

# Pillar creation: physical origins and connection to star formation

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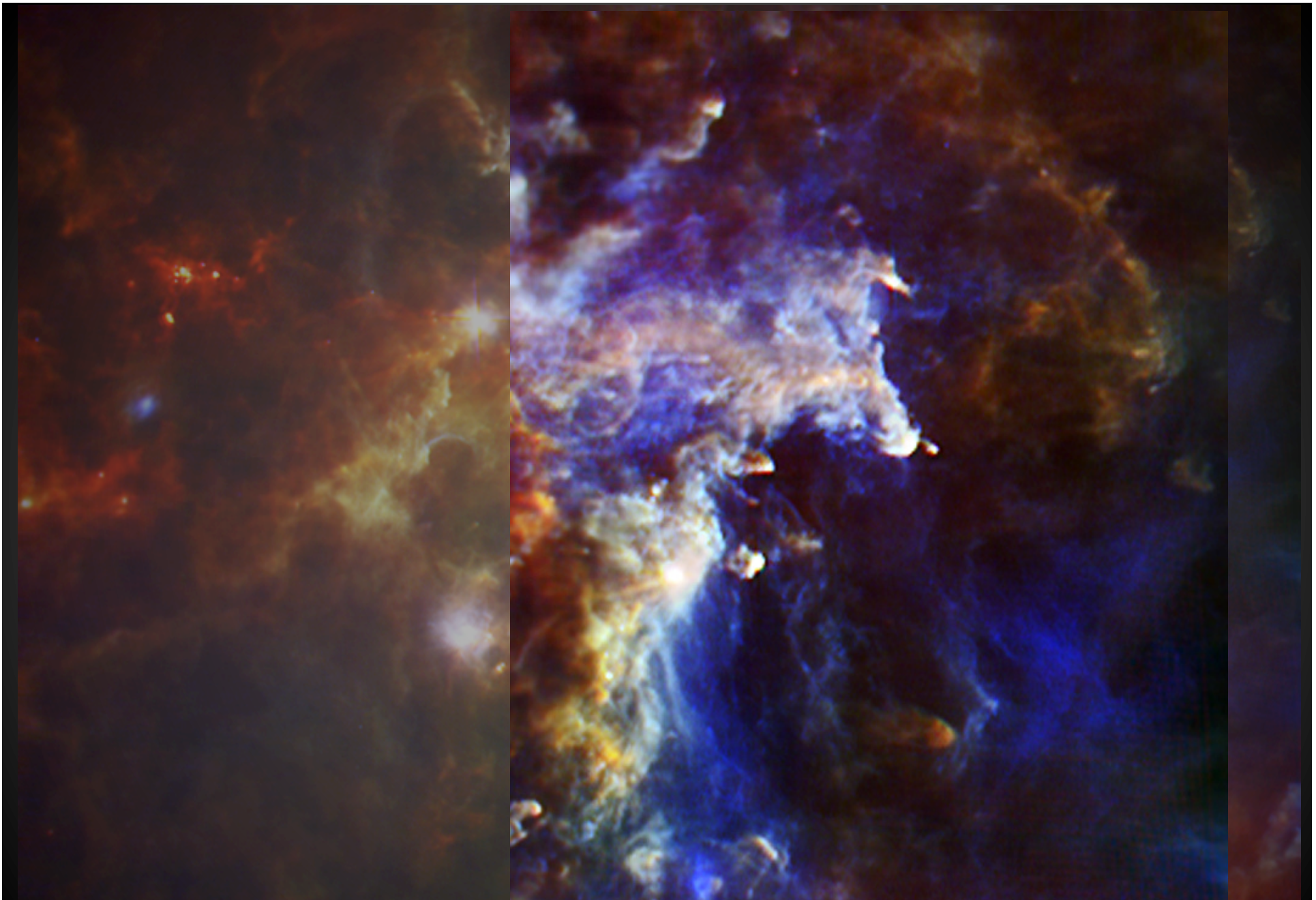
and the *Herschel imaging survey of OB Young Stellar objects*  
team

<http://hobys-herschel.cea.fr>

(Motte et al. 2010)

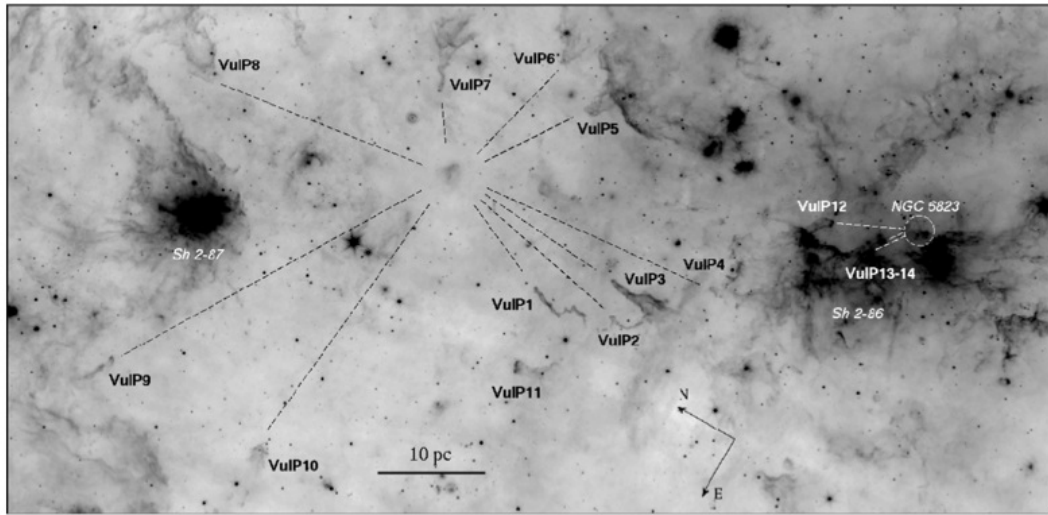


The Rosette Nebula, Schneider et al. 2010  
PACS (70, 160  $\mu\text{m}$ ) & SPIRE (250  $\mu\text{m}$ ) Herschel image



The Rosette Nebula, Schneider et al. 2010  
PACS (70, 160  $\mu\text{m}$ ) & SPIRE (250  $\mu\text{m}$ ) Herschel image

# Pillars and OB star clusters



The Vulpecula OB association (Billot et al. 2010)

