

Definitions:

- $\nu_{\text{rest}}$  : Rest frequency of an atom or a molecule.
- $\nu_{\text{source}}(n)$  : Frequency at channel= $n$  in the source frequency frame
- $v(n)$  : Velocity at channel= $n$
- $v_{\text{LSR}}$  : Radial velocity of a source in the LSR frame

Newstar/Nostar currently uses the following equation to convert frequency to velocity.

$$v_1(n) = c \left( \frac{\nu_{\text{rest}} - \nu_{\text{source}}(n)}{\nu_{\text{rest}}} \right) + v_{\text{LSR}} \quad (1)$$

However, to properly calculate the velocity, one needs to use the following equation.

$$\begin{aligned} v_2(n) &= c \left\{ \nu_{\text{rest}} - \left( 1 - \frac{v_{\text{LSR}}}{c} \right) \nu_{\text{source}}(n) \right\} \left( \frac{1}{\nu_{\text{rest}}} \right) \\ &= c \left( \frac{\nu_{\text{rest}} - \nu_{\text{source}}(n)}{\nu_{\text{rest}}} \right) + \frac{v_{\text{LSR}} \nu_{\text{source}}(n)}{\nu_{\text{rest}}} \end{aligned} \quad (2)$$

The difference between equations (1) and (2) is the error in velocity caused by this bug. i.e.

$$\begin{aligned} v_{\text{error}}(n) &= v_1(n) - v_2(n) = \frac{v_{\text{LSR}} (\nu_{\text{rest}} - \nu_{\text{source}}(n))}{\nu_{\text{rest}}} \\ &= \frac{v_{\text{LSR}}}{c} (v_1(n) - v_{\text{LSR}}) \end{aligned} \quad (3)$$

Therefore, one will need to use equation (3) to adjust to the correct velocity.