Structure of the gas in the Milky Way: X-ray absorption in the cold, warm and hot ISM

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(MPA)

with

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The X-ray Universe 2017

Rome, Italy

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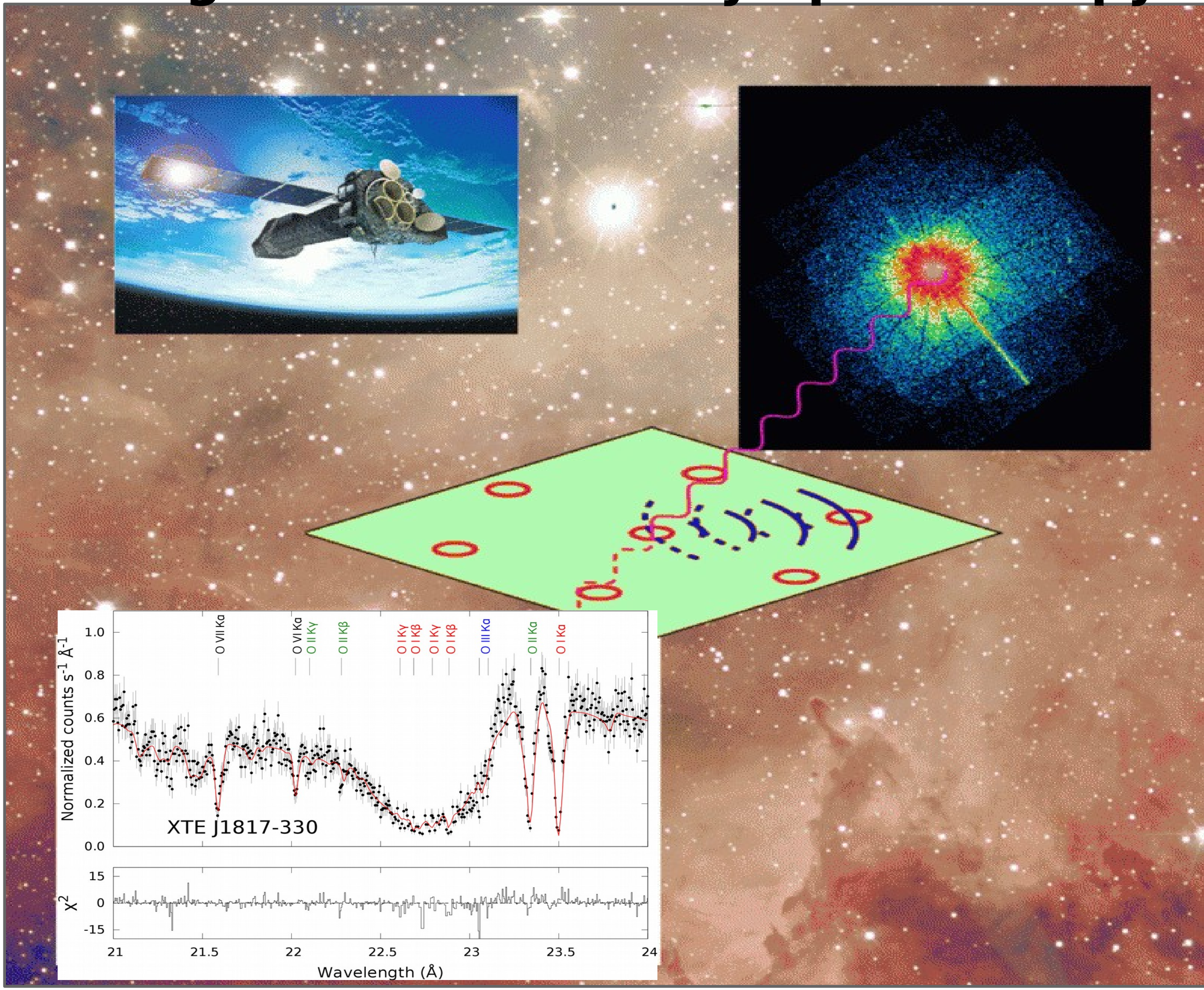
Max-Planck-Institut für Astrophysik

High-Resolution X-ray Spectroscopy

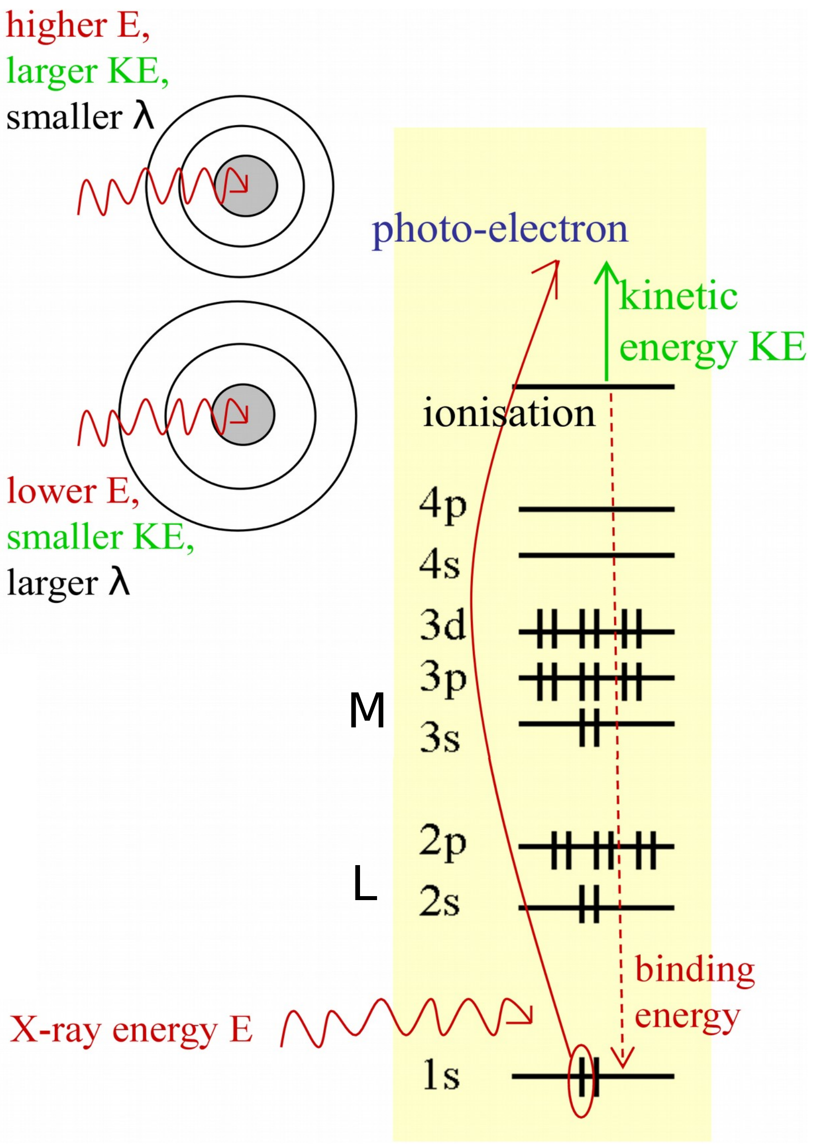


X-Ray Photoabsorption

- The atom is excited by a photon.
- There is one **photoabsorption cross-section** for each ion.
- There are two decay processes:

  X-ray fluorescence

  Auger effect.



ISM ABSORPTION AFFECTS ALL X-RAY SPECTRA!

Ionization Equilibrium: *Ioneq*

$$I_{obs}(E) = e^{-\tau} I_{source}(E)$$

$$\tau = \sum_{k,j} \sigma_{k,j} \cdot N_h \cdot A_k \cdot n_{k,j}$$

Gatuzz+17 (In preparation)

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$$\frac{dn_{k,j}}{dt}=(C_{k,j})-(D_{k,j})$$

- Photoionization (Verner et al. 1996).
- Auger probabilities (Kaastra & Mewe 1993).
- Collisional ionization (Voronov 1997)
- Radiative recombination (Verner & Ferland 1996)
- Dielectronic recombination (Arnaud & Rothenflug 1985)

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MODEL PARAMETERS:

- Temperature (Te)
- Ionization parameter (ξ)
- Hydrogen column density (N_h)
- Redshift (z)
- Turbulent broadening (υ_{turb})

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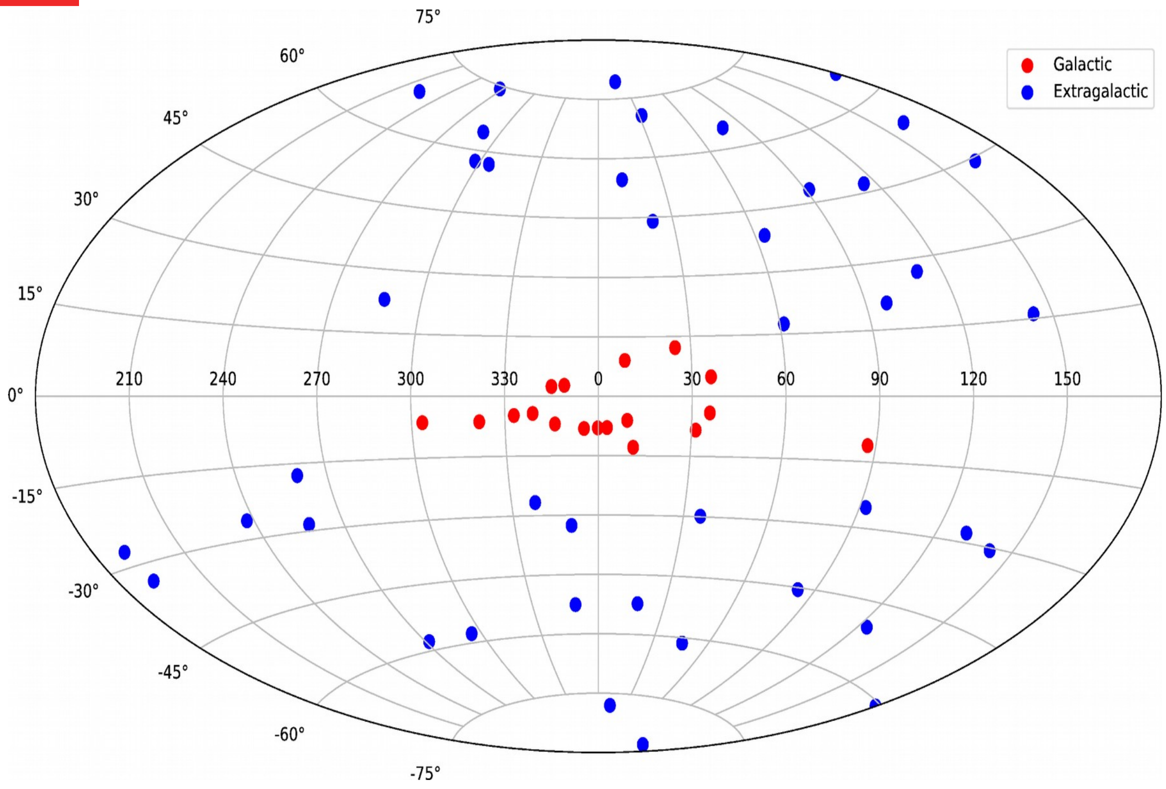
DATA SAMPLE



