3D Tomography of the Local Interstellar Medium

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Introduction

- Nom - Prénom : REMY Quentin

- Cursus :
  Licence physique fondamentale, Université Toulouse 3
  Master Cosmos Champs Particules, Université Montpellier 2

- Comment avez-vous eu votre contact pour la thèse ?
  Par l'intermédiaire de mes professeurs membres de la Collaboration Fermi

My thesis in few words

3D Tomography of the Local Interstellar Medium :

Decomposition in distances

Velocity-distance association

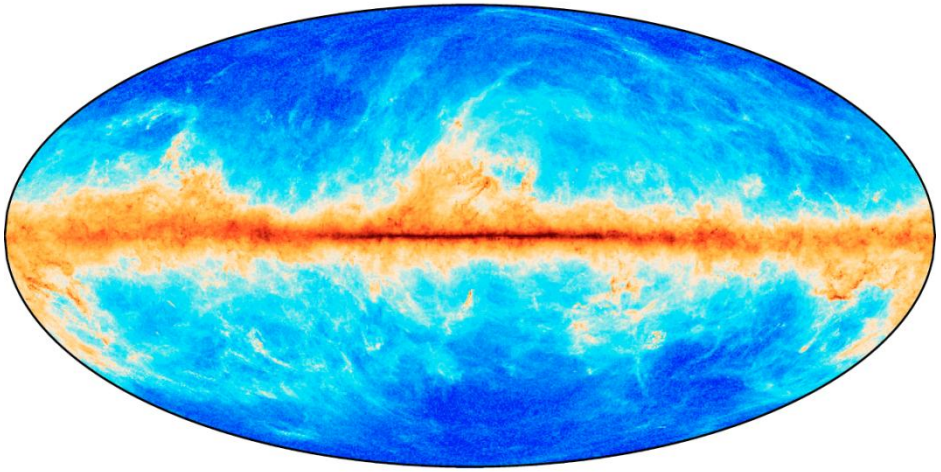
Stellar parallax

