A common origin for the X-ray/UV ionized gas in Mrk 509

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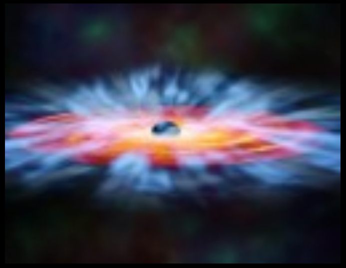
S. Bianchi (Roma Tre)
M. Cappi (Bologna)

and the Mrk 509 multiwavelength campaign consortium

SRON Netherlands Institute for Space Research

Netherlands Organisation for Scientific Research

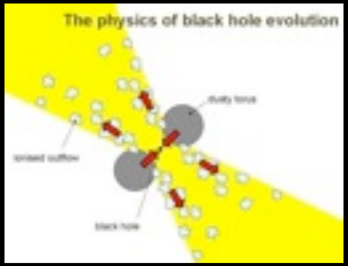
Cosmic Feedback mechanisms



1. Radiation
   - Huge bolometric output
   - Geometry of the nucleus matters
   - Heating, ionizing, accelerating…

2. Relativistic jets
   - Carry mass, energy, momentum
   - Source of high-energy cosmic rays?

3. Non-relativistic winds (outflows)
   - Probably ubiquitous
   - Important for coevolution of SMBH and host galaxy
   - Kinetic energy and mass outflow rates uncertain



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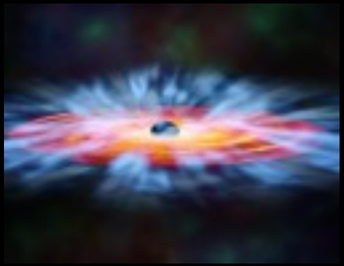

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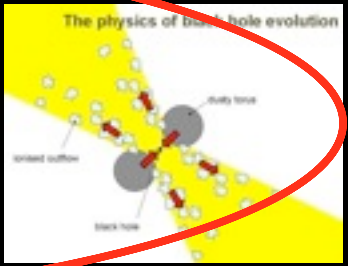
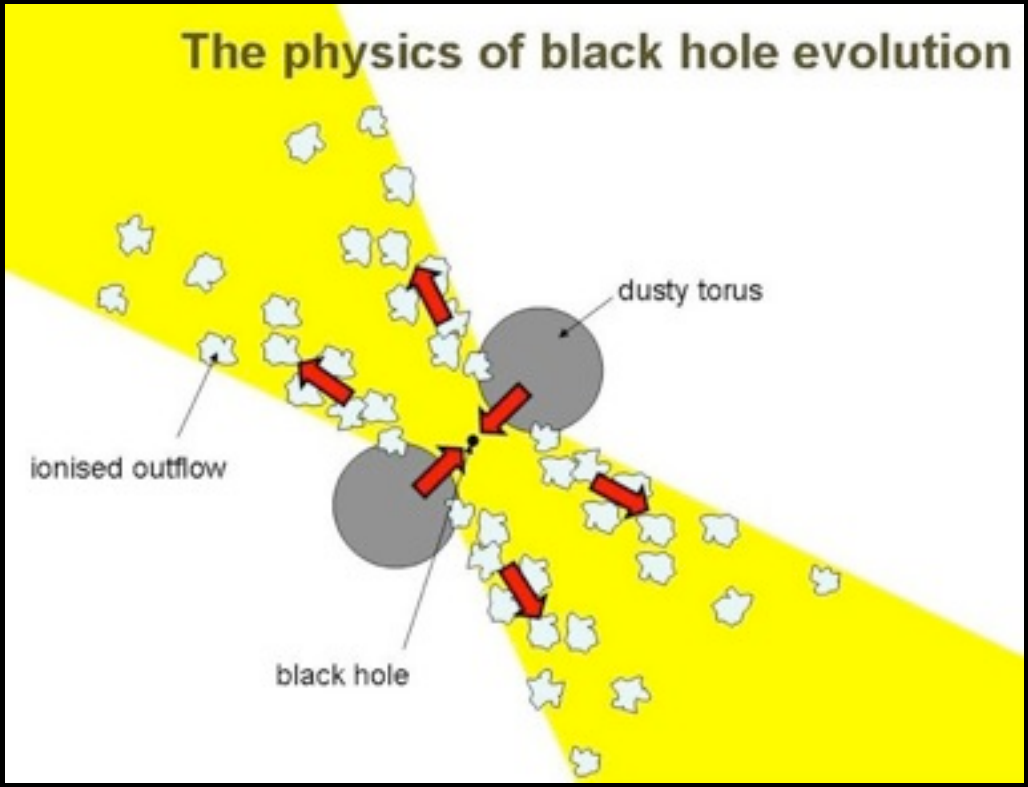


Outflows: the Warm Absorber



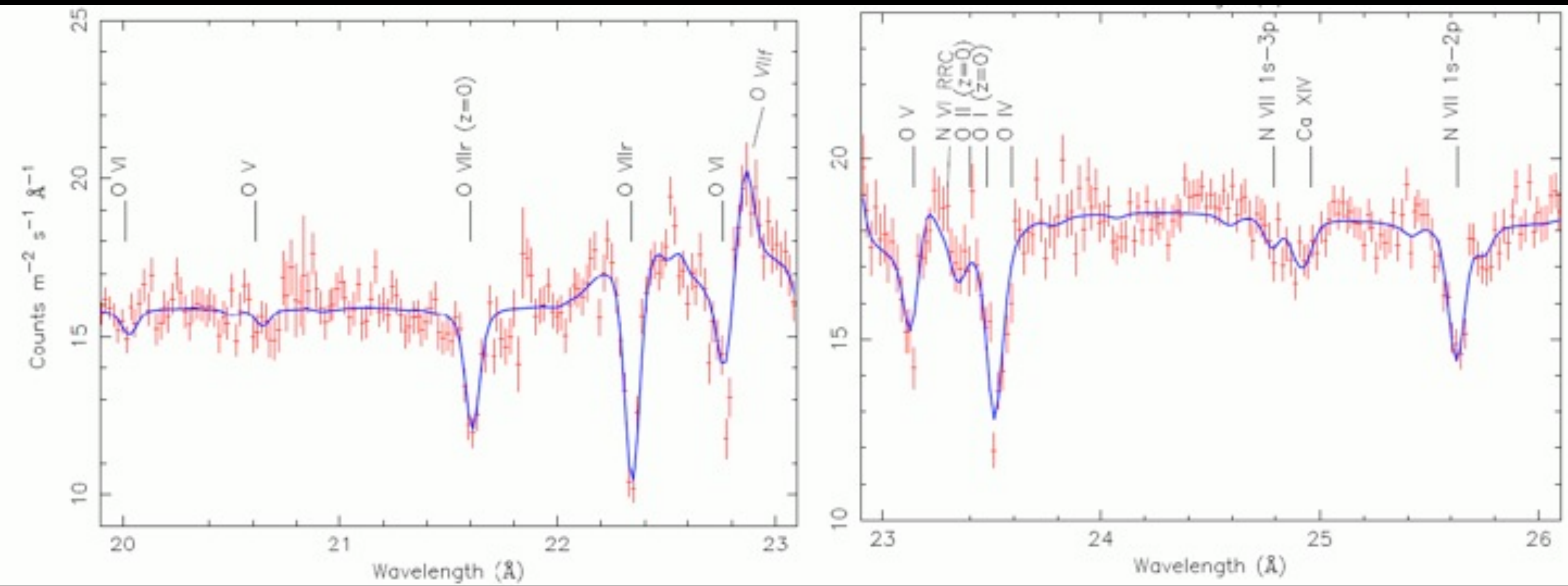
Ionized gas: wide range of ionization phases

$$\xi = L / nR^2$$

Absorption troughs in the soft X-ray spectrum

Blue-shifted features: outflows

Outflows: the Warm Absorber



600 ks XMM-Newton RGS Mrk 509

Detmers et al. (2011)

