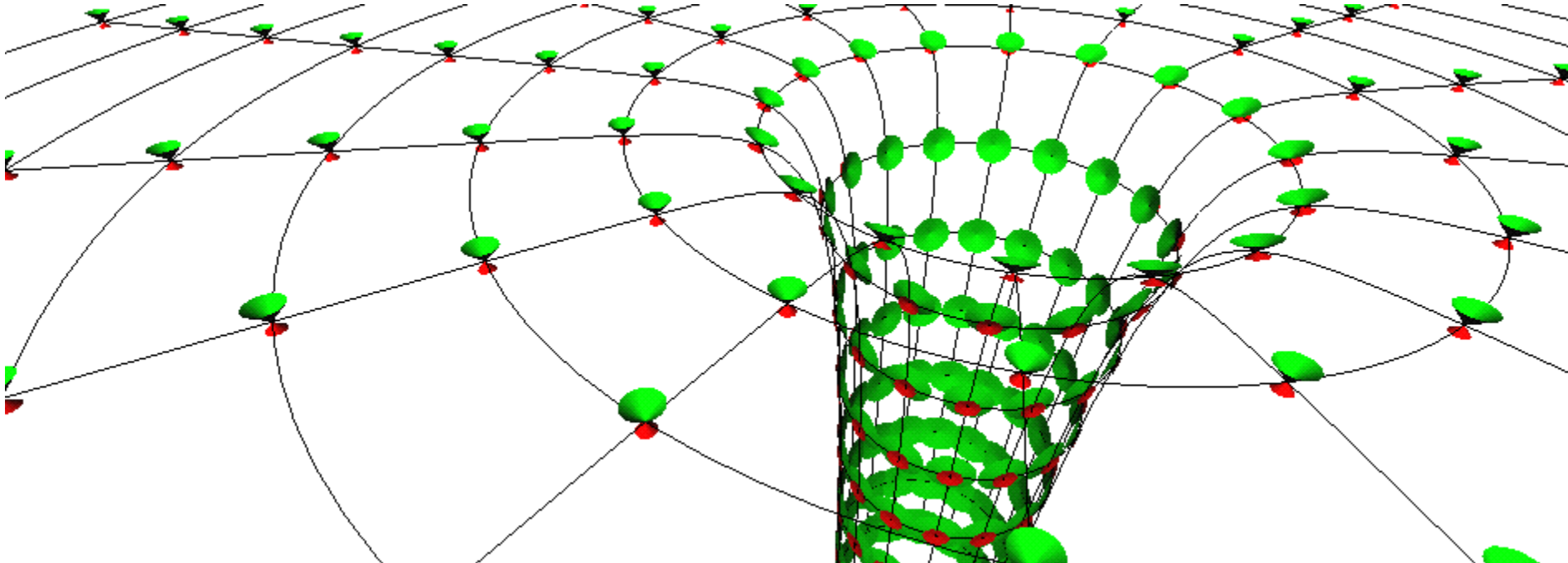
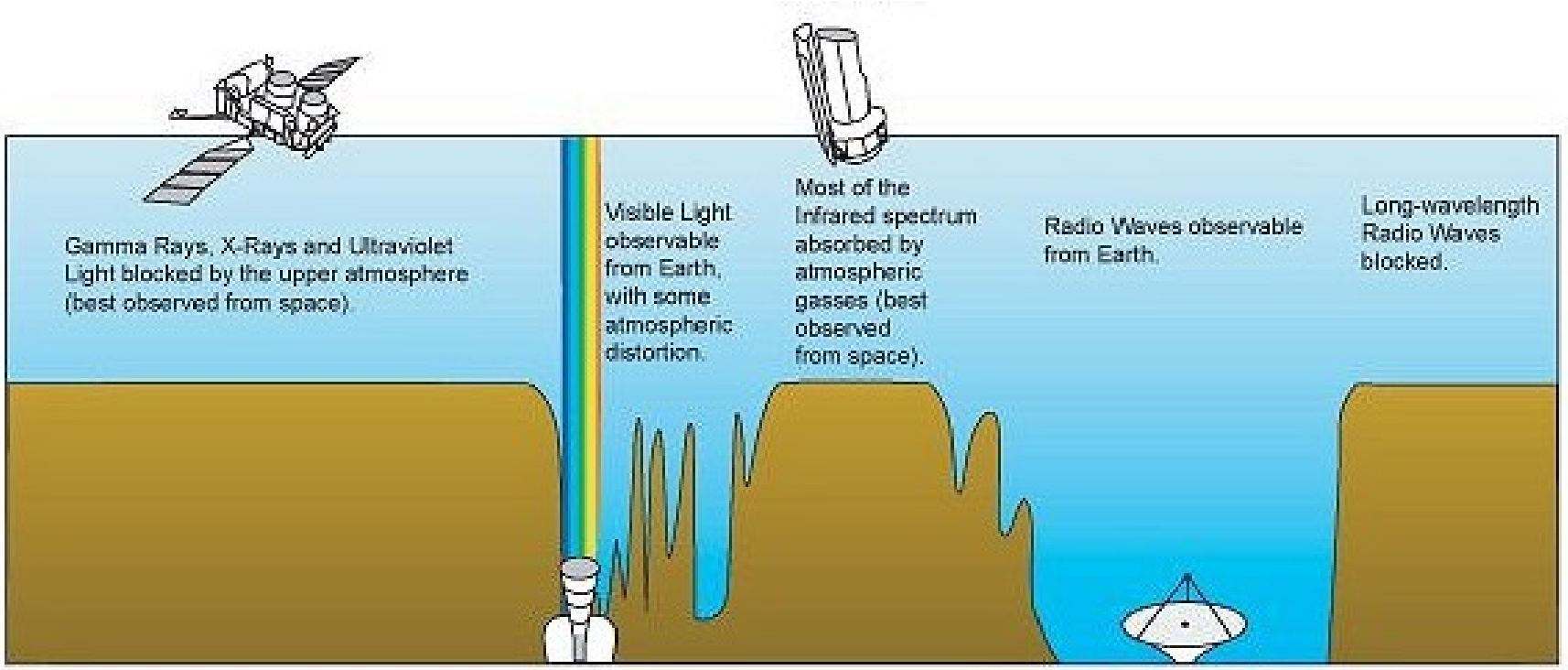
# Black holes and Active Galaxies and X-ray Astronomy

