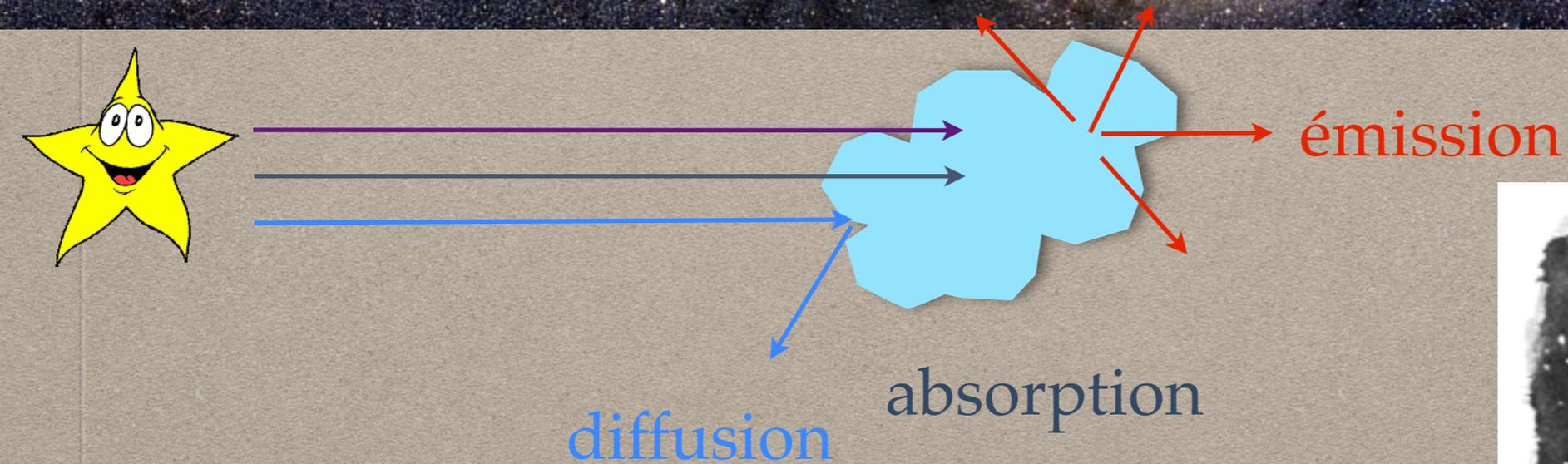




**LES POUSSIÈRES
INTERSTELLAIRES**

LES POUSSIÈRES INTERSTELLAIRES

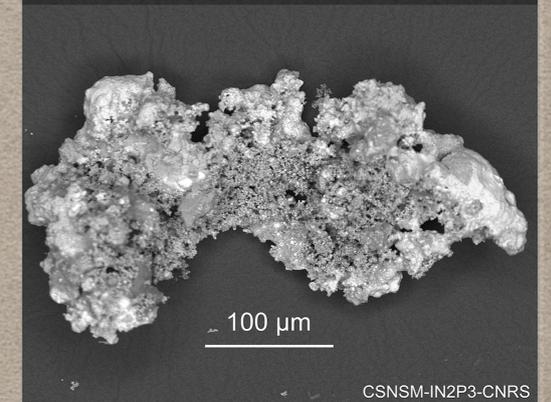
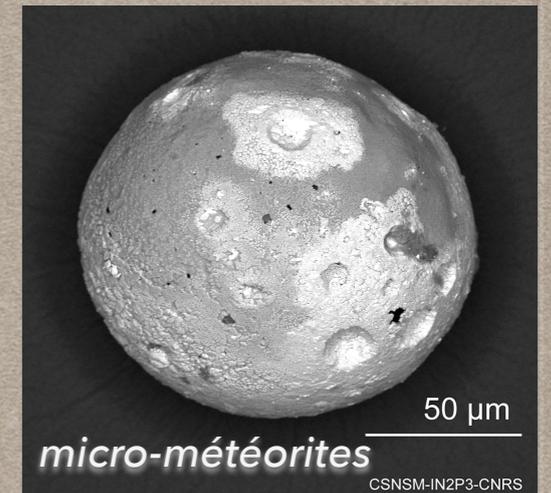


- 1% de la masse du gaz
- affecte le rayonnement: absorption, diffusion, rougissement, extinction, polarisation et émission
- La plupart des atomes de C, Si, Mg, Fe, Al, Ti, Ca sont dans les poussières

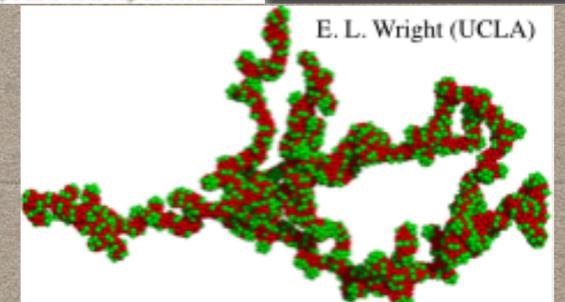
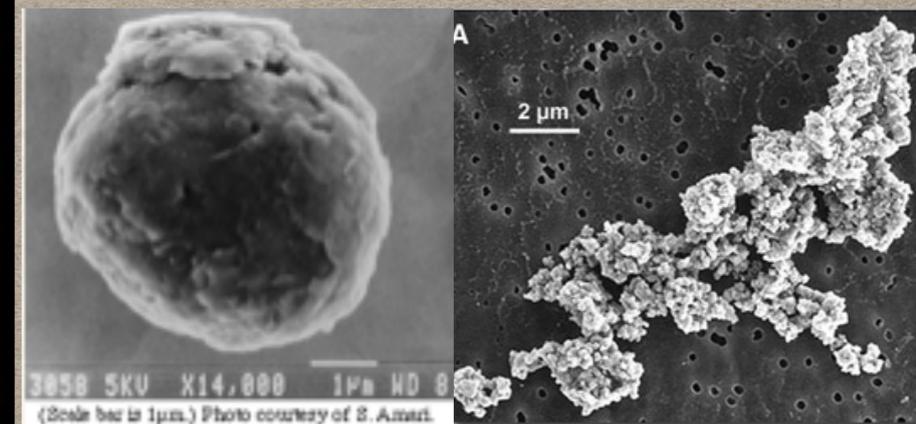
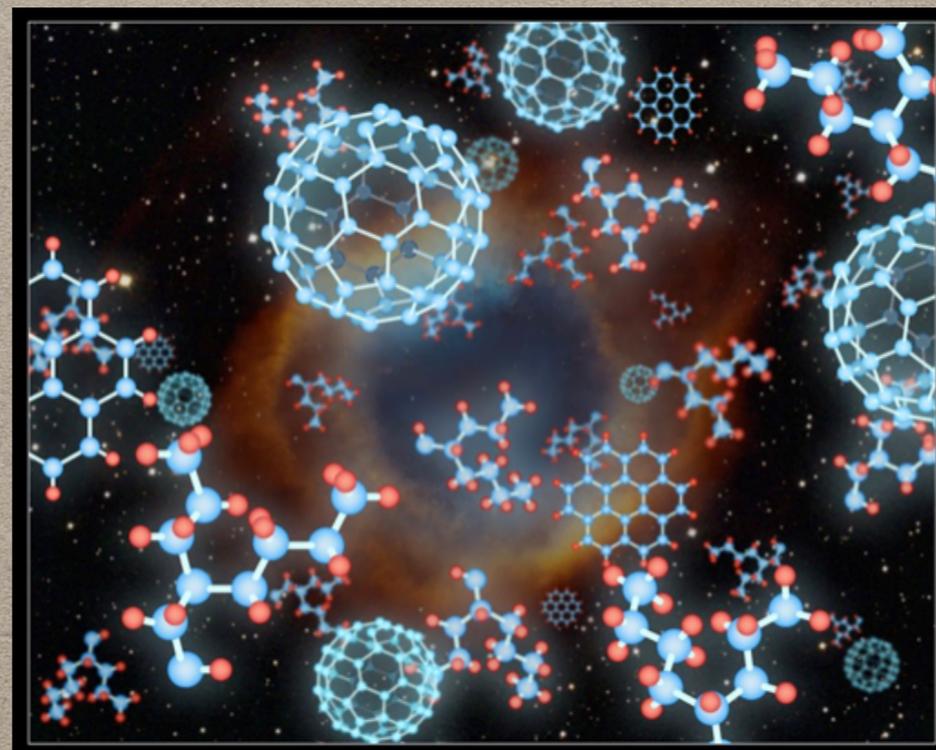
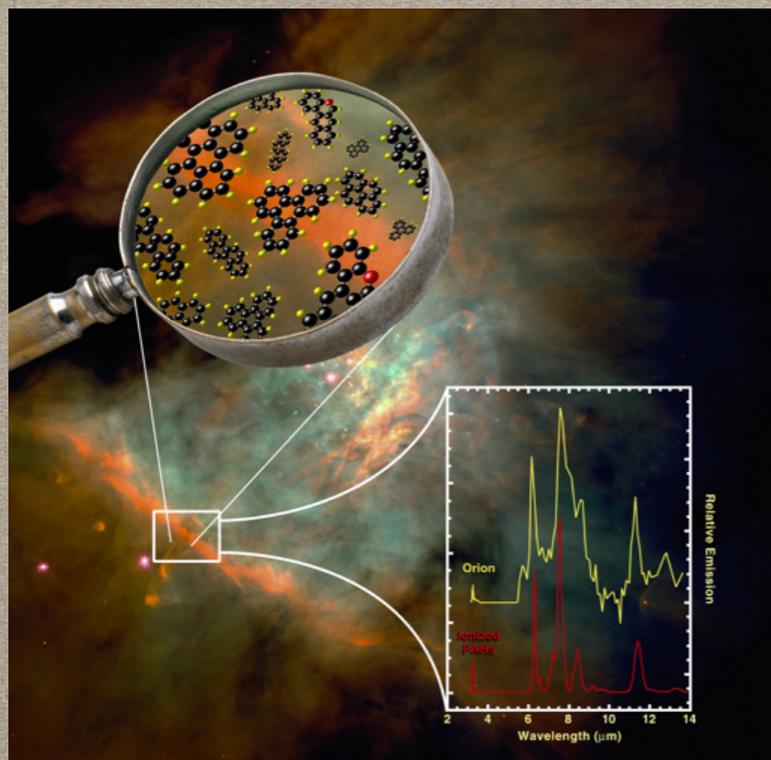


"Sure it's beautiful, but I can't help thinking about all that interstellar dust out there."

LES POUSSIÈRES INTERSTELLAIRES



- grains de carbone, de silicates, manteaux de **glace**
- tailles: grosses molécules à quelques microns
- PAHs: hydrocarbures aromatiques polycycliques





Pre-Collapse Black Cloud B68 (visual view)
(VLT ANTU + FORS 1)

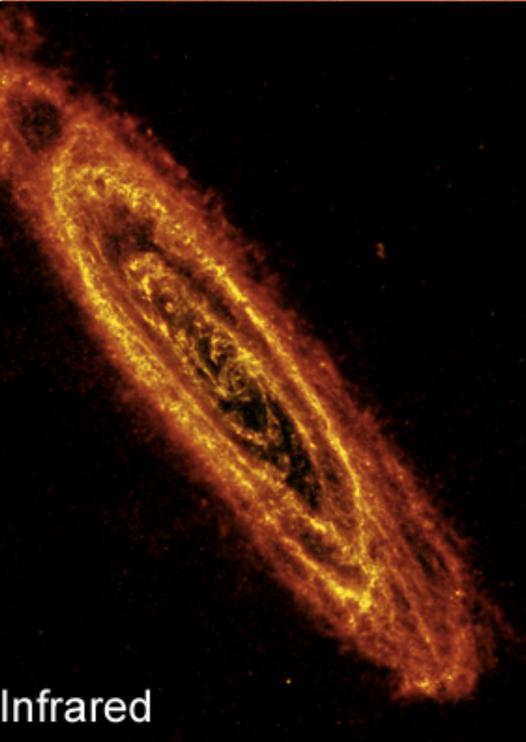
ESO PR Photo 12a/01 (16 January 2001)

© European Southern Observatory



Les poussières absorbent la lumière
Ultra-Violette et visible et ré-émettent
l'énergie dans l'infrarouge
(Observations avec des satellites)

Image credit: [Robert Gendler](#) (visible) ; ESA / Herschel / SPIRE / [HELGA](#) (far-infrared).



Infrared



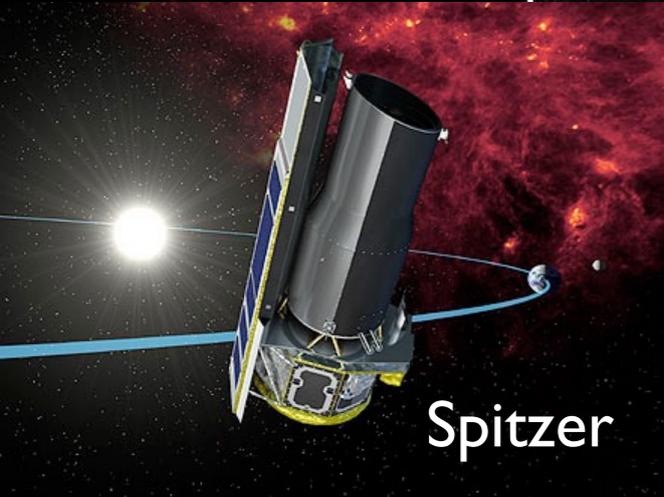
Visible & Infrared



Visible



centre galactique



Spitzer



Herschel

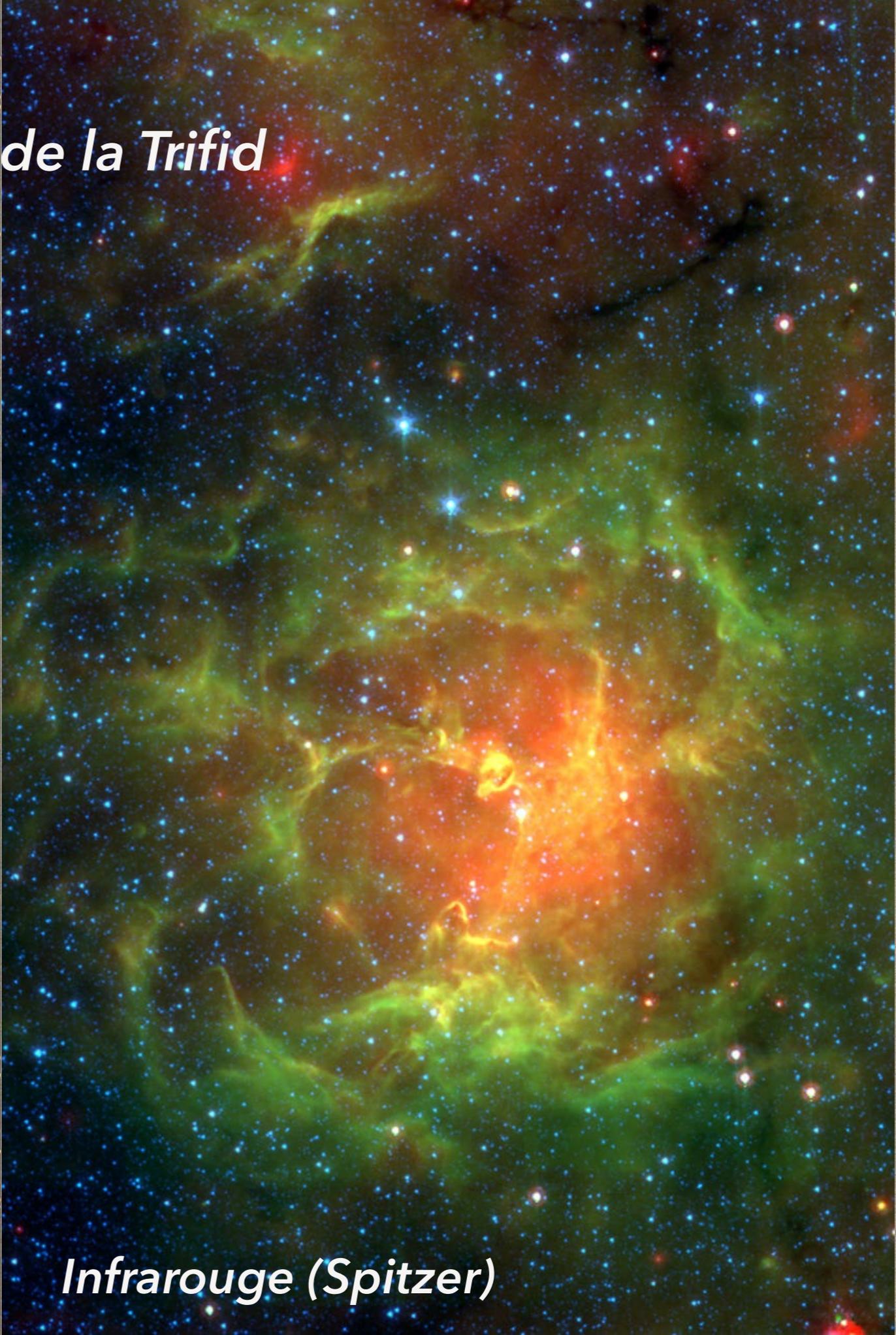


Planck

Nébuleuse de la Trifid



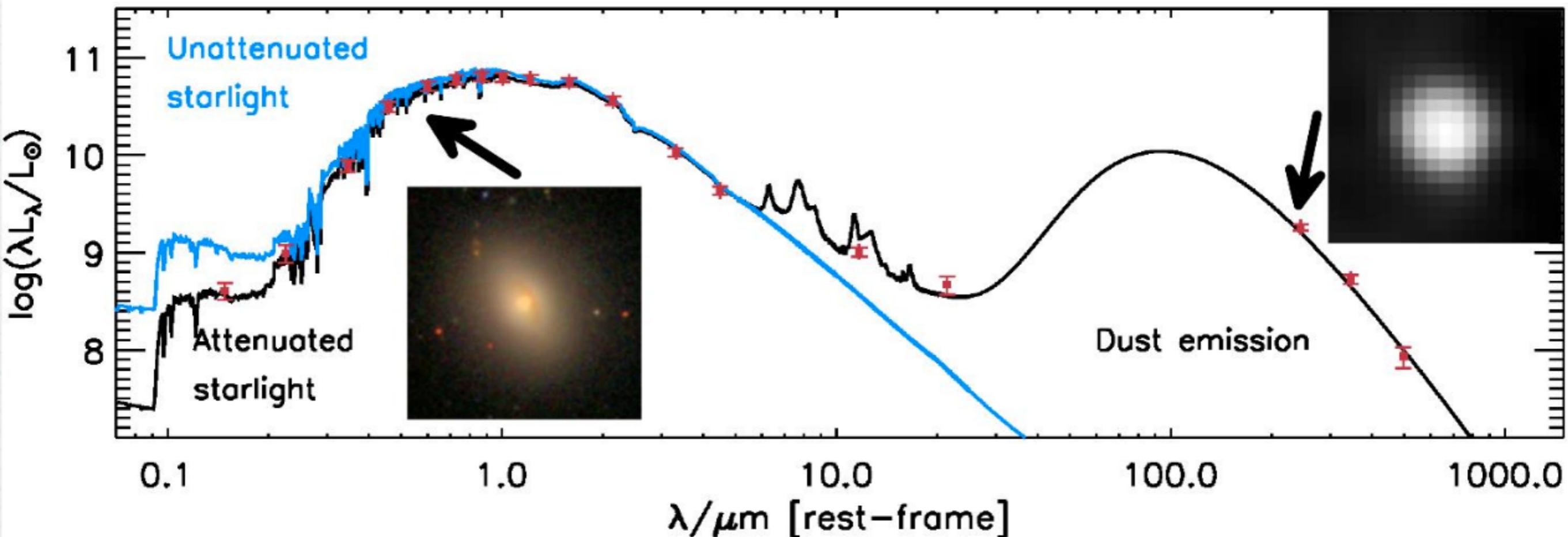
Visible (NOAO)



Infrarouge (Spitzer)

EXTINCTION

- absorption et diffusion de la lumière des étoiles
- L'énergie absorbée est ré-émise dans l'infrarouge moyen et lointain

