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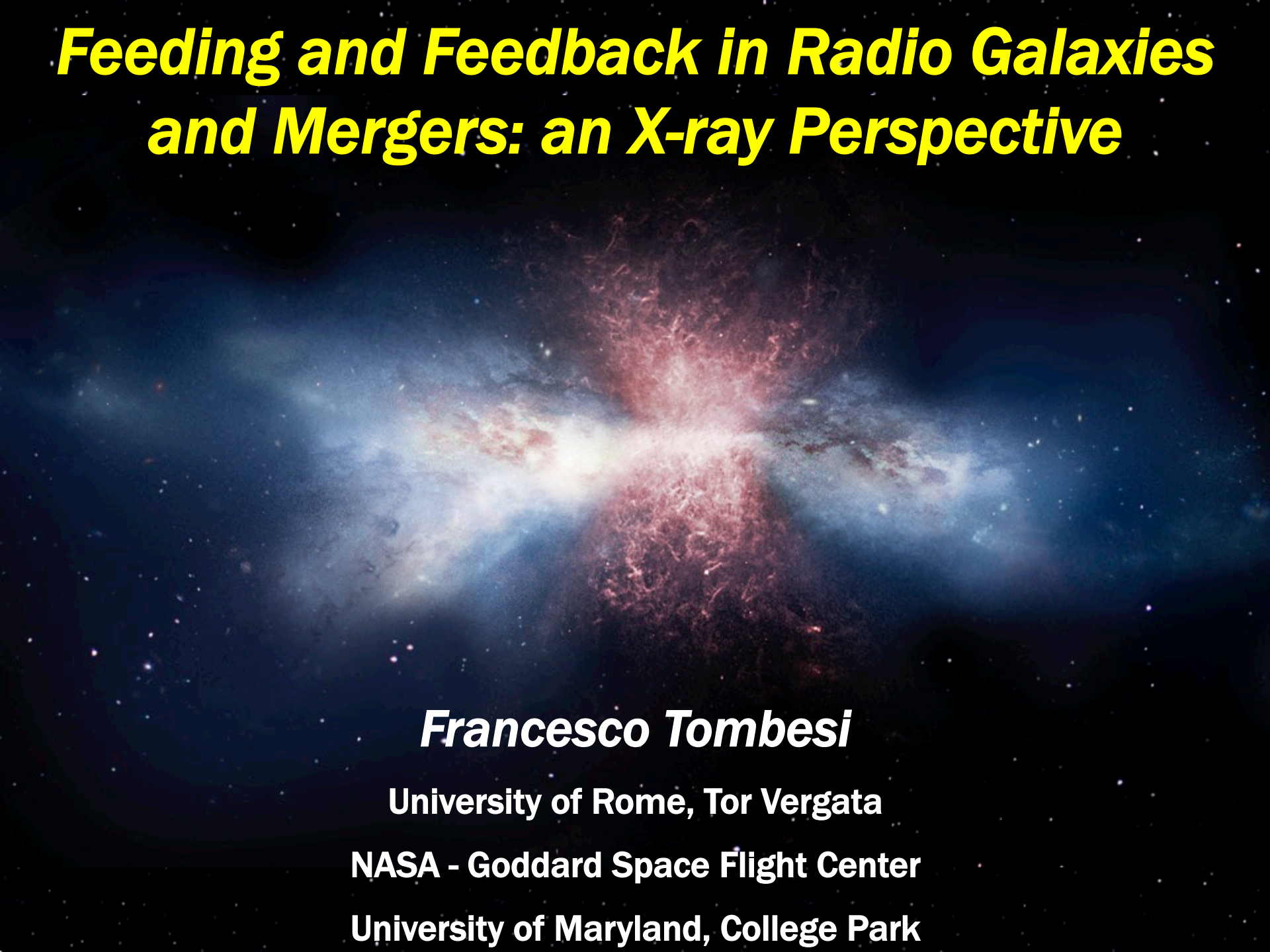
Feeding and Feedback in Radio Galaxies and Mergers: an X-ray Perspective



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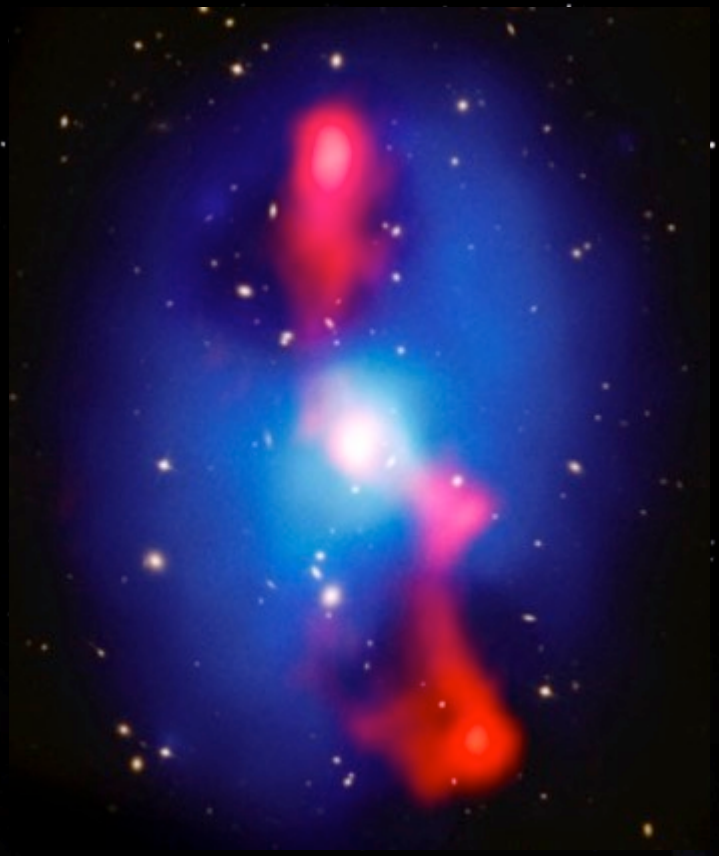
Flavors of black hole feedback

