Millimeter rotational lines as powerful diagnostics of the physical conditions inside a Giant Molecular Cloud - The Orion B case

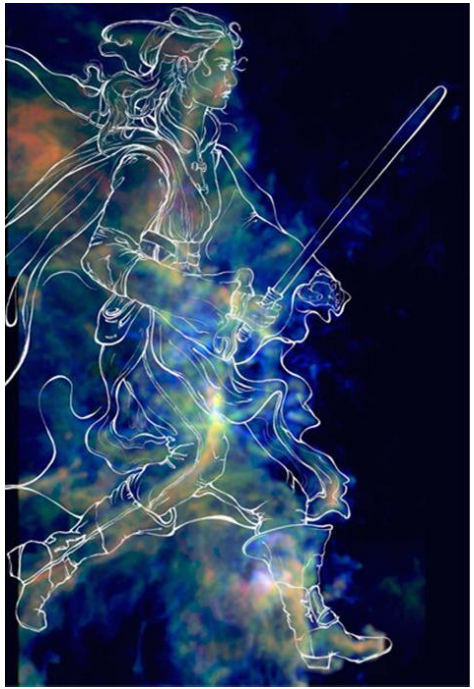


image credit & copyright: Audrey Pety

Athanasia Gkogkou, Elena Hoemann, Pierre Palud, Katherine Rawlins, Miriam Santa-Maria, Ksenia Telikova

Tutors: Emeric Bron & Jérôme Pety

Column Density estimation technique

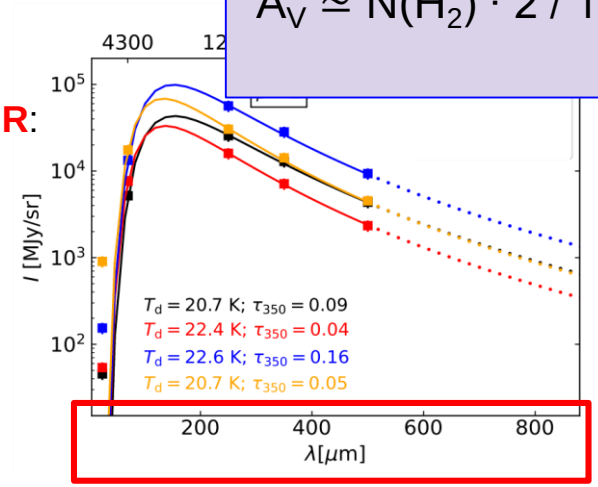
$M_{gas} \propto \mu\, m_H\, N(H_2)\ [M_\odot]$

Dust-continuum-emission observations

$N(H_2) = 1.35 \cdot 10^4 \cdot \tau_{850\mu m} \cdot 1.9$ [illegible]

$A_V \simeq N(H_2) \cdot 2 / 1.9 \cdot 10^{21}$ [mag]

In GMCs ->
dust emits in the FIR:
warm Big Grains
T_{dust} ~ 15 - 80 K

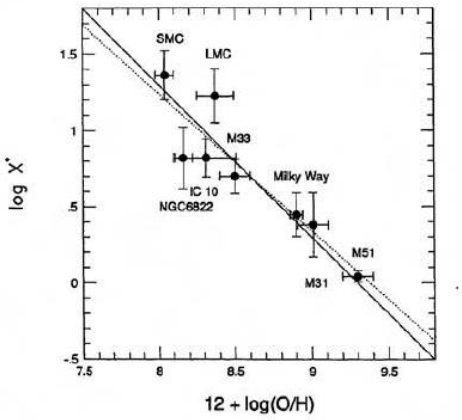


Need space telescopes like Herschel: None in the next decades.

X_{CO}: The CO-to-H_2 conversion factor

$N(H_2) = X_{CO} \cdot W(CO)$

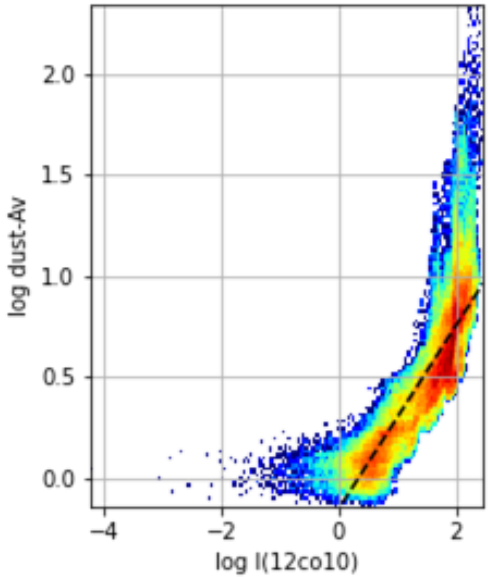
[illegible]% uncertainty in the inner disk
[illegible]e MW (Bolatto+13)
- Metallicity dependent (Arimoto+96)



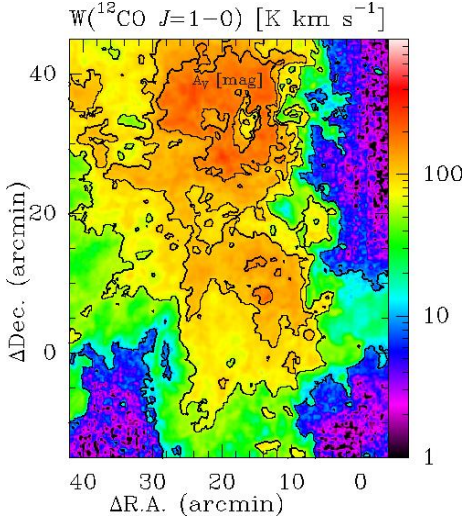
Observations of Orion B

Orion B GMC as a local template for interpreting Galactic and extragalactic molecular line observations.