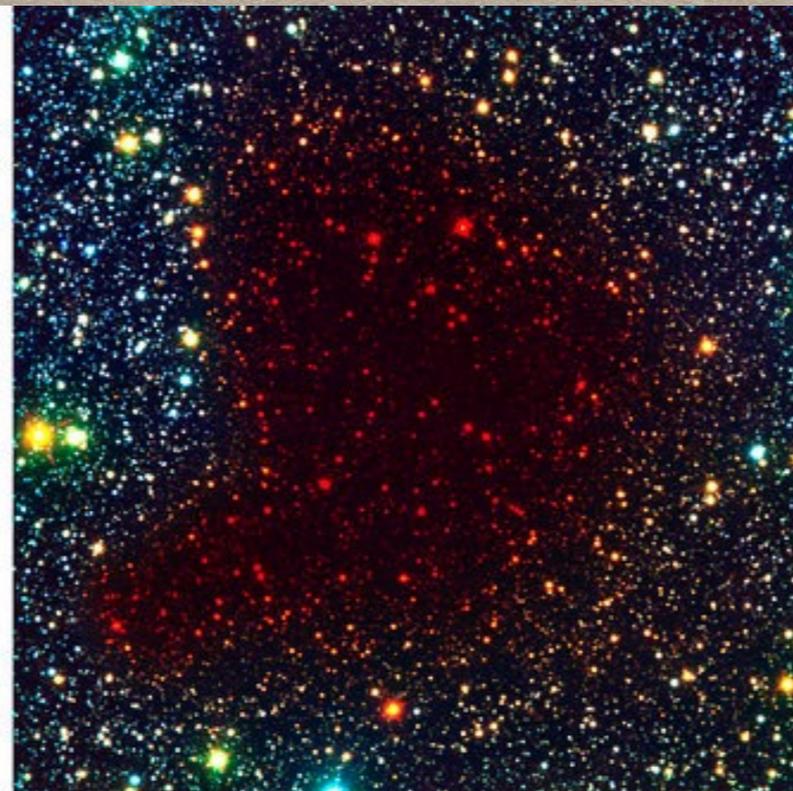


EXTINCTION

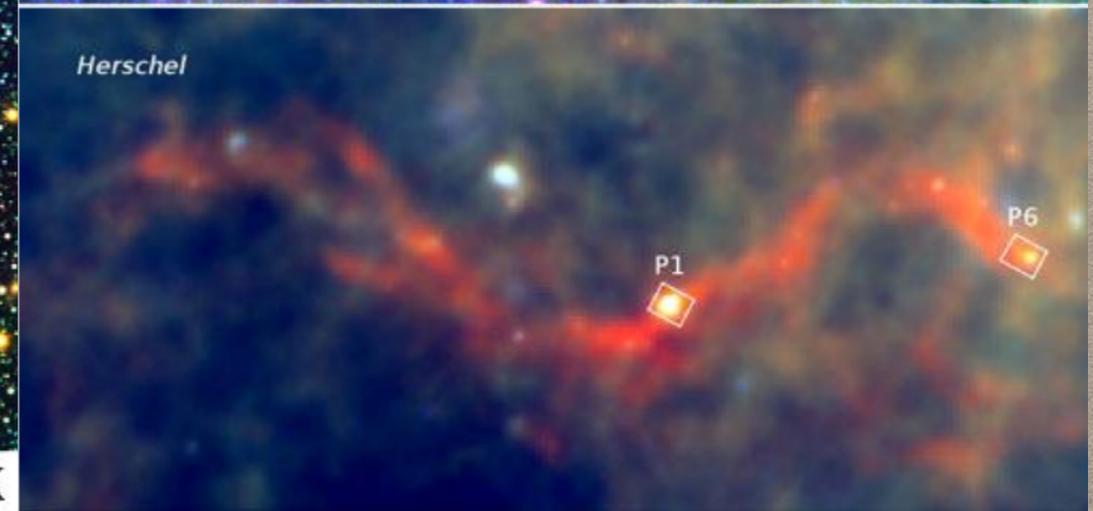
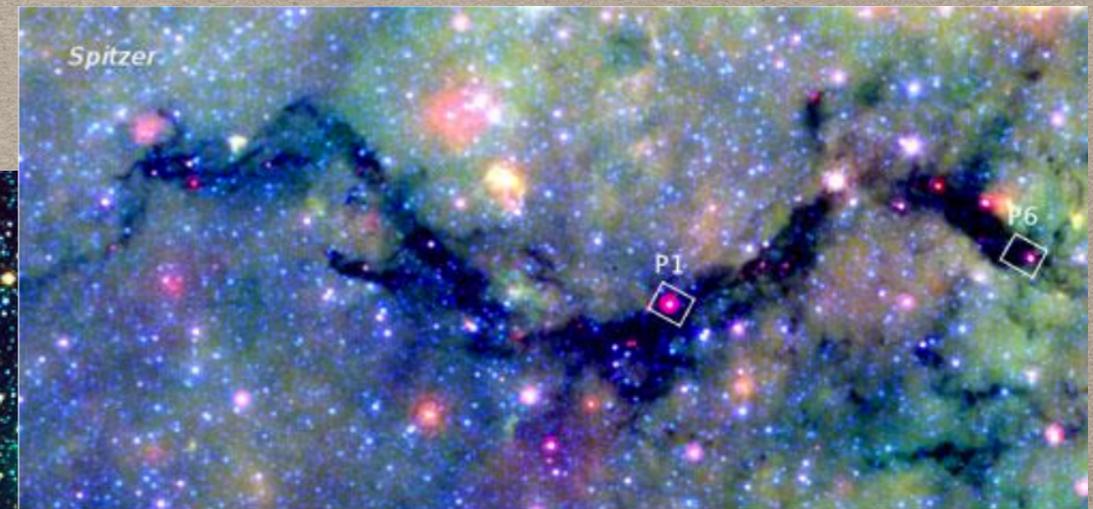
- extinction dans UV, visible, mais aussi IR
- La lumière diffusée est plus **bleue** que celle de l'étoile illuminatrice
- La lumière transmise est plus **rouge**
- Spécialiste maison: L. Cambrésy



B, V, I



B, I, K



visible



infrarouge proche





Visible

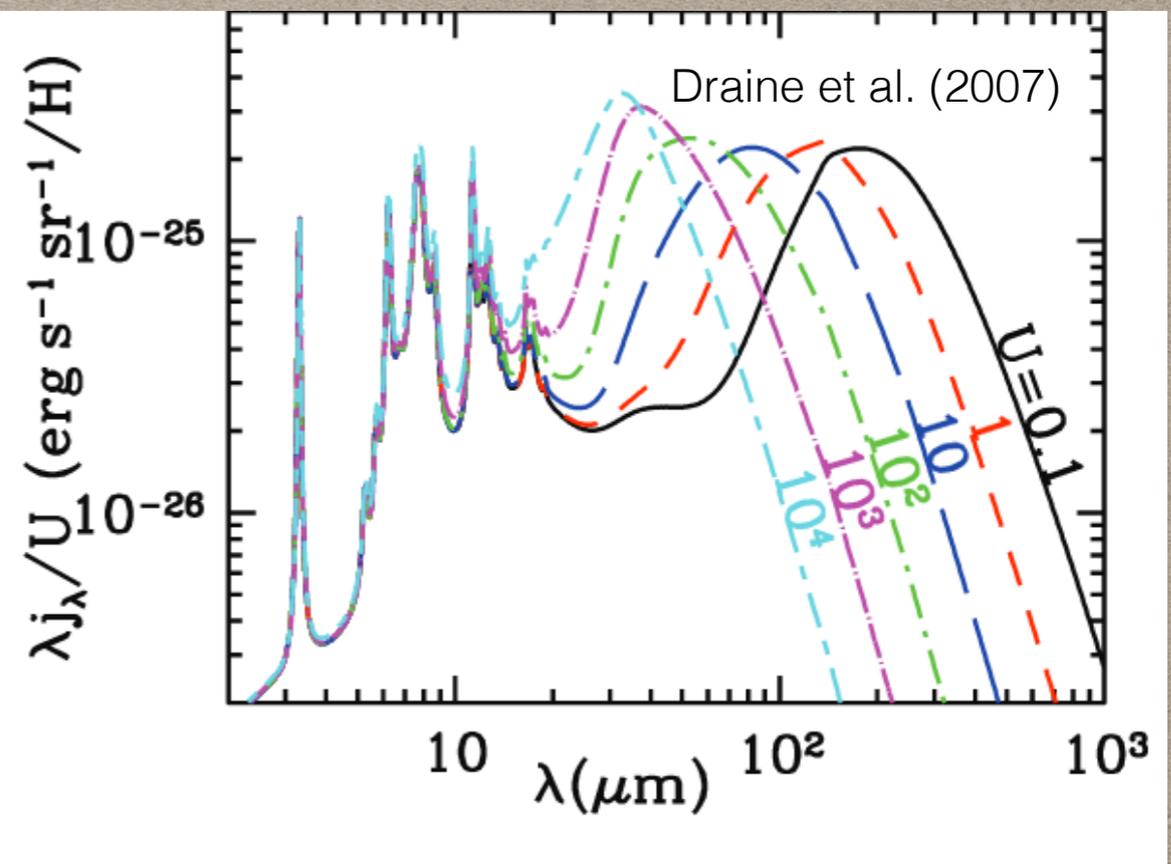
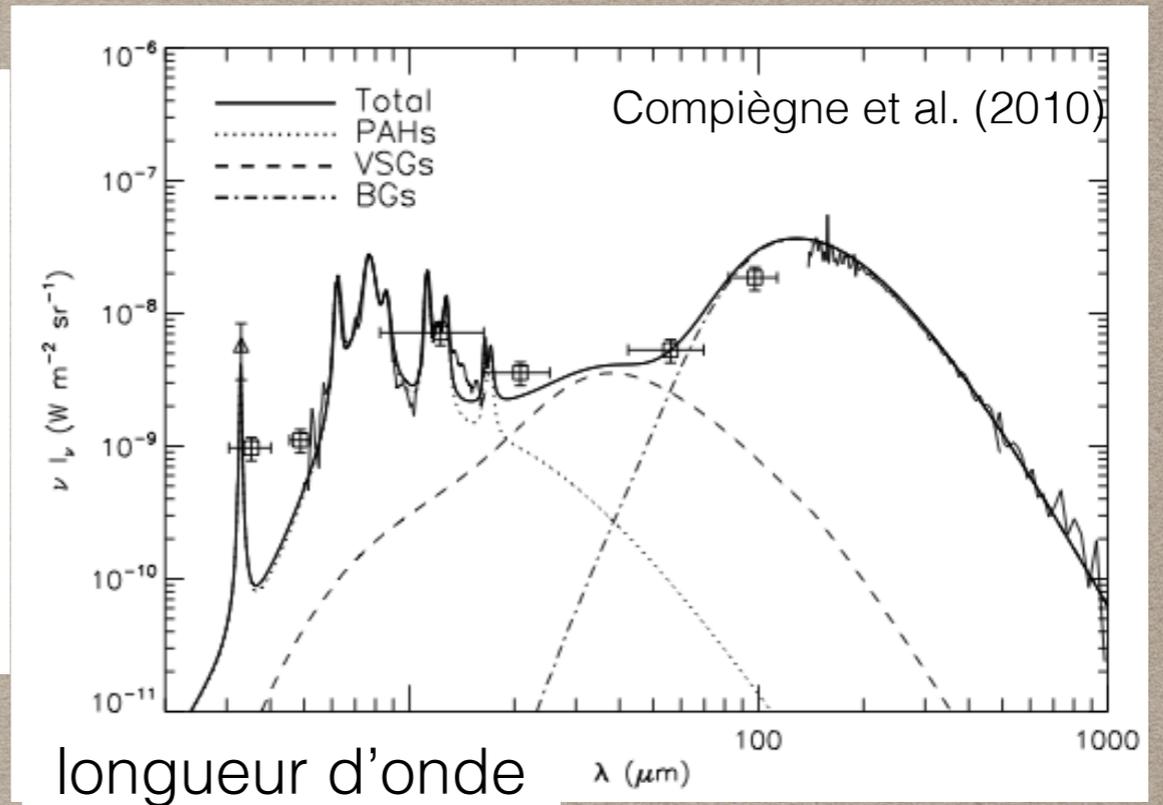


Infrared

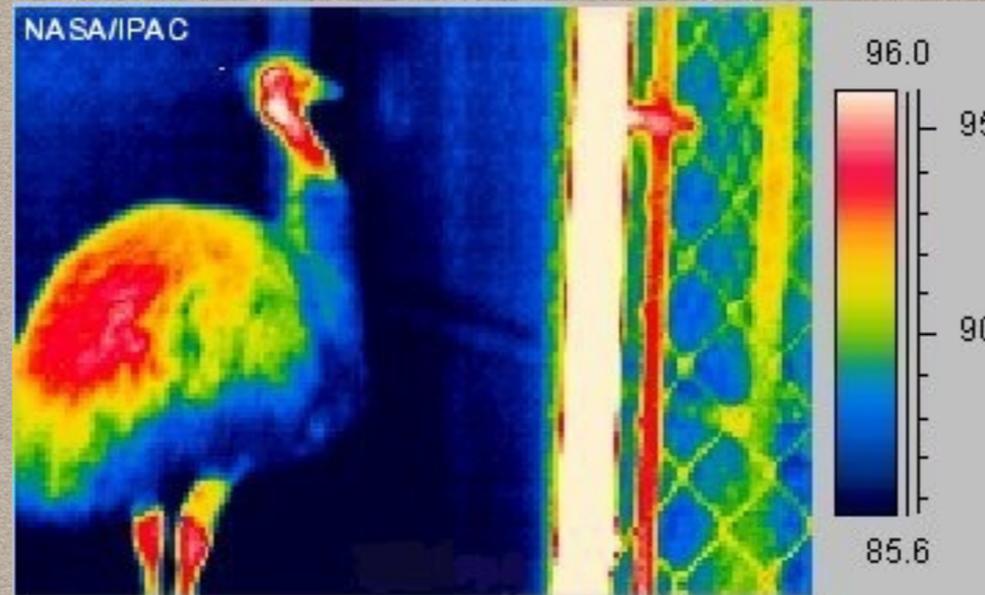
EMISSION DE LA POUSSIÈRE

- L'énergie absorbée est ré-émise dans l'infrarouge et le (sub-millimétrique)
- Suivant le domaine de longueur d'ondes:
 - émission des PAHs, petits grains, gros grains
 - émission des poussières chaudes à froides
- Spécialiste maison: C. Bot

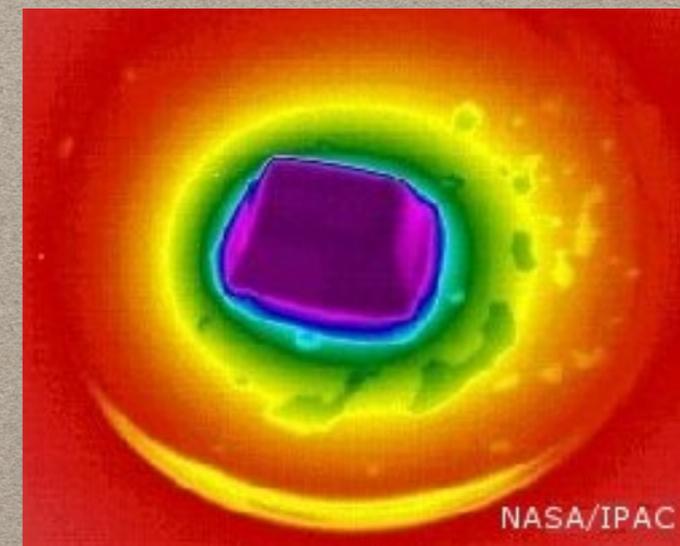
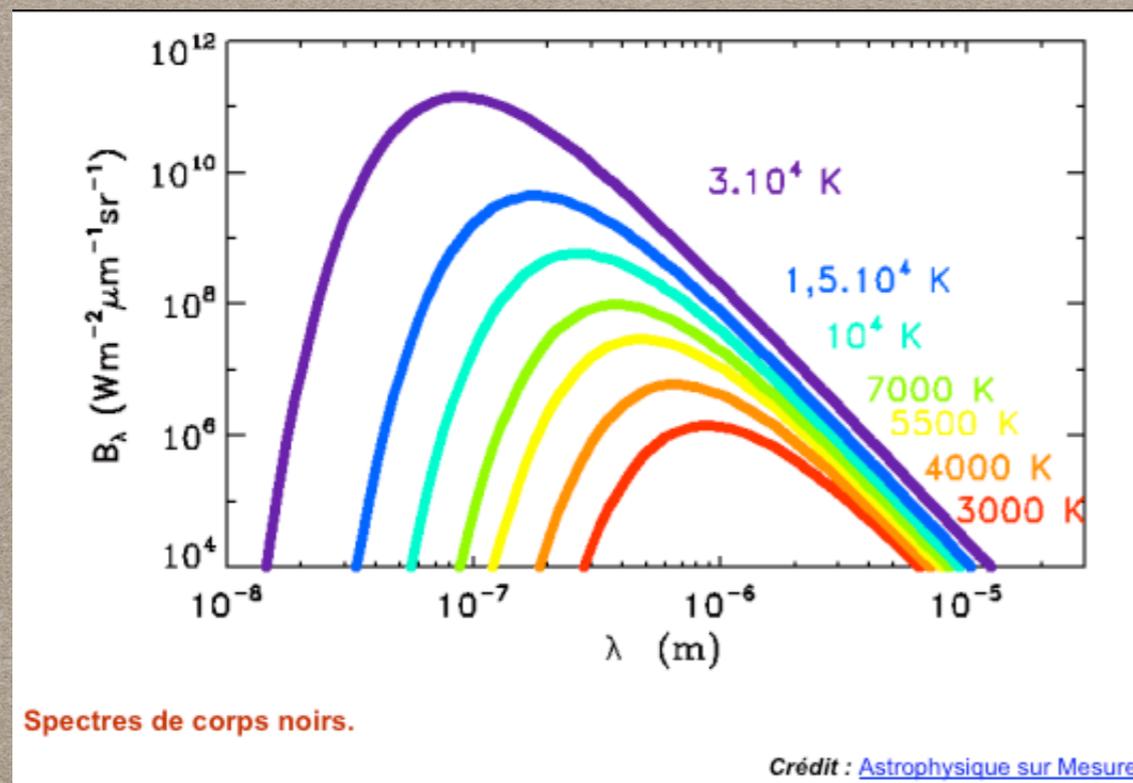
intensité lumineuse



RAYONNEMENT THERMIQUE



- corps noirs: le rayonnement dépend de la température



PREMIÈRES OBSERVATIONS

THE INFRARED-GALAXY PHENOMENON

FRANK J. LOW

Department of Space Science, Rice University, Houston, Texas, and Lunar and Planetary Laboratory, University of Arizona, Tucson

Received 1970 January 15; revised 1970 February 5

ABSTRACT

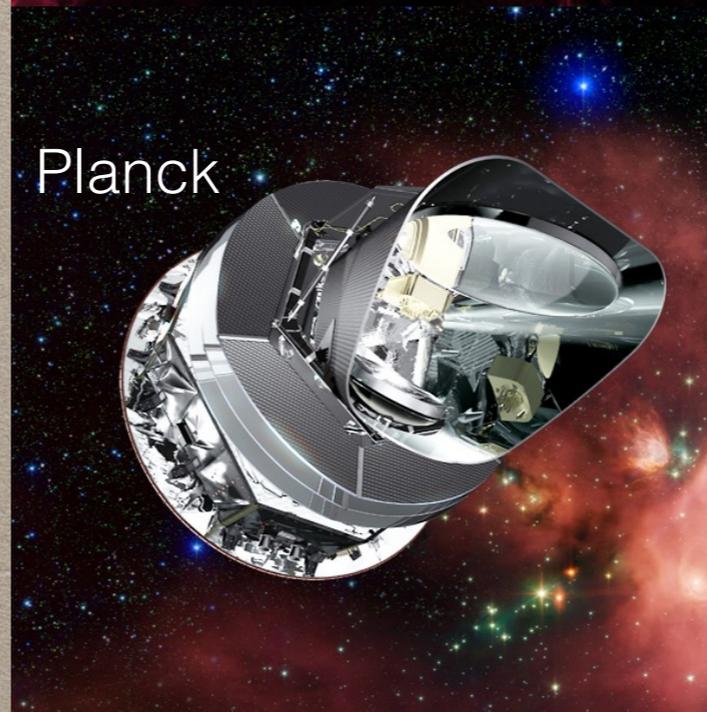
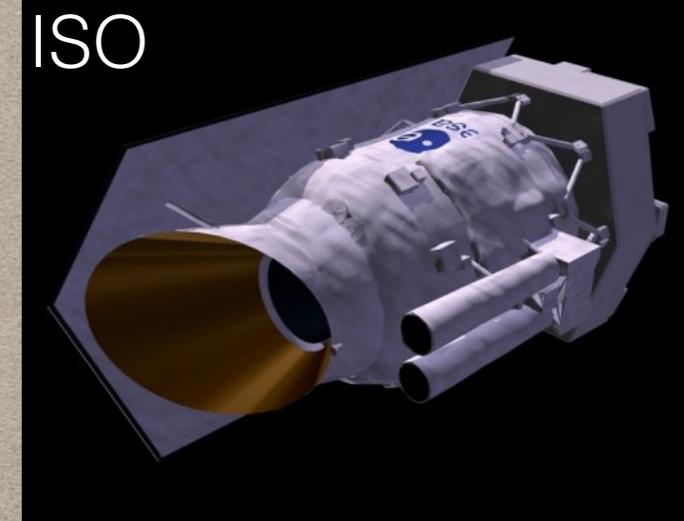
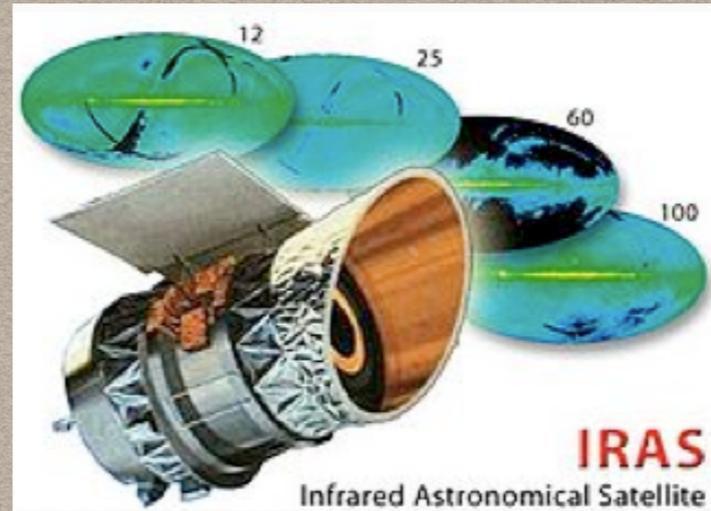
An ensemble of identical infrared sources, called irtrons, radiates the quiescent infrared continuum now found to characterize the nuclei of all galaxies. Continuous creation of matter and antimatter within the irtrons releases energies greater than 10^{62} ergs. The observed infrared continuum results from coherent synchrotron decay of electrons and positrons produced by annihilation. The observed infrared luminosities form an evolutionary sequence beginning with QSOs, extending to Seyfert galaxies and exploding galaxies, and ending with large spirals like our own.