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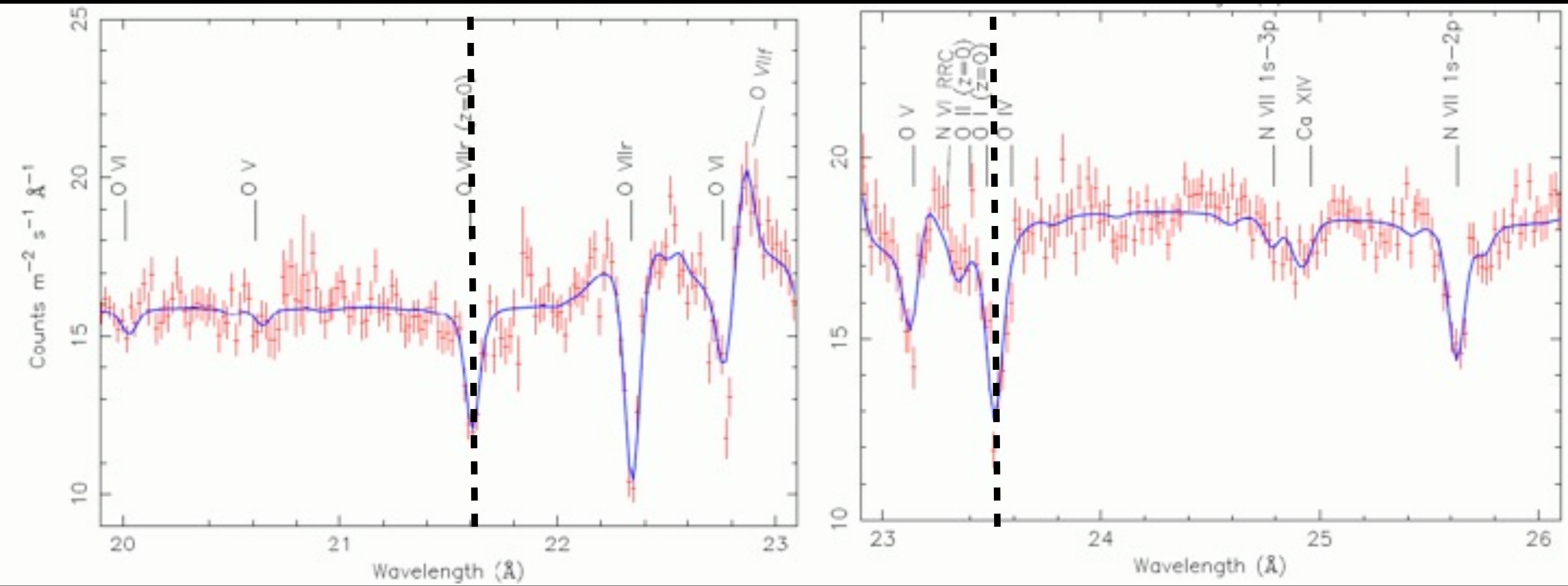

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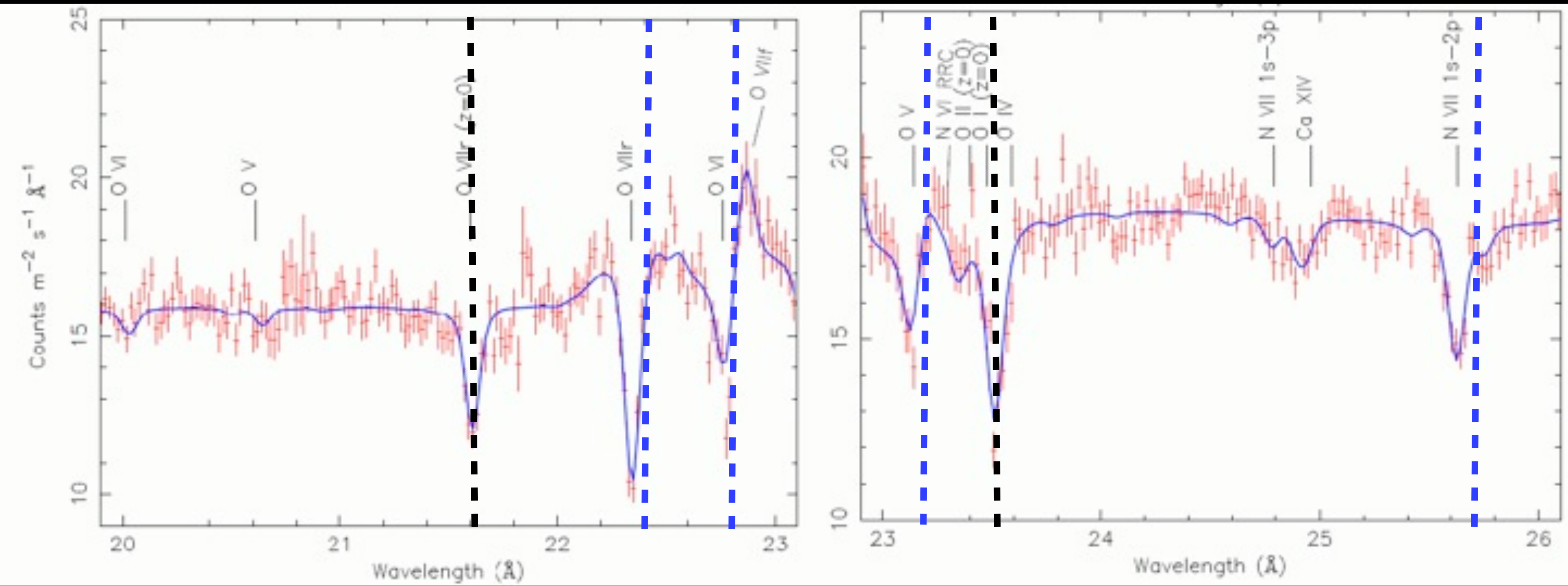

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Detmers et al. (2011)

Why Mrk 509?

1. Nearby and bright
   - $z = 0.034397$
   - L(1-1000 Ryd) = 3.2×10^{45} erg/s

2. Confirmed presence of intrinsic WA
   - Pounds+01, Yaqoob+03, Smith+07, Detmers+10

3. Confirmed presence of UV absorber
   - Crenshaw+99, Kriss+00, Kraemer+03

4. Slow variability
   - Suitable for reverberation studies

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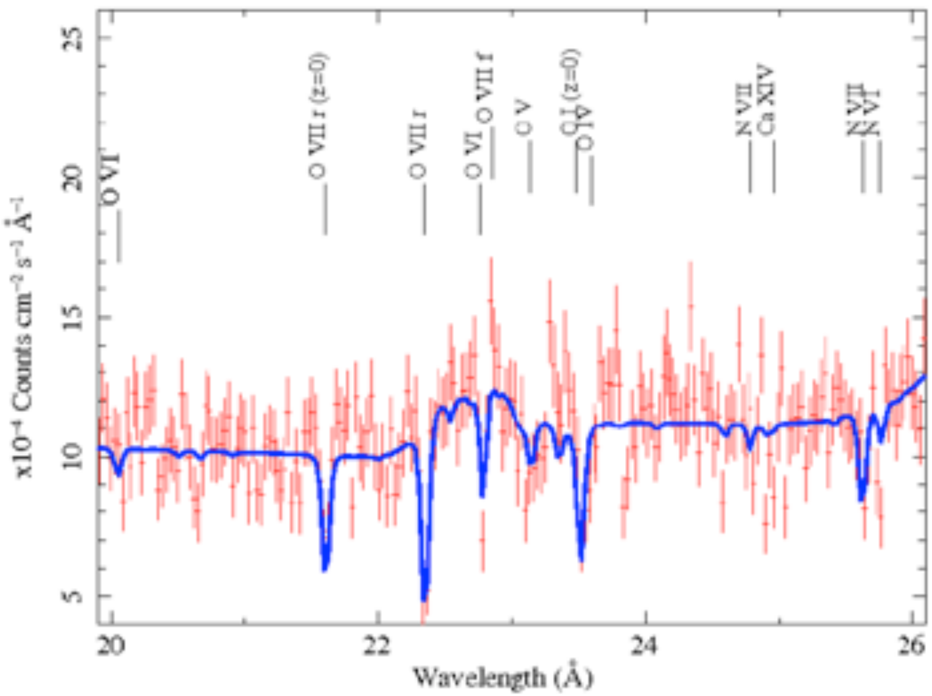
X-ray absorption in Mrk 509

Chandra LETGS 180 ks Ebrero et al. (2011)

