$1,2$

1

th


GILDAS
SOFTWARE

$T(i)$

$$f^{\mathrm{obs}}(i) = f^{\mathrm{obs}}_{\mathrm{tuned}} + (i - i_0)\,\delta f^{\mathrm{obs}},$$


fobs

i


$f^{\text{obs}}_{\text{tuned}}$

i_0

$$\frac{v^{\mathrm{obs}}}{c} = \frac{f^{\mathrm{rest}} - f^{\mathrm{obs}}}{f^{\mathrm{rest}}} = 1 - \frac{f^{\mathrm{obs}}}{f^{\mathrm{rest}}},$$


frest

$$\frac{f^{\rm obs}}{f^{\rm rest}} = 1 + d^{\rm obs} \quad \text{with} \quad d^{\rm obs} \equiv -\frac{v^{\rm obs}}{c}.$$

$$f^{\mathrm{rest}} = \frac{f^{\mathrm{obs}}}{1 + d^{\mathrm{obs}}}.$$

$$f^{\mathrm{rest}}(i) = f^{\mathrm{rest}}_{\mathrm{tuned}} + (i - i_0)\,\delta f^{\mathrm{rest}} \quad \text{with} \quad \delta f^{\mathrm{rest}} = \frac{\delta f^{\mathrm{obs}}}{1 + d^{\mathrm{obs}}_{\mathrm{sys}}} \quad \text{and} \quad d^{\mathrm{obs}}_{\mathrm{sys}} = -\frac{v^{\mathrm{obs}}_{\mathrm{sys}}}{c}.$$


frest
tuned

$$\frac{f^{\rm obs}_{\rm tuned}}{f^{\rm rest}_{\rm tuned}} = 1 + d^{\rm obs}_{\rm sys} \quad \text{with} \quad d^{\rm obs}_{\rm sys} \equiv -\frac{v^{\rm obs}_{\rm sys}}{c}.$$



$$\delta v^{\rm obs}(i) \equiv v^{\rm obs}(i) - v^{\rm obs}_{\rm sys}.$$

$$\frac{f^{\rm obs}(i)}{f^{\rm rest}_{\rm tuned}} = 1 + d^{\rm obs}(i) \quad \text{with} \quad d^{\rm obs}(i) \equiv -\frac{v^{\rm obs}(i)}{c}.$$

$$\delta v^{\mathrm{obs}}(i) = c\,\frac{f^{\mathrm{obs}}_{\mathrm{tuned}} - f^{\mathrm{obs}}(i)}{f^{\mathrm{rest}}_{\mathrm{tuned}}},$$

$$v^{\rm obs}(i) = v^{\rm obs}_{\rm sys} + (i - i_0)\,\delta v^{\rm obs} \quad \text{with} \quad \delta v^{\rm obs} = -c\frac{\delta f^{\rm obs}}{f^{\rm rest}_{\rm tuned}}.$$

$f_{\mathrm{LO}}^{\mathrm{obs}}$

$f_{\mathrm{RF}}^{\mathrm{obs}}$


$f_{\mathrm{IF}}^{\mathrm{obs}}$

$$f_{\mathrm{IF}}^{\mathrm{obs}}(i) = SB_{\mathrm{sign}} \left[f_{\mathrm{RF}}^{\mathrm{obs}}(i) - f_{\mathrm{LO}}^{\mathrm{obs}} \right]$$

$SB_{\text{sign}} = -1$

$$SB_{\text{sign}} = +1$$

$$f_{\mathrm{IF}}^{\mathrm{obs}}(i) = f_{\mathrm{IFtuned}}^{\mathrm{obs}} + (i - i_0)\,\delta f_{\mathrm{IF}}^{\mathrm{obs}},$$

$$f^{\mathrm{obs}}_{\mathrm{IFtuned}} \equiv SB_{\mathrm{sign}} \left(f^{\mathrm{obs}}_{\mathrm{RFtuned}} - f^{\mathrm{obs}}_{\mathrm{LO}} \right) \equiv \mathrm{cste}.$$


f obs
IFtuned

$$f_{\mathrm{RF}}^{\mathrm{obs}}(i) = (f_{\mathrm{LO}}^{\mathrm{obs}} + SB_{\mathrm{sign}}\, f_{\mathrm{IFtuned}}^{\mathrm{obs}}) + SB_{\mathrm{sign}}\,(i - i_0)\,\delta f_{\mathrm{IF}}^{\mathrm{obs}}.$$