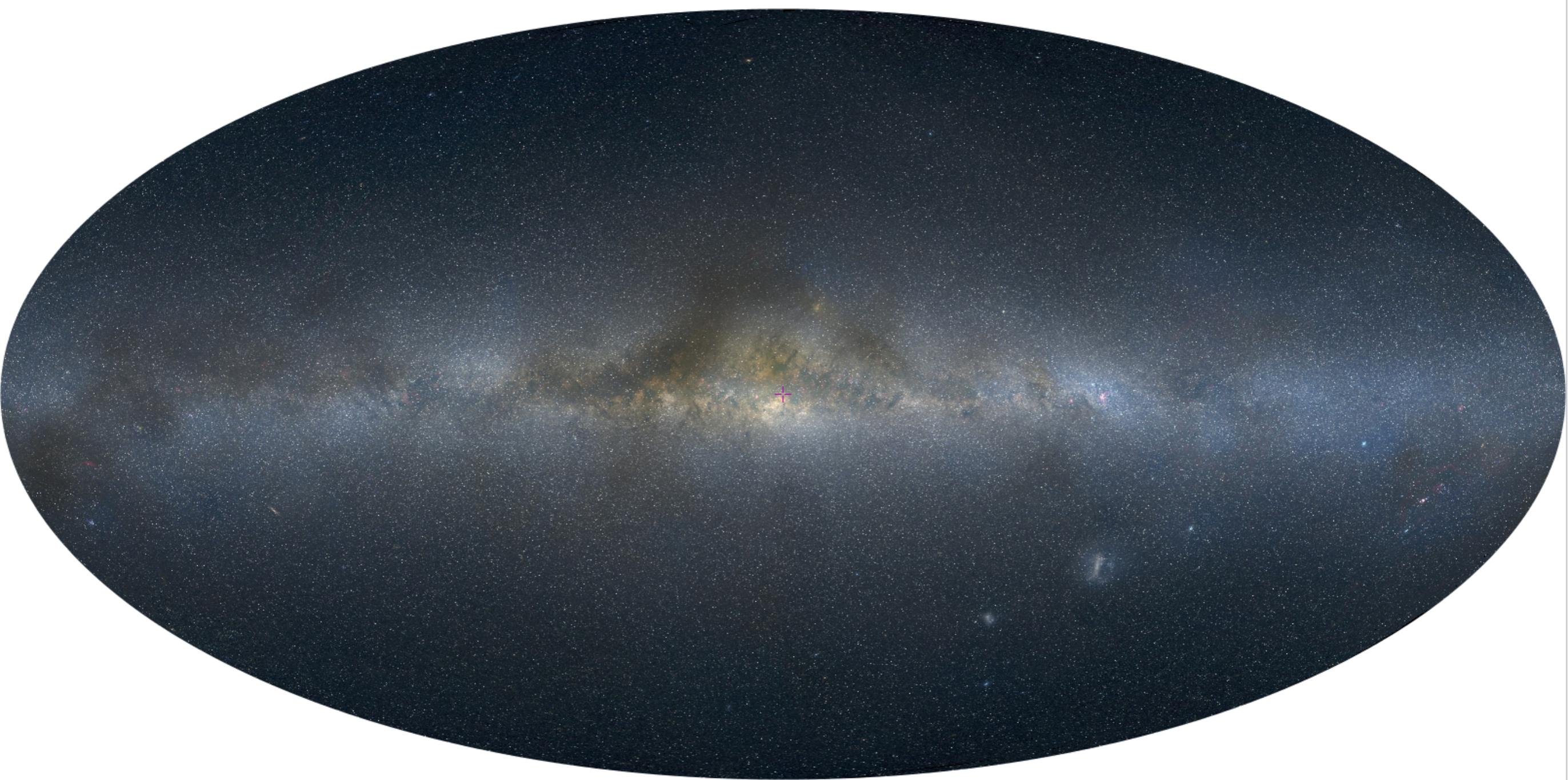
domaine d'observations
récent



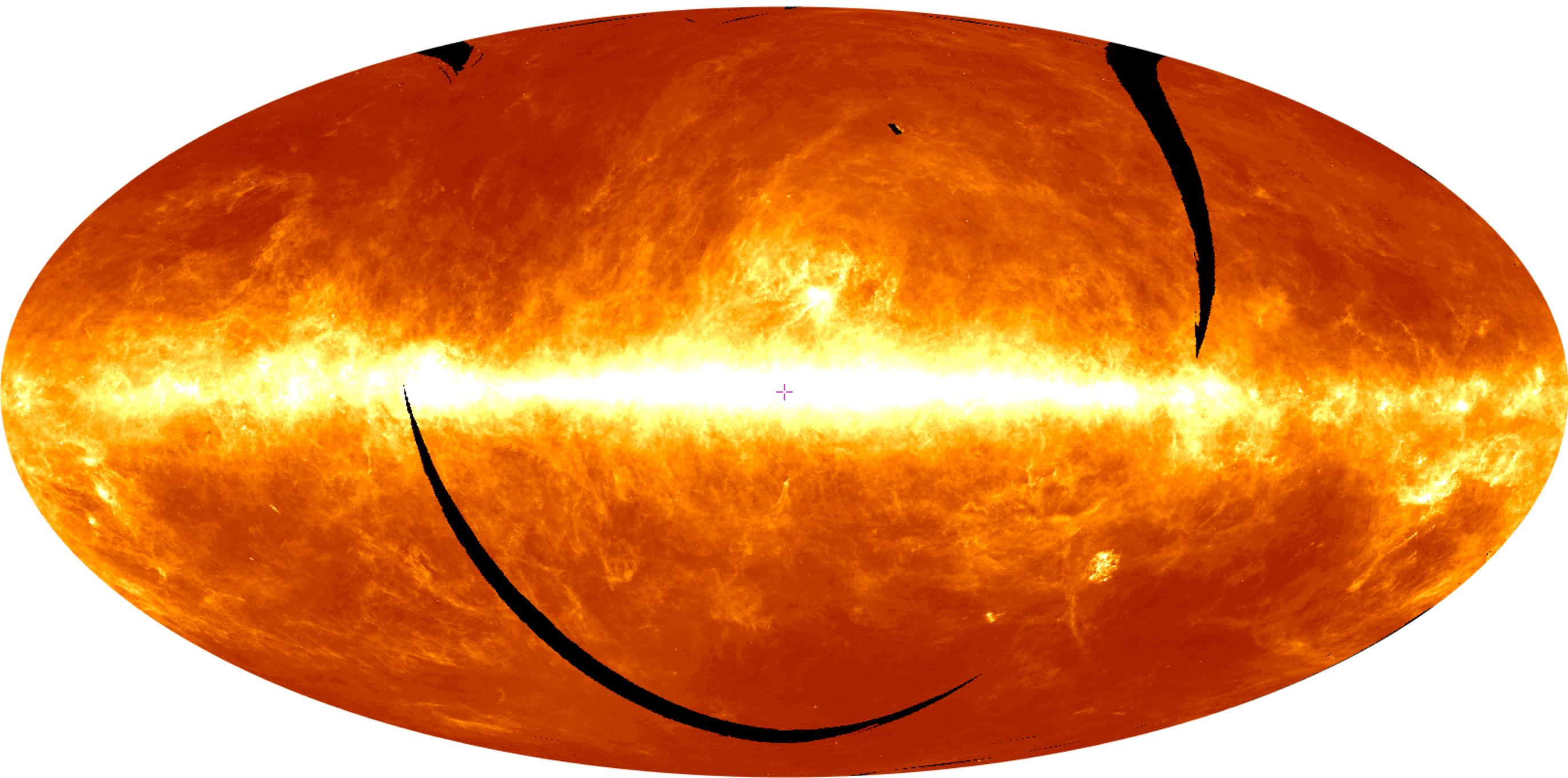
LA RÉVOLUTION DES SATELLITES INFRAROUGES

- IRAS 1983
- DIRBE 1990-1994
- ISO 1995-1998
- Spitzer 2003-2009
- Herschel 2009-2013
- Planck 2009-2013



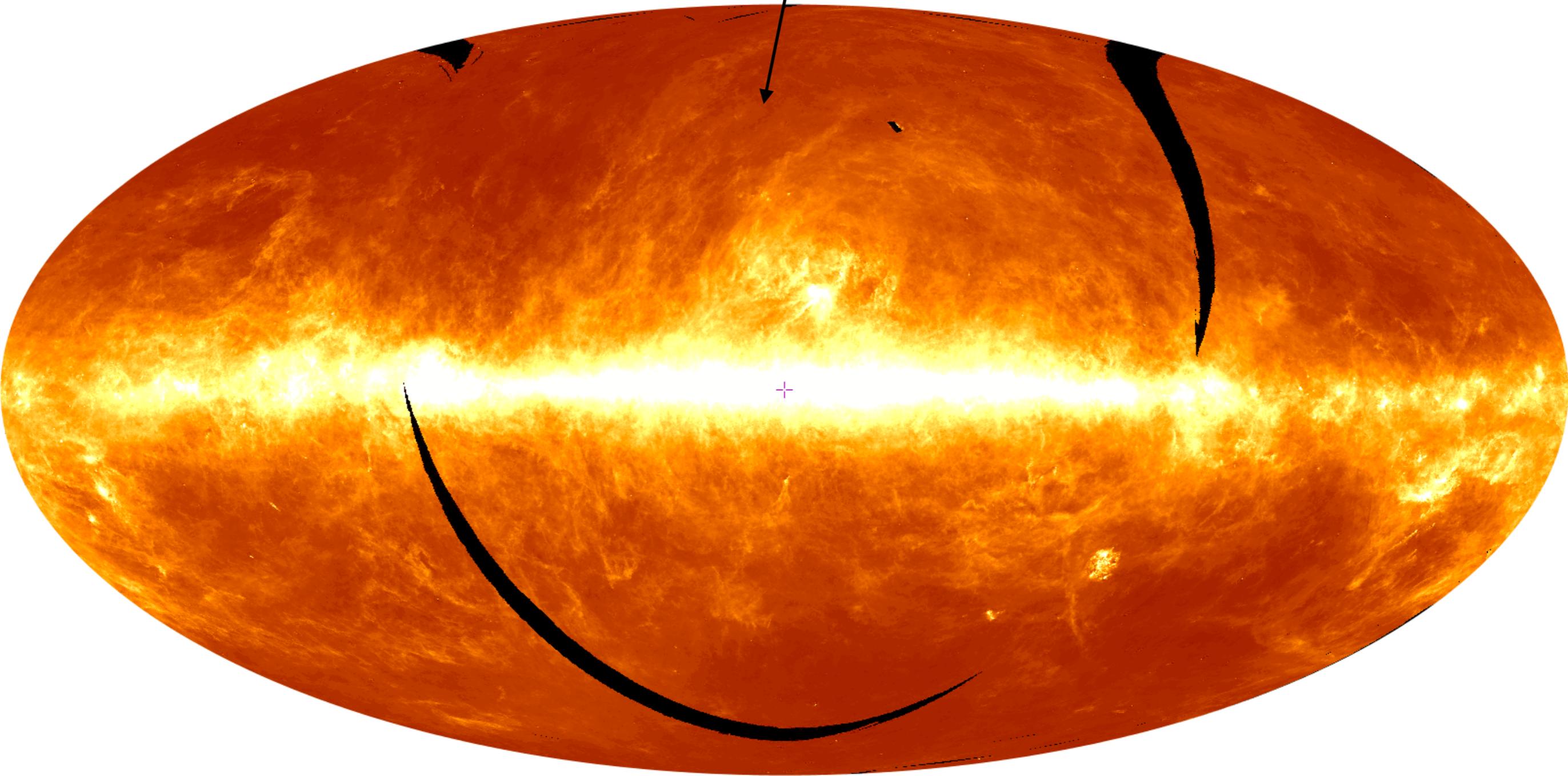


tout le ciel dans le domaine visible (crédit: Mellinger)

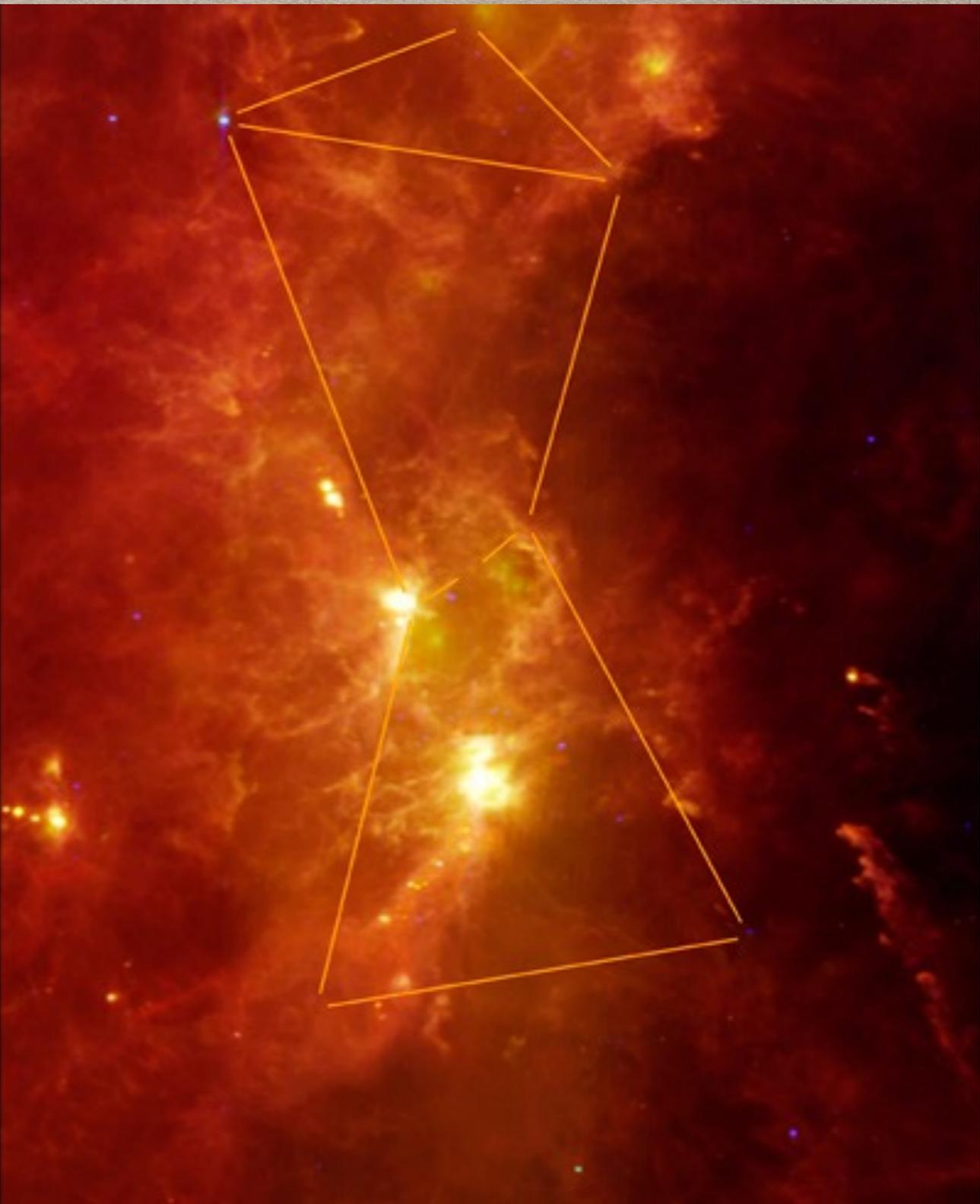
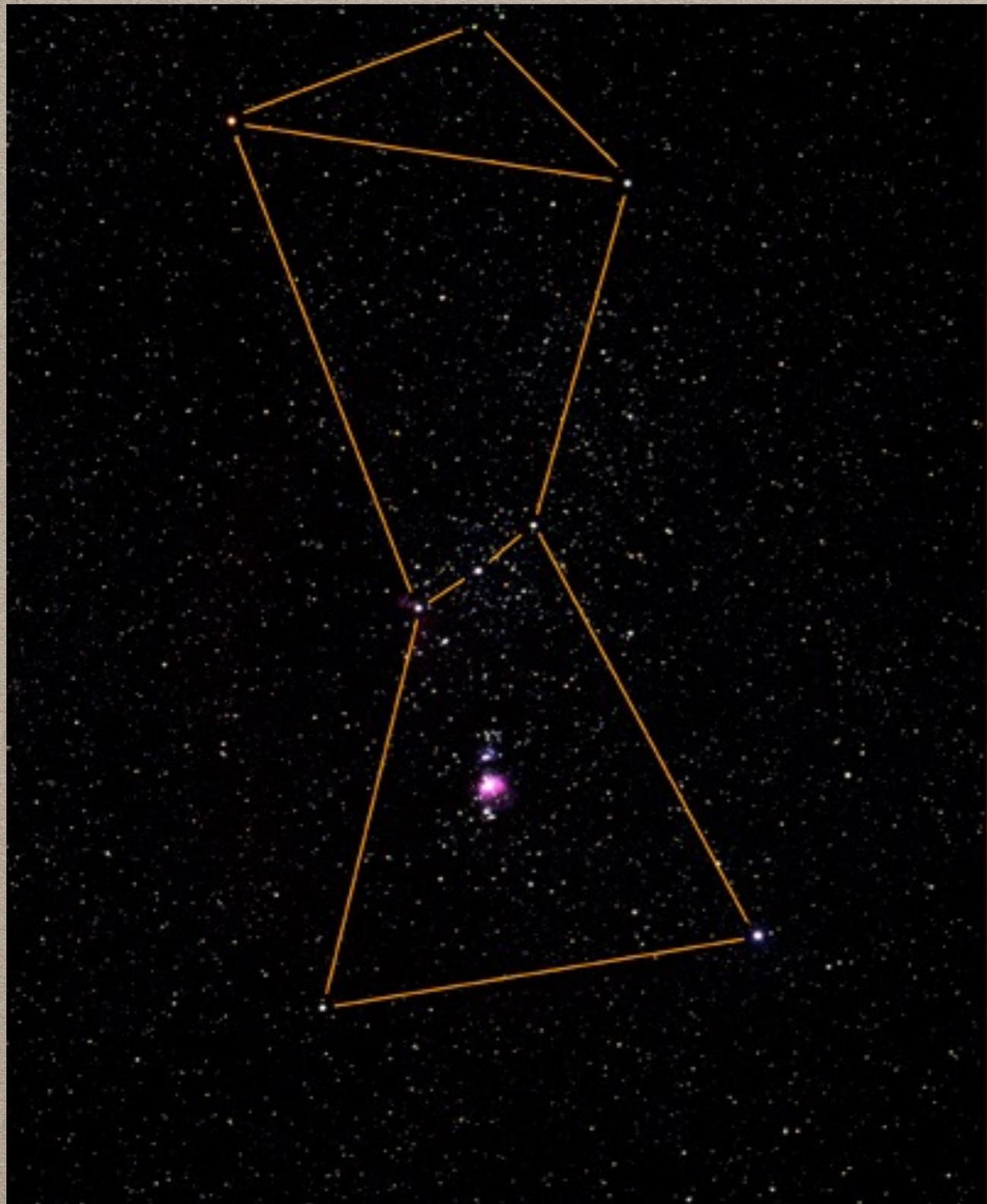


tout le ciel dans le domaine infrarouge lointain (IRAS)

Des poussières partout!