## A personal view of UK-Japan collaboration

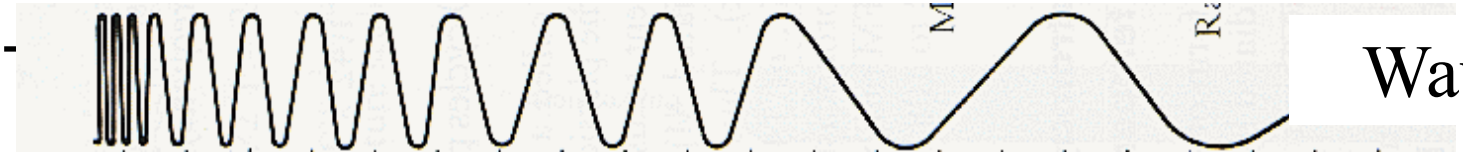
Prof Chris Done, University of Durham



# X-rays blocked by atmosphere



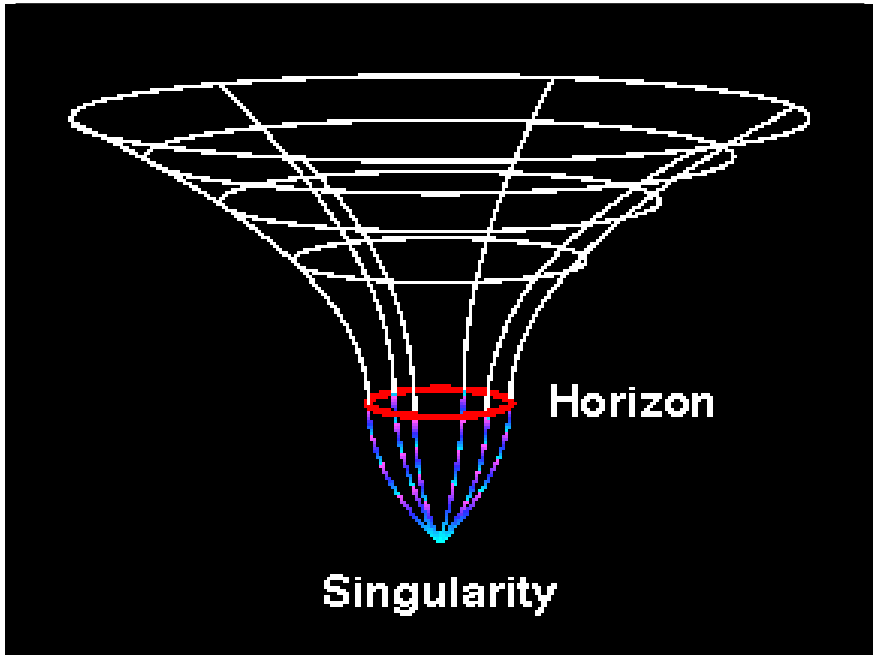

X-rays Visible Radio



Wavelength

# Observing black holes?

- How to test this ?
- The thing about a black hole, its main distinguishing feature is its black! And the thing about space, your basic space colour is its black! So how are you supposed to see them ? Red Dwarf



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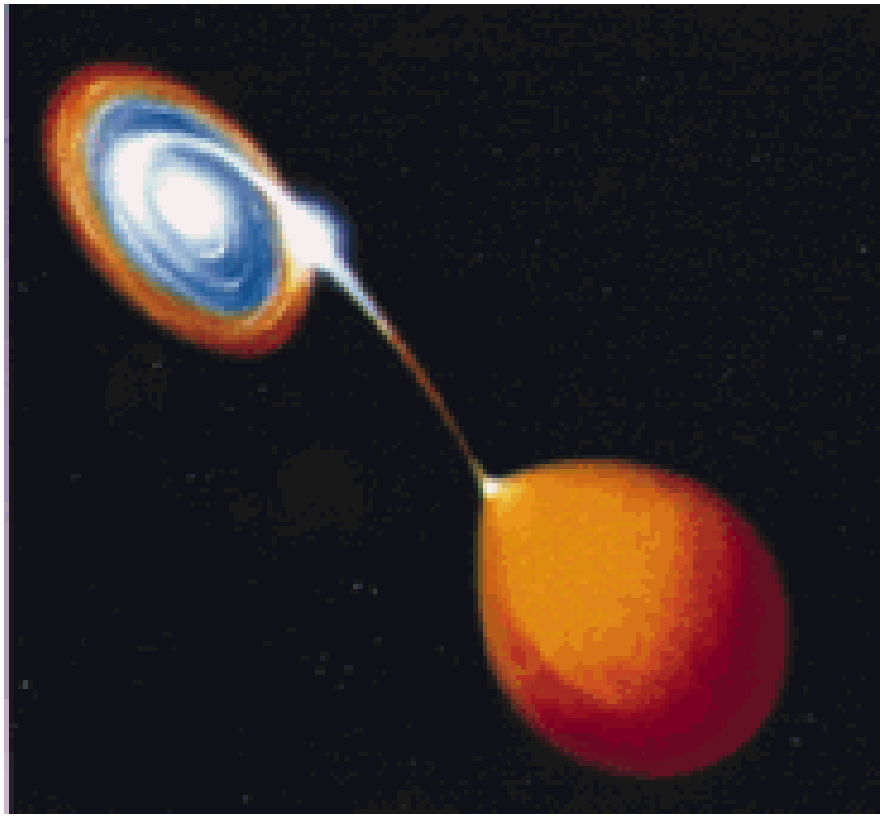
# Accretion

- Single particles orbit
- Gravitational orbits - inner ones faster
- Continuous ring of gas – friction dissipates energy so material can fall inwards
- Enormous energy released by infalling matter - BRIGHT accretion discs glowing X-ray hot