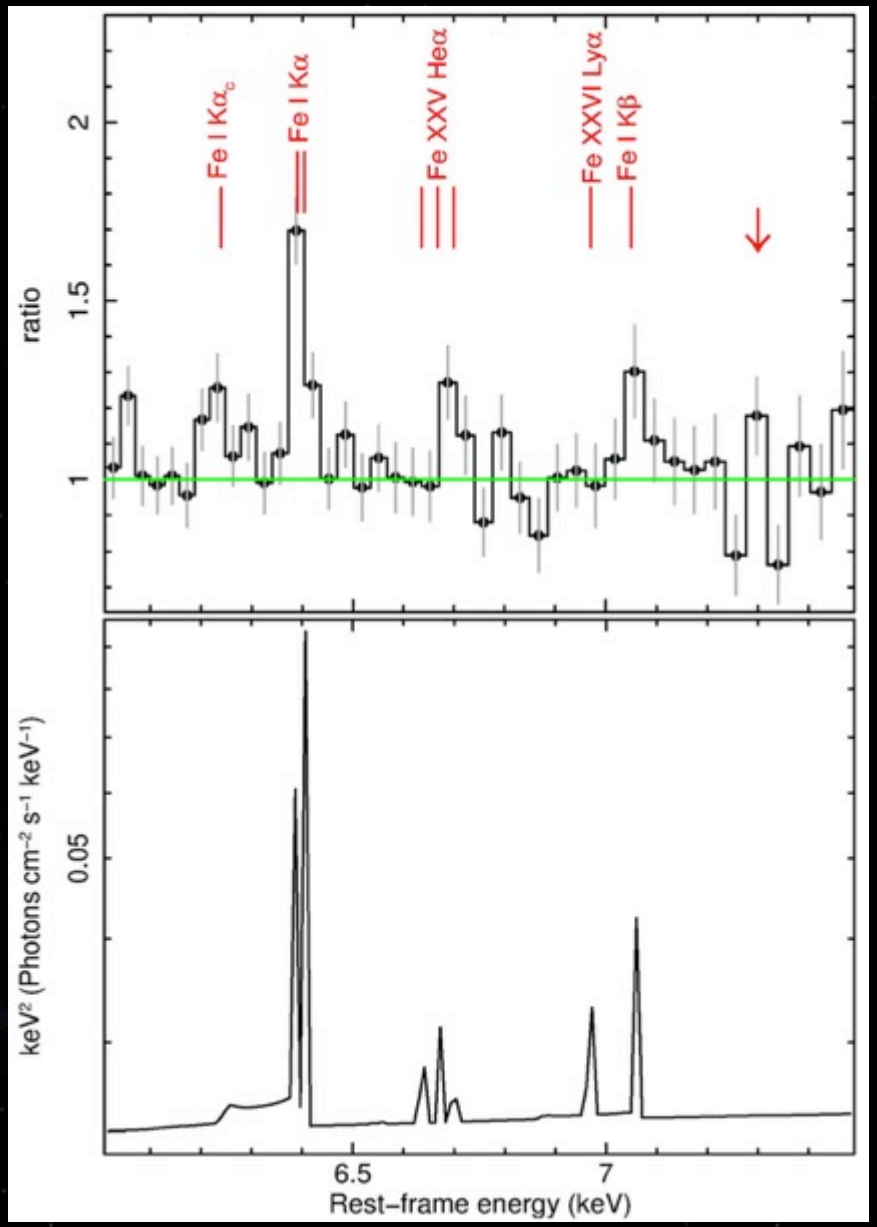
Relativistic jets



Disk winds

- Large program Chandra HETG, 3C 390.3, 3C 120, 3C 111
- Most radio-loud AGN are (minor) mergers (Chiaberge et al. 2015)