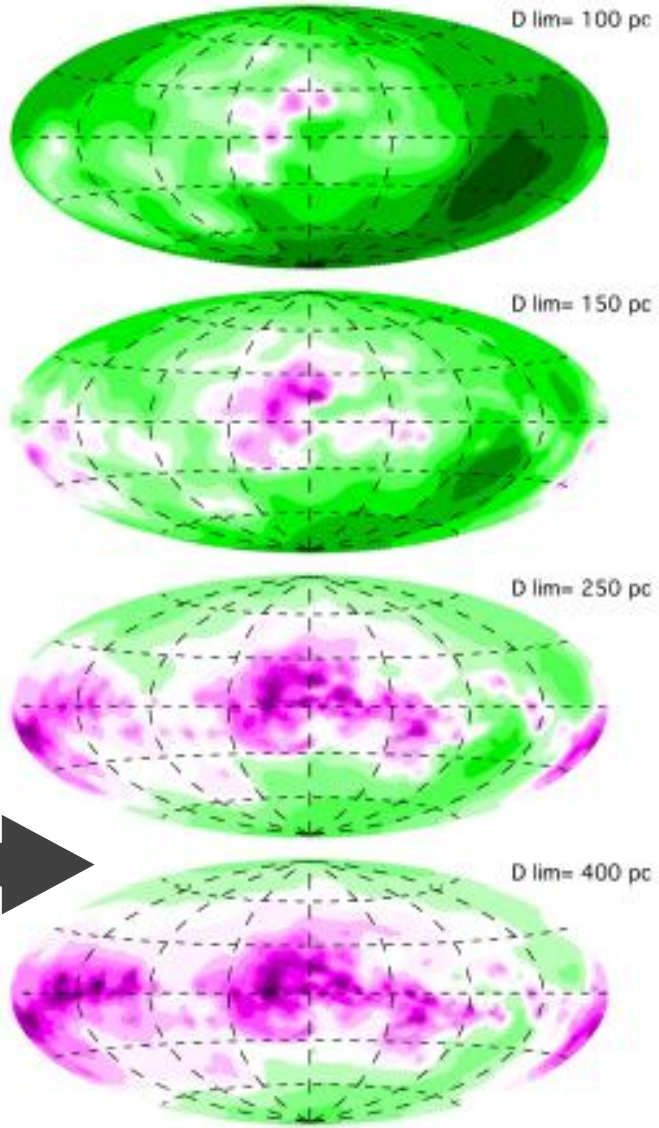
Gas and dust

Molecular clouds

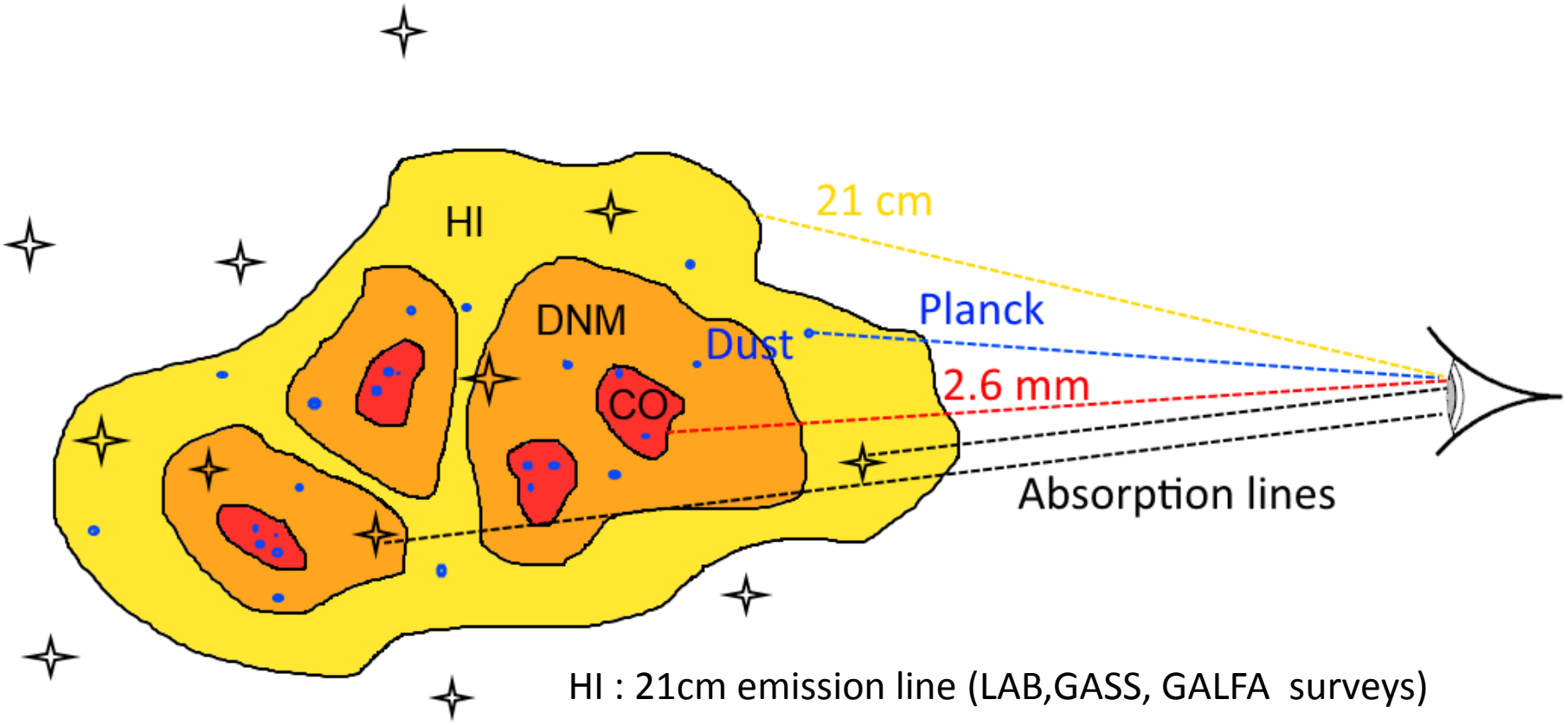
Dark gas

500 pc of the sun





Observations from gas and dust



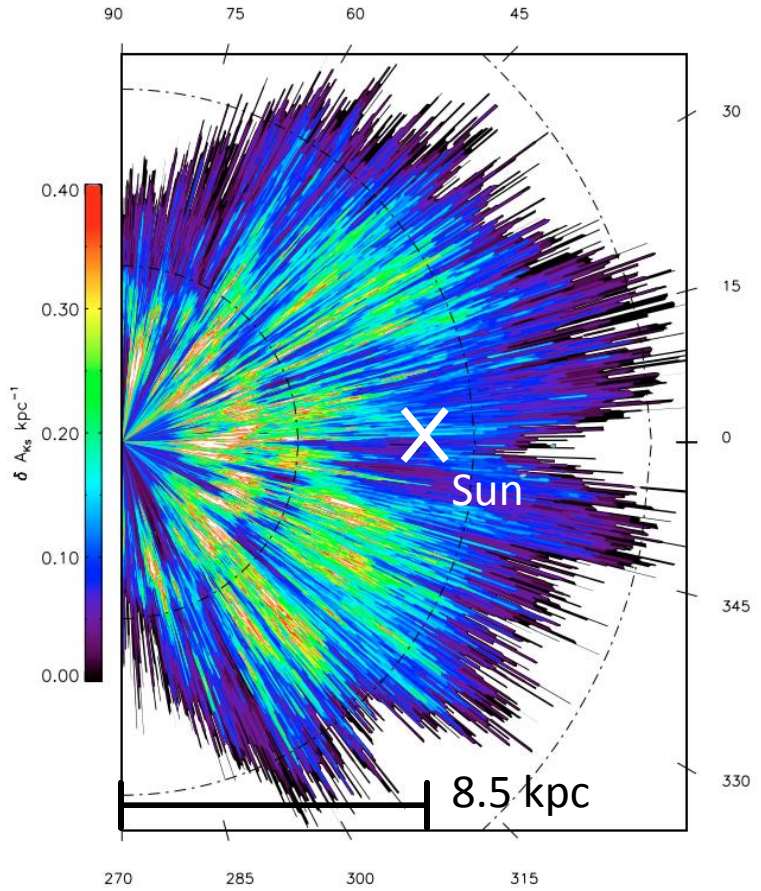
HI : 21cm emission line (LAB,GASS, GALFA surveys)

CO : 2.6 mm emission line (Cfa survey)

Dust : optical depth τ_{353} (Planck)

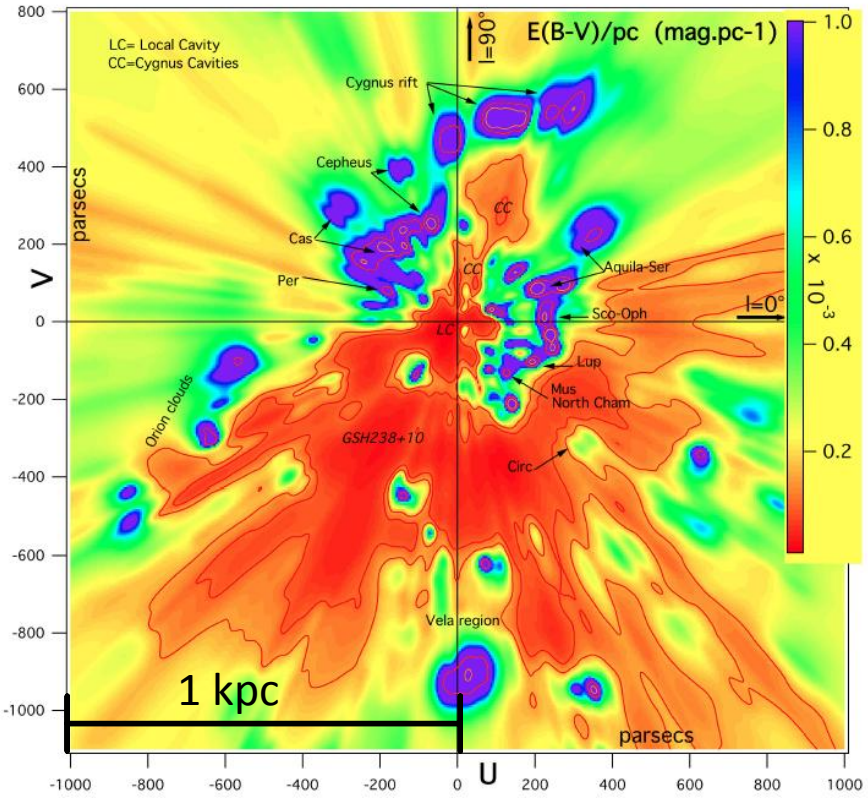
Stars : NaI and CaII absorption lines, extinction

3D maps from stellar extinction by dust



Marshall *et al.* 2006

- Extinction from 2MASS modelled in 3D
- Large scale distribution
- Not enough stars in solar Neighbourhood

