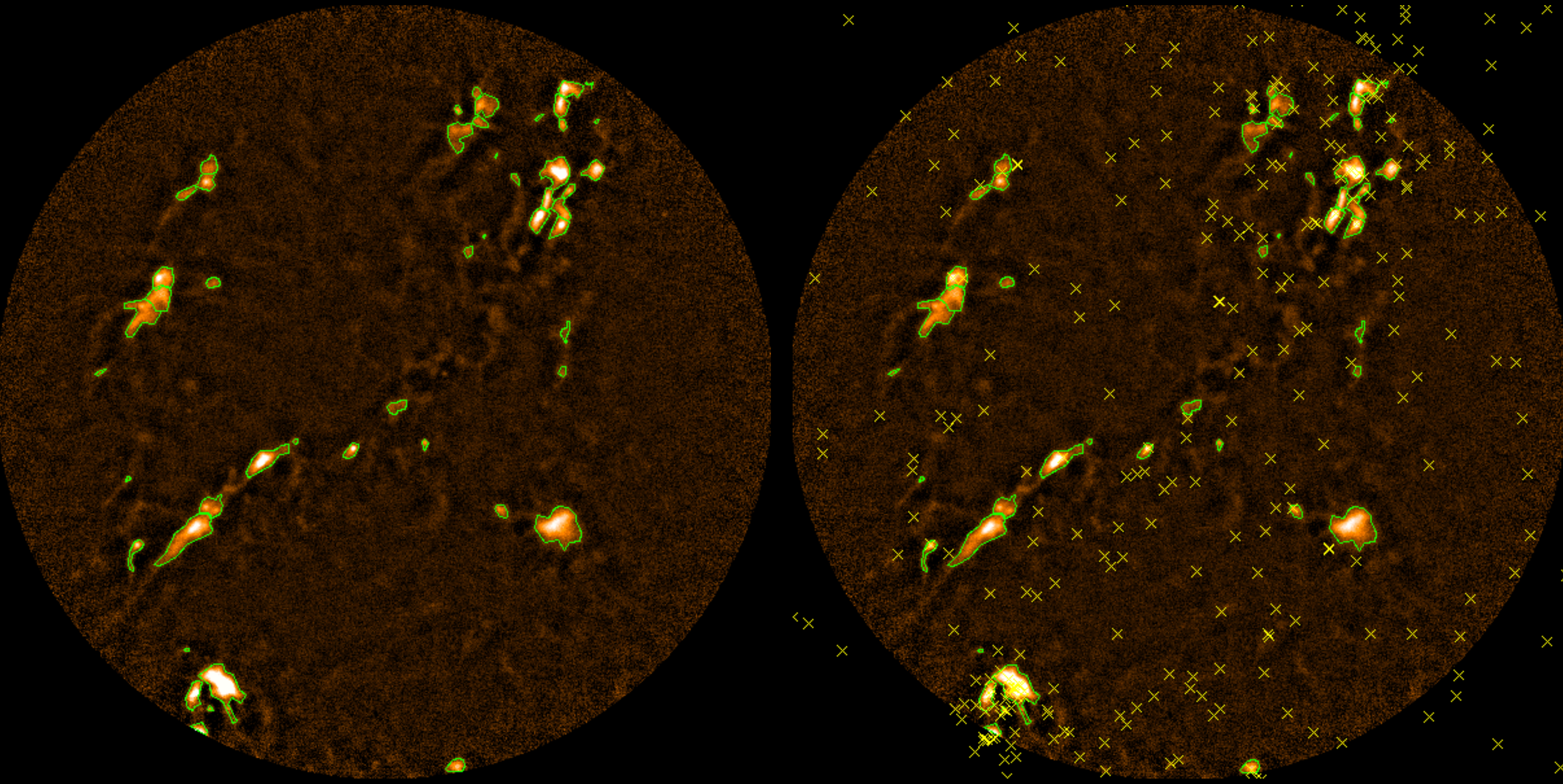
Assignment 2

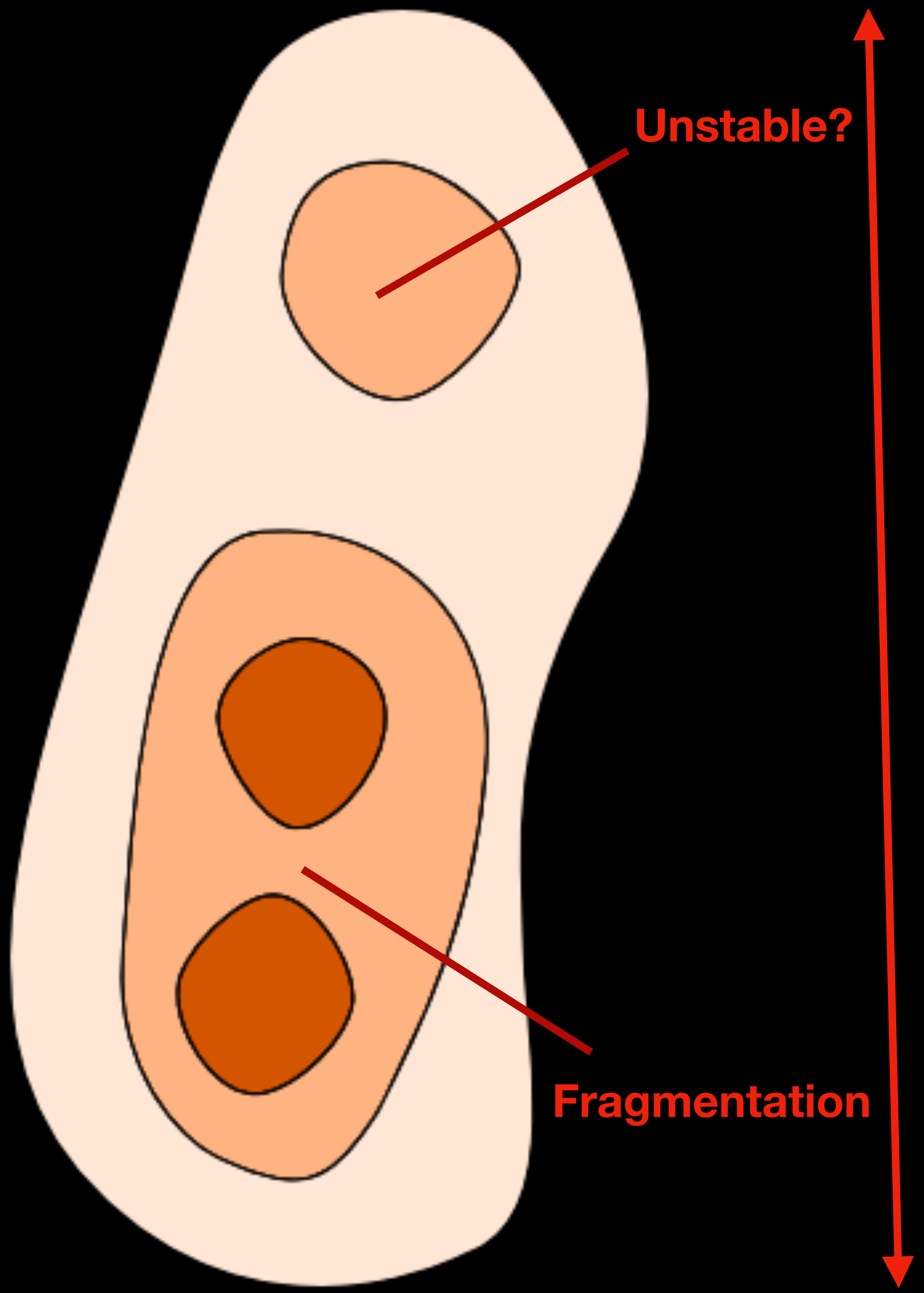
Clumpfinding and Synergy Between Datasets



