Comparison of velocity profiles of light hydrides toward the Galactic Center region

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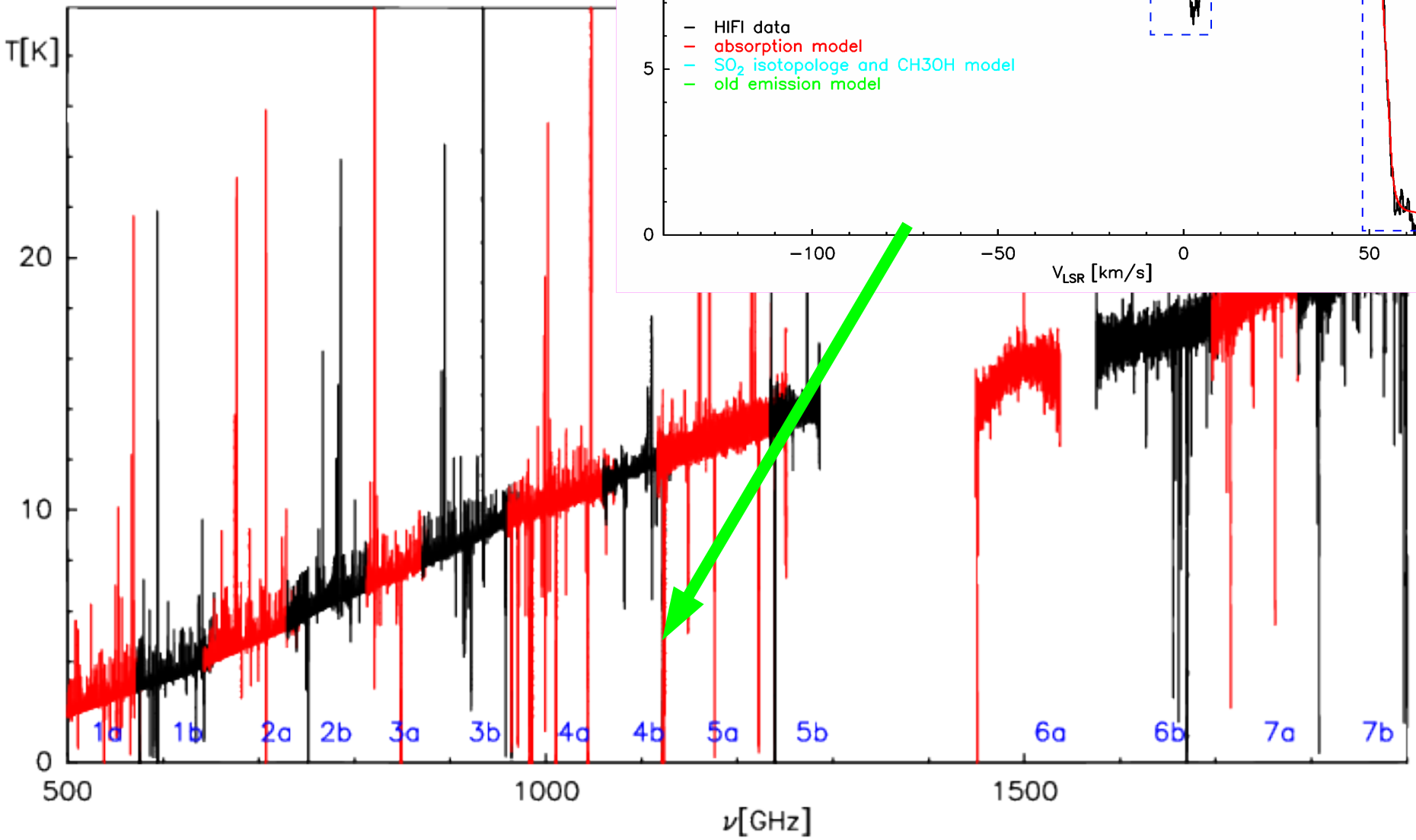
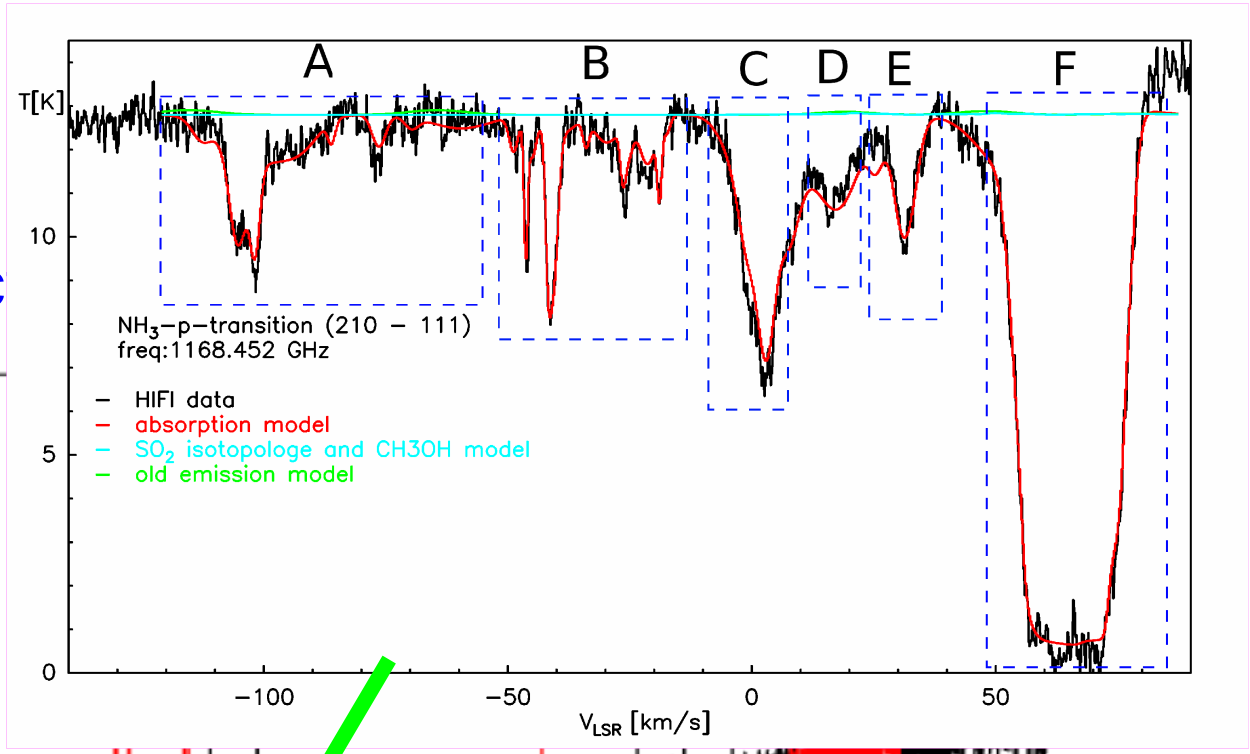
Most of the work
on fitting spectra

Denis Büchel,
Master Thesis

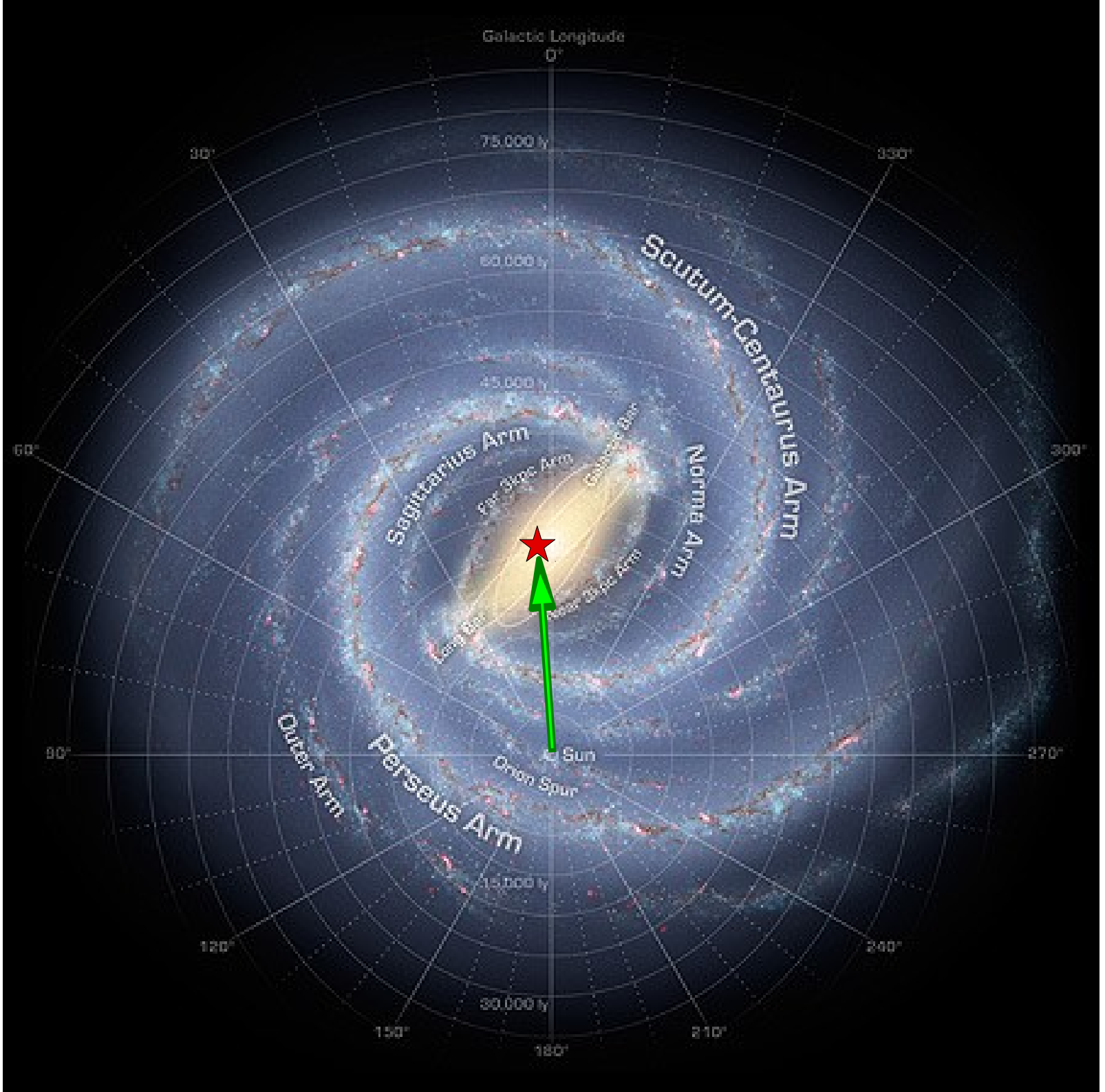
using data acquired in the
HEXOS GT KP

SgrB2(M) corrected spec





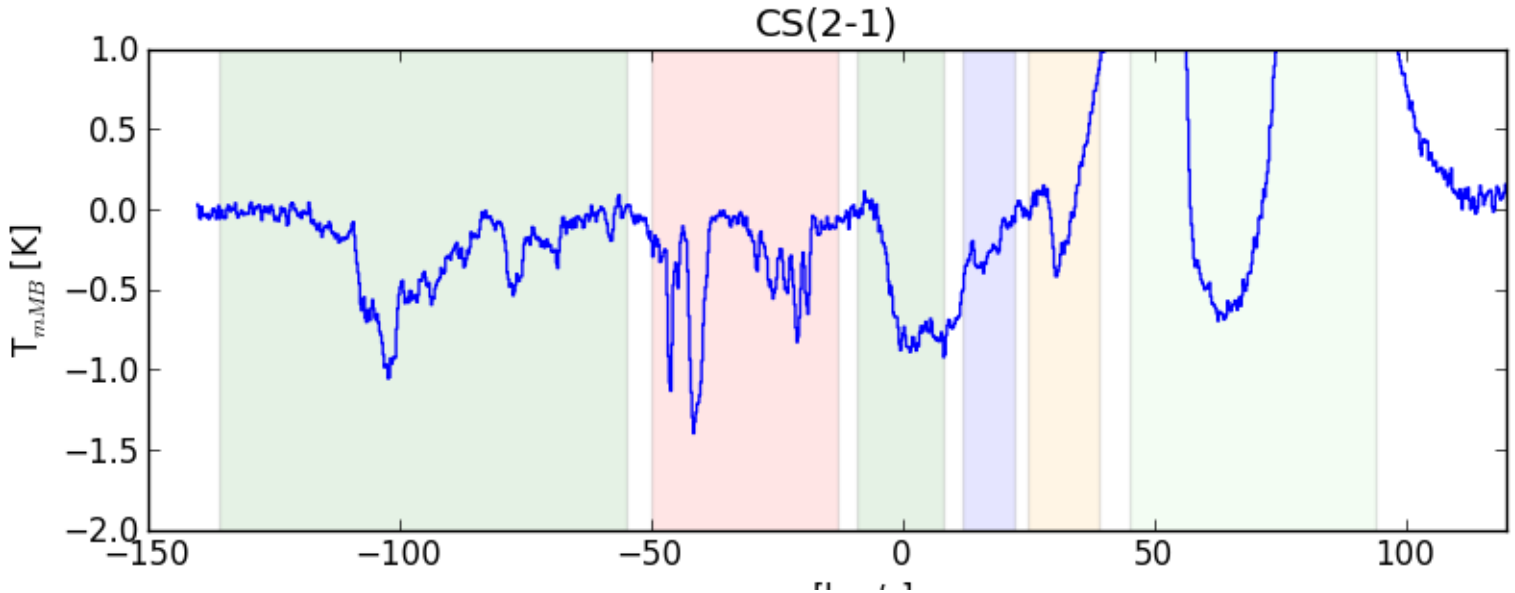
Where does the absorption come from?


Galactic Longitude
0°
30°
330°
60°
300°
90°
270°
120°
240°
150°
210°
180°
15,000 ly
30,000 ly
45,000 ly
60,000 ly
75,000 ly
Scutum-Centaurus Arm
Sagittarius Arm
Norma Arm
Perseus Arm
Outer Arm
Far 3kpc Arm
Near 3kpc Arm
Orion Spur
Sun


M51 (HST picture)
Dust lanes: molecular clouds
Hα: newly formed stars

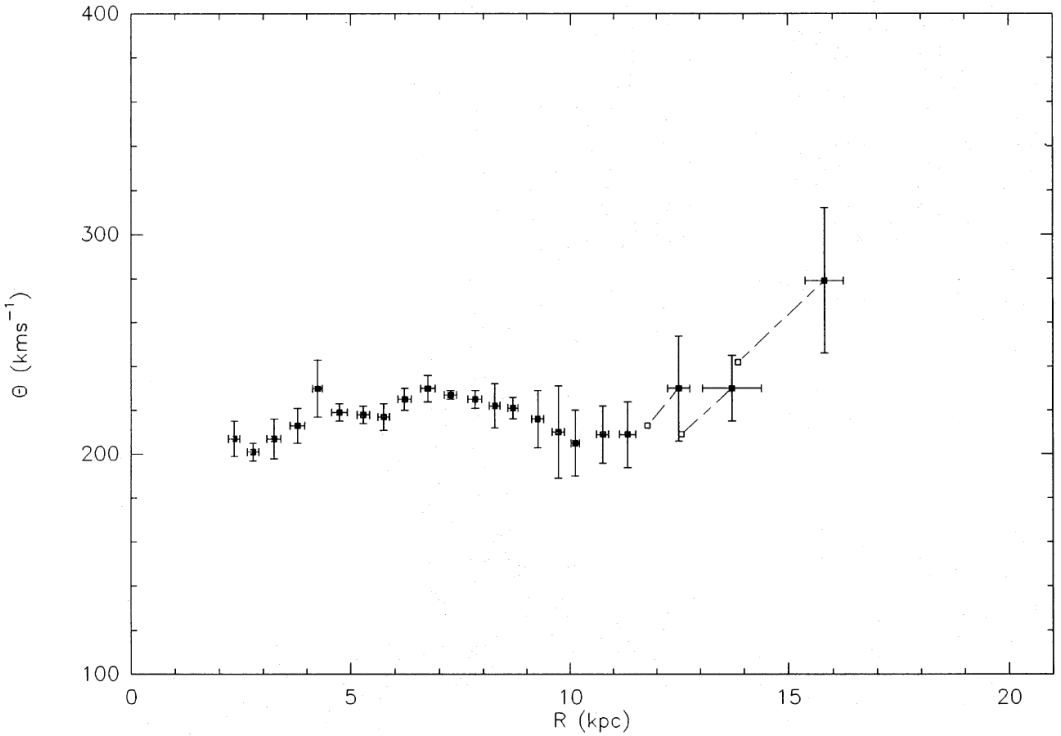
Motivation
(from the HEXOS proposal)

Sgr B2 – Deep Molecule Search: Sgr B2 (M) is the strongest submillimeter continuum source in the Galaxy. This makes it the best candidate for absorption studies (see Polehampton et al., 2003), probing the entire line of sight between the Sun and the Galactic center, with clouds in the Orion, Sagittarius, and Scutum spiral arms easily identified at separate velocities (e.g., Greaves & Nyman, 1996). The HIFI and PACS line surveys toward Sgr B2(M) (and also N) will therefore probe, in absorption, the low-density gas that provides the initial chemical conditions out of which the GMCs would have formed. Deep, targeted observations toward Sgr B2(S), complemented



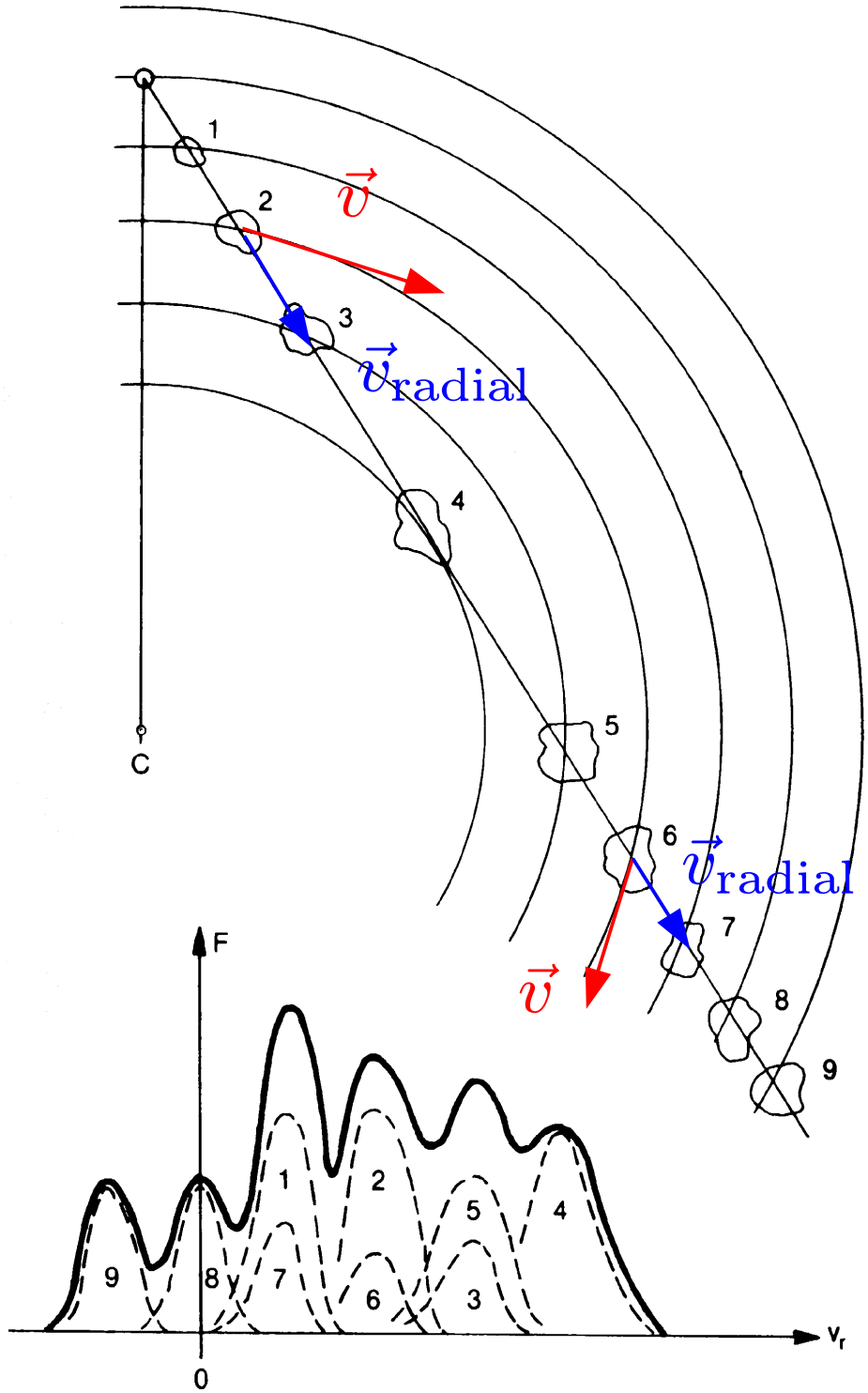
...not quite as easy as that

Kinematic distances



Rotation curve of the Galaxy:
Brand & Blitz 1993

Circular orbits, only v(R)