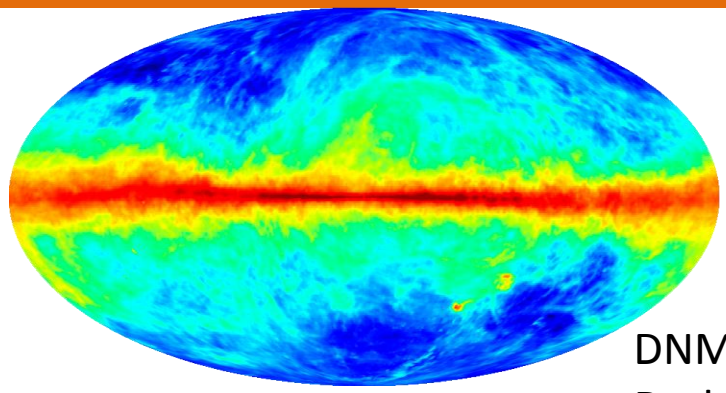


Lallement *et al.* 2013

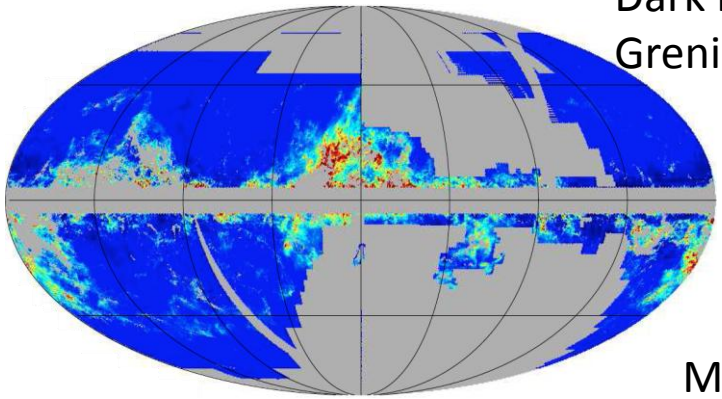
- Local ISM from stellar extinction/reddening
- Holes and clouds mapping
- Not precise structure of the clouds

Thesis main tasks

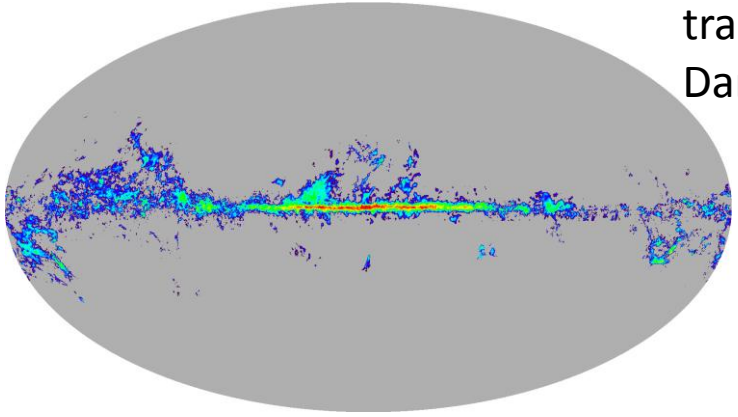
- Tomography of the local clouds :
  - Separation of cloud entities (in space and velocity)
  - Velocity-distance relation
  - Stellar distance : parallax
- Trace and estimate gas mass :
  - ISM modelling with dust and γ-rays
  - Map the DNM
  - Test the tracing reliability



Atomic phase traced by HI
Kalberla et al. 2005



DNM
Dark Neutral Medium
Grenier et al. 2005



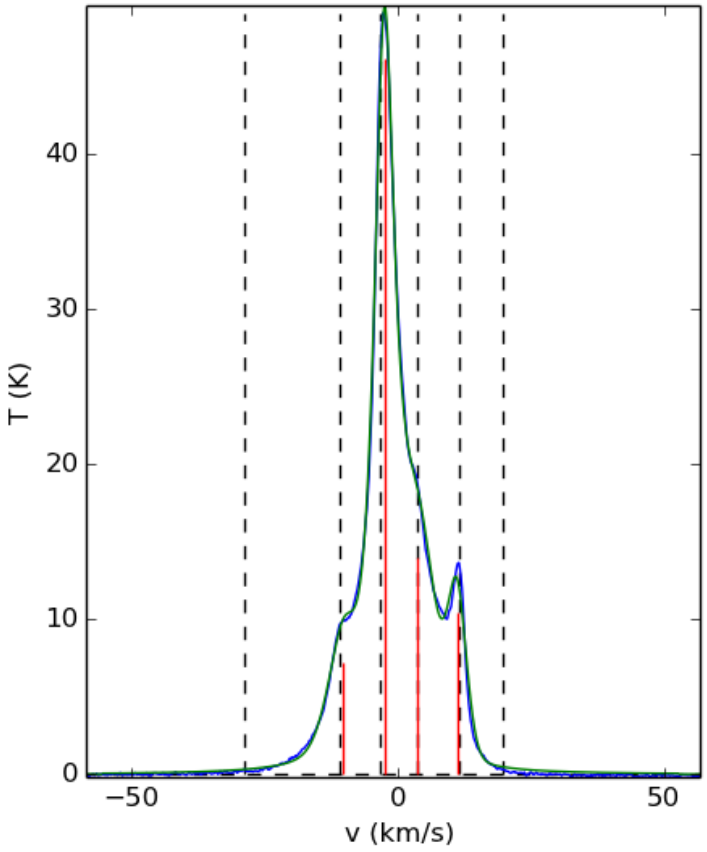
Molecular phase traced by CO
Dame et al. 2001

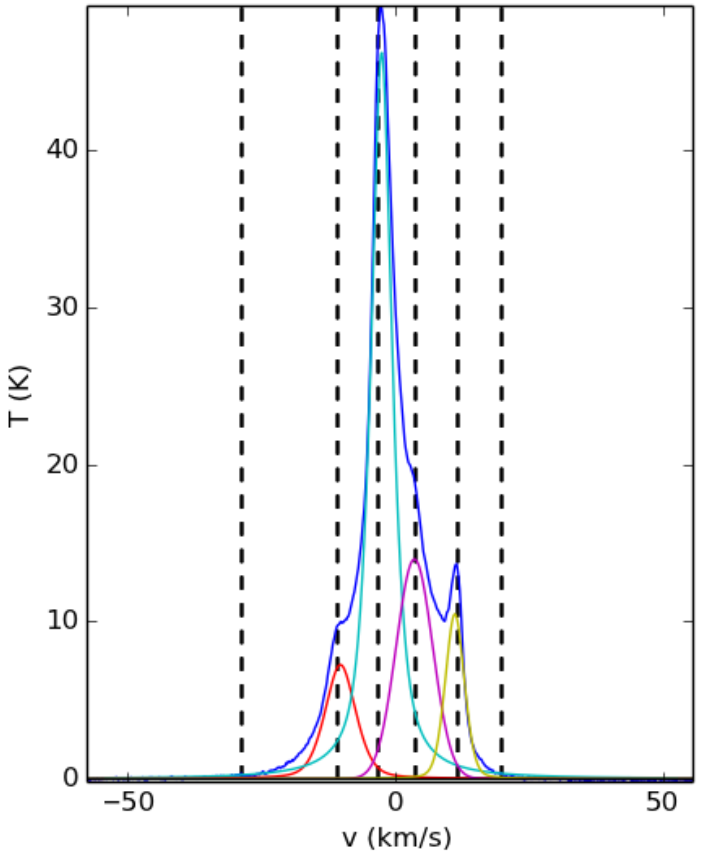
I – Clouds separation and distance association