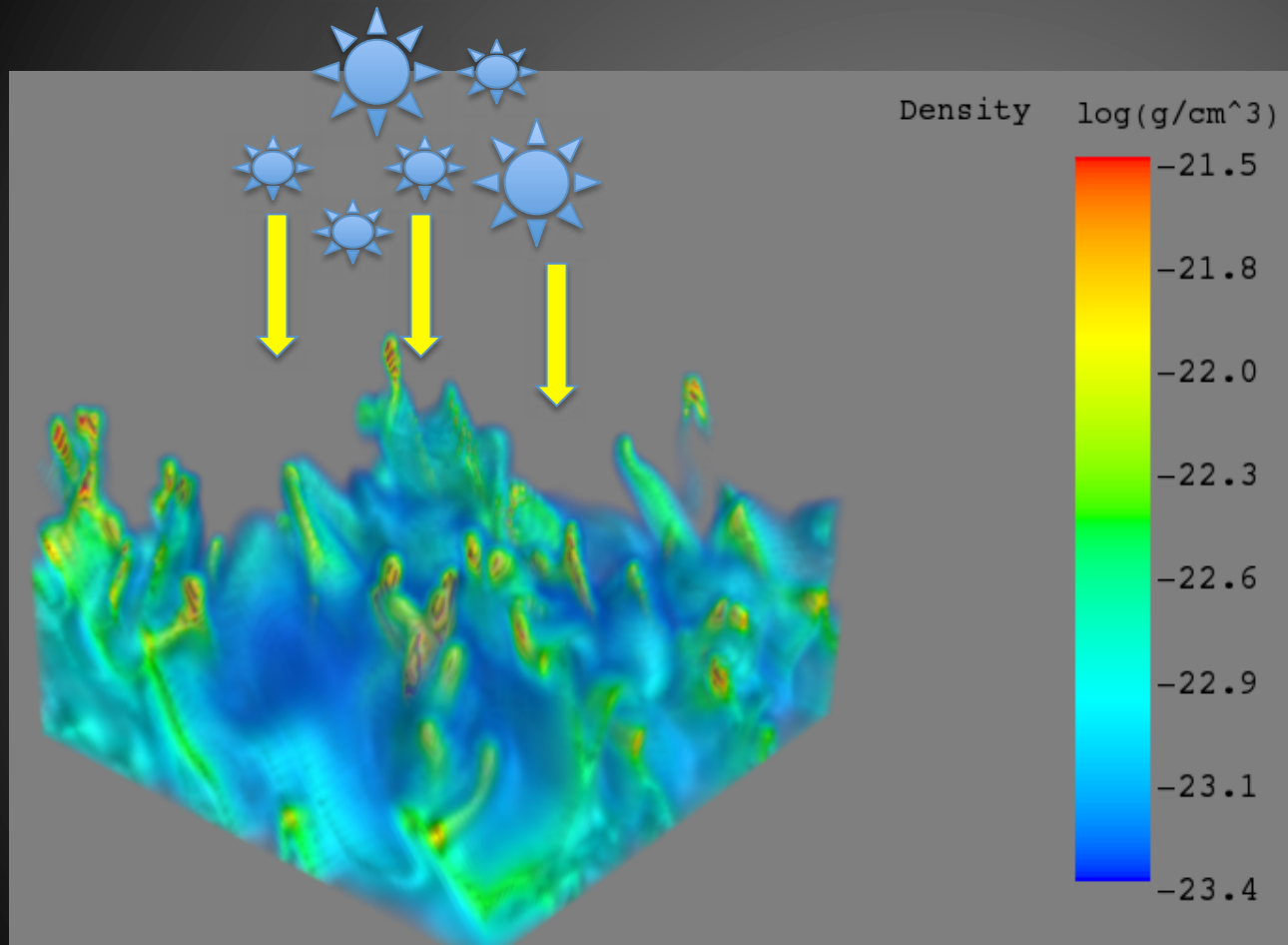


NGC3603



ESO VLT / M16

# How and when do pillars form ?

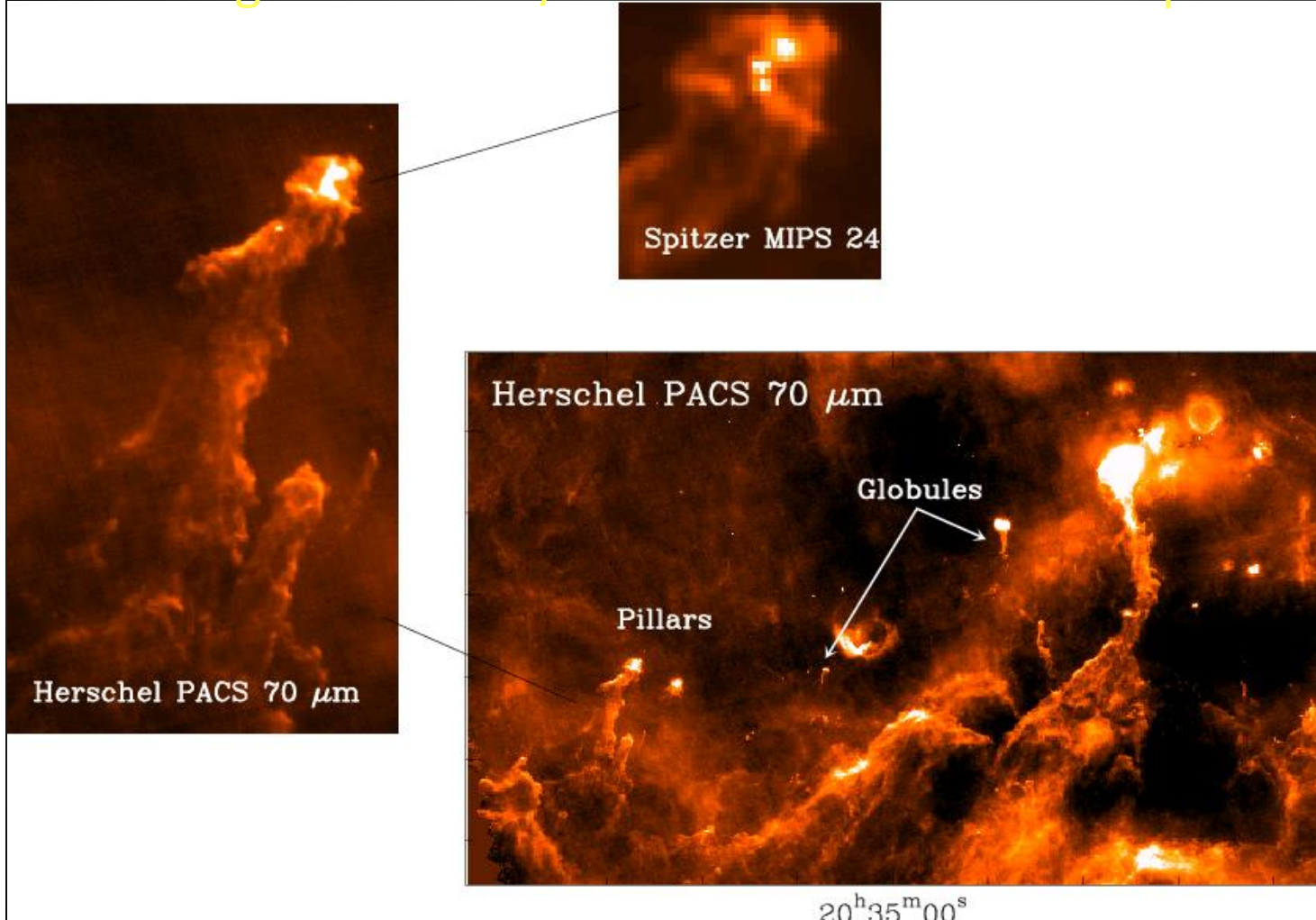


HERACLES simulation of pillar formation from the ISM

- Is strong UV radiation mandatory for their formation ?
- Under what temperature and density conditions do pillars form ?
- What is the physical relation between pillars and globules ?