$f^{\text{obs}}_{\text{RFtuned}}$

$f_{\text{sig}}^{\text{obs}}$

$f_{\text{ima}}^{\text{obs}}$

$$f_{\rm sig}^{\rm obs}(i) = f_{\rm sig,tuned}^{\rm obs} + SB_{\rm sign}\,(i - i_0)\,\delta f_{\rm IF}^{\rm obs} \quad \text{with} \quad f_{\rm sig,tuned}^{\rm obs} \equiv f_{\rm LO}^{\rm obs} + SB_{\rm sign}\,f_{\rm IFtuned}^{\rm obs},$$

$$f_{\rm ima}^{\rm obs}(i) = f_{\rm ima,tuned}^{\rm obs} - SB_{\rm sign}\,(i - i_0)\,\delta f_{\rm IF}^{\rm obs} \quad \text{with} \quad f_{\rm ima,tuned}^{\rm obs} \equiv f_{\rm LO}^{\rm obs} - SB_{\rm sign}\,f_{\rm IFtuned}^{\rm obs}.$$







$$\delta f_{\mathrm{IF}}^{\mathrm{obs}} > 0$$

$$f_{\rm sig}^{\rm obs}(i) = f_{\rm sig,tuned}^{\rm obs} + (i - i_0)\,\delta f_{\rm IF}^{\rm obs} \quad \text{with} \quad f_{\rm sig,tuned}^{\rm obs} \equiv f_{\rm LO}^{\rm obs} + SB_{\rm sign}\, f_{\rm IFtuned}^{\rm obs},$$

$$f_{\rm ima}^{\rm obs}(i) = f_{\rm ima,tuned}^{\rm obs} - (i - i_0)\,\delta f_{\rm IF}^{\rm obs} \quad \text{with} \quad f_{\rm ima,tuned}^{\rm obs} \equiv f_{\rm LO}^{\rm obs} - SB_{\rm sign}\, f_{\rm IFtuned}^{\rm obs}.$$

$$\delta f_{\mathrm{IF}}^{\mathrm{obs}} > 0.$$

$$f_{\mathrm{sig}}^{\mathrm{rest}}(i) = f_{\mathrm{sig,tuned}}^{\mathrm{rest}} + (i - i_0)\,\delta f^{\mathrm{rest}},$$

$$f_{\mathrm{ima}}^{\mathrm{rest}}(i) = f_{\mathrm{ima,tuned}}^{\mathrm{rest}} - (i - i_0)\,\delta f^{\mathrm{rest}},$$

$$\delta f^{\rm rest} = \frac{\delta f^{\rm obs}_{\rm IF}}{1 + d^{\rm obs}_{\rm sys}} \quad \text{and} \quad d^{\rm obs}_{\rm sys} = -\frac{v^{\rm obs}_{\rm sys}}{c}.$$





$$SB_{\mathrm{sep}}^{\mathrm{obs}} \equiv SB_{\mathrm{sign}} \left[f_{\mathrm{sig,tuned}}^{\mathrm{obs}} - f_{\mathrm{ima,tuned}}^{\mathrm{obs}} \right] .$$

$$SB_{\mathrm{sep}}^{\mathrm{obs}} = \mathrm{cste} = 2\, f_{\mathrm{IFtuned}}^{\mathrm{obs}}.$$

$$\frac{f^{\text{obs}}_{\text{sig,tuned}}}{f^{\text{rest}}_{\text{sig,tuned}}} = 1 + d^{\text{obs}}_{\text{sys}} \qquad \frac{f^{\text{obs}}_{\text{ima,tuned}}}{f^{\text{rest}}_{\text{ima,tuned}}} = 1 + d^{\text{obs}}_{\text{sys}}\,.$$

$$SB_{\mathrm{sep}}^{\mathrm{rest}} \equiv SB_{\mathrm{sign}} \left[f_{\mathrm{sig,tuned}}^{\mathrm{rest}} - f_{\mathrm{ima,tuned}}^{\mathrm{rest}} \right].$$

$$SB_{\rm sep}^{\rm obs} = SB_{\rm sep}^{\rm rest} \left[1 + d_{\rm sys}^{\rm obs}\right],$$