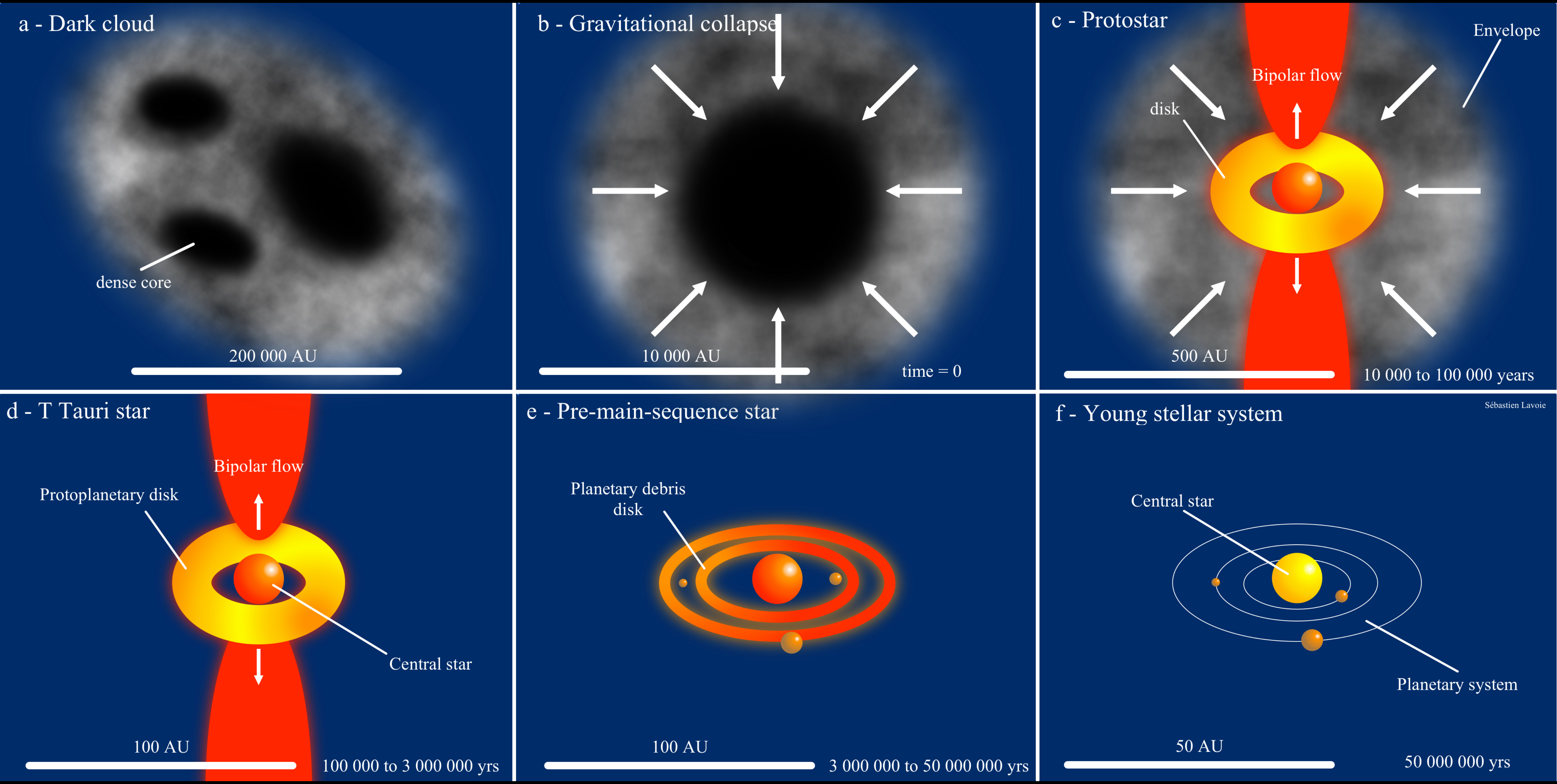
Dr. Steve Mairs (ASTR351L Spring 2019)