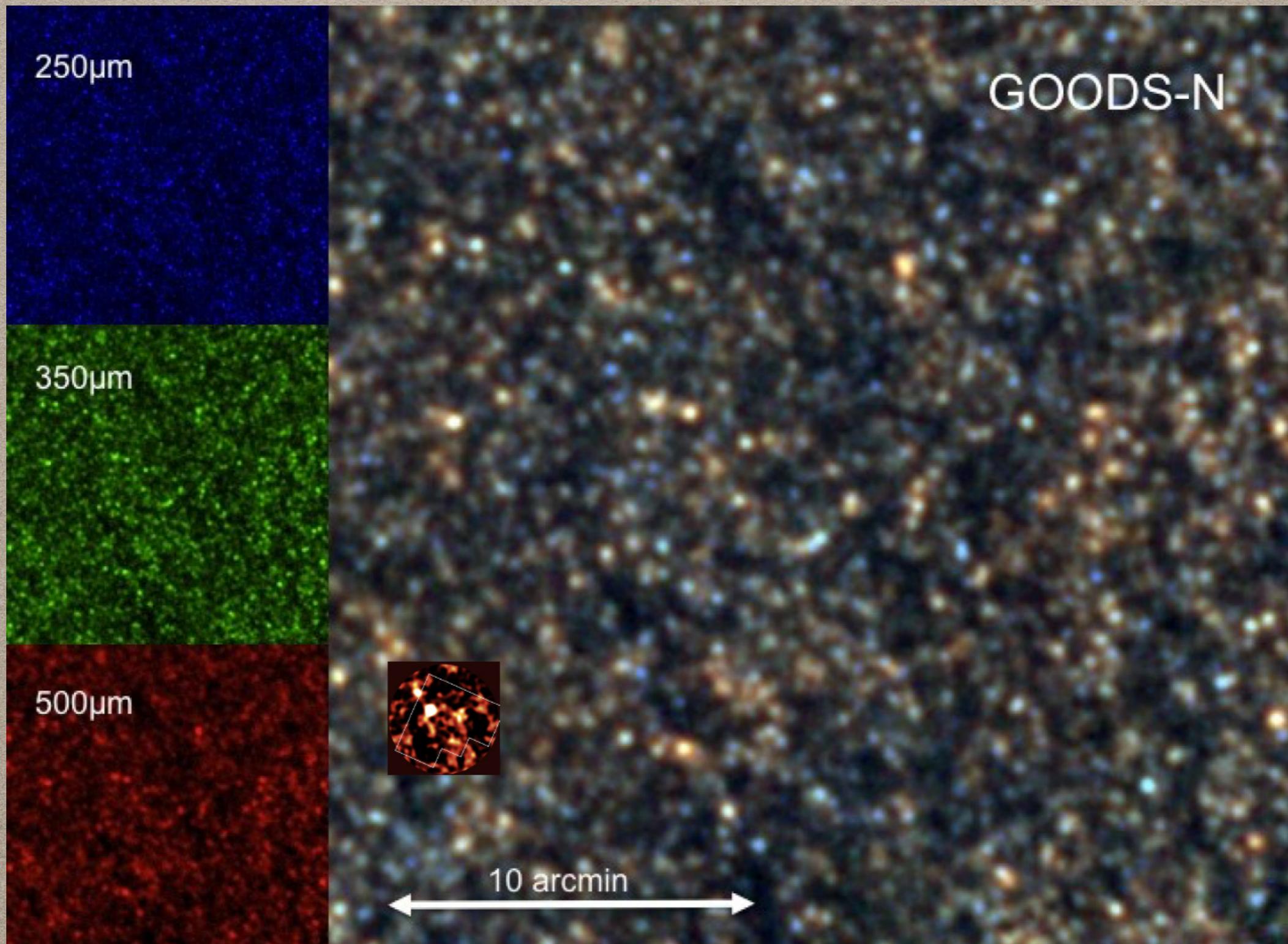


tout le ciel dans le domaine infrarouge lointain (IRAS)



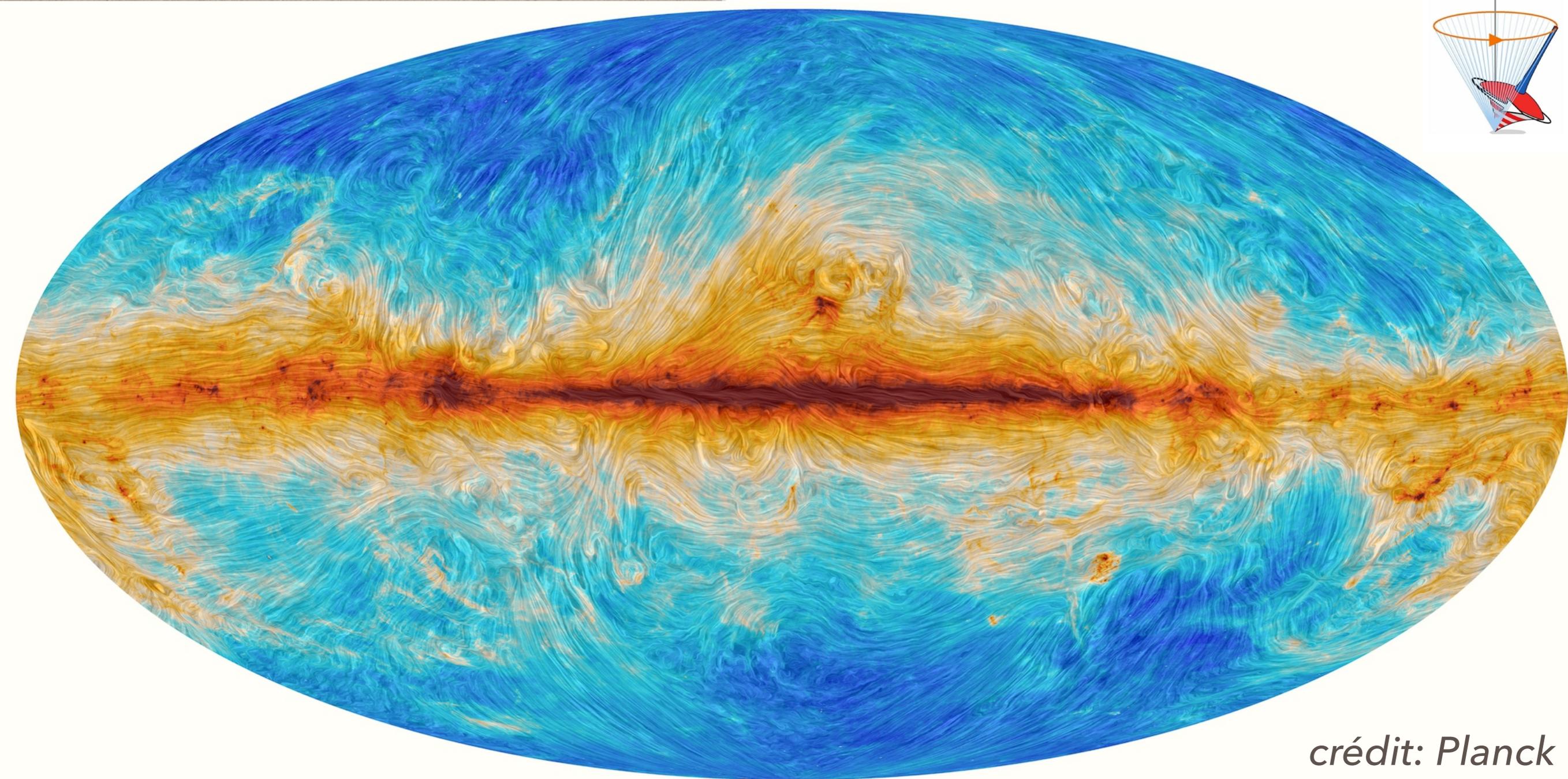
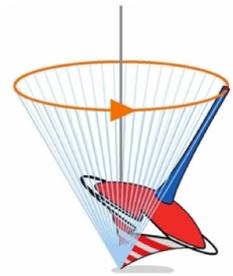
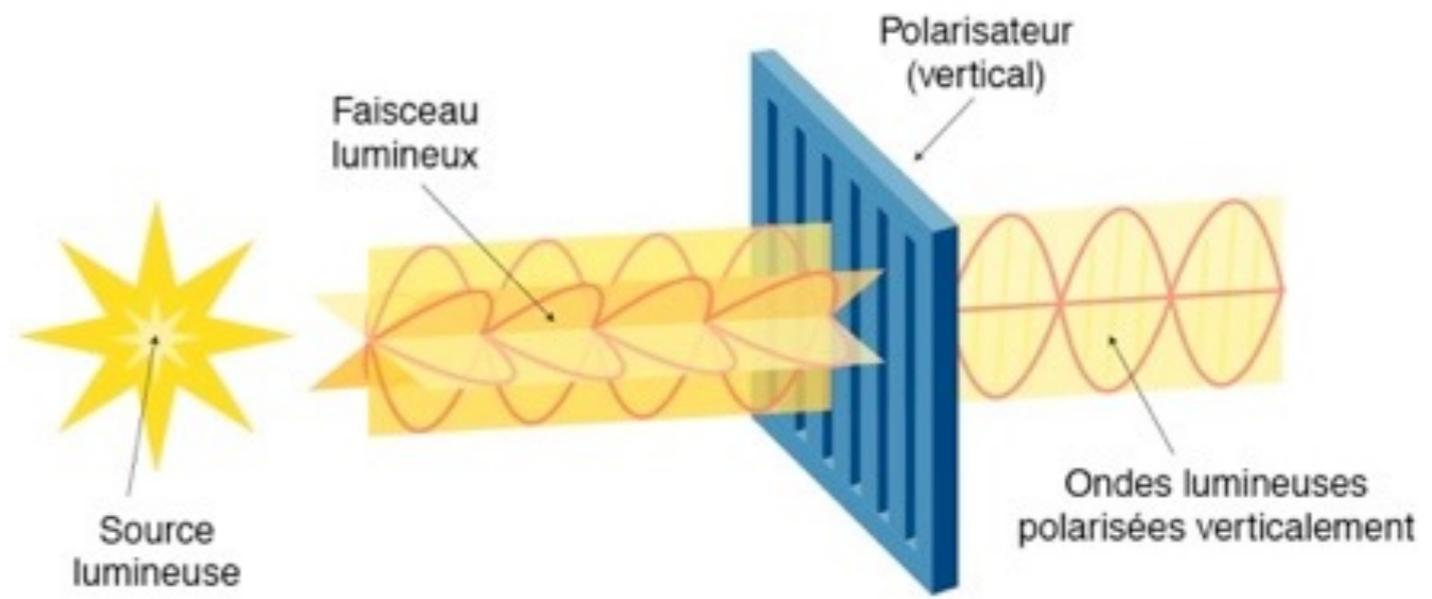
POUSSIÈRES DANS LES CHAMPS PROFONDS

- Scuba: 5 galaxies
- Des milliers de galaxies observées avec Herschel

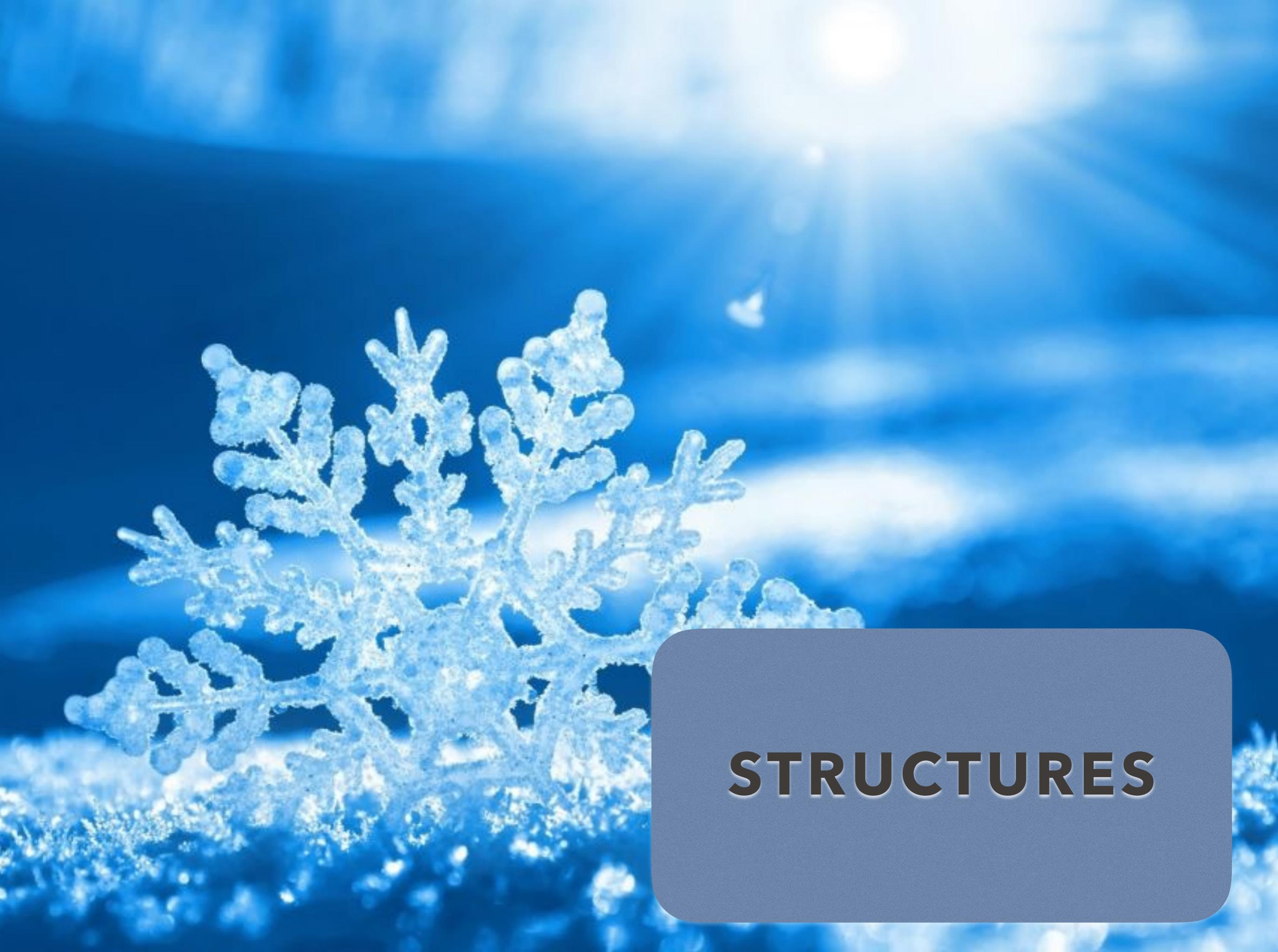


POLARISATION

- nous informe sur la direction des lignes de champ magnétique et sur la forme des grains de poussière

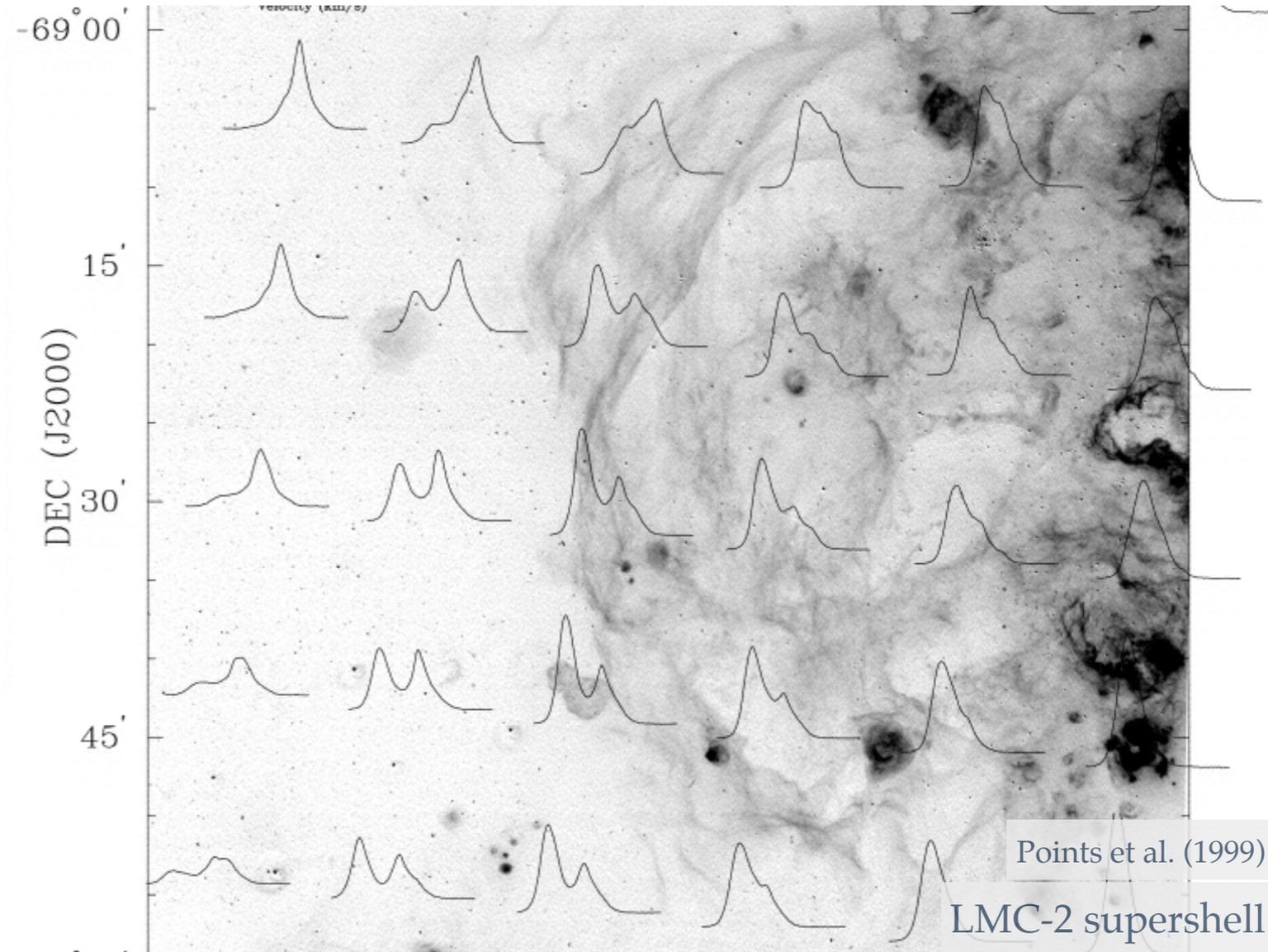
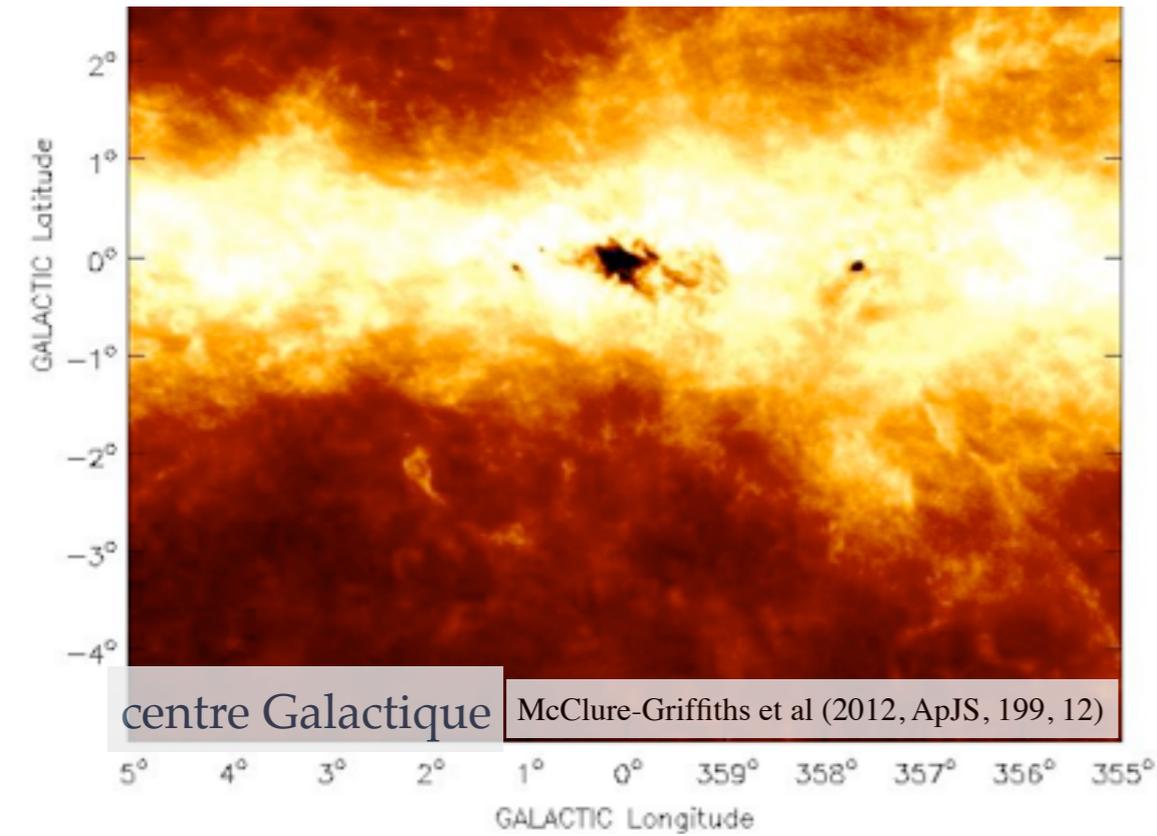


crédit: Planck

A large, intricate, white snowflake-like structure is the central focus, set against a vibrant blue background. The background features a bright sunburst or lens flare effect in the upper right corner, creating a sense of depth and light. The snowflake has a complex, branching, and porous appearance, resembling a natural ice crystal or a highly detailed architectural model. The overall composition is clean and modern, with a strong color palette of blues and whites.