$$f^{\mathrm{rest}}_{\mathrm{ima,tuned}} = f^{\mathrm{rest}}_{\mathrm{sig,tuned}} - \frac{SB^{\mathrm{obs}}_{\mathrm{sep}}}{SB_{\mathrm{sign}}\left[1 + d^{\mathrm{obs}}_{\mathrm{sys}}\right]}.$$

$$f^{\mathrm{lsr}} = f^{\mathrm{obs}} + f^{\mathrm{rest}} \, \frac{v_{\mathrm{sys}}^{\mathrm{obs}} - v_{\mathrm{sys}}^{\mathrm{lsr}}}{c},$$

$$f^{\rm obs} = f^{\rm rest}\left(1 - \frac{v_{\rm sys}^{\rm obs}}{c}\right) \quad \text{and} \quad f^{\rm lsr} = f^{\rm rest}\left(1 - \frac{v_{\rm sys}^{\rm lsr}}{c}\right).$$

$$\left[SB_{\rm sign}\, f^{\rm rest}\, (v_{\rm sys}^{\rm obs} - v_{\rm sys}^{\rm lsr})/c\right]$$

$$f^{\mathrm{lsr}}_{\mathrm{sig,tuned}} = f^{\mathrm{obs}}_{\mathrm{sig,tuned}} + f^{\mathrm{rest}}_{\mathrm{sig,tuned}} \frac{v^{\mathrm{obs}}_{\mathrm{sys}} - v^{\mathrm{lsr}}_{\mathrm{sys}}}{c}.$$

$$f^{\mathrm{lsr}}(i) = f^{\mathrm{obs}}(i) + f^{\mathrm{rest}}_{\mathrm{sig,tuned}} \, \frac{v^{\mathrm{obs}}_{\mathrm{sys}} - v^{\mathrm{lsr}}_{\mathrm{sys}}}{c},$$

$$f^{\mathrm{lsr}}(i) = f^{\mathrm{obs}}(i) + f^{\mathrm{rest}}(i)\,\frac{v_{\mathrm{sys}}^{\mathrm{obs}} - v_{\mathrm{sys}}^{\mathrm{lsr}}}{c}.$$

$$\Delta f^{\mathrm{lsr}}(i) = (i - i_0)\,\delta f^{\mathrm{rest}}\,\frac{v_{\mathrm{sys}}^{\mathrm{obs}} - v_{\mathrm{sys}}^{\mathrm{lsr}}}{c}.$$

$i = i_0$





δf^{meas}

$\mathrm{km\,s^{-1}}$

δv^{meas}

$v_{\text{sys}}^{\text{meas}}$

$d_{\mathrm{sys}}^{\mathrm{meas}}$

$$f_{\mathrm{sig}}^{\mathrm{rest}}(i) = f_{\mathrm{sig,tuned}}^{\mathrm{rest}} + (i - i_0)\,\delta f^{\mathrm{rest}},$$

$$f_{\mathrm{ima}}^{\mathrm{rest}}(i) = f_{\mathrm{ima,tuned}}^{\mathrm{rest}} - (i - i_0)\,\delta f^{\mathrm{rest}},$$

$$\delta f^{\mathrm{rest}} = \frac{\delta f_{\mathrm{IF}}^{\mathrm{meas}}}{1 + d_{\mathrm{sys}}^{\mathrm{meas}}} \quad \text{and} \quad d_{\mathrm{sys}}^{\mathrm{meas}} = -\frac{v_{\mathrm{sys}}^{\mathrm{meas}}}{c},$$



$v_{\text{sys}}^{\text{meas}}$

$$v^{\mathrm{meas}}(i) = v^{\mathrm{meas}}_{\mathrm{sys}} + (i - i_0)\,\delta v^{\mathrm{meas}} \quad \text{with} \quad \delta v^{\mathrm{meas}} = -c\frac{\delta f^{\mathrm{meas}}}{f^{\mathrm{rest}}_{\mathrm{tuned}}}.$$

$$v^{\mathrm{lsr}}(i) = v^{\mathrm{lsr}}_{\mathrm{sys}} + (i - i_0)\,\delta v^{\mathrm{lsr}} \quad \text{with} \quad \delta v^{\mathrm{lsr}} = -c\frac{\delta f^{\mathrm{lsr}}}{f^{\mathrm{rest}}_{\mathrm{tuned}}}.$$