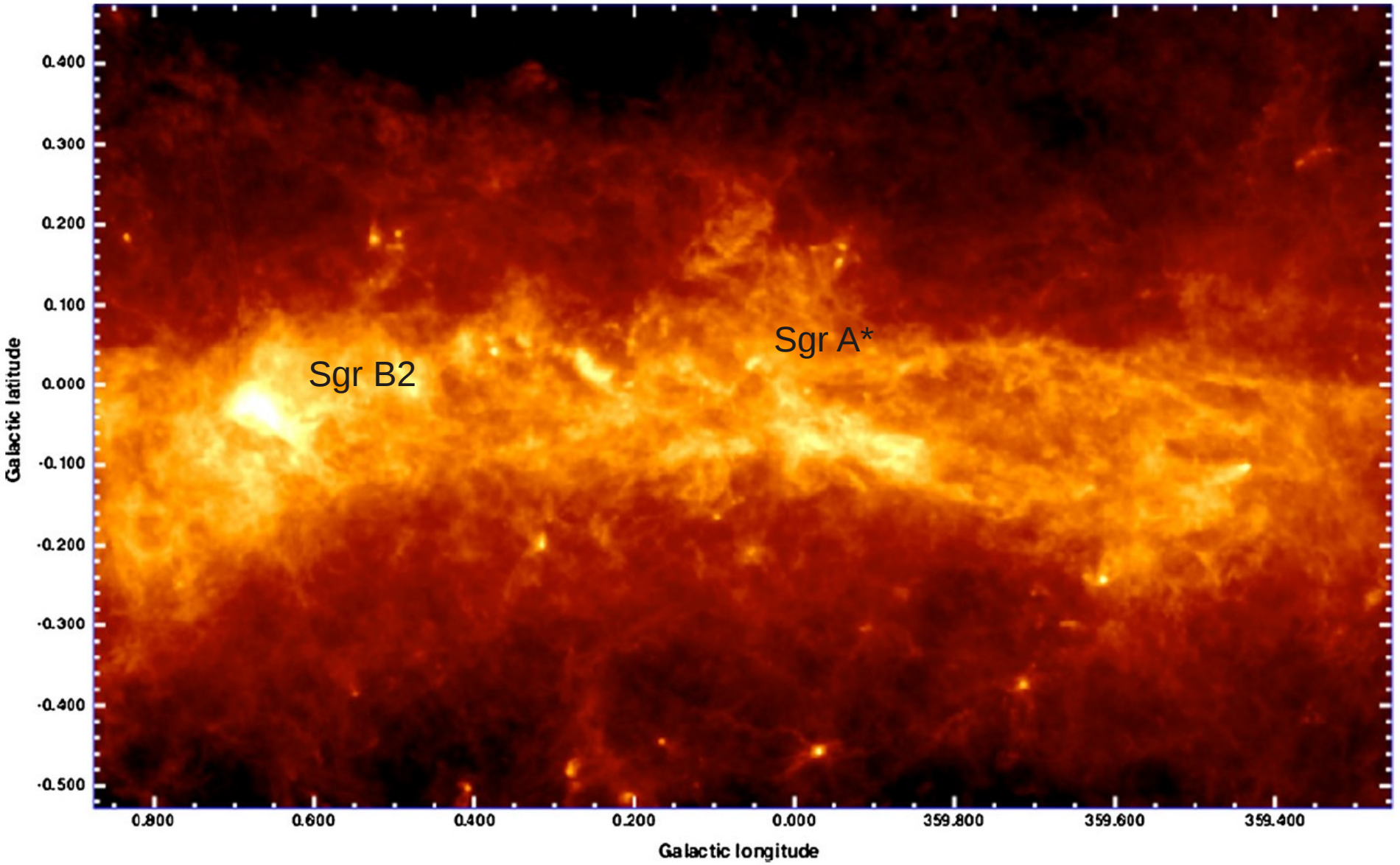
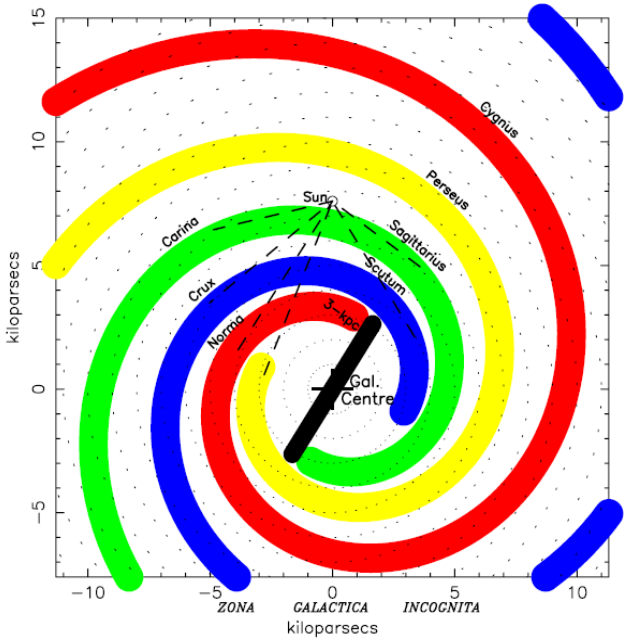
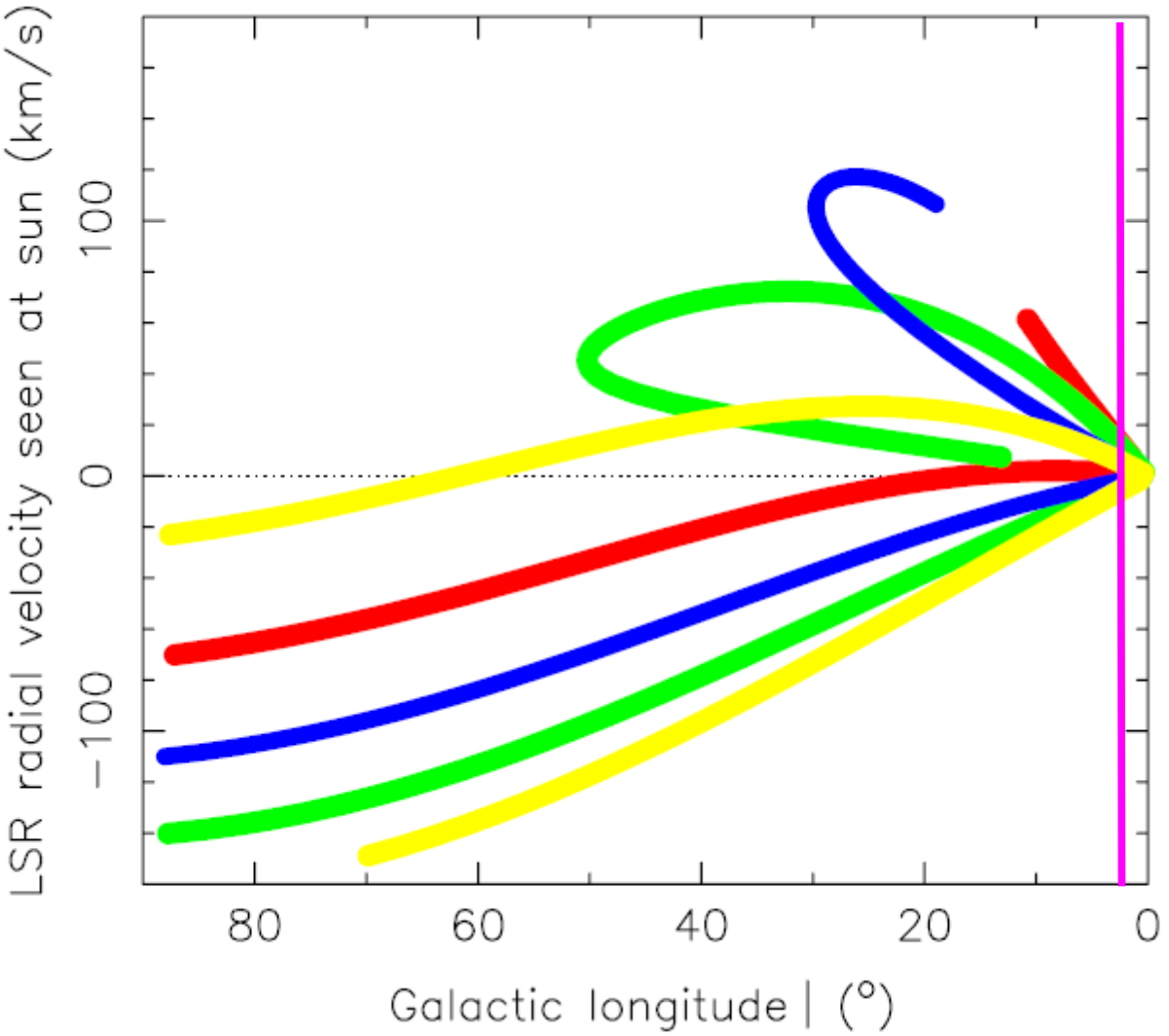


Figure 2. *Herschel* SPIRE 250 μm image of the Galactic center region.

Molinari et al. 2011



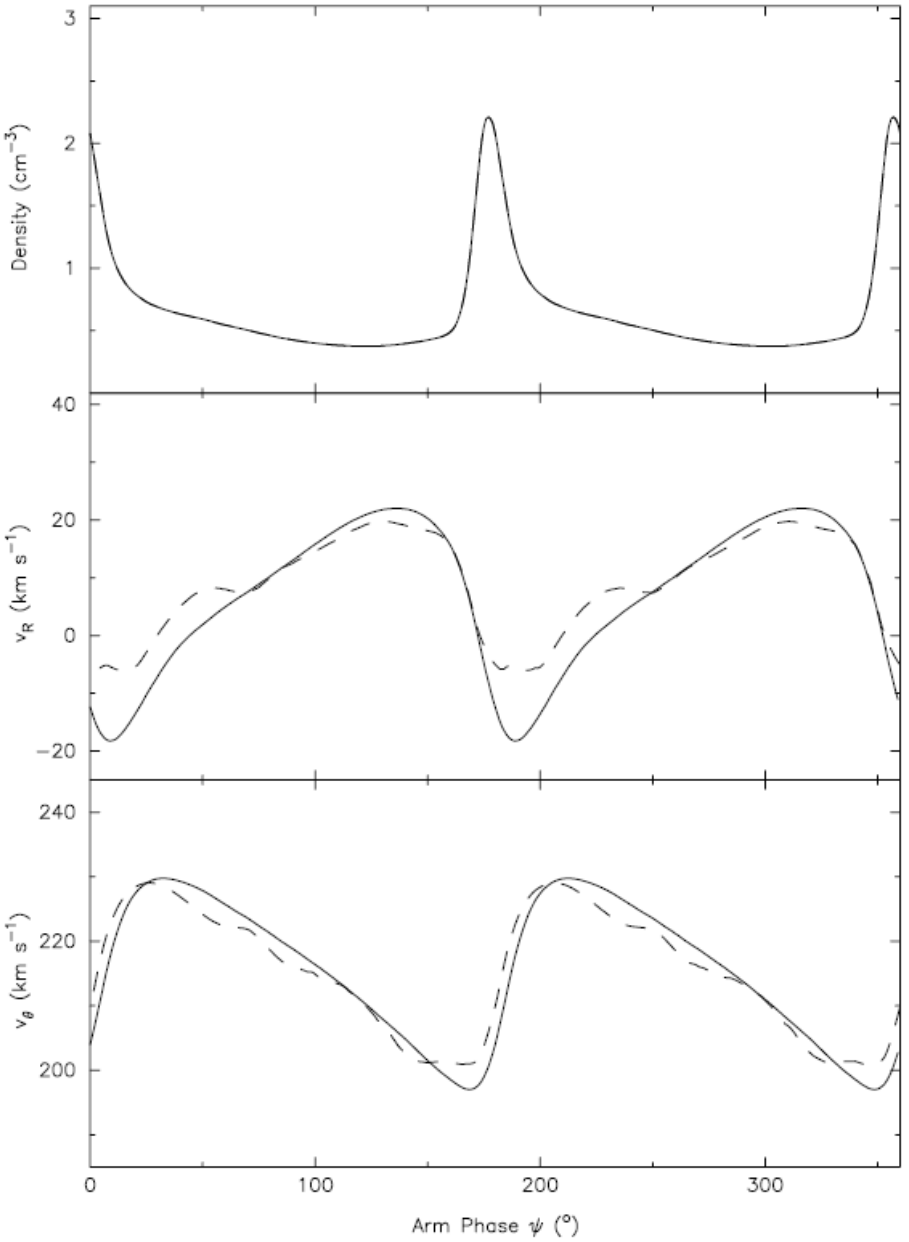
Close to Galactic center:
Very little velocity difference between different spiral arms

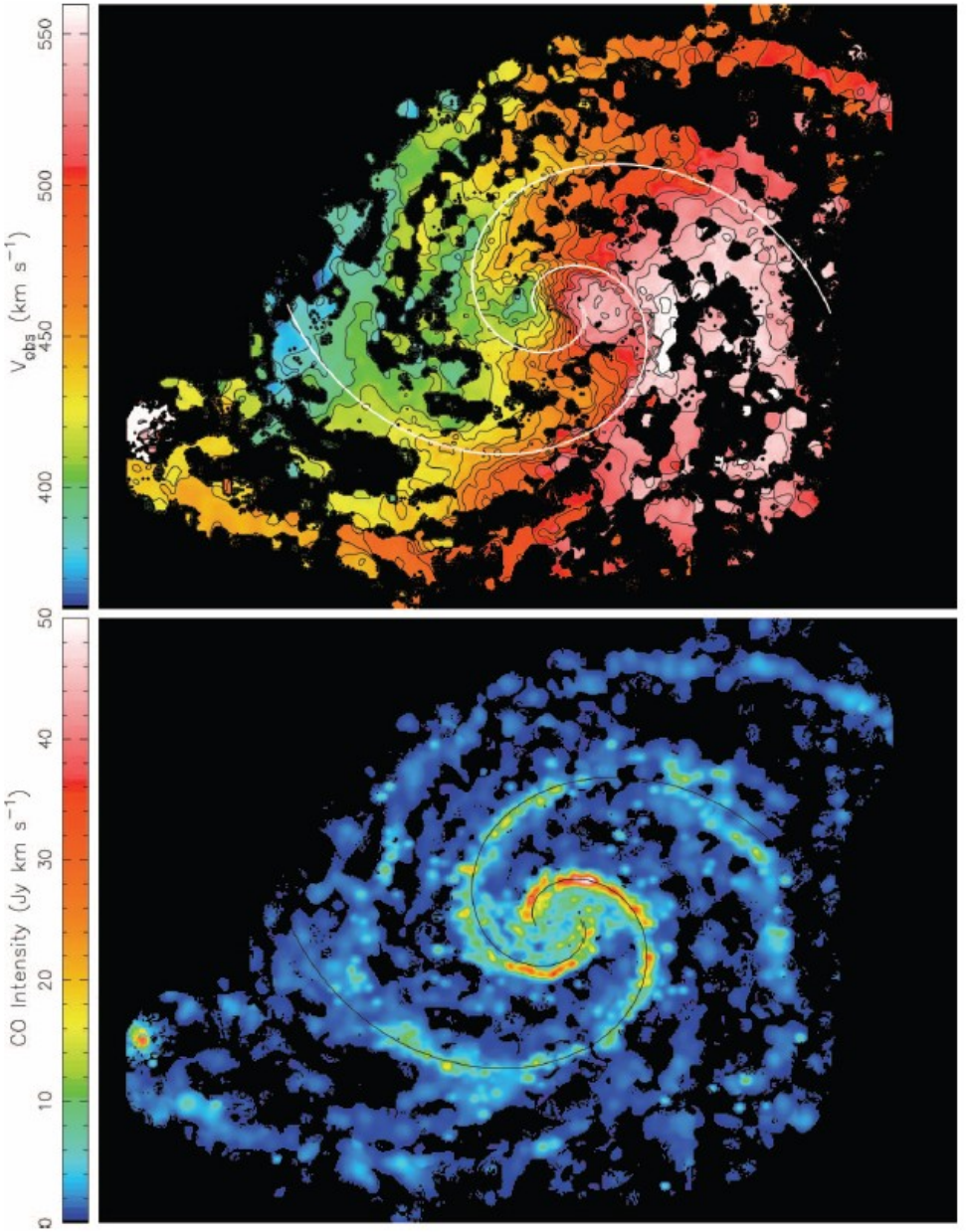


NB: objects move on circular orbits, but spiral arms are non-circular density waves