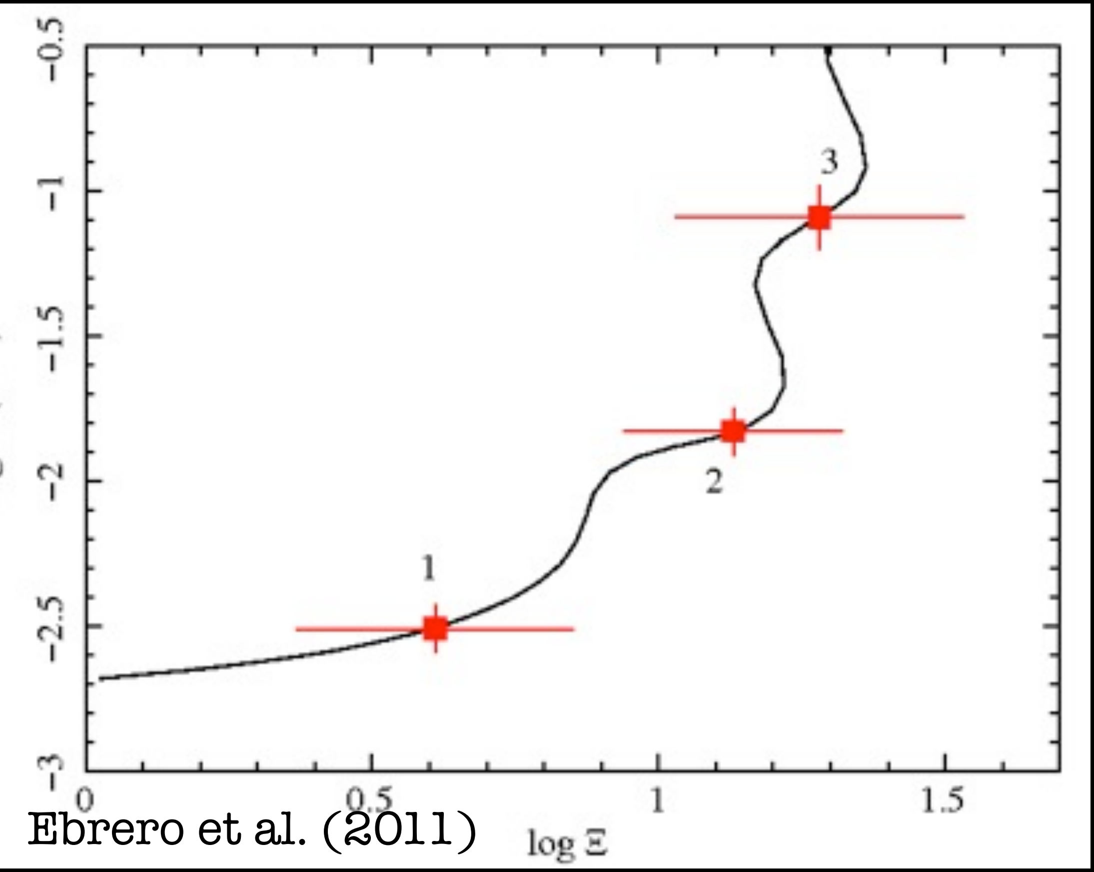


X-ray warm absorber

Three ionization phases

log ξ (erg cm s^{-1})	log N_H (cm^{-2})	v_{out} (km s^{-1})
1.1 ± 0.1	20.3 ± 0.2	70 ± 50
2.3 ± 0.1	20.7 ± 0.1	-200 ± 80
3.2 ± 0.2	20.8 ± 0.3	-460 ± 150

Structure of the X-ray absorber



Ebrero et al. (2011)

Outflowing components are in pressure equilibrium

Redshifted component probably not part of the same structure

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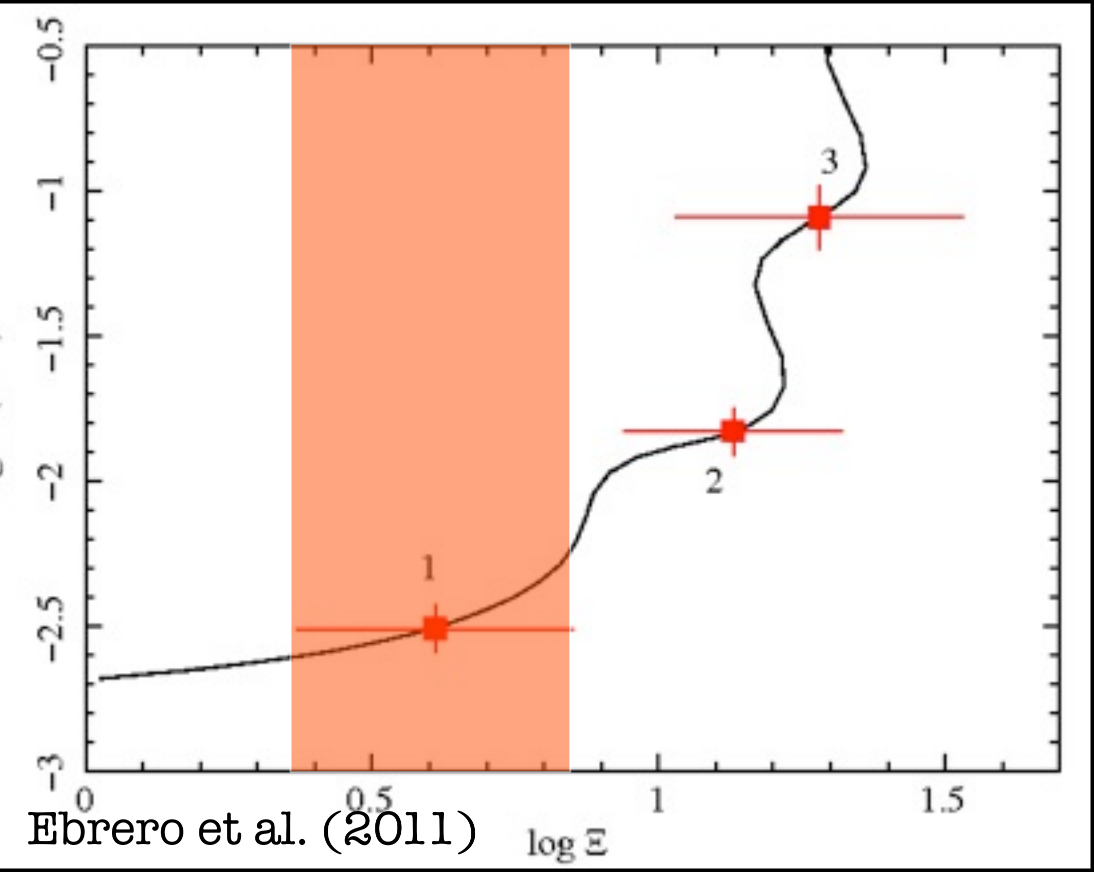

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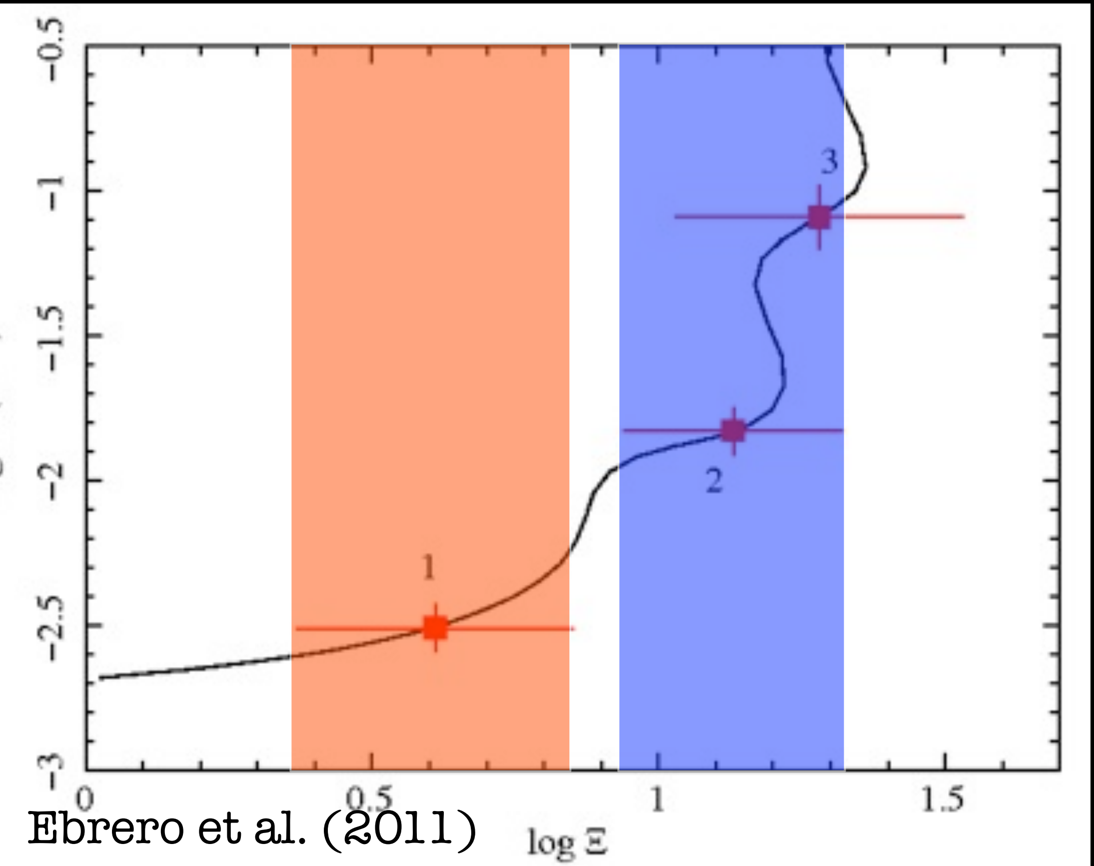

