461; Popping+19_MNRAS482]

Effect:

- Increases H_2 formation on dust
- Boosts line emission at high critical densities

Turbulent fragmentation



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Simulations of driven, supersonic, self-gravitating, magneto-hydrodynamic (MHD) turbulence agree with a lognormal probability density function (PDF):

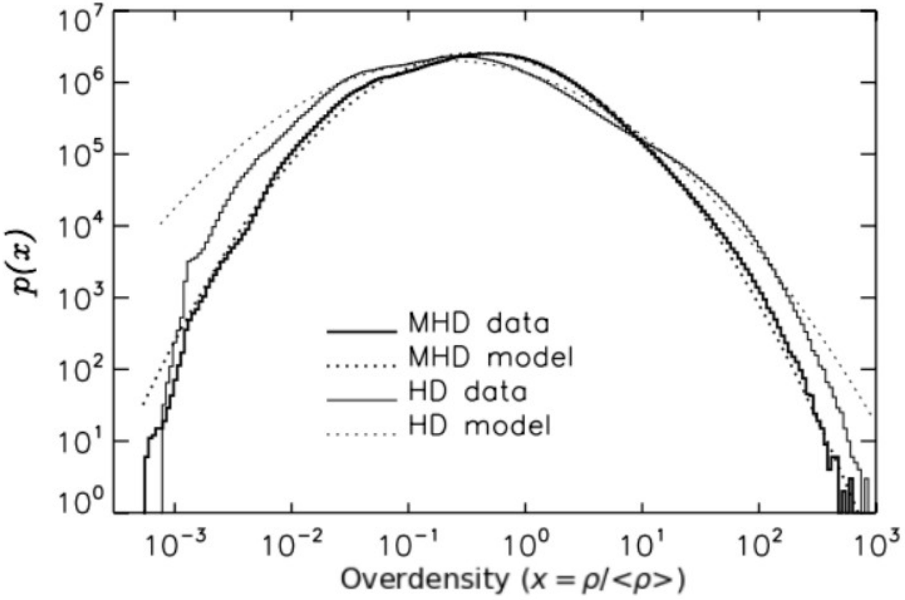
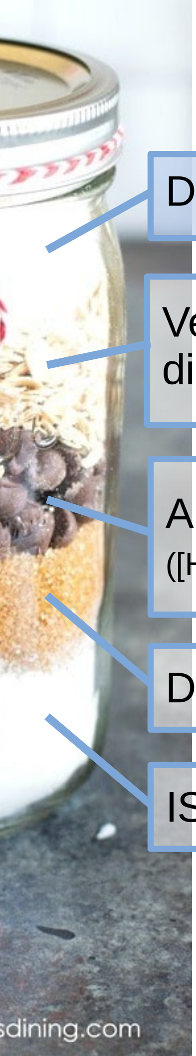


Figure 2. Pdf of gas density for the MHD and HD snapshots used as initial conditions for the star formation simulations (solid lines). The lognormal models used in this work are also shown (dotted lines).

[Padoan&Nordlund+11_ApJ730]