HI and CO velocity separation

- Observed line profile = sum of lines emitted along a line of sight
  = sum of pseudo-Voigt functions

- Coherent cloud = cluster of lines in position and velocity



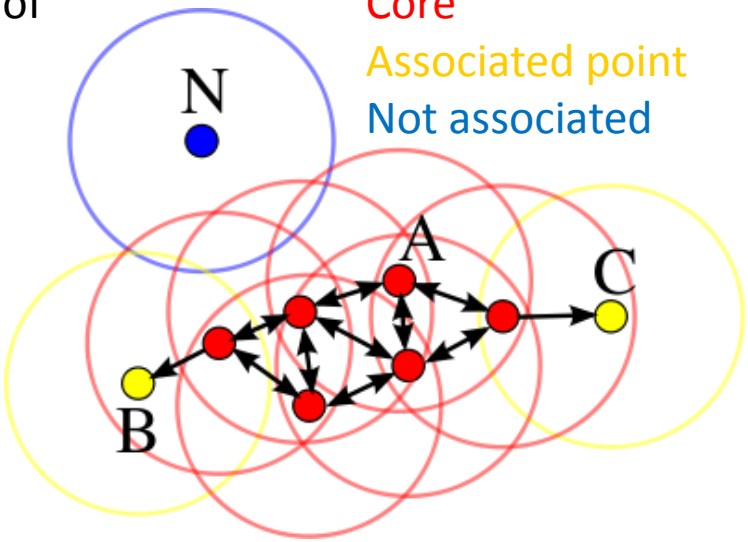


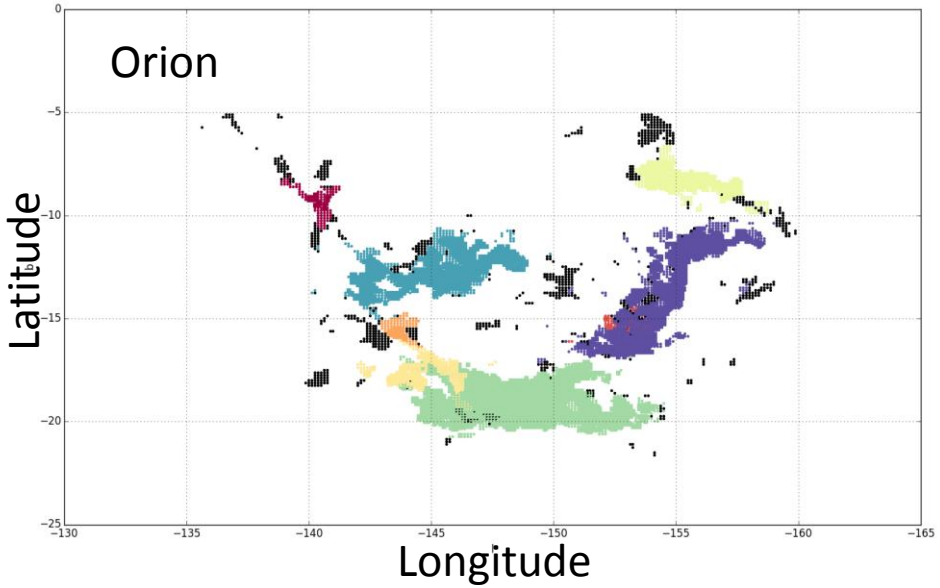
Clustering algorithm

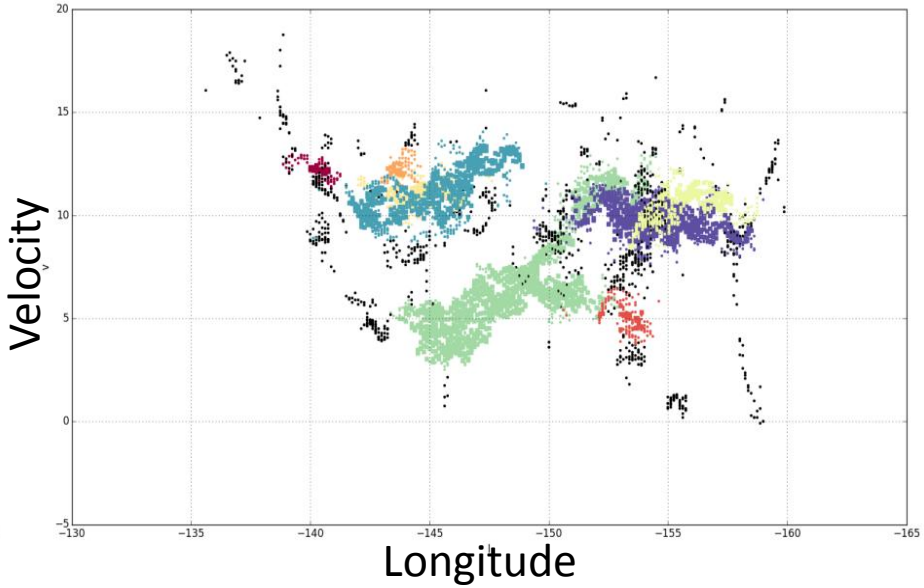
- Based on **DBSCAN** (Density-Based Spatial Clustering of Applications with Noise)

  2 parameters :
  - MinPts, minimum number of points to form a core
  - ε, maximal distance to associate a point to a core

- Multi-scale implementation to scan a range of density level







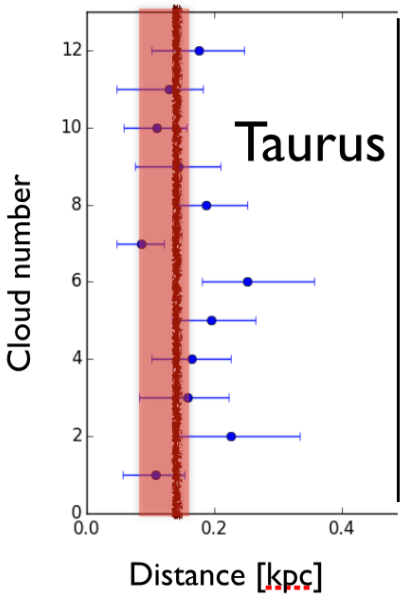
Distance estimates from 3D stellar extinction

