The Collisional and Photoionized Plasma in the Polarized NLS1 galaxy Mrk 1239

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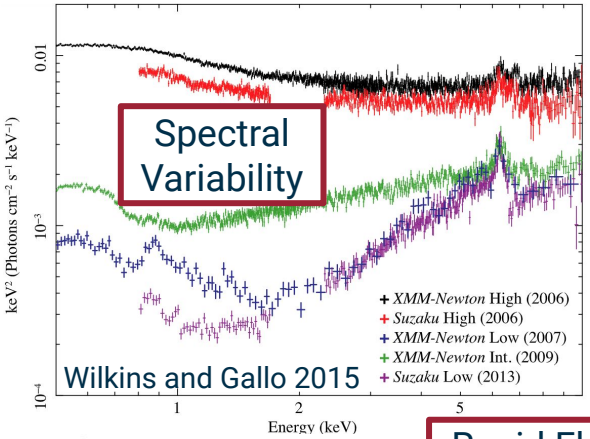
Arcus Community Science

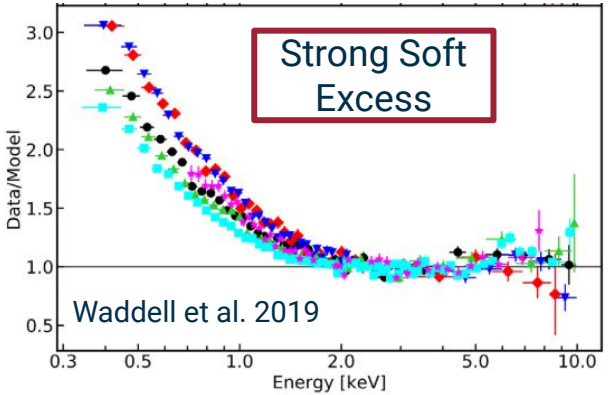
The X-ray Properties of NLS1

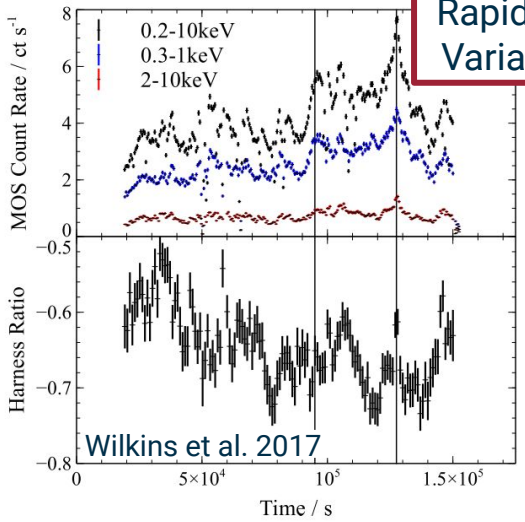
These AGN typically have (eg: Waddell & Gallo 2020):

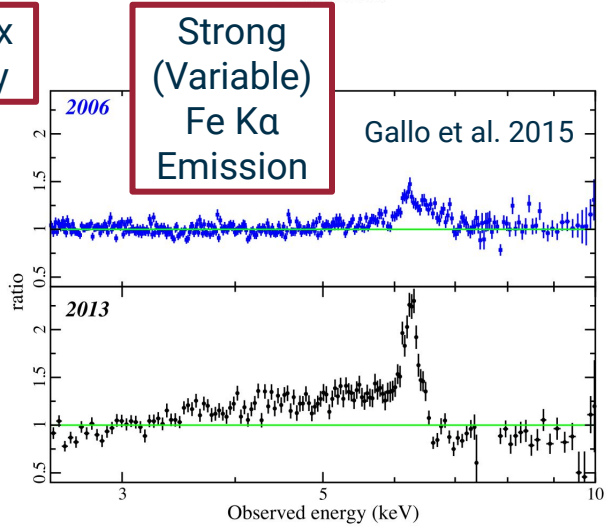
- Strong Soft Excess
- **Steep Power Law**
- **Low Column Densities**
- Strong Fe Kα Emission
- Strong Variability, Especially in the Soft X-rays