Turbulent fragmentation



Density, n_H

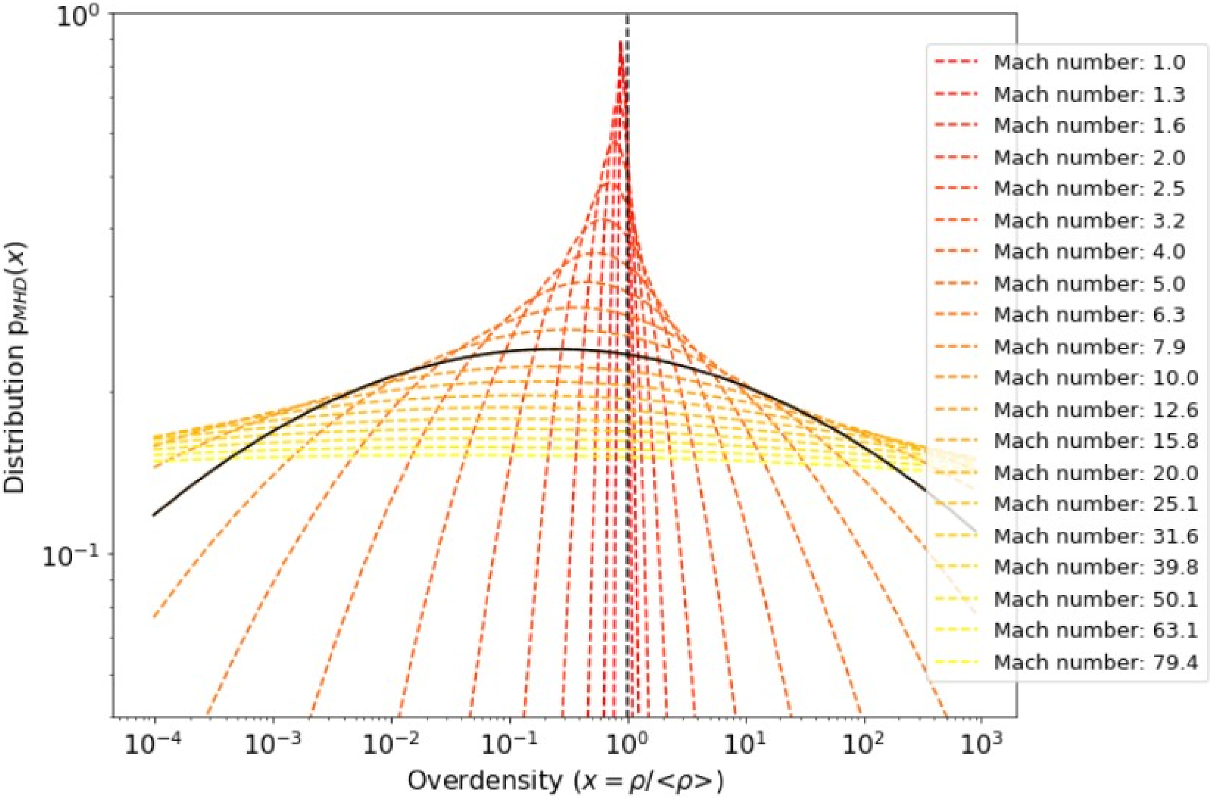
Velocity dispersion, σ_v

Abundances
([He/H], [C/H], [N/H]...)

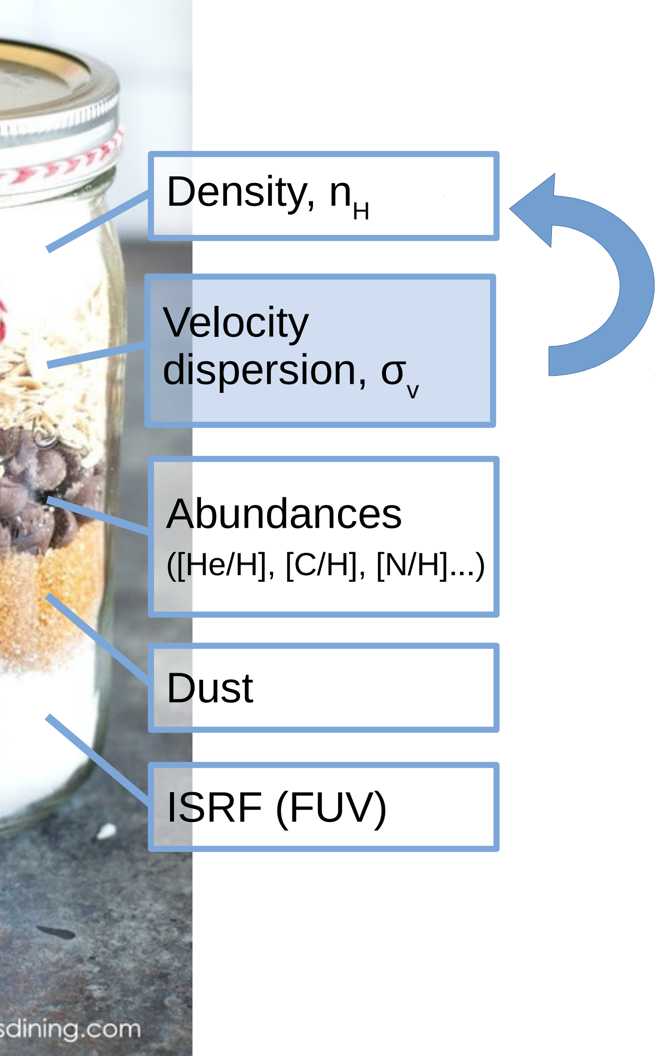
Dust

ISRF (FUV)

Higher Mach number will broaden the density distribution:



Velocity dispersion on cloud scales



- Can be used to derive Mach number and density PDF
- Affects line widths and line pumping/shielding [Ferland+17_hazy1.pdf]

Solution #1:
Calculate velocity dispersion from hot ISM pressure:

$$\sigma^2 = P/\rho_{cell}$$

[Narayanan&Krumholz2014_MNRAS442]

Velocity dispersion on cloud scales

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Solution #2:
Assume a Mach number of 10 typical of molecular clouds
[Leung+20_inprep,Pallottini+19_MNRAS487,Vallini+19_MNRAS4514]