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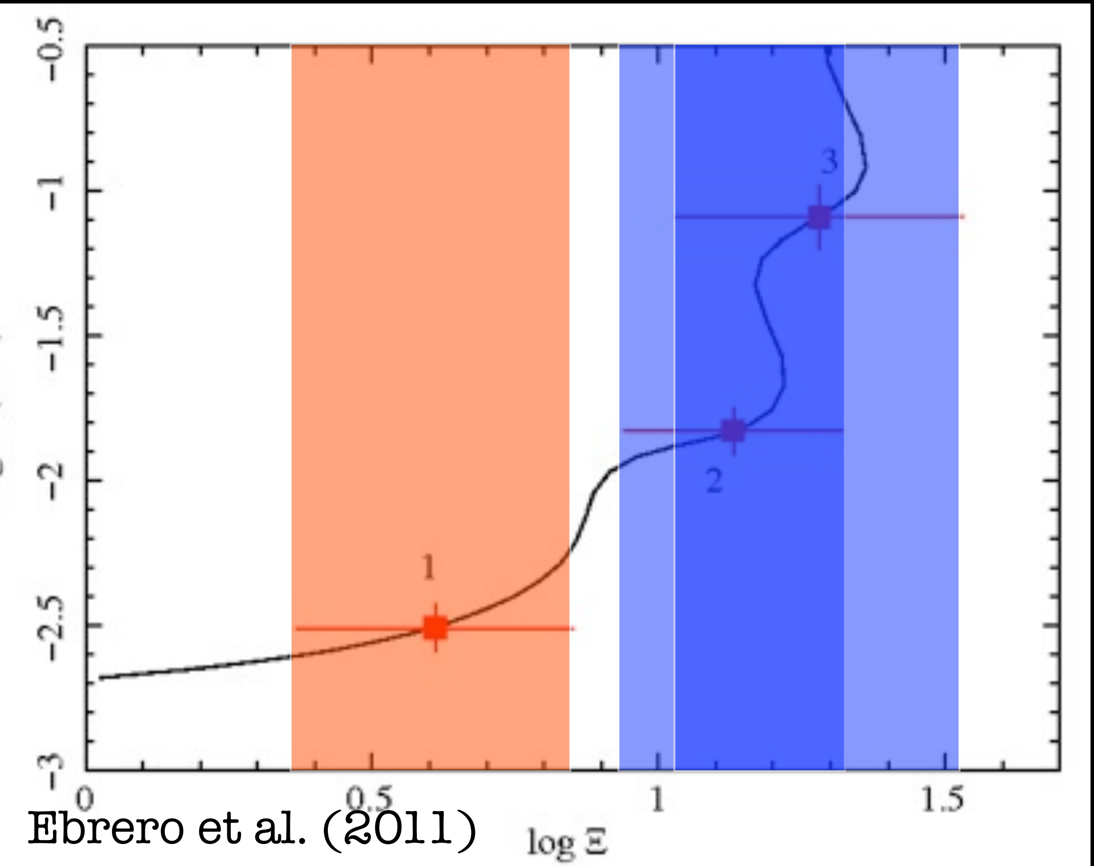

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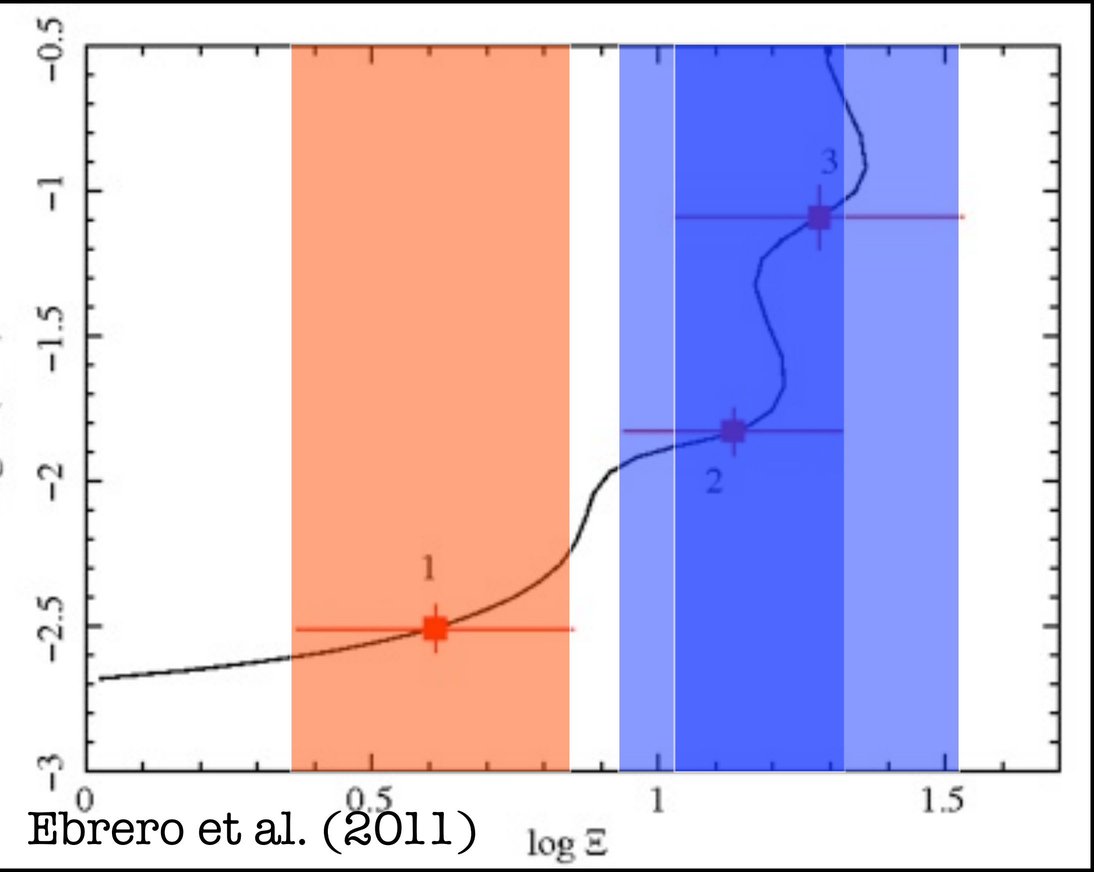

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Outflowing components are in pressure equilibrium

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Using dynamical arguments:

R_1 < 6 kpc
R_2 < 300 pc
R_3 < 50 pc

Mass outflow rate ~ 1.4 $M_\odot\ yr^{-1}$

L_K ~ 0.001% L_{bol}

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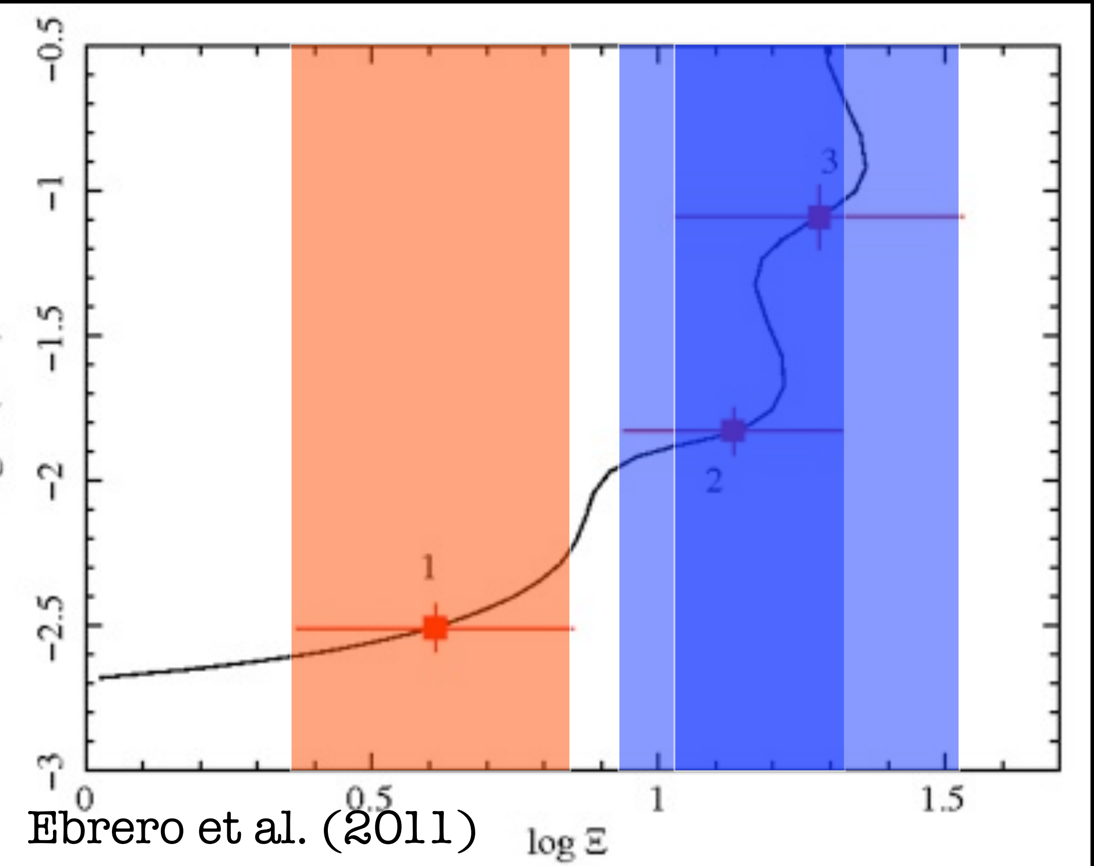