See Gallo 2018, for a recent review



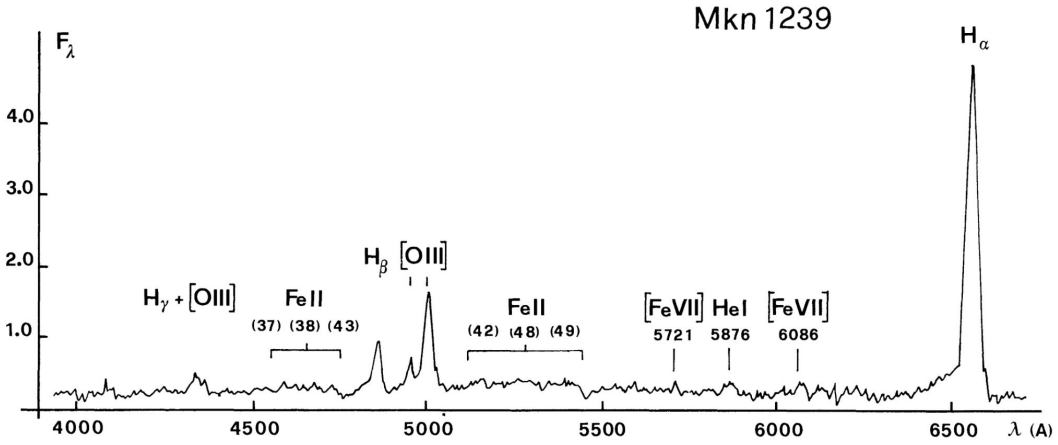




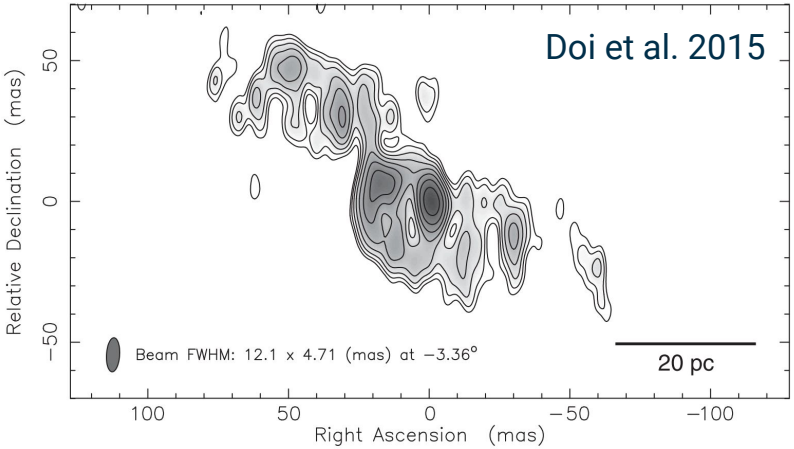


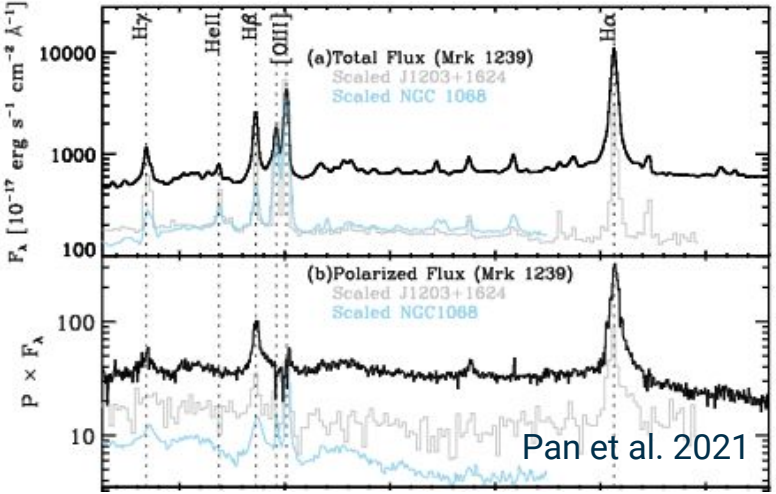
Mrk 1239: A Prototypical NLS1?

Mrk 1239 was part of the original sample Osterbrock and Pogge (1985) used to define Narrow Line Seyfert 1s based on optical spectra but even early data showed some atypical properties…



Spectra from Rafanelli and Bonoli (1984)





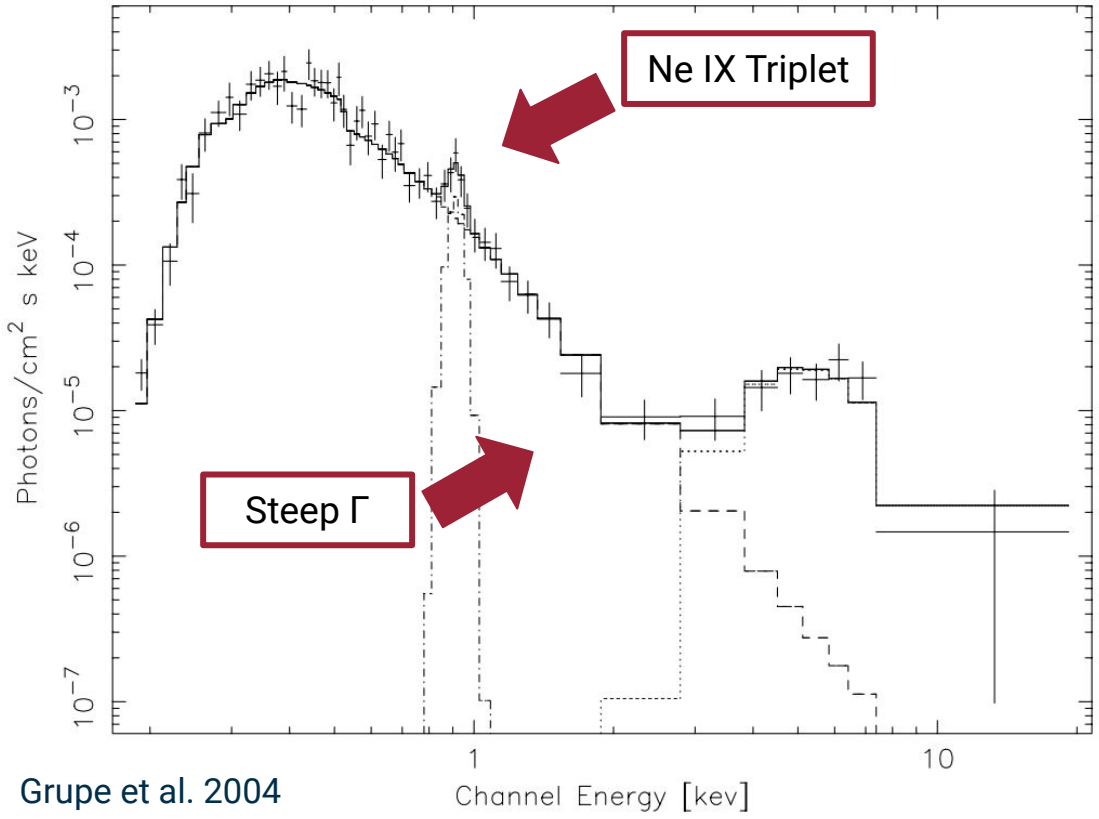
Evidence of Non- Stellar Radio Emission

Radio Loud?