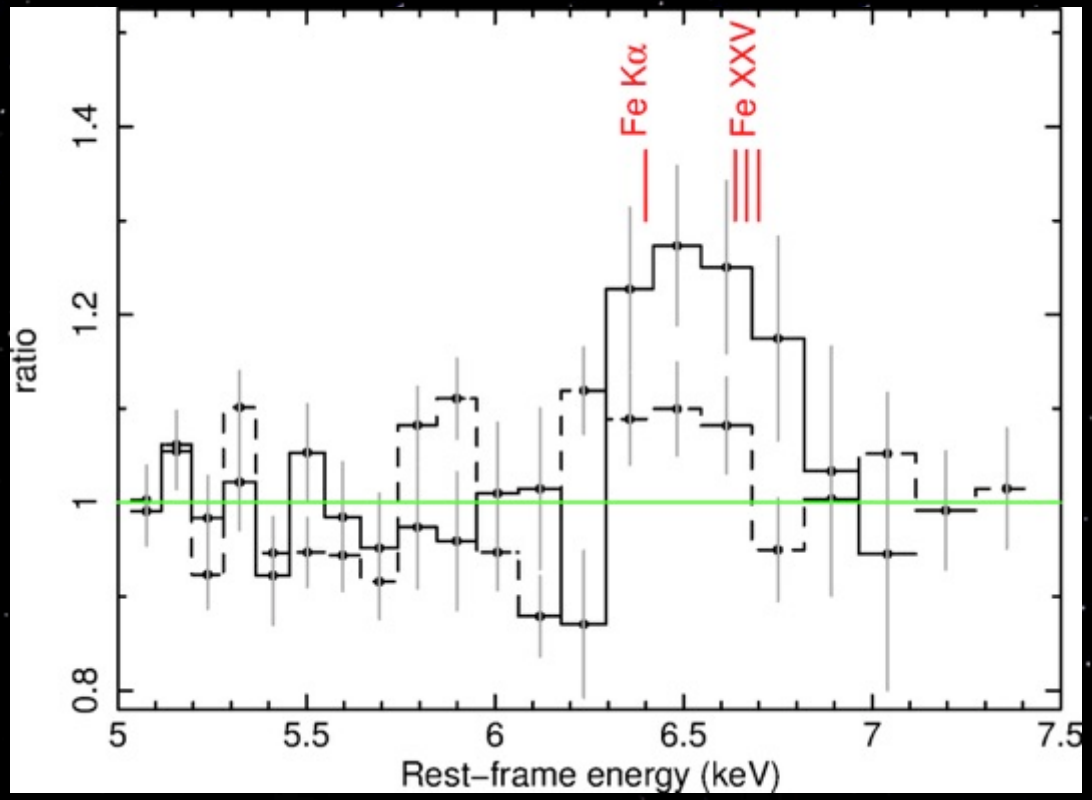
Feeding: Fe K emission lines in 3C 120



- Series of neutral/ionized Fe K lines (including Fe K Compton shoulder)
- Fe Kα FWHM~2,300 km/s, comparable to optical BLR (i~20°)
- $R=0.22\pm0.04$, $N_H>6\times10^{24}$ cm^{-2}
- Compton thick equatorial clumps?
- Ionized emitter $\log\xi\sim3.7$ at <~2pc
- Ionized absorber $v_{out}\sim20{,}000$ km/s, $\log\xi\sim3.5$ erg s^{-1} cm, $N_H\sim3\times10^{21}$ cm^{-2}
- Emission/absorption from disk wind?

(Tombesi et al. 2017)

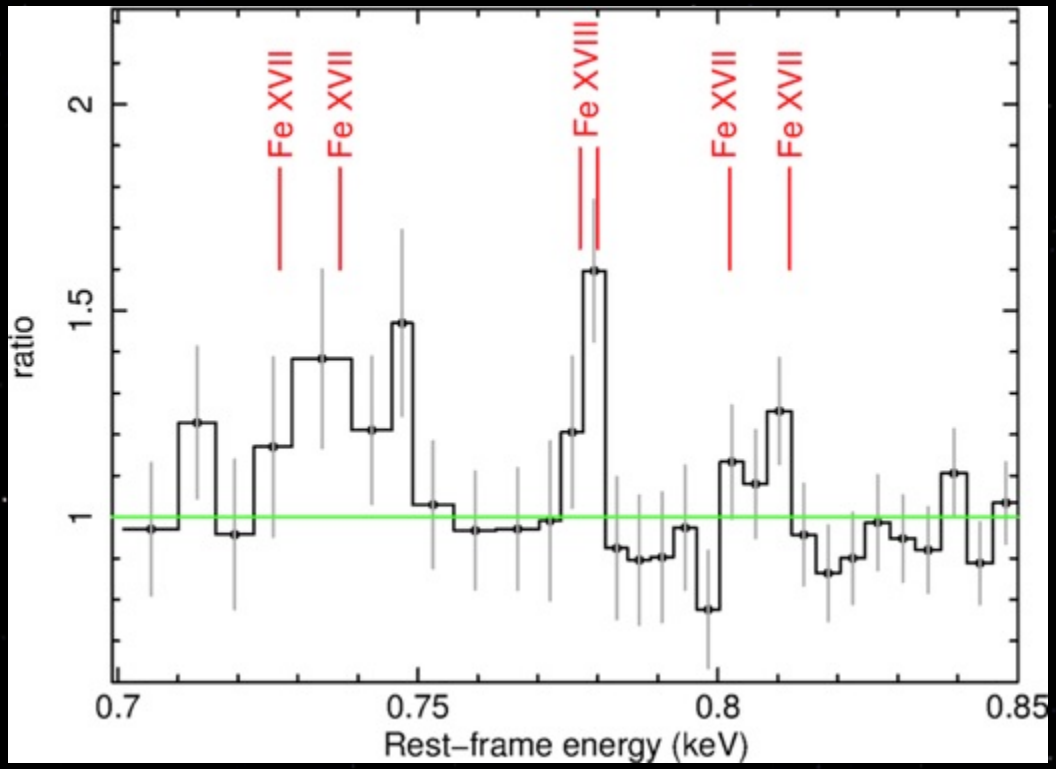
Feeding: Fe K emission lines in 3C 390.3



(Tombesi et al. 2016)

- Fe Kα E=6.40±0.4 keV, FWHM=8,300±3,300 km/s
- Lowly ionized, high column (*xillver*) reflection logξ=1.3±0.3 erg s^{-1} cm
- Line width consistent with optical Hα, origin in BLR or outer accretion disk?

