AGN PHYSICS
Corona (temperature) and Disk (density)

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WHAT DETERMINES CORONAL TEMPERATURE?
Coronal properties

• Corona in AGN is responsible for all X-ray flux >1 keV

• 15<kT<150 keV, most 50-150 keV (Fabian+15,17; Ricci+17; Tortosa+17; Lanzuisi+19)

• R<10 $r_g$ for much of the power (Kara+16; Chartas+17)

• Some could be outflowing (Beloborodov99, Malzac+01, Wilkins+14), probably not static!

• Lower part dominates reflection, upper part dominates observed power-law
CORONA IS RADIATIVELY COMPACT
Dimensionless compactness parameter, GuilbertFabianRees83

\[ \ell = \frac{L}{R m_e c^3} \]

\[ l = \left( \frac{m_p}{m_e} \right) \left( \frac{R}{R_S} \right)^{-1} \left( \frac{L}{L_{Edd}} \right) \]

For AGN, \( \ell \) typically 10-1000
Compton cooling time < light crossing time
Photon Column Density = Density \times Size

\[ N_\gamma = \frac{L}{4\pi R^2 c E_\gamma} R \]

\[ N_\gamma = 2 \times 10^{26} \left( \frac{L}{L_{\text{Edd}}} \right) \left( \frac{R_S}{R} \right) \left( \frac{E_\gamma \text{ MeV}}{E_\gamma} \right) \]

\[ \tau = 200 \left( \frac{\sigma}{\sigma_T} \right) \left( \frac{L}{L_{\text{Edd}}} \right) \left( \frac{R_S}{R} \right) \left( \frac{E_\gamma \text{ MeV}}{E_\gamma} \right) \]
Schematic from Fabian94

PAIR PRODUCTION: electron-positron pairs form when photons and/or particles collide at energies $> m_e c^2 = 511 \text{keV}$

photon-photon collisions: $\gamma + \gamma \rightarrow e^\pm$ requires $\frac{\epsilon_1}{m_e c^2} \frac{\epsilon_2}{m_e c^2} > 2$

Svensson, 82,84, Zdziarski 85, many other papers and workers 80s + 90s

Concept of PAIR THERMOSTAT introduced

Schematic from Fabian94
PAIR PRODUCTION: electron-positron pairs form when photons and/or particles collide at energies \( m_e c^2 = 511 \text{keV} \).

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Concept of PAIR THERMOSTAT introduced

Schematic from Fabian94
Effect of addition of nonthermal particles
- Hybrid Plasma

\[ \frac{I_h}{I_s} = 1 \]

\[ \frac{I_h}{I_s} = 0.1 \]

Uses BELM, similar results for EQPAIR

Fabian, Lohfink, Belmont, Malzac, Coppi 17
See Zdziarski+93, Ghisellini+93, Coppi99...
MAXI J1820+070

D. J. K. Buisson et al.
With GR corrections

\[ \ell_{\text{nth}}/\ell_h = 0.0 \]

\[ \ell_{\text{nth}}/\ell_h = 0.01 \]

\[ \ell_{\text{nth}}/\ell_h = 0.09 \]

\[ \ell_{\text{nth}}/\ell_h = 0.17 \]

\[ \ell_{\text{nth}}/\ell_h = 0.23 \]

\[ \ell_{\text{nth}}/\ell_h = 0.29 \]

\[ \ell_{\text{nth}}/\ell_h = 0.33 \]
High Density Reflection

Measuring the density of the reflecting surface
HIGH Density Reflection Models appropriate

Coronal power

\[ f \]

\[ M (M_\odot) \]

\[ \log \text{density} = \]

AGN

“Standard”

BHB

10^8

10^7

10^6

10 M_\odot

Garcia+16

from Svensson & Zdziarski94
Garcia+16

$E^*F_E$ (erg cm$^{-2}$ s$^{-1}$)

$E$ (eV)

$\Gamma=2.3$, $\xi=50$

$\log(n_e)=15$

$\log(n_e)=16$

$\log(n_e)=17$

$\log(n_e)=18$

$\log(n_e)=19$

Incident
High Density Fit to low state

IRAS13224-3809

$n=10^{19}$

Energy (keV)
Densities $>10^{19}$ cm$^{-3}$

- Suite of models built by Michael Parker and Jiachen Jiang using the late Randy Ross’ code REFLIONX_HD (see Fabian&Ross07).
- “There are shifts of ionization potential and K-threshold energies, albeit very minor ($<<$eV). The shift grows with effective charge ($Z_{eff}=Z-N+1$). Meanwhile, there are virtually no shifts in the energy/wavelength of lines (Deprince et al. 2018, 2019).
- Dielectronic Recombination (DR) suppression affects heating/cooling and ionization balance. Current tests indicate enhancement of soft flux and Fe K emission, but this effect might depend on ionization (still under investigation, Garcia et al. in prep.)”
- REFLIONX_HD models applied to Cyg X-1 (Tomsick+18) and GX339-4 (Jiang+19a); RELXILLD used for low mass AGN (Jiang+19b).
Radiation Pressure Dominated

Gas Pressure Dominated

Jiang+19
The graph illustrates the relationship between the mass accretion rate (denoted as $\dot{m}$) and the black hole mass ($m_{\text{BH}}$) on a logarithmic scale. The black hole mass is plotted on the x-axis, while the mass accretion rate is on the y-axis. Different lines represent different values of a parameter $f$, with $f=0$, $f=0.7$, and $f=0.9$. The regions labeled as "radiation" and "gas" indicate different regimes of mass accretion processes. The horizontal lines at $10\% m_{\text{Edd}}$ and $1\% m_{\text{Edd}}$ provide reference points, with $m_{\text{Edd}}$ denoting the Eddington luminosity.
• High density reflection is important for BHB and AGN with $M_{BH} < 5 \times 10^7 \, M_{\text{sun}}$.

• Extraction of energy from disc to corona plays an important role.

• Discs in luminous AGN are radiation-pressure supported and discs in BHB gas-pressure supported following results from SZ94 (i.e. modified SS73).
NGC4151

Lubinski+10       see alsoKeck+15, Beuchert+17

INTEGRAL

Exteme flux states of NGC 4151

OSSE, Comptel
INTEGRAL/PICsIT   SPI

Lubinski+10       see alsoKeck+15, Beuchert+17
NuSTAR results

Blue AGN, Red BHB

$R=10r_g$ unless indications otherwise    Fabian+15