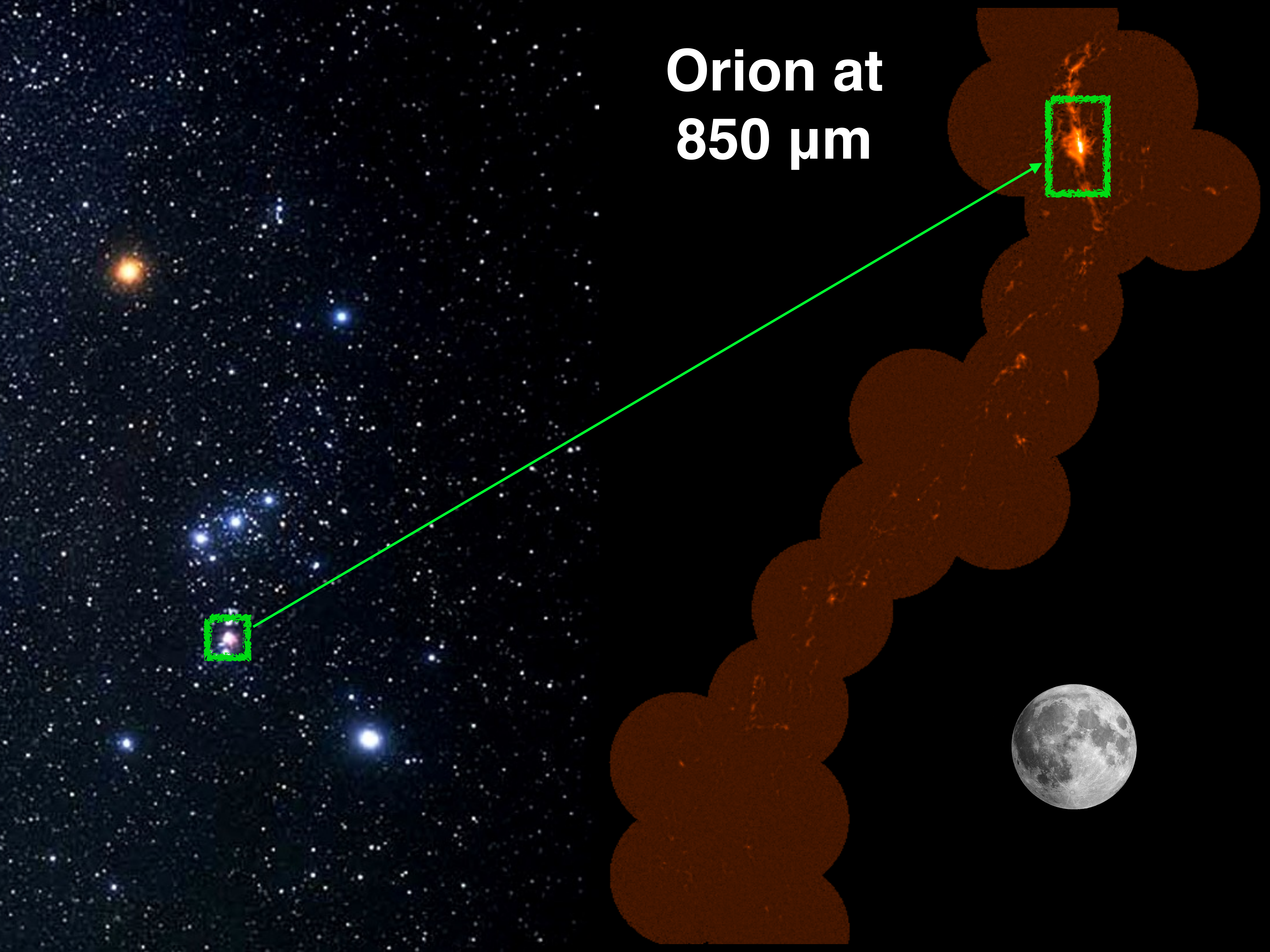
Overview

1. Star Formation
2. YSOs
3. Clumpfinding
4. Catalogues
5. Mass Equations

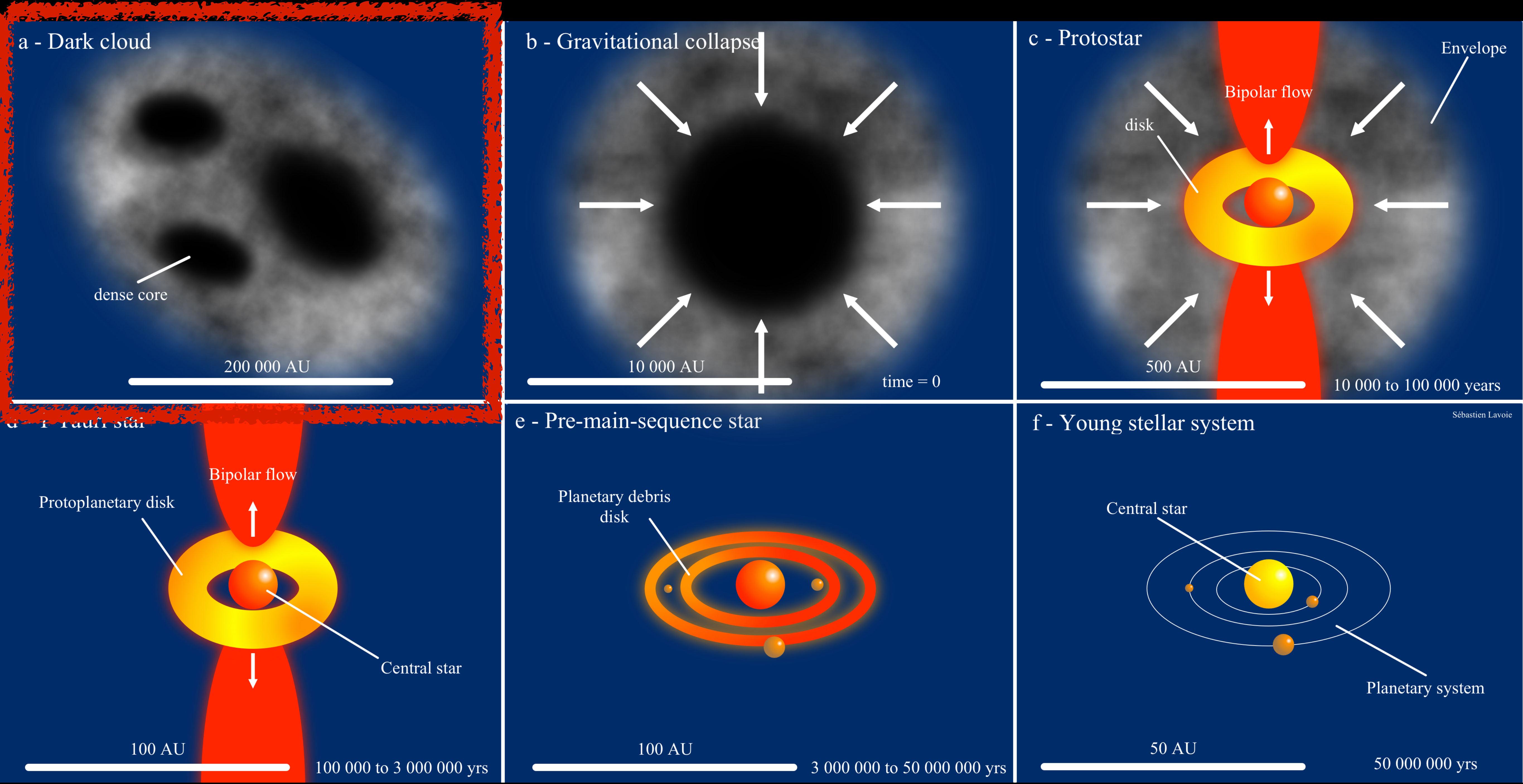


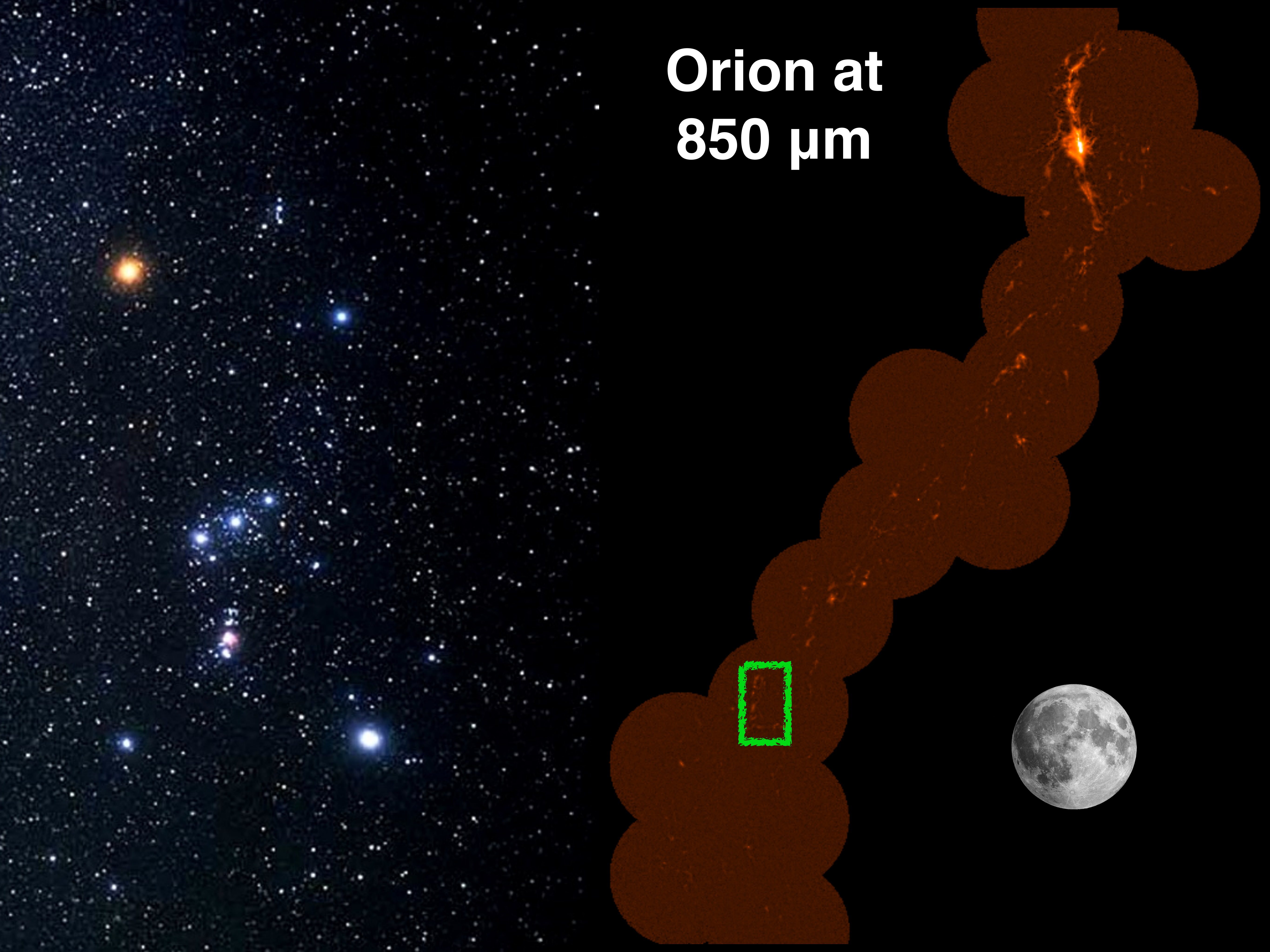
Star Formation in a Nutshell

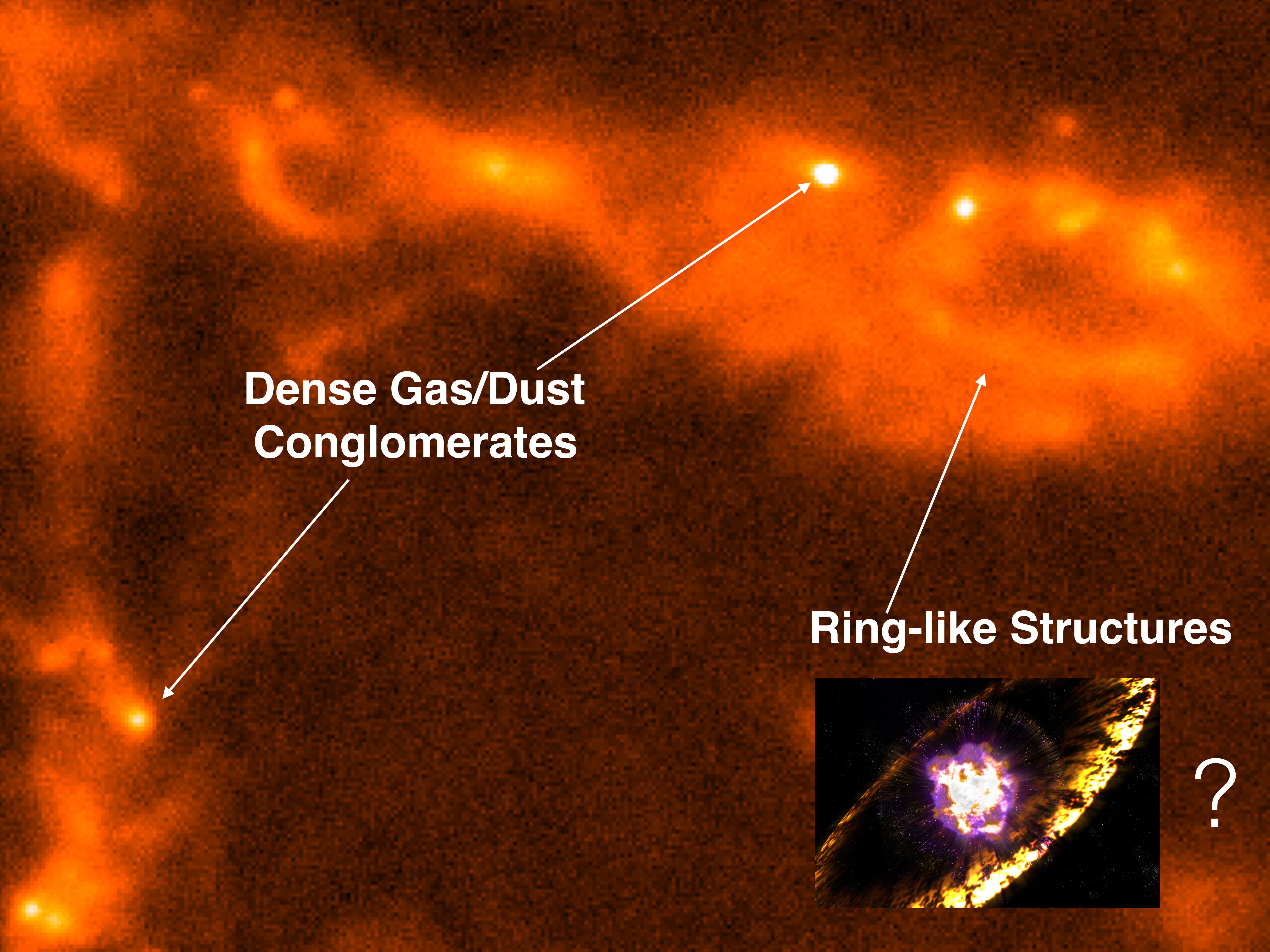



Orion at
850 µm

