Reduction and Analysis Techniques - Spectral lines

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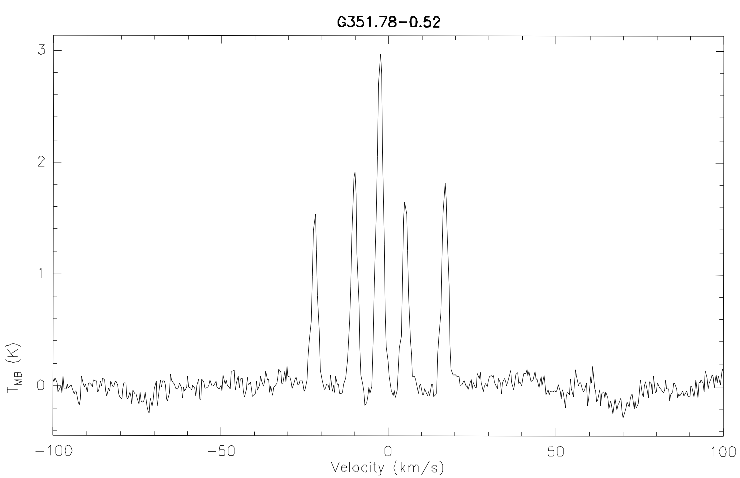
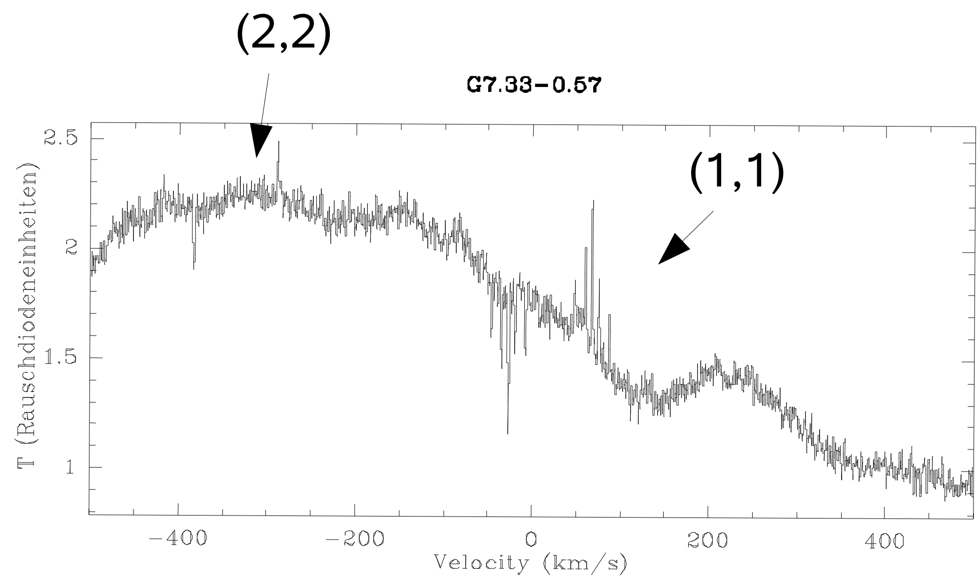
Observing Methods