$$v^{\mathrm{lsr}}(i) = v^{\mathrm{lsr}}_{\mathrm{sys}} + (i - i_0)\,\delta v^{\mathrm{obs}} \quad \text{with} \quad \delta v^{\mathrm{obs}} = -c\frac{\delta f^{\mathrm{obs}}}{f^{\mathrm{rest}}_{\mathrm{tuned}}}.$$

$$\frac{\delta v^{\rm obs} - \delta v^{\rm lsr}}{\delta v^{\rm lsr}} = \frac{\delta f^{\rm obs}}{\delta f^{\rm lsr}} - 1 = \frac{1 + d_{\rm sys}^{\rm lsr}}{1 + d_{\rm sys}^{\rm obs}} - 1.$$

v/c

$$\frac{\delta v^{\rm obs} - \delta v^{\rm lsr}}{\delta v^{\rm lsr}} = \frac{v^{\rm obs}_{\rm sys} - v^{\rm lsr}_{\rm sys}}{c} \sim 10^{-4}.$$

$\sim 250\,\mathrm{km\,s^{-1}}$


kHz

$$\delta f^{\mathrm{lsr}} = \delta f^{\mathrm{obs}} \, \frac{1 + d_{\mathrm{sys}}^{\mathrm{obs}}}{1 + d_{\mathrm{sys}}^{\mathrm{lsr}}}, \quad \delta v^{\mathrm{lsr}} = -c \frac{\delta f^{\mathrm{lsr}}}{f_{\mathrm{tuned}}^{\mathrm{rest}}}, \quad \text{and} \quad d^{\mathrm{lsr}} = 1 - \frac{v^{\mathrm{lsr}}}{c}.$$



$$f^{\mathrm{rest}}_{\mathrm{sig,old}} + (i - i_{0,\mathrm{old}})\,\delta f^{\mathrm{rest}},$$

$$f^{\mathrm{rest}}_{\mathrm{sig,new}} + (i - i_{0,\mathrm{new}})\,\delta f^{\mathrm{rest}},$$

$$\delta f^{\mathrm{rest}} = \frac{\delta f_{\mathrm{IF}}^{\mathrm{meas}}}{1 + d_{\mathrm{sys}}^{\mathrm{meas}}}.$$

$$i_{0,\mathrm{new}} = i_{0,\mathrm{old}} + \frac{f^{\mathrm{rest}}_{\mathrm{sig,new}} - f^{\mathrm{rest}}_{\mathrm{sig,old}}}{\delta f^{\mathrm{meas}}_{\mathrm{IF}}} \left(1 + d^{\mathrm{meas}}_{\mathrm{sys}}\right)$$



$$f^{\mathrm{rest}}_{\mathrm{ima,old}} - (i - i_{0,\mathrm{old}})\,\delta f^{\mathrm{rest}},$$

$$f^{\mathrm{rest}}_{\mathrm{ima,new}} - (i - i_{0,\mathrm{new}})\,\delta f^{\mathrm{rest}},$$



$$f^{\mathrm{rest}}_{\mathrm{sig,old}} + (i_{0,\mathrm{new}} - i_{0,\mathrm{old}})\, \delta f^{\mathrm{rest}},$$



$$f^{\mathrm{rest}}_{\mathrm{ima,old}} - \left(i_{0,\mathrm{new}} - i_{0,\mathrm{old}}\right) \delta f^{\mathrm{rest}}.$$

$$f^{\text{rest}}_{\text{ima,new}} + f^{\text{rest}}_{\text{sig,new}} = f^{\text{rest}}_{\text{sig,old}} + f^{\text{rest}}_{\text{ima,old}}.$$

$$\delta v_{\mathrm{new}}^{\mathrm{meas}} = -c \frac{\delta f^{\mathrm{meas}}}{f_{\mathrm{sig,new}}^{\mathrm{rest}}}.$$

$$f^{\mathrm{meas}} = (1 + d^{\mathrm{meas}}_{\mathrm{old}})\, f^{\mathrm{rest}}_{\mathrm{old}} = (1 + d^{\mathrm{meas}}_{\mathrm{new}})\, f^{\mathrm{rest}}_{\mathrm{new}},$$

$$d_{\text{old}}^{\text{meas}} = -\frac{v_{\text{sys,old}}^{\text{meas}}}{c} \quad \text{and} \quad d_{\text{new}}^{\text{meas}} = -\frac{v_{\text{sys,new}}^{\text{meas}}}{c}.$$