# Do all pillars form stars and of which types ?

## New insights in the IR/submm with Herschel & Spitzer



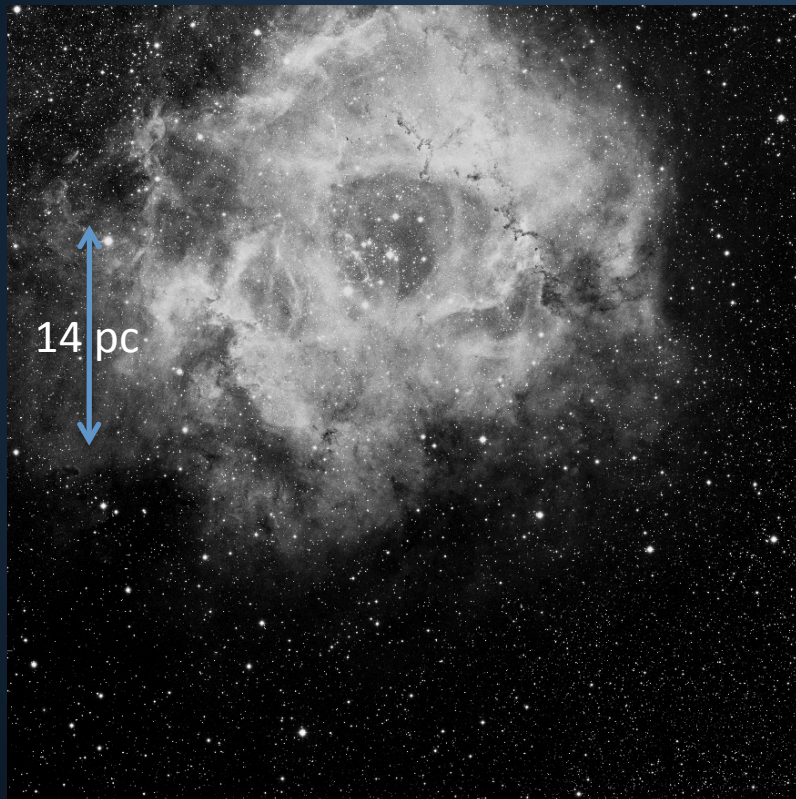
- Is star formation enhanced or hindered in pillars ?

- Is star formation triggered or revealed in pillars ?

- Which stars form under which initial conditions in the pillars ?

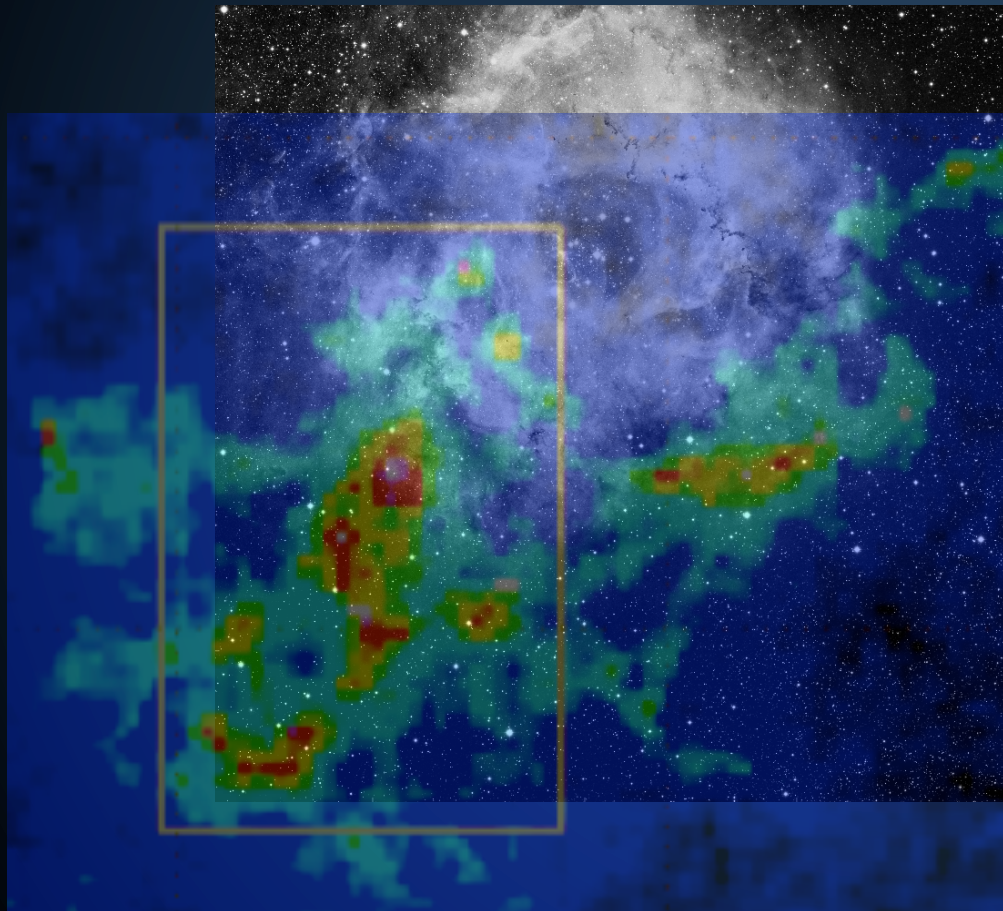
Herschel & Spitzer views of pillars in Cygnus X

# The Rosette Nebula



- $l=207^\circ$ ,  $b=-2.1^\circ$  in Monoceros at 1.6 kpc.
- NGC2244: an OB association of  $\sim 70$  high-mass stars (7 O stars).
- Ionising flux:  $10^{50}$  ph/s
- NGC2244: 2-4 Myr
- HII region
- $10^4 M_\odot$  gas nebula.