Velocity dispersion on cloud scales

Density, n_H

Velocity dispersion, σ_v

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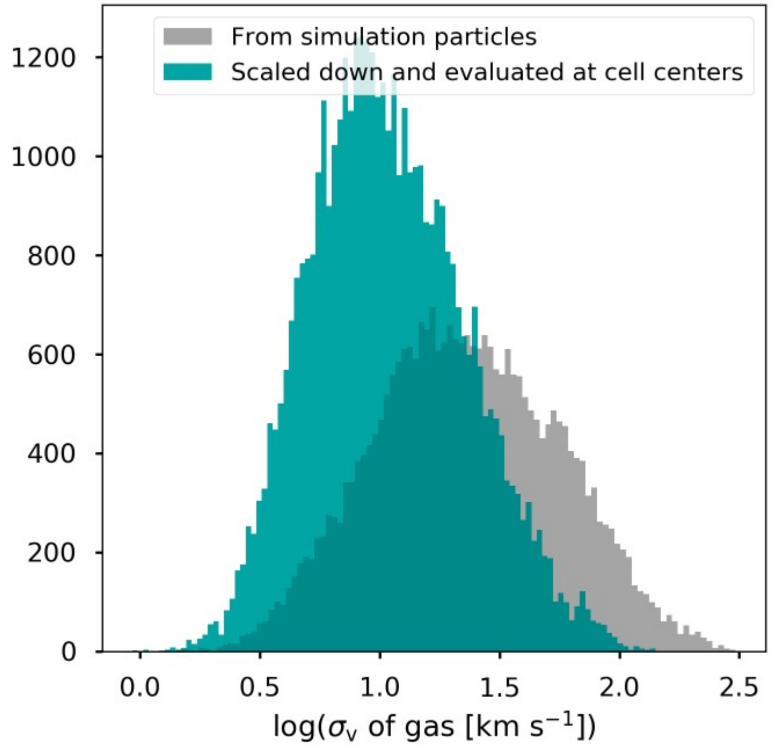
([He/H], [C/H], [N/H]...)

Dust

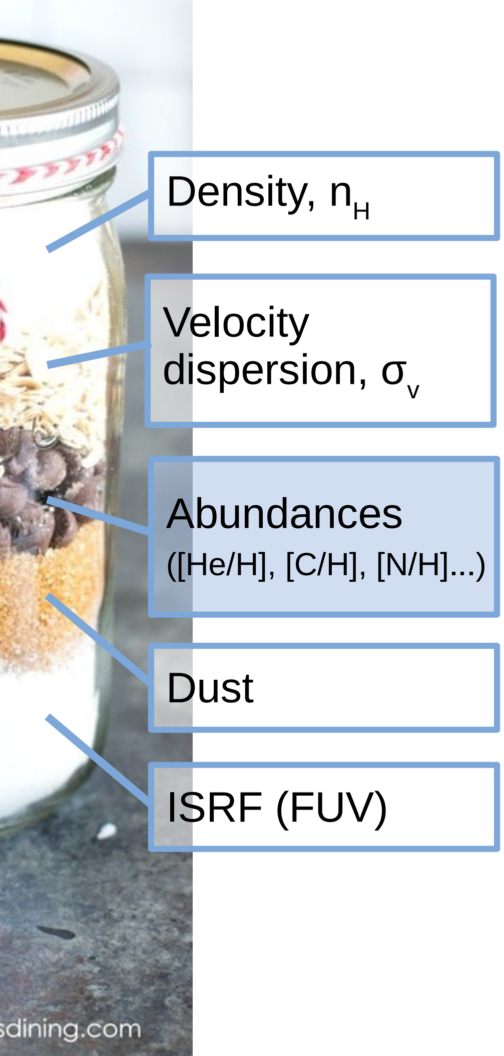
ISRF (FUV)

- Can be used to derive Mach number and density PDF
- Affects line widths and line pumping/shielding [Ferland+17_hazy1.pdf]

Solution #3:
Very crude: Scaling σ_v from smoothing length scale to cloud size by assuming σ_v scales with $(1/\text{length})^{1/3}$:



Scaling ISM abundances with total metallicity



What we all do, although adopting more specific abundances can change your results:

Scaling ISM abundances with total metallicity

Density, n_H

Velocity dispersion, σ_v

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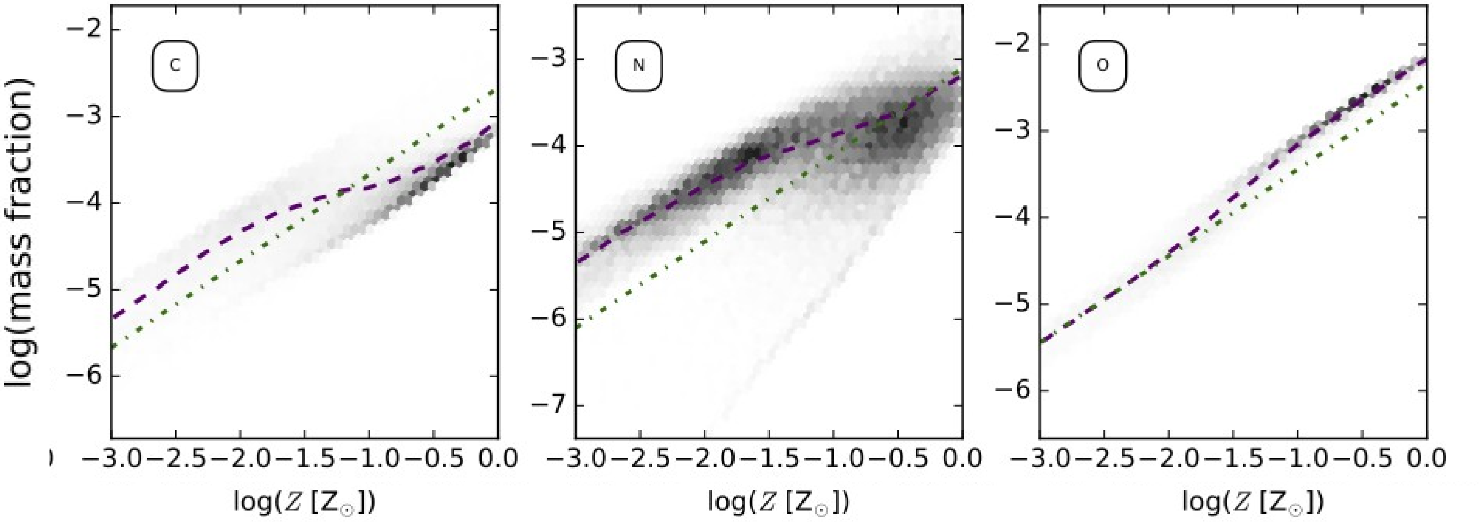
([He/H], [C/H], [N/H]...)

Dust

ISRF (FUV)

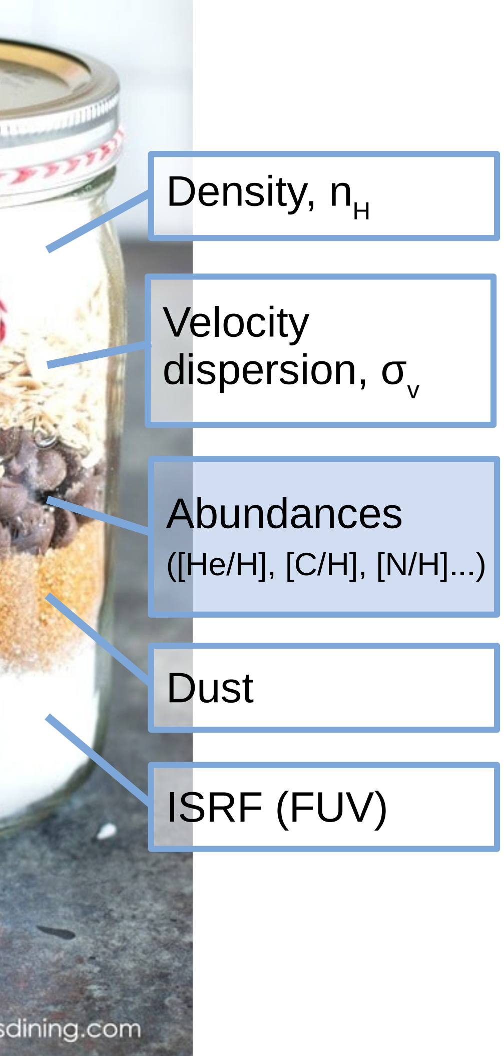
What we all do, although adopting more specific abundances can change your results:

Alternatively: use elemental abundances tracked by the simulation!