STRUCTURES

Un milieu extrêmement inhomogène



❖ filaments, coquilles, ...

❖ Aspect fractal, dominé par la turbulence

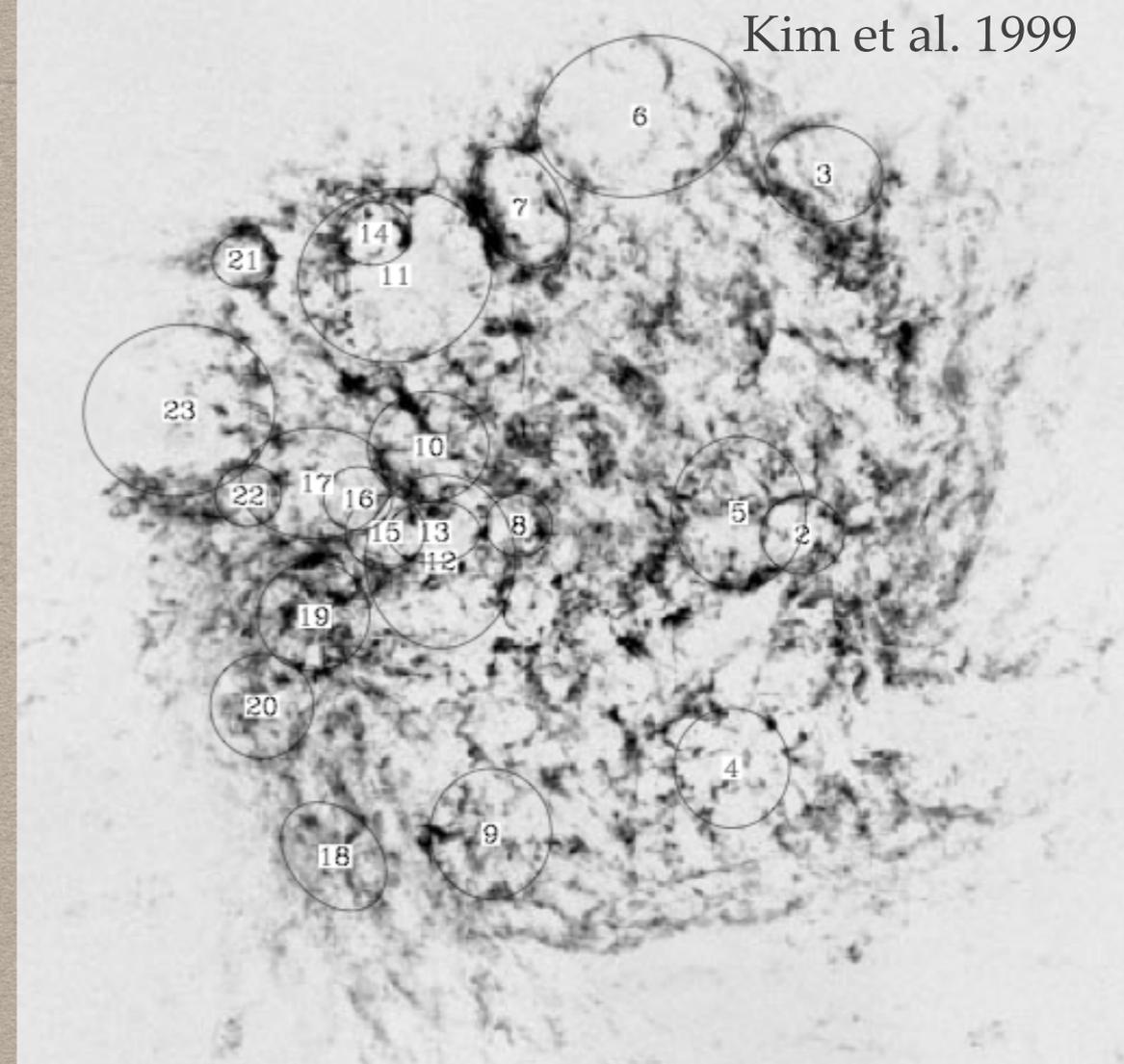
voile d'Orion



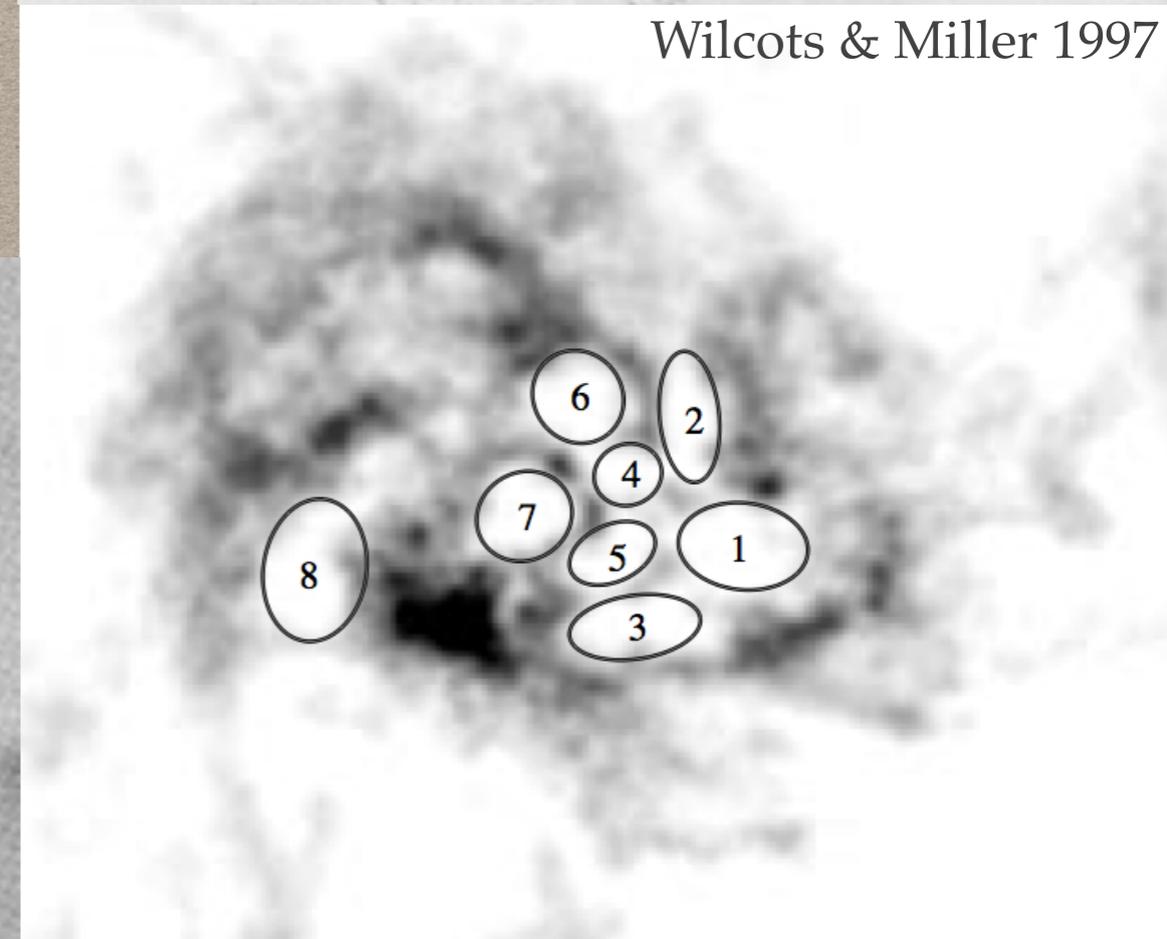
SHELLS, GIANT SHELLS, SUPERSHELLS

- observées en H α , H I, CO
- vents stellaires ou ondes de densité?
 - LMC: 12-25% sont le résultat direct de la formation d'étoiles
 - M33: il faudrait 10^{53} ergs, il n'y a pas d'amas stellaires, sans doute dues à des ondes de densité
 - IC10: certaines viennent de l'action de SN, d'autres de vents stellaires

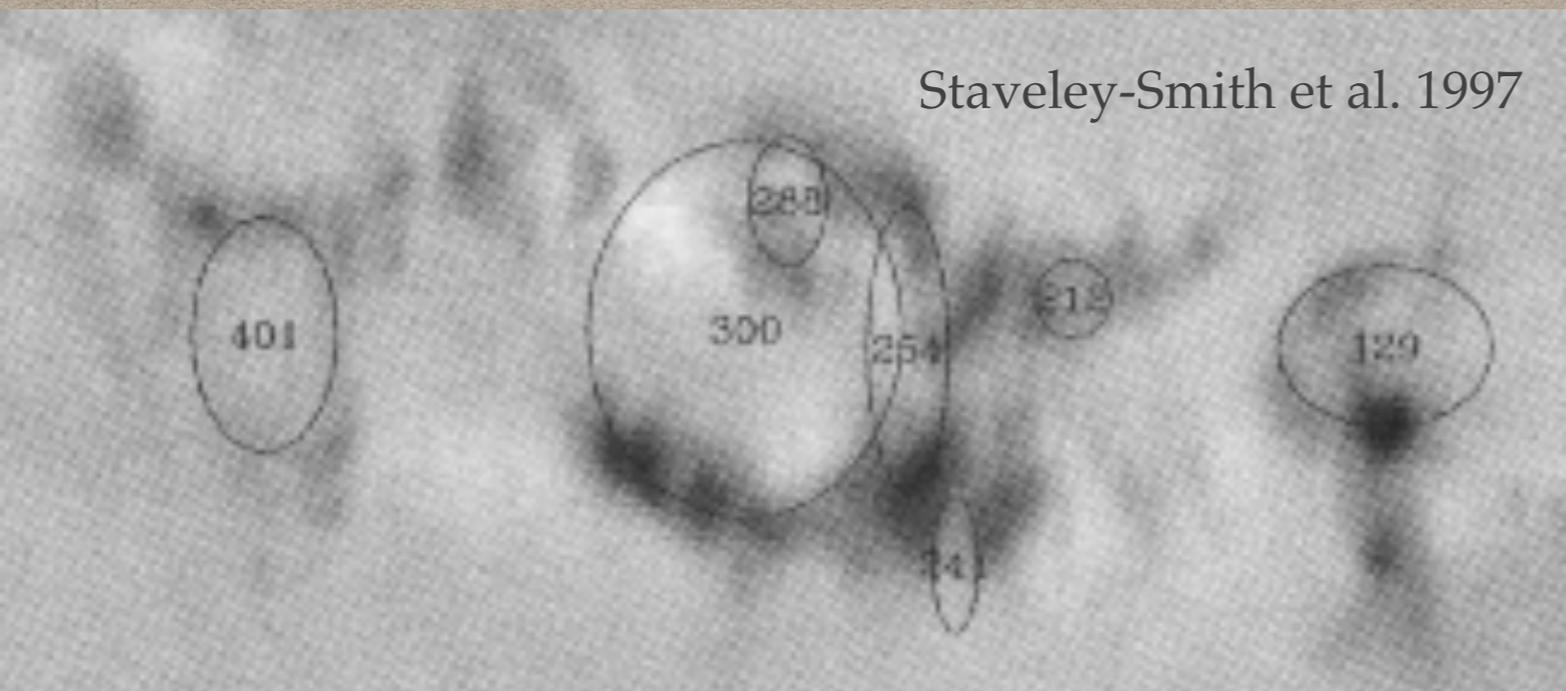
Kim et al. 1999



Wilcots & Miller 1997



Staveley-Smith et al. 1997



BUBBLES

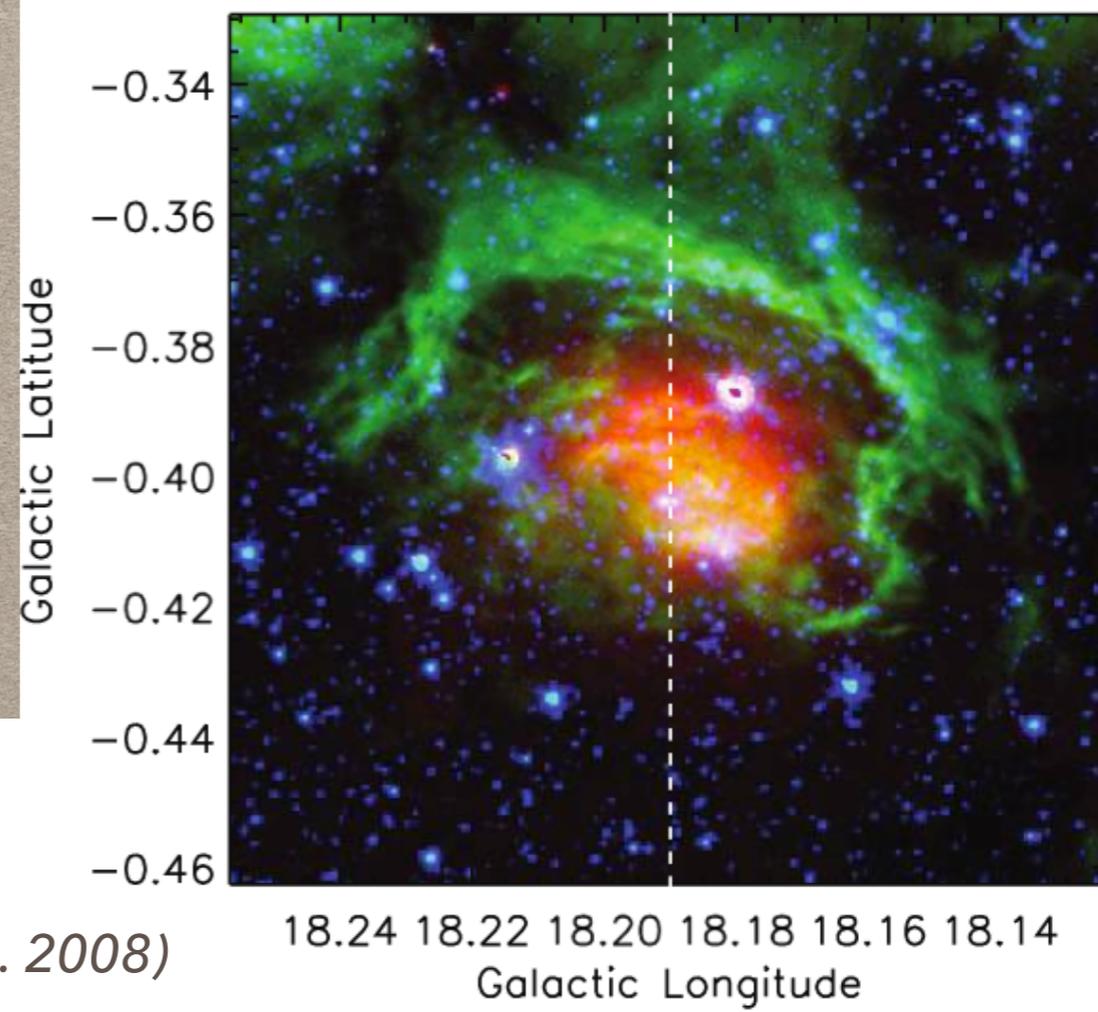
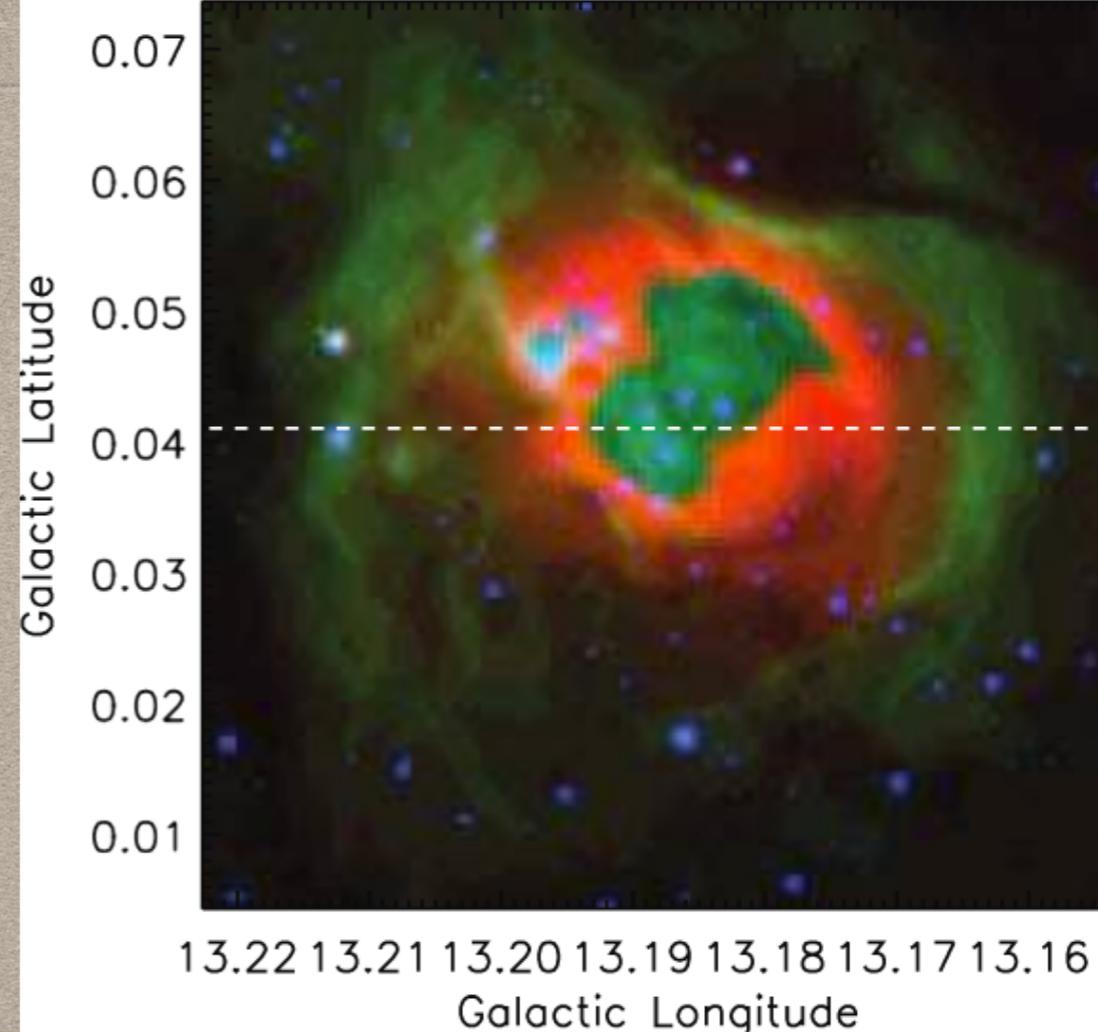
- observées en IR moyen
- tailles beaucoup plus petites que les coquilles
- plus de 600 bulles dans le plan Galactique ont été vues avec Spitzer
- elles sont produites par le rayonnement stellaire excitant les PAHs et chauffant la poussière au centre. Parfois une région HII est observable au centre mais pas toujours

bleu: 4.5 μ m (étoiles)

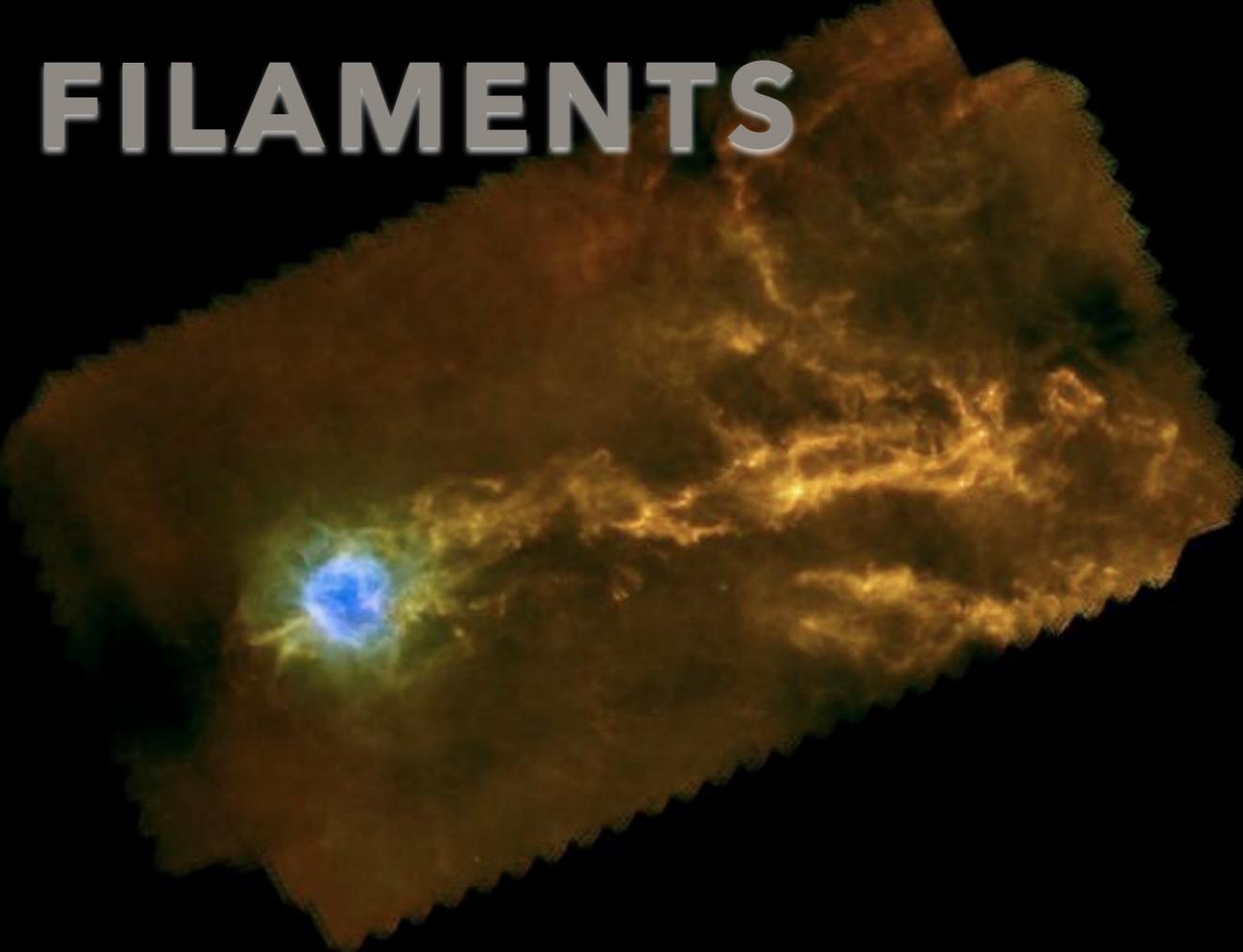
rouge: 24 μ m (poussière chaude)

vert: 8 μ m (PAHs)