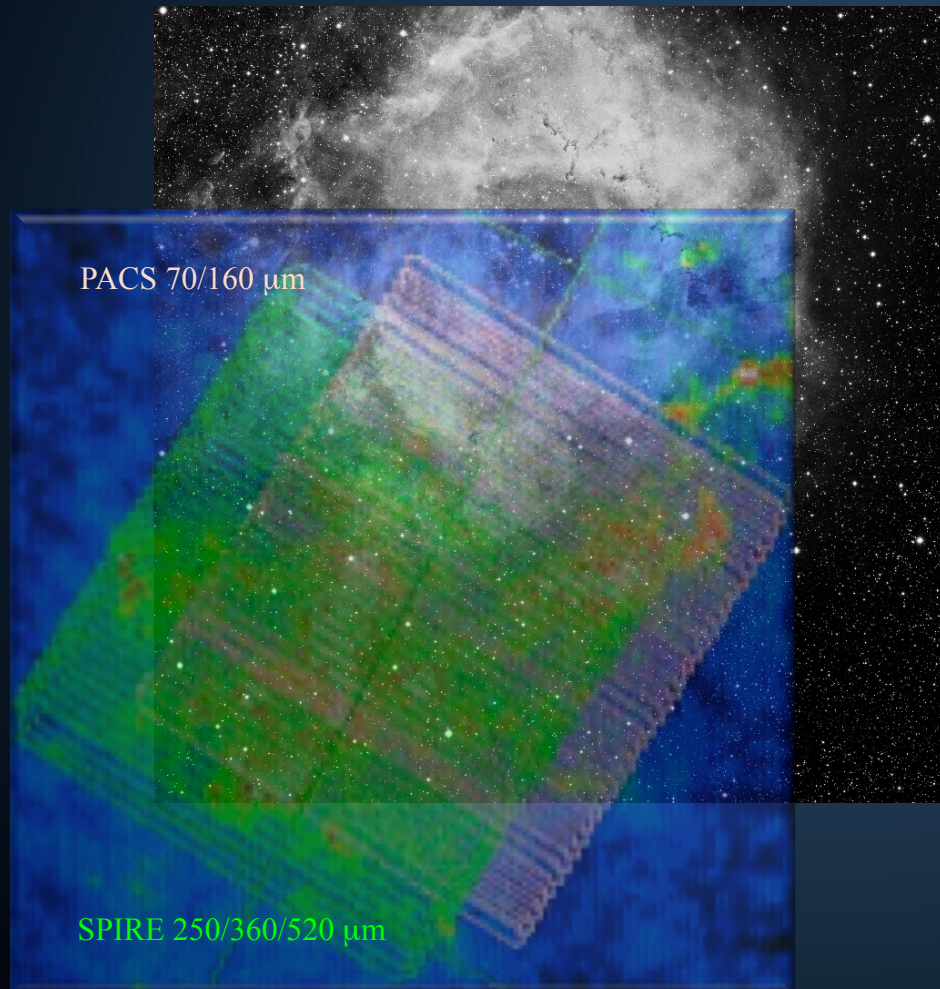
# Rosette Nebula: Molecular cloud



- NIR extinction:  $A_v$  from 5 to 15.
- Molecular cloud surrounding the OB star cluster.
- Target for Herschel

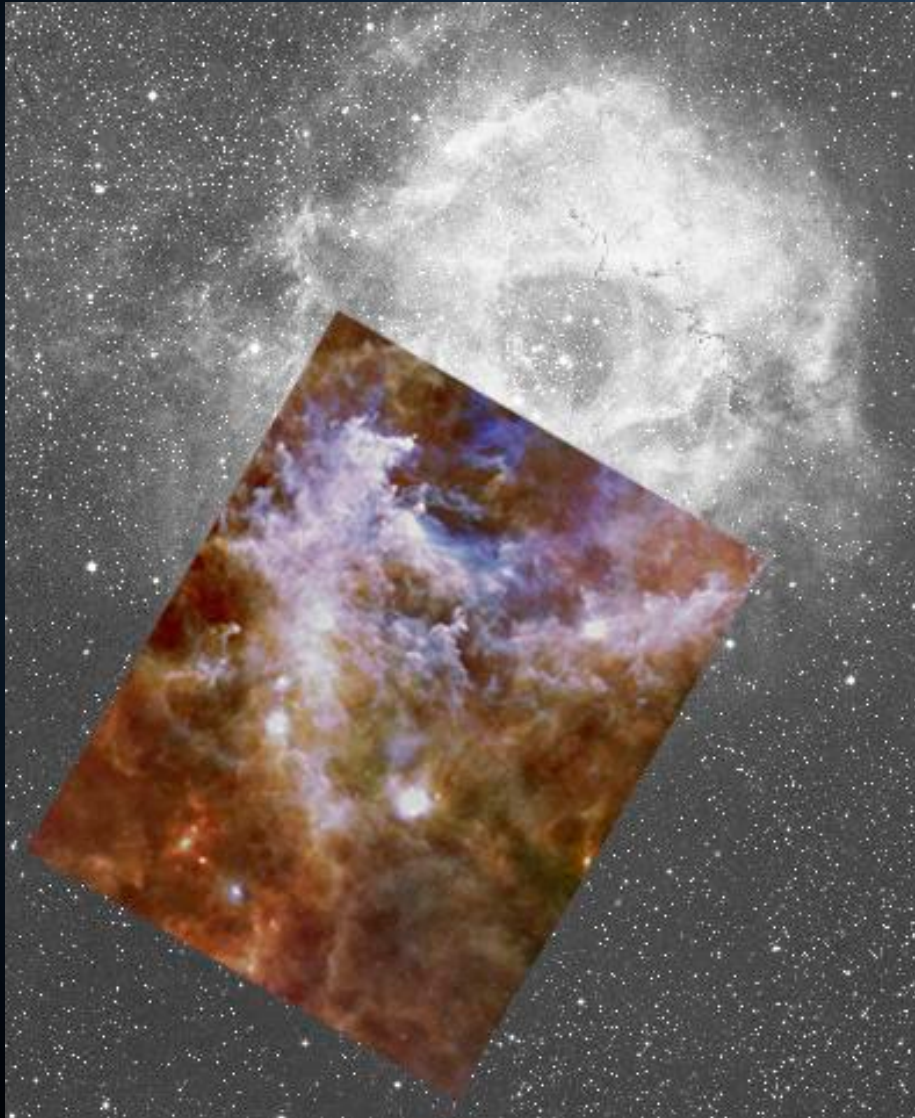


# Rosette Nebula: Herschel observations



- HOBYS key programme (Motte et al. 2010).
- PACS (70, 160  $\mu\text{m}$ ) & SPIRE (250, 350, 500  $\mu\text{m}$ ) in parallel mode.
- Scanning speed: 20''/s
- Two cross-linked coverages of size  $1^{\circ}45' \times 1^{\circ}25'$  were performed.
- See Schneider et al. 2010

# The Rosette Nebula seen by Herschel



- Herschel: three-colour FIR & submm image (70, 160, 500  $\mu\text{m}$ ).
- Optical image:  $\text{H}_\alpha$  from the DSS.
- See: Schneider et al. 2010