position switching



frequency switching



advantages: good baseline

total time on source ⇨ increased s/n ratio

disadvantage: decreased s/n ratio,

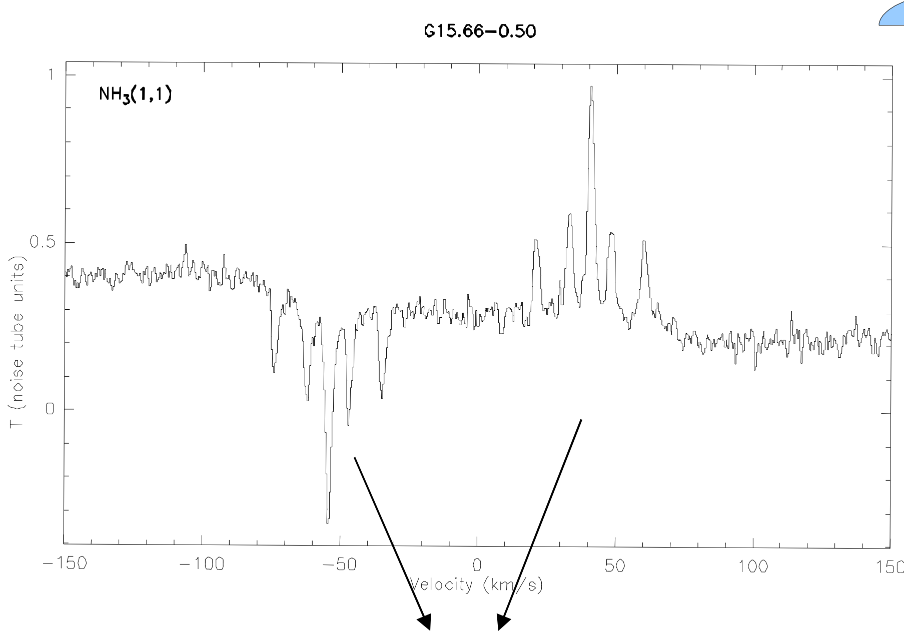
baseline variations

offset must be free of emission

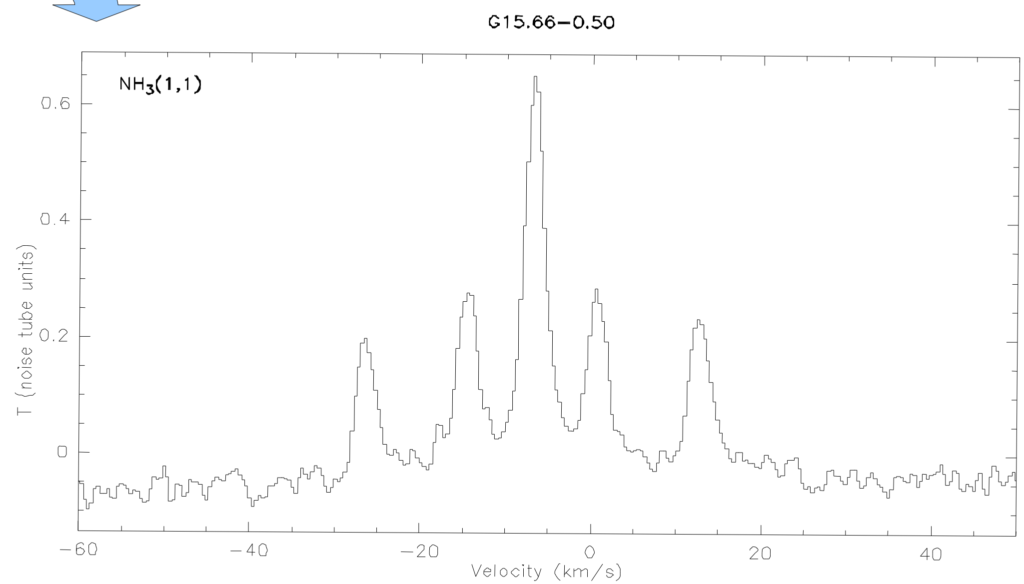
Reduction: Step 1

Frequency switching

folding different phases



7.5 MHz



using shift and subtract algorithm

Reduction: Step 2

Baseline subtraction

- fluctuations in the baseline

⇒ setting a window around the spectral line, subtraction of a polynomial of order 3 to 7

Polynomial $P(x)=\sum_{i=0}^{n} a_i x^i , n \geqslant 0$

least square algorithm: estimation of unknown parameter a in $f(x_i;a)$ predicting the true value of y for any x