# Spectra of accretion flow: disc

- Differential Keplerian rotation
- Friction: gravity → heat
- Thermal emission: $L = A\sigma T^4$
- Temperature increases inwards until minimum radius $R_{\rm lso}(a_*)$
  For $a_*=0$ and $L \sim L_{\rm Edd}$ $T_{\rm max}$ is
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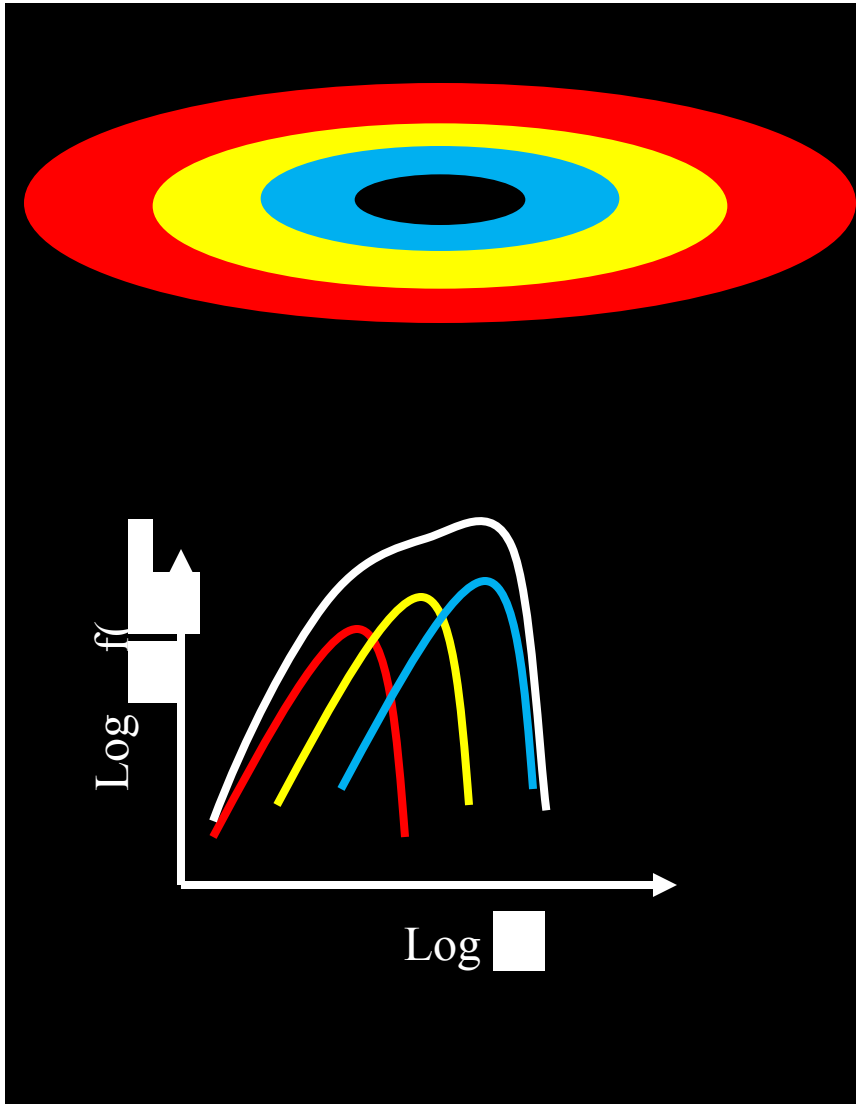

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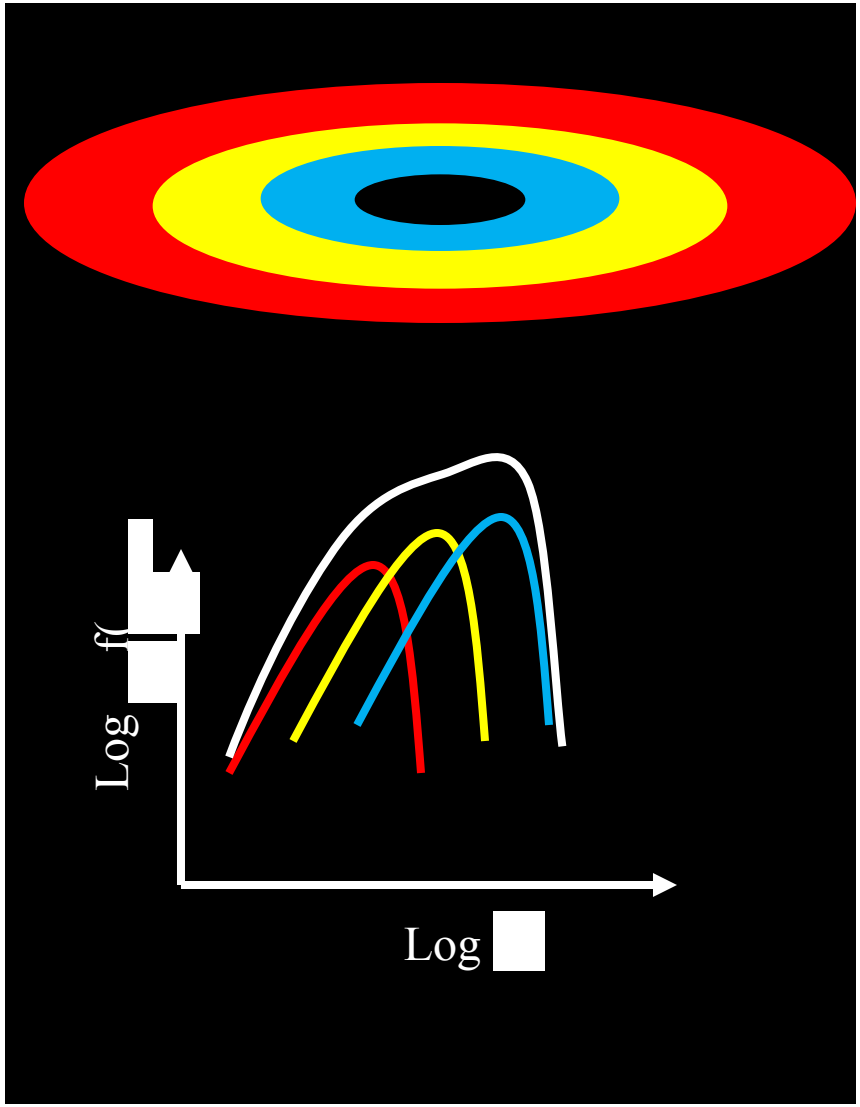