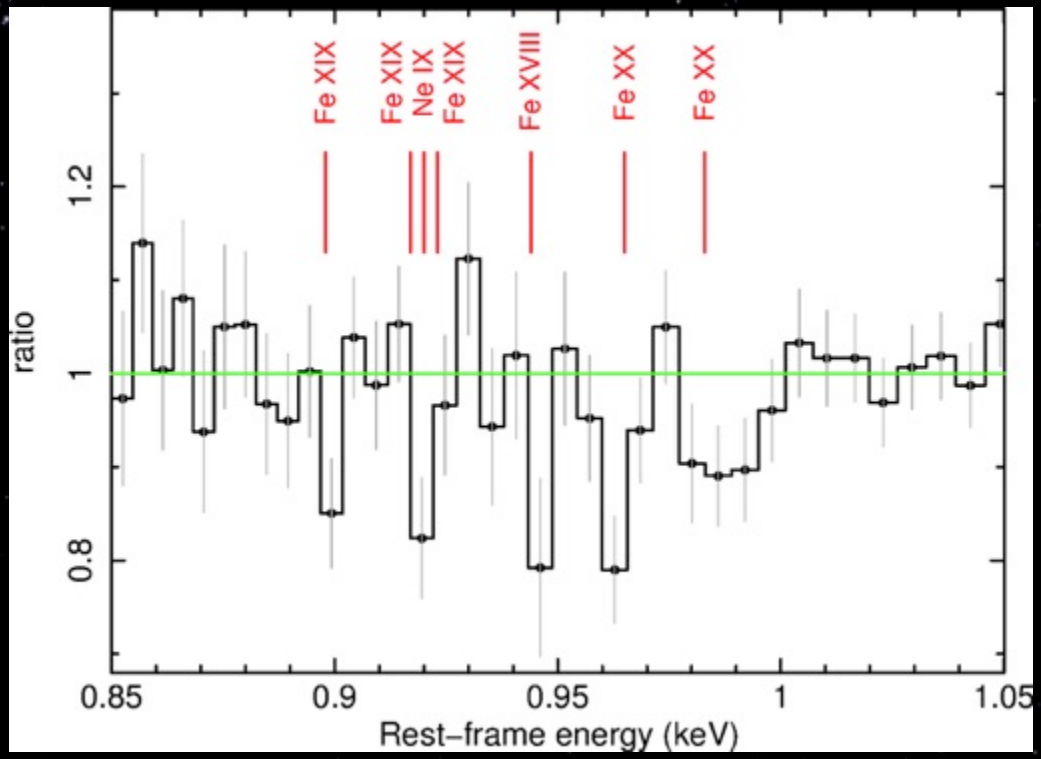
Feedback: soft X-ray emission lines in 3C 390.3



(Tombesi et al. 2016)

- Series of emission lines due to Fe L transitions (Fe XVII-XVIII)
- Hot ISM emission, kT=0.5±0.1 keV, FWHM ~ 3,000 km/s
- Luminosity L_{ISM}~3x10^{42} erg/s, t_{cool} ~$10^{7\text{-}8}$ yrs. What is the heating source?
- Mechanical energy from AGN jet/disk wind is L_K ~$10^{44\text{-}45}$ erg/s

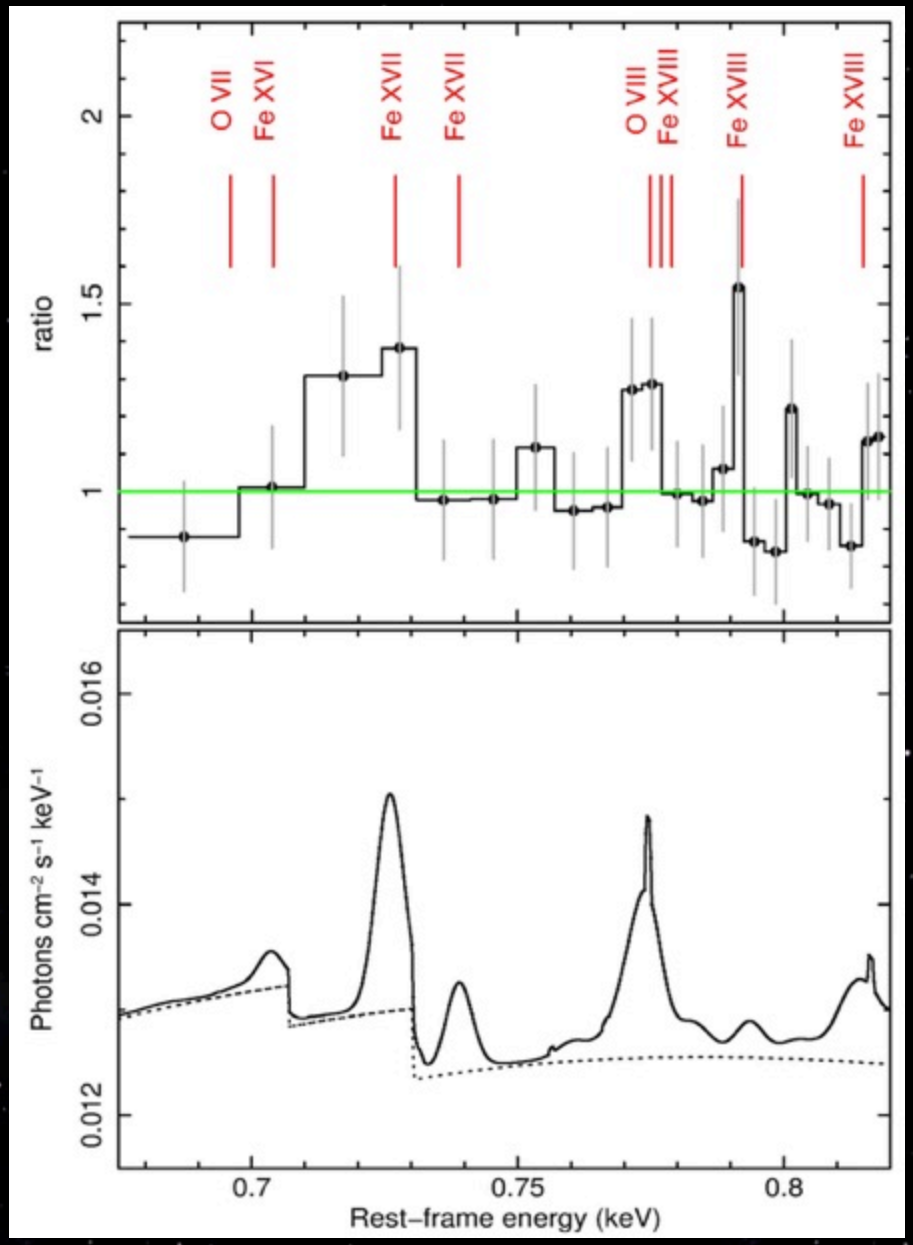
Feedback: soft X-ray absorption lines in 3C 390.3