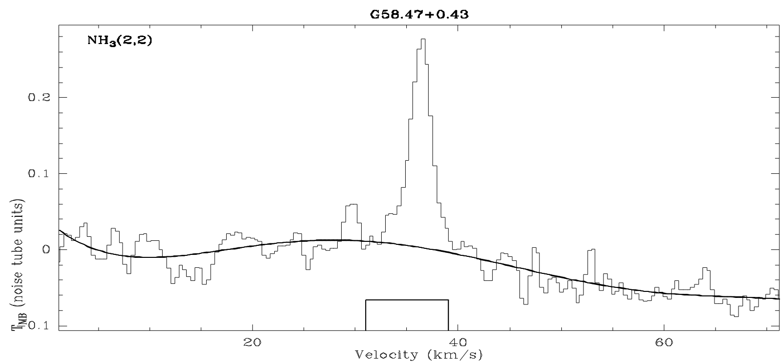
- N known x values,
- corresponding measurements y,
- prediction $f(x_i;a)$, expected error σ

$$\chi^2=\sum_{i=1}^{N}\left(\frac{y_i-f(x_i;a)}{\sigma_i}\right)^2$$

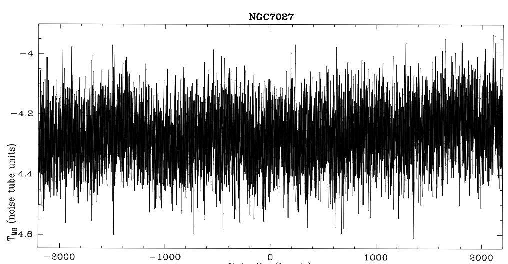
choose a value of a, which gives the smallest χ^2

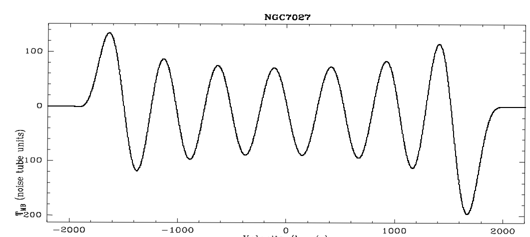
Reduction: Step 2

Baseline subtraction

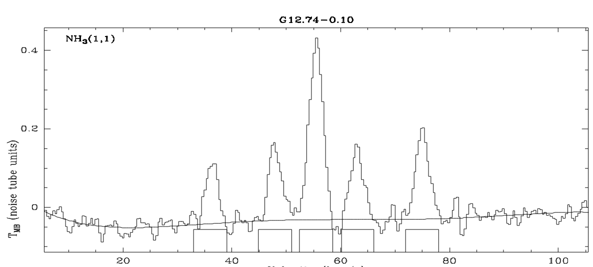


Do not subtract a polynomial of high order!