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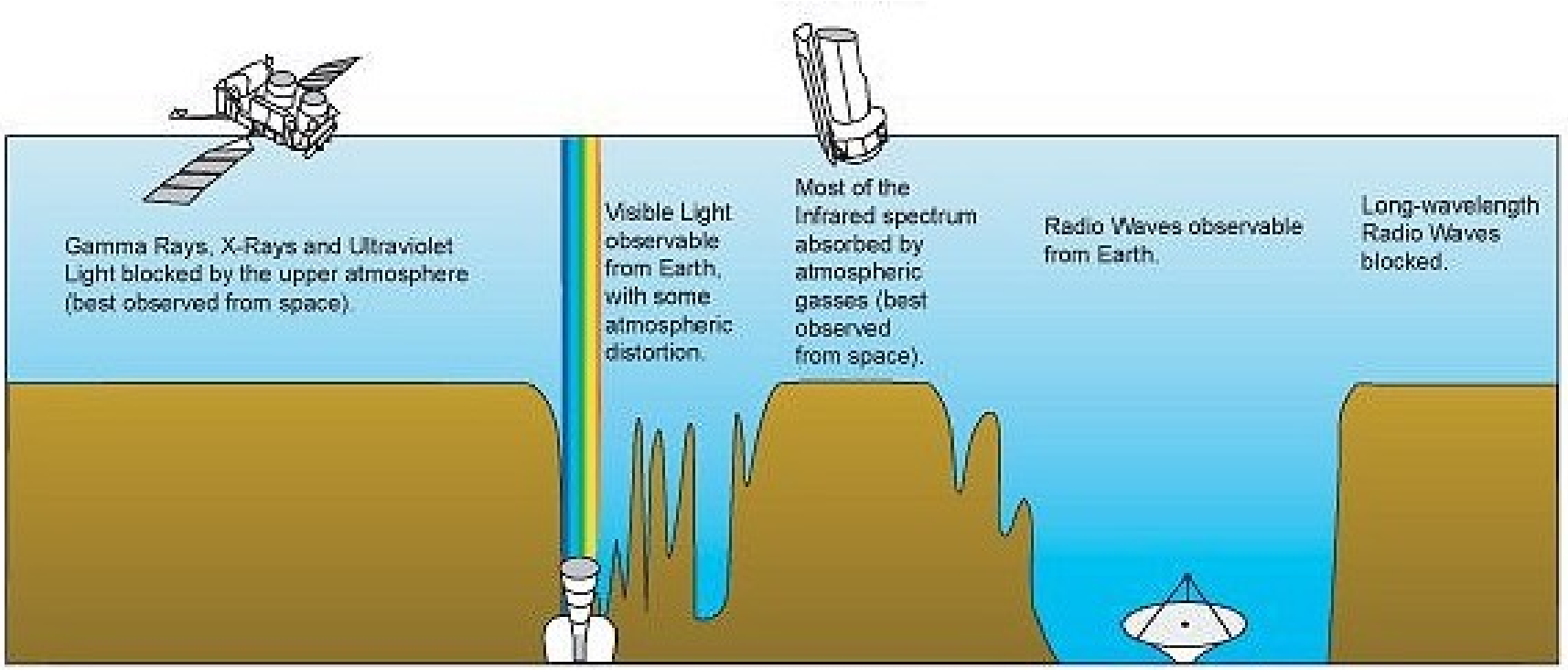


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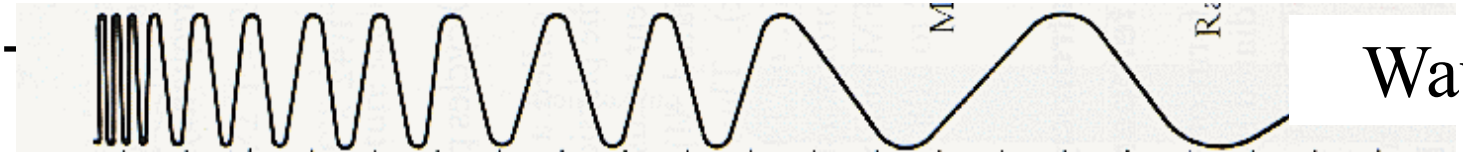

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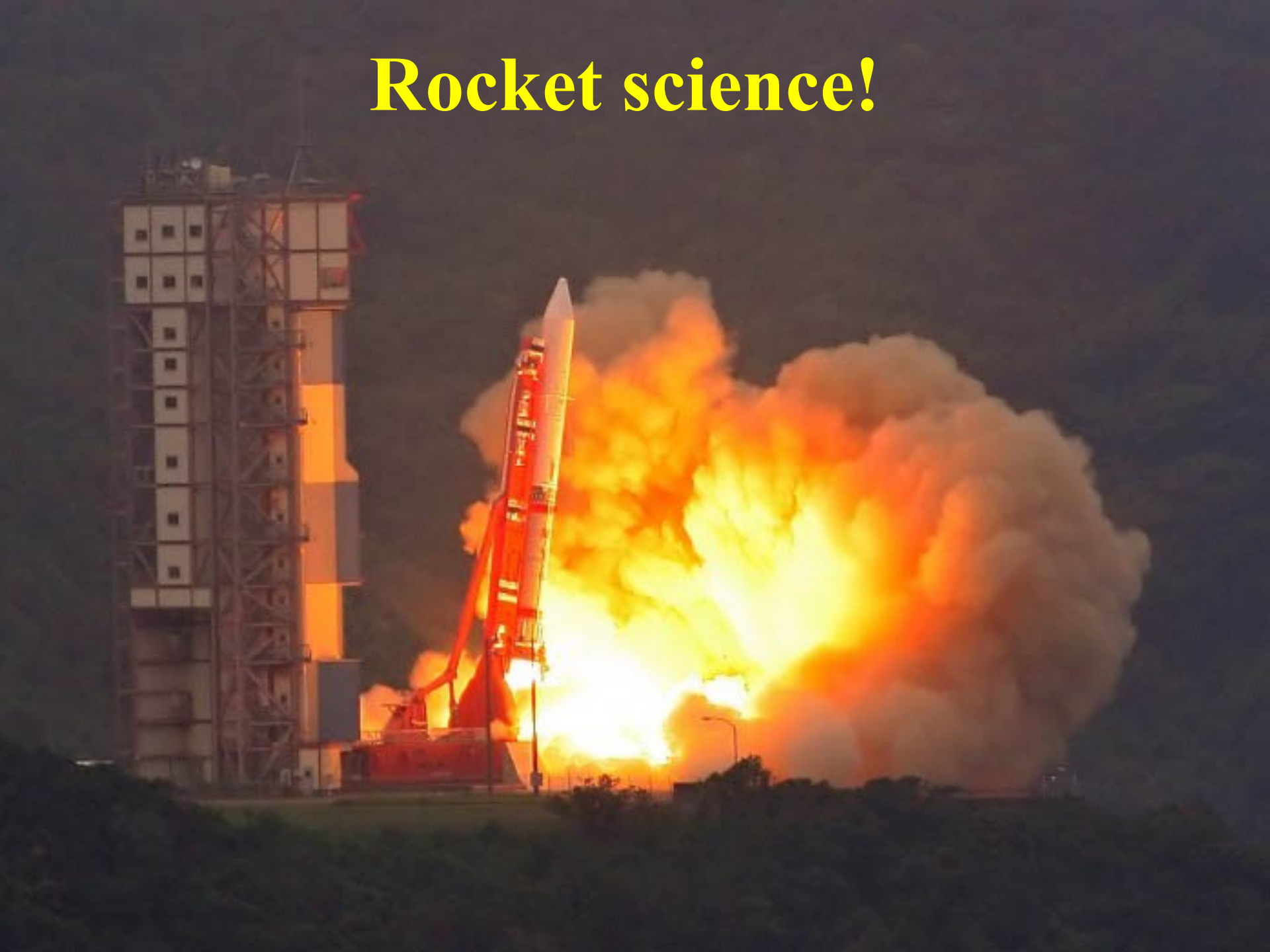
# Rocket science!