(Tombesi et al. 2016)

- Series of absorption lines from higher Fe L transitions (Fe XVIII, Fe XIX, Fe XX)
- Warm absorber? $\log N_H = 20.7 \pm 0.1$ cm^{-2}, $\log\xi = 2.3 \pm 0.5$, $v_{out} < 150$ km s^{-1}
- R~3.5pc–3.5kpc, $P_{wa} \sim 0.001\%\ L_{bol}$

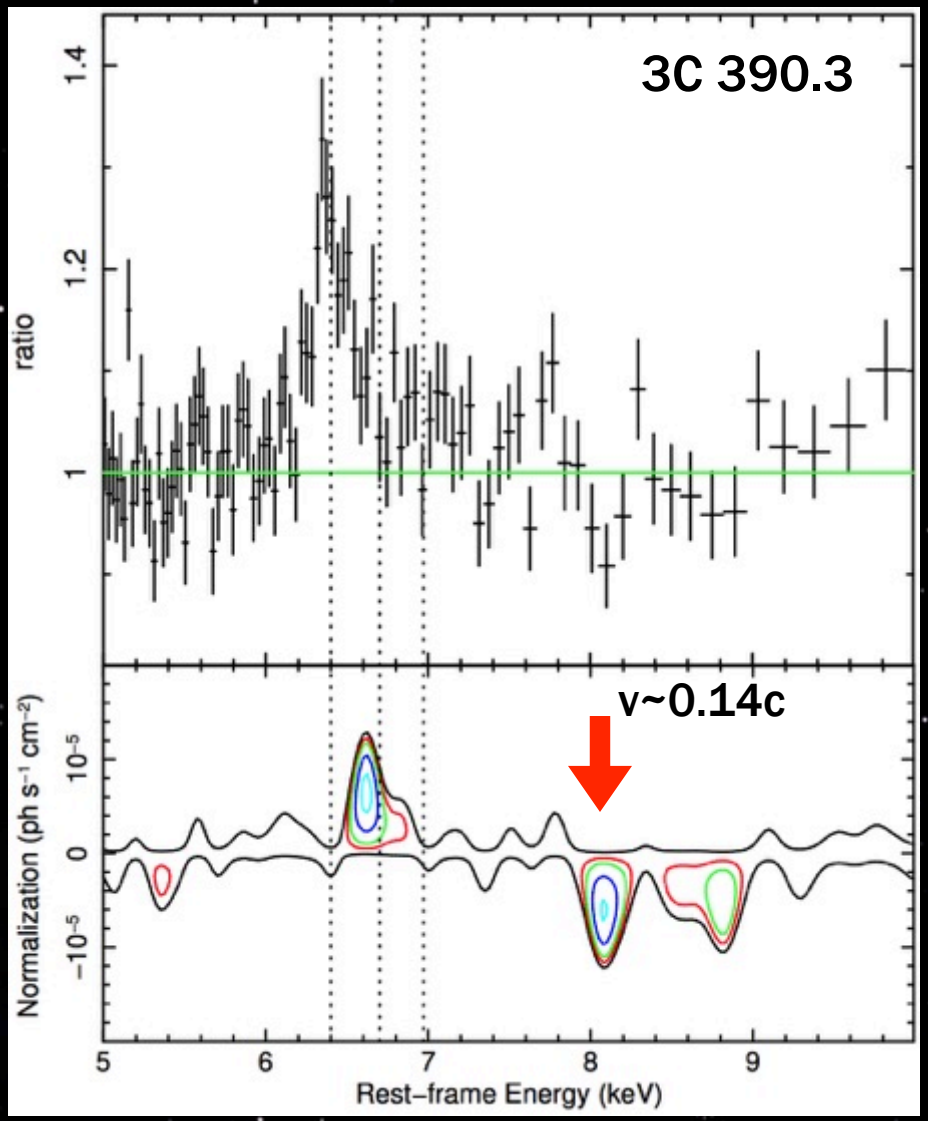
Feedback: soft X-ray emission lines in 3C 120