...but there is more, and worse

Vallée 2008





Streaming motions in spiral arms
Here: M51
Shetty et al. 2007

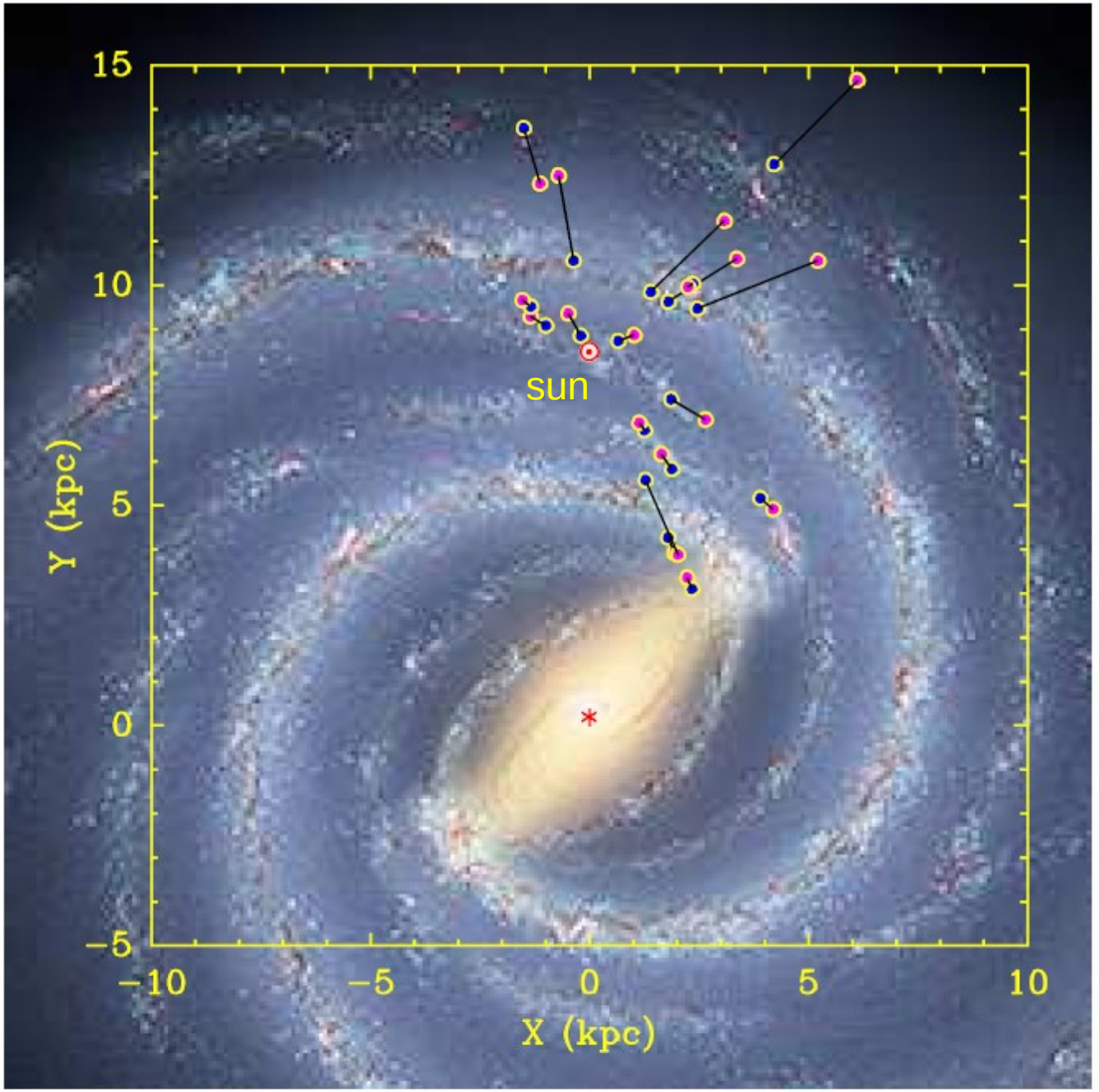
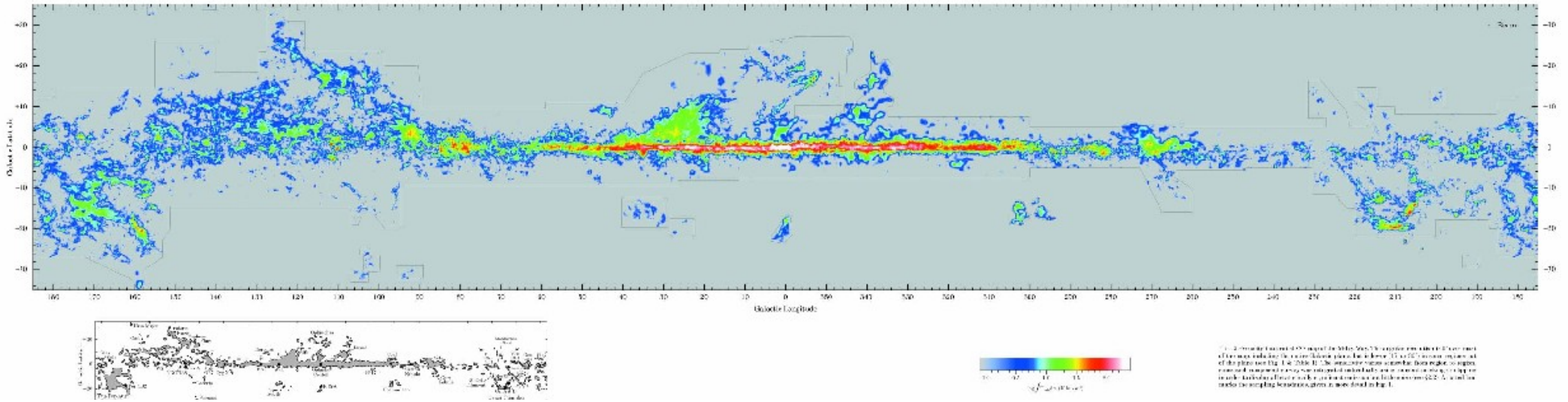
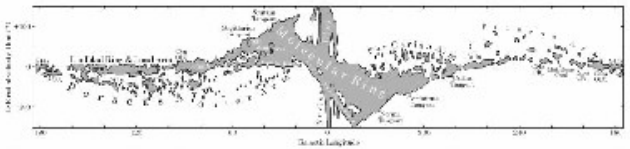
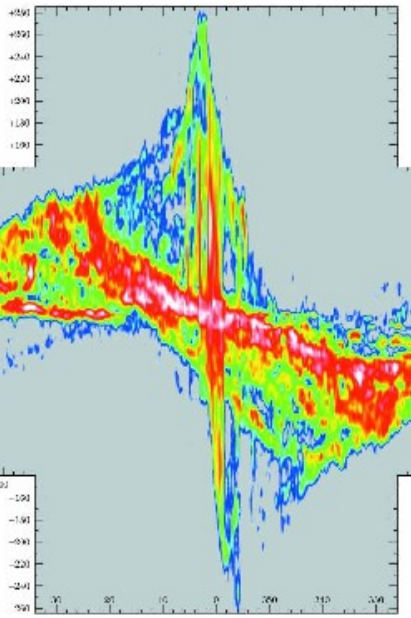


Figure 6. Locations of the star-forming regions determined by trigonometric parallax (dark blue circles) and by kinematic distances (light magenta circles), assuming IAU recommended values of $R_0 = 8.5$ kpc and $\Theta_0 = 220$ km s^{-1} and the standard solar motion to define the LSR.

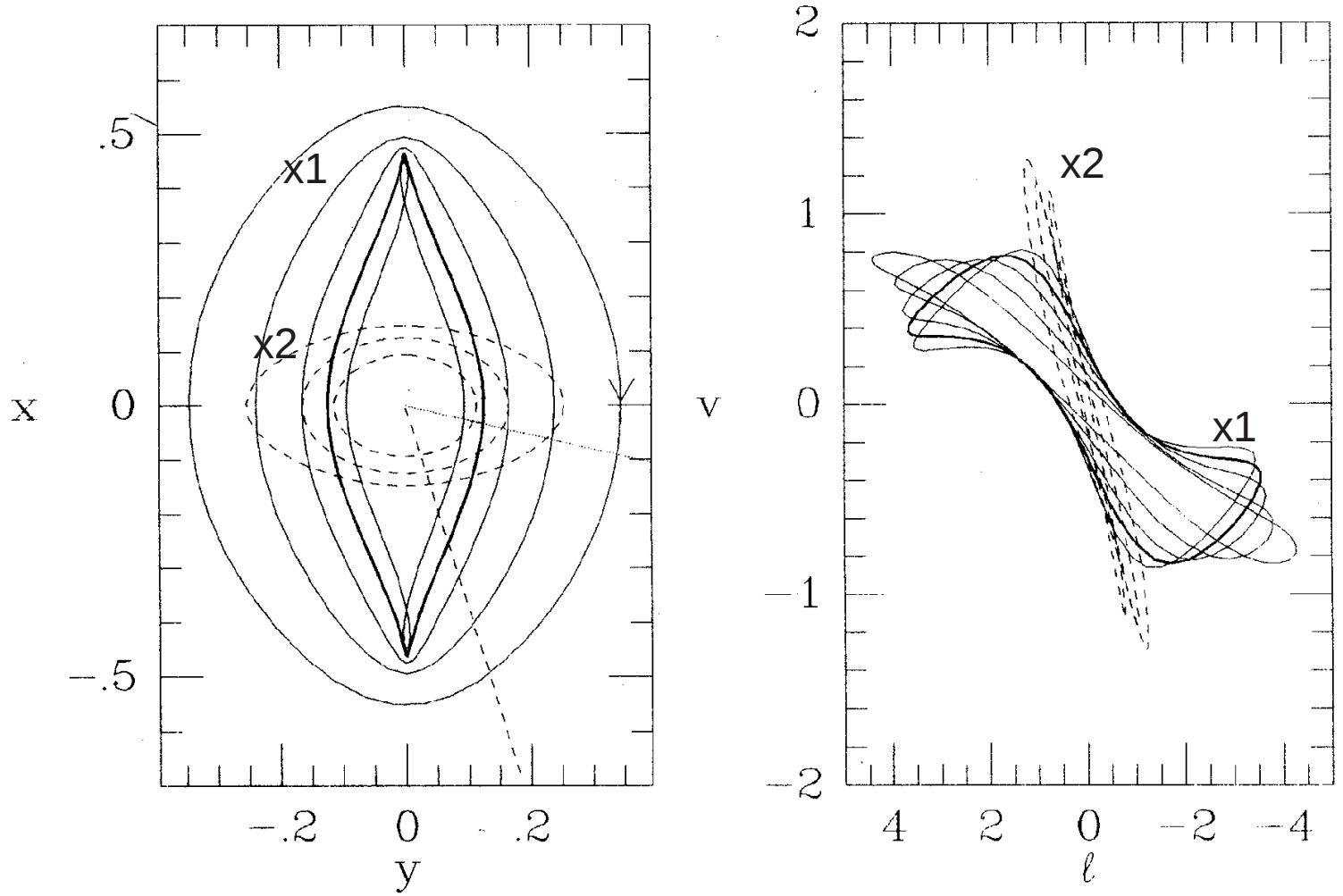
Reid et al. 2009


Galactic Latitude
Galactic Longitude

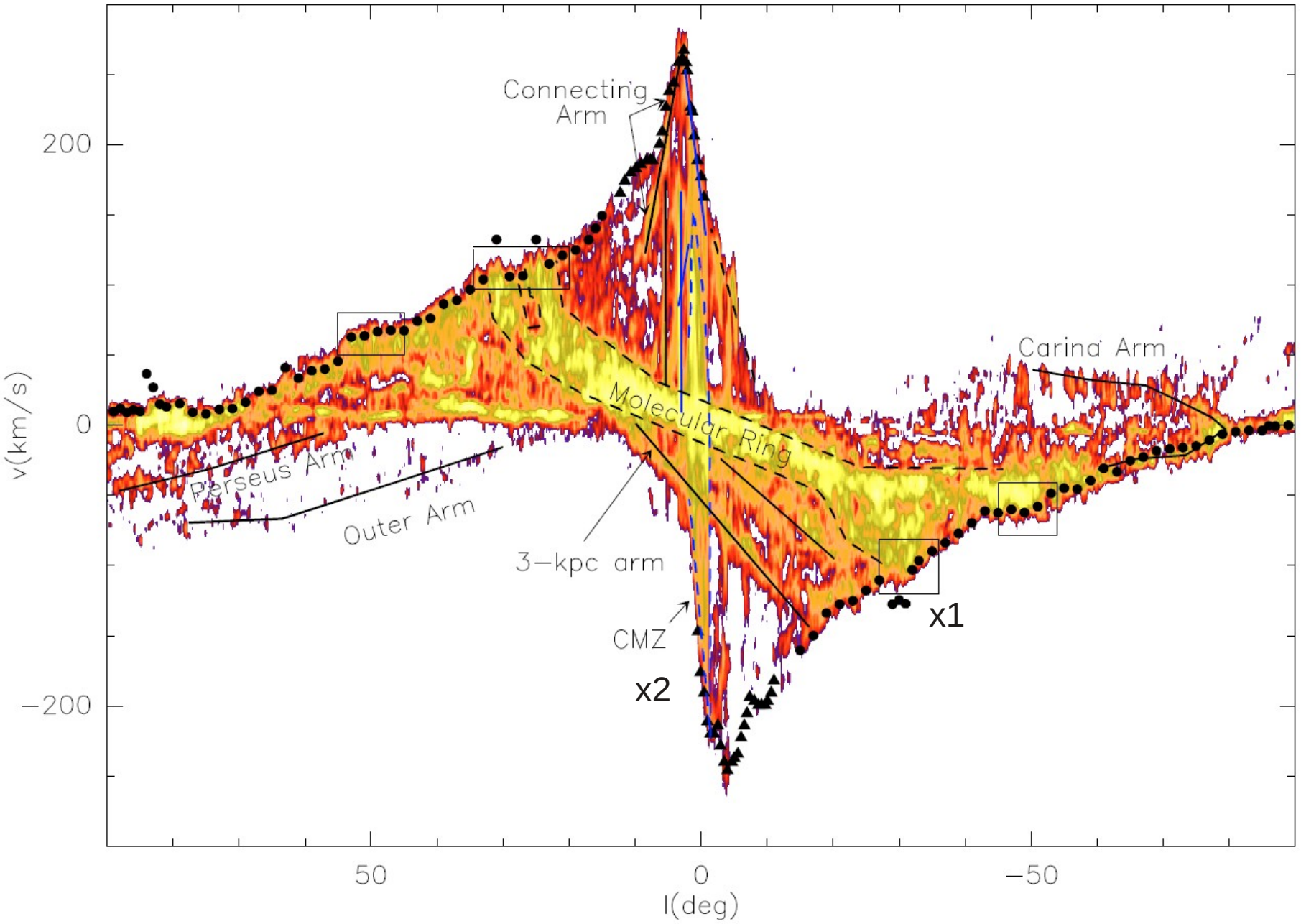

Galactic Longitude



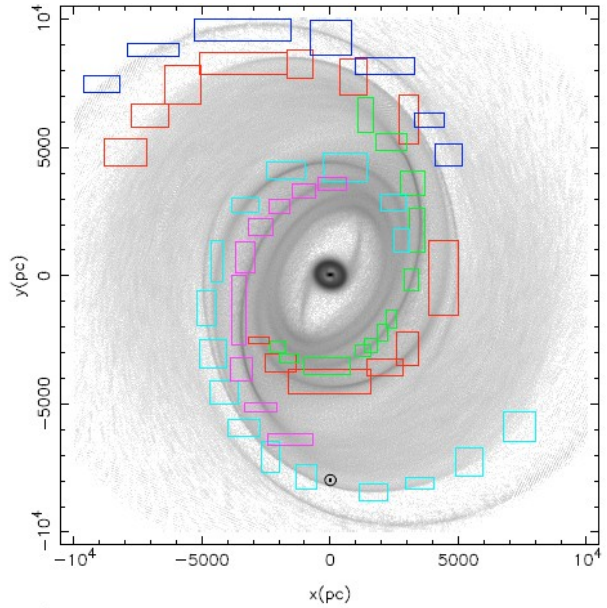
LSR radial velocity (km s⁻¹)
Galactic Longitude
Galactic Longitude