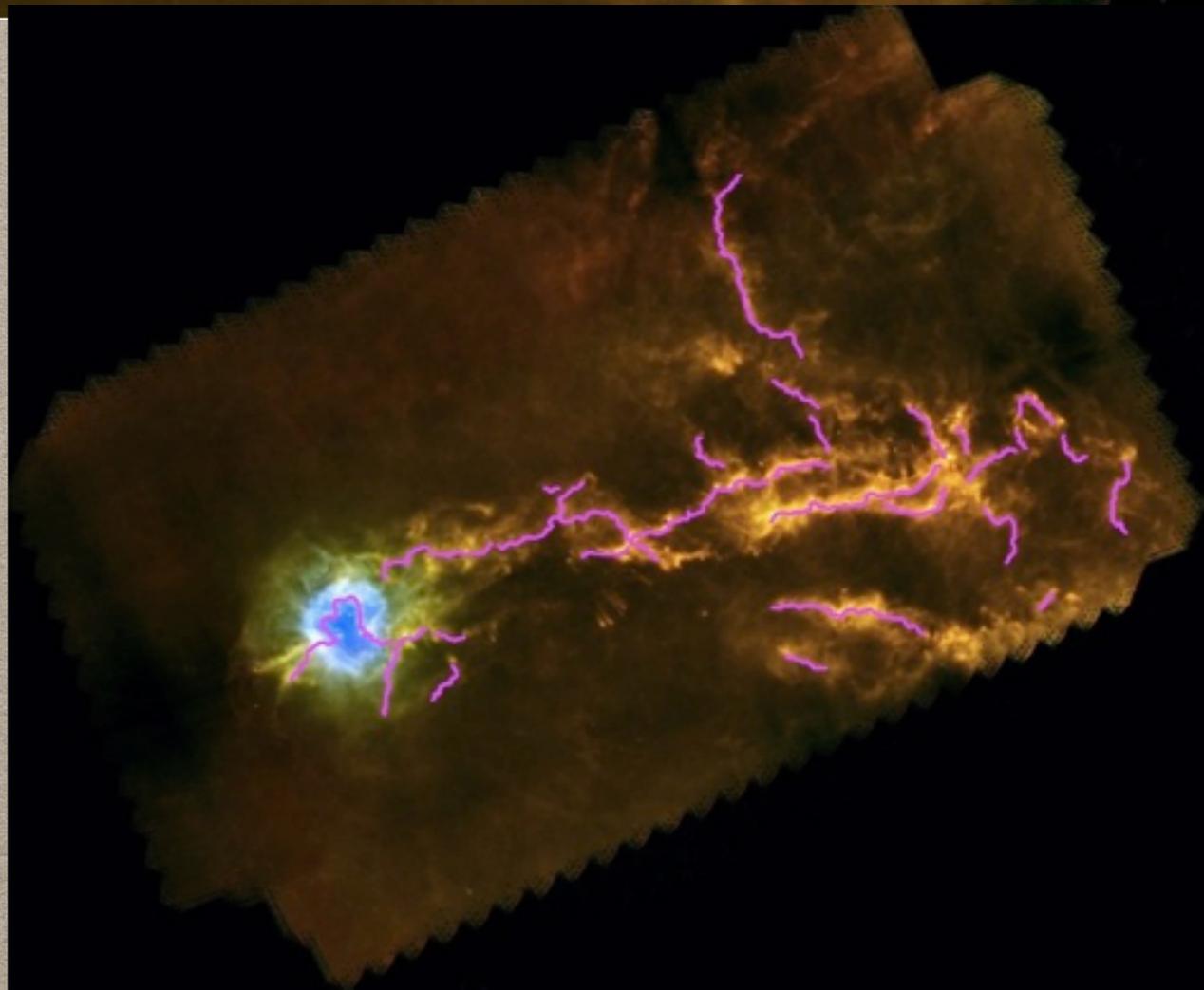
(Watson et al. 2008)



FILAMENTS



- découverts dans l'IR lointain/sub-mm avec Herschel
- épaisseur caractéristique de 0.1 pc (correspond à la taille où les mouvements turbulents deviennent plus lents que la vitesse du son)
- les coeurs préstellaires et les proto-étoiles semblent se former dans ces filaments



crédit: P. André

BOW SHOCK

- zone d'interaction entre le vent stellaire d'une étoile et le milieu interstellaire
- L'étoile ou le nuage de gaz peuvent être en mouvement

Zeta Oph



NASA, JPL-Caltech, Spitzer Space Telescope

LL Orionis

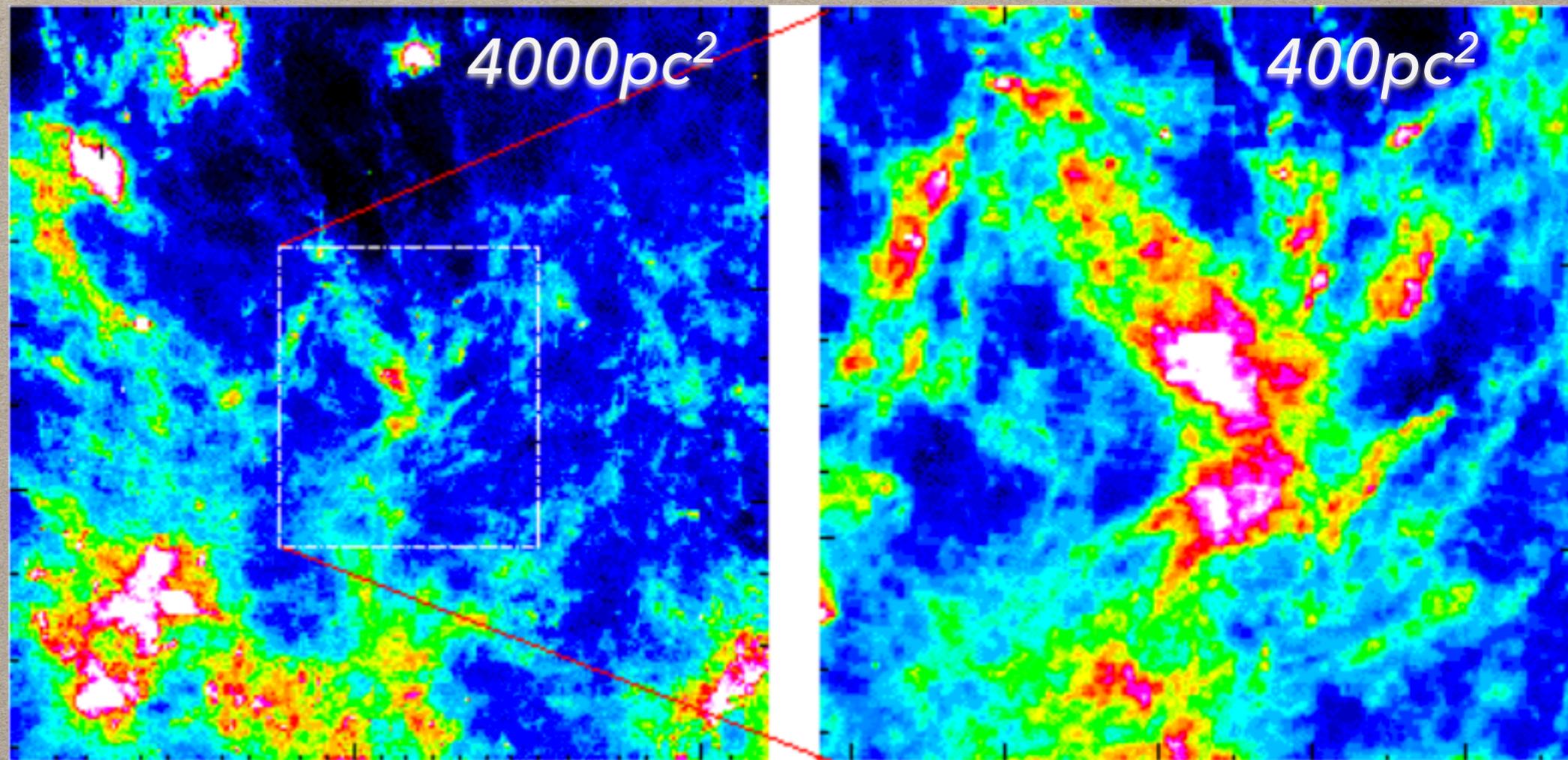


Alpha Cam



AUTO-SIMILARITÉ?

- en lien avec la turbulence
- similaire à l'idée des fractales



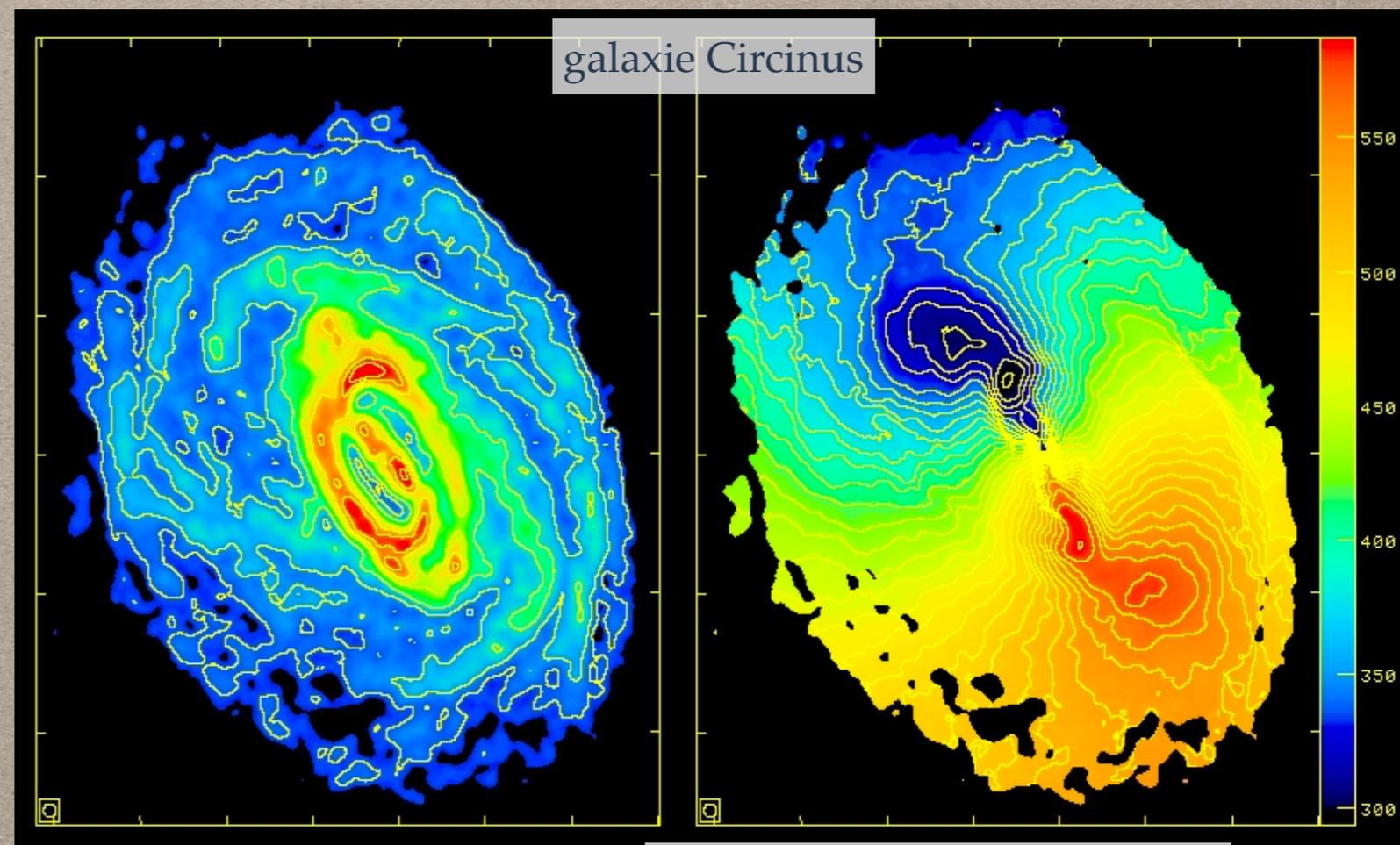
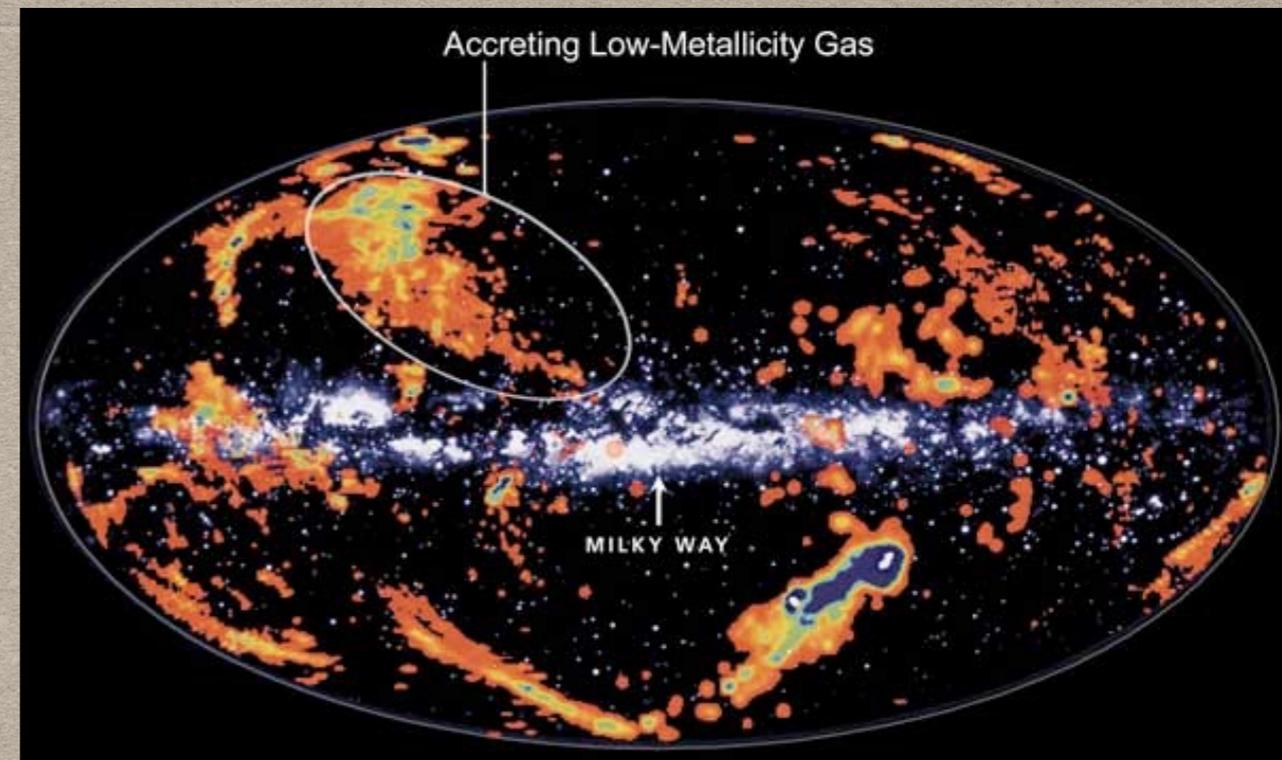
*Carte IRAS 100m du complexe
de nuages moléculaires du taureau*



**LE MILIEU
INTERSTELLAIRE
COMME OUTIL**

VISION 3D

- l'essentiel du MIS est dans le disque de la Galaxie
- raies de HI, CO, H α
- Effet Doppler



Crédits: ATNF, CSIRO, University of Queensland

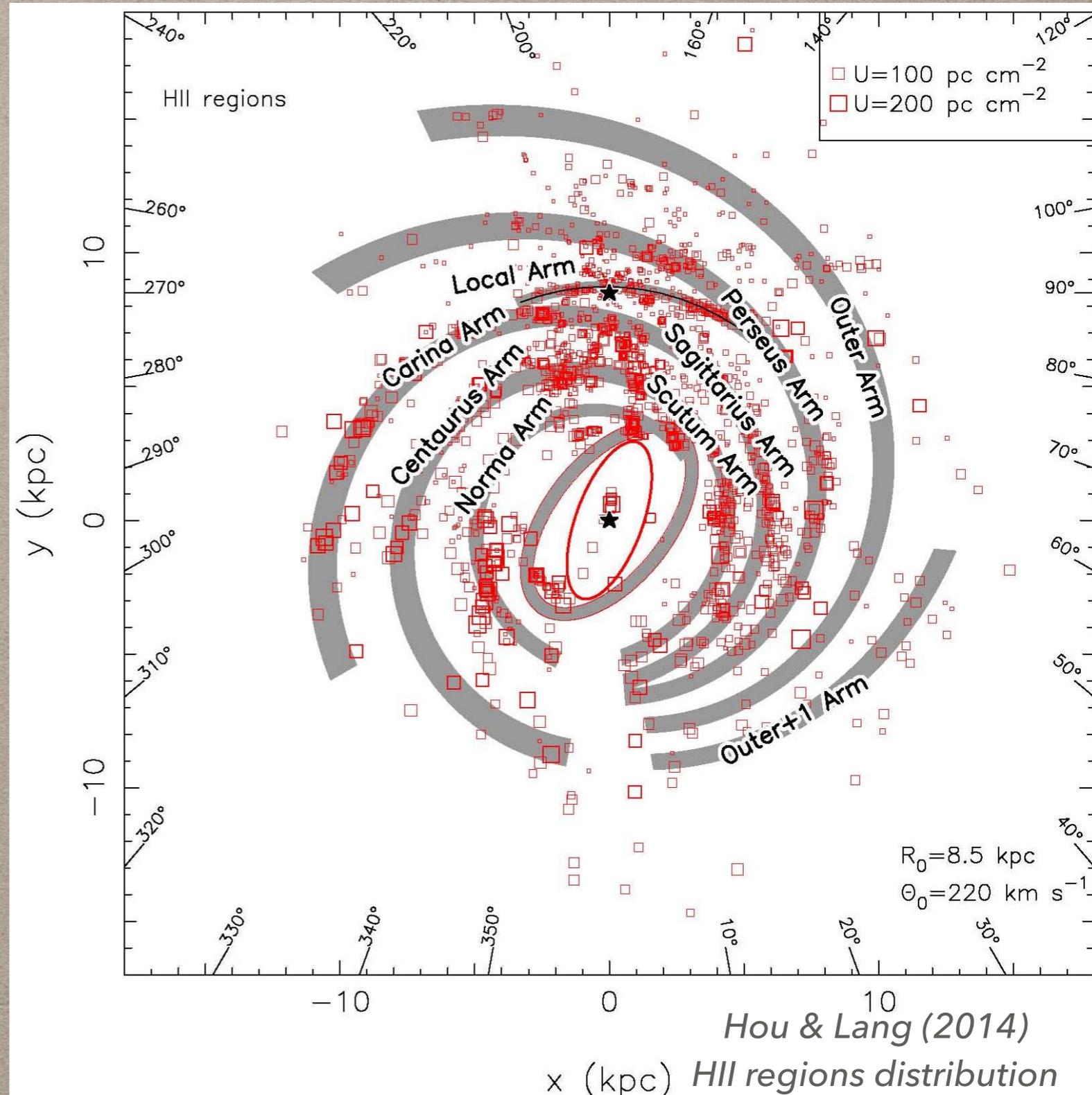
objet qui se rapproche: décalage vers le bleu