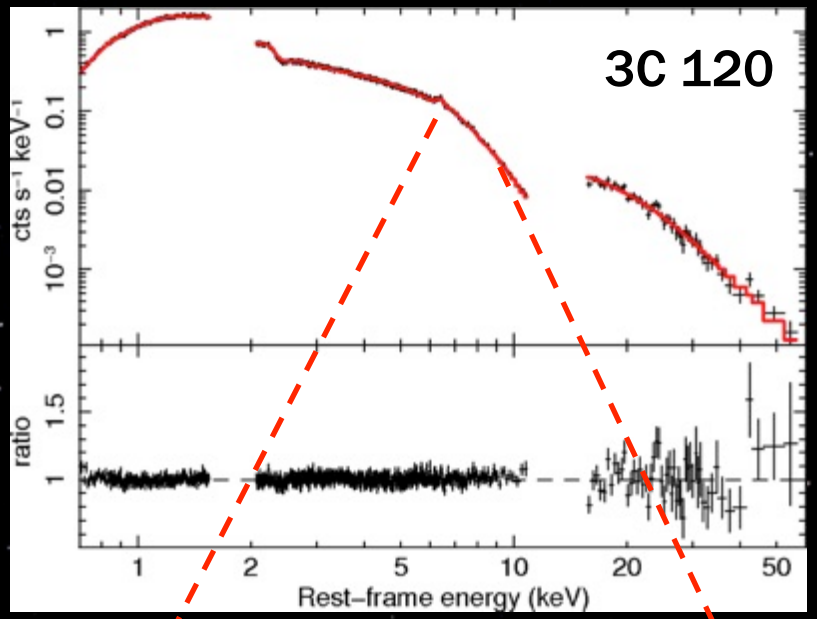
- Emission lines, possibly from OVII/VIII and Fe L (Fe XVI/XVII/XVIII)
- Hot gas T~10^7 K, broad emission line FWHM~2400 km/s
- L_{hot}~1.5×10^{42} erg/s, t_{cool} ~$10^{6\text{-}7}$ yrs
- Consistent with expanding ~kpc scale hot bubble with shock velocity ~1000 km/s
- Bubble inflated by AGN winds/jets?

(Tombesi et al. 2017)