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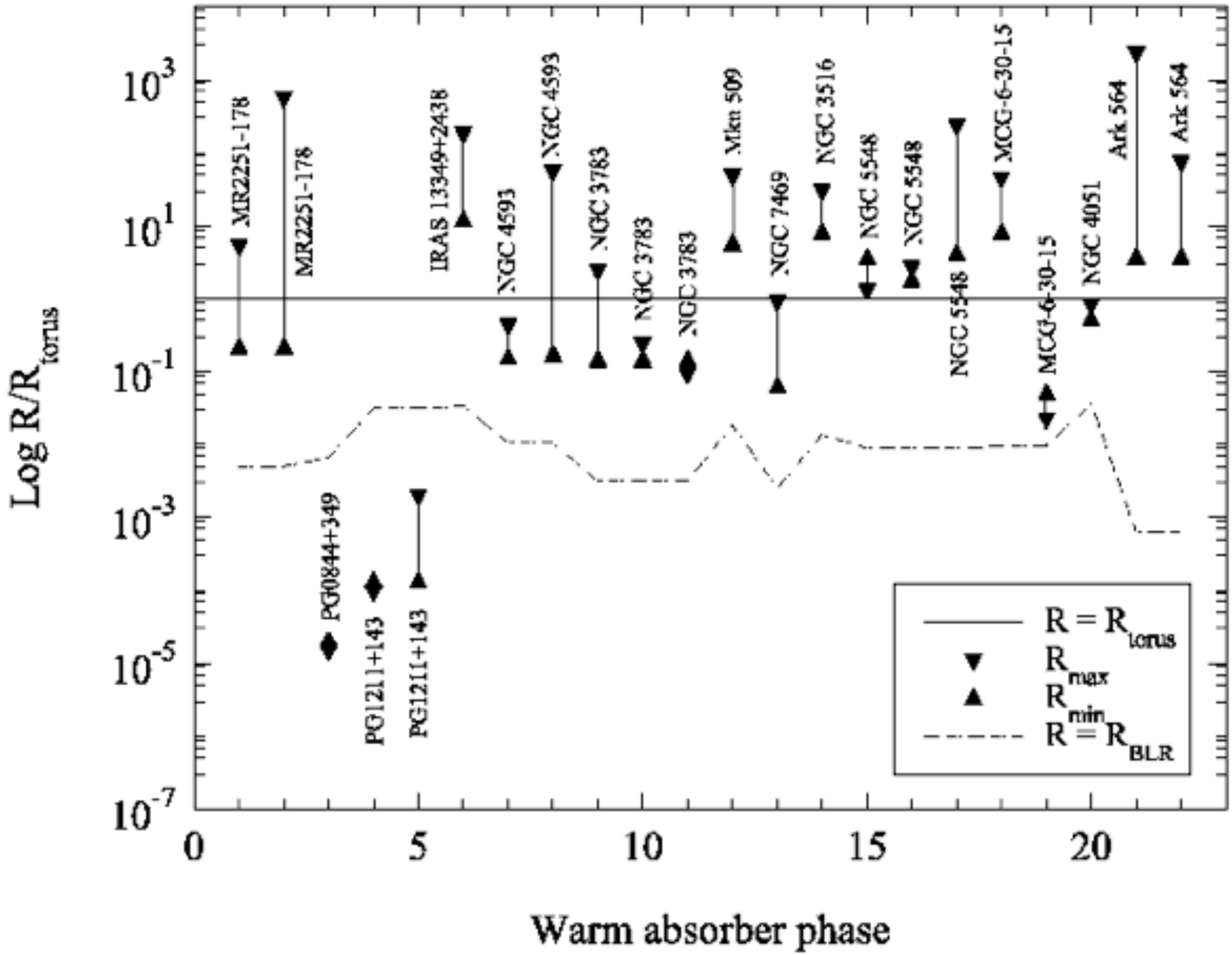
Location: Outflowing components may originate in the torus
Feedback: Impact on the host galaxy ISM is negligible

Blustin et al. (2005)



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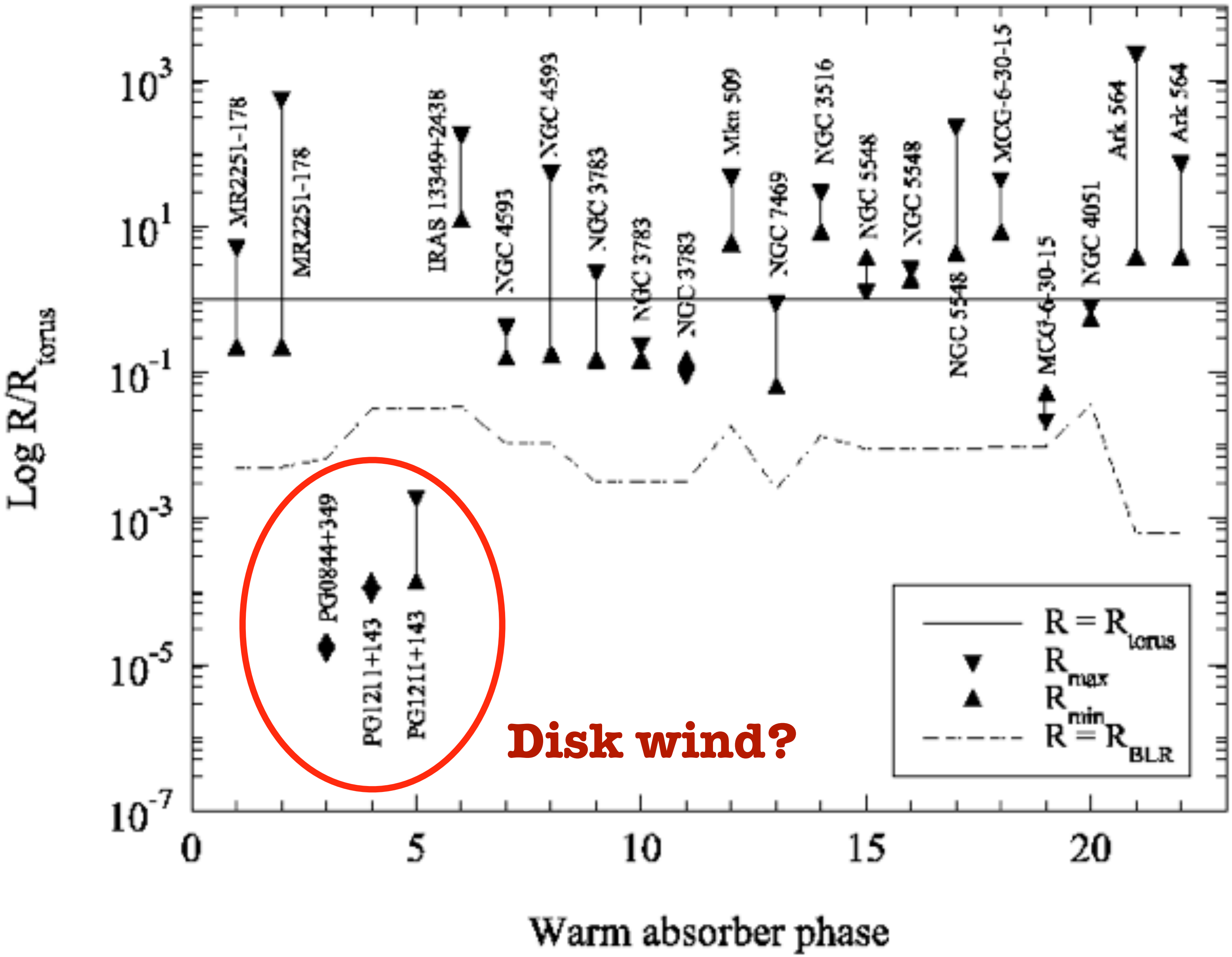