Polarised Emission Lines

Evidence of Scattered Emission

Mrk 1239: An Early Glimpse with X-rays



Grupe et al. 2004

This early X-ray work was characterized by several key results:

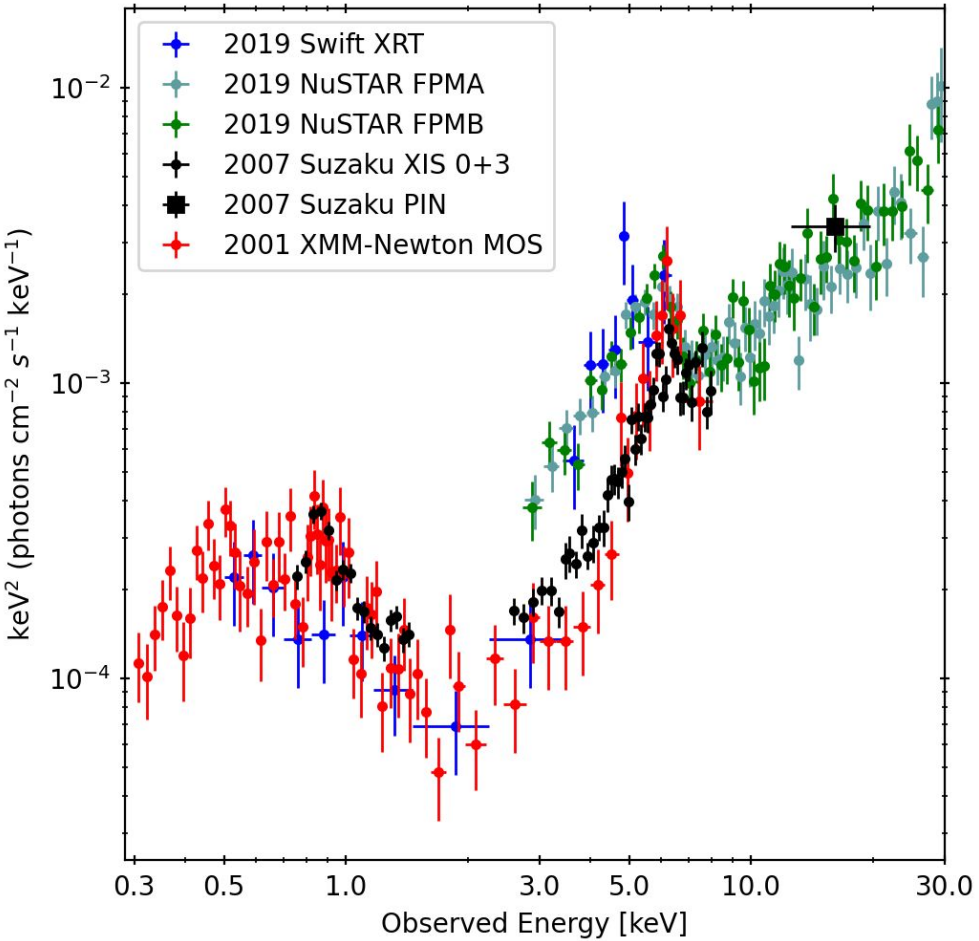
1. High absorption
    a. Consistent with optical polarization seen by Goodrich (1989)
2. High photon index
3. An over abundance of Neon
    a. As evidenced by the presence of a Ne IX triplet and lack of O VII Triplet

Unfolded spectra of Mrk 1239 spanning 18 years

Buhariwalla et al. 2020

Key features of the unfolded spectra include:

1. Strong soft excess
2. Consistency in the soft band (below 3 keV)
3. Variability above 3 keV

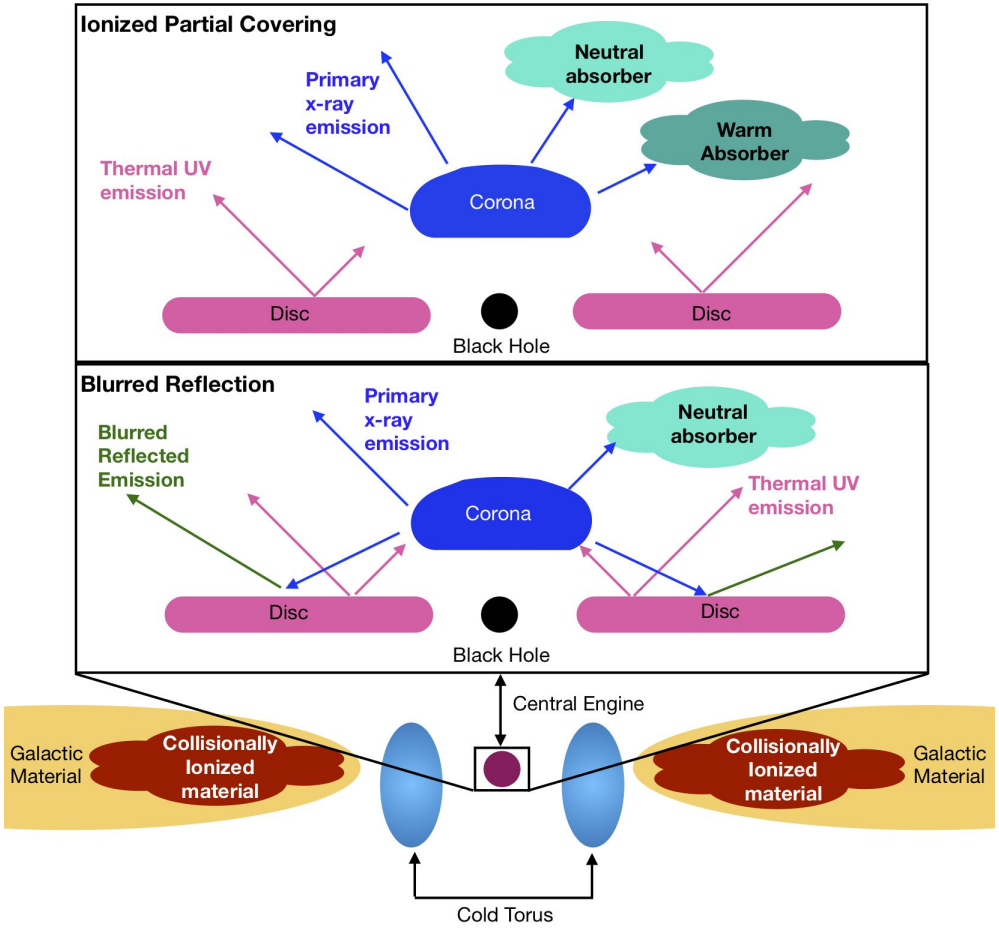


Physical Interpretation of the Emission from Mrk 1239

Buhariwalla et al. 2020

Questions remain:

1. Can we confirm extended emission?
2. Can we confirm the presence of ionized Emission? What are the abundances?
3. Is there a blend of collisionally ionized and photoionized emission?
4. Where are these plasma(s) located? (eg. NLR, BLR, torus…)



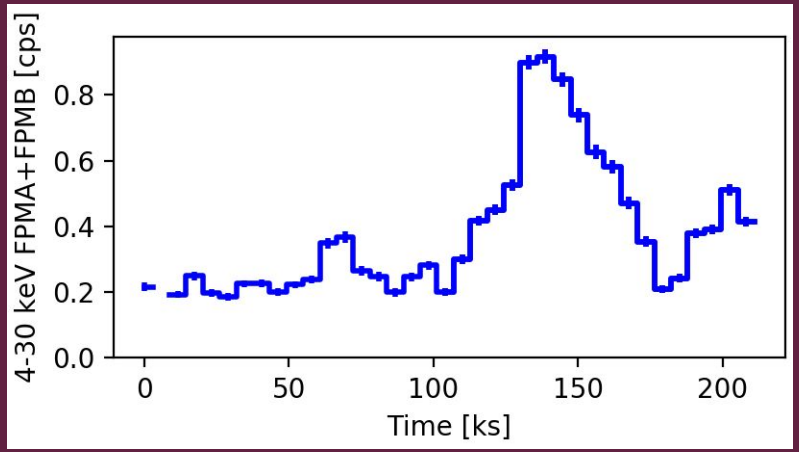
Recent observations of Mrk 1239

Chandra– (2.1ks; April 11th 2021)
- Excellent spatial resolution

XMM-Newton– (105 ks; Nov. 4th 2021)
- Excellent energy resolution
- 0.3 – 10 keV

NuSTAR – (101 ks; Nov. 4th 2021)
- High energy spectra
- ~3 – 79 keV

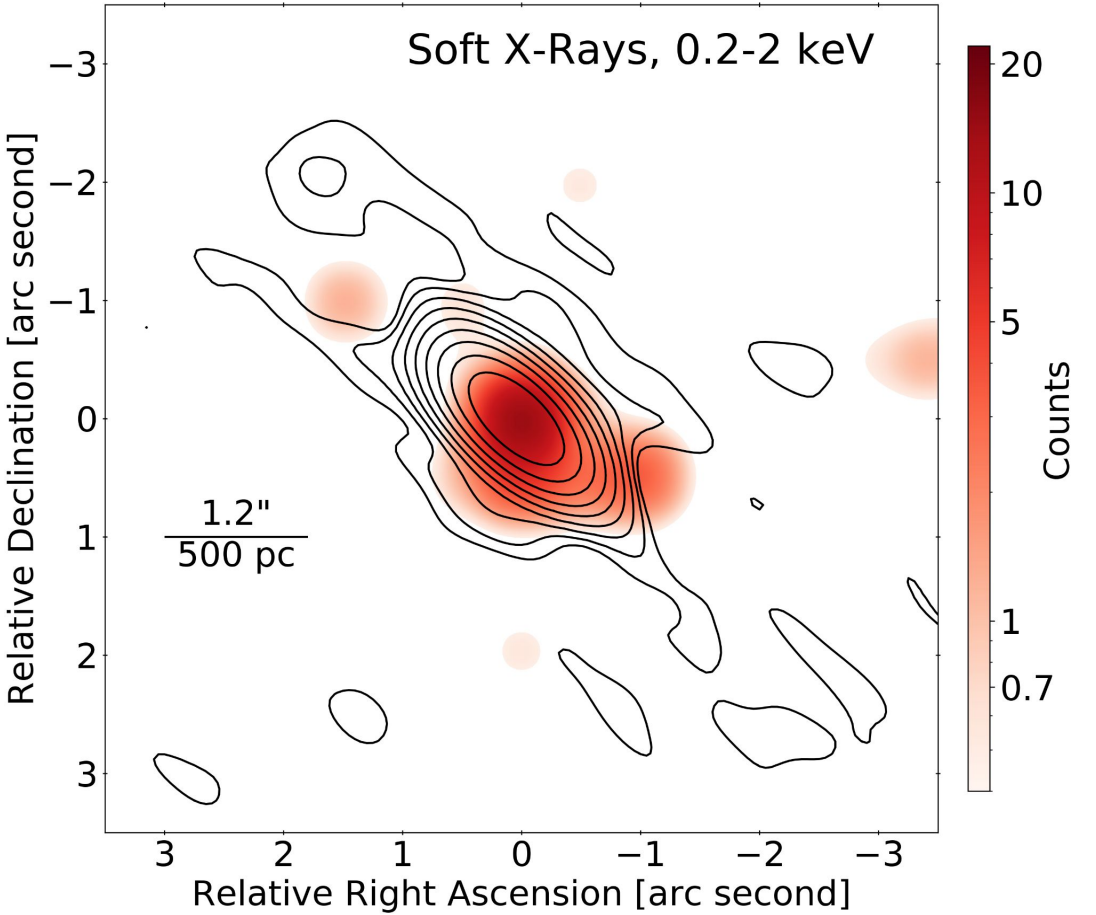
Swift – (~20ks in 18 observations)
- Two burst of short observations one in Nov 2021, the other in Dec 2022