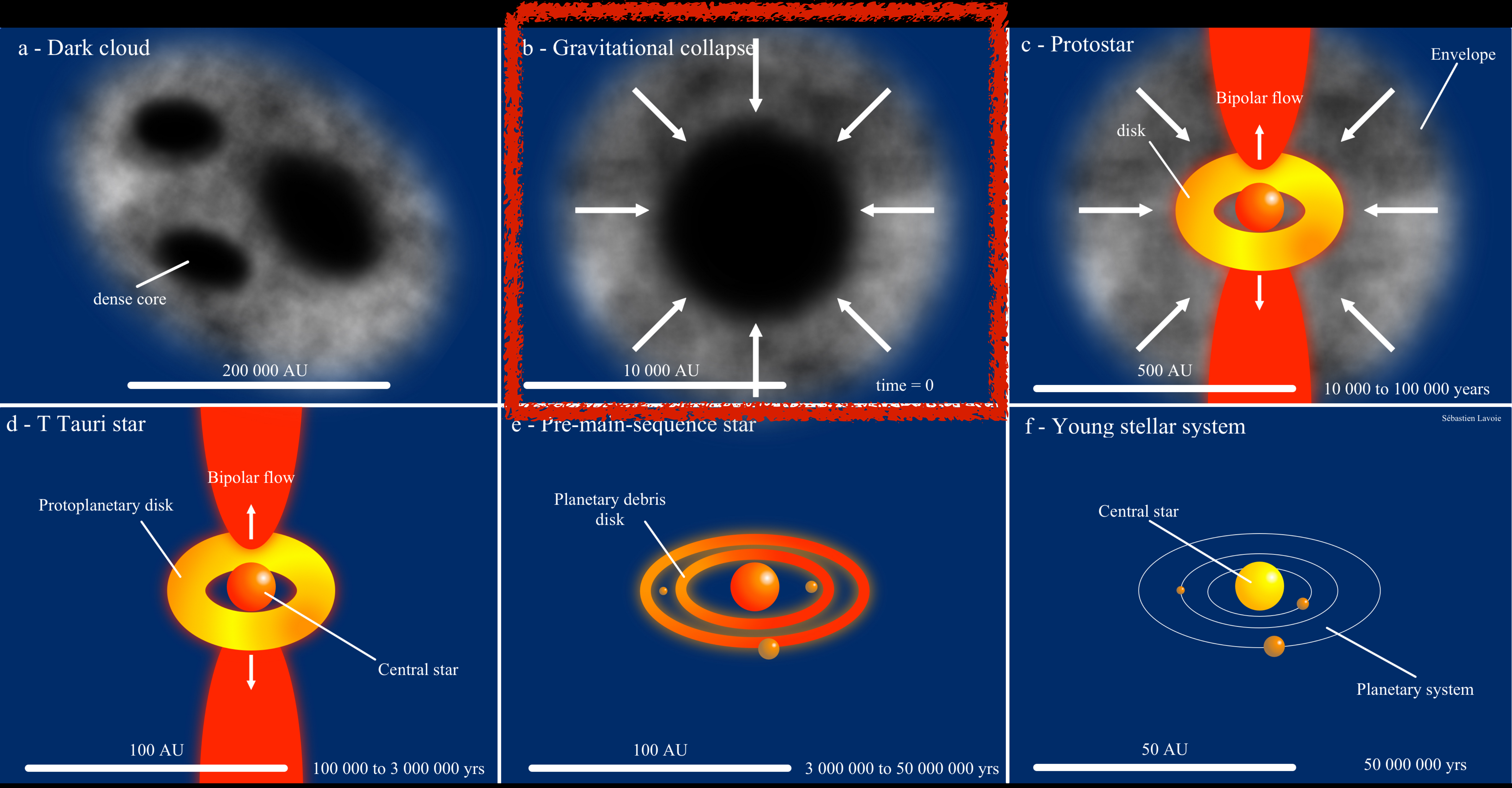
Star Formation in a Nutshell




Orion at
850 µm


Dense Gas/Dust
Conglomerates
Ring-like Structures
?

Star Formation in a Nutshell



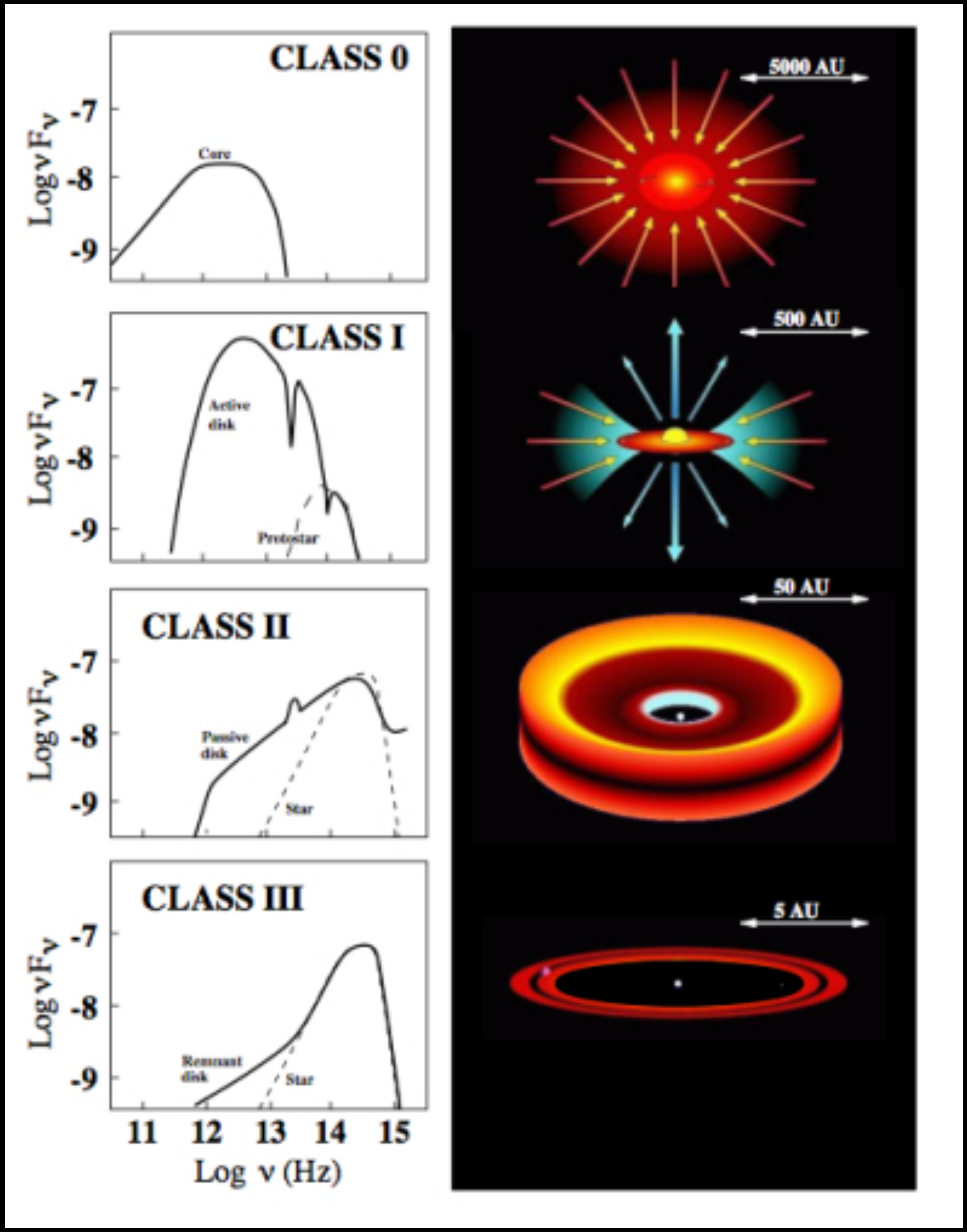
Young Stellar Objects: YSOs

We use infrared telescopes to identify and classify YSOs

The class is proportional to age!