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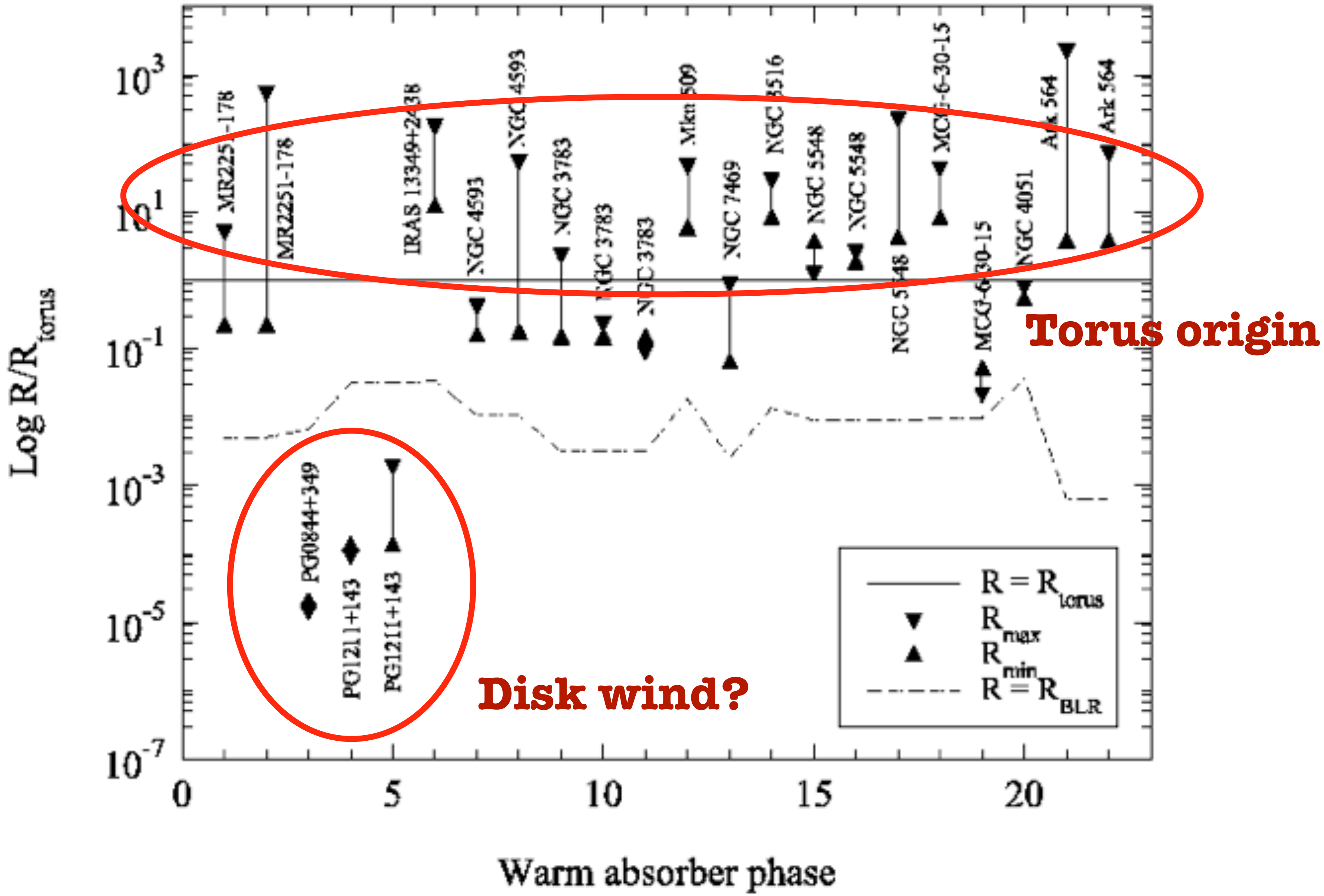
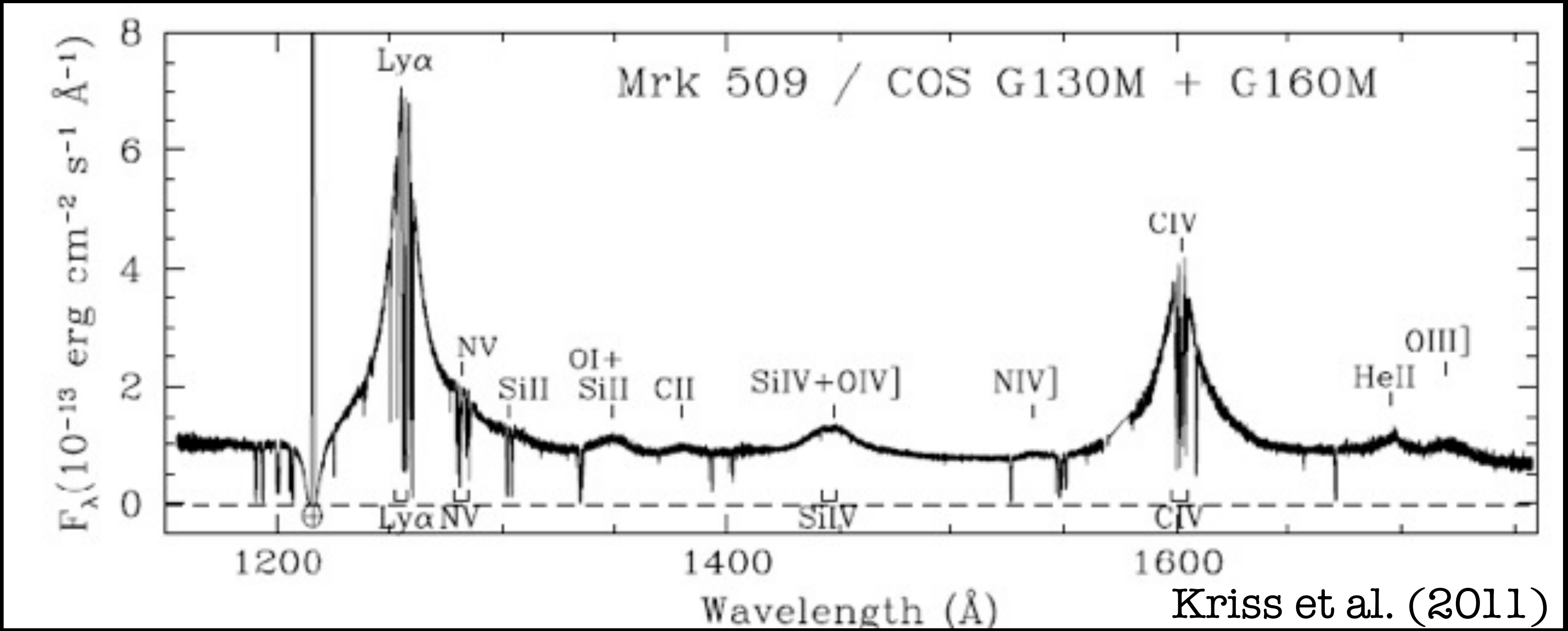


UV absorption in Mrk 509

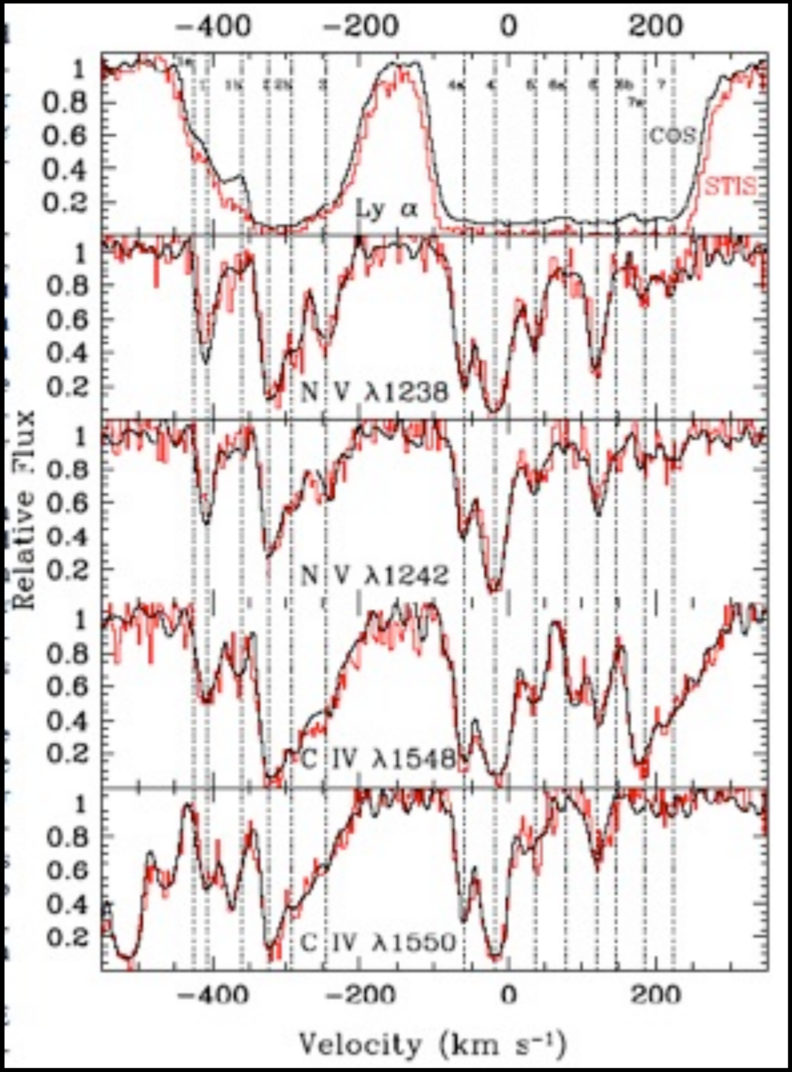


Kriss et al. (2011)

Observed by FUSE (Kriss+00), HST-STIS (Kraemer+03), HST-COS (Kriss+11)

Emission lines: Lyα, CIV, NV, SiIV (HST-COS), OVI (FUSE)
Foreground absorption: 7 ISM components, 3 Lyα IGM features
Intrinsic absorption: 13 kinematic components

UV absorption in Mrk 509



Gaussian profile fit in optical depth:
- Outflow velocity
- Ionic column density
- Covering factor

13 distinct kinematic components:
- 7 blueshifted wrt the systemic vel.
- 6 redshifted wrt the systemic vel.
- Not all seen in all ions

$-408 < v_{out} < 222$ km/s

High covering factors

Most likely thermal winds from the torus rather than disk winds

Kriss et al. (2011)