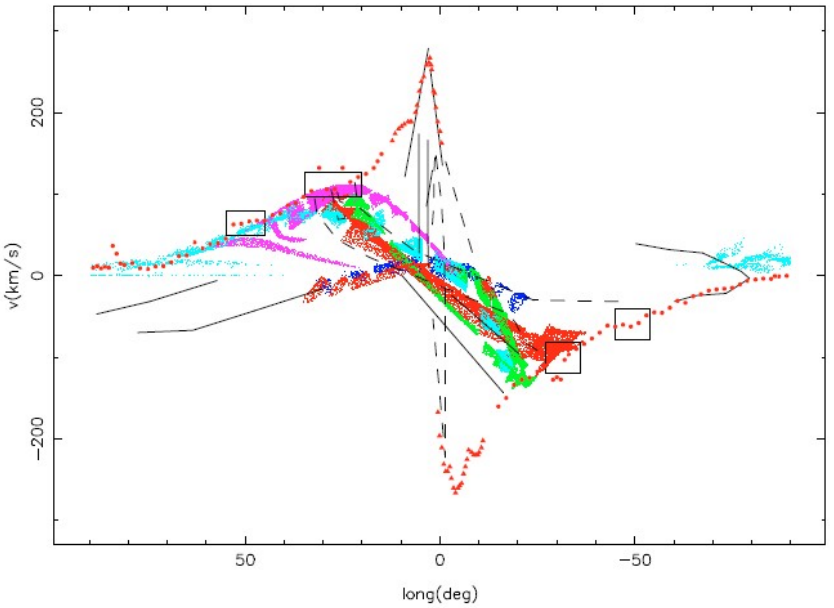


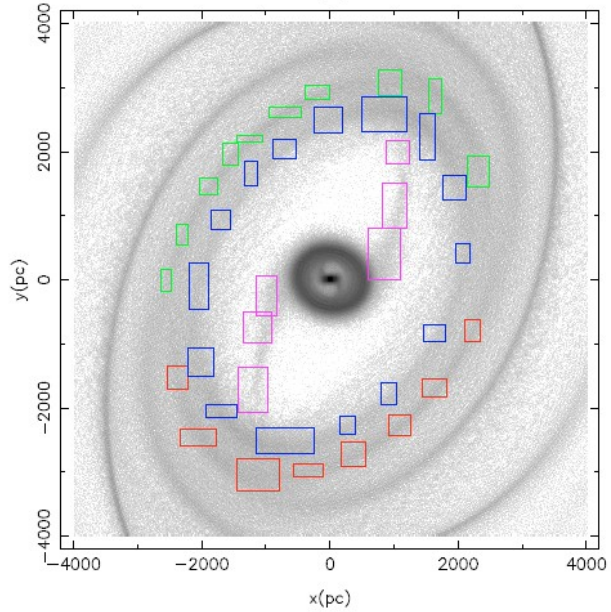
Binney et al. 1991

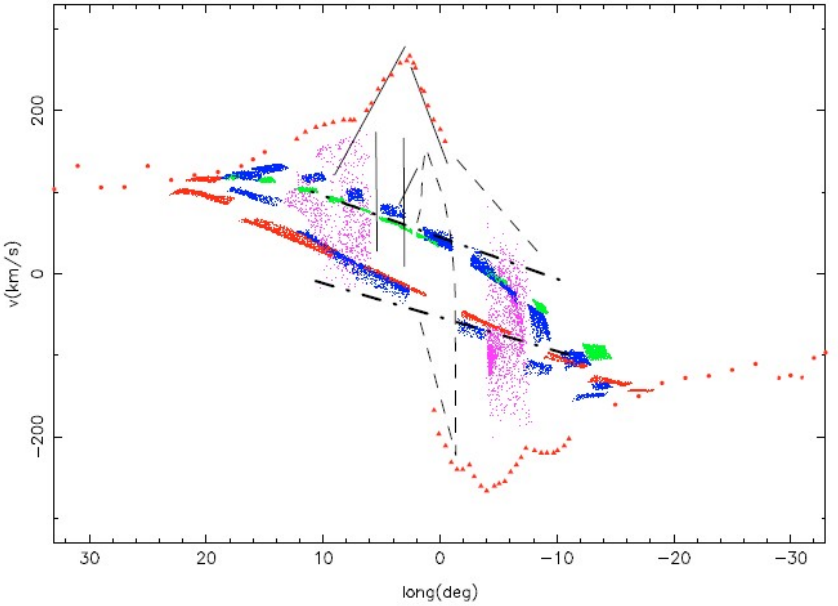


Dame et al. 2001



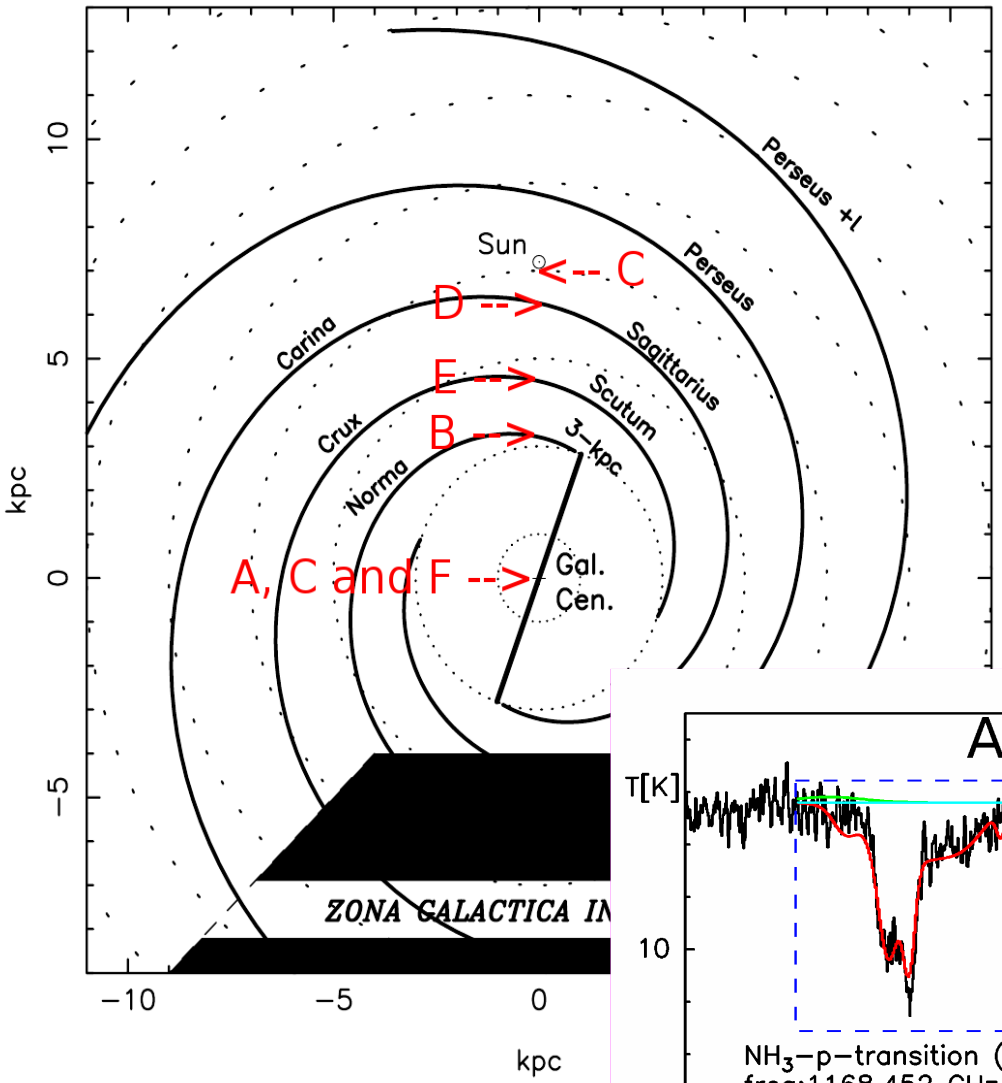




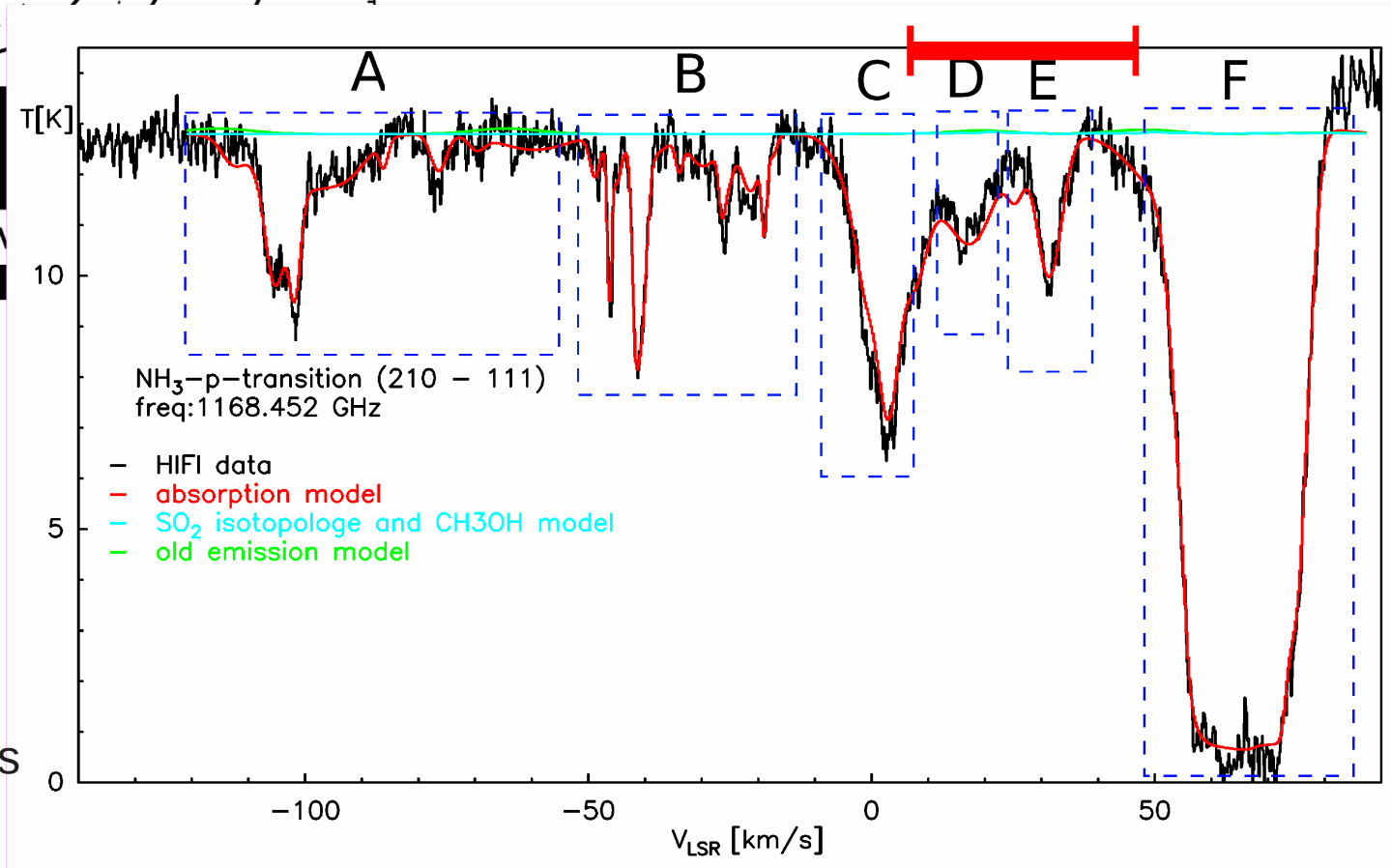


Rodriguez-Fernandez & Combes 2008

...plus peculiar motions – contraction, expansion, etc.



Contamination by outflow wings from SgrB2(M)

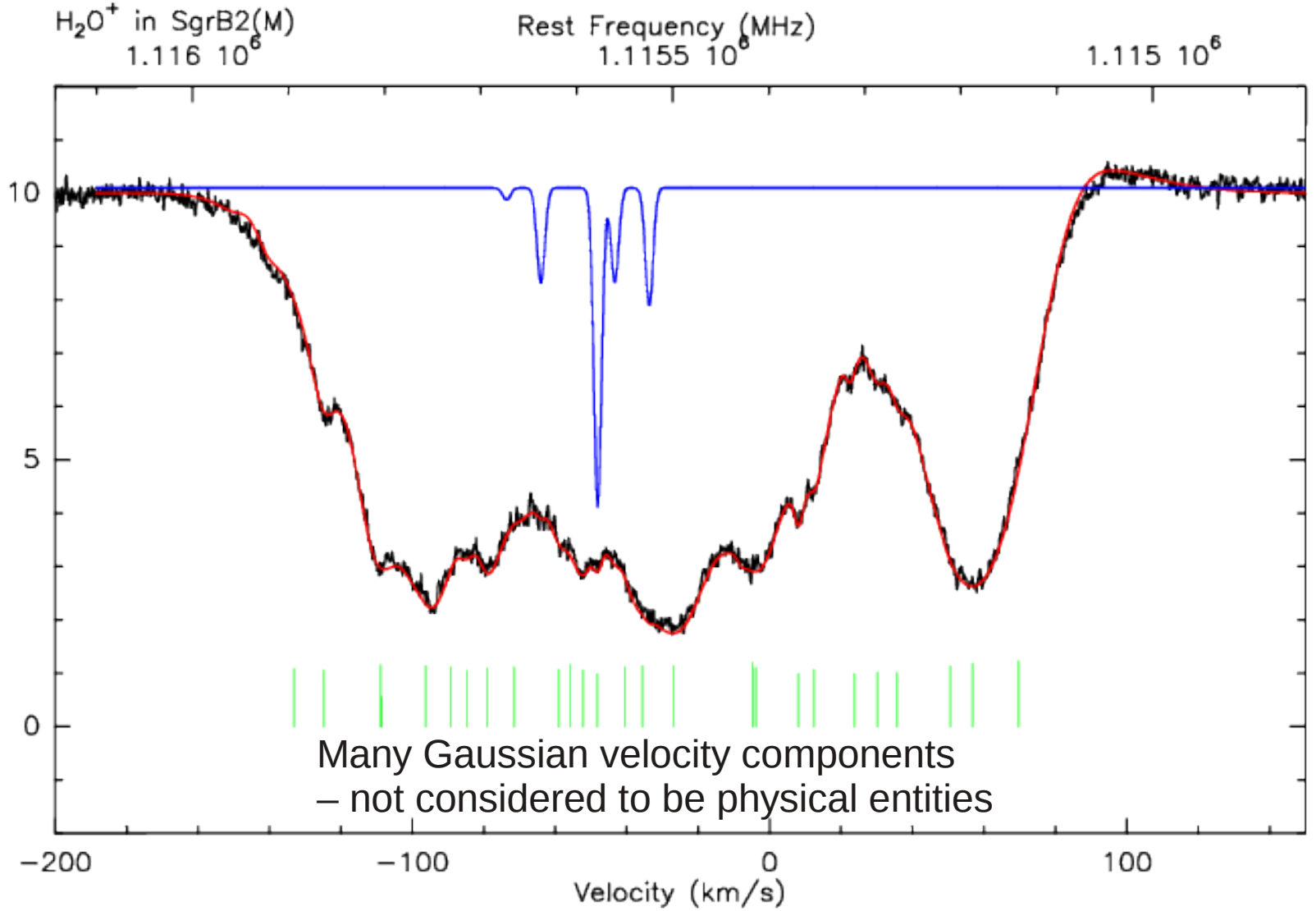


Büchel 2012, Master Thesis

Velocity fitting

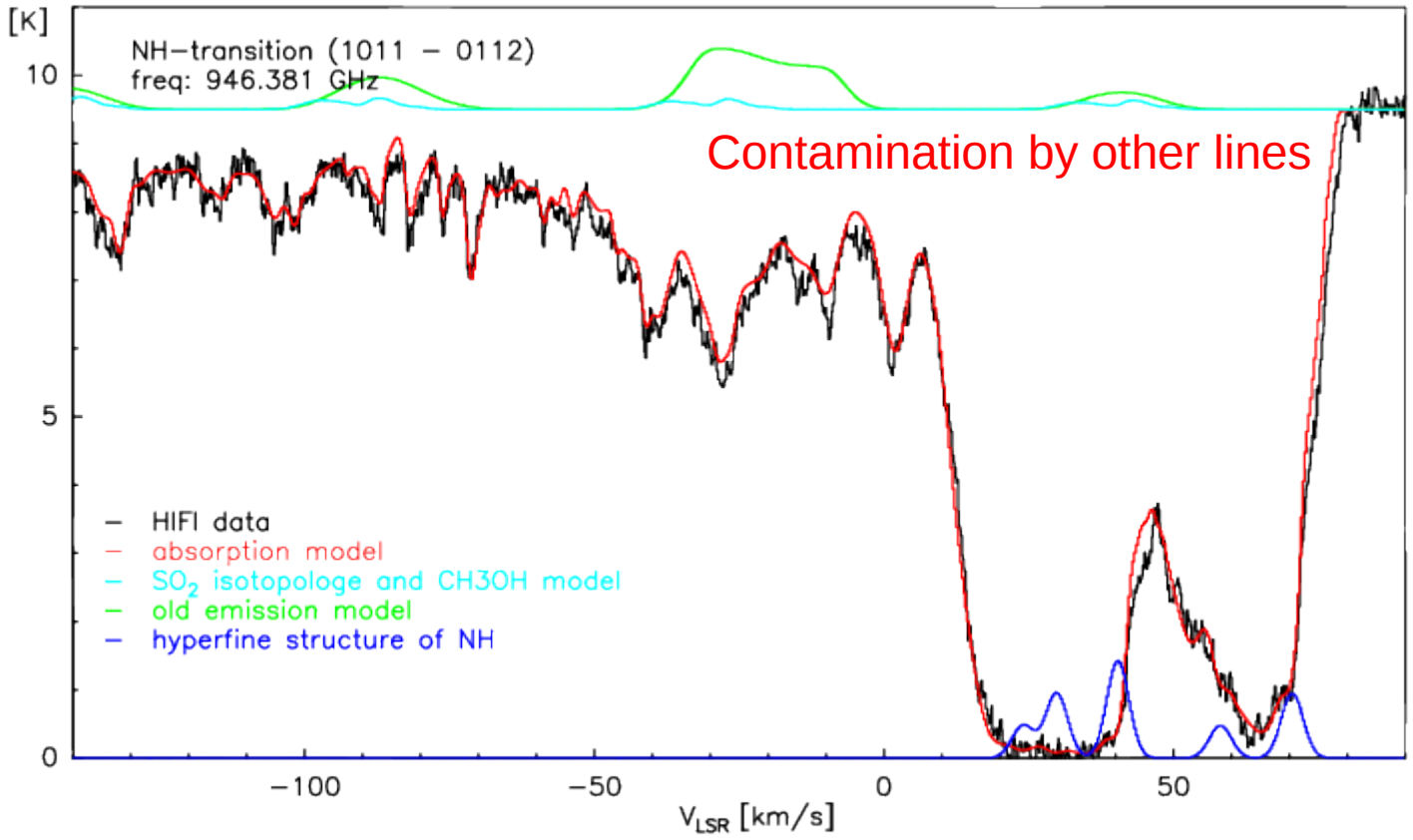
H_2O^+

Fits by XLASS and MAGIX using data from CDMS and JPL
And from Müller, priv. comm.