One square degree map across the full 3mm band (84.5 to 115.5 GHz) with angular resolution: 31'' ~ 60 mpc



^{12}CO *J*= 1-0	^{12}CN *N*= 1-0	^{12}CS *J*= 2-1
^{13}CO *J*= 1-0	C^{17}O *J*= 1-0	C^{18}O *J*= 1-0
HCO$^+$ *J*= 1-0	HCN *J*= 1-0	HNC *J*= 1-0
H^{13}CO$^+$ *J*= 1-0	N_2H^+ *J*= 1-0	CH_3OH *J*= 2-1
c-C_3H_2 *J*= 1-0	CCH *J*= 1-0	^{32}SO *J*=3-2



Multidimensional data: Principal Component Analysis

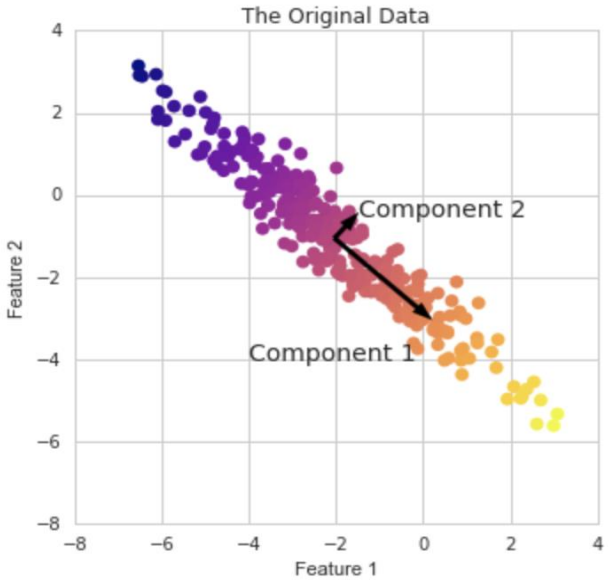
We are interested in:
Is there any relation between the features (12D data)?
Clusterization of the data in a lower dimensions?

Principal Component Analysis (PCA):
find **linear** relations between the features

Mathematically: find new orthogonal basis with maximum variance of the data along them

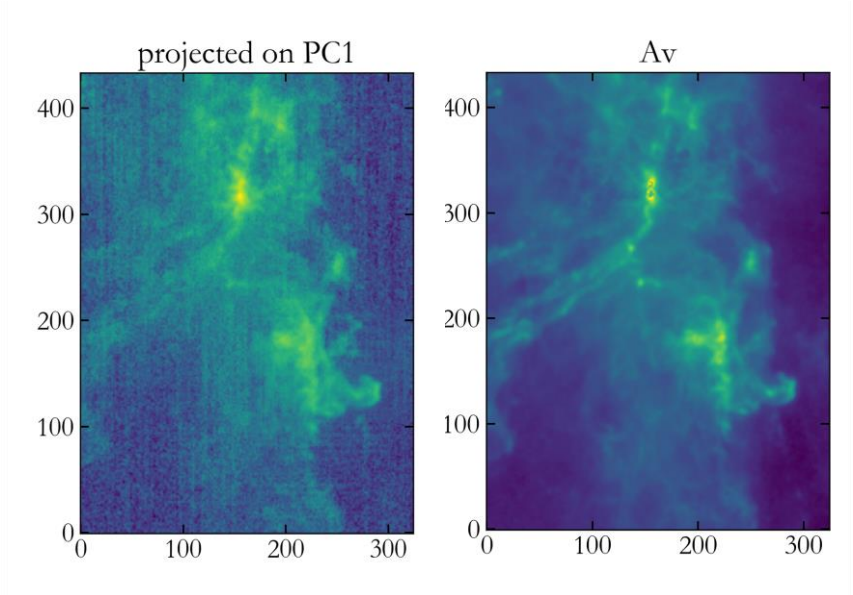
Technically: singular value decomposition of the data
Python: scikit-learn (Pedregosa *et al.*, JMLR 12, pp. 2825-2830, 2011)