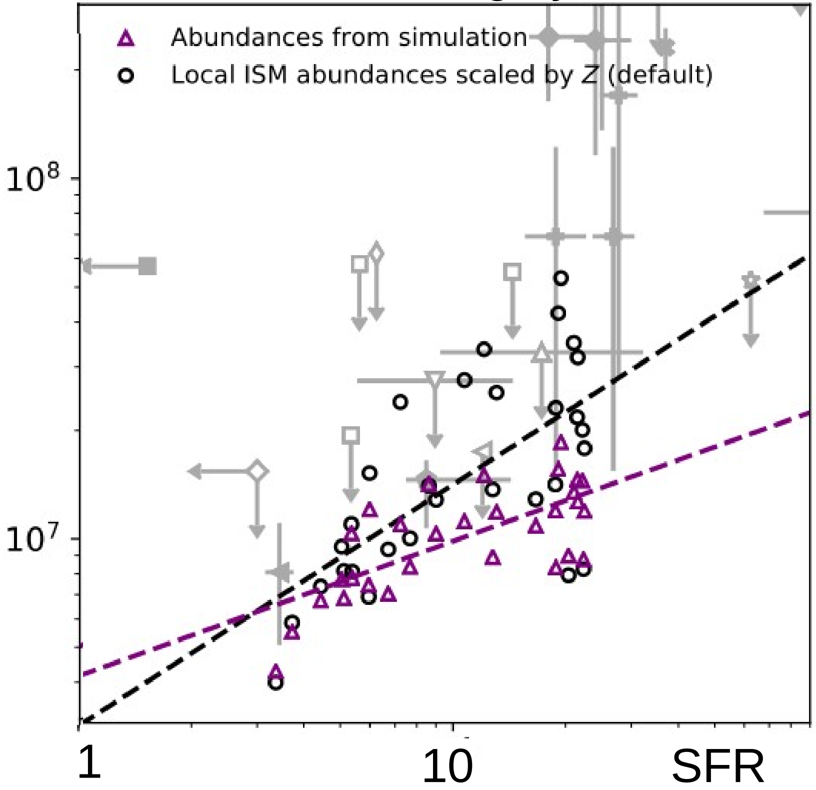
[Olsen+17]

Scaling ISM abundances with total metallicity



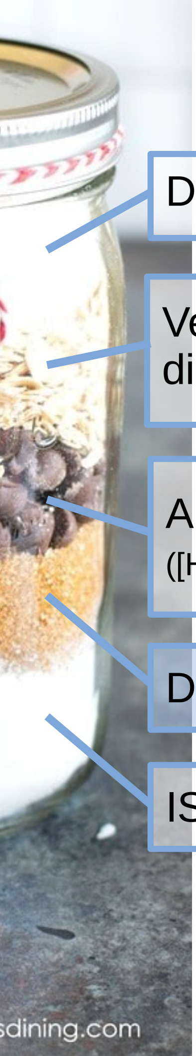
log(mass fraction)

What we all do, although adopting more specific abundances can change your results:



[Olsen+17]

Scaling metallicity by a DTM factor



Density, n_H

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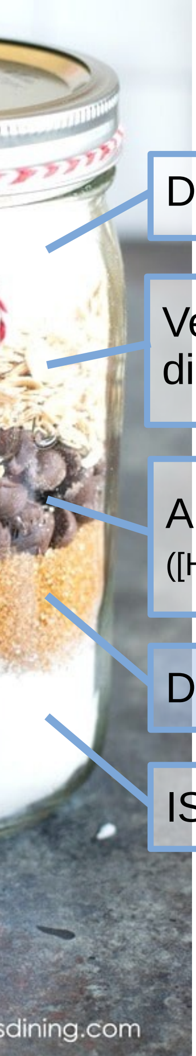
Scaling metallicity by a DTM factor



Density, n_H

Velocity dispersion, σ_v

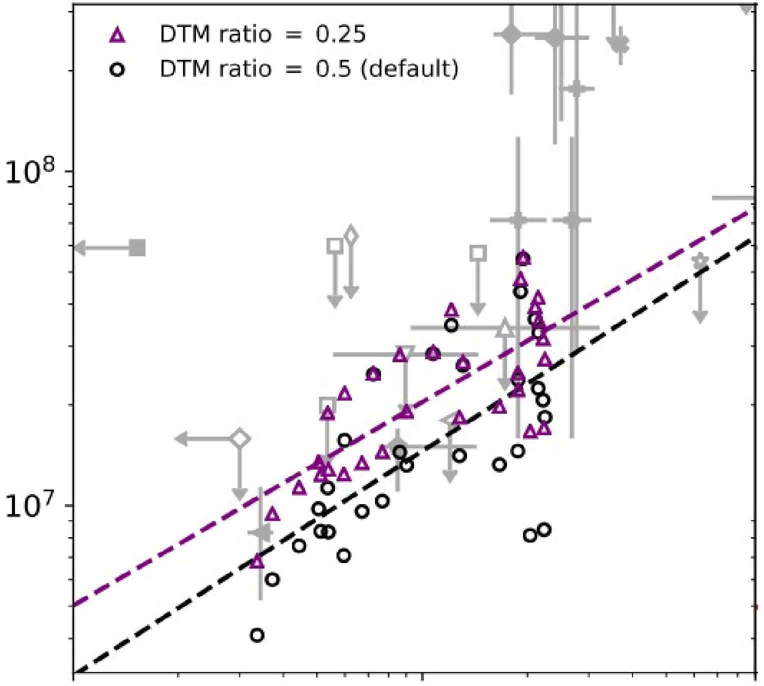
Abundances ([He/H], [C/H], [N/H]...)