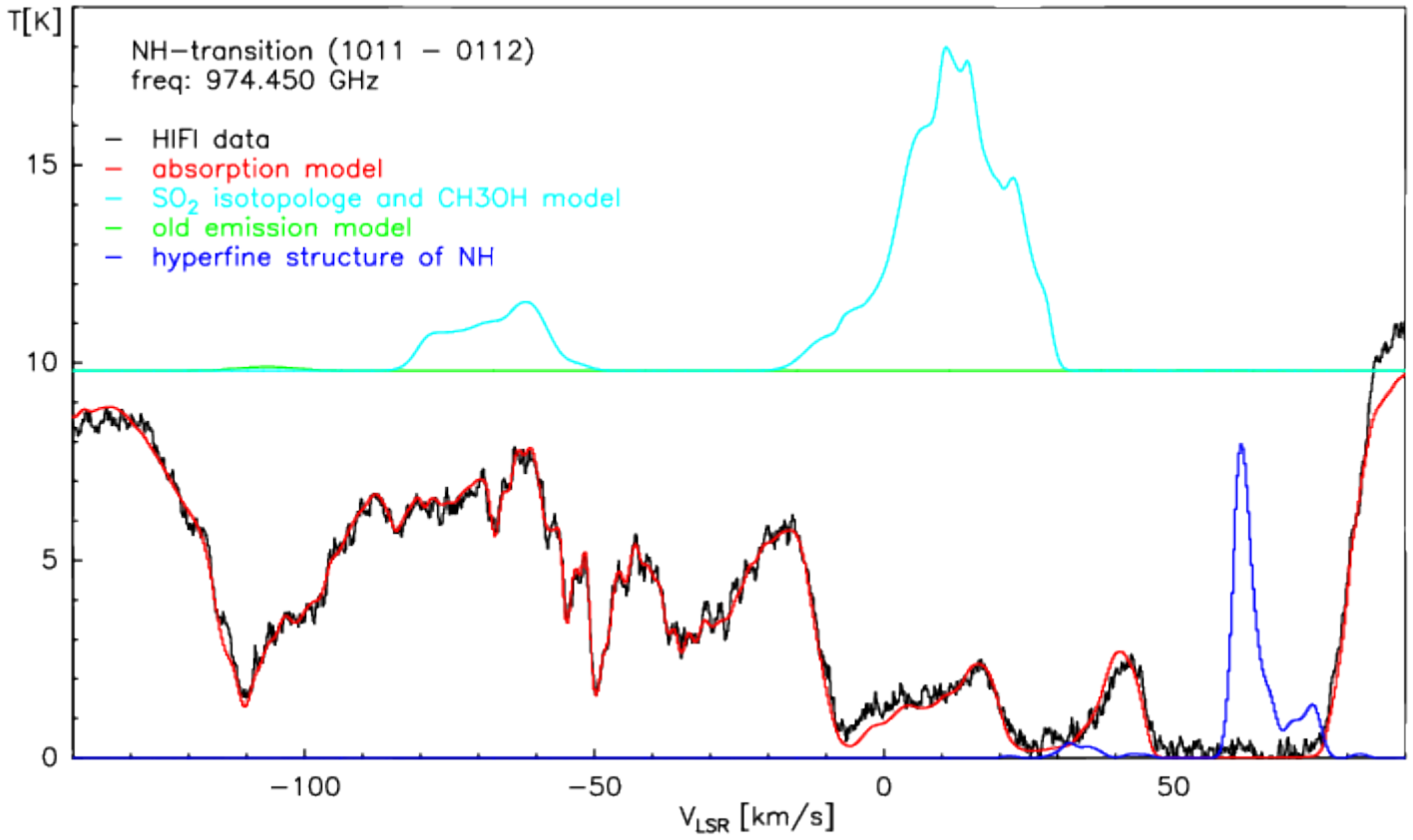


Schilke et al., 2010

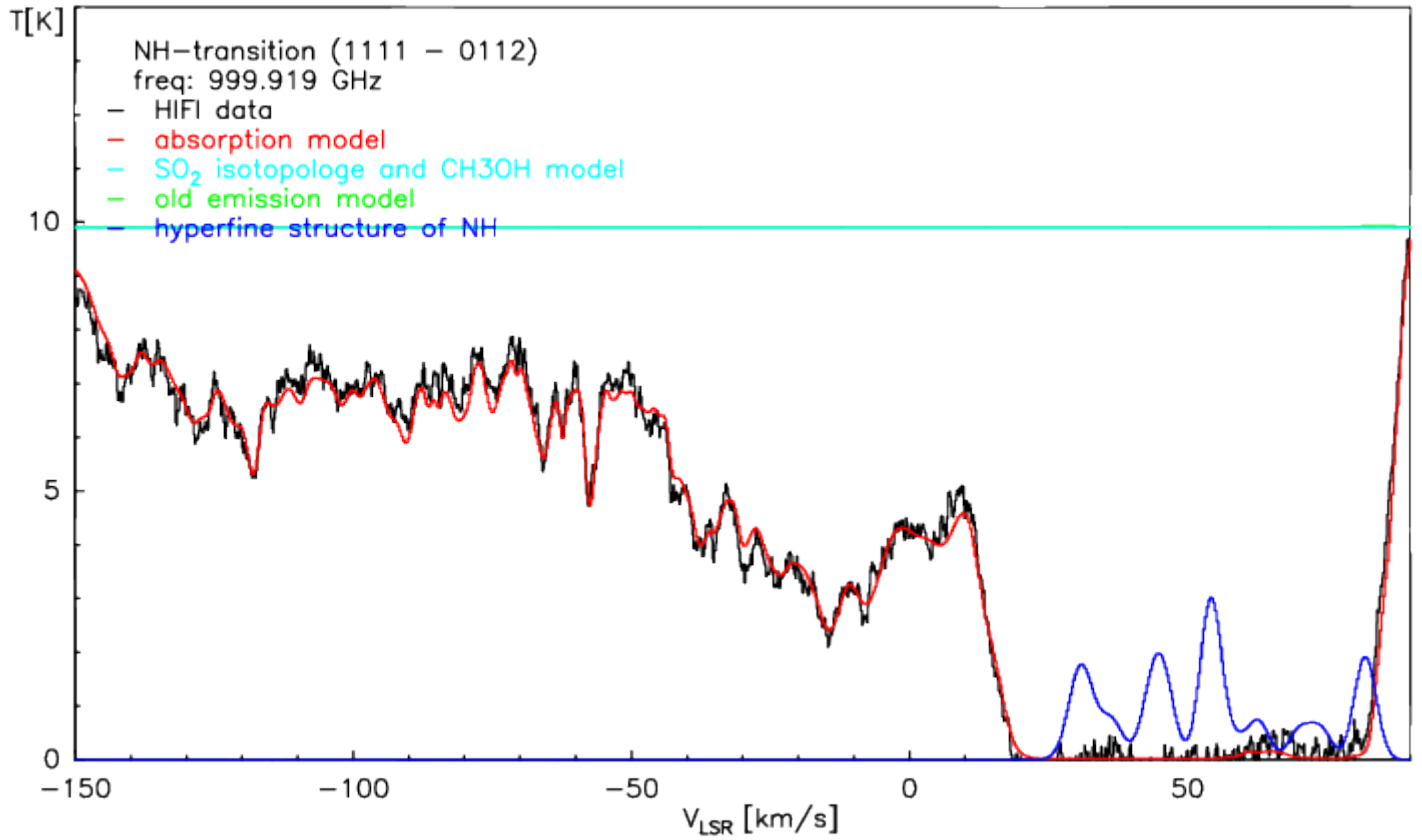
Absorption line fits: method



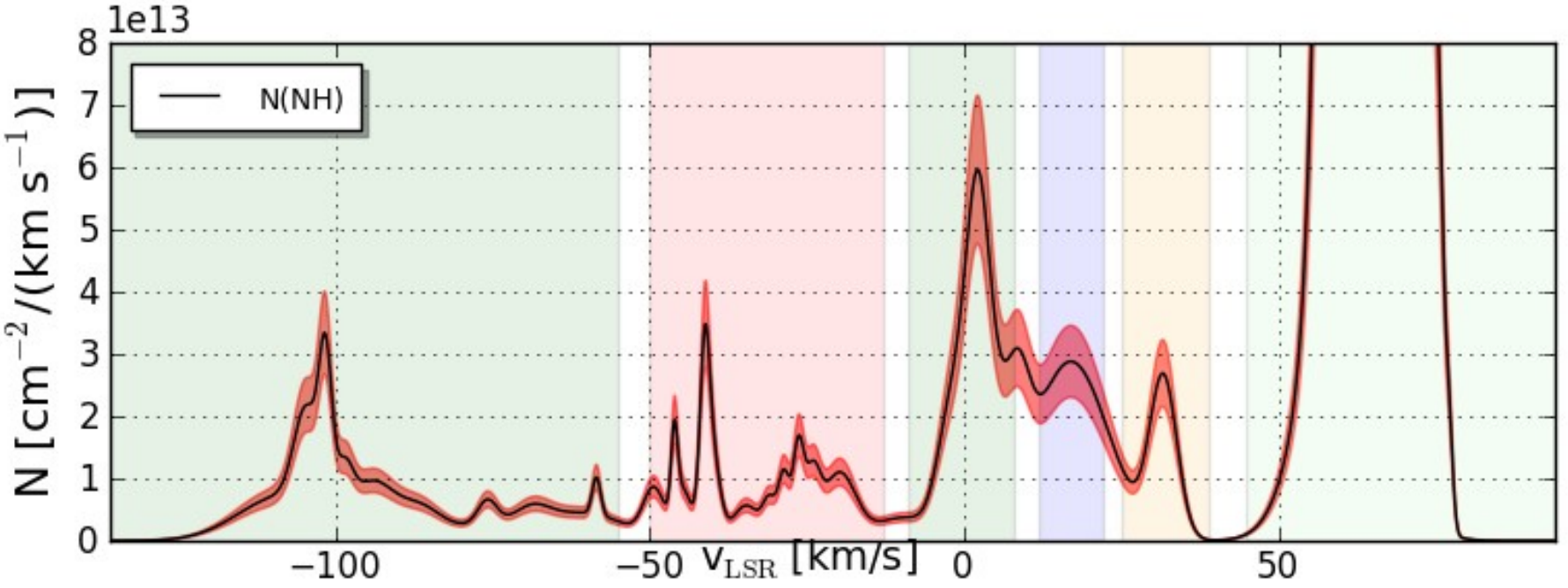
Absorption line fits: method



Absorption line fits: method

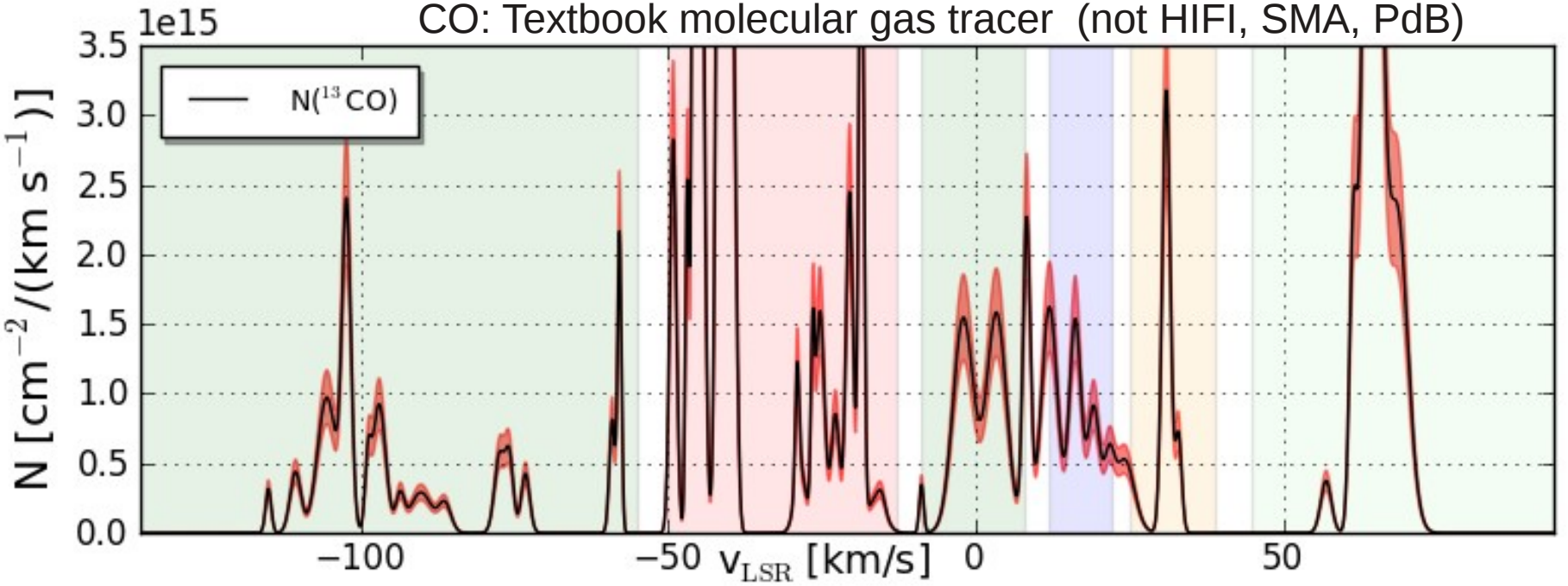


Absorption line fits: result

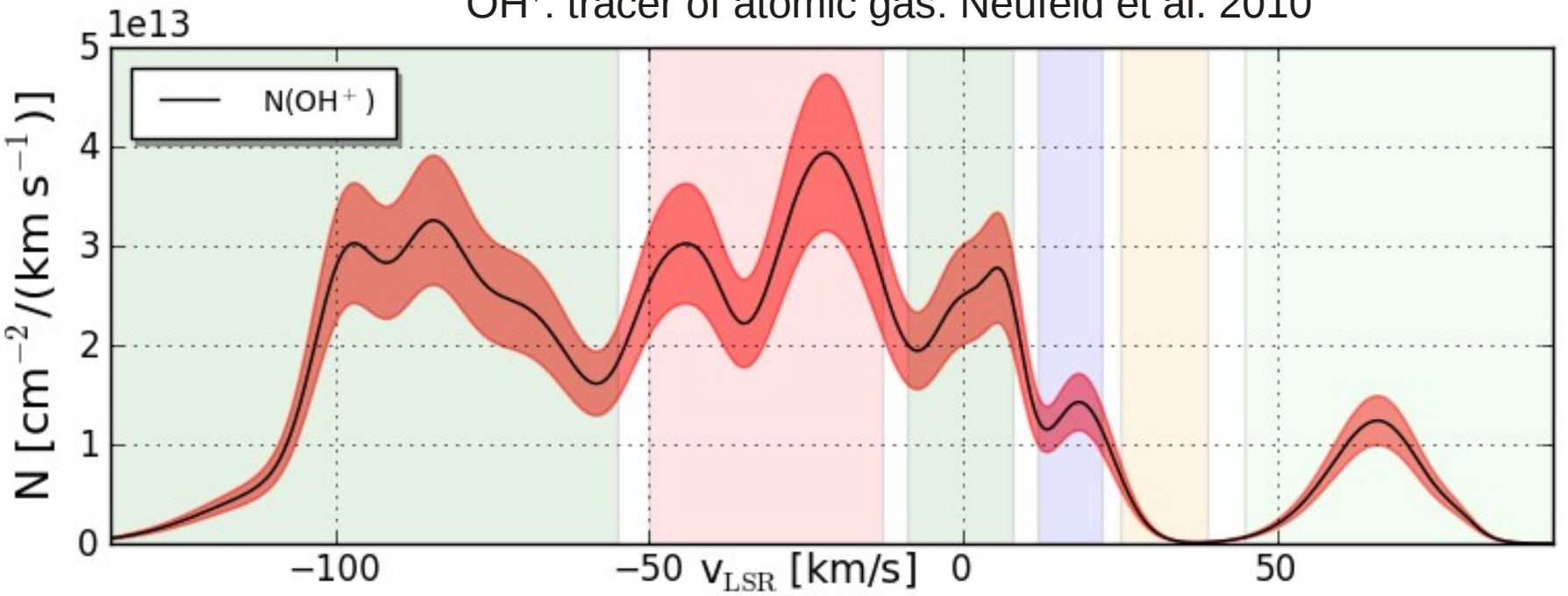


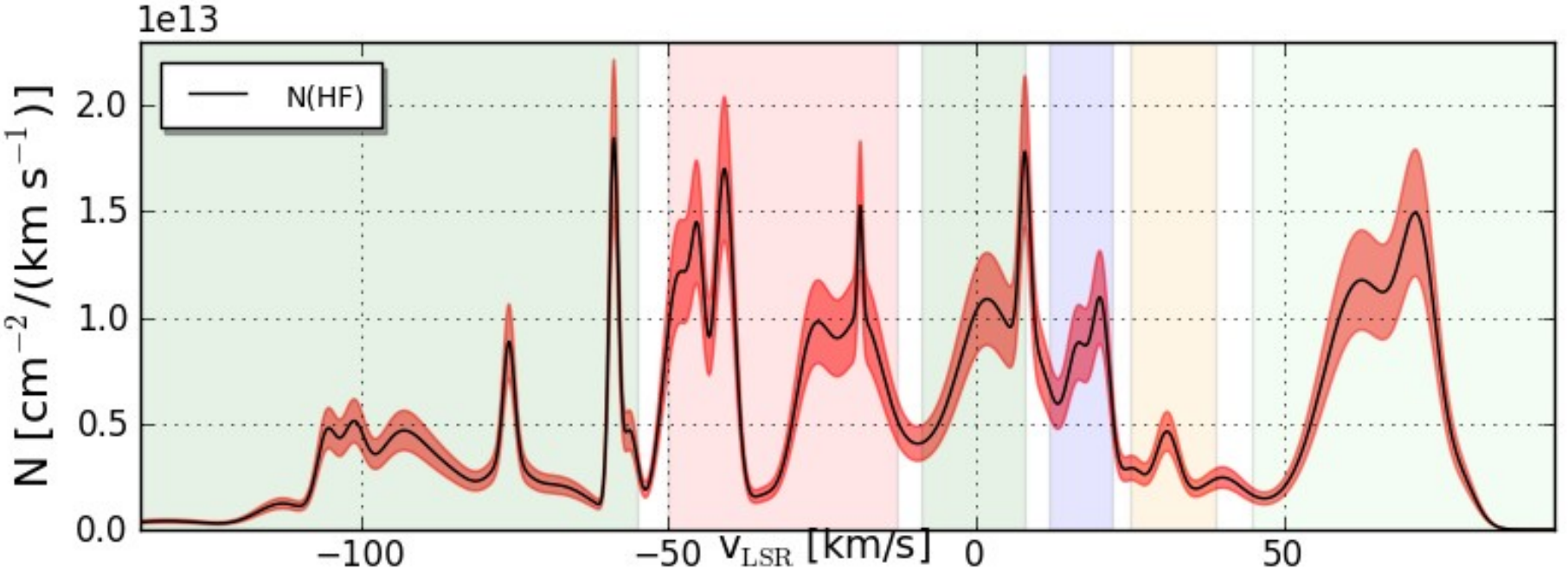
Qualitative results: Line shapes

CO: Textbook molecular gas tracer (not HIFI, SMA, PdB)

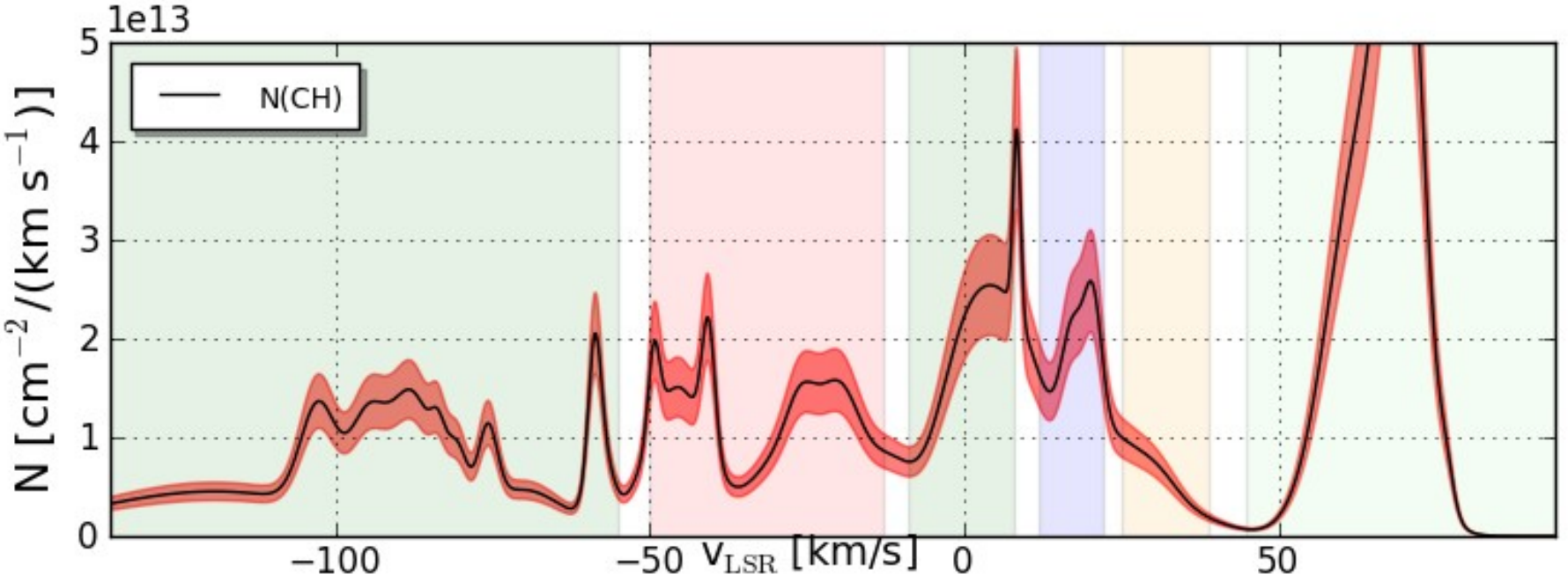


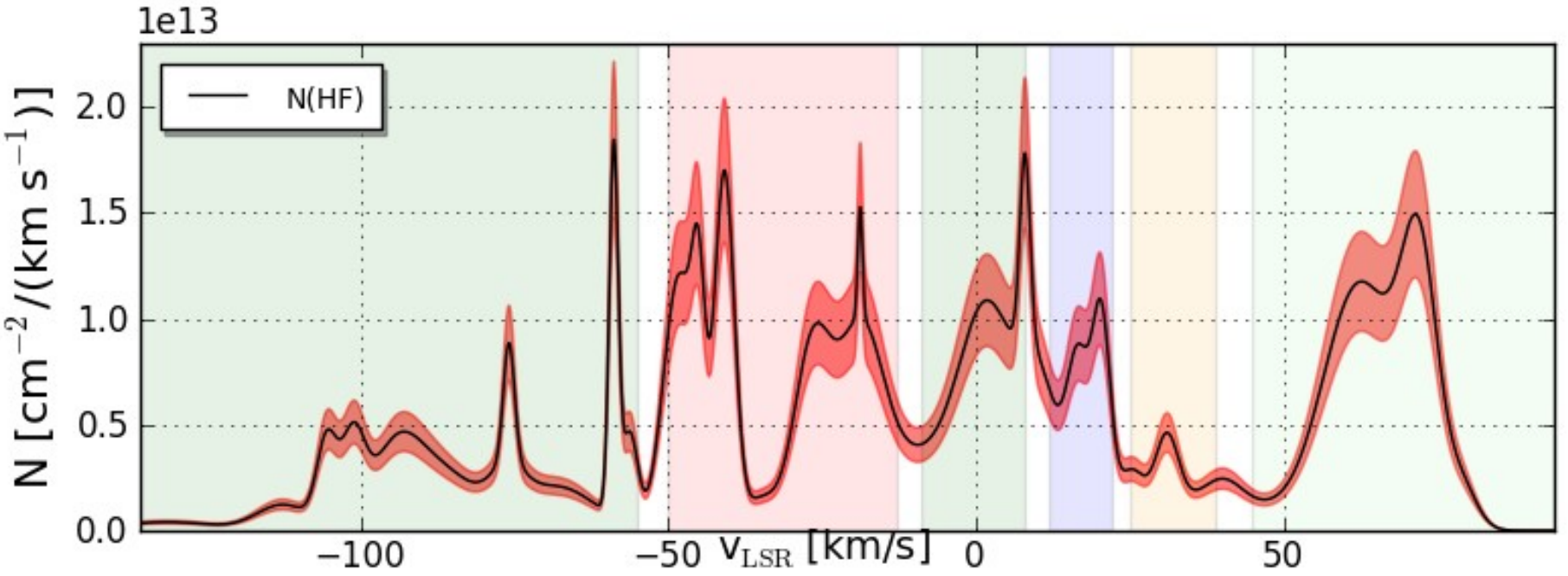
OH$^+$: tracer of atomic gas: Neufeld et al. 2010