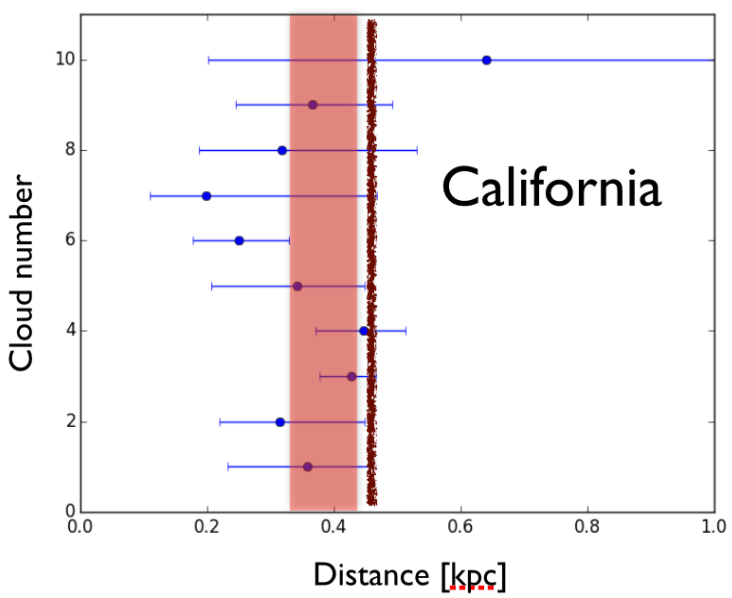
New extinction distances

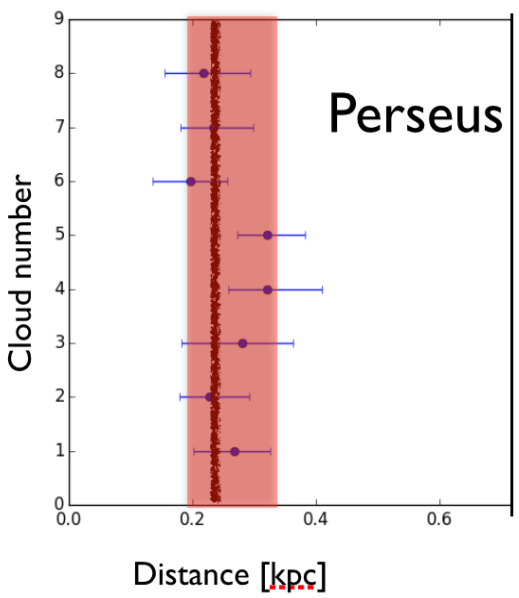
Literature values

Range of distances from Schlafly et al. (2014)

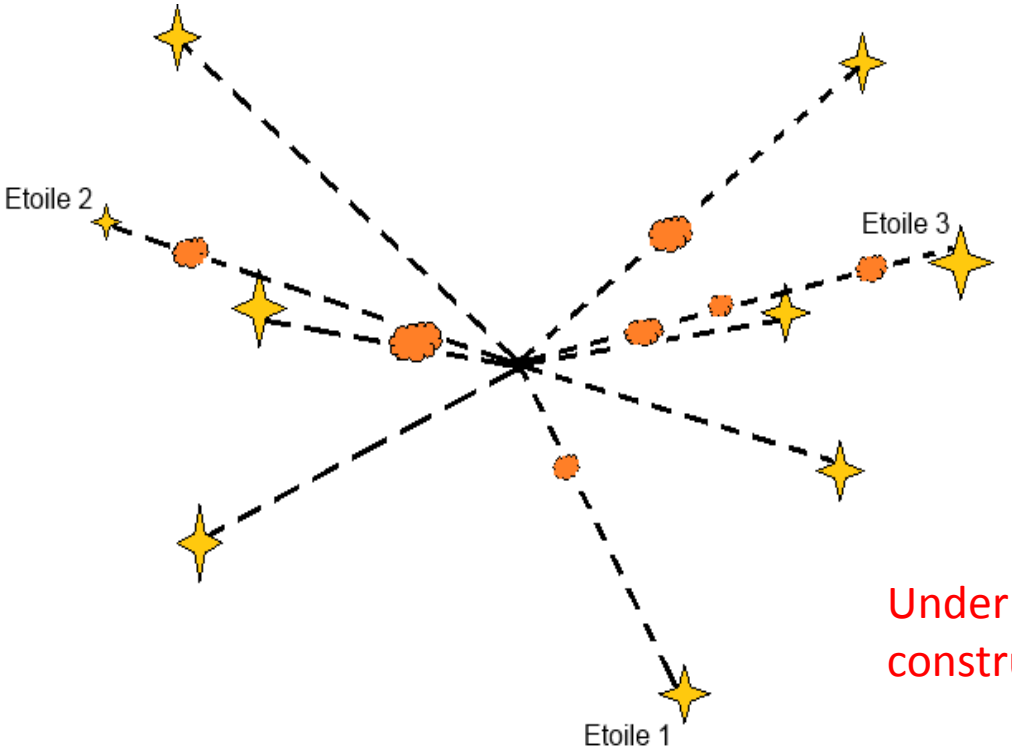
PRELIMINARY



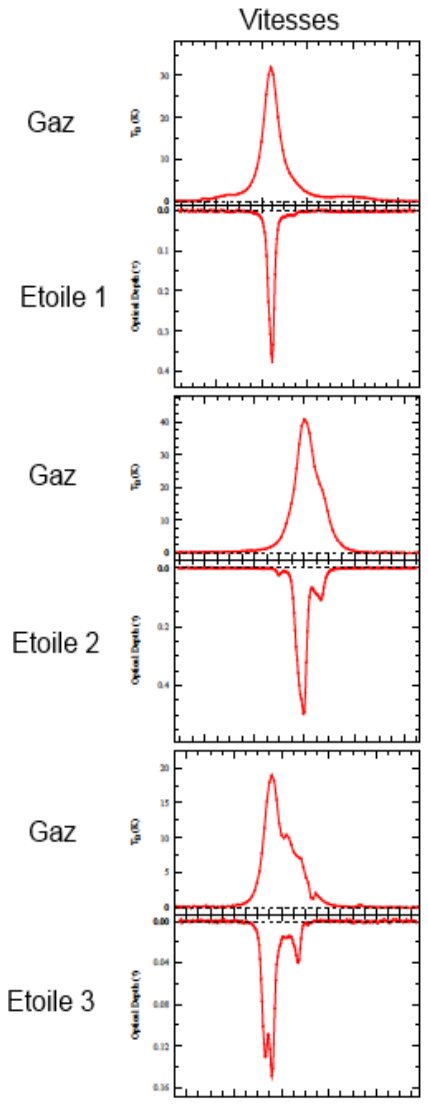




Distance association with stellar spectroscopy



Under construction



- How to relate the gas intercepting starlight and the gas seen in emission : relate emission (HI, CO) and absorption lines (NaI, CaII, DIB)
- Gas distance constraints by stellar positions
- Large number of targets required