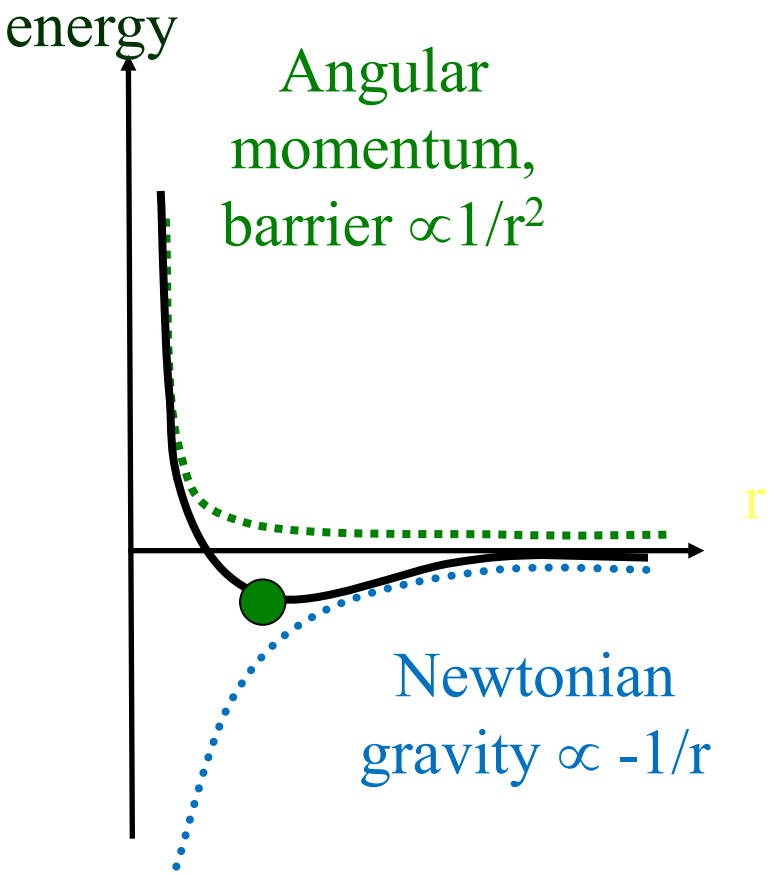


# X-rays are how black holes were discovered

- Nobel Prize to Giaconni in 2002 for discovery of cosmic X-ray sources
- Flew Geiger counter on a rocket in 1962!
- Discovered accretion powered sources
- BH were proposed before this, but no-one had thought of accretion as a way that we could see them!
- X-ray astronomy transforms black holes from theoretical speculation to observable objects

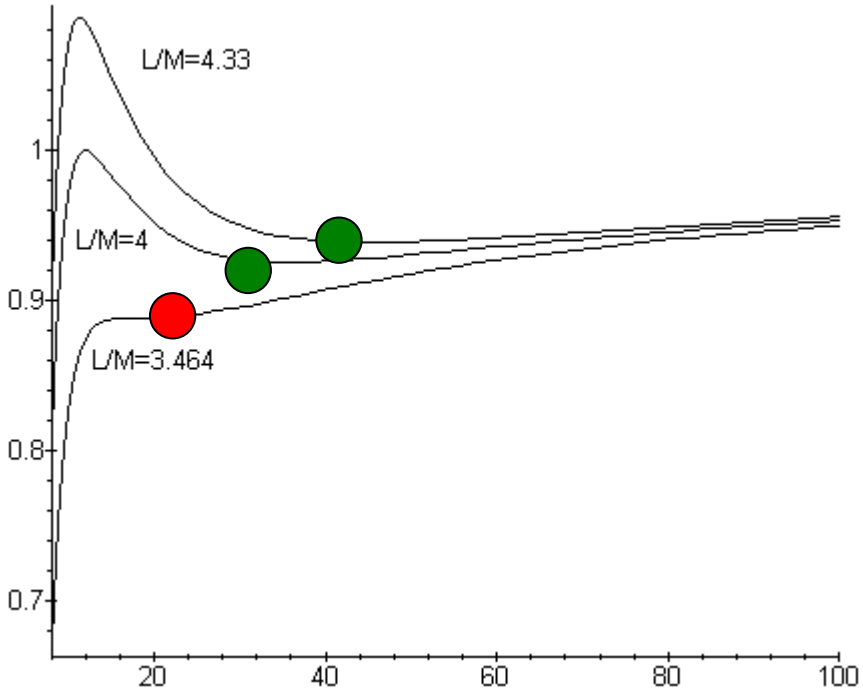
# Orbits in general relativity

- Newtonian orbits
- Gravity attractive – wants to be closer in.
- but if closer then rotate faster due to angular momentum conservation
- Bigger outward centrifugal force!
- Stable orbits everywhere



# Orbits in general relativity

- Not true in general relativity
- When within a factor ~3 of the event horizon then no more stable orbits
- Last stable circular orbit – sets the inner edge of the disc!
- Depends on black hole spin