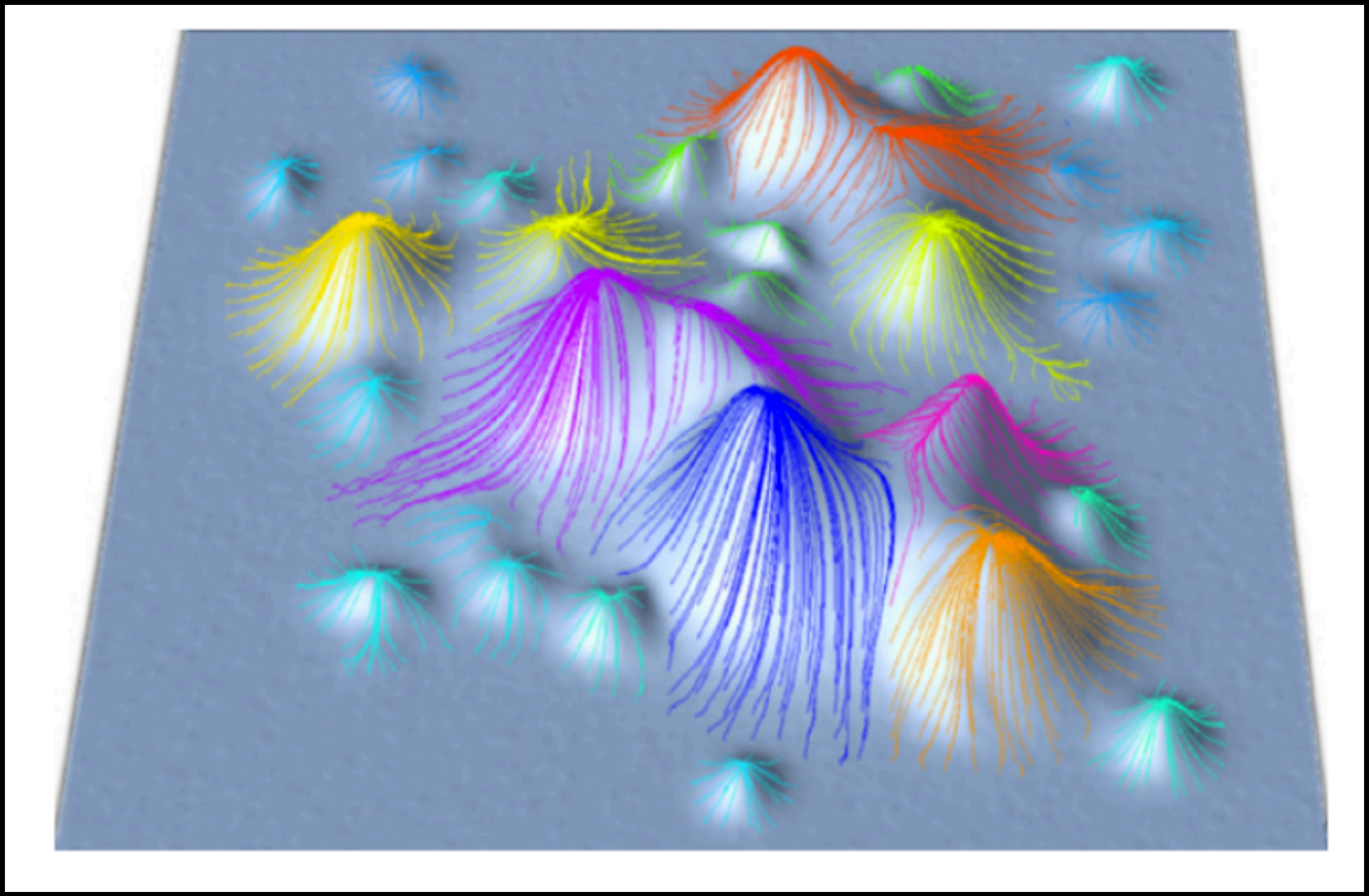
We expect to see Class 0/I associated with SCUBA-2 clumps (early SF!)

These data have a lot of synergy With the JCMT's!



Clumpfinding: The FellWalker Algorithm

The FellWalker algorithm is tuned to identify compact, localised emission

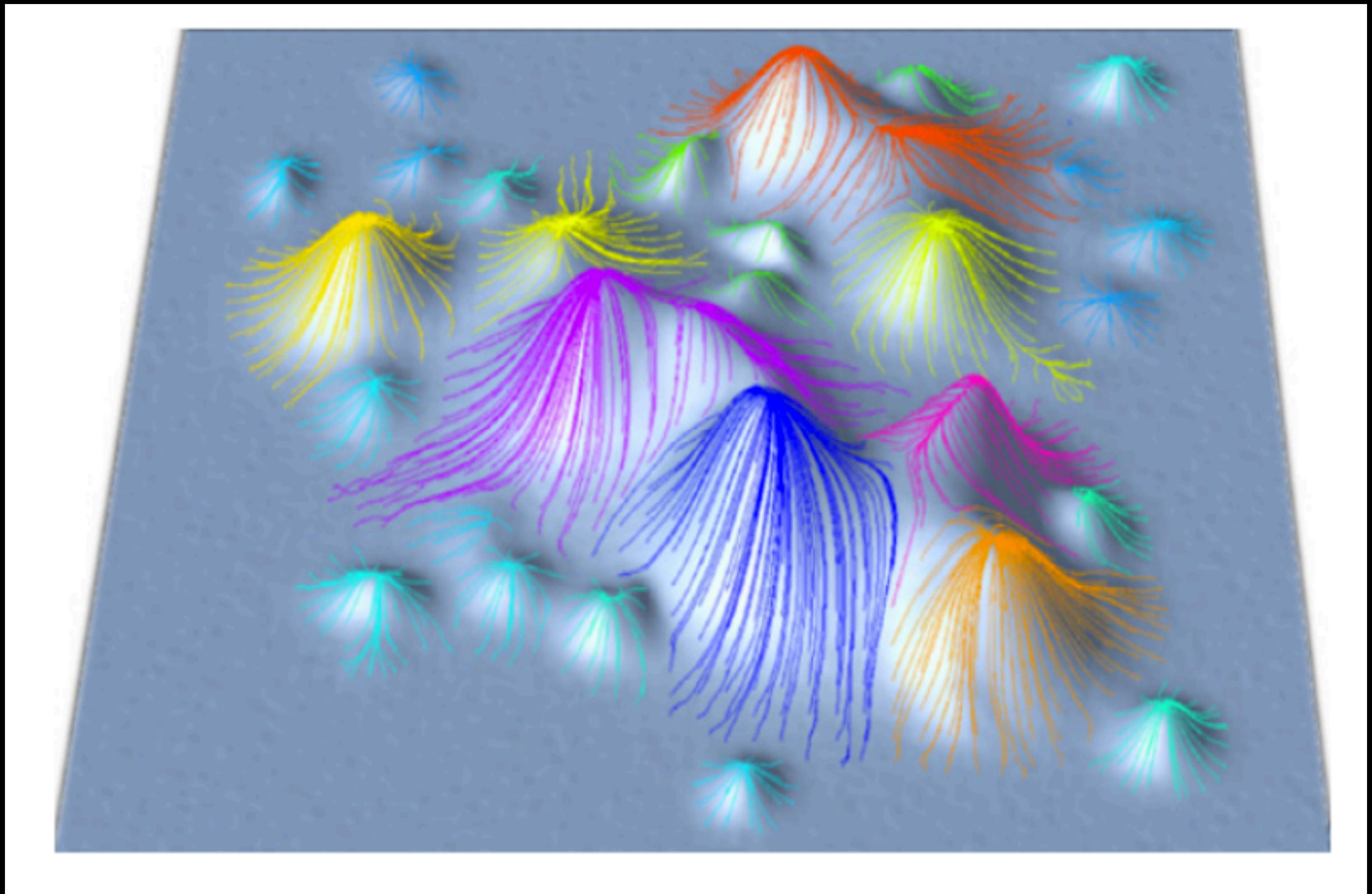


Each pixel is considered in an image and the steepest gradients up to an emission peak are identified

Checks are performed to ensure the peak is not a noise spike

Clumpfinding: The FellWalker Algorithm

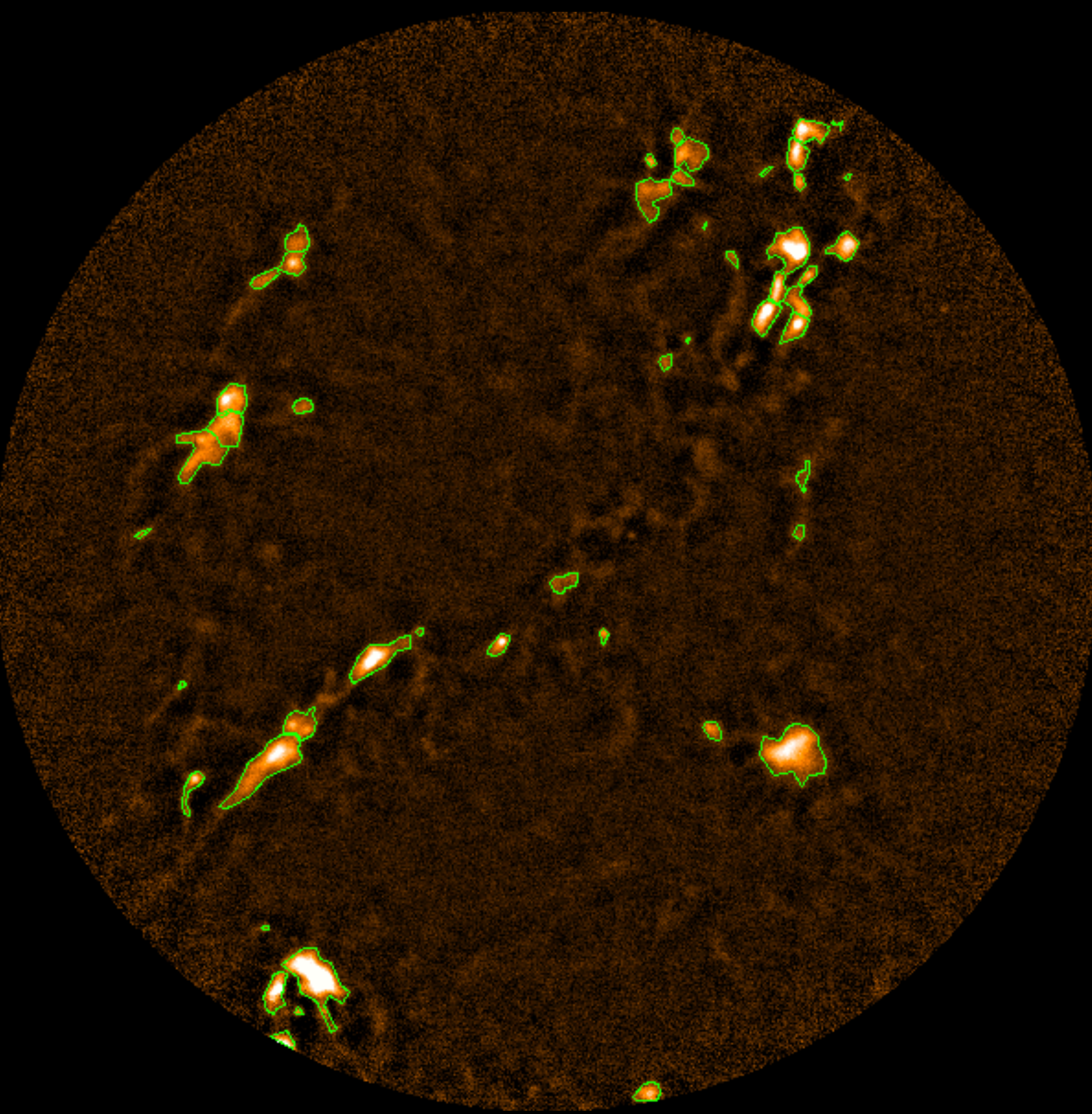
The local maximum is assigned an identifying integer and all the pixels above a user-defined threshold that were included in the path to the peak are assigned the same integer.