Galactic Sources → LMXB
Extragalactic Sources → Blazars

> 1000 counts in the 21-24 A wavelength region

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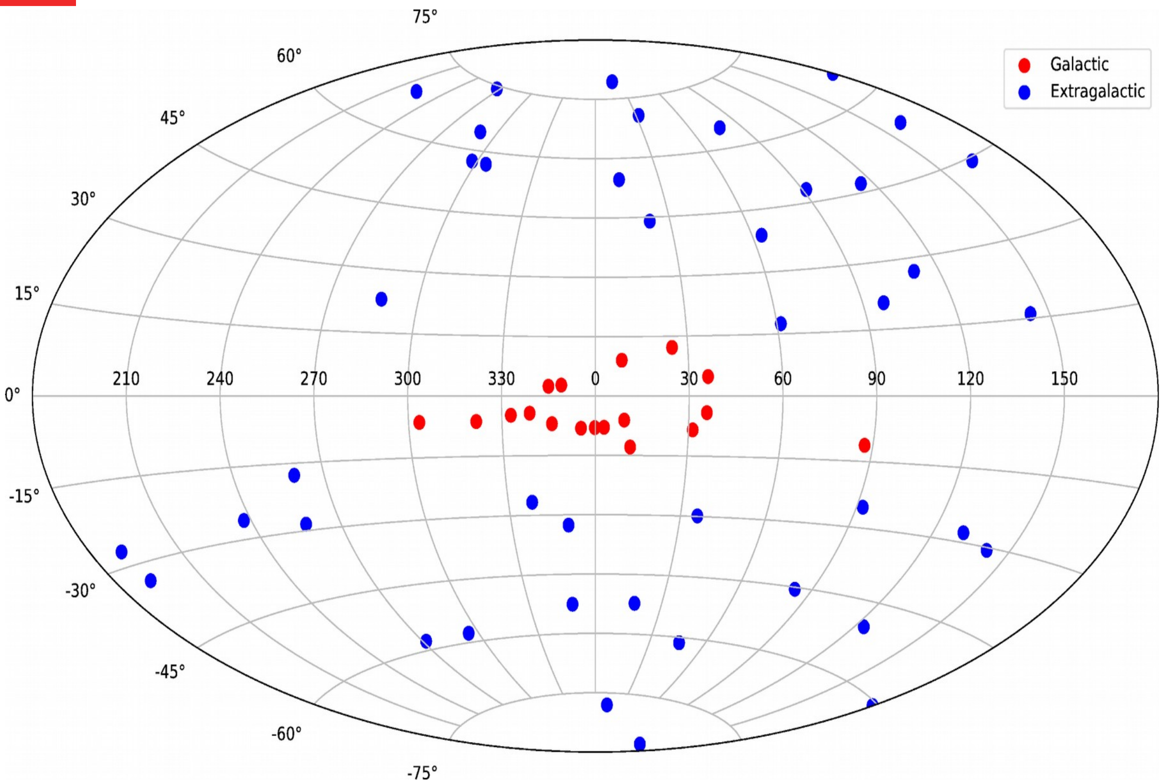

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We did not impose additional constrains! (e.g. O VII Ka detection)

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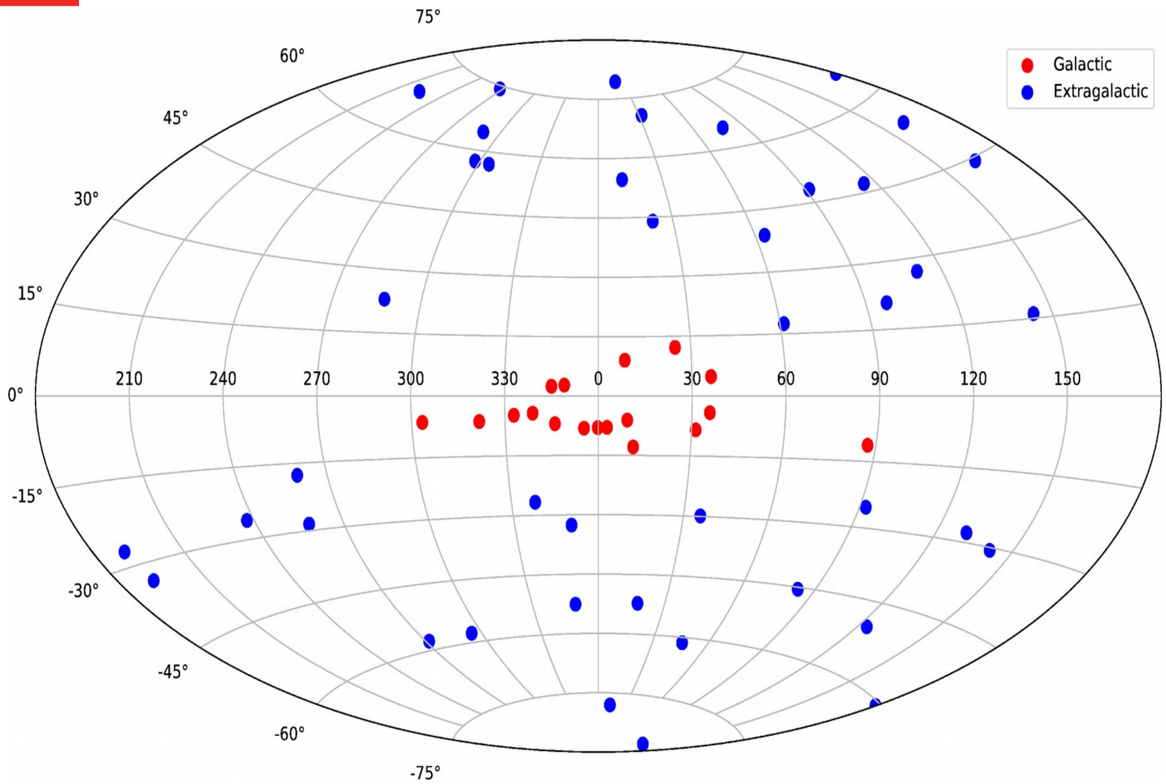

Galactic Sources → LMXB
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We did not impose additional constrains! (e.g. O VII Ka detection)

18 Galactic sources - 41 Extragalactic sources
165 observations from Chandra
257 observations from XMM-Newton

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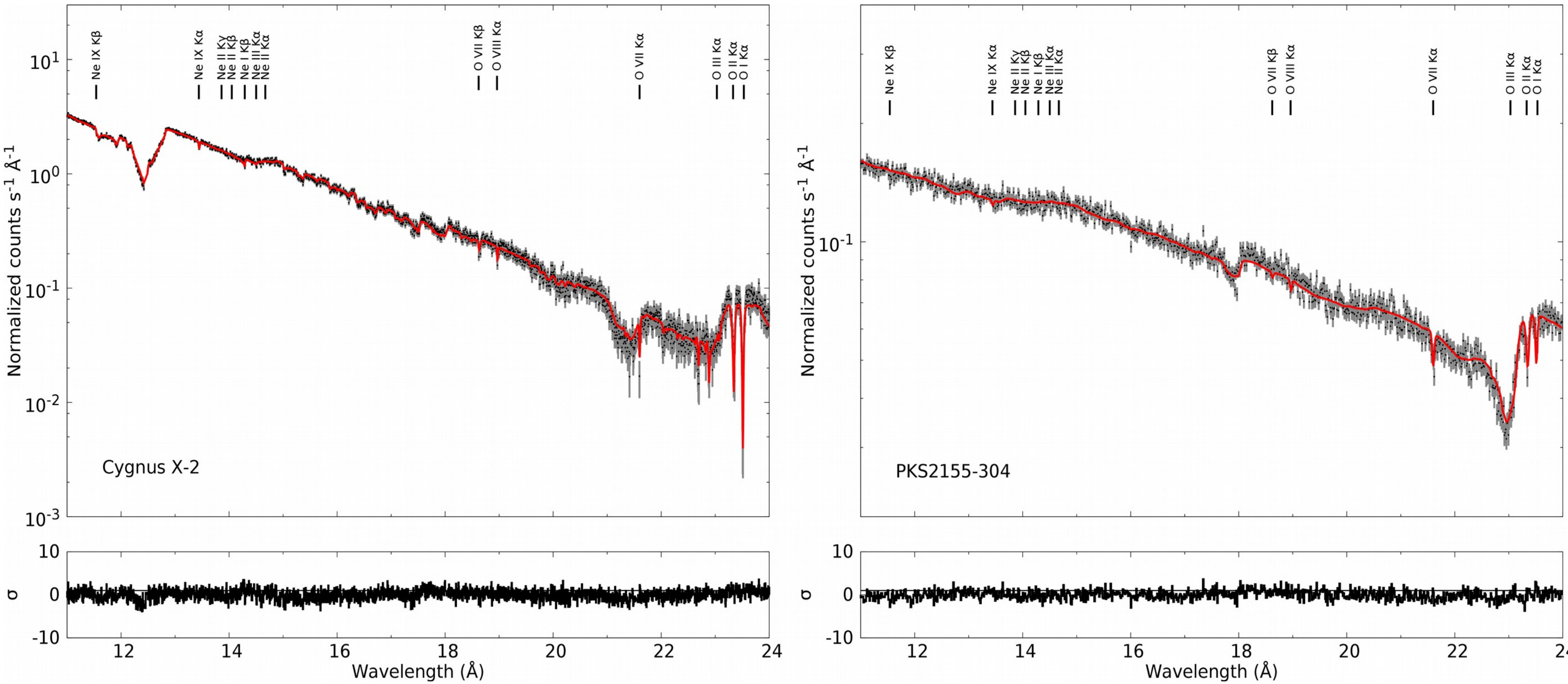
A detailed analysis of the ISM



COLD COMPONENT (Te ~ 10000 K): O I, Ne I, Fe I, Metallic Fe

WARM COMPONENT (Te ~ 51000 K): O II, O III, Ne II, Ne III

HOT COMPONENT (Te ~ 1.9 MK): Ne IX, O VII, O VIII

¡COLLISIONAL IONIZATION EQUILIBRIUM!