X-ray/UV kinematic agreement

UV Component	v_{out}[a]	N_{CIV}[b]	N_{NV}[b]	N_{OVI}[b,c]	LETGS[d]
1	−408 ± 5	31.2 ± 1.5	107.0 ± 9.5	215.0 ± 47.2	3
1b	−361 ± 13	16.3 ± 6.1	17.5 ± 1.6	154.9 ± 39.0	3?
2	−321 ± 5	136.3 ± 41.7	149.0 ± 10.7	566.2 ± 118.0	3?
2b	−291 ± 6	128.9 ± 41.4	130.6 ± 11.3	1248.1 ± 395.5	2?
3	−244 ± 5	47.7 ± 7.2	88.6 ± 8.1	675.2 ± 157.1	2
4a	−59 ± 5	66.3 ± 2.1	93.6 ± 6.8	804.5 ± 387.2	
4	−19 ± 5	250.0 ± 11.0	323.6 ± 12.2	8797.0 ± 4120.3	
5	37 ± 5	36.2 ± 16.9	38.3 ± 11.1	683.5 ± 429.3	1
6a	79 ± 12	5.6 ± 2.3	20.6 ± 6.4	518.8 ± 398.5	1
6	121 ± 5	12.3 ± 6.4	56.1 ± 4.0	3436.1 ± 6985.0	1?
6b	147 ± 8	17.6 ± 5.3	5.5 ± 1.8	104.5 ± 234.6	
7a	184 ± 6	3.6 ± 1.1	21.0 ± 2.9	660.2 ± 176.7	
7	222 ± 6	6.4 ± 0.8	23.5 ± 2.7	667.4 ± 1105.3	

Ebrero et al. (2011)

The X-ray components match well with 3 UV kinematic components.

Blend with others within the large(r) X-ray error bars.

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The X-ray and UV absorbing gas are likely co-located.

Is it the same gas?

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X-ray and UV kinematics match

Moderate outflow velocities in X-rays and UV

Ionic column densities for CIV, NV, OVI (FUSE) match

X-ray and UV absorbers consistent with torus origin

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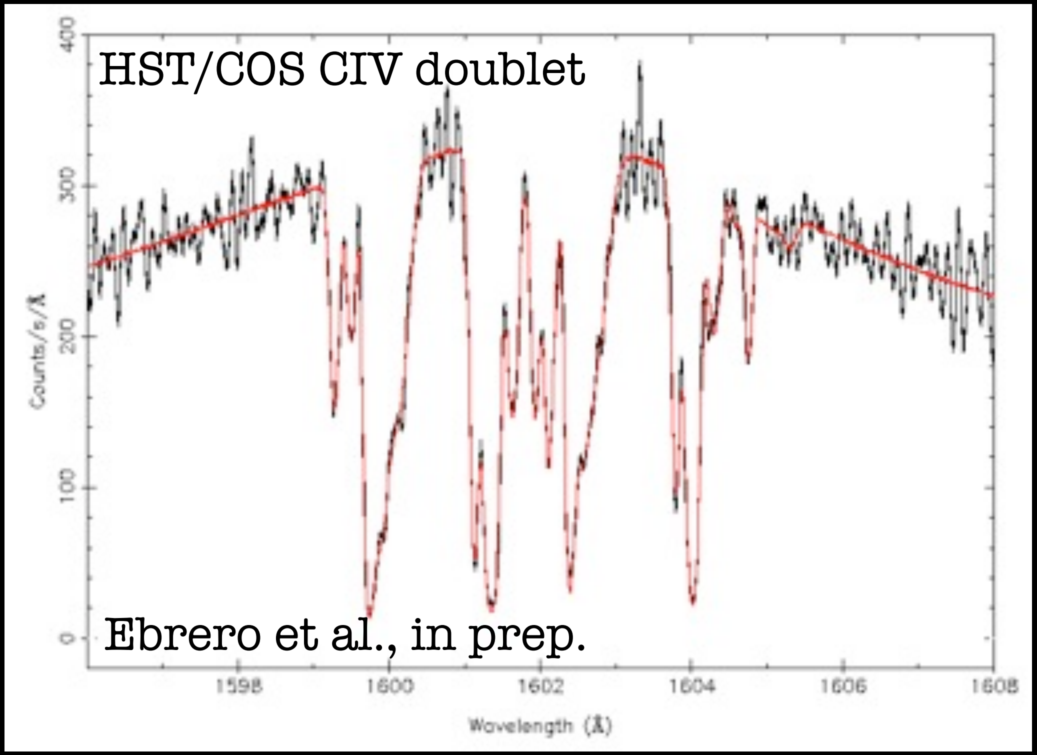
Ionization states that produce UV absorption are typically too low to produce significant X-ray absorption

Work in progress...



Fit UV absorber in the same manner as the X-ray absorber

Transmission of a slab of material where all the N_{ion} are linked through a photoionization balance model (CLOUDY)

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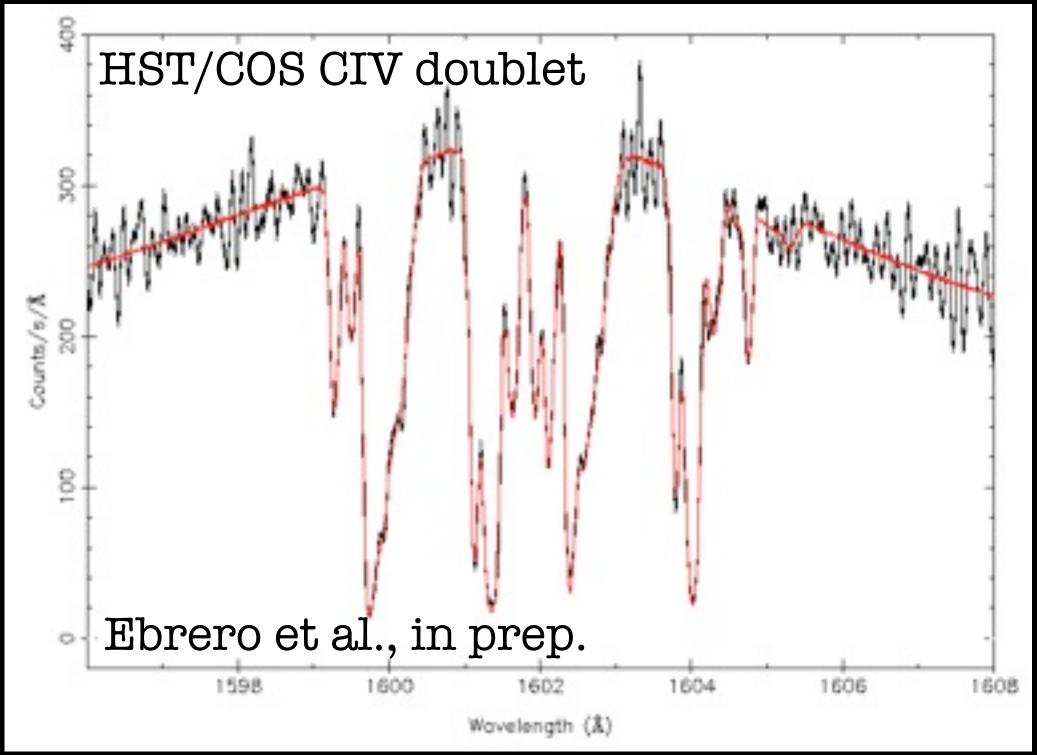

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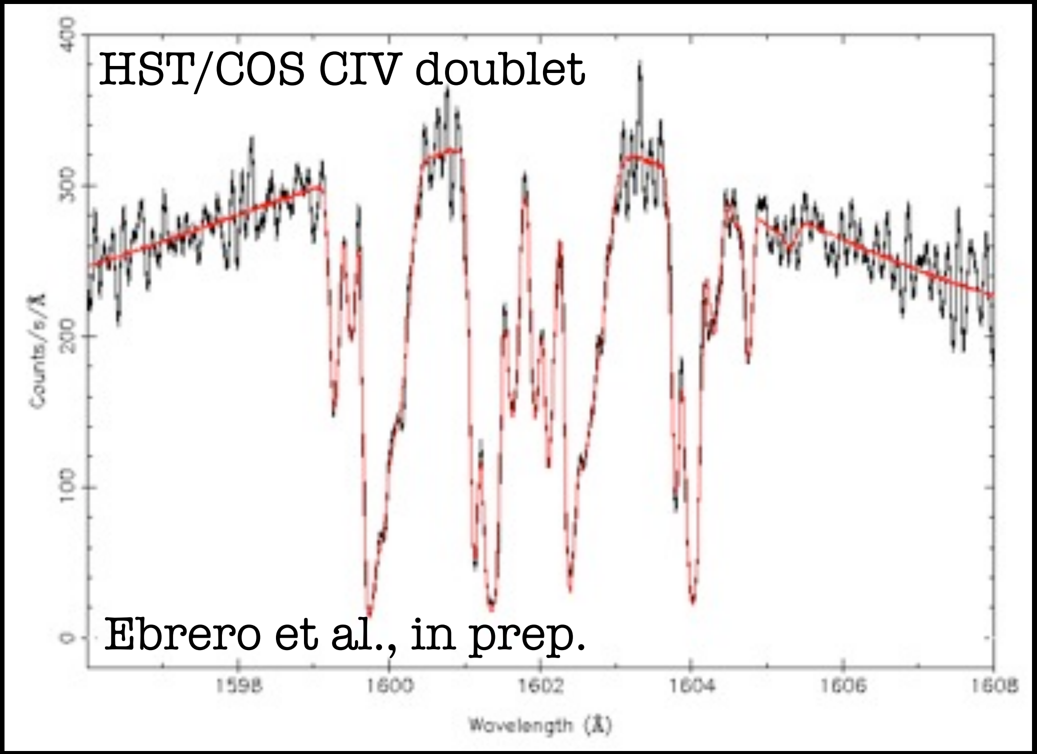

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log ξ much lower than that of the X-ray WA

$\xi = L / nR^2 \Rightarrow \xi \propto 1/n \Rightarrow n_{UV}$ higher

A possible scenario for the X-ray/UV absorption

The UV-absorbing gas consists of low column density, high-density low-ionization clouds embedded in a low-density high-ionization gas responsible for the X-ray absorption (Ebrero et al. 2011, Kriss et al. 2011, Ebrero et al., in prep).