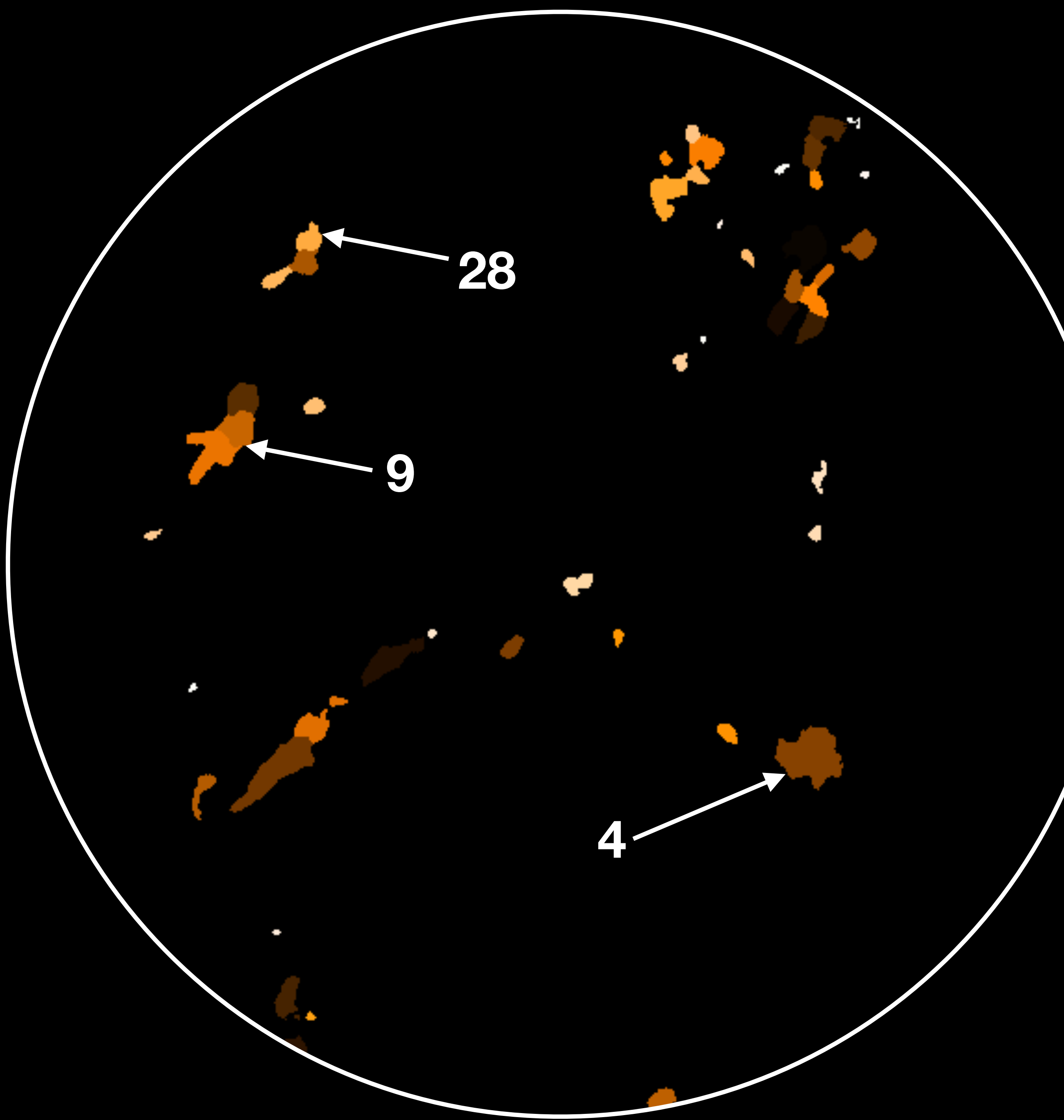
Clumps are split up based on the depth of the dips between peaks

Clumpfinding: The FellWalker Algorithm

FellWalker Results Overplotted



The FellWalker "Outmap"



FellWalker(/Starlink) Catalogues

Along with a map of all the clumps, you get all their properties!

Clump properties:
=================

Index	Peak1	Peak2	Cen1	Cen2	Size1	Size2	Sum	Peak	Volume
	[deg]	[deg]	[deg]	[deg]	[arcsec]	[arcsec]	[mJy/arcsec**2]	[mJy/arcsec**2]	[arcsec.arcsec]
1	84.078347464	-6.3702023965	84.080822271	-6.3698287328	23.597389887	25.557410599	957.90378552	14.287727755	11551.566081
2	83.787792654	-5.9324240813	83.790521841	-5.9298555939	18.061132739	17.440381945	338.09362167	5.3071041595	6223.835474
3	83.806774394	-5.9668730242	83.80774354	-5.9693267682	11.231936721	15.83318411	154.14101902	3.286650273	3151.9412054
4	84.048123139	-6.1791003383	84.045586381	-6.1775466848	23.254268798	17.465261715	232.05856865	2.6809412036	5743.9602465
5	84.100719347	-6.4101949377	84.099944442	-6.408989366	11.61618633	7.9947327103	60.694069156	2.2462847358	1231.9377751
6	83.787780569	-5.9746458031	83.788936564	-5.9763488488	11.77735589	13.45416516	94.470488508	2.1784927294	2527.9492504
7	84.104063397	-6.3768614621	84.105122274	-6.3786483037	10.662613945	19.635360762	138.60234127	2.1421993346	3279.8602215
8	83.785580109	-5.8579804284	83.782183932	-5.8582897216	17.761819387	11.763204351	130.65733434	1.8606473945	3263.863152
9	84.135238199	-6.0212990195	84.132835374	-6.0211912301	14.888715333	14.352001194	152.31351124	1.8286955336	3807.918331
10	83.78892741	-5.8702032795	83.788823051	-5.872274241	8.9248787519	16.478792884	100.73750776	1.7347762566	2607.8992784

Peak1, Peak2 = Location of the peak

Cen1, Cen2 = Location of the centre of the clump

Size1, Size2 = Weighted average size along each axis

Sum = Flux from all pixels in the clump simply added up together

Peak = Flux of the peak pixel contained within clump

Volume = Area in 2D

FellWalker(/Starlink) Catalogues

Clump properties:
=================

Index	Peak1	Peak2	Cen1	Cen2	Size1	Size2	Sum	Peak	Volume
	[deg]	[deg]	[deg]	[deg]	[arcsec]	[arcsec]	[mJy/arcsec**2]	[mJy/arcsec**2]	[arcsec.arcsec]
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<u>** PAY ATTENTION TO UNITS ****</u>**