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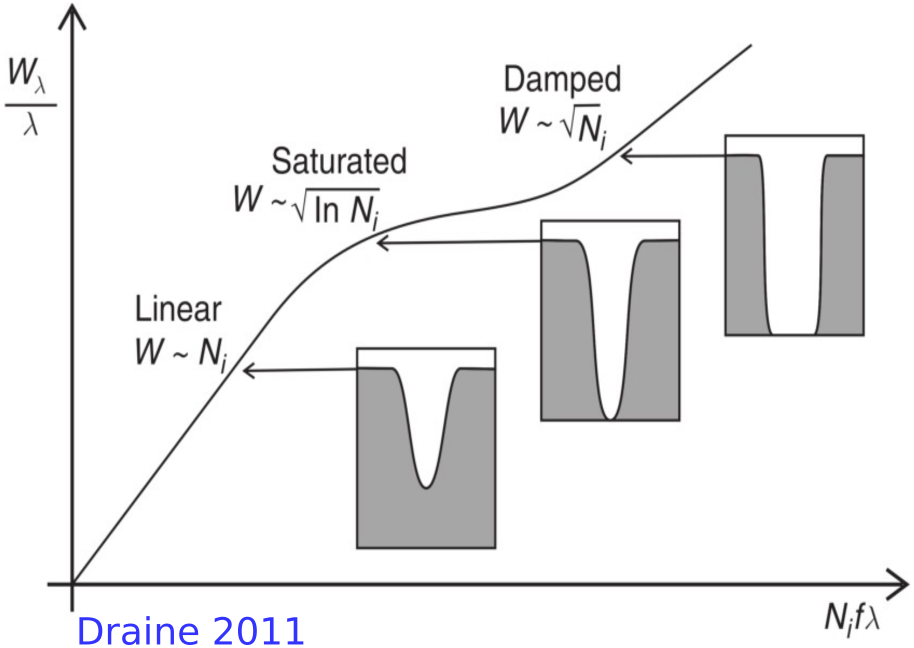
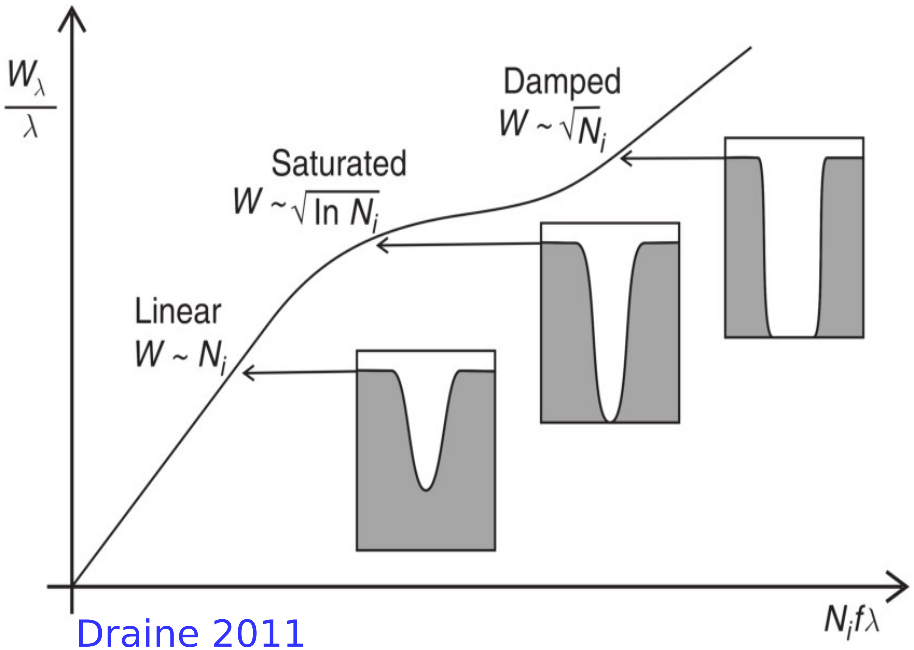
SATURATION OF THE LINES



Draine 2011

SATURATION OF THE LINES



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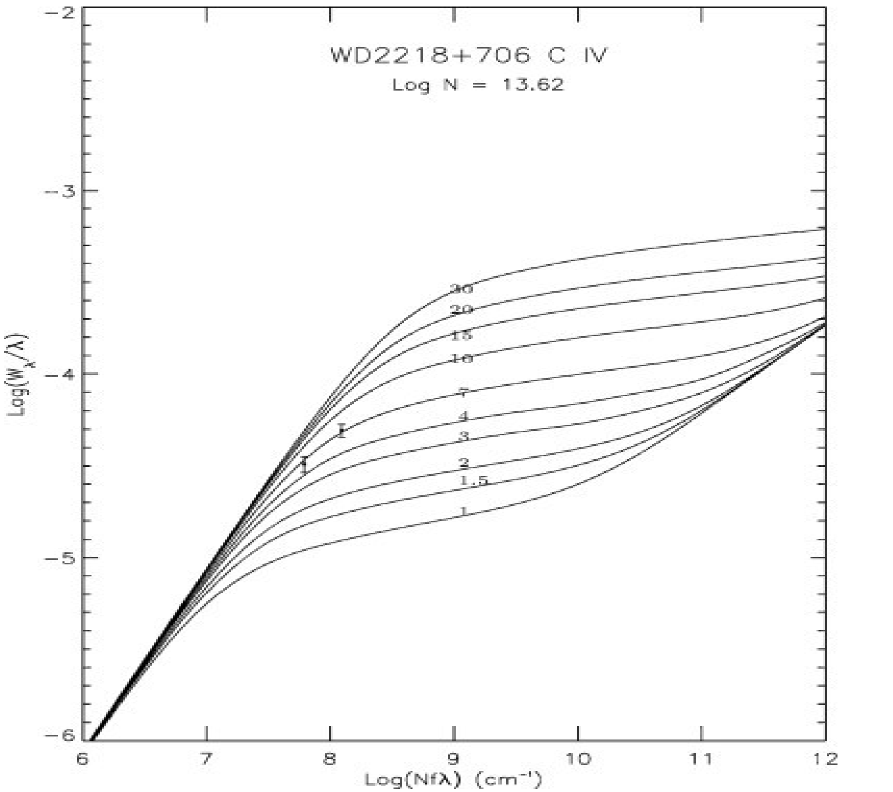

Bannister et al. 2003

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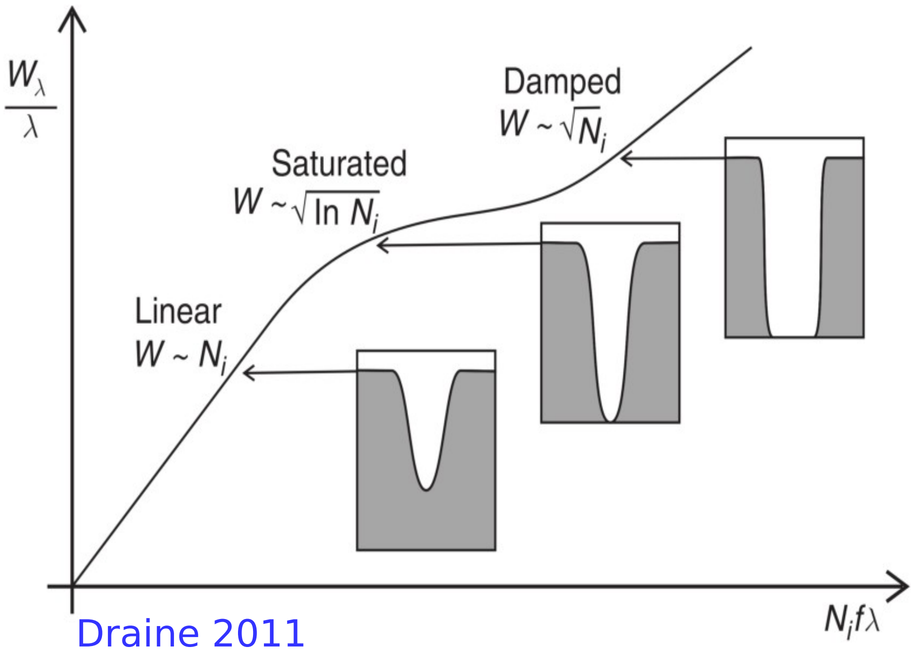