$$f_{\mathrm{new}}^{\mathrm{rest}} = f_{\mathrm{old}}^{\mathrm{rest}} \, \frac{1 + d_{\mathrm{old}}^{\mathrm{meas}}}{1 + d_{\mathrm{new}}^{\mathrm{meas}}}.$$



$$f^{\mathrm{rest}}_{\mathrm{sig,tuned}} + (i - i_{0,\mathrm{new}})\,\delta f^{\mathrm{rest}}_{\mathrm{new}}$$

$$\left[f^{\mathrm{rest}}_{\mathrm{sig,tuned}} + (i - i_{0,\mathrm{old}})\,\delta f^{\mathrm{rest}}_{\mathrm{old}}\right]\ \frac{1 + d^{\mathrm{meas}}_{\mathrm{old}}}{1 + d^{\mathrm{meas}}_{\mathrm{new}}}.$$

$$i_{0,\mathrm{new}} = i_{0,\mathrm{old}} + \frac{f^{\mathrm{rest}}_{\mathrm{sig,tuned}}}{\delta f^{\mathrm{meas}}_{\mathrm{old}}} \left[d^{\mathrm{meas}}_{\mathrm{new}} - d^{\mathrm{meas}}_{\mathrm{old}} \right],$$

$$\delta f^{\rm rest}_{\rm new} = \delta f^{\rm rest}_{\rm old}\,\frac{1+d^{\rm meas}_{\rm old}}{1+d^{\rm meas}_{\rm new}}, \quad i.e., \quad \delta f^{\rm meas}_{\rm new} = \delta f^{\rm meas}_{\rm old}.$$

$$f^{\mathrm{rest}}_{\mathrm{ima,tuned,new}} - (i - i_{0,\mathrm{new}})\,\delta f^{\mathrm{rest}}_{\mathrm{new}}$$

$$\left[f^{\mathrm{rest}}_{\mathrm{ima,tuned,old}} - (i - i_{0,\mathrm{old}})\,\delta f^{\mathrm{rest}}_{\mathrm{old}}\right]\ \frac{1 + d^{\mathrm{meas}}_{\mathrm{old}}}{1 + d^{\mathrm{meas}}_{\mathrm{new}}}.$$

$$f_{\mathrm{ima,new}}^{\mathrm{rest}} = f_{\mathrm{ima,old}}^{\mathrm{rest}} \frac{1 + d_{\mathrm{old}}^{\mathrm{meas}}}{1 + d_{\mathrm{new}}^{\mathrm{meas}}} - f_{\mathrm{sig,tuned}}^{\mathrm{rest}} \frac{d_{\mathrm{new}}^{\mathrm{meas}} - d_{\mathrm{old}}^{\mathrm{meas}}}{1 + d_{\mathrm{new}}^{\mathrm{meas}}}.$$

$$d_{\mathrm{old}}^{\mathrm{meas}} = -\frac{v_{\mathrm{lsr}}^{\mathrm{meas}} + v_{\mathrm{sys,old}}^{\mathrm{lsr}}}{c} \quad \text{and} \quad d_{\mathrm{new}}^{\mathrm{meas}} = -\frac{v_{\mathrm{lsr}}^{\mathrm{meas}} + v_{\mathrm{sys,new}}^{\mathrm{lsr}}}{c}.$$

$$d_{\mathrm{new}}^{\mathrm{meas}} = d_{\mathrm{old}}^{\mathrm{meas}} + \frac{v_{\mathrm{sys,old}}^{\mathrm{lsr}} - v_{\mathrm{sys,new}}^{\mathrm{lsr}}}{c}.$$

$$f^{\mathrm{obs}} = f^{\mathrm{rest}} \frac{\sqrt{c^2 - {v^{\mathrm{obs}}}^2}}{c + v_{\parallel}^{\mathrm{obs}}},$$

$$v^{\mathrm{obs}\,2} = v_{\parallel}^{\mathrm{obs}\,2} + v_{\perp}^{\mathrm{obs}\,2}$$

$$v_{\parallel}^{\mathrm{obs}} \gg v_{\perp}^{\mathrm{obs}}$$

$$f^{\mathrm{obs}} = f^{\mathrm{rest}} \sqrt{\frac{c - v_{\parallel}^{\mathrm{obs}}}{c + v_{\parallel}^{\mathrm{obs}}}}.$$

$$f^{\mathrm{obs}} = f^{\mathrm{rest}} \left(1 - \frac{v_{\parallel}^{\mathrm{obs}}}{c} \right) .$$