Dust

ISRF (FUV)

What we all do, although at least some FIR lines can be affected by a lower DTM:

$L_{[CII]}$



1 10 SFR

[Olsen+17]

Summing up light from nearby stars

Density, n_H

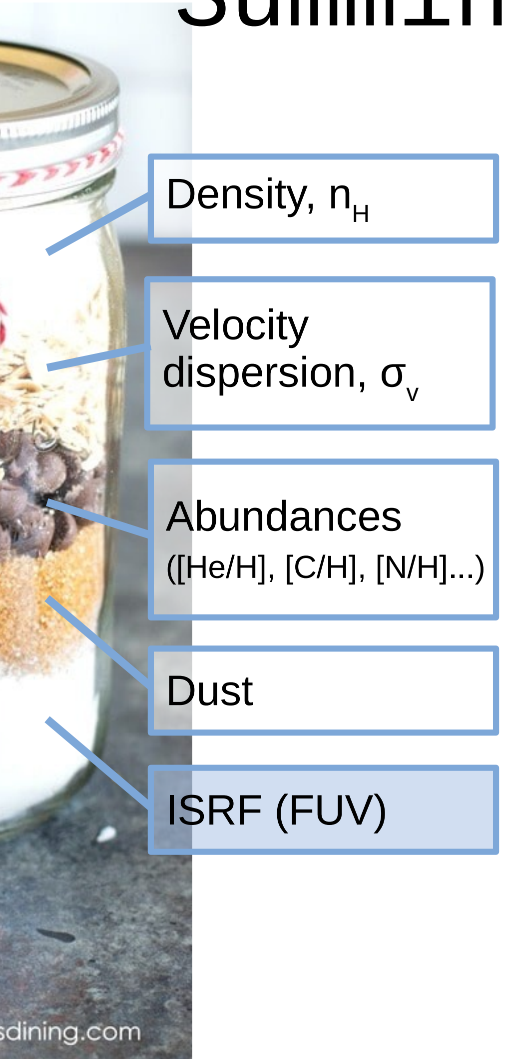
Velocity dispersion, σ_v

Abundances ([He/H], [C/H], [N/H]...)

Dust

ISRF (FUV)

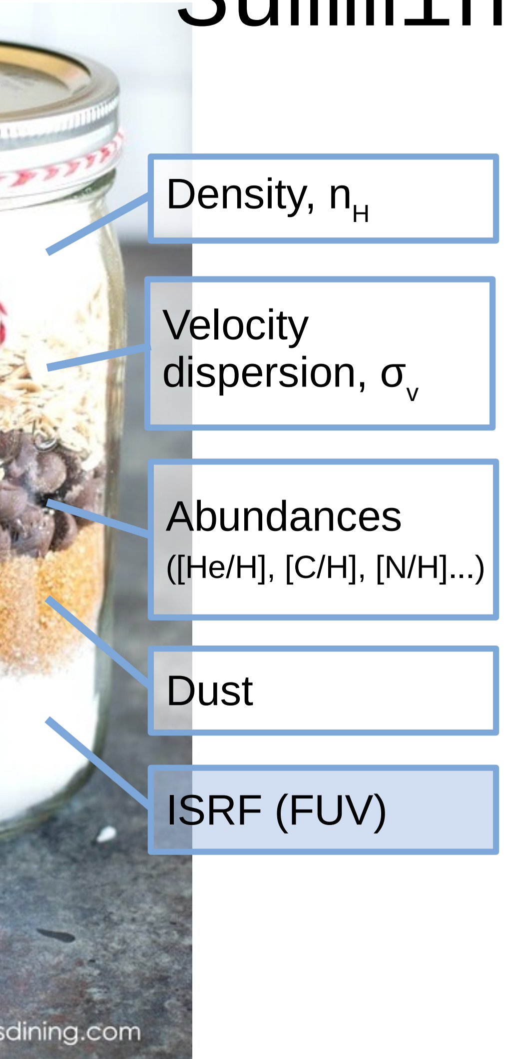
Summing up light from nearby stars



Basic recipe:

stellar population SED generator
+
radiative transfer

Summing up light from nearby stars



Basic recipe:

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If you just need galaxy-integrated luminosity:
https://powderday.readthedocs.io/en/latest/