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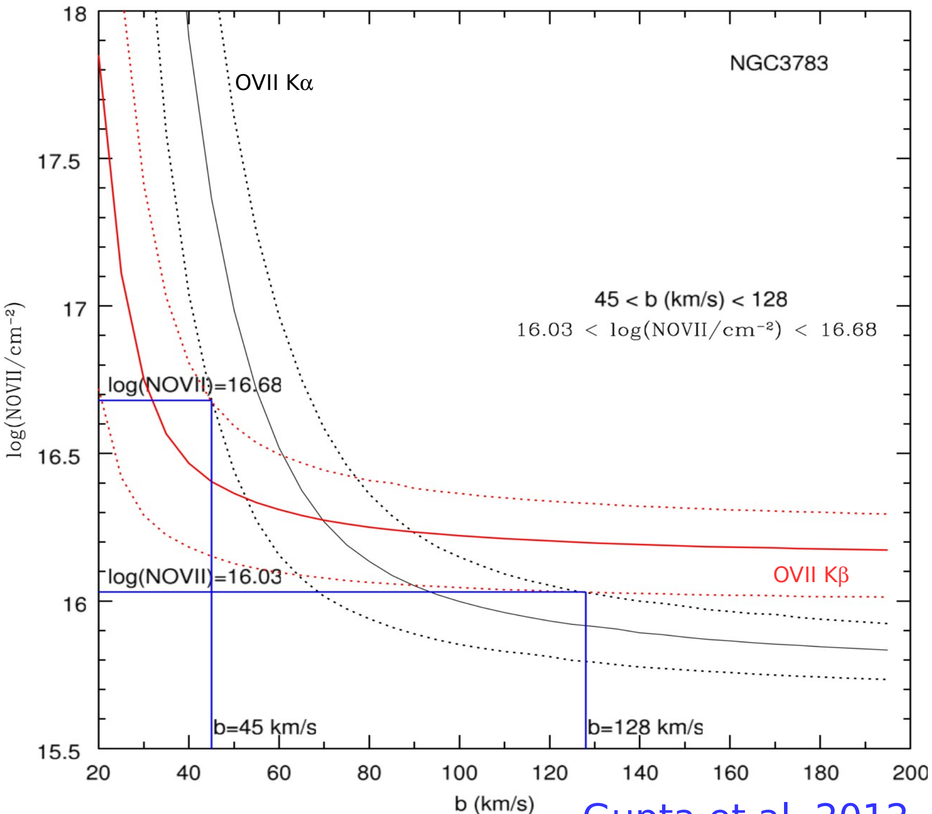

Gupta et al. 2012

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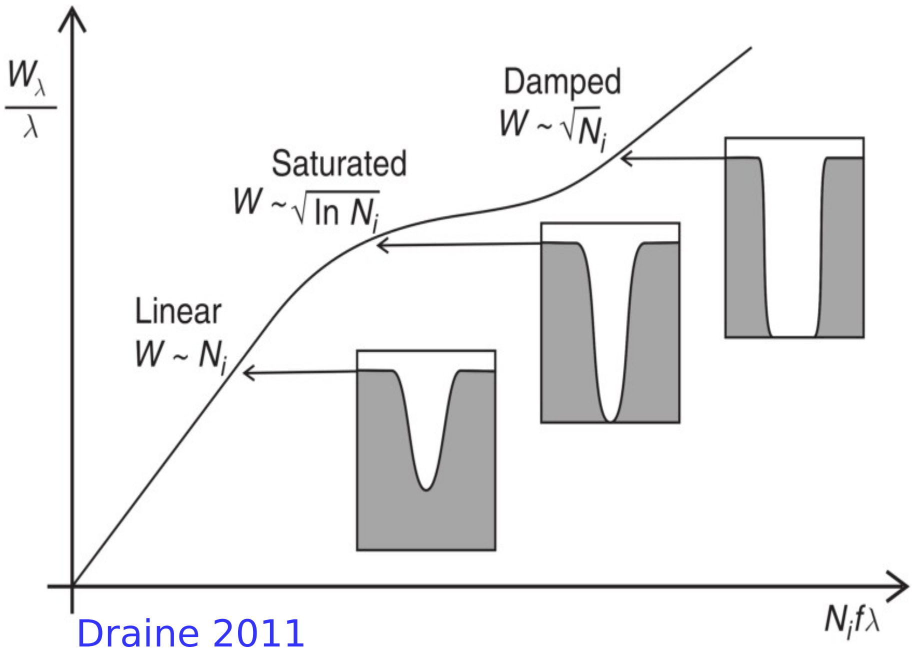
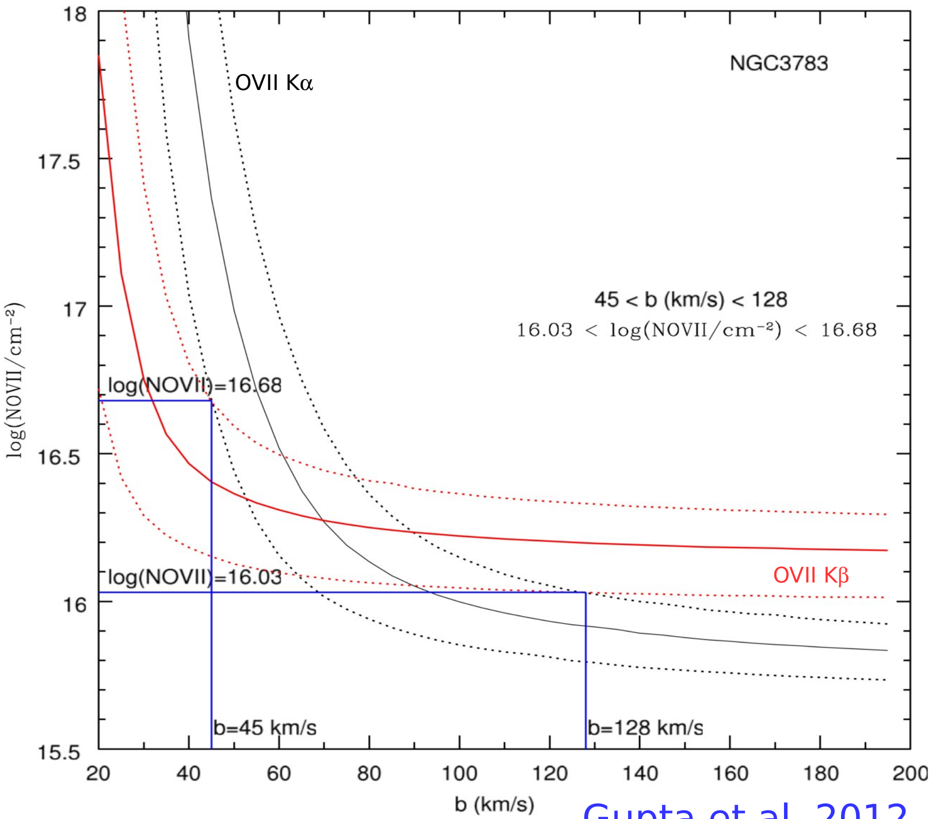


Draine 2011

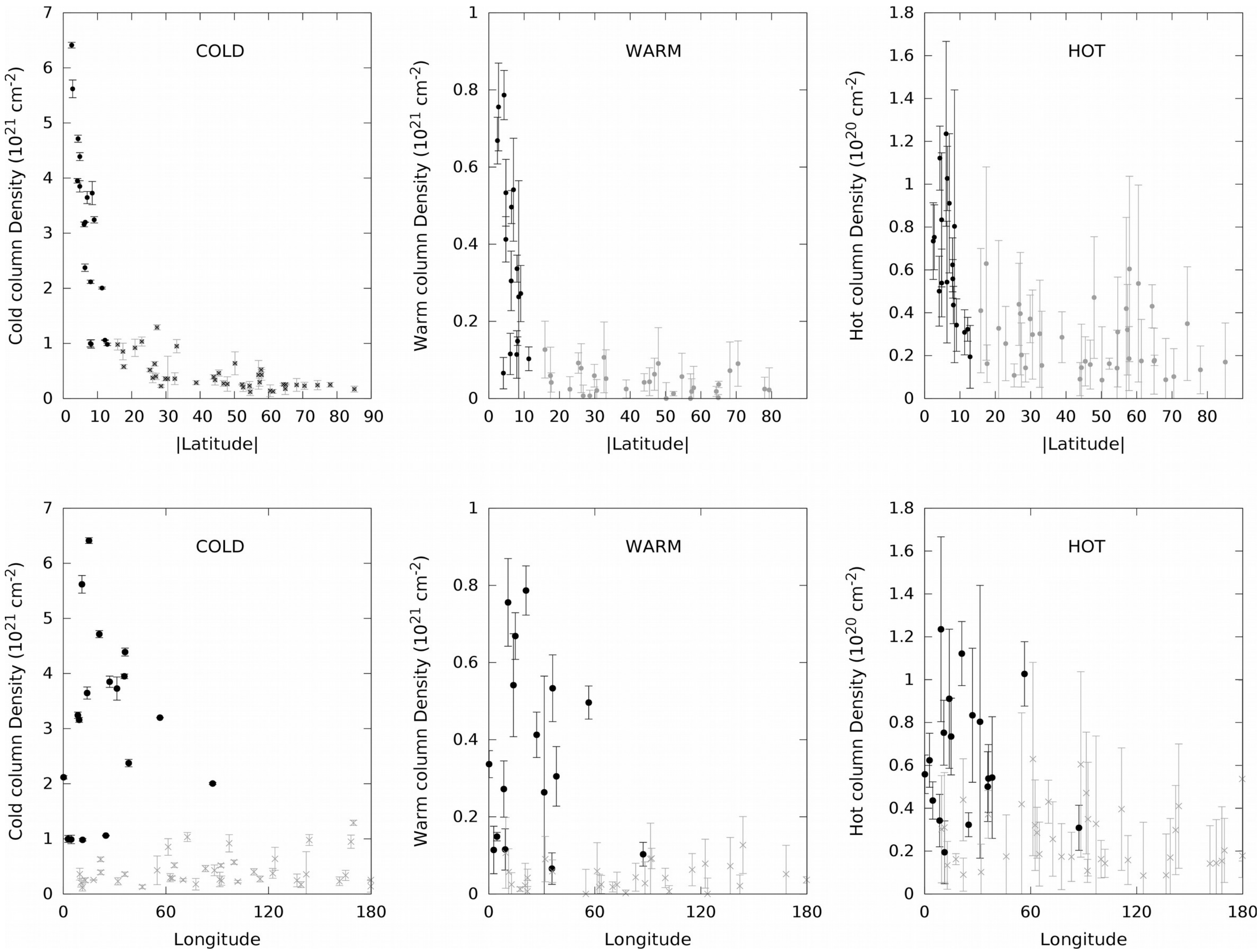


Gupta et al. 2012

Galactic sources: υ_{turb} = 75 km/s (cold-warm) υ_{turb} = 60 km/s (hot)