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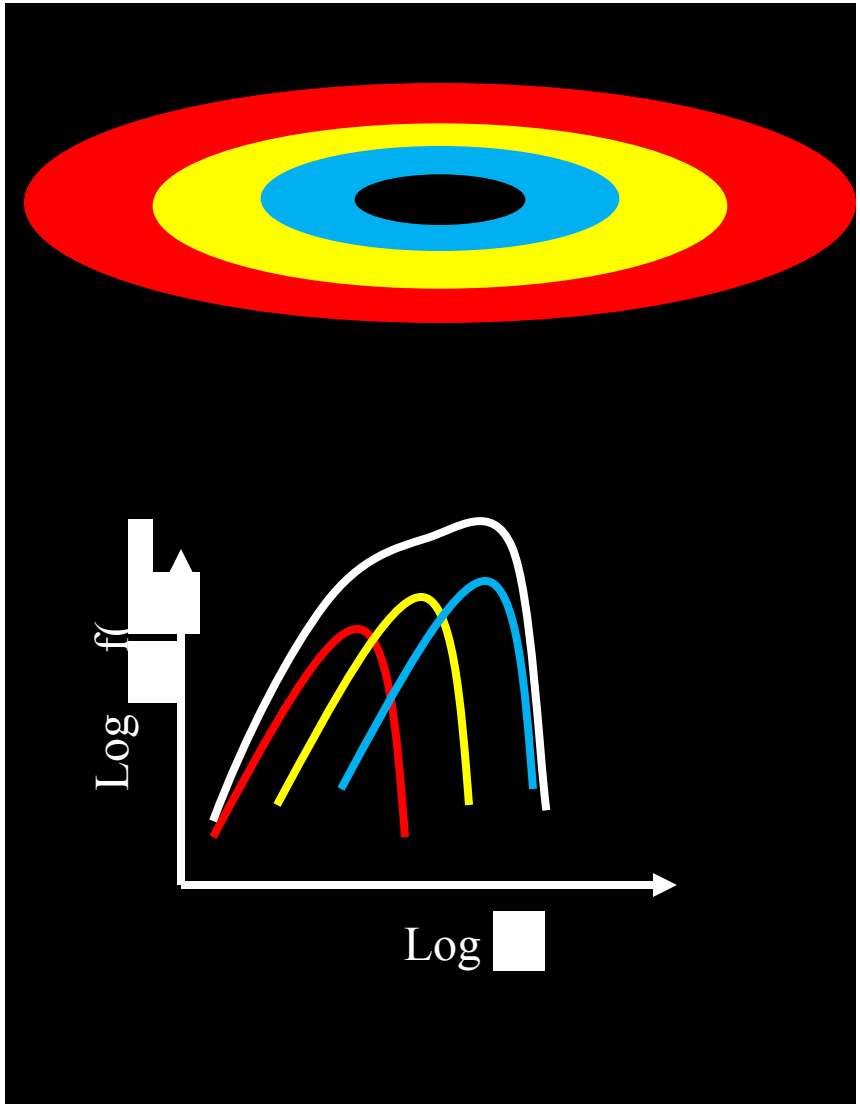
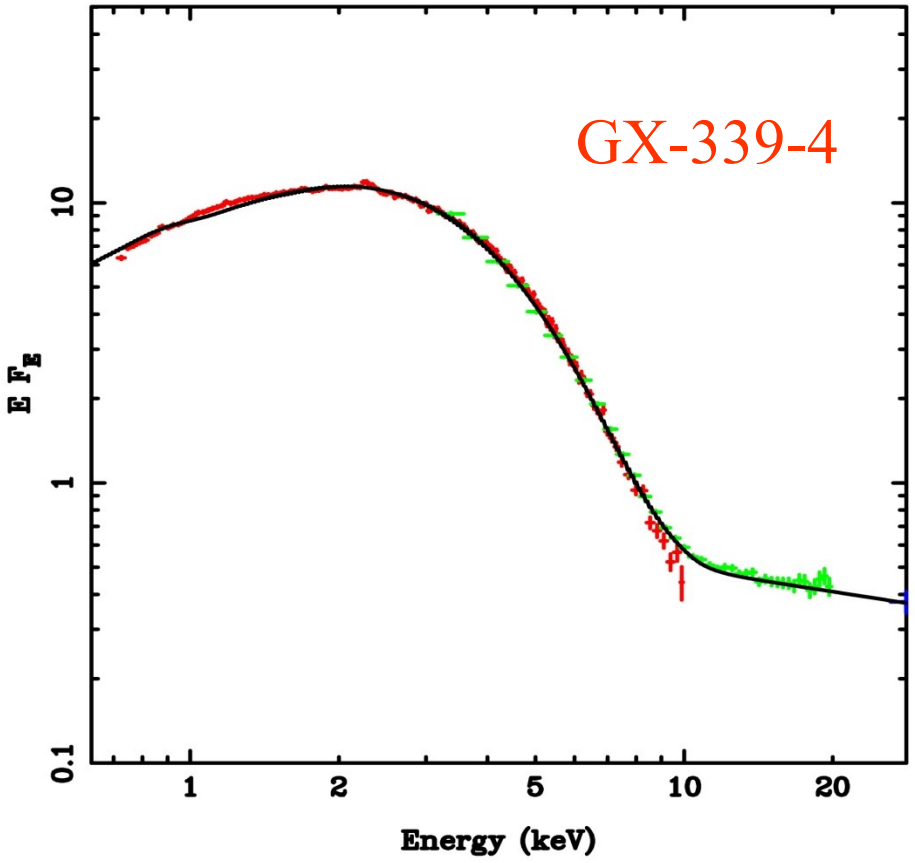


# Observed disc spectra in BHB!!

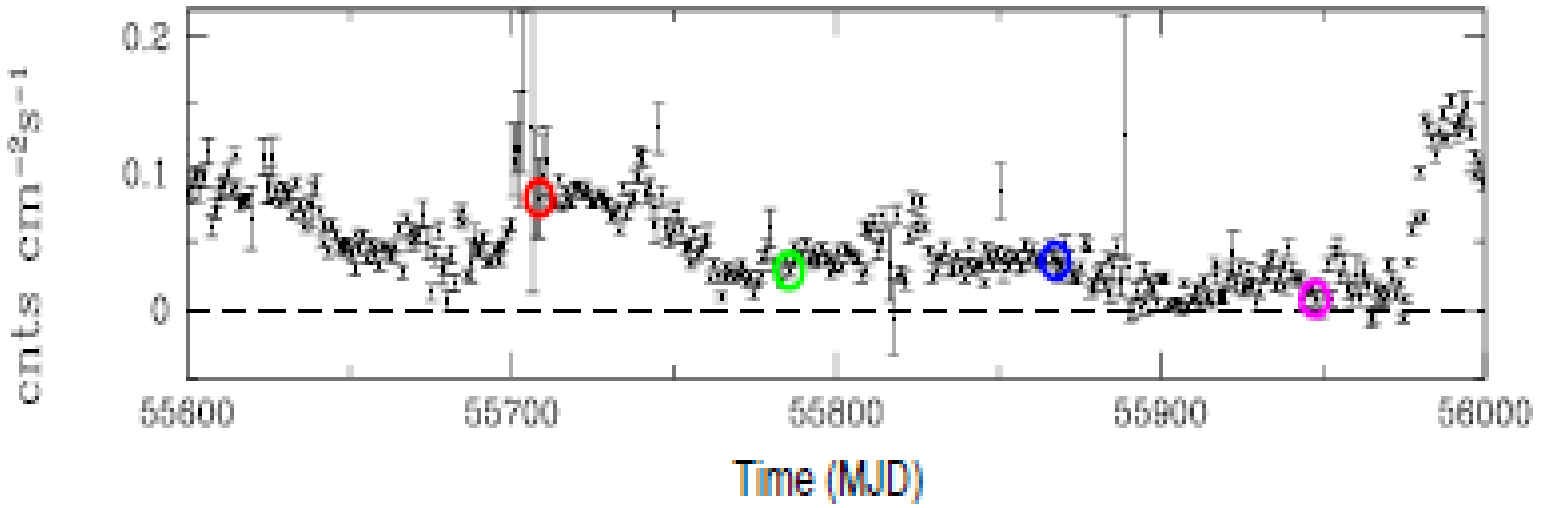
- Fit disc models to get maximum temperature and flux in the disc
- $L=2\pi D^2 F/\cos i = A T^4$
- $A=2\pi r_{in}^2 R_g^2$ ($R_g=GM/c^2$)
- Get one measure of inner radius IF we know the system parameters!