# The Rosette Nebula

Schneider et al. 2010

Henneman et al. 2010

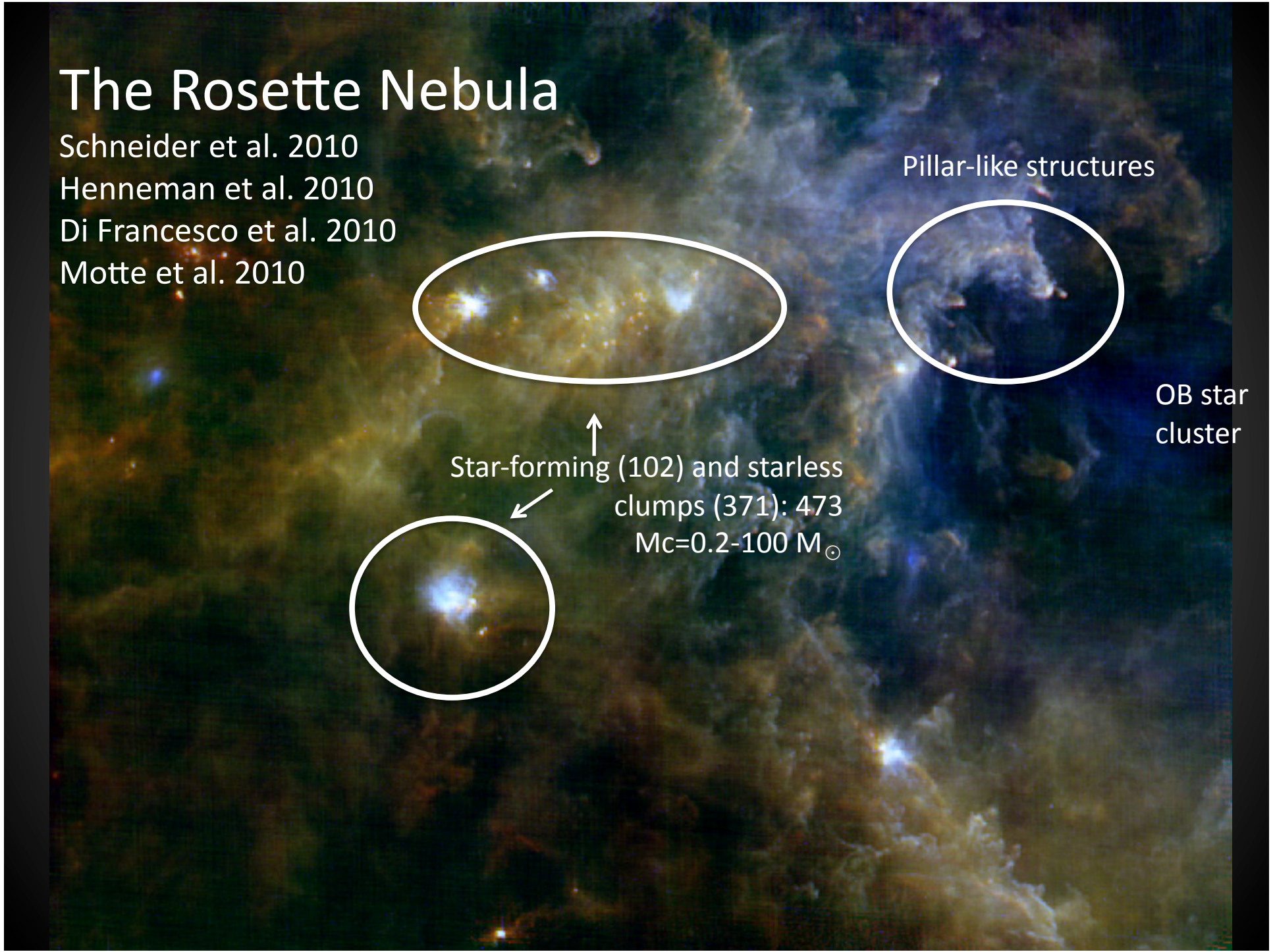
Di Francesco et al. 2010

Motte et al. 2010

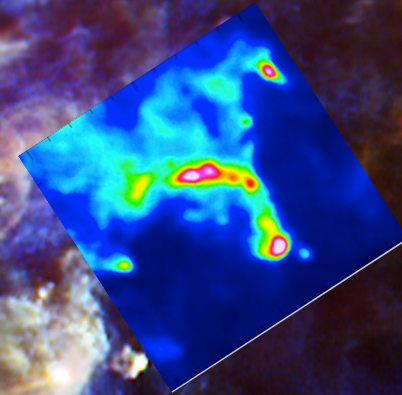
Pillar-like structures

OB star cluster

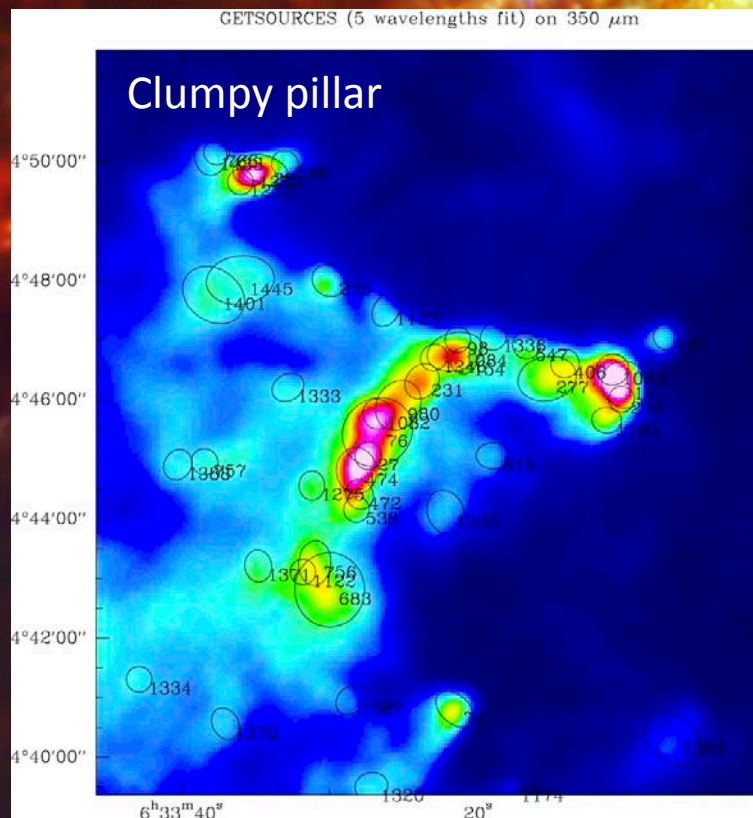
Star-forming (102) and starless  
clumps (371): 473  
 $M_c = 0.2 - 100 M_{\odot}$



Do the OB star cluster and associated HII region shape the pillar-like structures? Do they trigger star formation inside?