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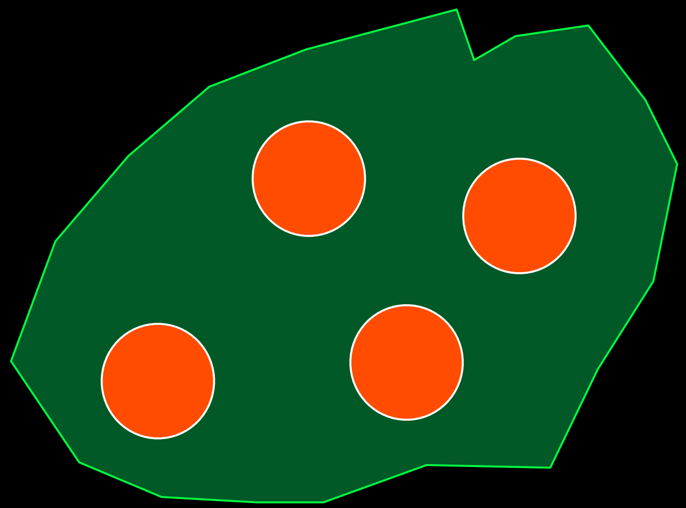

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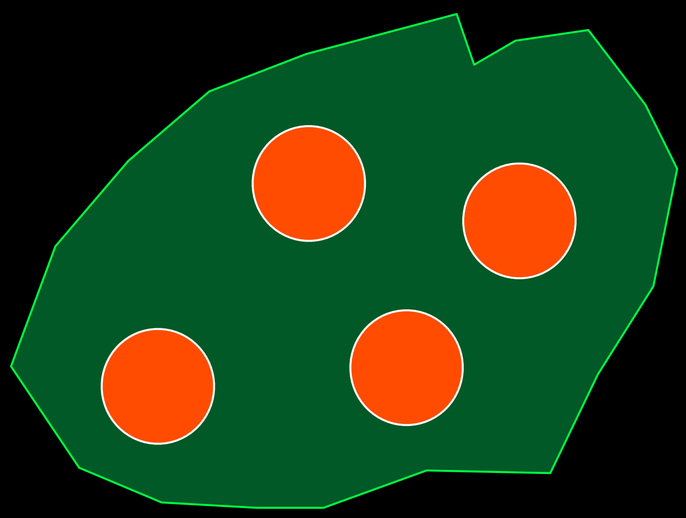

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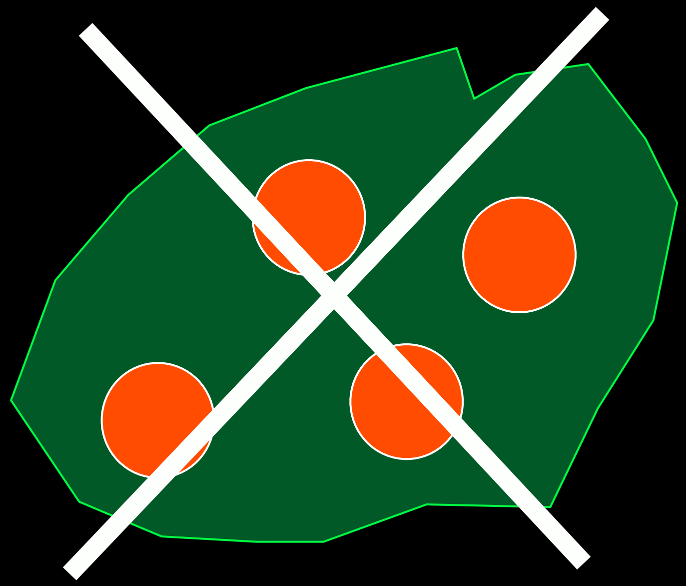

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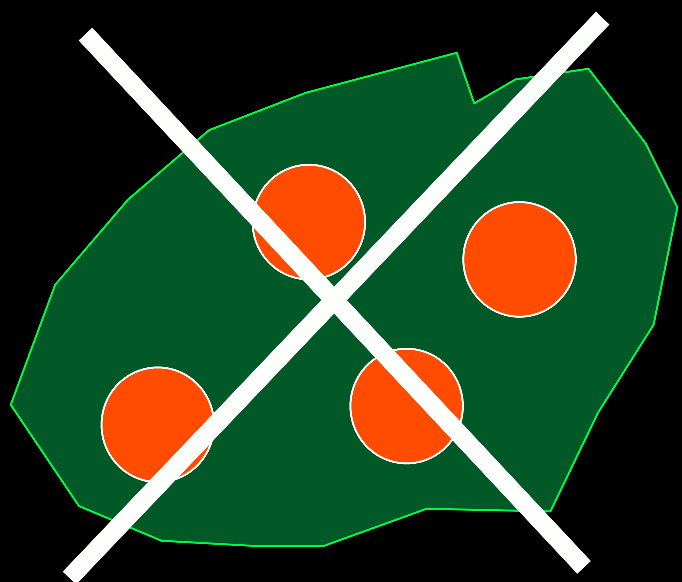
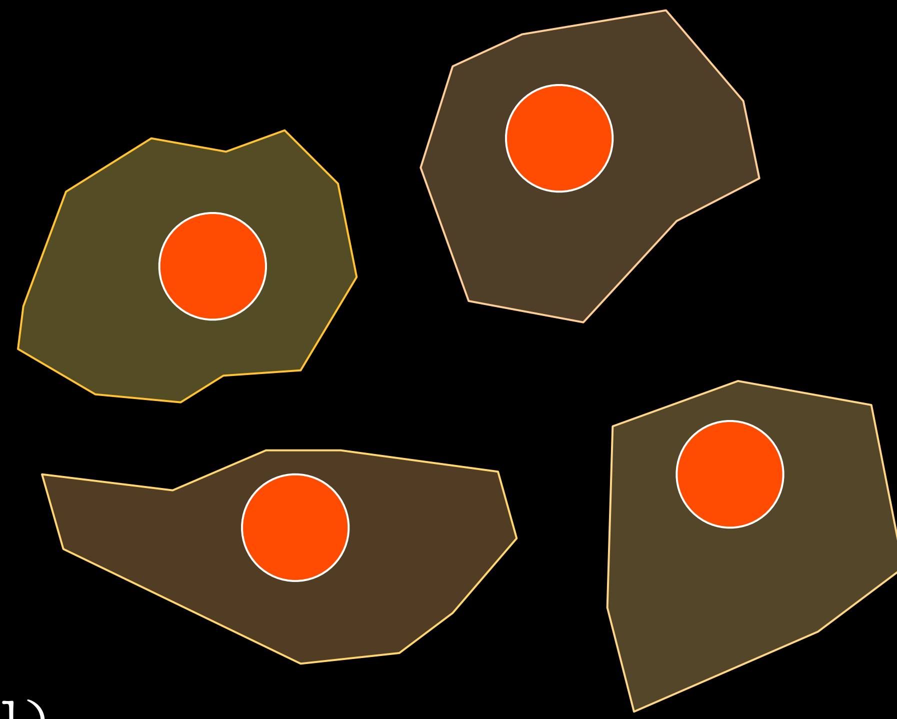
A possible scenario for the X-ray/UV absorption

The UV-absorbing gas consists of low column density, high-density low-ionization clouds embedded in a low-density high-ionization gas responsible for the X-ray absorption (Ebrero et al. 2011, Kriss et al. 2011, Ebrero et al., in prep).





The X-ray WA is a discrete distribution of ionization phases (Detmers et al. 2011)

Summary

Mrk 509 has been subject of an ambitious extensive multiwavelength campaign. As part of it, Mrk 509 was simultaneously observed in X-rays by Chandra-LETGS, and in the UV by HST/COS.

The X-ray WA shows three ionization phases with distinct outflows velocities.

The UV shows a complex absorber with up to 13 kinematic components.

The X-ray and the UV absorbing gas are likely co-located and are consistent with thermal winds originating in the torus.

The ionization state of the UV absorbing gas is too low to produce significant X-ray absorption. A likely explanation is that it consists of high-density clouds embedded in a low-density high-ionization X-ray absorbing gas.