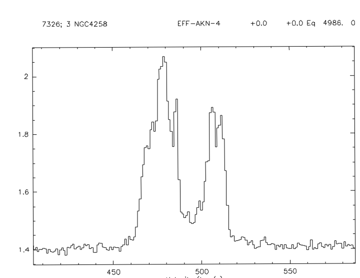




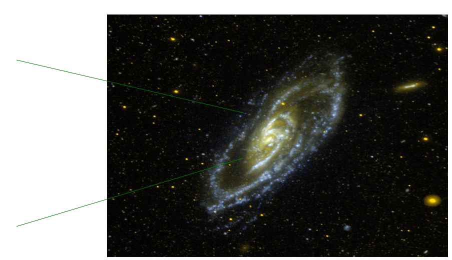
Ammonia HFS



Megamaser



NGC4258



Reduction: Step 3

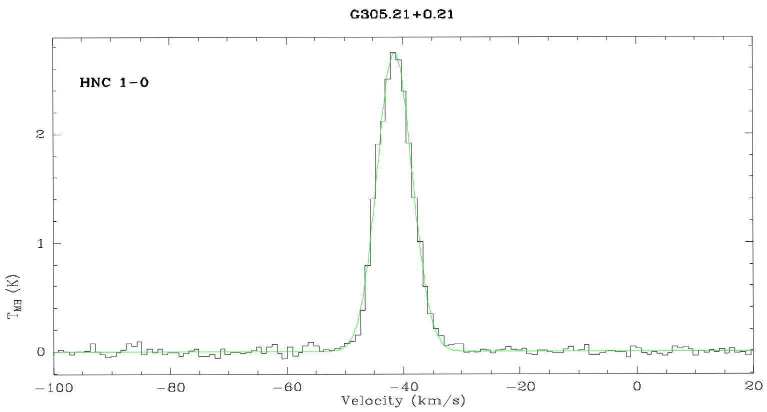
Gauss Fit

Gaussian function: $$f(x;\mu,\sigma)=\frac{1}{\sigma\sqrt{2\pi}}e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

with the expected value μ and the variance σ^2

Fitting: $$f(x,A,B,C)=A\,e^{-\left(\frac{x-B}{C}\right)^2}$$

use of least square algorithm: $$\chi^2=\sum_{i=1}^{N}\left(\frac{y_i-f(x_i,A,B,C)}{\sigma_i}\right)^2$$

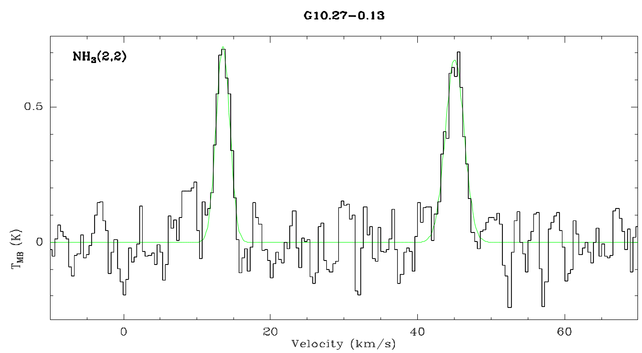


Reduction: Step 3

Gauss Fit

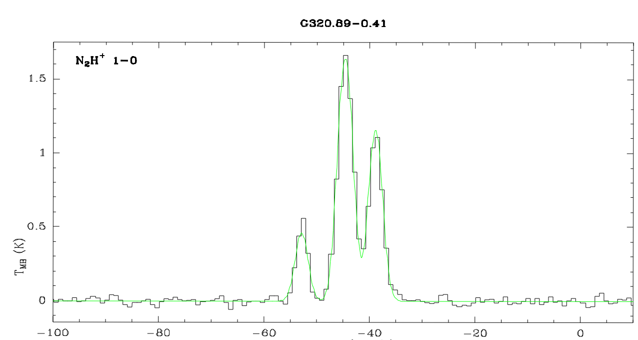
Gaussian function with N components: $$f(x, A_i, B_i, C_i) = \sum_{i=1}^{N} A_i e^{-\left(\frac{B_i - x}{C_i}\right)^2}$$

· 2 components:

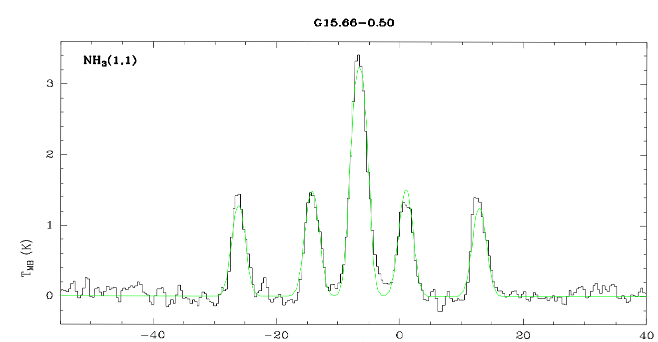


· further iterations for Hyperfine components

N_2H^+ 1-0:



NH_3 (1,1):