2D example

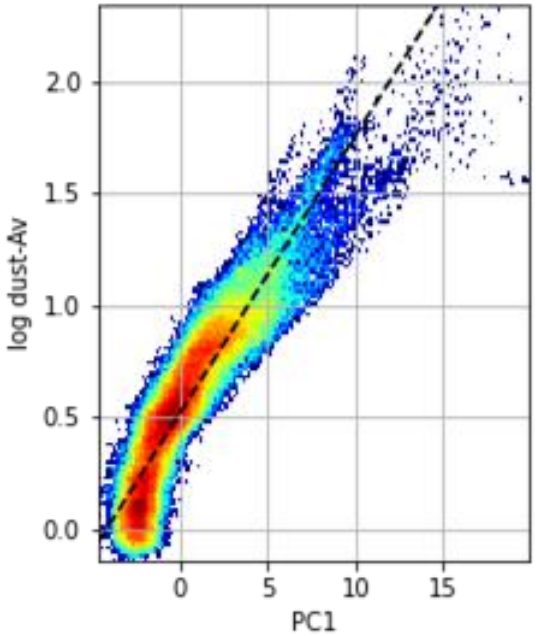


PCA of 12 rotation lines intensities

Data projected to the first Principal Component reflect visual extinction



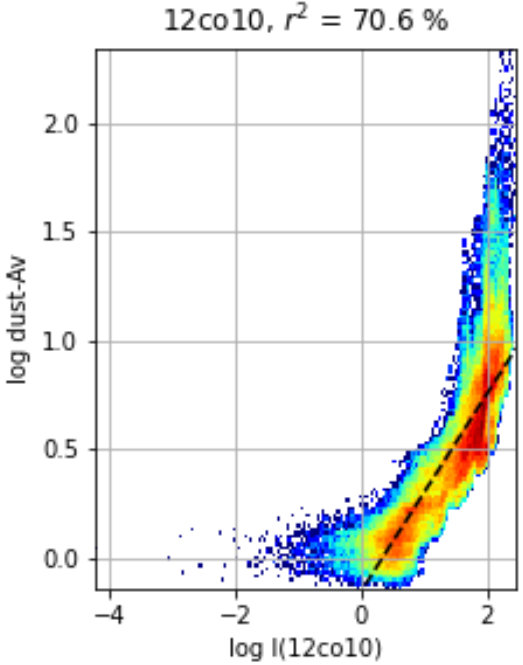
Correlations between data projected of the PCs and Av



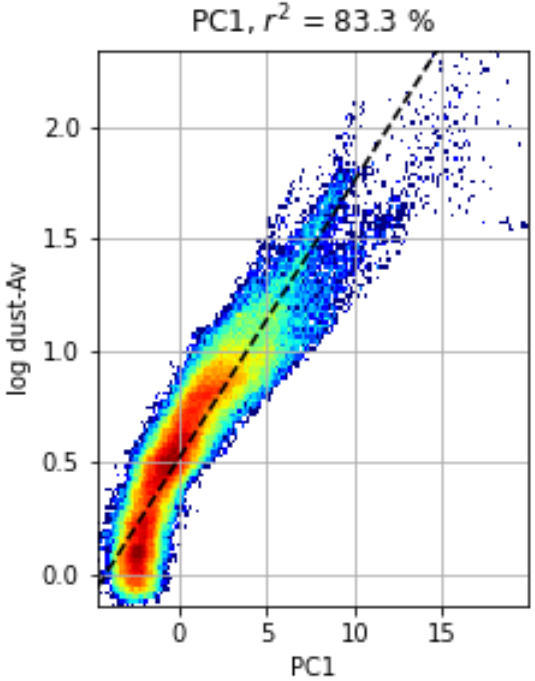
Methods comparison

	bias	std error
X_{CO}	0.67	0.89
PC1	0.00	0.24

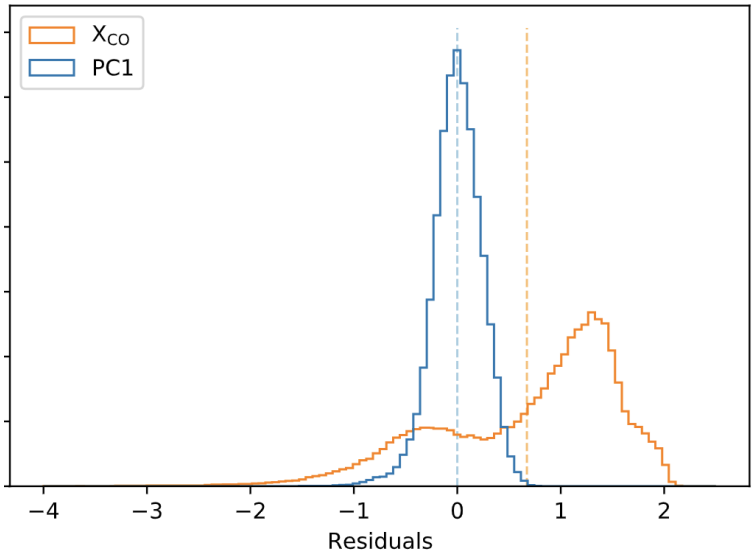
with X_{CO} method



with PC1



comparison of errors on log dust-AV prediction



Summary

Conclusions

- 12 line intensities from Orion B GMC
- PCA yields better results
- PCs **1**, **2**, **3**: **column density**, **bulk density**, **FUV radiation**

Perspectives

- Interpret the higher principal components
- Non-linearities: random forests, other techniques
- Identify most significant lines