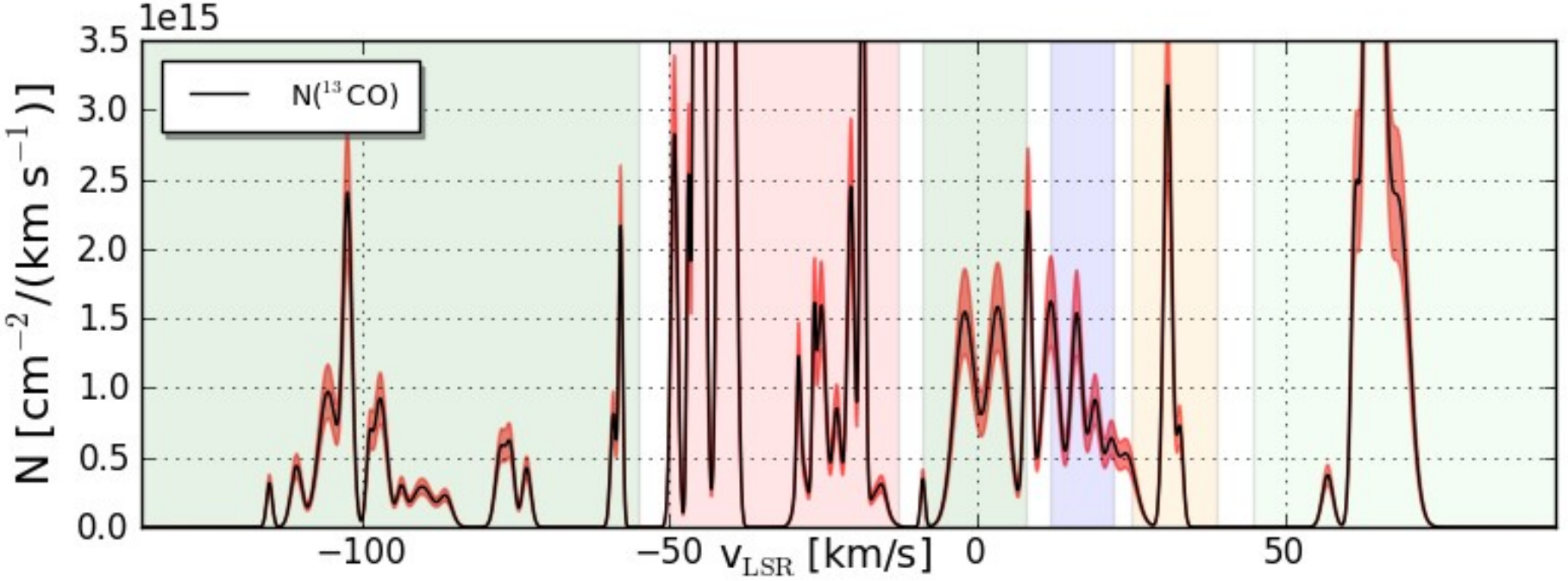
HF and CH: two H_2 tracers

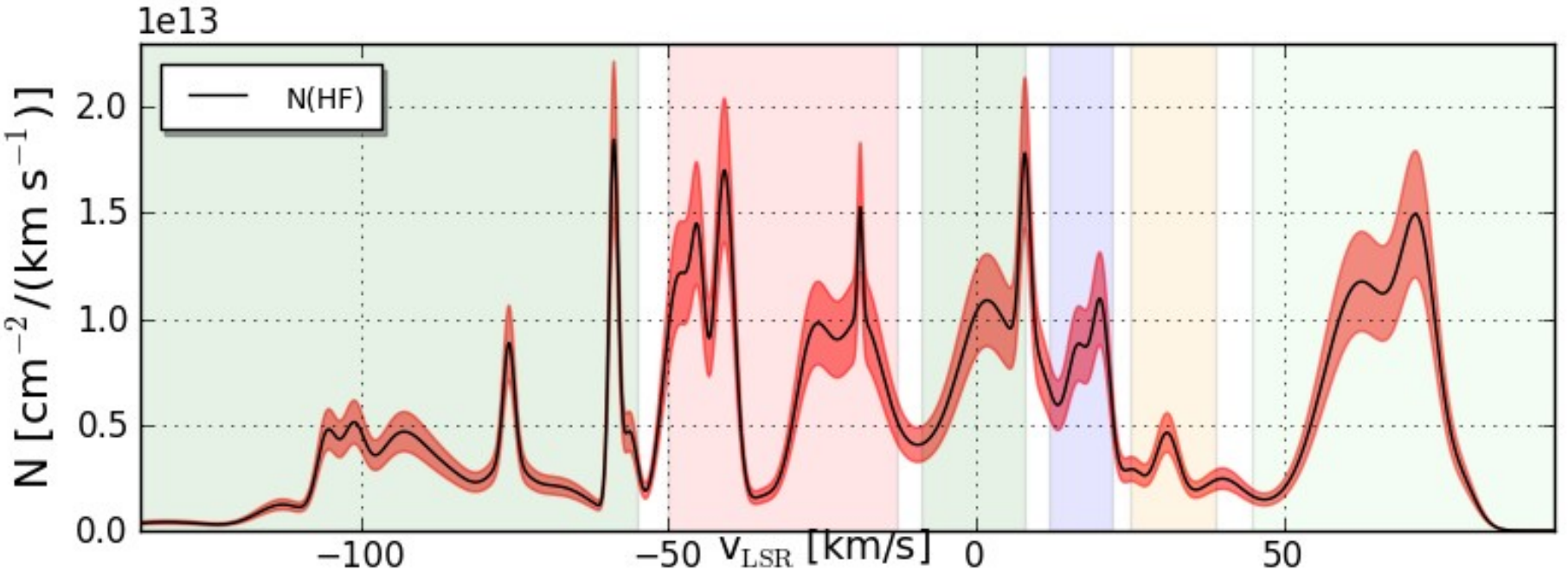




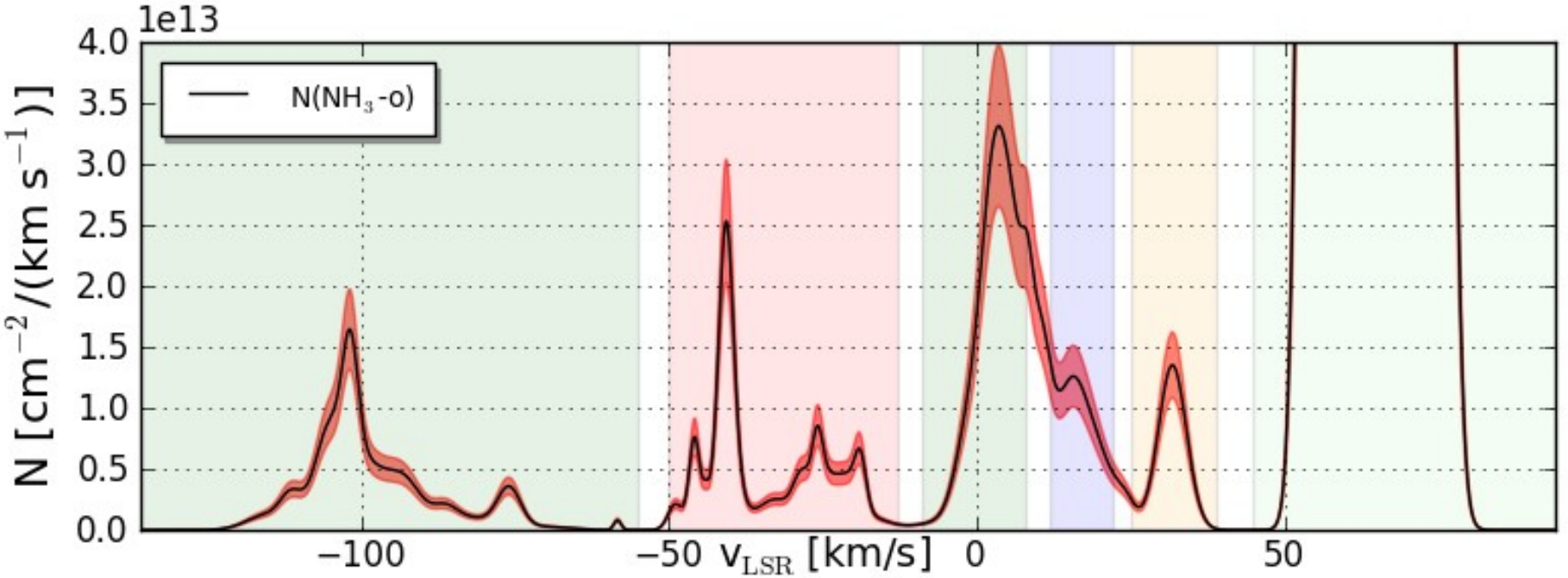
CO doesn't work at all! Just seems to trace cloud cores.

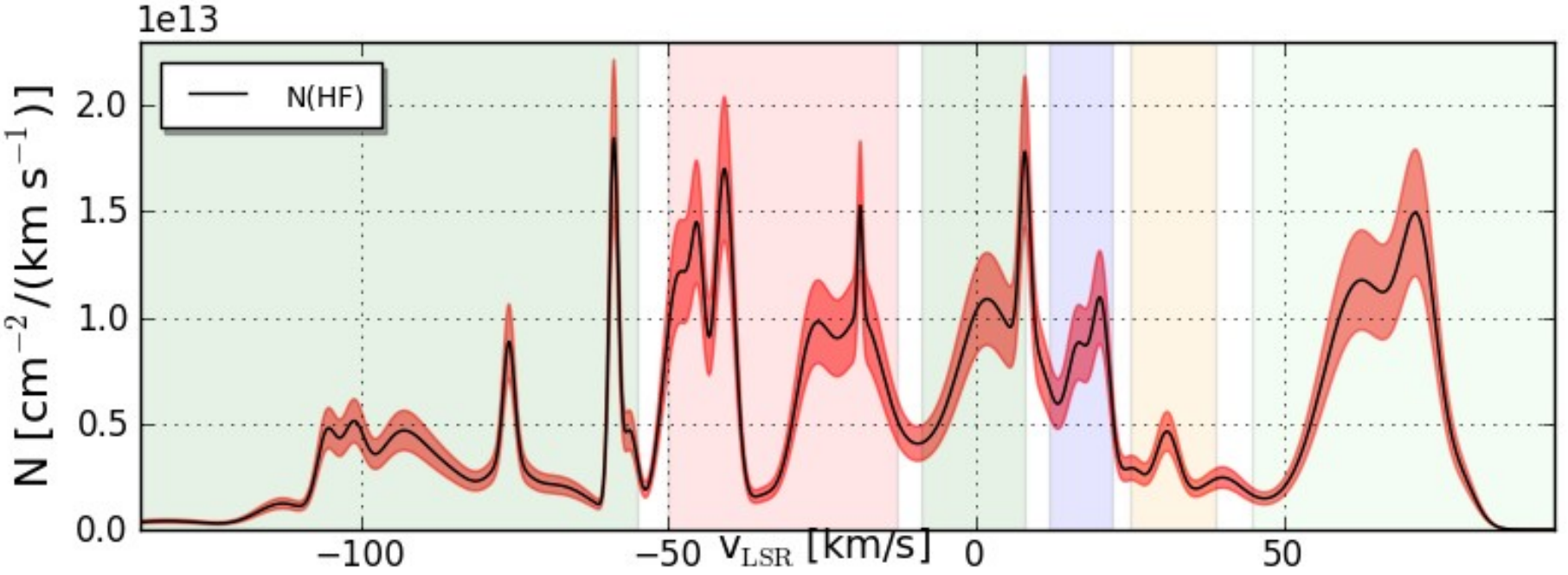
Textbooks need to be rewritten



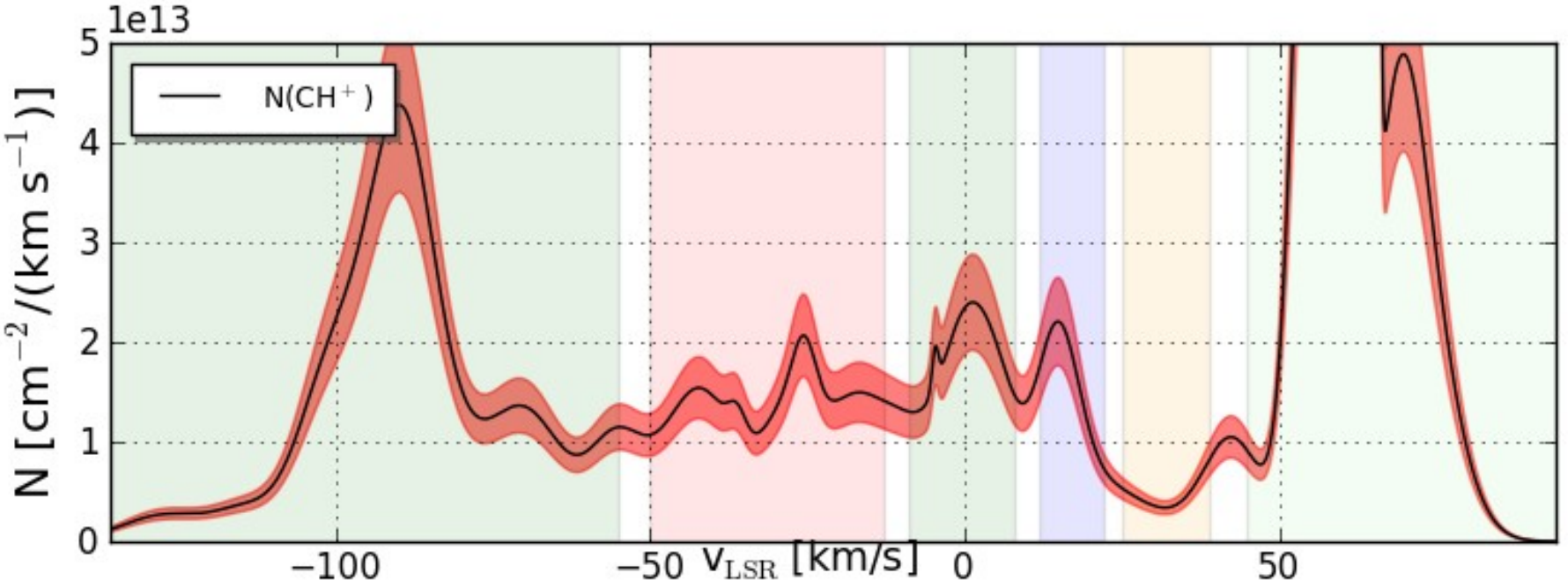


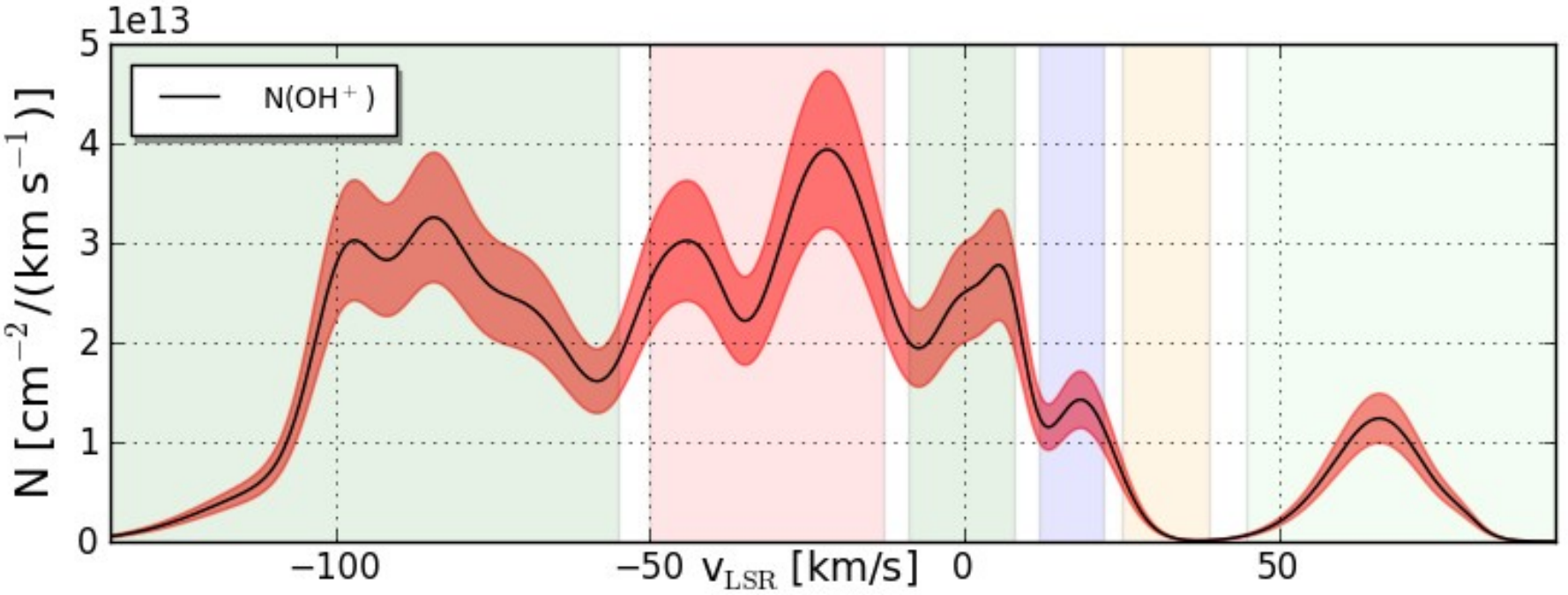
Ammonia: denser gas



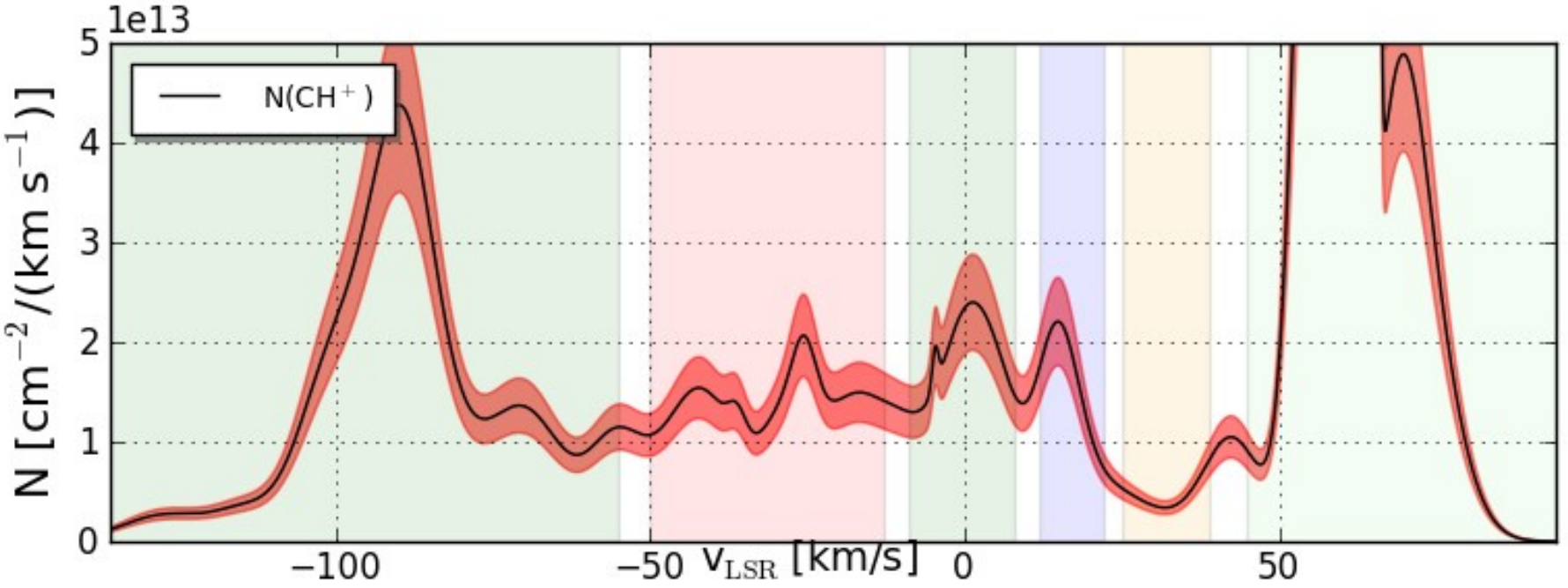


CH$^+$: intermediate between molecular (traced by HF)