objet au repos

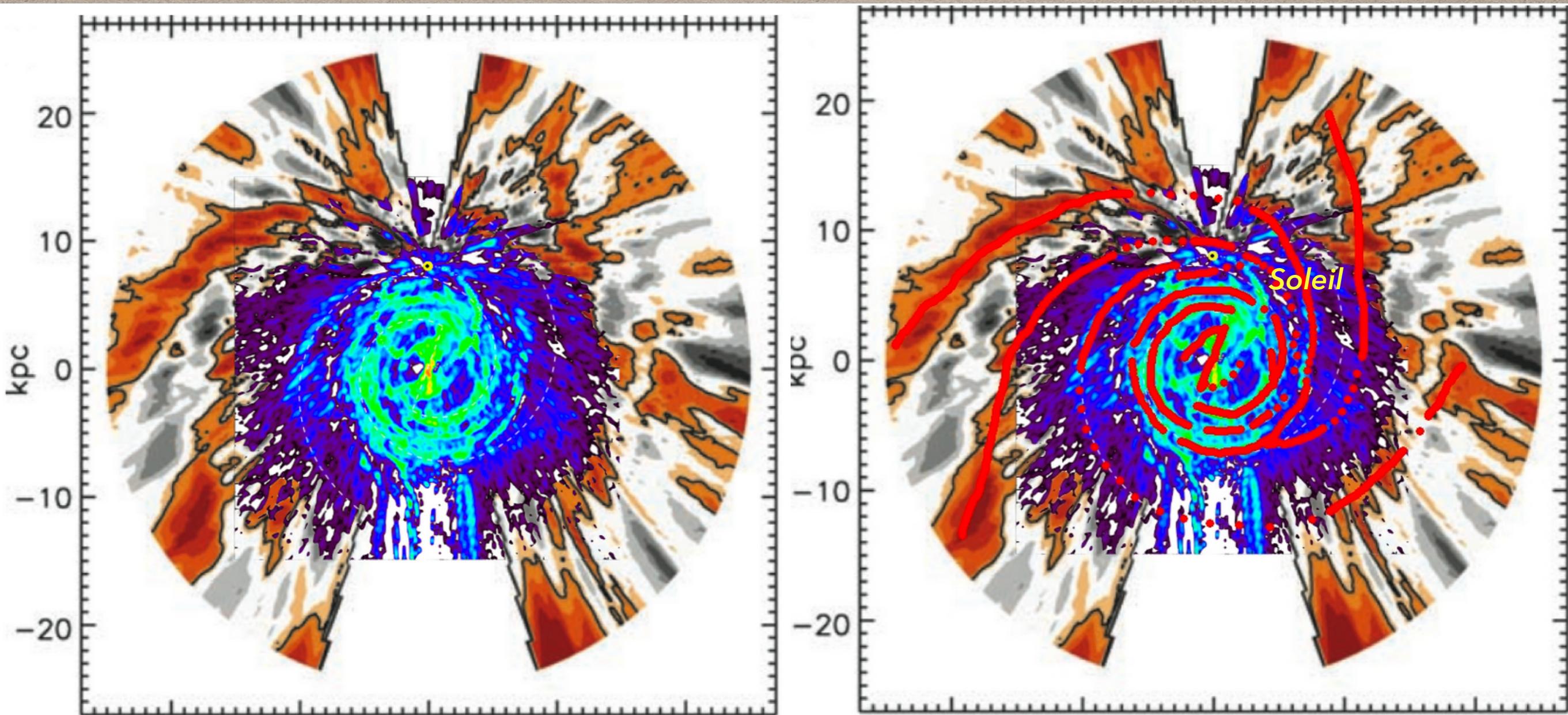
objet qui s'éloigne: décalage vers le rouge

TRACER LA STRUCTURE DE LA VOIE LACTEE

- utilisation des vitesses (raies)
- Régions HII
- gaz HI

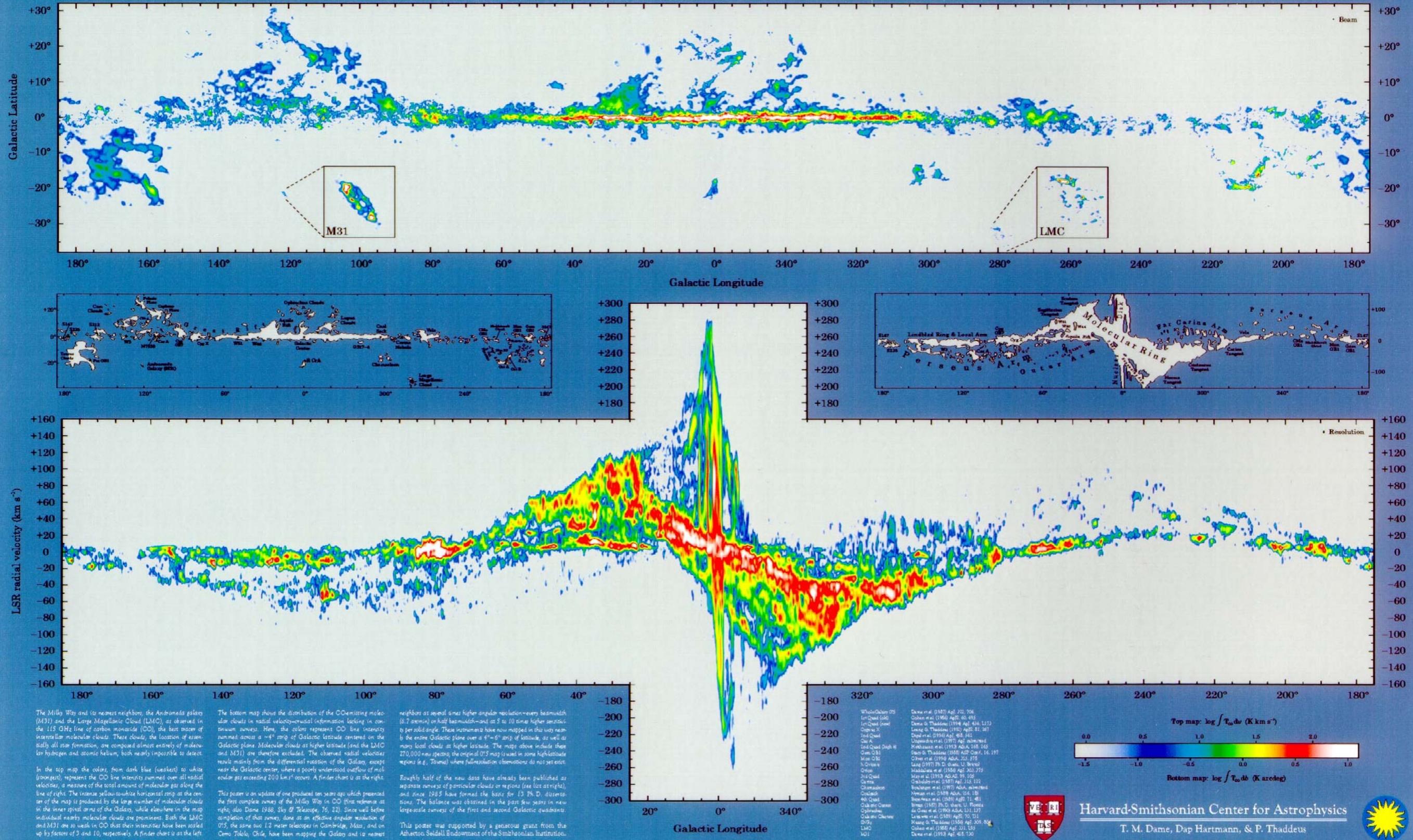


TRACER LA STRUCTURE DE LA VOIE LACTEE



distribution du gaz HI
Pohl et al. 2008, Levine et al. 2006

The Milky Way in Molecular Clouds



The Milky Way and its nearest neighbors, the Andromeda galaxy (M31) and the Large Magellanic Cloud (LMC), as observed in the 115 GHz line of carbon monoxide (CO), the best tracer of interstellar molecular clouds. These clouds, the location of essentially all star formation, are composed almost entirely of molecular hydrogen and atomic helium, both nearly impossible to detect.

In the top map the colors, from dark blue (weakest) to white (strongest), represent the CO line intensity summed over all radial velocities, a measure of the total amount of molecular gas along the line of sight. The intense yellow-to-white horizontal strip at the center of the map is produced by the large number of molecular clouds in the inner spiral arms of the Galaxy, while elsewhere in the map individual nearby molecular clouds are prominent. Both the LMC and M31 are so weak in CO that their intensities have been scaled up by factors of 3 and 10, respectively. A finder chart is at the left.

The bottom map shows the distribution of the CO-emitting molecular clouds in radial velocity-circular information lacking in conventional surveys. Here, the colors represent CO line intensity summed across a ~4° strip of Galactic longitude centered on the Galactic plane. Molecular clouds at higher latitude (and the LMC and M31) are therefore excluded. The observed radial velocities result mainly from the differential rotation of the Galaxy, except near the Galactic center, where a poorly understood outflow of molecular gas exceeding 200 km/s occurs. A finder chart is at the right.

This poster is an update of one produced ten years ago which presented the first complete survey of the Milky Way in CO (first reference: see also Dane 1988, *Sky & Telescope*, 76, 22). Since well before completion of that survey, done at an effective angular resolution of 0.15, the same two 12 meter telescopes in Cambridge, Mass., and on Cerro Tololo, Chile, have been mapping the Galaxy and its nearest

neighbors at several times higher angular resolution—every beamwidth (8.7 arcmin) on half beamwidth—and at 5 to 10 times higher sensitivity per solid angle. These instruments have now mapped in this way nearly the entire Galactic plane over a 4°-6° strip of longitude, as well as many local clouds at higher latitude. The maps above include these 270,000 new spectra; the original 0.15 map is used in some high-latitude regions (e.g., Triana) where full-resolution observations do not yet exist.

Roughly half of the new data have already been published as separate surveys of particular clouds or regions (see list at right), and since 1985 have formed the basis for 13 Ph.D. dissertations. The balance was obtained in the past few years in new large-scale surveys of the first and second Galactic quadrants.

This poster was supported by a generous grant from the Atherton Seidell Endowment of the Smithsonian Institution.

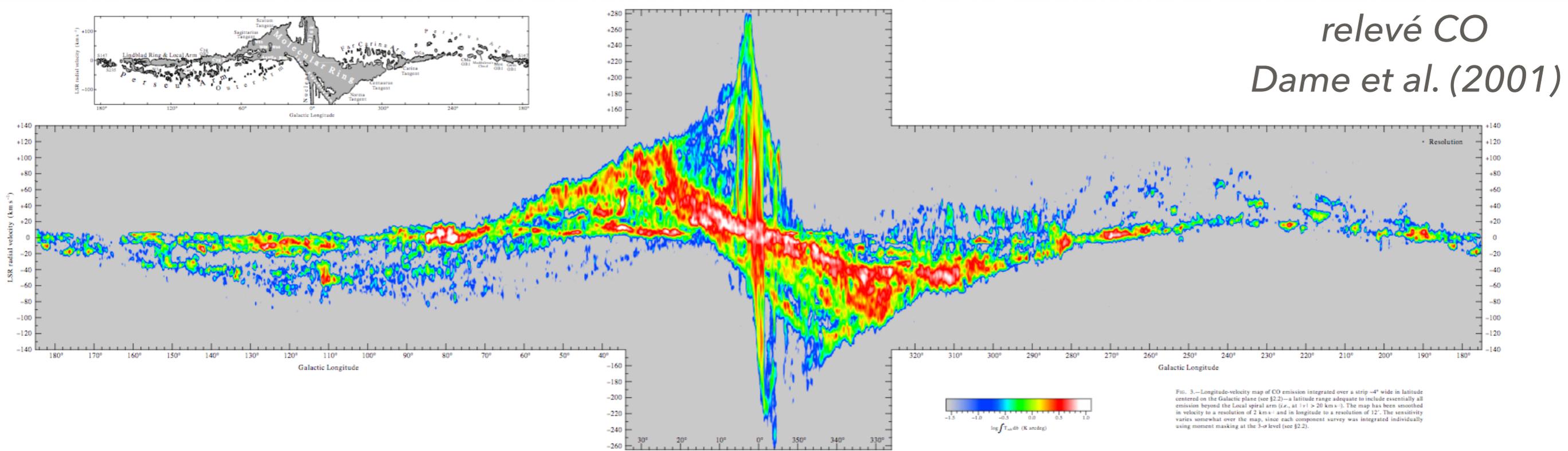
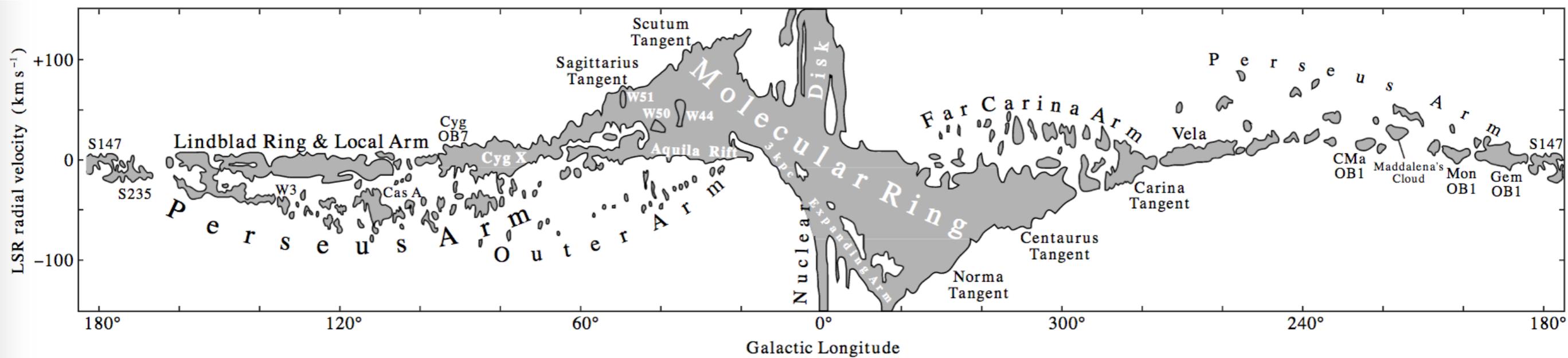
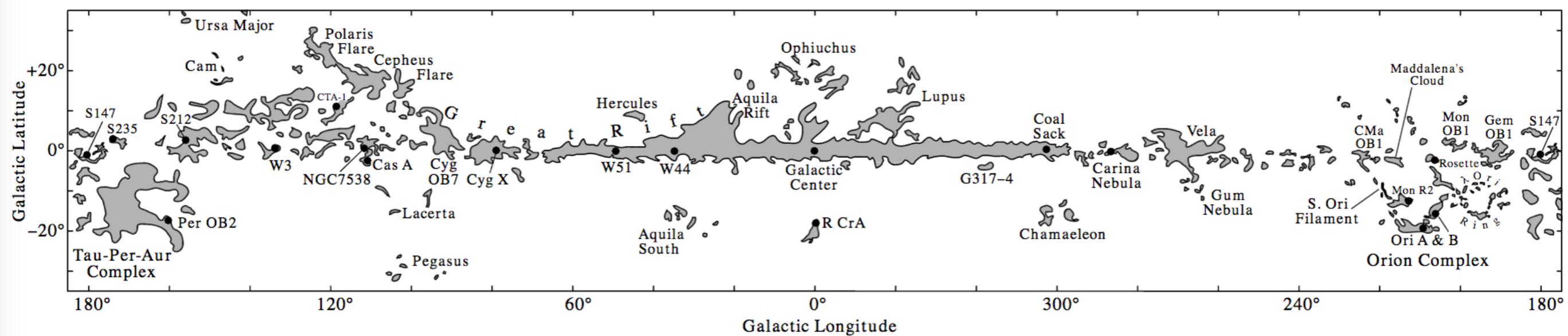
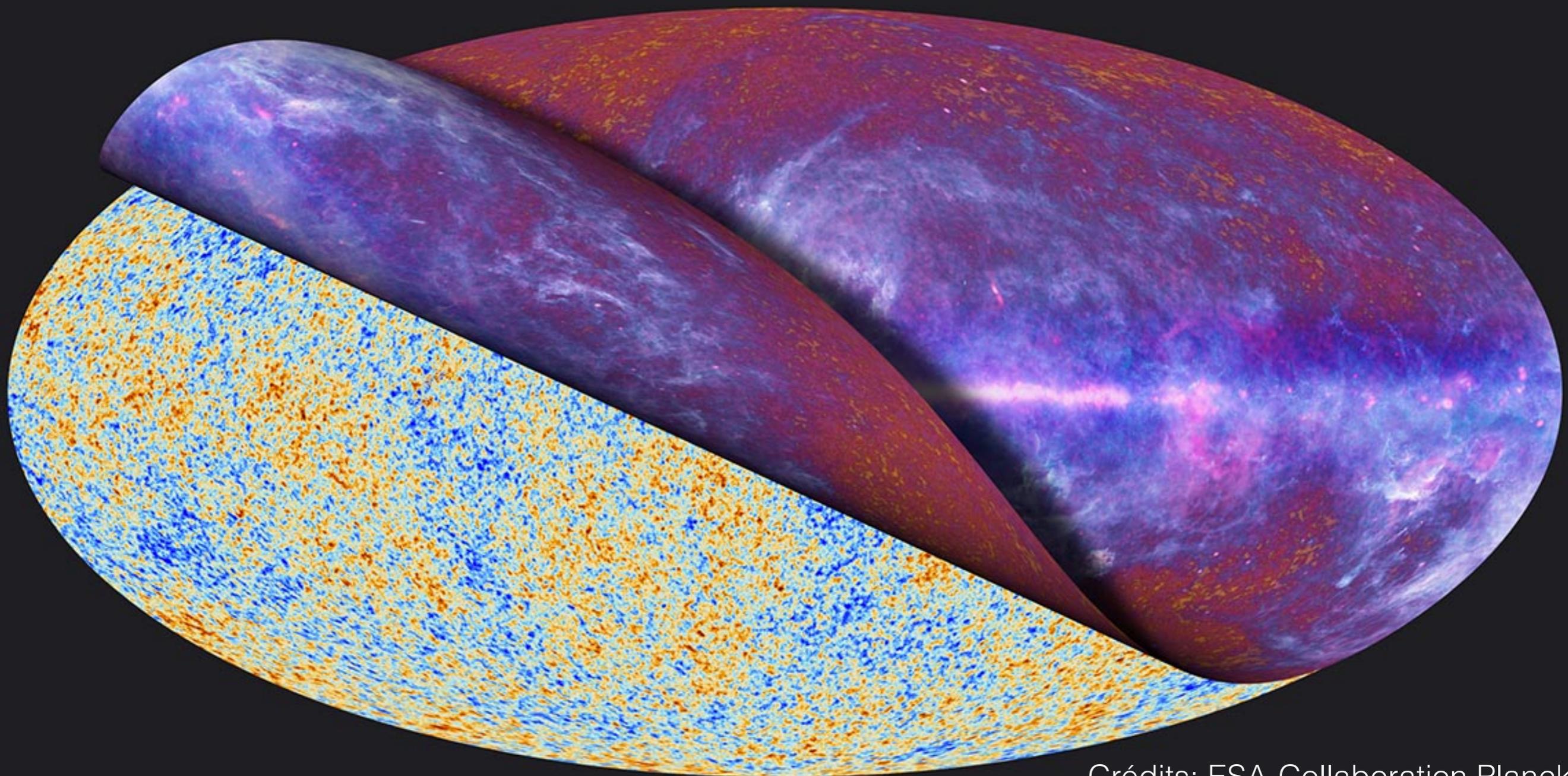


FIG. 3.—Longitude-velocity map of CO emission integrated over a strip $\sim 4^\circ$ wide in latitude centered on the Galactic plane (see §2.2)—a latitude range adequate to include essentially all emission beyond the Local spiral arm (i.e., at $|v_l| > 20 \text{ km s}^{-1}$). The map has been smoothed in velocity to a resolution of 2 km s^{-1} and in longitude to a resolution of $12'$. The sensitivity varies somewhat over the map, since each component survey was integrated individually using moment masking at the $3\text{-}\sigma$ level (see §2.2).