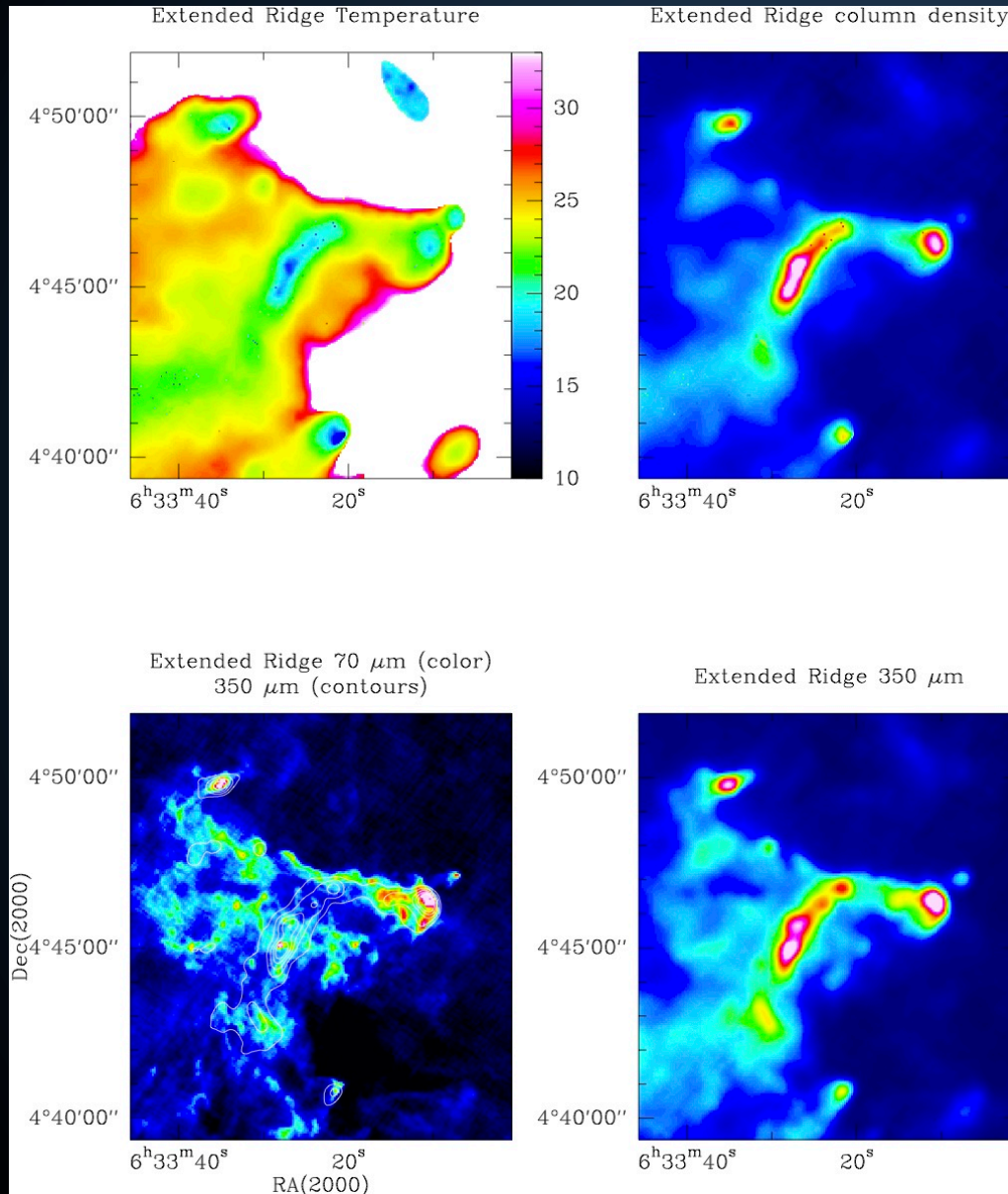


OB star cluster



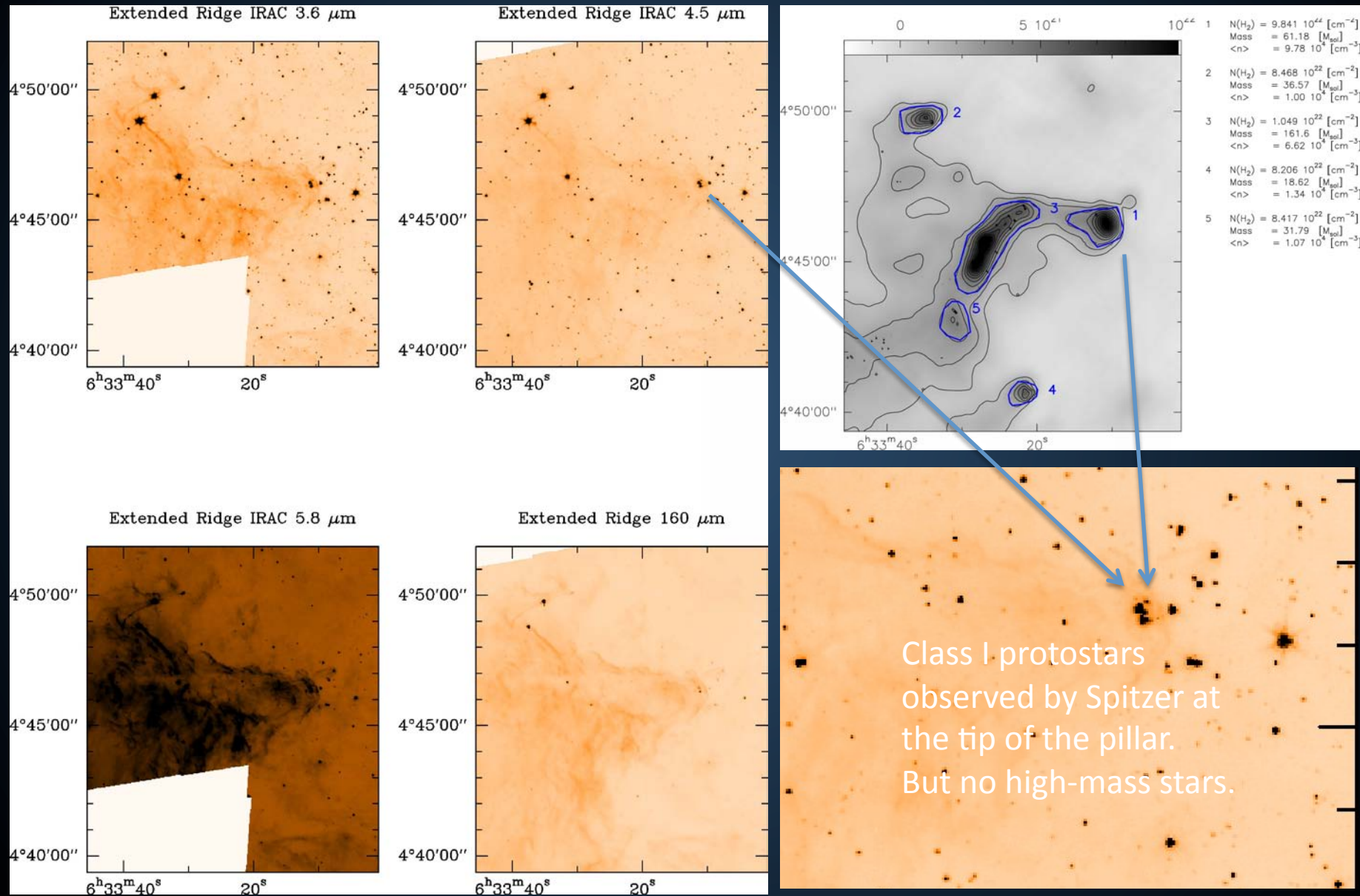
Schneider et al. 2010  
Di Francesco et al. 2010