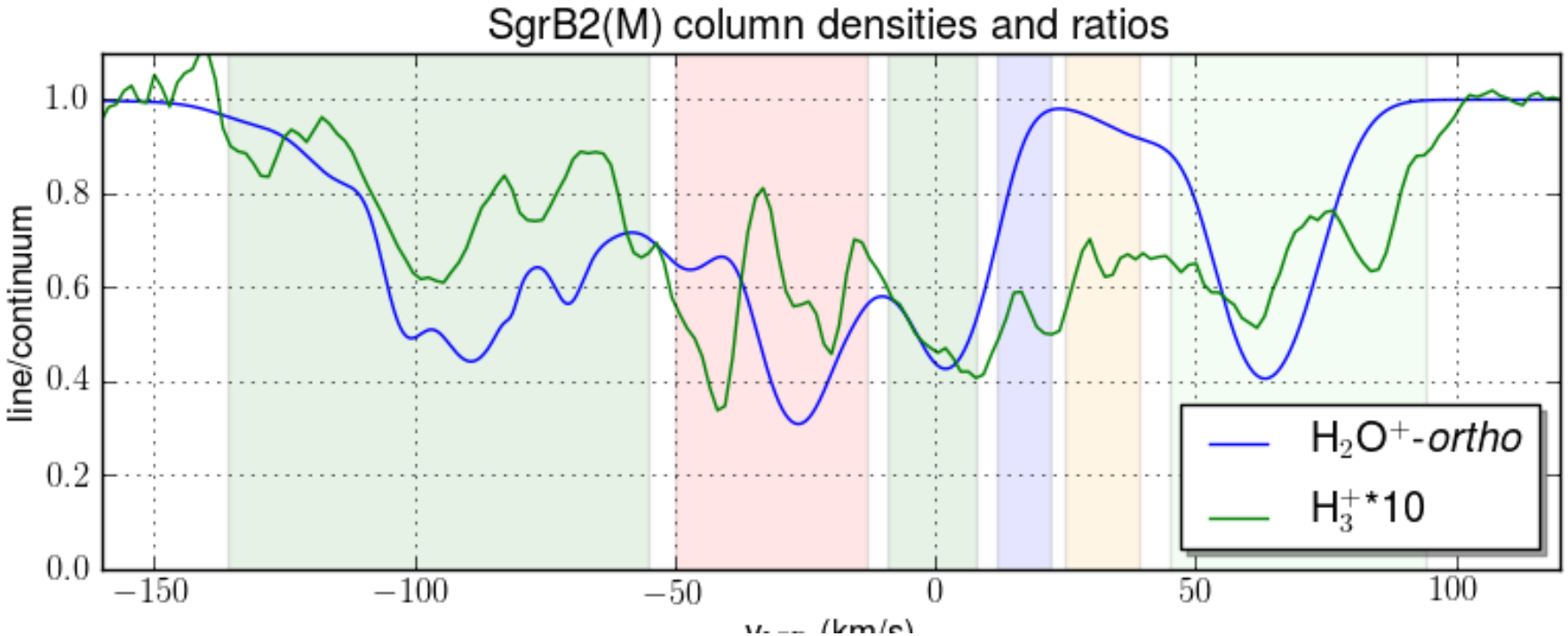




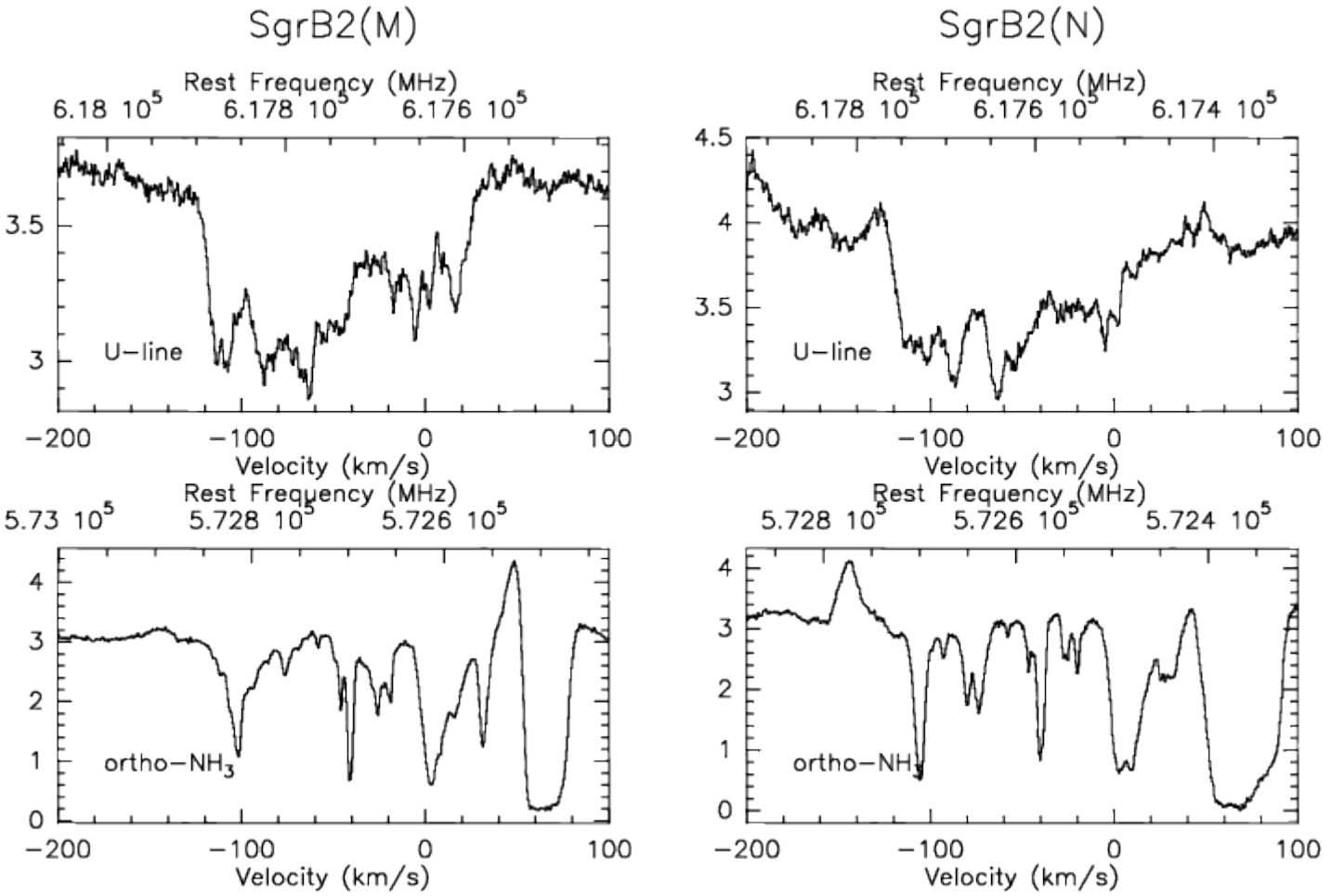
CH^+: intermediate between molecular (traced by HF) and atomic (traced by OH^+)



H_2O^+ and H_3^+

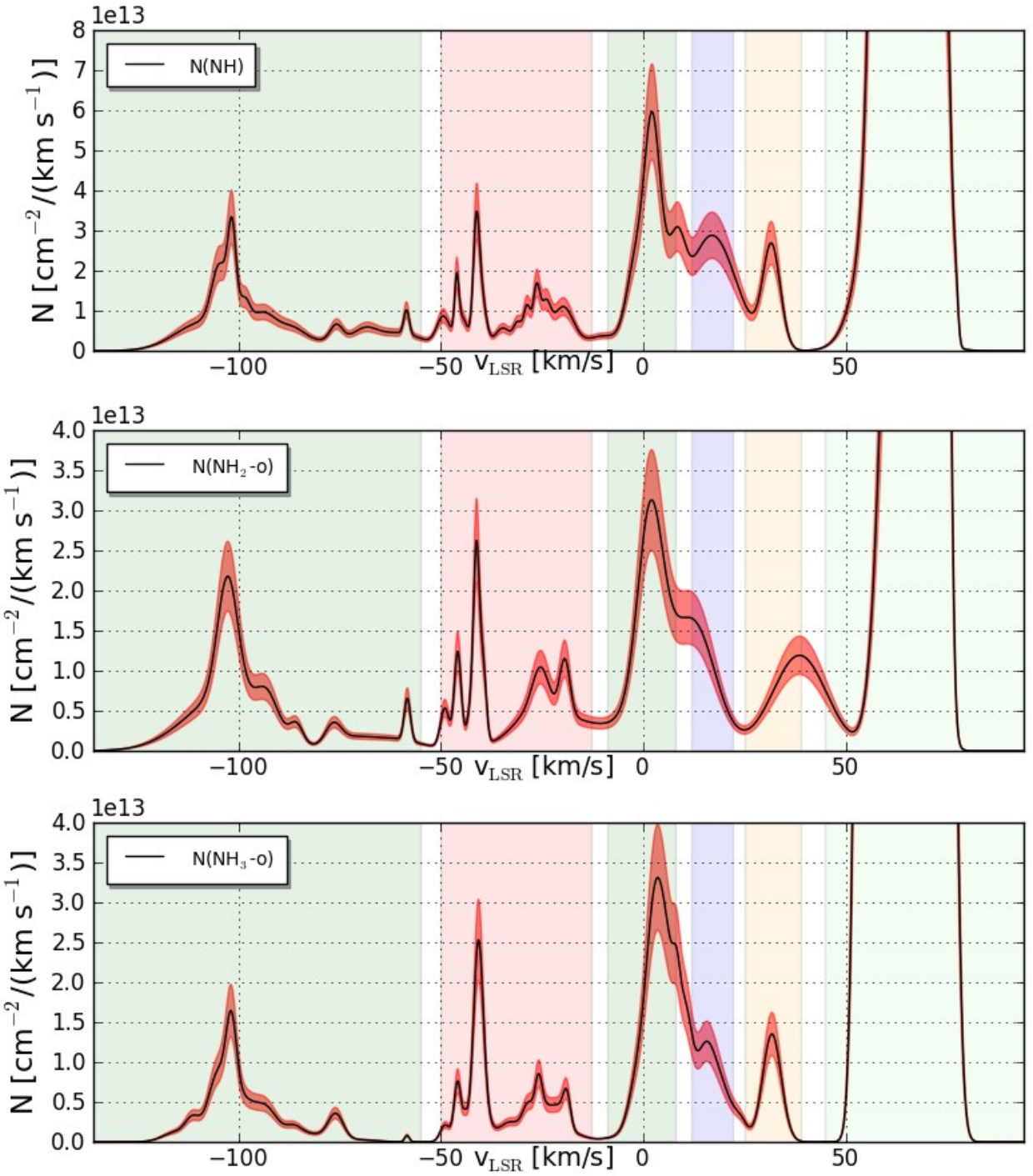

SgrB2(M) column densities and ratios
line/continuum
1.0
0.8
0.6
0.4
0.2
0.0
−150
−100
−50
0
50
100
H2O+-ortho
H3+*10

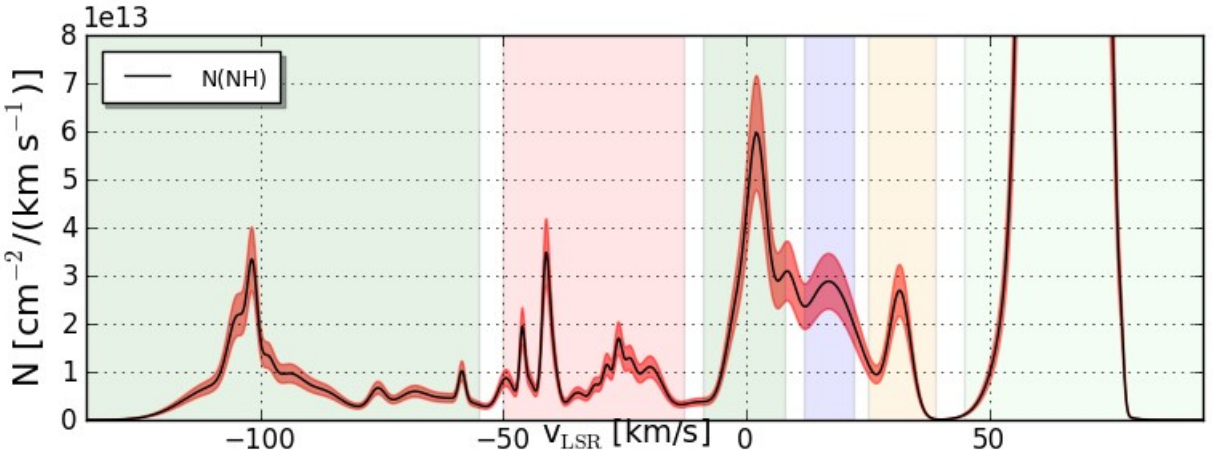
U-line: 617.512 GHz
Anybody???

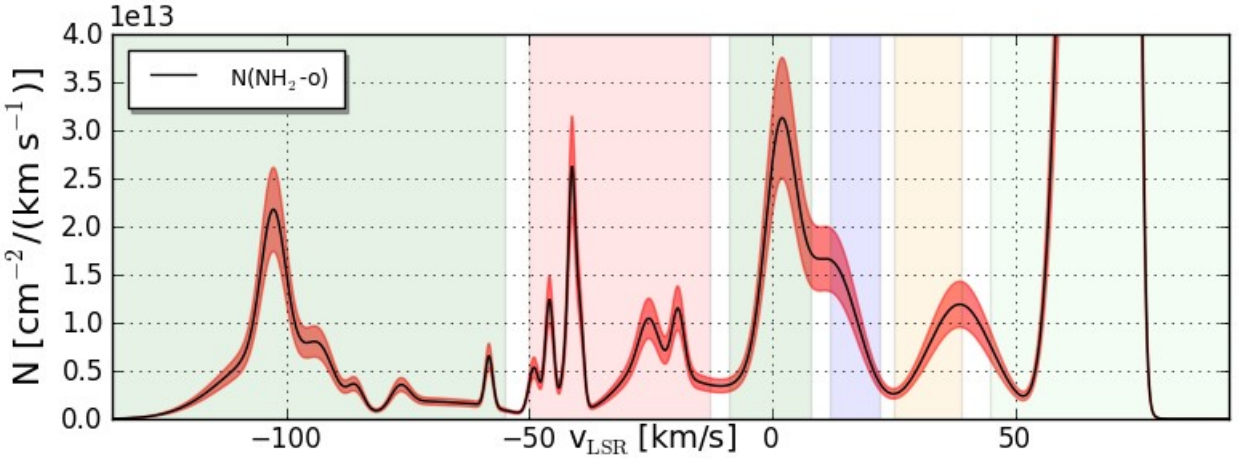


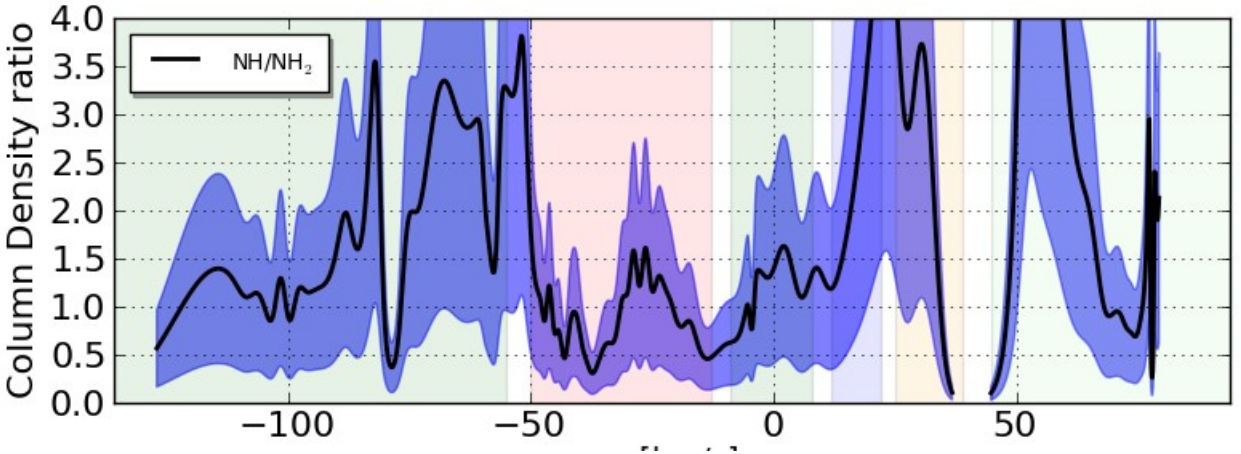
Metastable electronic states? Anions?

Quantitative Results

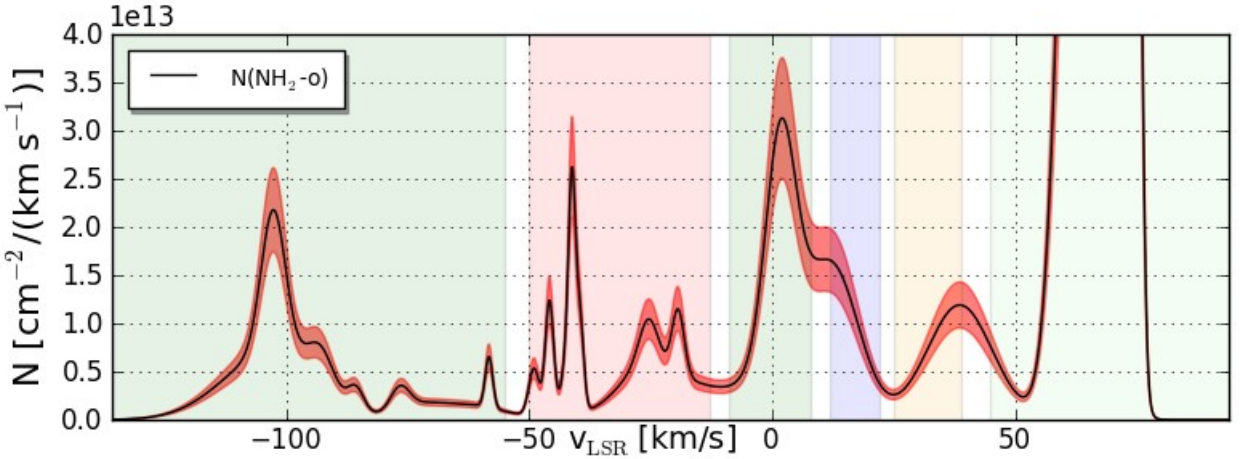

1e13
N(NH)
N [cm^{-2}/(km s^{-1})]
v_{LSR} [km/s]
1e13
N(NH$_2$-o)
N [cm^{-2}/(km s^{-1})]
v_{LSR} [km/s]
1e13
N(NH$_3$-o)
N [cm^{-2}/(km s^{-1})]
v_{LSR} [km/s]

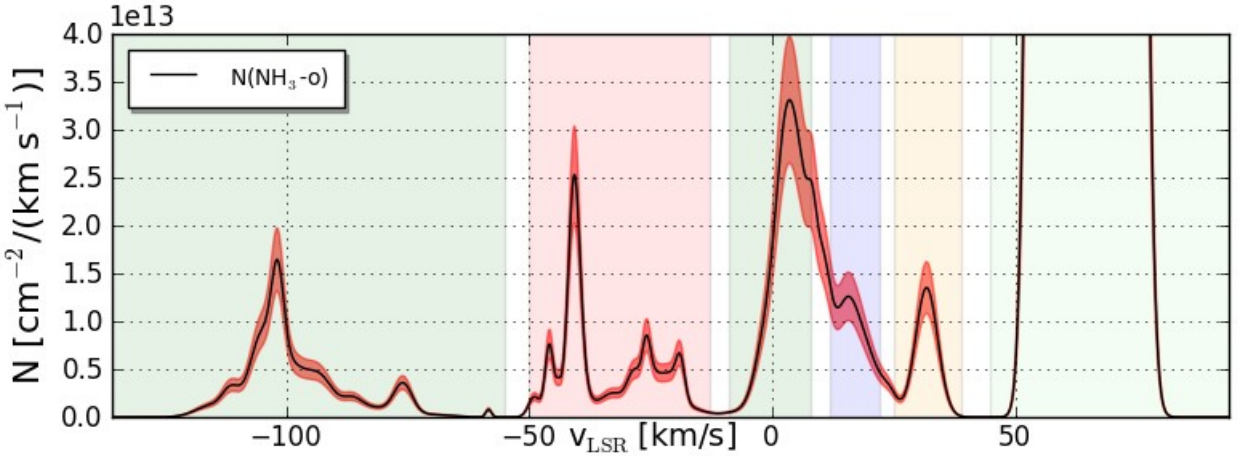

1e13
N(NH)
N [cm^{-2}/(km s^{-1})]
v_{LSR} [km/s]