Note that a proper total flux is in units of <u>mJy</u> or <u>Jy</u>

In the example above, the units are mJy/arcsec^2

<u>So you need to multiply by the area of a pixel! (In arcsec^2)</u>

The Physics of Stability: Mass

Begin with a modified blackbody equation to describe the flux:

$$I_\nu = B(T_d) \times [1 - e^{-\tau_\nu}]$$

Flux at frequency ν

Dust Temperature

Optical Depth

Planck Equation

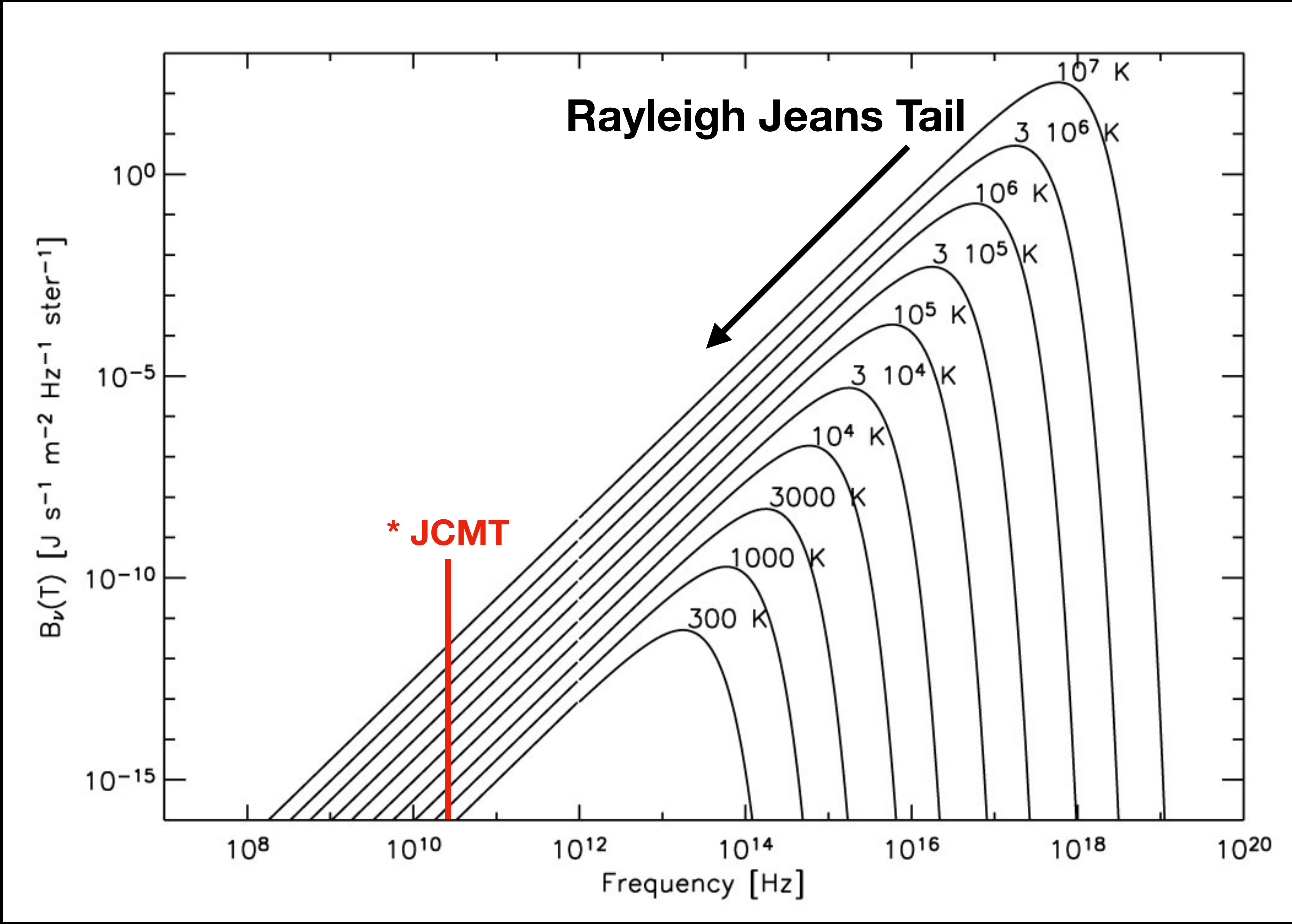
We are on the Rayleigh Jeans tail of the blackbody ($\tau_\nu << 1$):

So, Taylor Expand $e^{-\tau_\nu}$

$$I_\nu = B(T_d) \times [1 - (1 - \tau_\nu)]$$

$$I_\nu = B(T_d) \times \tau_\nu$$

The Physics of Stability: Mass



The Physics of Stability: Mass

Let's take a look at the total flux, S_ν:

$$S_\nu = \int I_\nu d\Omega$$

Add flux
Over solid angle
Of source

$$S_\nu = \int B(T_d) \times \tau_\nu \, d\Omega$$

$$S_\nu = B(T_d) \times \tau_\nu \times \Omega$$

$$\tau_\nu = N\sigma_\nu$$

$$\tau_\nu = N\rho\kappa_\nu/n$$

$$\tau_\nu = N\mu m_H \kappa_\nu$$

Column
Density

Number density
of core

Mass density
of core

Opacity of
core

$$S_\nu = B(T_d) \times N\mu m_H \kappa_\nu \times \Omega$$

The Physics of Stability: Mass

$$S_\nu = B(T_d) \times N\mu m_H \kappa_\nu \times \Omega$$

Mean Molecular Weight
x
Mass of Hydrogen

2D Area of core

Distance to core

$$S_\nu = B(T_d) \times (M/r^2)\mu m_H \kappa_\nu \times (r^2/D^2)$$

Mass of core

$$S_\nu = (2h\nu^3/c^2) \times \{1/[\exp(h\nu/k_B T_d) - 1]\} \times M\mu m_H \kappa \times (1/D^2)$$

Solve for the mass of the core, M, combine constants, change units….

The Physics of Stability: Mass

$$\boxed{M_{345GHz} = 0.074 \times (S_{345GHz}/1\ \mathrm{Jy}) \times (D/100\ \mathrm{pc})^2 \times (\kappa_{345GHz}/0.01\ \mathrm{cm^2\ g^{-1}}) \times [\exp(17\ \mathrm{K} / T_d) - 1]\ M_\odot}$$

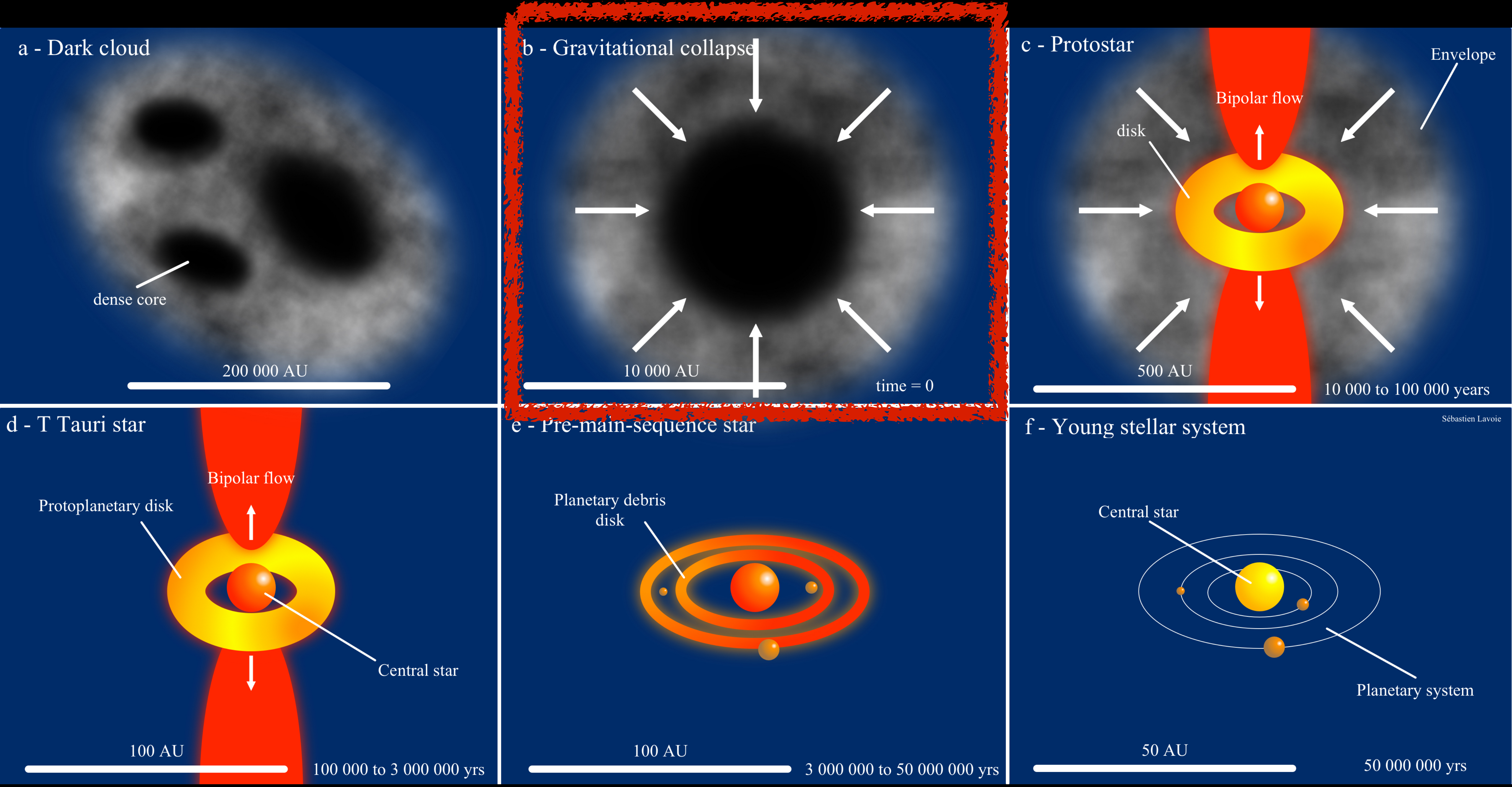
Good $\kappa_{345GHz} = 0.01\ \mathrm{cm^2\ g^{-1}}$

Good $T_d = 15$ K

S_{345GHz} comes from FellWalker Catalogue (“Sum”) - but check the units!!