$$v^{\rm obs}(i) = v^{\rm obs}_{\rm sys} + (i - i_0)\,\delta v^{\rm obs} \quad \text{with} \quad \delta v^{\rm obs} = -c\frac{\delta f^{\rm obs}}{f^{\rm rest}_{\rm tuned}}.$$

$$\lambda^{\mathrm{obs}} = \lambda^{\mathrm{rest}} \sqrt{\frac{c + v_{\parallel}^{\mathrm{obs}}}{c - v_{\parallel}^{\mathrm{obs}}}}.$$

$$\lambda^{\mathrm{obs}} = \lambda^{\mathrm{rest}} \left(1 + \frac{v_{\parallel}^{\mathrm{obs}}}{c} \right) .$$

$$f^{\mathrm{obs}} = \frac{f^{\mathrm{rest}}}{1 + \frac{v_{\parallel}^{\mathrm{obs}}}{c}}.$$

$$v_{\rm opt}^{\rm obs}(i) = v_{\rm sys,opt}^{\rm obs} + (i - i_0)\,\delta v_{\rm opt}^{\rm obs} \quad \text{with} \quad \delta v_{\rm opt}^{\rm obs} = +c\,\frac{\delta\lambda^{\rm obs}}{\lambda_{\rm tuned}^{\rm rest}}.$$

v_1

$$f^{\text{obs}}_{\text{tuned,conv1}} = f^{\text{rest}}_{\text{tuned}}\, D_1(v_1),$$

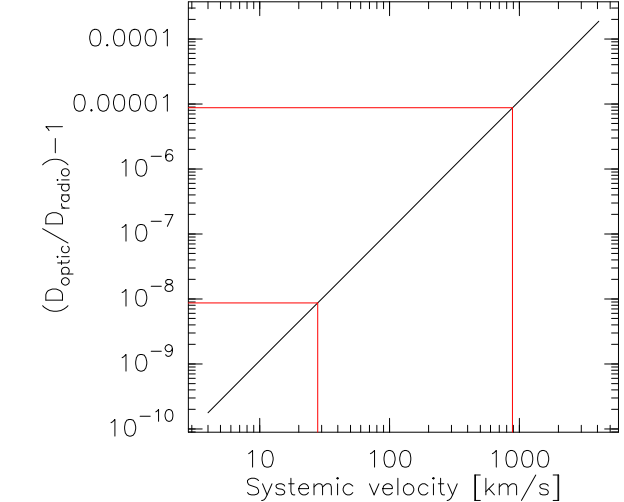


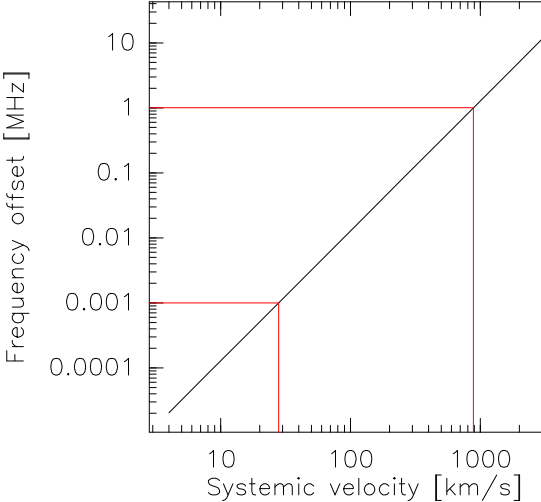
$$D_{\mathrm{opt}}(v_{\mathrm{opt}}) = \frac{1}{1 + \frac{v_{\mathrm{opt}}}{c}}.$$



$$f^{\mathrm{rest}}(i) = f^{\mathrm{rest}}_{\mathrm{apparent}} + (i - i_0)\,\delta f^{\mathrm{rest}}_{\mathrm{apparent}},$$

$$f^{\text{rest}}_{\text{apparent}} = f^{\text{rest}}_{\text{tuned}} \frac{D_1(v_1)}{D_2(v_1)}, \quad \text{and} \quad \delta f^{\text{rest}}_{\text{apparent}} = \delta f^{\text{rest}}_{\text{tuned}} \frac{D_1(v_1)}{D_2(v_1)}.$$


0.0001
0.00001
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
$(D_{optic}/D_{radio})-1$
10
100
1000
Systemic velocity [km/s]