Extragalactic sources: υ_{turb} = 60 km/s (cold-warm) υ_{turb} = 110 km/s (hot)

DISTRIBUTION OF THE GAS



Gatuzz+17 (In preparation)

DISTRIBUTION OF THE GAS

$$N_i = \int_{observer}^{source} n_i(r)\,dr$$

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COLD-WARM COMPONENTS (Robin et al. 2003)

$$n(r) = n_0\, e^{-\left(\frac{R}{R_c}\right)}\, e^{-\left(\frac{|z|}{z_c}\right)}$$

$$R^2 = r^2\cos^2 b - 2rR_{sun}\cos b\cos l + R_{sun}^2 \qquad z = r^2\sin^2(b)$$

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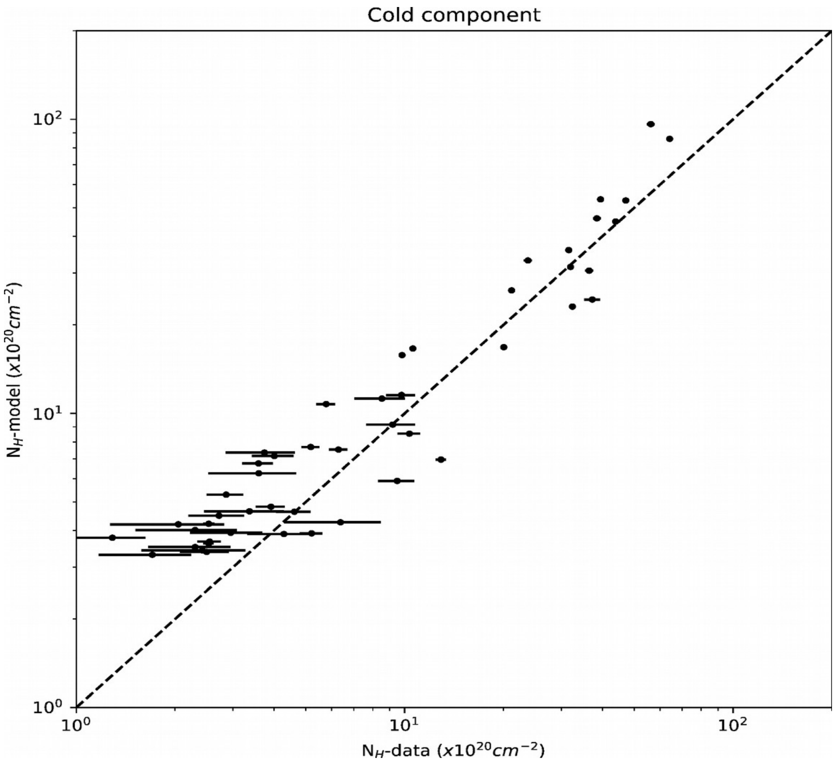
HOT COMPONENT (Nicastro et al. 2016)

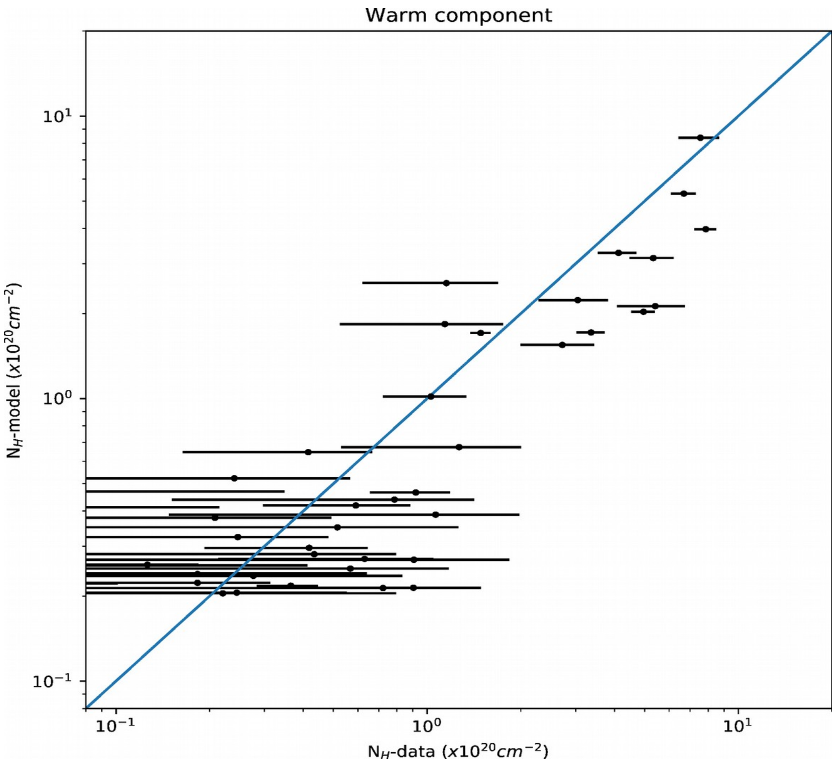
$$n(r) = n_{flat}(r) + n_{sph}(r)$$

$$n_{flat}(r) = \frac{n_{0,flat}}{\left[1 + \left(\frac{R}{R_{c,flat}}\right)^2 + \left(\frac{z}{z_{c,flat}}\right)^2\right]^{3\beta_{flat}/2}} \qquad n_{sph}(r) = \frac{n_{0,sph}}{\left[1 + \left(\frac{r}{r_{c,sph}}\right)^2\right]^{3\beta_{sph}/2}}$$

Gatuzz+17 (In preparation)

DENSITY PROFILES



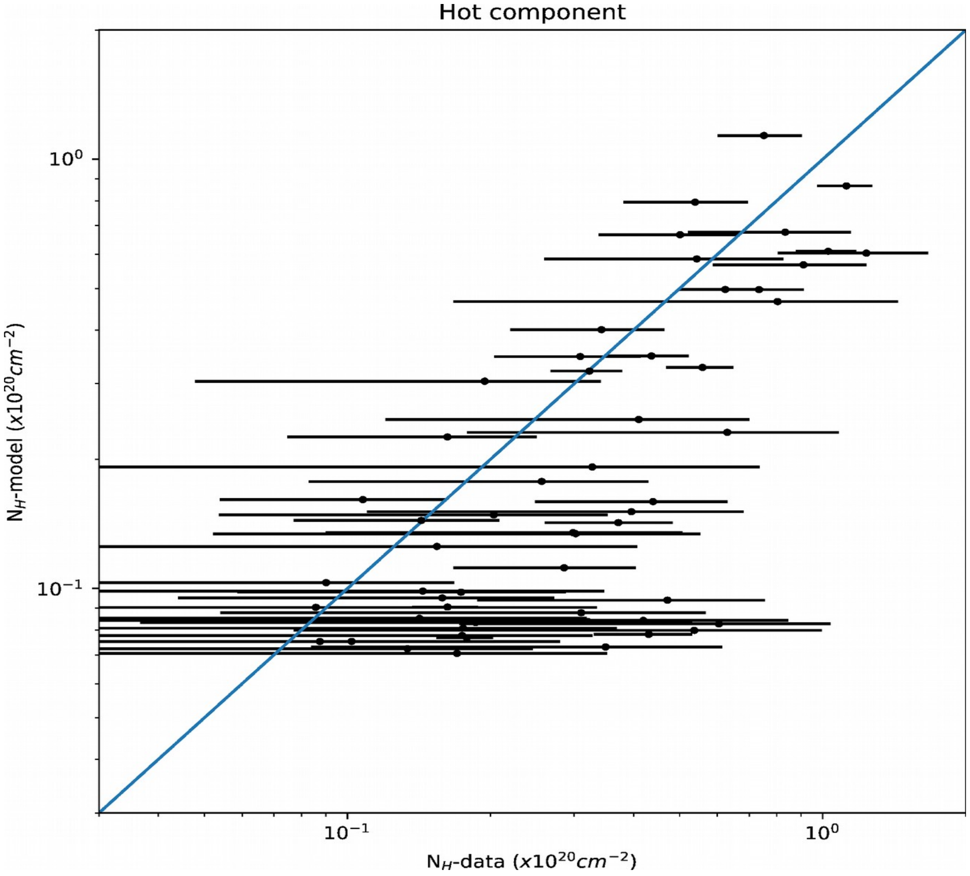


$n_0 = (10.28 \pm 5.14)\, cm^{-3}$
$R_c = (4.46 \pm 2.23)\, kpc$
$z_c = (0.34 \pm 0.10)\, kpc$
$\chi / d.o.f = 67.2/56$

$n_0 = (1.25 \pm 1.14)\, cm^{-3}$
$R_c = (2.91 \pm 1.02)\, kpc$
$z_c = (0.10 \pm 0.01)\, kpc$
$\chi / d.o.f = 72.8/56$

Gatuzz+17 (In preparation)