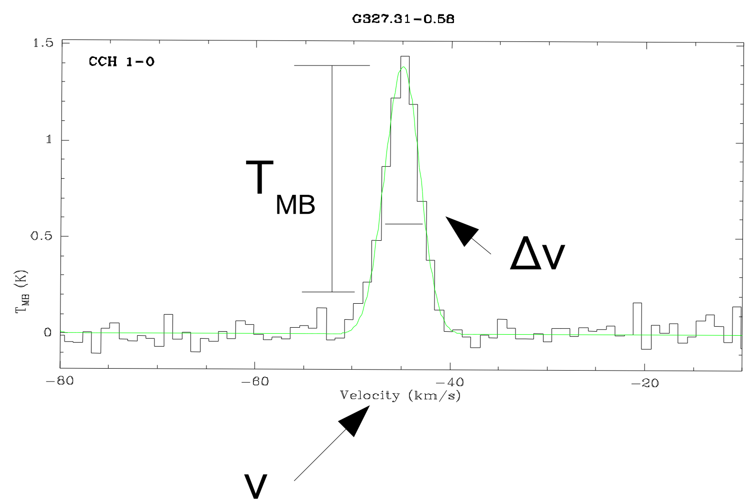


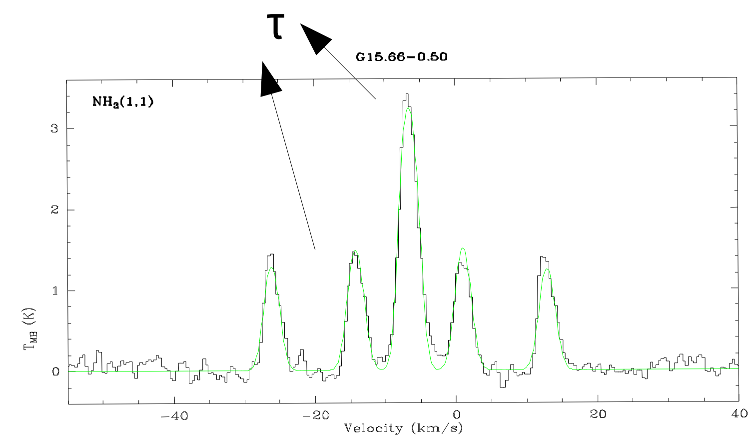
Analysis

Line parameter

Fitting of spectra:

- velocity v
- linewidth Δv
- line temperature T_{MB}
- optical depth τ





velocities: - radial motion of the source with respect to the observer

- to calculate kinematical distances using rotation curve

optical depth: for τ < 1 $\frac{T_{MB}(J,K,m)}{T_{MB}(J,K,s)} = \frac{\tau(J,K,m)}{a\tau(J,K,m)}$ for τ > 1 $\frac{T_{MB}(J,K,m)}{T_{MB}(J,K,s)} = \frac{1-e^{-\tau(J,K,m)}}{1-e^{-a\tau(J,K,m)}}$

with a = 0.22, 0.28 (Ho & Townes, 1983)

- to obtain the population of an energy level

Analysis

Line parameter

linewidth: $$\Delta v_{therm} = \sqrt{\frac{8\ln(2)kT_{kin}}{m}}$$ with the Boltzmann constant k, kinetic temperature T_{kin} and mass of the molecule m

comparison with observed linewidth Δv_{obs}:

$$\Delta v_{ntherm} = \sqrt{\Delta v_{obs}^2 - \Delta v_{therm}^2}$$ nonthermal component

large linewidth might

- hint at turbulences within the observed object, e.g. star forming regions
- result from clumping within the beam
- be due to velocity gradients due to rotation of a cloud, galaxy

Analysis

Line parameter

line temperature: - give the intensity of the observed transition

- ratio of T_{MB} of different rotational levels gives the gas temperature of a source