Kolehmainen et al 2010

# BHB – Quasars for the impatient

- BRIGHT! Huge amounts of data, long term variability (days –years) in mass accretion
- LMC X-3 as seen by the MAXI all sky monitor on ISS




DGK07

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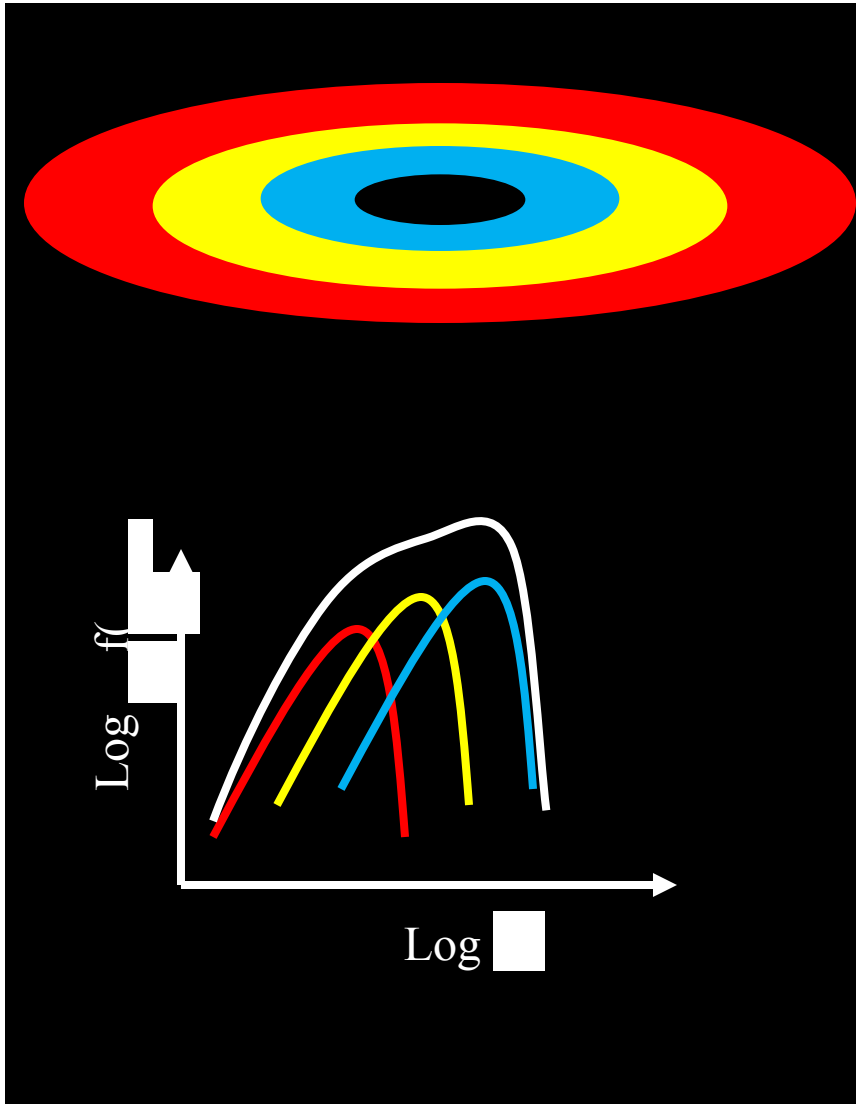