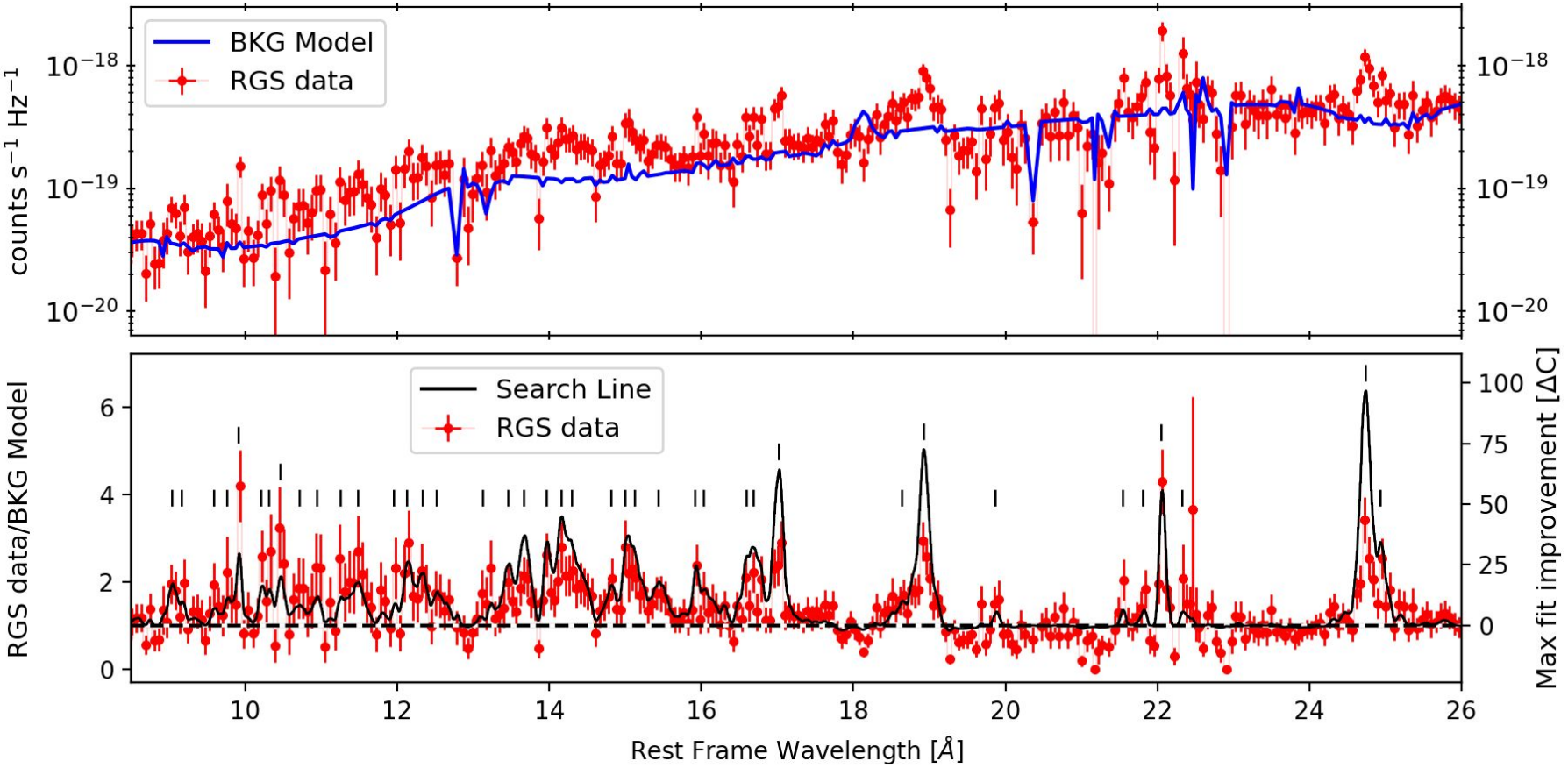


Extended Soft Emission in the Chandra Image

2.1 ks snapshot with Chandra with radio contours overlaid.

The radio contours are taken from Järvelä et al. 2022 (rms = 10μJy beam^{-1} and the contours are drawn at -3, 3x2n, n ∈ [0, 9] beam size is 0.37 x 0.17 kpc).





Ionized Emission Lines are Observed!