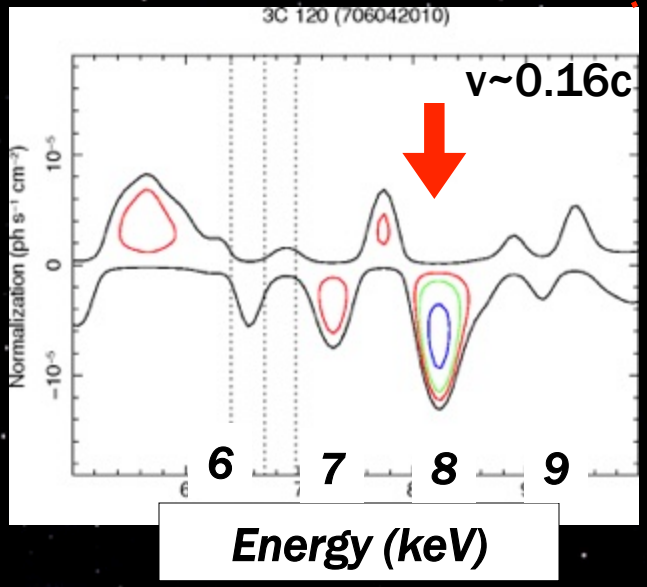
Ultrafast outflows in radio galaxies



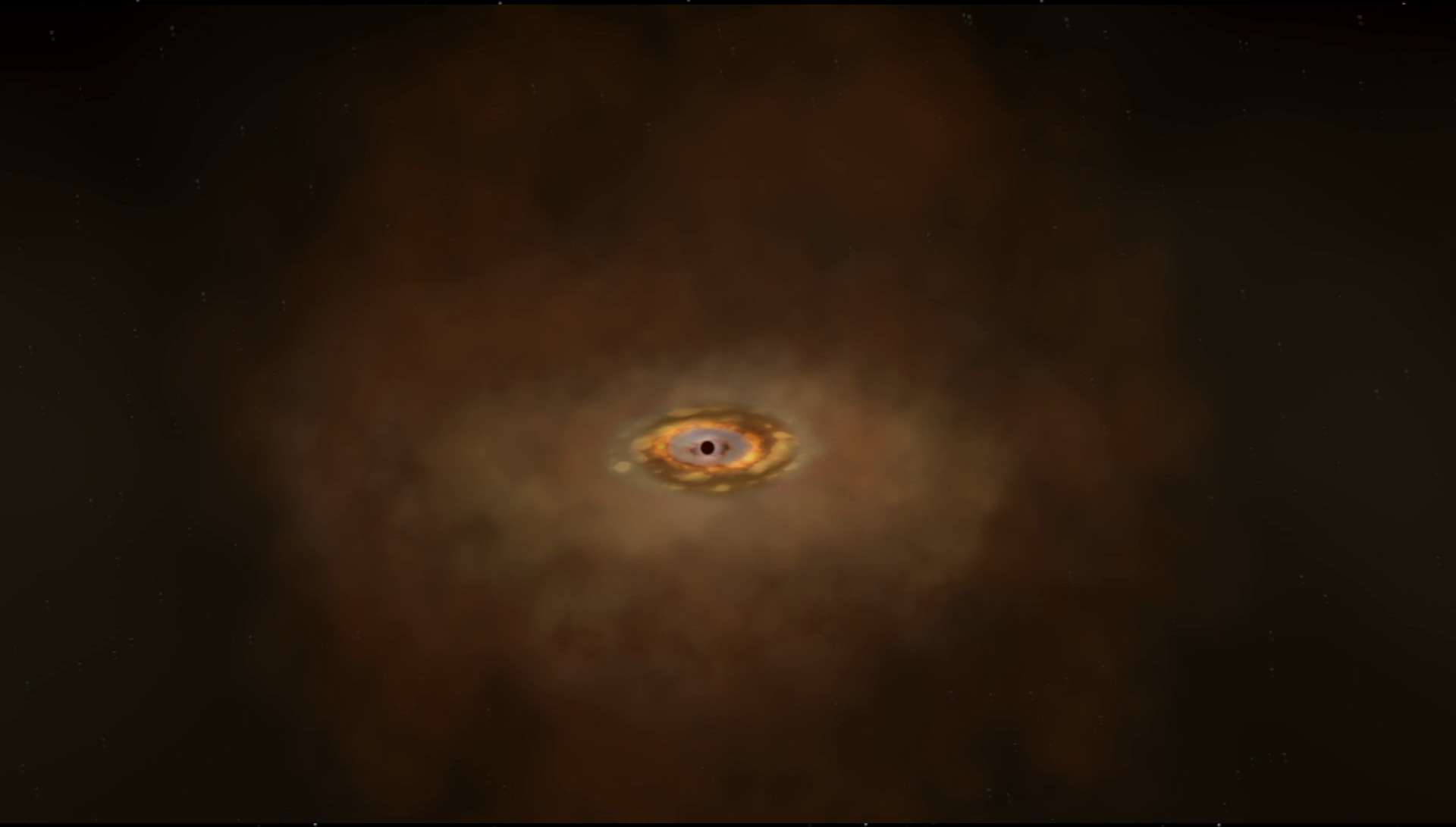
(Gofford et al. 2013)



(Tombesi et al. 2014)

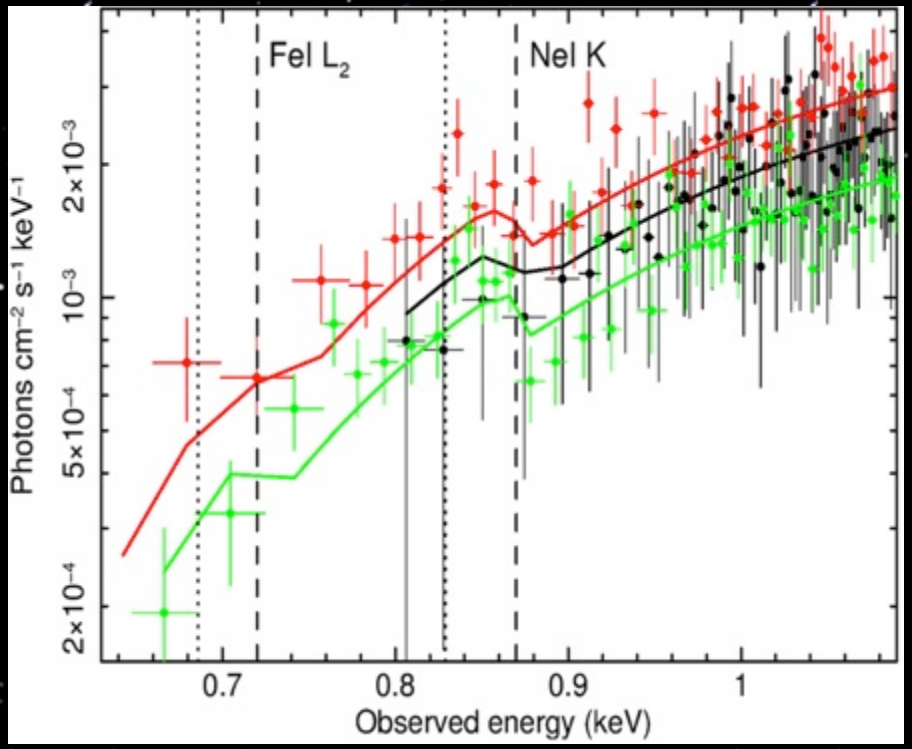


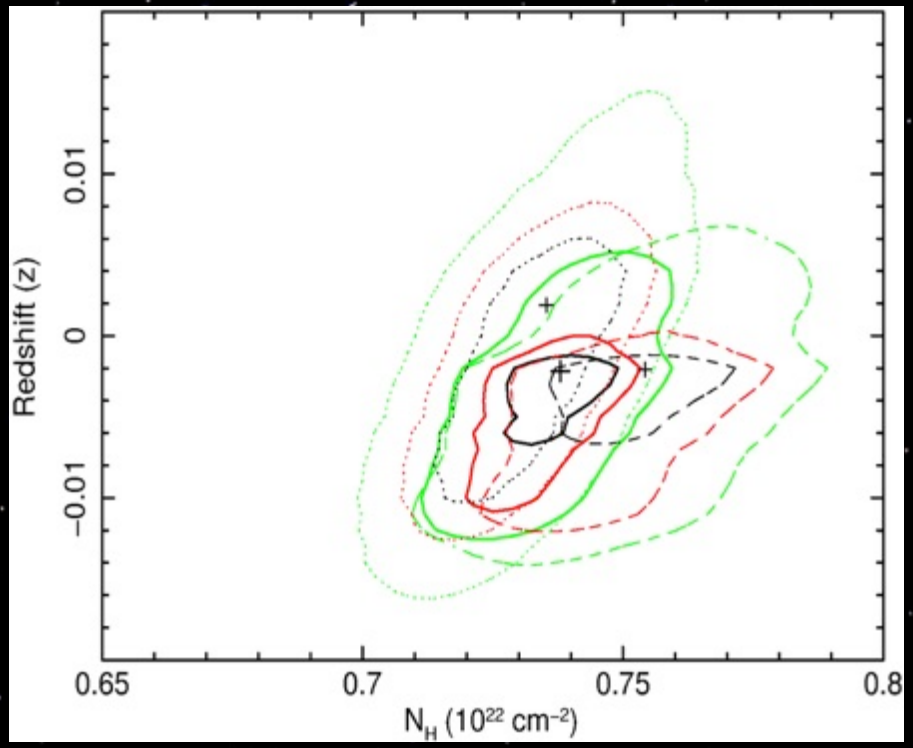
Hot bubble inflated by black hole winds/jets?