10
1
0.1
0.01
0.001
0.0001
Frequency offset [MHz]
10
100
1000
Systemic velocity [km/s]

10^{-5}

$$f^{\rm rest}_{\rm sig,new} = f^{\rm rest}_{\rm sig,old}\,\frac{D_{\rm optic}(v^{\rm obs}_{\rm sys,old})}{D_{\rm radio}(v^{\rm obs}_{\rm sys,new})}, \qquad f^{\rm rest}_{\rm ima,new} = f^{\rm rest}_{\rm ima,old}\,\frac{D_{\rm optic}(v^{\rm obs}_{\rm sys,old})}{D_{\rm radio}(v^{\rm obs}_{\rm sys,new})},$$

$$\delta f^{\rm meas}_{\rm new} = \delta f^{\rm meas}_{\rm old}\,\frac{D_{\rm optic}(v^{\rm obs}_{\rm sys,old})}{D_{\rm radio}(v^{\rm obs}_{\rm sys,new})}, \quad \text{and} \quad \delta v^{\rm meas}_{\rm new} = -c\frac{\delta f^{\rm meas}_{\rm new}}{f^{\rm rest}_{\rm sig,new}}.$$







$$f^{\mathrm{rest}}_{\mathrm{sig,new}} = f^{\mathrm{rest}}_{\mathrm{sig,old}} \frac{D_{\mathrm{relat}}(v^{\mathrm{obs}}_{\mathrm{sys,old}})}{D_{\mathrm{relat}}(v^{\mathrm{obs}}_{\mathrm{sys,new}})}, \qquad f^{\mathrm{rest}}_{\mathrm{ima,new}} = f^{\mathrm{rest}}_{\mathrm{ima,old}} \frac{D_{\mathrm{relat}}(v^{\mathrm{obs}}_{\mathrm{sys,old}})}{D_{\mathrm{relat}}(v^{\mathrm{obs}}_{\mathrm{sys,new}})},$$

$$\delta f_{\mathrm{new}}^{\mathrm{meas}} = \delta f_{\mathrm{old}}^{\mathrm{meas}} \, \frac{D_{\mathrm{relat}}\left(v_{\mathrm{sys,old}}^{\mathrm{obs}}\right)}{D_{\mathrm{relat}}\left(v_{\mathrm{sys,new}}^{\mathrm{obs}}\right)}, \quad \text{and} \quad \delta v_{\mathrm{new}}^{\mathrm{meas}} = -c \frac{\delta f_{\mathrm{new}}^{\mathrm{meas}}}{f_{\mathrm{sig,new}}^{\mathrm{rest}}}.$$

$$\frac{D_{\mathrm{relat}}(v^{\mathrm{obs}}_{\mathrm{sys,old}})}{D_{\mathrm{relat}}(v^{\mathrm{obs}}_{\mathrm{sys,new}})} = \frac{D_{\mathrm{relat}}(v^{\mathrm{lsr}}_{\mathrm{sys,old}})}{D_{\mathrm{relat}}(v^{\mathrm{lsr}}_{\mathrm{sys,new}})}.$$

$$f^{\rm rest}_{\rm sig,new} = f^{\rm rest}_{\rm sig,old}\,\frac{D_{\rm relat}(v^{\rm lsr}_{\rm sys,old})}{D_{\rm relat}(v^{\rm lsr}_{\rm sys,new})}, \qquad f^{\rm rest}_{\rm ima,new} = f^{\rm rest}_{\rm ima,old}\,\frac{D_{\rm relat}(v^{\rm lsr}_{\rm sys,old})}{D_{\rm relat}(v^{\rm lsr}_{\rm sys,new})},$$

$$\delta f_{\mathrm{new}}^{\mathrm{meas}} = \delta f_{\mathrm{old}}^{\mathrm{meas}} \, \frac{D_{\mathrm{relat}}(v_{\mathrm{sys,old}}^{\mathrm{lsr}})}{D_{\mathrm{relat}}(v_{\mathrm{sys,new}}^{\mathrm{lsr}})}, \quad \text{and} \quad \delta v_{\mathrm{new}}^{\mathrm{meas}} = -c \frac{\delta f_{\mathrm{new}}^{\mathrm{meas}}}{f_{\mathrm{sig,new}}^{\mathrm{rest}}}.$$

$v_{\mathrm{sys}}^{\mathrm{lsr}}$