DENSITY PROFILES



$$n_{0,flat} = (0.48 \pm 0.17)\, x\, 10^{-2}\, cm^{-3}$$

$$R_{c,flatt} = (50)\, kpc$$

$$z_{c,flat} = (0.41 \pm 0.12)\, kpc$$

$$\beta_{flat} = (0.96 \pm 0.47)$$

$$n_{0,sph} = (2.06 \pm 0.37)\, x\, 10^{-2}\, cm^{-3}$$

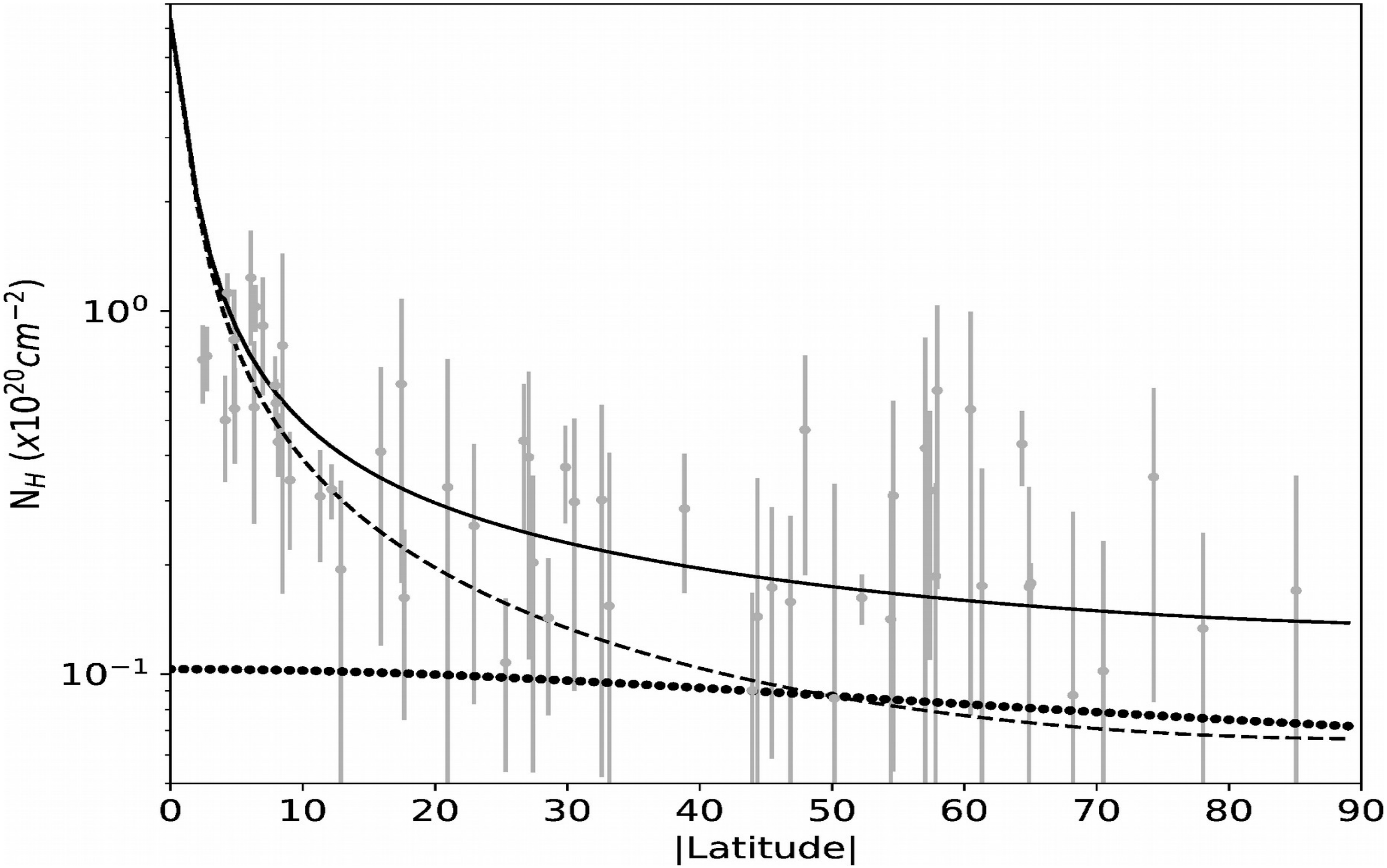
$$r_{c,sph} = (2)\, kpc$$

$$\beta_{sph} = (0.78 \pm 0.29)$$

$$\chi / d.o.f = 78.6/54$$

Gatuzz+17 (In preparation)

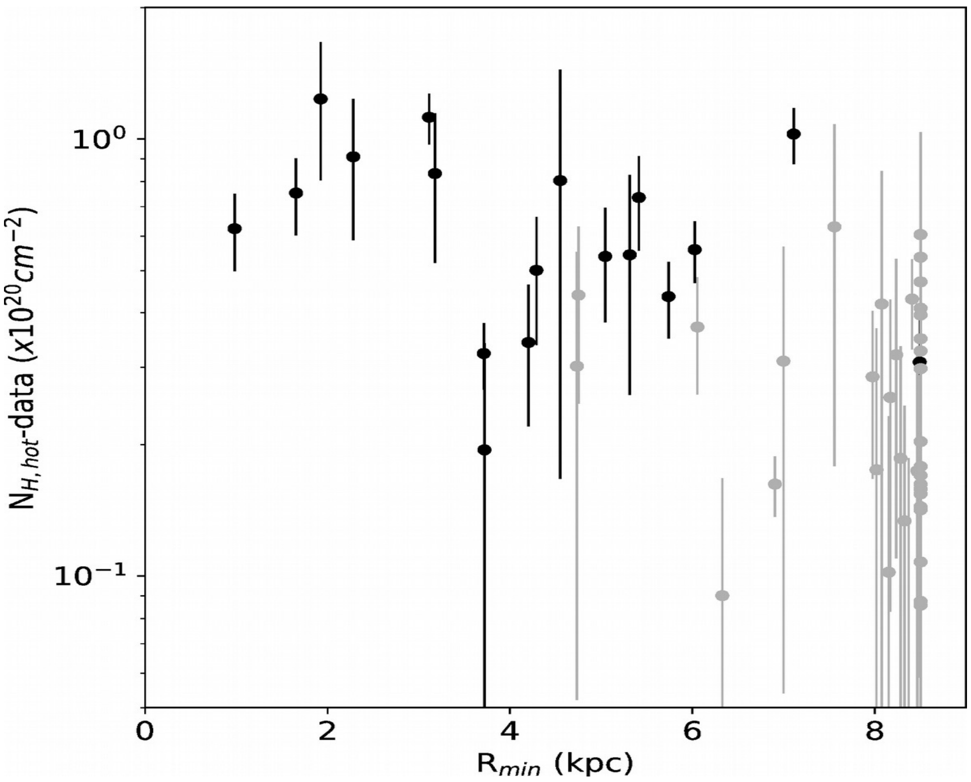
DENSITY PROFILES

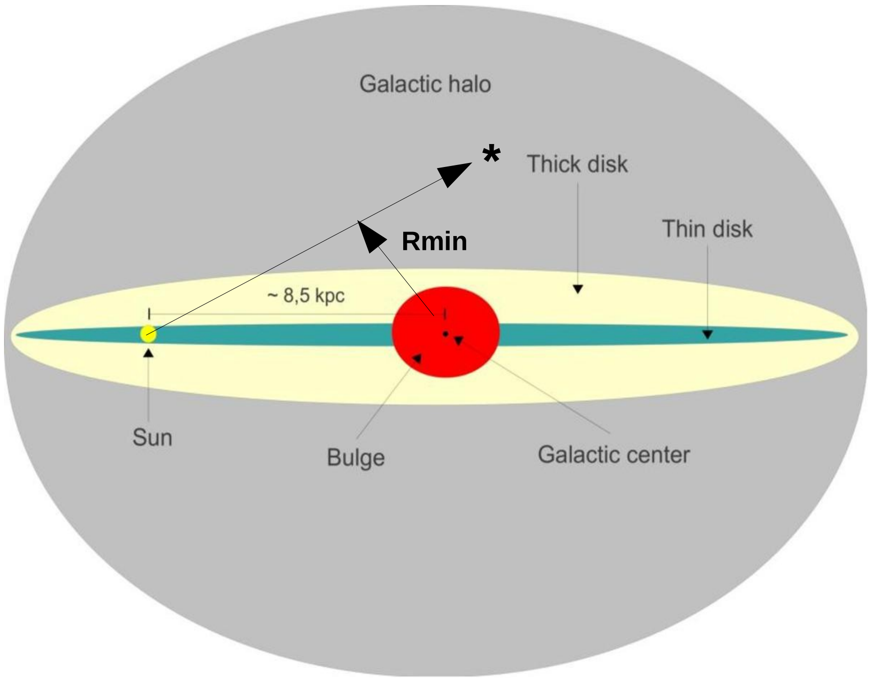


— Total density profile - - - Flattened component ··· Spherical component

Gatuzz+17 (In preparation)