Find the distance, D, to the Orion Nebula

The Physics of Stability: Jeans Mass



Stronger Pressure

More Heat

=

Expansion

=

No star formation

Stronger Gravity

More Stuff

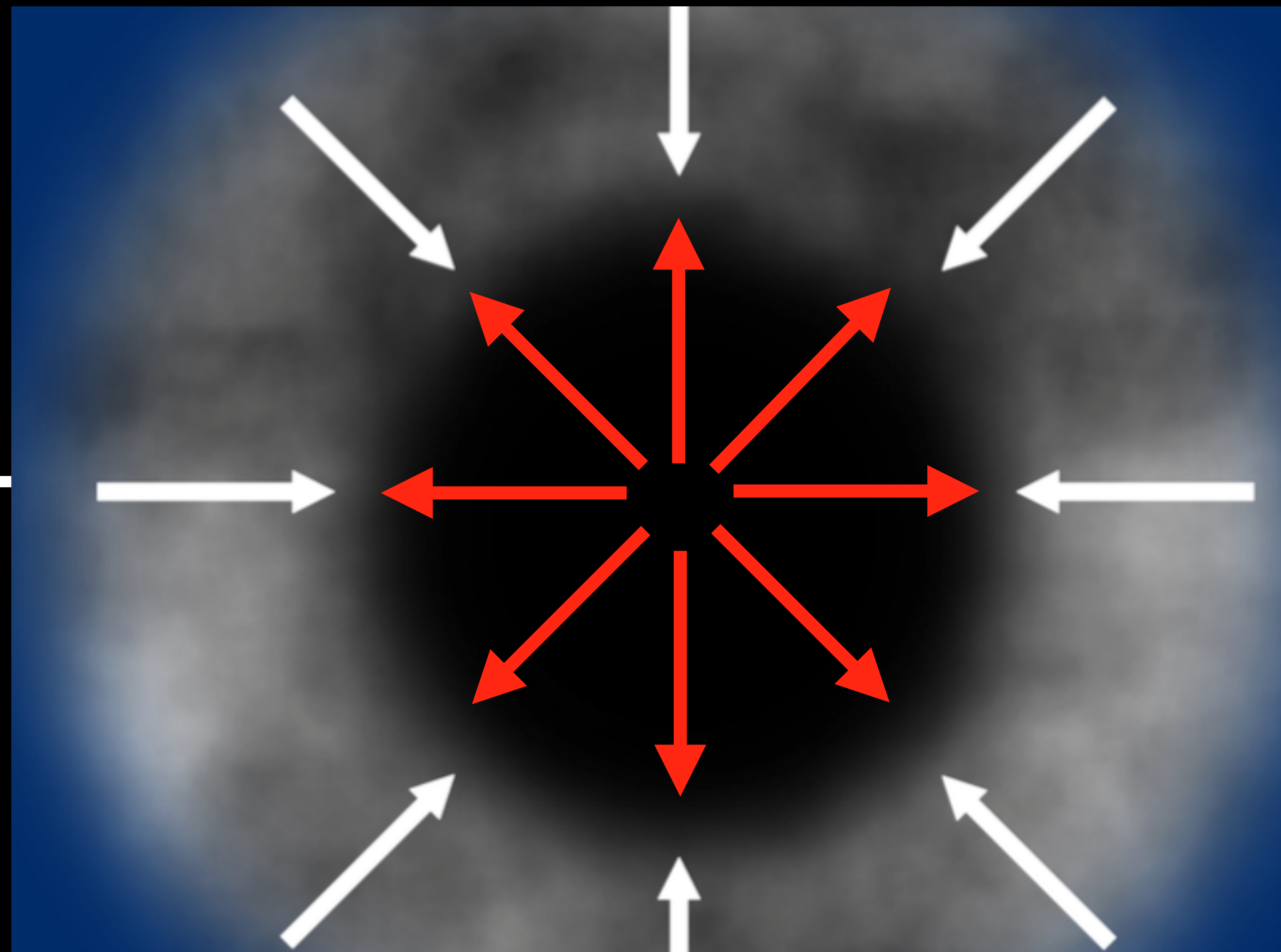
=

Collapse

=

Star Formation

Gravity



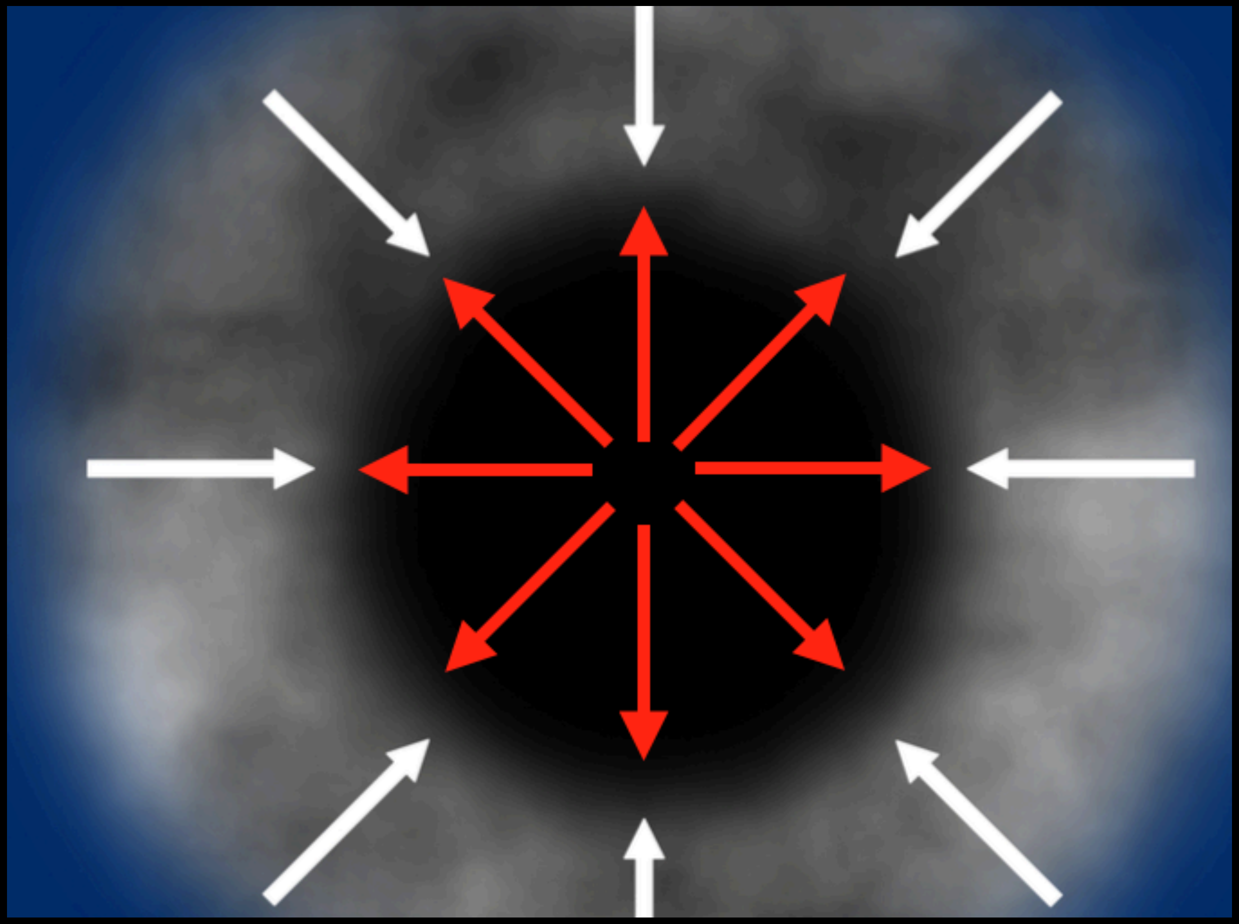
Thermal Pressure

A constant struggle!

The Physics of Stability: Jeans Mass

Jeans Mass: The maximum mass a core can have before collapsing under its own gravity if there is only thermal pressure trying to prevent

It can be beautifully derived from first principles just using the continuity equation and Euler's equation (but I'll spare you the horror)



Mass of core < Jeans Mass: Oscillating Wave Solution

Mass of core >/= Jeans Mass: Runaway Collapse!

The Physics of Stability: Jeans Mass

The Jeans mass, M_J, in a nice, approximate form:

$$M_J = 2.9 \times (15\ K / T_d) \times (R / 0.07\ pc)\ M_{\odot}$$

Radius of the core assuming it has a spherical configuration
****THE UNITS ARE IN PARSECS****

$M / M_J < 1$ ——————> **STABLE TO COLLAPSE**

$M / M_J \geq 1$ ——————> **UNSTABLE**