# Rosette Nebula - Pillars

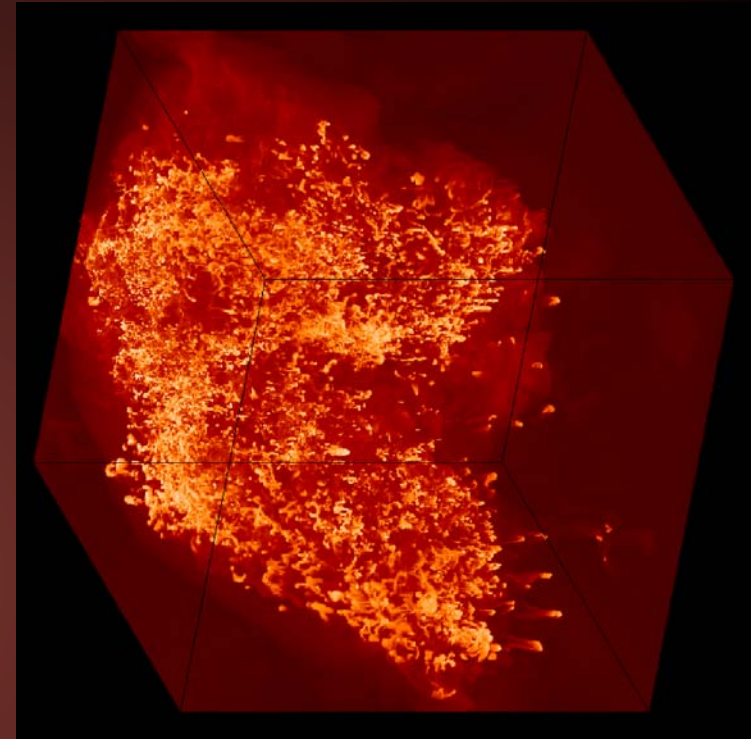
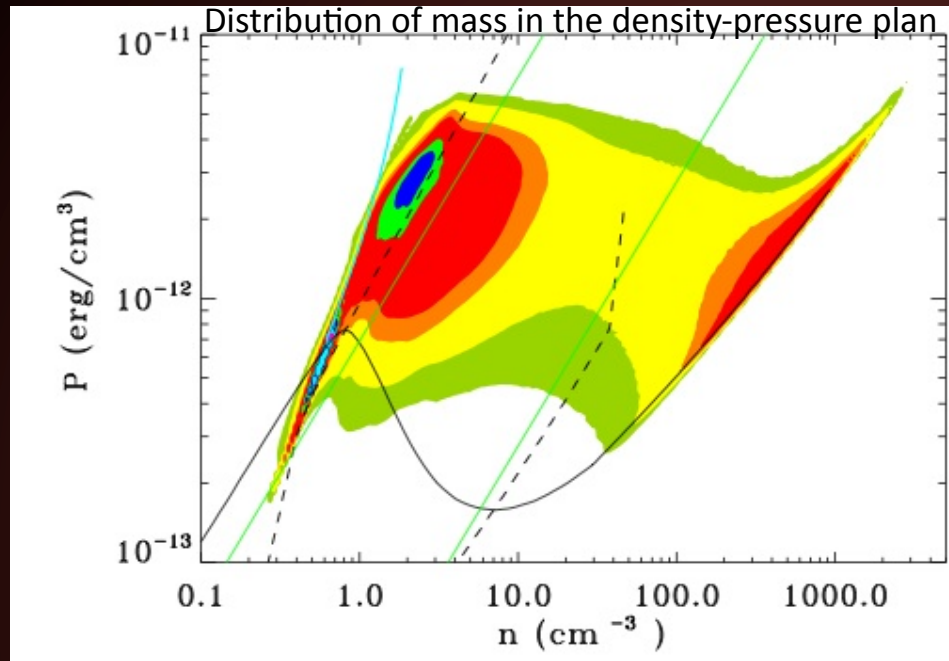


- Distance from OB star cluster: 10 pc
- Size: ~10 pc
- Temperatures: 10-30 K
- Pillar surface @ 30 K
- Pillar inside clumps @ 15 K
- $N: 10^{21} - 10^{23} \text{ cm}^{-2}$
- Mean density:  $0.3 \text{ cm}^{-3}$
- Peak clump densities:  $10^4 - 10^5 \text{ cm}^{-3}$

# Rosette Nebula – Pillar star formation



# Pillar formation: Simulation



HERACLES code (e.g. Audit & Hennebelle 2009)

- Second order Godunov type hydrodynamics code (finite volumes on fixed grid).
- Turbulent initial ISM gas.
- Biphasic gas with cooling function (Wolfire et al. 1995).
- Hydrodynamics (density, velocity and energy through Euler equations).
- Gravity (external source) and self-gravity included.
- Impact of UV star radiation solved with radiative transfer equation.
- Possibility of including a module of magneto-hydrodynamics.