DENSITY PROFILES





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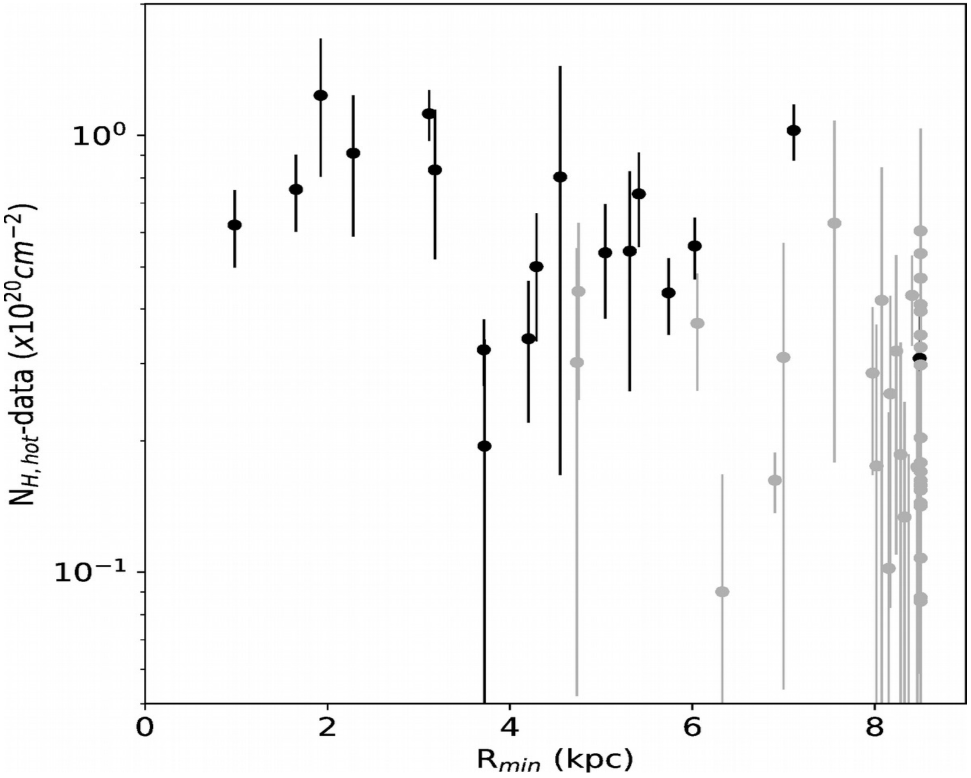
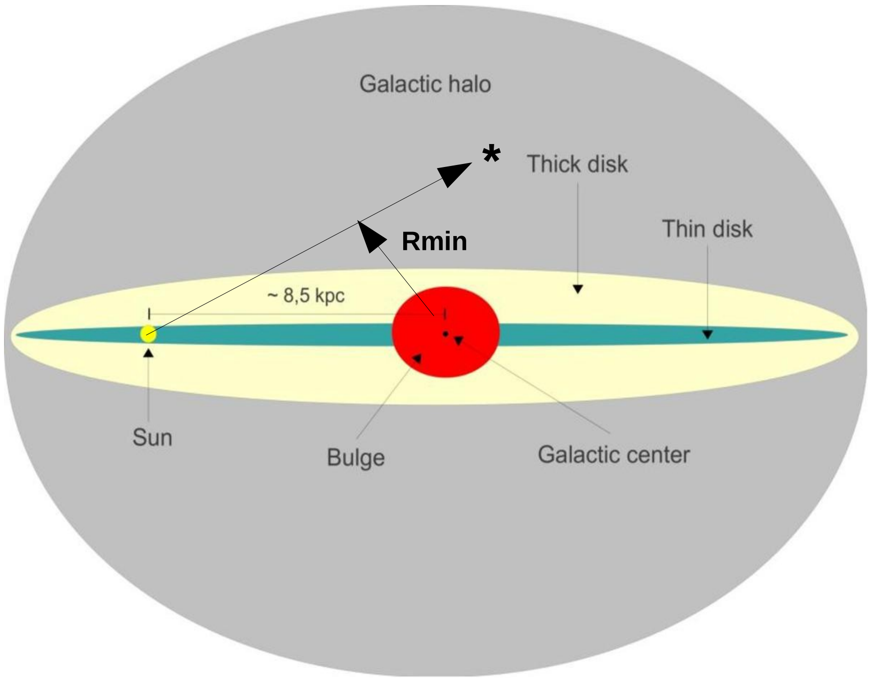
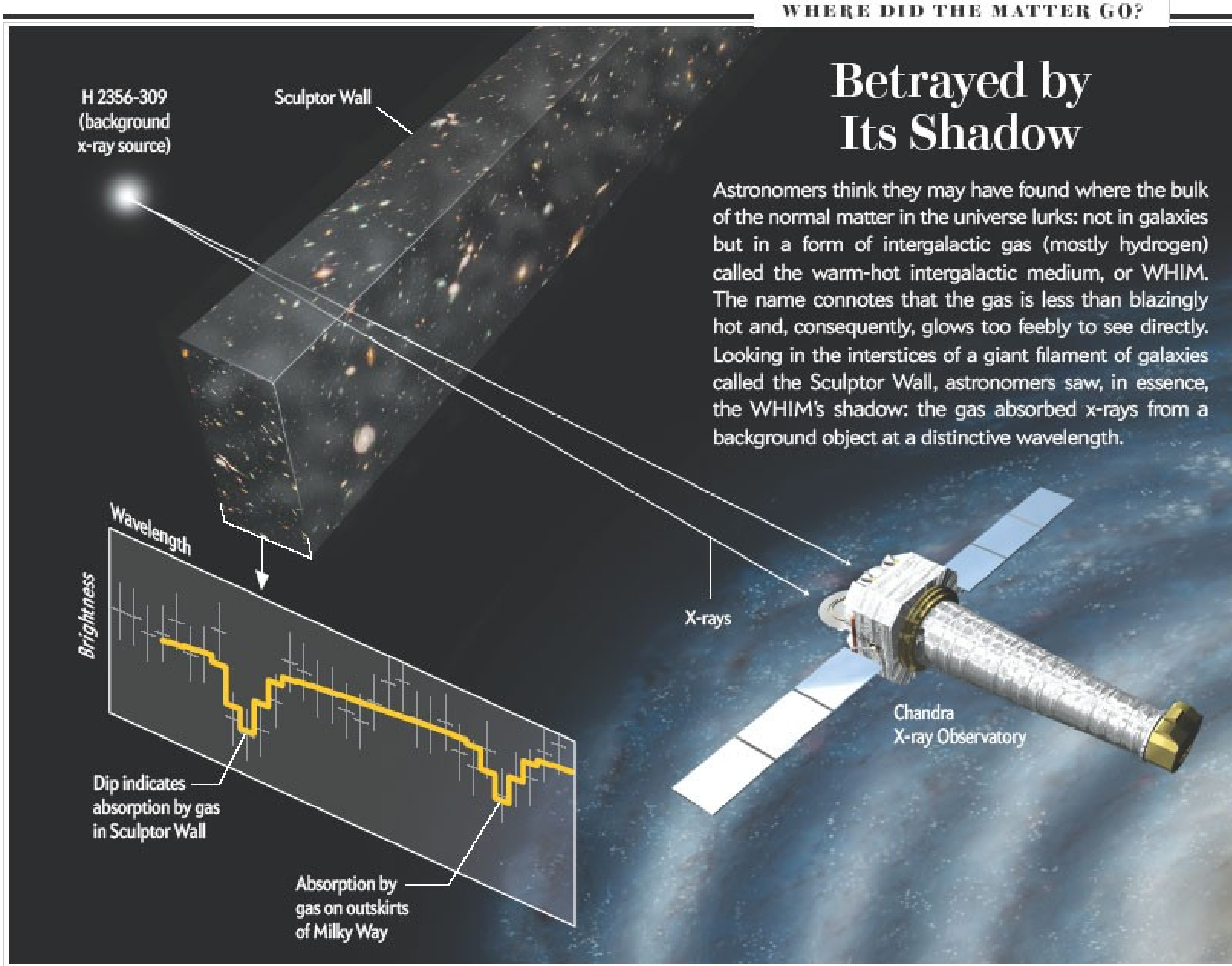




WE DO NOT HAVE ENOUGH INFORMATION IN ORDER TO CONSTRAIN THE GALACTIC CENTER PROPERTIES!

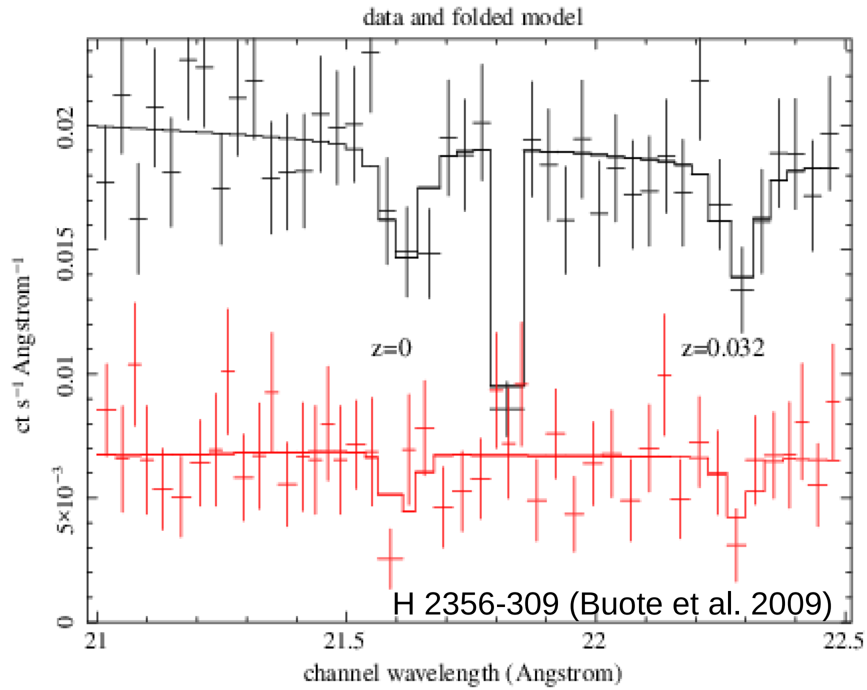
Gatuzz+17 (In preparation)



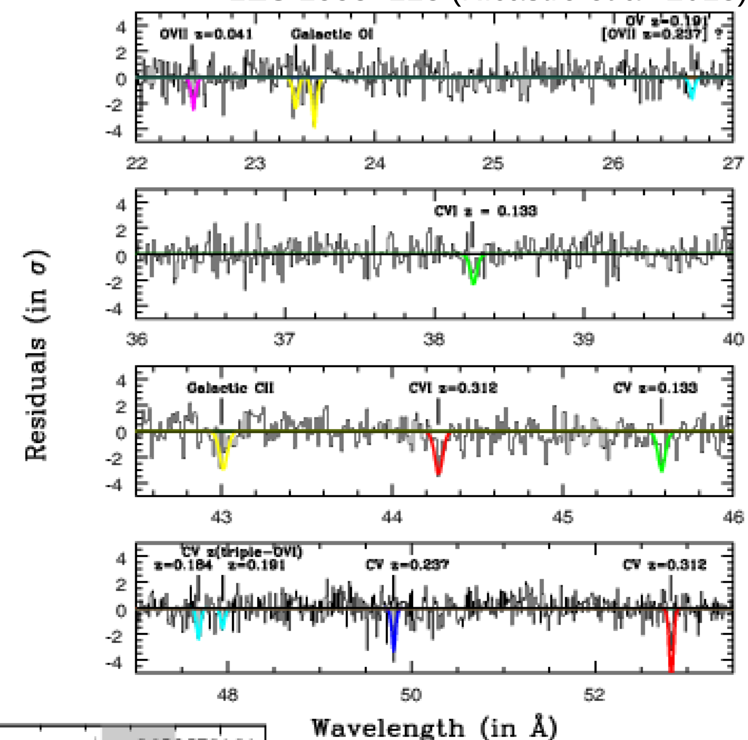
Buote+09, Fang+10, Zappacosta+10, Fang+11, Zappacosta+12