- together with distances necessary for mass and luminosity estimation

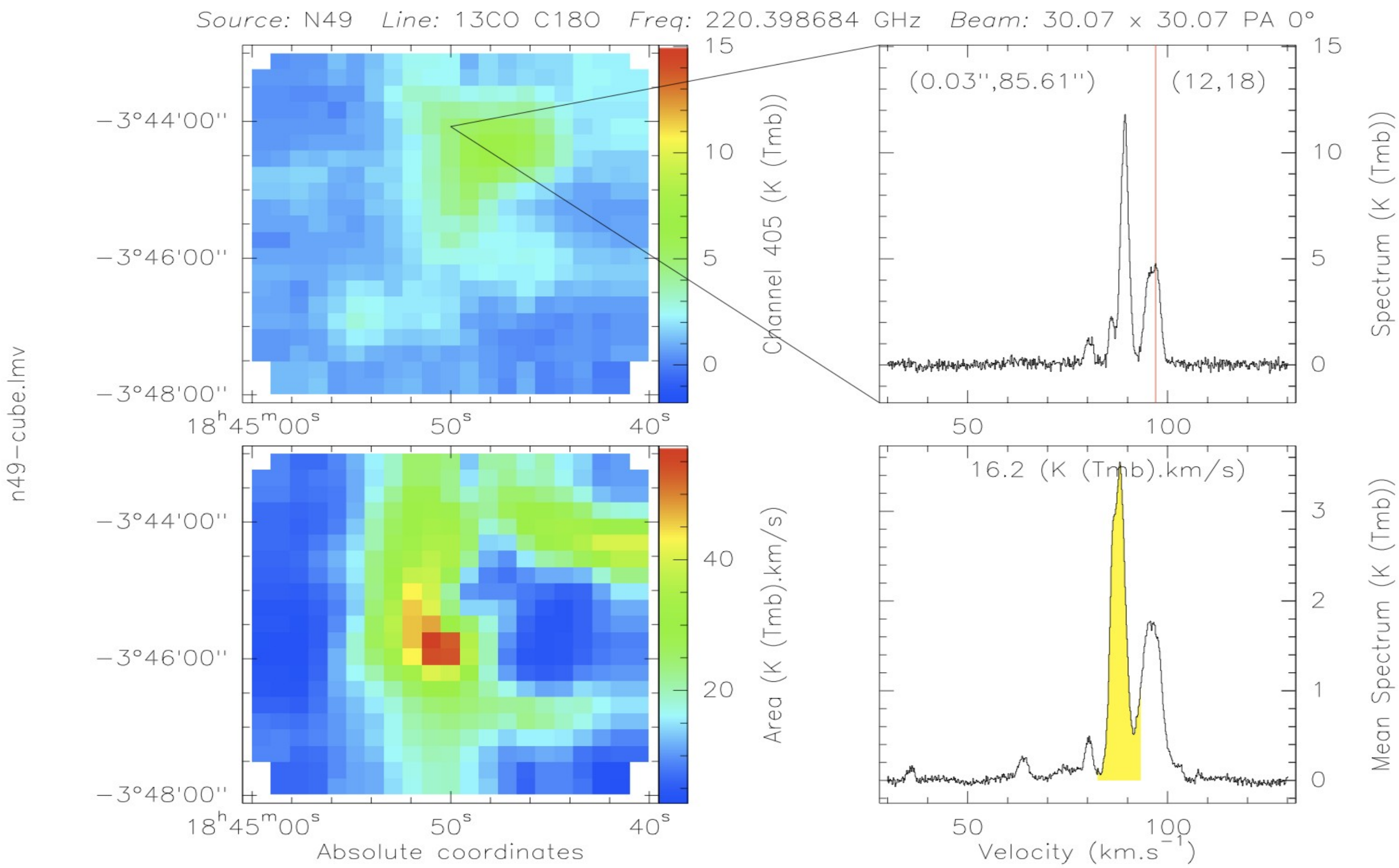
- excitation temperature $T_{ex} = \frac{T_{MB}}{1 - e^{-\tau}} + 2.7\,K$

⇒ beam filling factor : $\eta = \frac{T_{ex}}{T_{kin}}$

fraction of the beam filled by the observed source

Analysis

Mapping



Thanks for your attention!