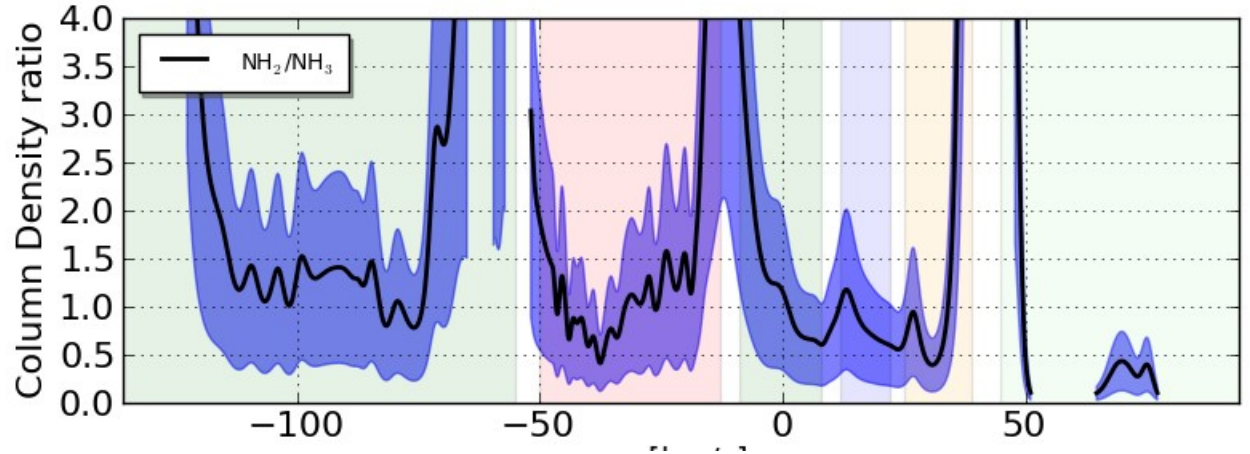

1e13
N(NH$_2$-o)
N [cm^{-2}/(km s^{-1})]
v_{LSR} [km/s]


NH/NH$_2$
Column Density ratio

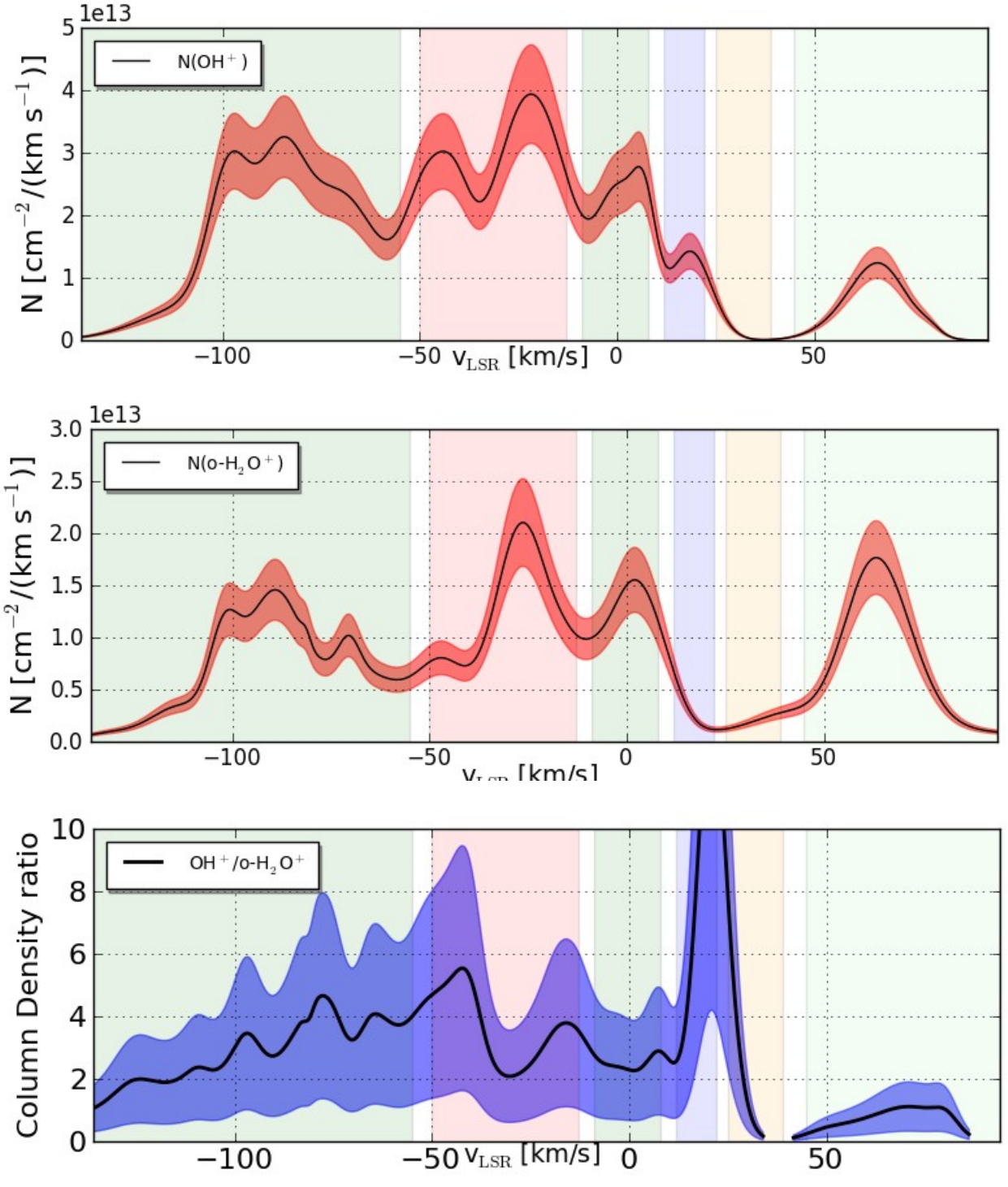
NH/NH$_2$ ≈ 2.2

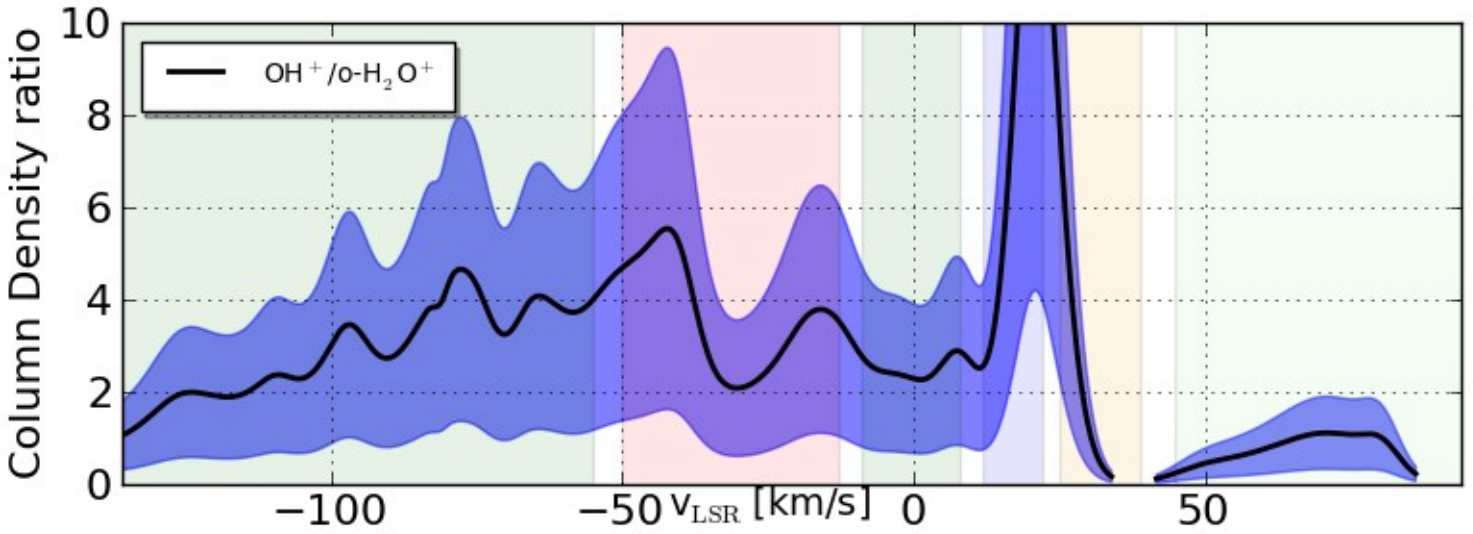




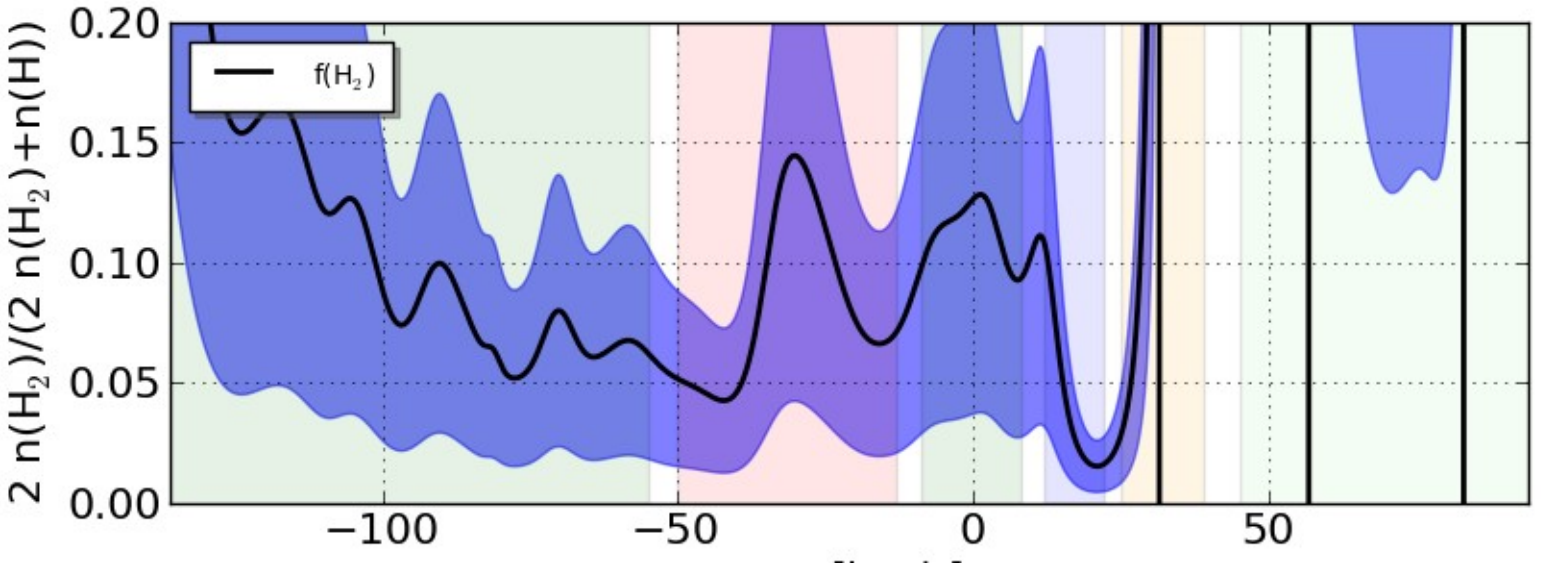


$NH_2/NH_3 \approx 1.3$


1e13
N(OH$^+$)
N [cm^{-2}/(km s^{-1})]
v_{LSR} [km/s]
1e13
N(o-H_2O^+)
N [cm^{-2}/(km s^{-1})]
v_{LSR} [km/s]
OH$^+$/o-H_2O^+
Column Density ratio
v_{LSR} [km/s]



Neufeld et al., Gerin et al. 2010: OH^+, H_2O^+ reside in atomic/molecular transition zone
Here: also, molecular fraction is similarly low (0.04-0.12 vs. 0.02-0.08 outside the GC)

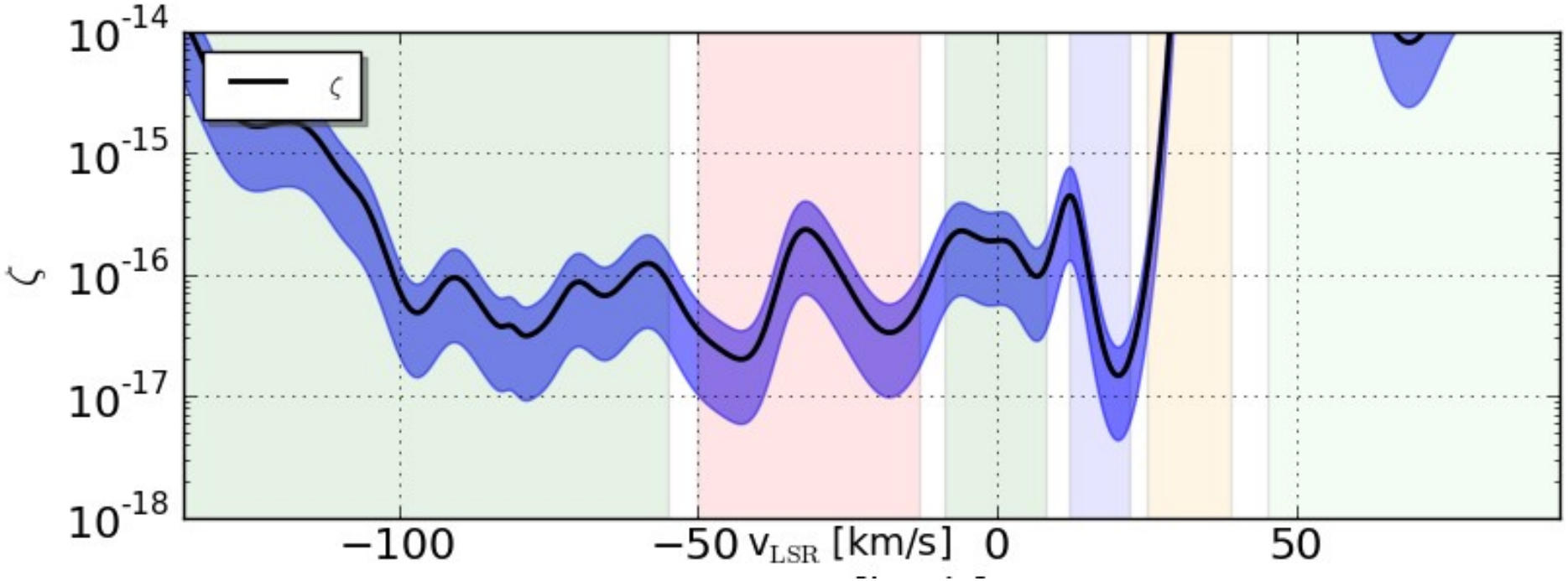


Neufeld et al., 2010: determination of cosmic ray rate

H_2 column density from CH

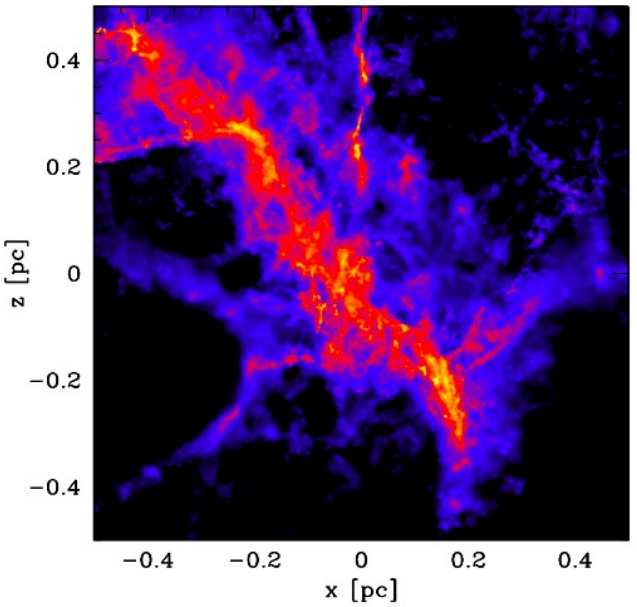
n_H column density from $n(H_2)/f(H_2)$ determined by OH^+/H_2O^+

Very crude assumptions – needs to be examined in more detail, but right order of magnitude

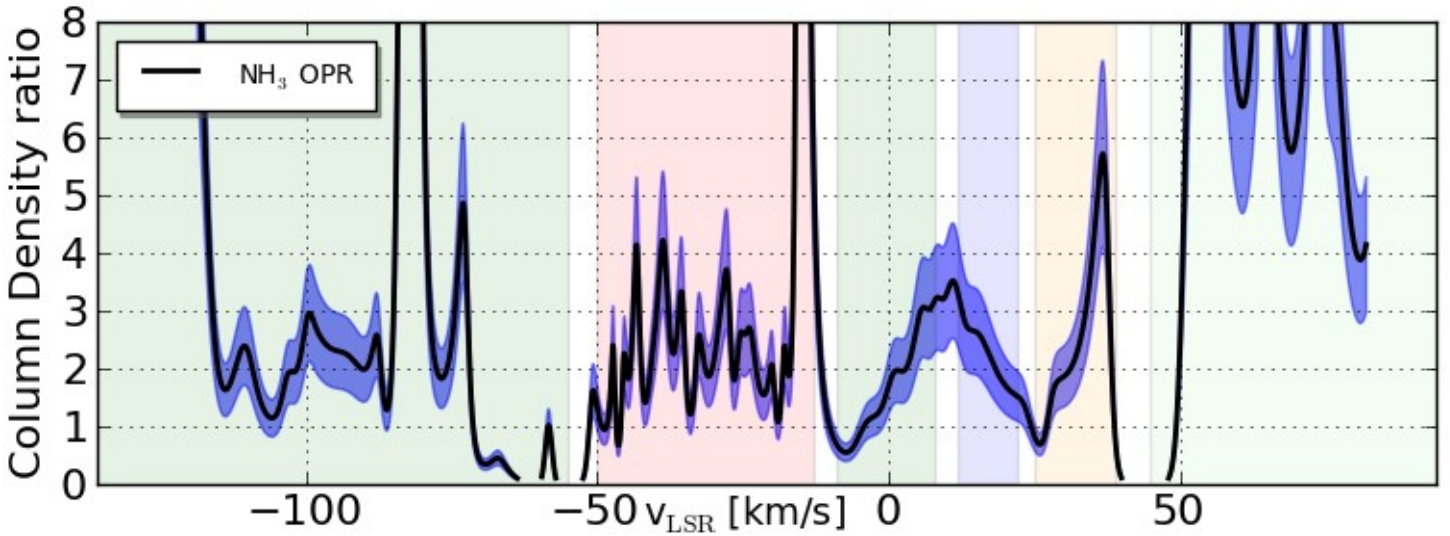


Outlook

- We have only scratched at the surface
- Analysis is revealing chemical composition of atomic/molecular interfaces
- ...as a function of position in Galaxy (with caveats)
- Link with MHD models of cloud formation including chemistry needed



Smith et al. 2010



NH_3 ortho/para ratio