La poussière est aussi un avant-plan
des études cosmologiques

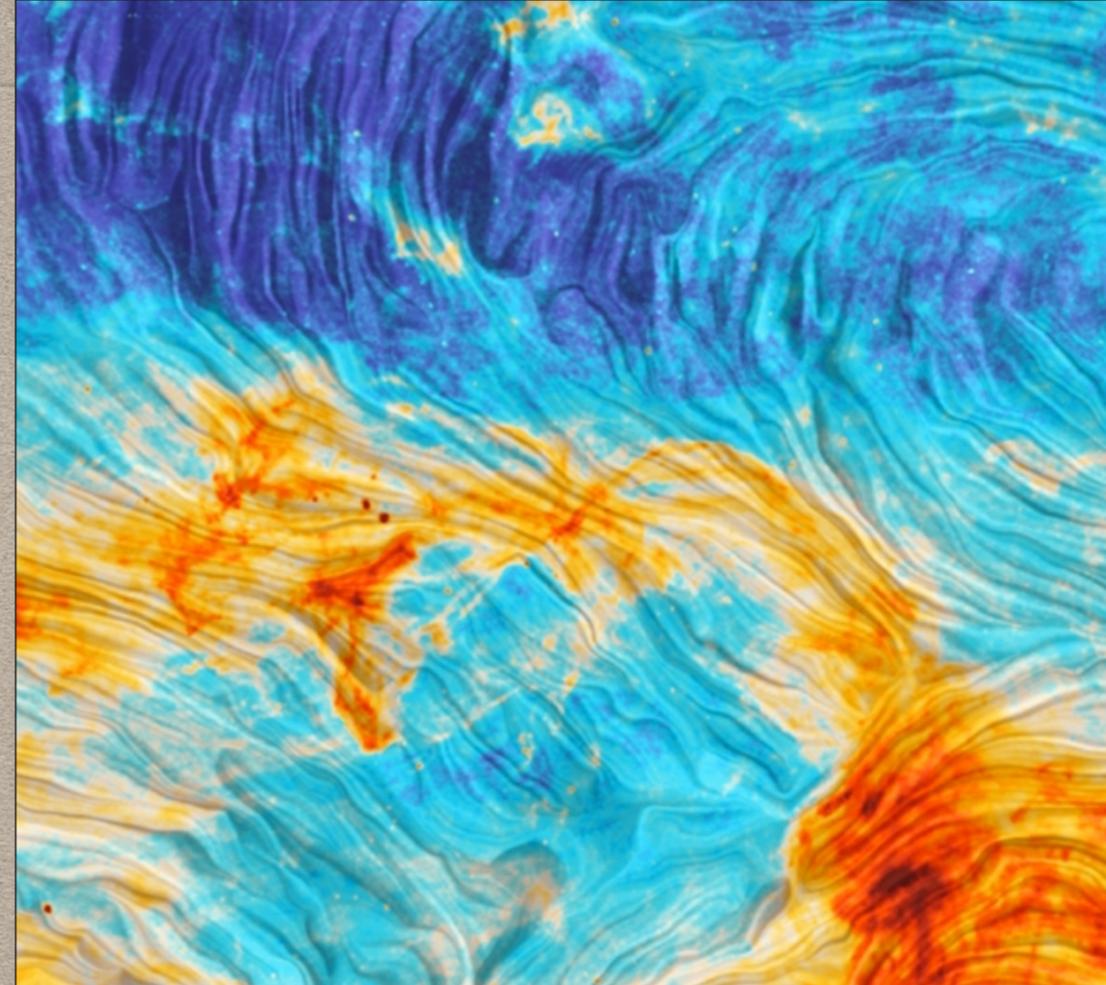


CHAMPS MAGNETIQUES

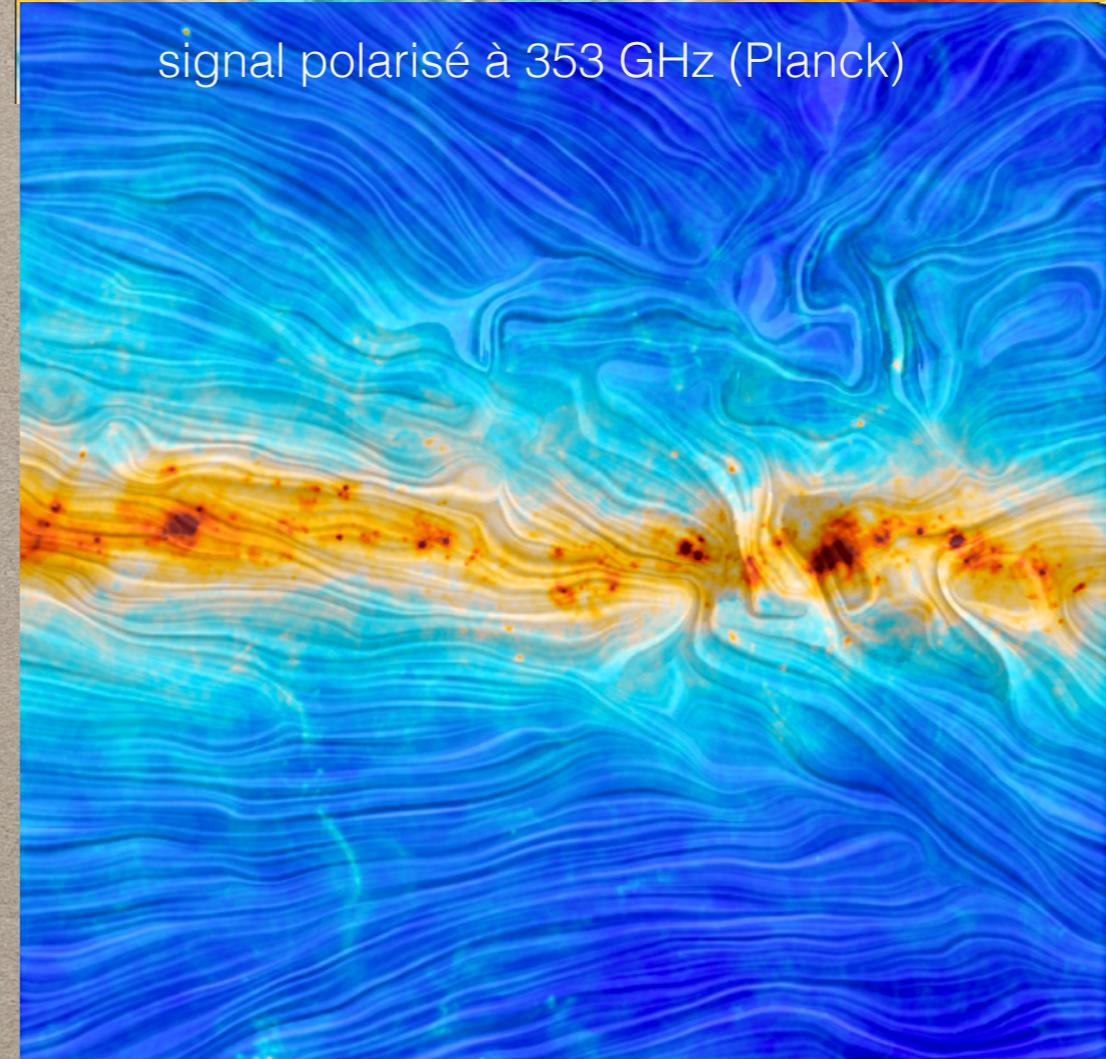
- lumière polarisée par les poussières
- grande échelle, petite échelle
- formation d'étoiles, freine l'effondrement



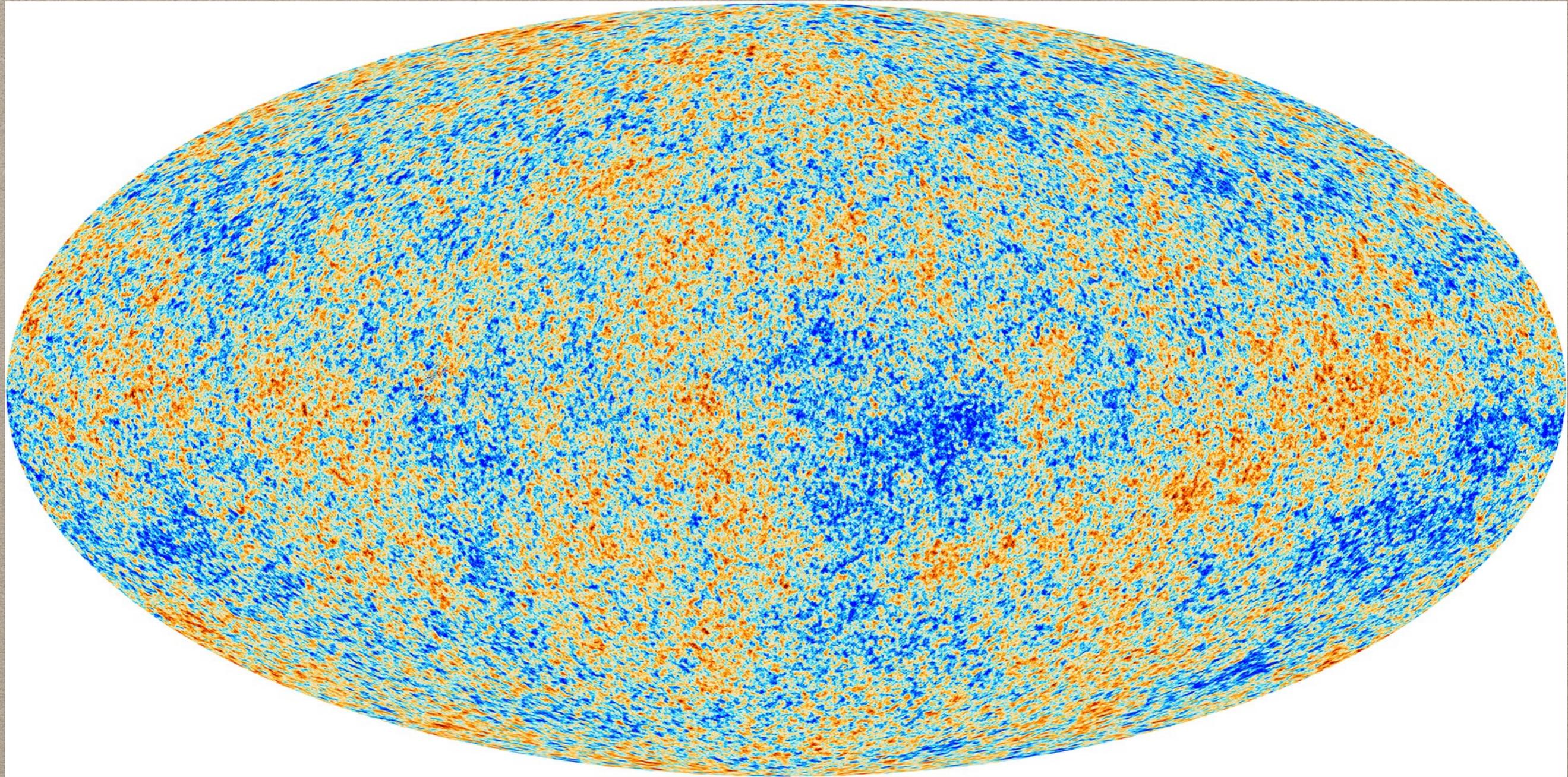
signal polarisé M51



signal polarisé à 353 GHz (Planck)

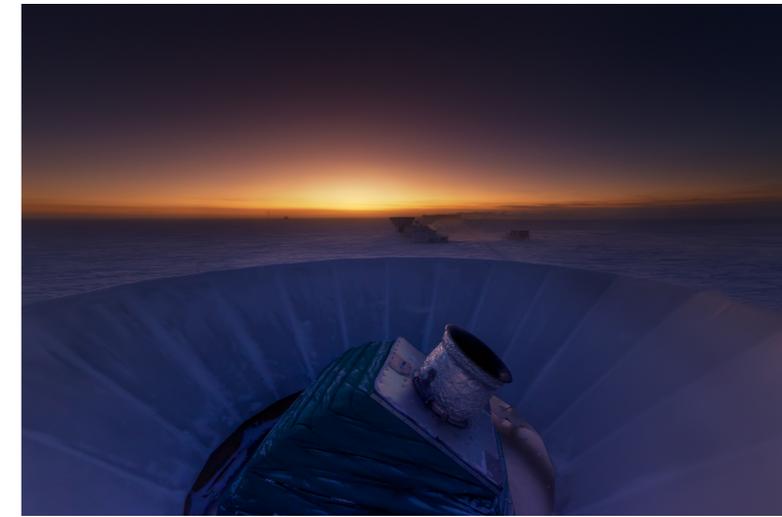
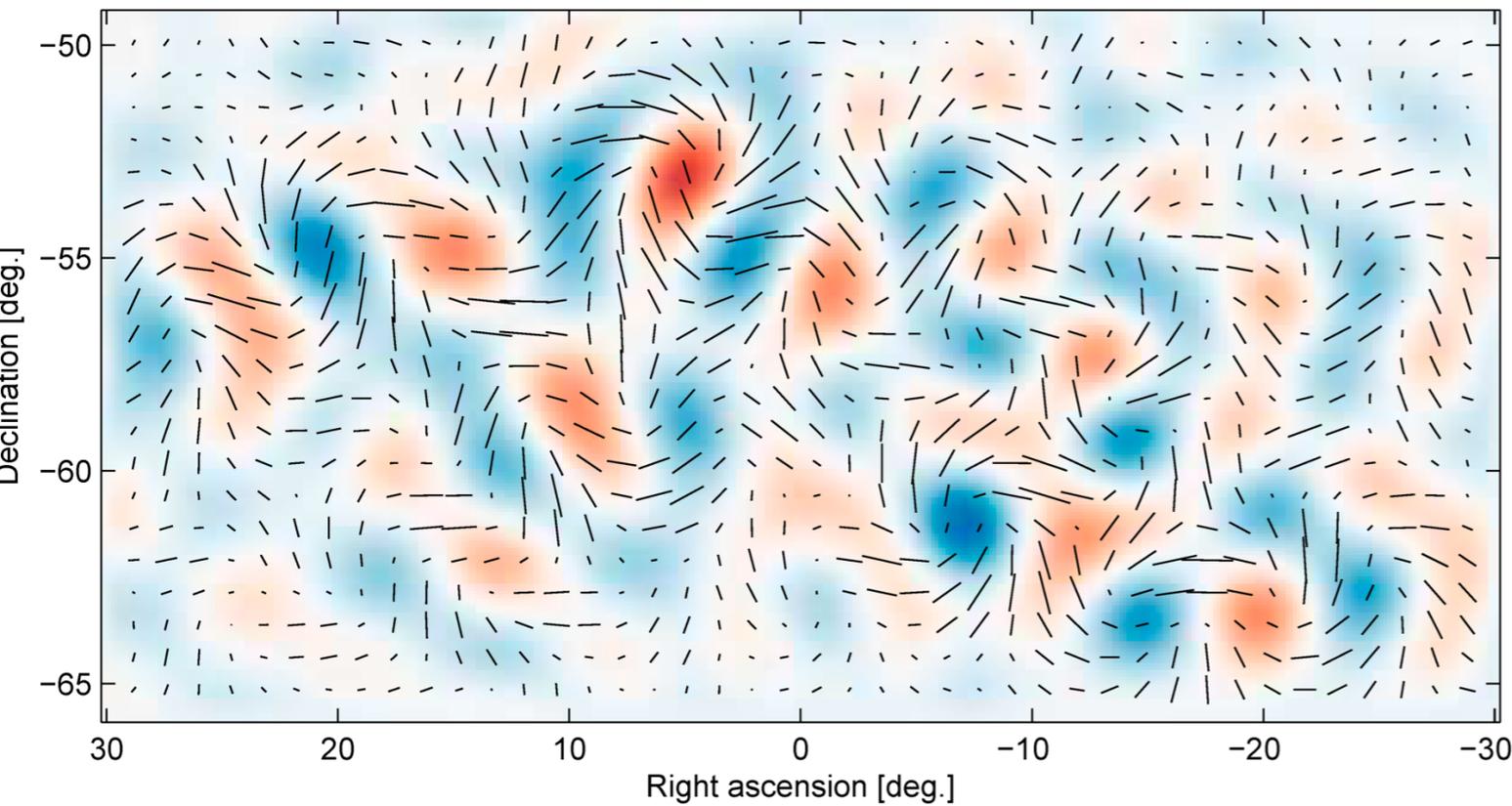


Les fluctuations du fond diffus cosmologique pourraient porter la trace des ondes gravitationnelles primordiales (visible en polarisation)



BICEP2 B-mode signal

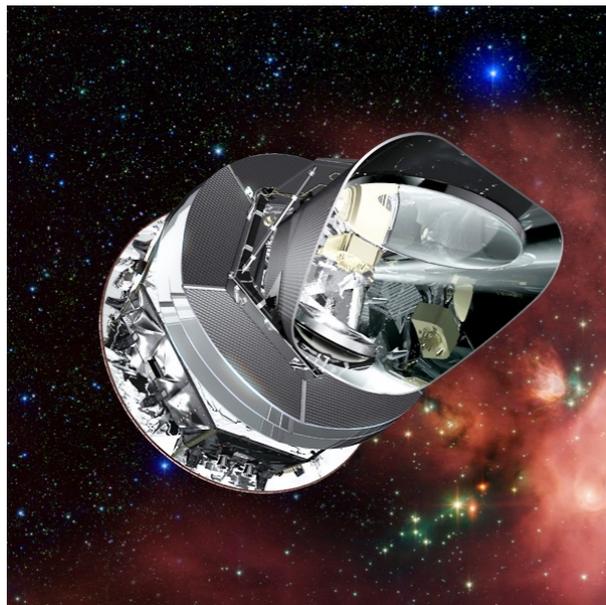
crédit: collaboration BICEP2



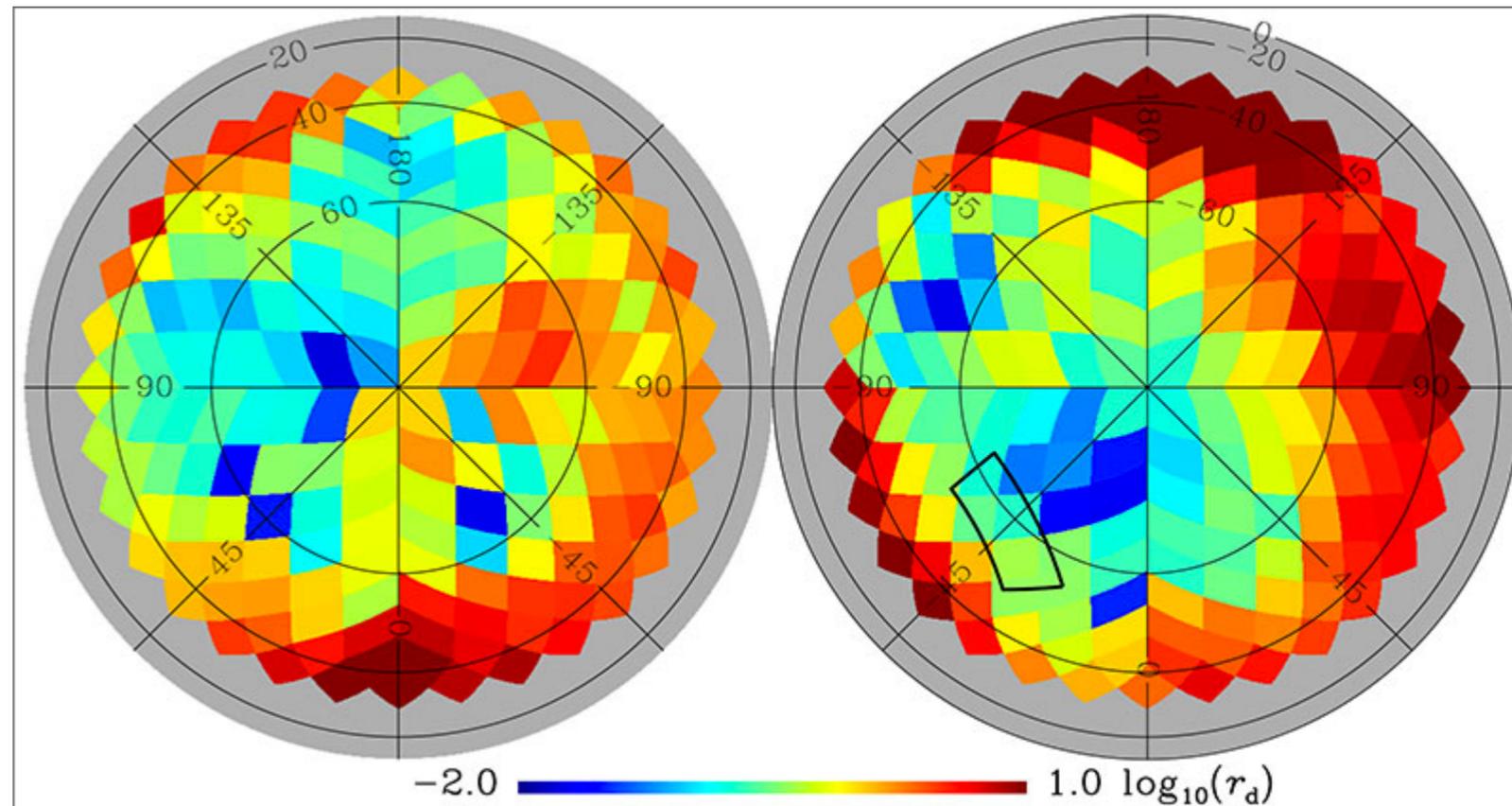
BUZZ!
mars et septembre 2014

poussières ou ondes gravitationnelles?

en fait plutôt poussières.... ondes gravitationnelles non exclues



crédit: collaboration Planck



LE MILIEU INTERSTELLAIRE: PETIT MAIS COSTAUD!

- Siège de la formation des molécules:
physique-chimie du milieu interstellaire
- Redistribue l'énergie des étoiles
 - absorption/émission par les poussières
 - refroidissement par le gaz
- c'est à partir du milieu interstellaire que se forment les étoiles et les planètes
 - rôle important dans le cycle de la matière observable