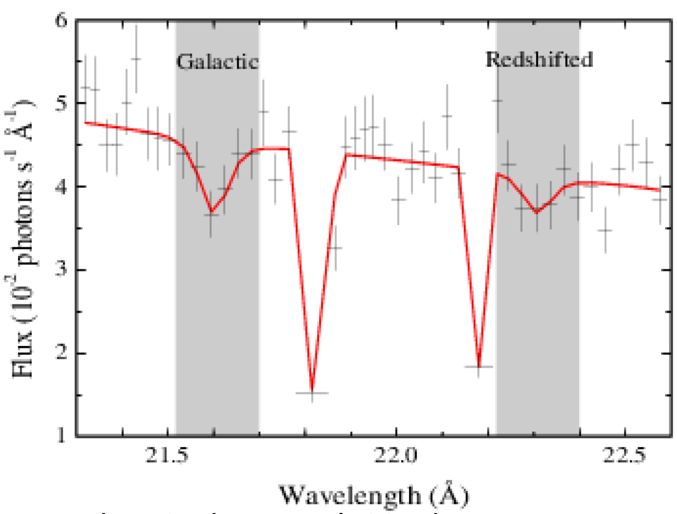
O VII Ka AT z≃0.03 FROM WHIM

1ES 1553+113 (Nicastro et al. 2013)

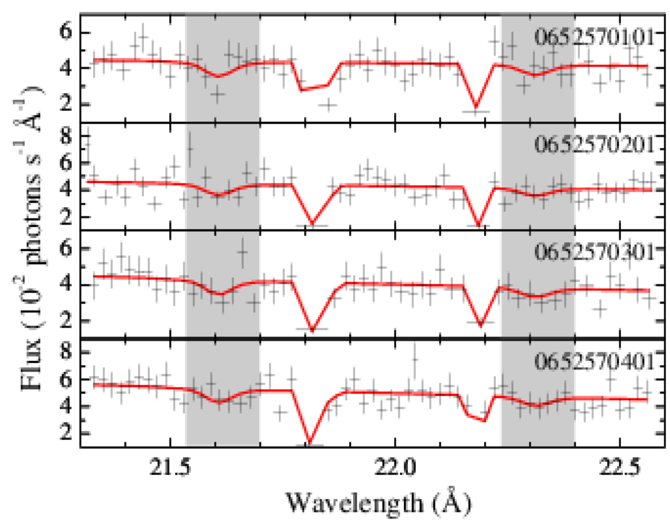


H 2356-309 (Buote et al. 2009)



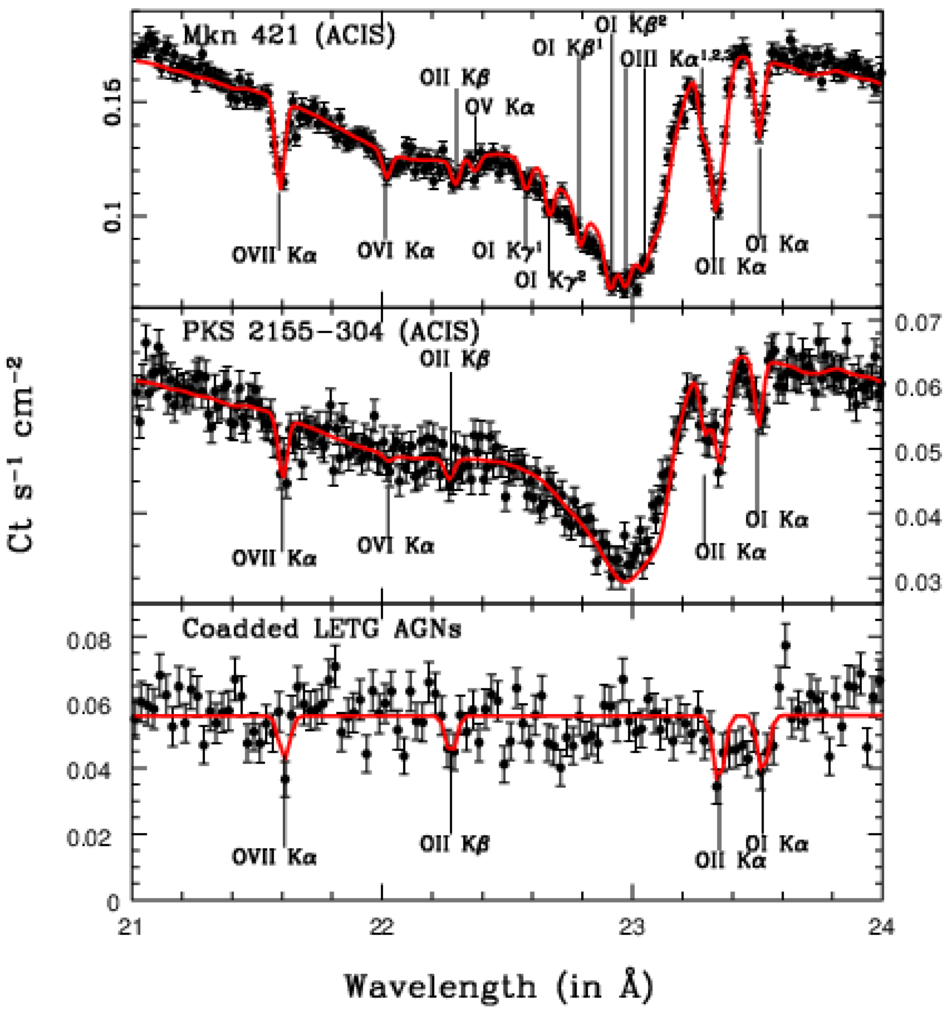


Mkn 501 (Ren et al. 2014)



ATOMIC DATA WARNING!

O VII Ka at z≃0.03 from WHIM
(Buote et al. 2009, Fang et al. 2010, Ren et al. 2014)

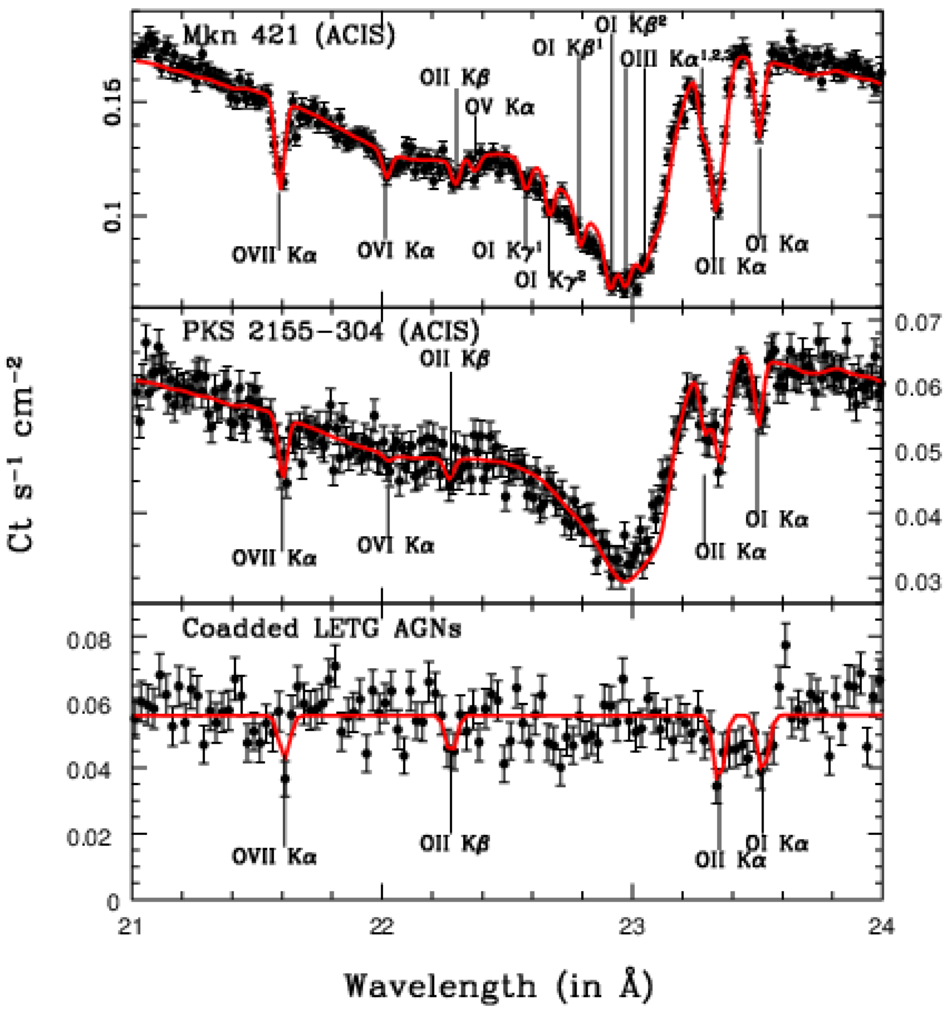


ATOMIC DATA WARNING!

O VII Ka at z≃0.03 from WHIM
(Buote et al. 2009, Fang et al. 2010, Ren et al. 2014)

OR

O II Kβ at z = 0 from ISM
(Nicastro et al. 2016)



Conclusions

- We have developed a new X-ray absorption model, called ***IONeq***, which consider ionization equilibrium conditions.

- We have analyzed 18 galactic and 41 extragalactic sources in order to study the X-ray absorption features due to the local ISM.

- The geometrical dependence of the hot absorbers observed in LMXBs spectra provides a hint about the ISM origin of such component.

- We used the column density values obtained from the X-ray spectra to compute density profiles for all three ISM gas components.

- the absence of column density values near the galactic center leads to degeneracy between some of the density profile parameters and therefore some assumptions are required.

THANK YOU!