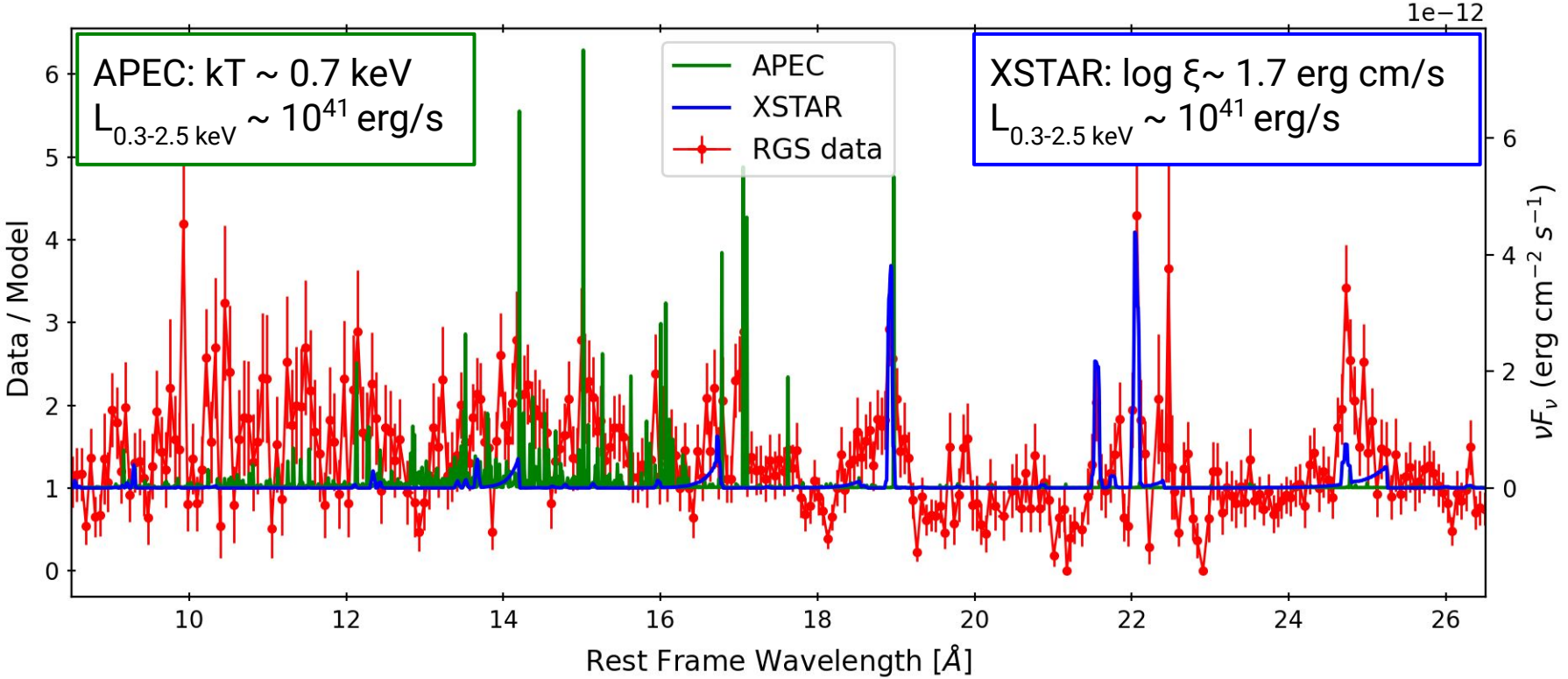
40 Identified Lines

Line ID	Wavelength [Å]
Fe XX $5d \rightarrow 2p$	9.05 ± 0.04
Mg XI $2p \rightarrow 1s$	9.2 ± 0.2
Fe XXI $4d \rightarrow 2p$	9.60 ± 0.08
Fe XXI $4d \rightarrow 2p$	9.8 ± 0.2
Fe XIX $5d \rightarrow 2p$	$9.92^{+0.01}_{-0.02}$
Ne X $3p \rightarrow 1s$	10.22 ± 0.04
Fe XVIII * $5d \rightarrow 2p$	$10.32^{+0.06}_{-0.05}$
Fe XVII $7d \rightarrow 2p$	$10.47^{+0.03}_{-0.04}$
Fe XXIV $3p \rightarrow 2s$	$10.7^{+0.1}_{-0.2}$
Fe XXIII $3p \rightarrow 3s$	$10.96^{+0.06}_{-0.04}$
Fe XVII $5d \rightarrow 2p$	$11.26^{+0.04}_{-0.13}$
Fe XXIV $3s \rightarrow 2p$	11.49 ± 0.05
Fe XXII $3d \rightarrow 2p$	12.0 ± 0.2

Line ID	Wavelength [Å]
Ne X $2p \rightarrow 1s$	$12.14^{+0.03}_{-0.04}$
Fe XXI $3d \rightarrow 2p$	$12.34^{+0.06}_{-0.04}$
Fe XX $3p \rightarrow 2p$	$12.531^{+0.1}_{-0.2}$
Fe XX $3d \rightarrow 2p$	$13.1^{+0.6}_{-0.3}$
Ne IX $2p \rightarrow 1s$	$13.47^{0.05}_{-0.03}$
Ne IX $2s \rightarrow 1s$	$13.68^{+0.04}_{-0.03}$
Fe XXI $3p \rightarrow 2p$	$13.98^{+0.03}_{-0.02}$
Fe XVIII $3d \rightarrow 2p$	$14.17^{+0.03}_{-0.02}$
Fe XVIII† $3d \rightarrow 2p$	$14.31^{+0.03}_{-0.12}$
O VIII $5p \rightarrow 1s$	$14.82^{+0.05}_{-0.03}$
Fe XVII $3d \rightarrow 2p$	$15.01^{+0.02}_{-0.04}$
Fe XIX $3s \rightarrow 2p$	$15.13^{+0.06}_{-0.04}$
Fe XVII $3d \rightarrow 2p$	$15.44^{+0.04}_{-0.08}$
Fe XVIII $3s \rightarrow 2p$	$15.93^{+0.02}_{-0.03}$

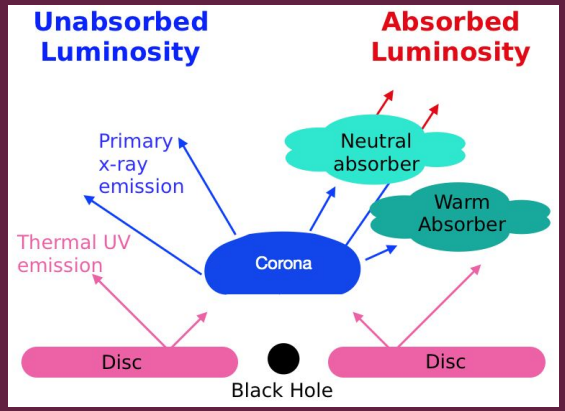
Line ID	Wavelength [Å]
Fe XVIII $3s \rightarrow 2p$	$16.05^{+0.04}_{-0.2}$
Fe XVI $3s \rightarrow 2p$	$16.60^{+0.05}_{-0.03}$
Fe XVII $3s \rightarrow 2p$	$16.70^{+0.04}_{-0.09}$
Fe XVII $3s \rightarrow 2p$	17.03 ± 0.02
O VII $3p \rightarrow 1s$	$18.65^{+0.2}_{-0.03}$
O VIII $2p \rightarrow 1s$	18.93 ± 0.02
N VII $4p \rightarrow 1s$	$19.88^{+0.05}_{-0.06}$
O VII $2p \rightarrow 1s$	$21.55^{+0.04}_{-0.03}$
O VII $2p \rightarrow 1s$	$21.82^{+0.06}_{-0.04}$
O VII $2s \rightarrow 1s$	$22.06^{+0.01}_{-0.02}$
Fe XXIV $5f \rightarrow 3d$	$22.3^{+0.1}_{-0.2}$
N VII $2p \rightarrow 1s$	$24.74^{+0.02}_{-0.01}$
N VI $3p \rightarrow 1s$	$24.94^{+0.02}_{-0.04}$