II – Trace and estimate gas mass : Modelling the Interstellar Medium

Tracing interstellar gas

- Using cosmic-ray interaction with gas

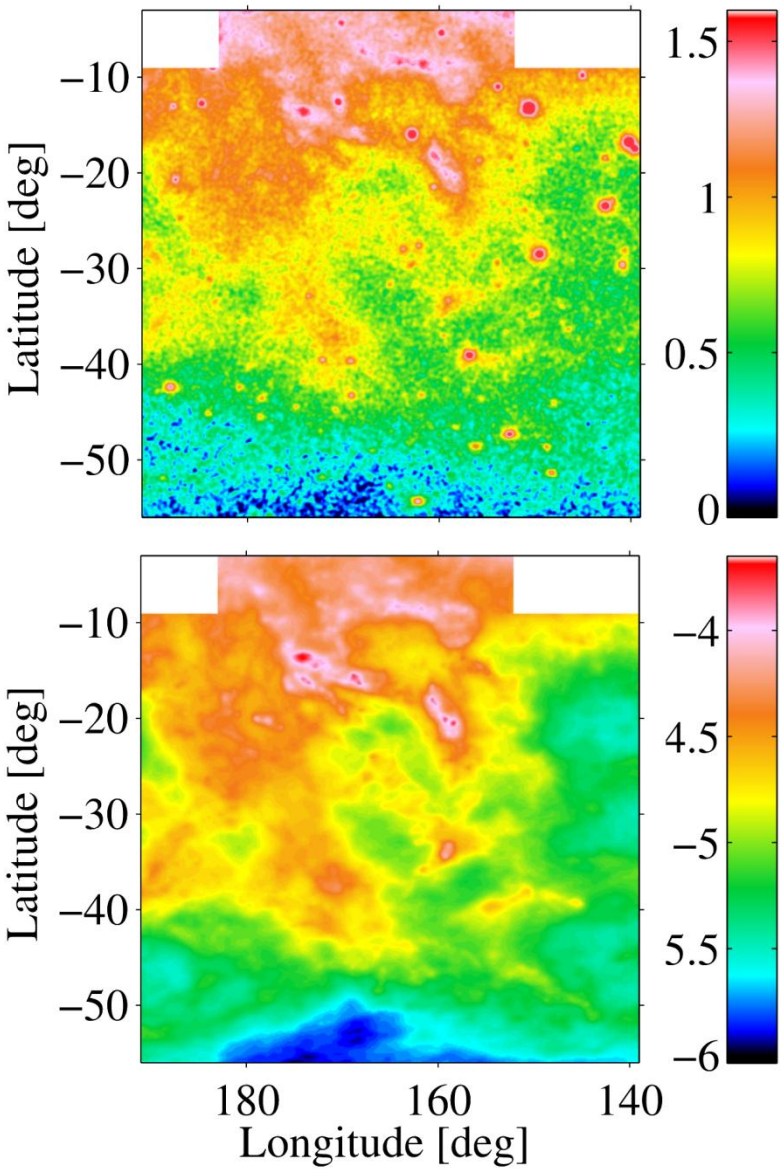
  $n_{CR} + n_H$ -> γ-rays

  Fermi data

- Using dust optical depth :

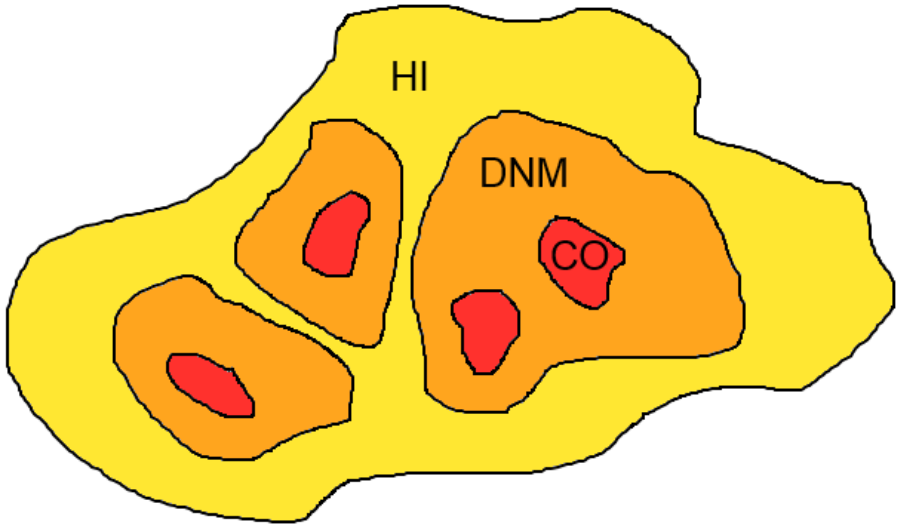
  n_{dust}-> $\tau_{353} = I_\nu / B_\nu$

  Planck data



Total gas column density :
HI-bright
Dark Neutral Medium (DNM)
CO-bright

Traceability conditions



All gas phases well traced if :

- Uniform Cosmic-Ray density n_{CR}
- Uniform dust to gas ratio and grain emissivity κ_ν

Within a cloud

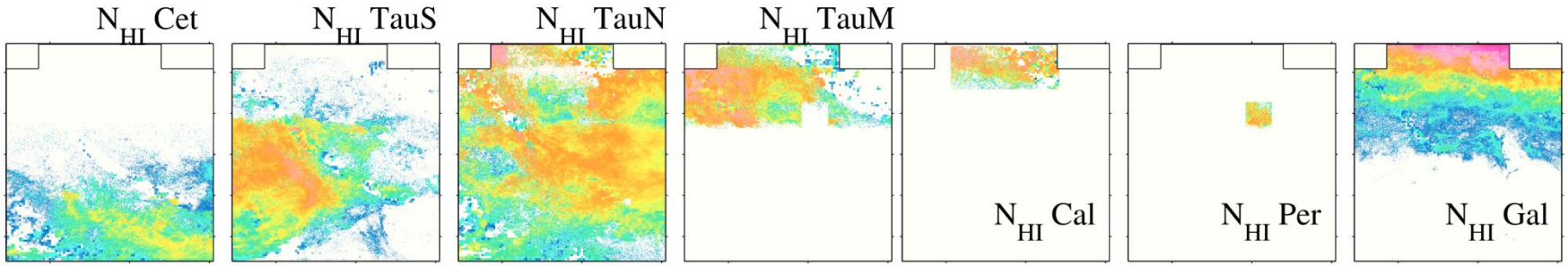
- DNM structure and mass
- CO to H_2 conversion factor X_{CO}
- Large grain properties, dust/gas ratios in each phase