(credit: NASA/GSFC)

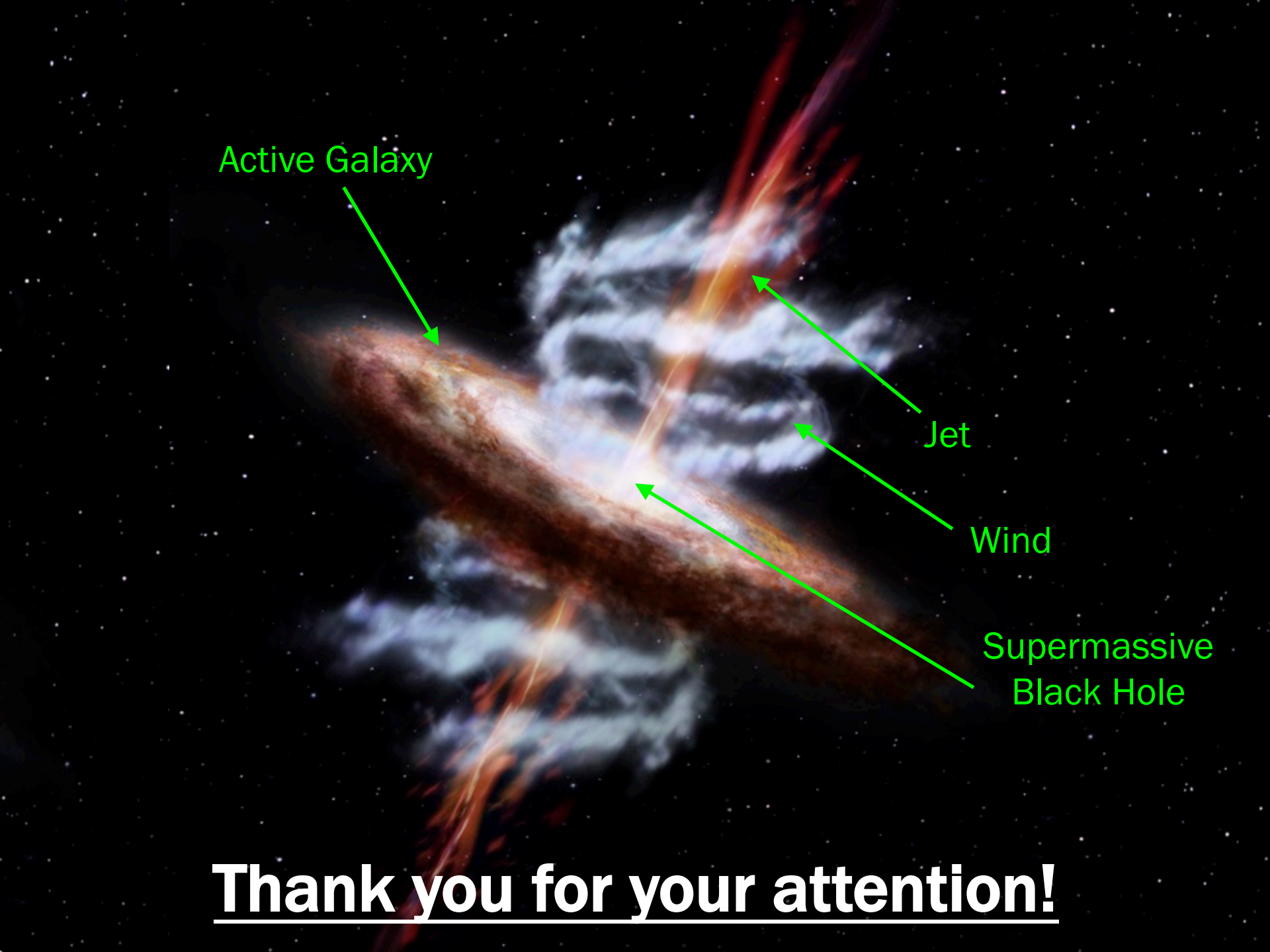
Excess Galactic Molecular Absorption in 3C111





(Tombesi et al. 2017)

- Atomic HI from radio surveys $N_H = 3\times10^{21}$ cm^{-2} + extra $N_H = 4.4\times10^{21}$ cm^{-2}
- Line of sight absorption from the Taurus molecular cloud in the Milky Way
- Need to consider total Galactic column density of $N_H = 7.4\times10^{21}$ cm^{-2} !!



Thank you for your attention!