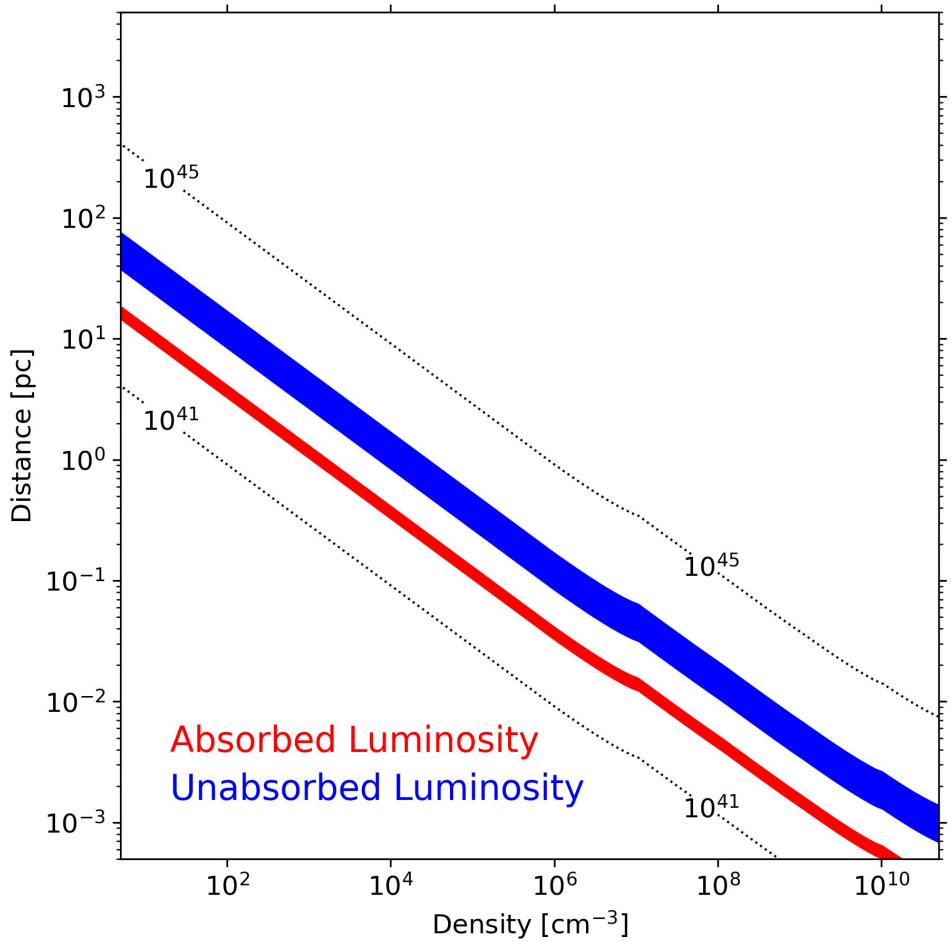
Blended plasma – APEC predicts SFR ~ 3 $M_\odot$/yr



What is the Origin of Photoionized plasma?

$$\xi = \frac{L}{nr^2}$$

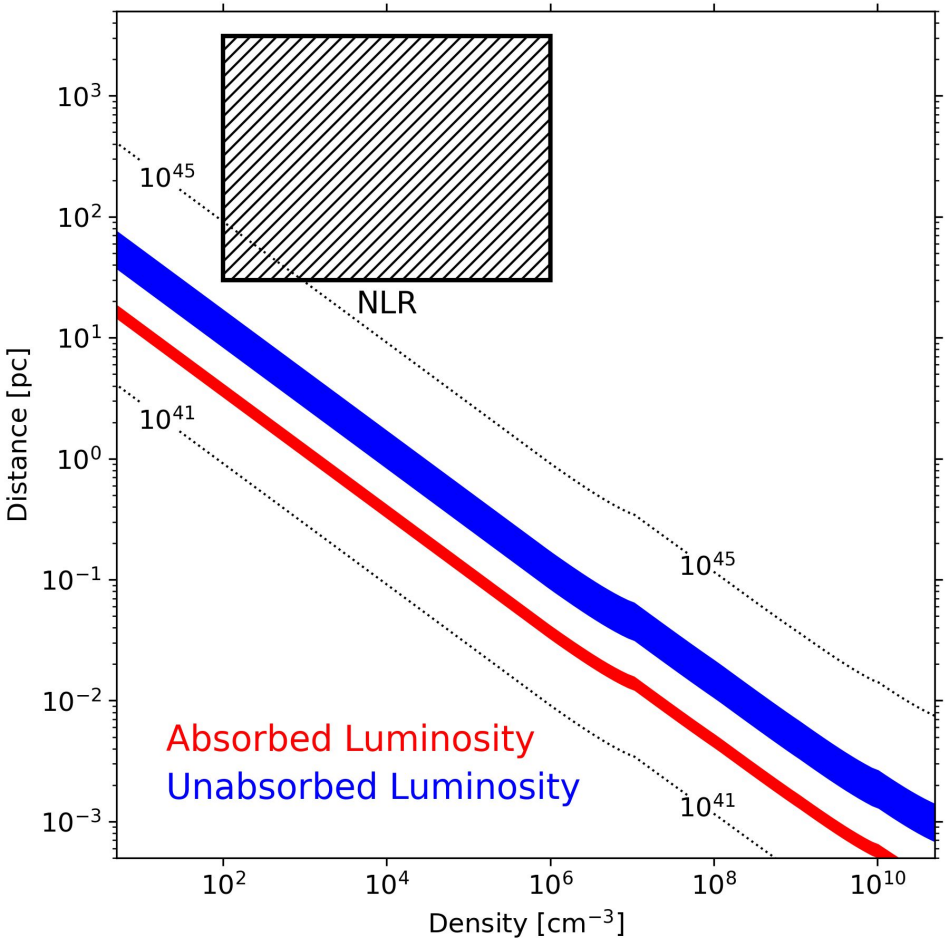




What is the Origin of Photoionized plasma?

$$\xi = \frac{L}{nr^2}$$

NLR outer radius is estimated using R_{NLR}- $L_{[O\ III]}$ relationship found by Bennert et al. (2002), the inner radius is taken to be 30 pc (see Komossa & Schulz 1997)