γ-rays and dust models

Linear combination of HI and CO separated in (l, b, v, d), HII, DNM, COsat and non-ISM ancillary data :

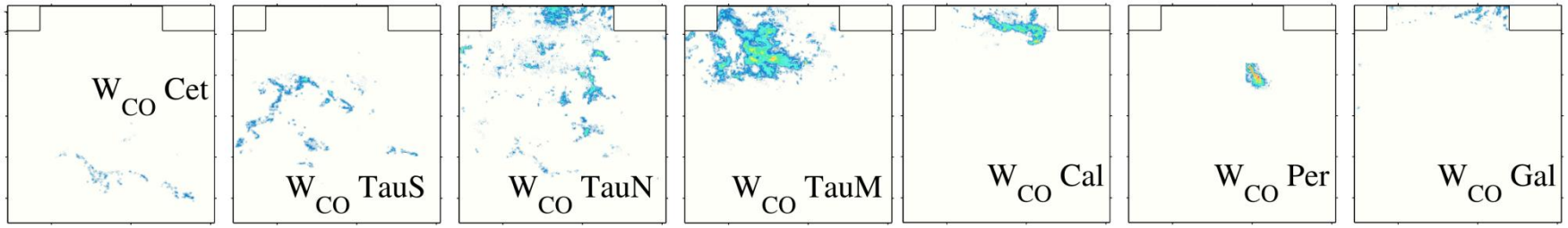
$\tau, \gamma =$

$\sum_{HI}$



220 pc 160 pc 230pc 150 pc 410 pc 280pc

$+\sum_{CO}$



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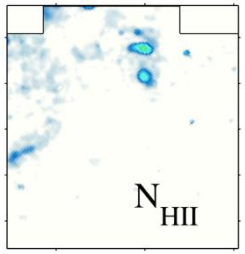

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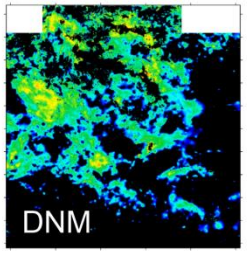

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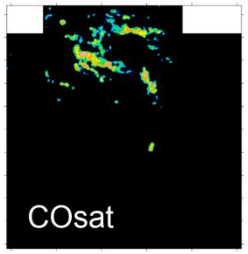
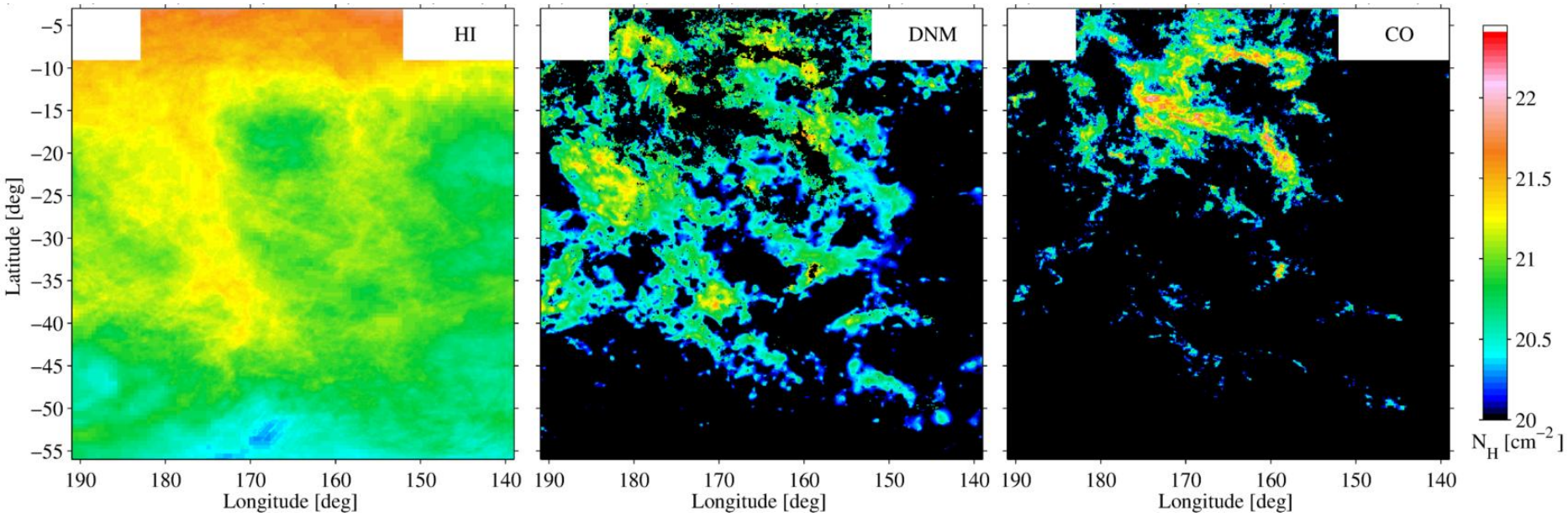
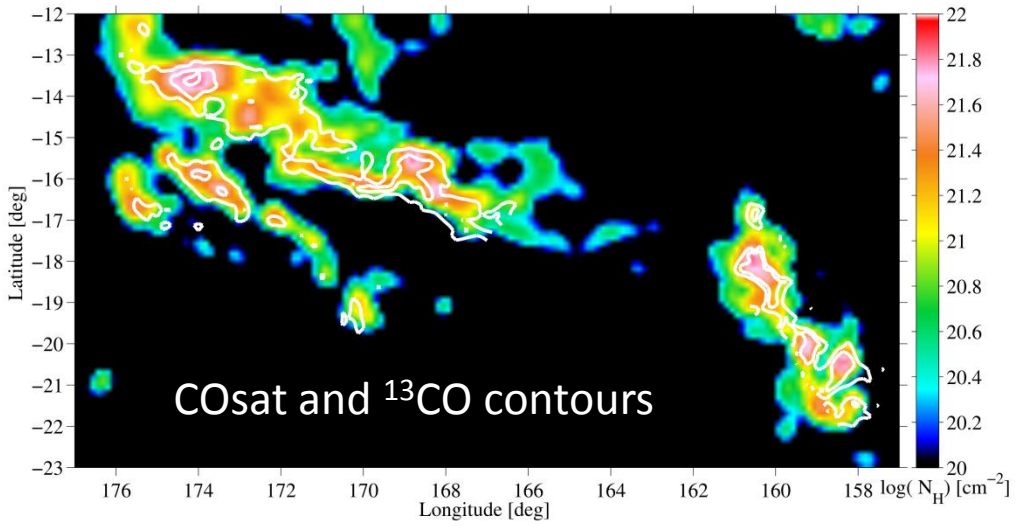