# Pillar formation: Simulation

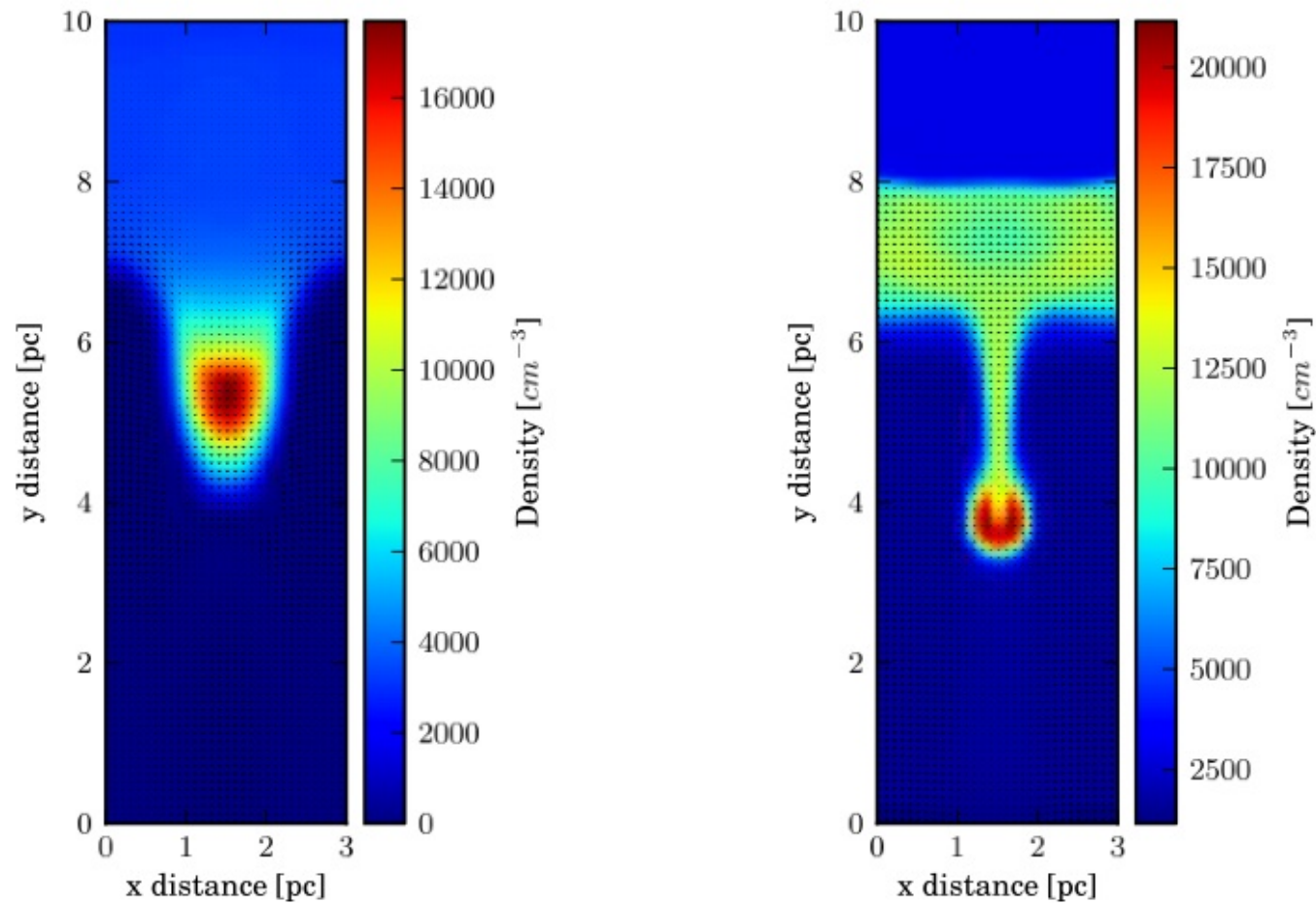
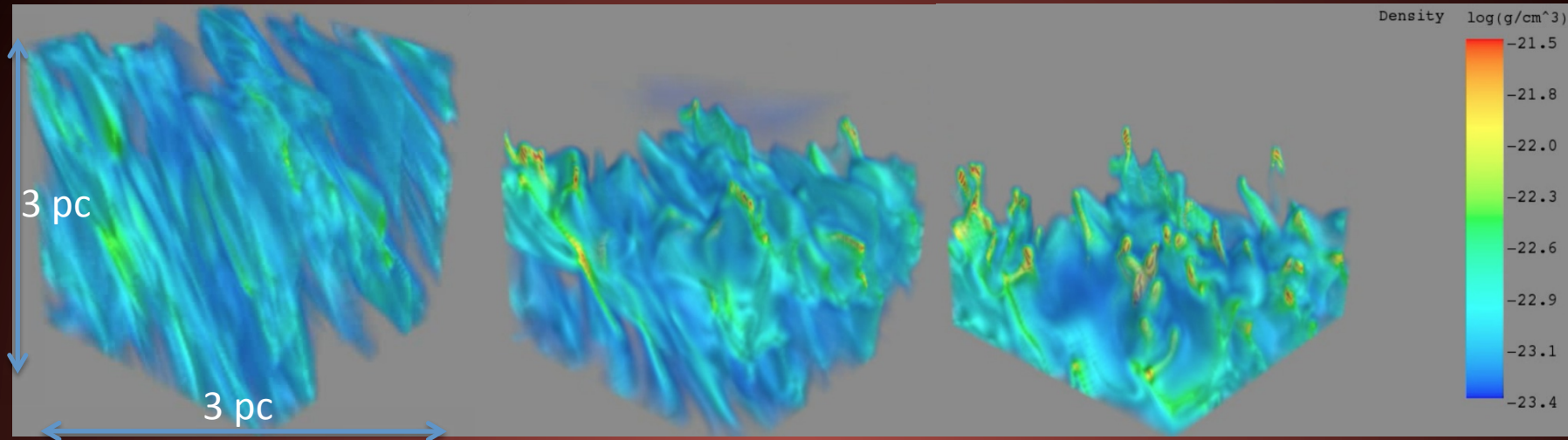


Figure 12: Clump in a homogeneous medium; left:  $t = 15 My$  under gravity  $g = 10^{-10} cm/s^2$ , right:  $t = 1 My$  under a ionization front  $F = 8.10^9 \gamma/s/cm^2$



# Pillar formation: Simulation



Start with:

- Weakly turbulent atomic gas (subsonic).
- $\langle n \rangle = 10 \text{ cm}^{-3}$
- Ionisation by OB stars at  $10^{50}$  ph/s.

+250 000 yr

- Formation of denser filaments due to ionisation.

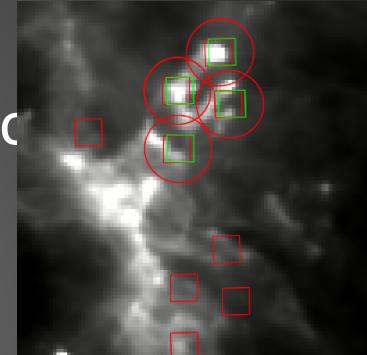
+500 000 yr

- Filaments and globules.
- $\langle n \rangle = 10^3 \text{ cm}^{-3}$
- Initial turbulent velocities are not necessarily conserved.

# Summary and perspective

## Rosette Nebula

- Precise temperature and column density maps of pillars have been obtained.
- Pillars form low-mass stars.



## Towards a classification of pillars/globules ?

- Pillar forming with molecular cloud
- Pillar forming around already formed molecular cloud
- Globules separating from pillars
- Star-forming pillars
- Future projects: simulation + spectral line observations (OT Herschel proposal)

## The Rosette Nebula

The HOBYS key programme with the Herschel space observatory  
ESA, PACS & SPIRE consortia

[http://hobys-herschel.cea.fr](http://hobys-herschel cea.fr)

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