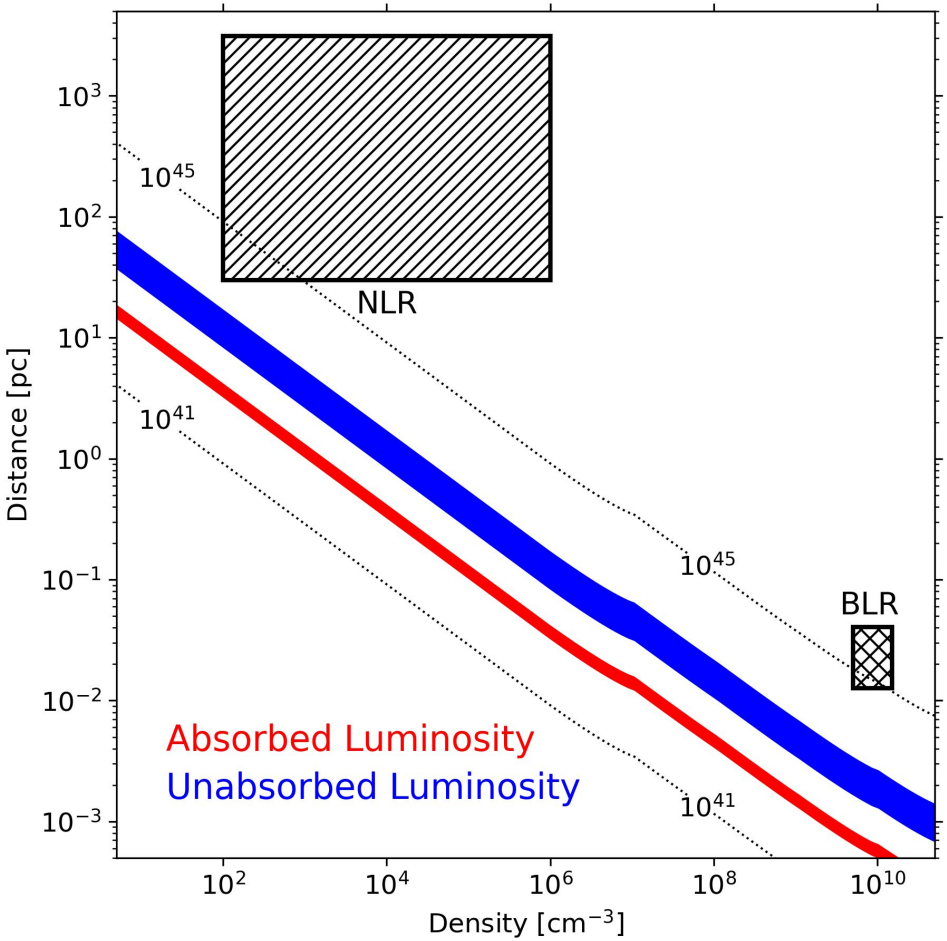


What is the Origin of Photoionized plasma?

$$\xi = \frac{L}{nr^2}$$

BLR size is estimated using R_{BLR}- $\lambda F_\lambda(5100Å)$ relationship found by Kaspi et al. 2005.

$\lambda F_\lambda(5100Å)$ is taken from Pan 2021 and Grupe 2004.

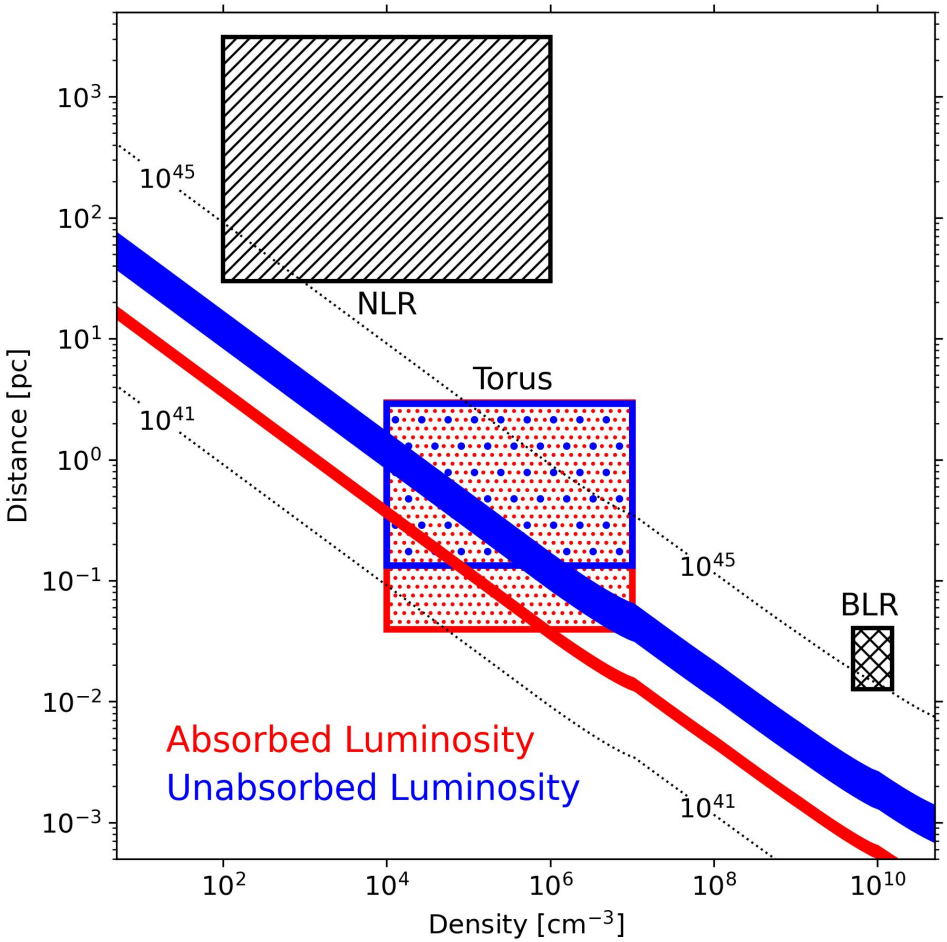


What is the Origin of Photoionized plasma?

$$\xi = \frac{L}{nr^2}$$

Torus outer radius is measured to be 3pc based on 12μm observations by Tristram et al. 2011

Torus inner radius is based on the dust sublimation radius, where the $L_{2\text{-}10\ keV}$ is calculated from models used in Buhariwalla 2020



Arcus vs RGS in Mrk 1239