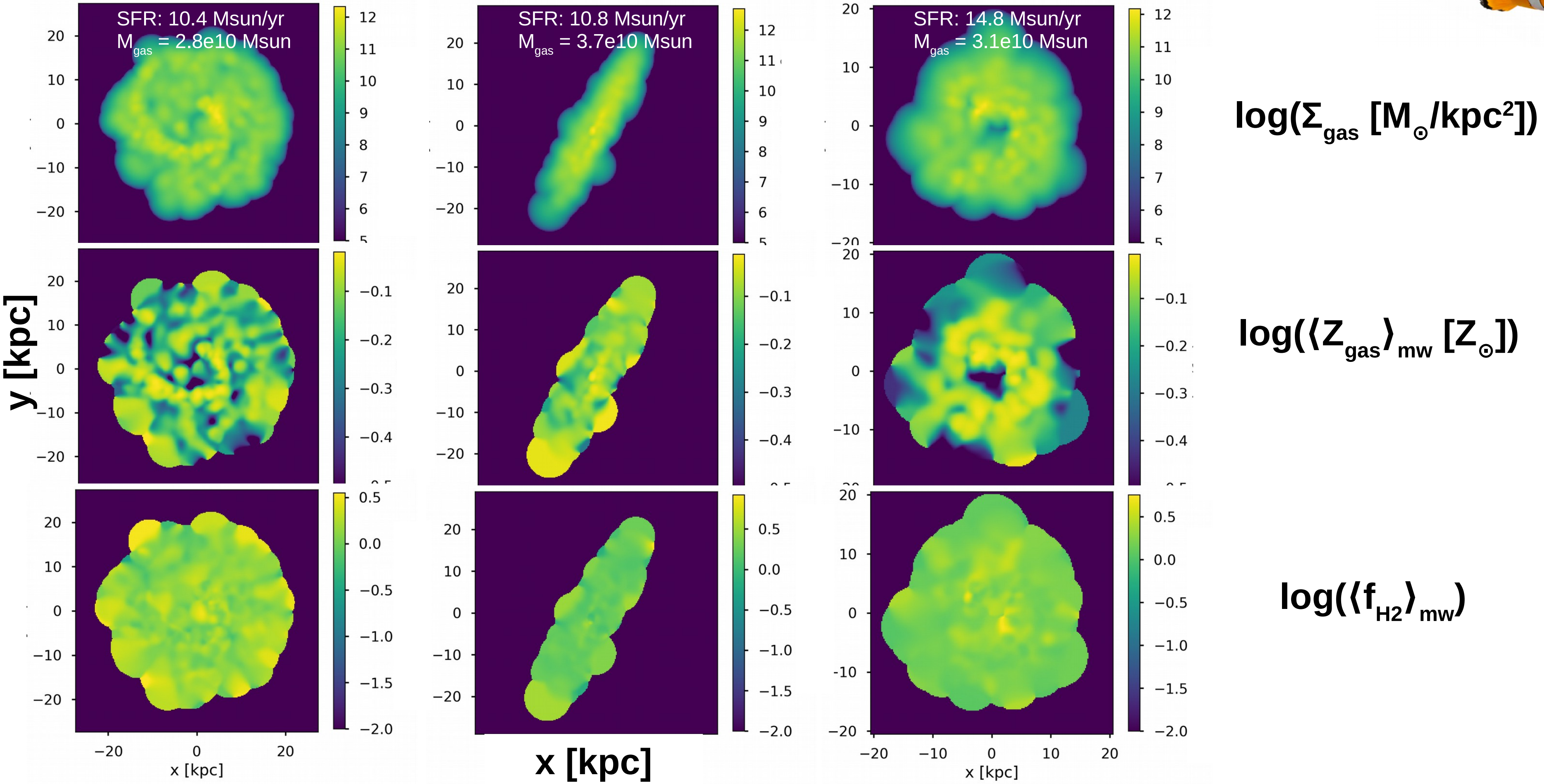
If you need intensity in each cell:

http://www.skirt.ugent.be/version9/_version9.html

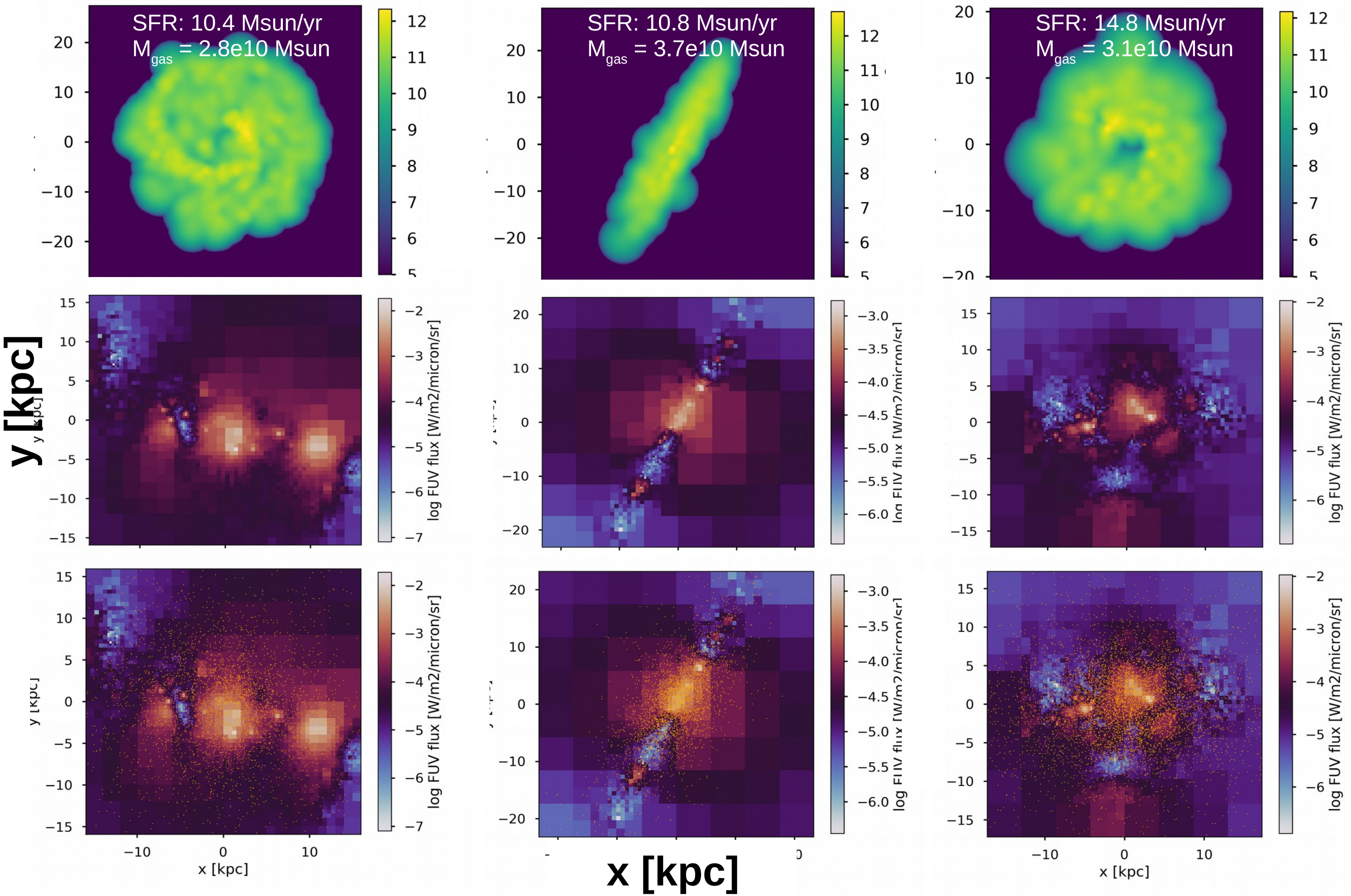
Baby steps with z=0 SIMBA galaxies

- Extracting a handful of galaxies from 100Mpc box
- Mapping with swiftsimio.visualisation.projection()
- Running SKIRT v9

Baby steps with z=0 SIMBA galaxies



Baby steps with z=0 SIMBA galaxies



log(Σ_{gas} [$M_\odot$/kpc^2])

log(FUV flux [W/m^2/micron/sr])

With stars

Conclusions

Where is SIGAME v3 in reaching SIMBA:

- finding the best way to estimate cloud-scale vel disp (for nH)
- checking SKIRT v9 results
- making Cloudy grid
- considering MAPPINGS for shock-heated regions
- considering splitting stellar particles?

Unknowns:
- how much can we trust dust?

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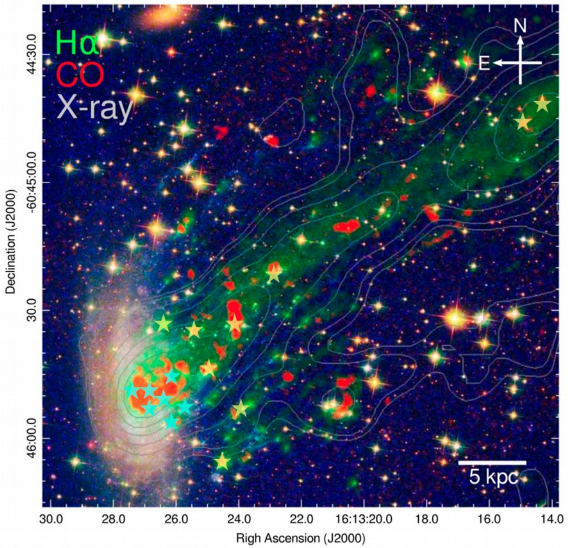
Unknowns:
- how much can we trust dust?
- do we have any jellyfish galaxies?



The Norma cluster galaxy ESO 137-001
[Jáchym+19_ApJ883]