\+ non-ISM ancillary data

Gas phases content





Mass distribution :

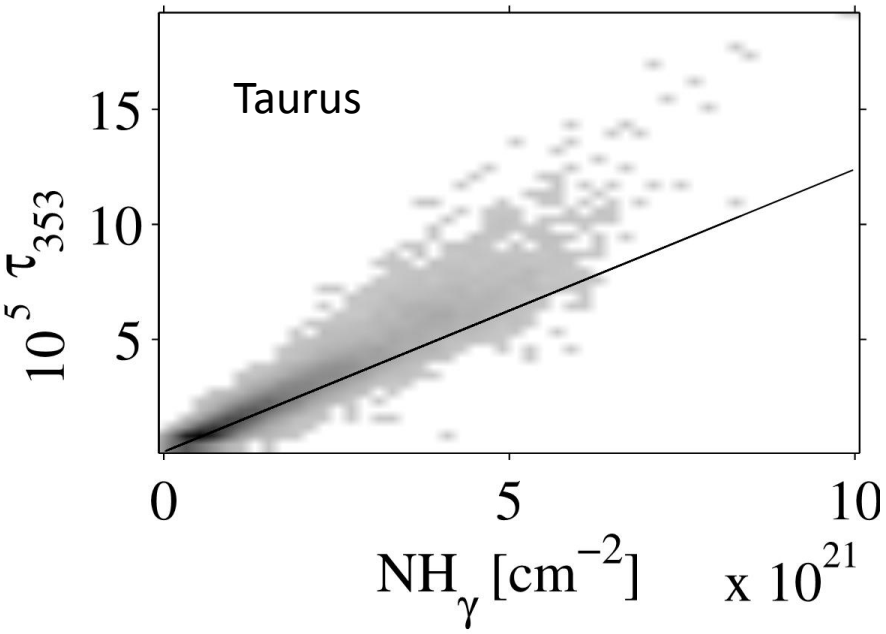
70% HI

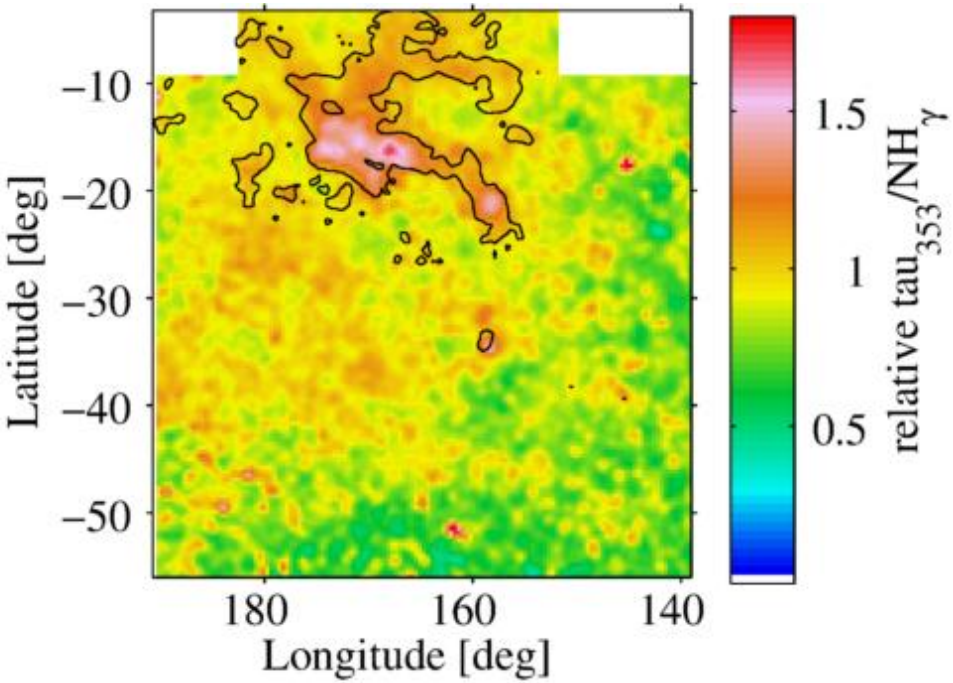
15% DNM

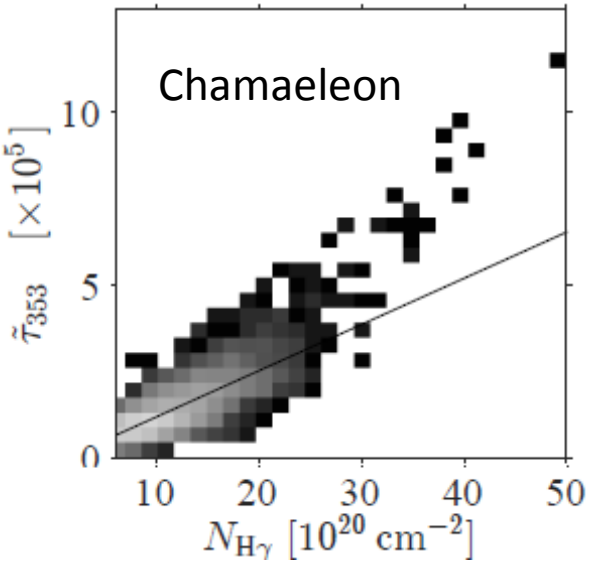
12% CO-bright

3% CO-saturated

Evolution of dust grains ?







- Taurus + Chamaeleon : τ_{353} non-linear increase with N_H
- Dense molecular clouds : large variation of τ_{353}/N_H
- Dust grain evolution : emissivity increases with gas density

Conclusions and perspectives

- Decomposition of HI and CO in coherents clouds in velocity
  - Method built and tested
  - Application to Taurus region : publication this summer
  - Extension to Galactic anticenter

- Velocity-distance association with stellar spectroscopy and parallax
  - under construction
  - application to Gaia data this autumn

- Dust and γ-rays tracing of gas mass in Taurus
  - maps of DNM and COsat components
  - Evidence for decrease in X_{CO} from cloud enveloppe to core
  - Evidence for grain emissivity changes with gas density in Taurus, as in Chamaeleon