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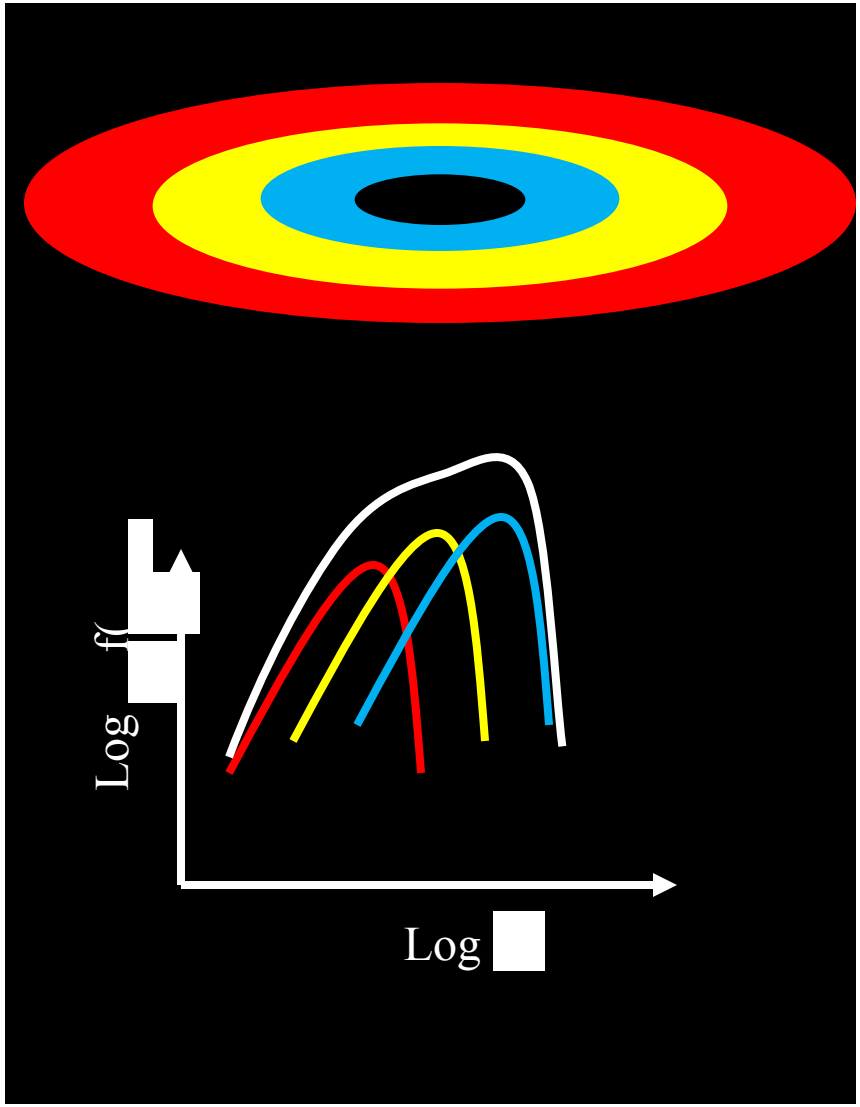
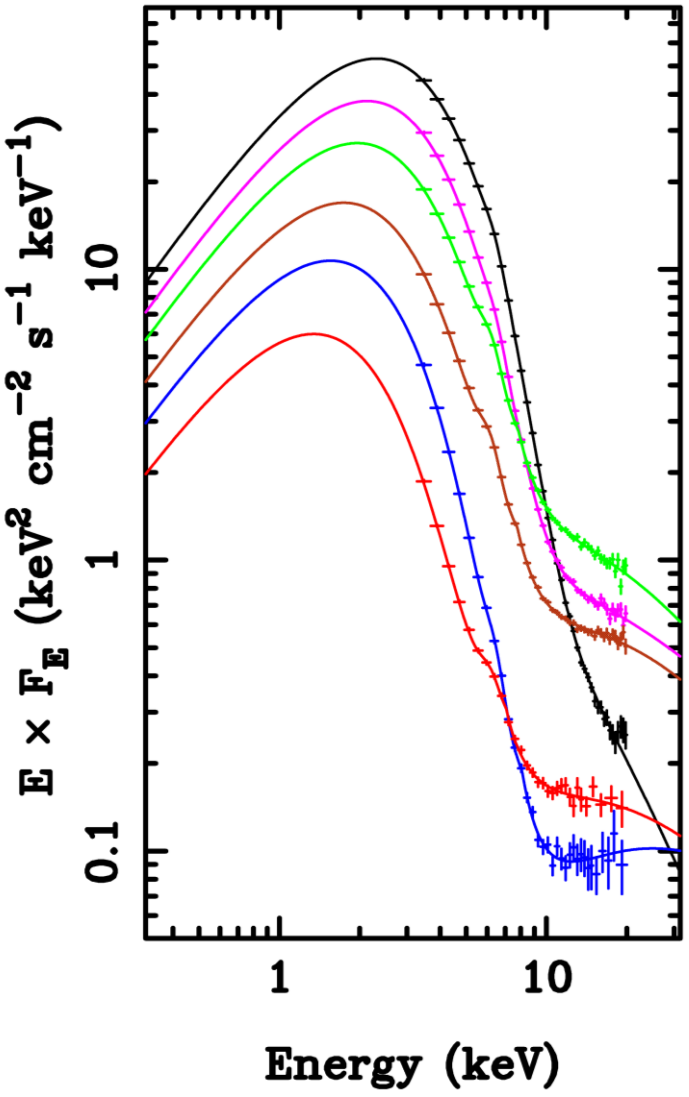
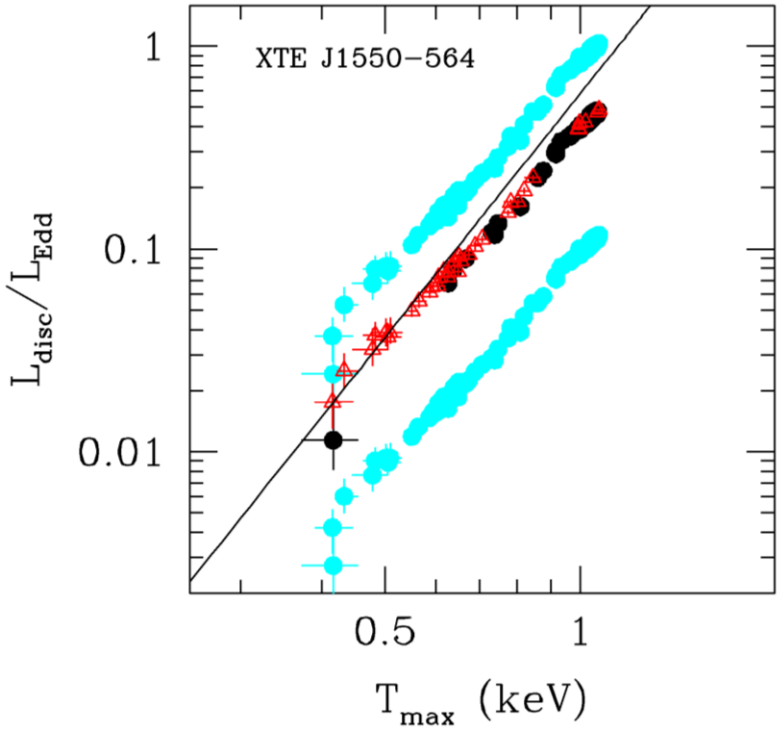


# Variability of disc: long timescale

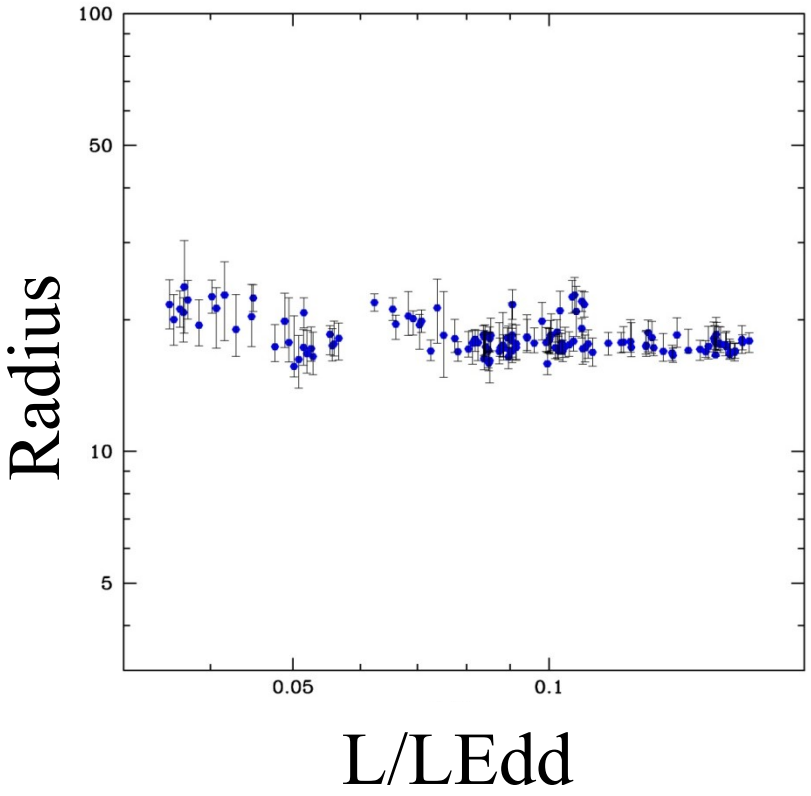


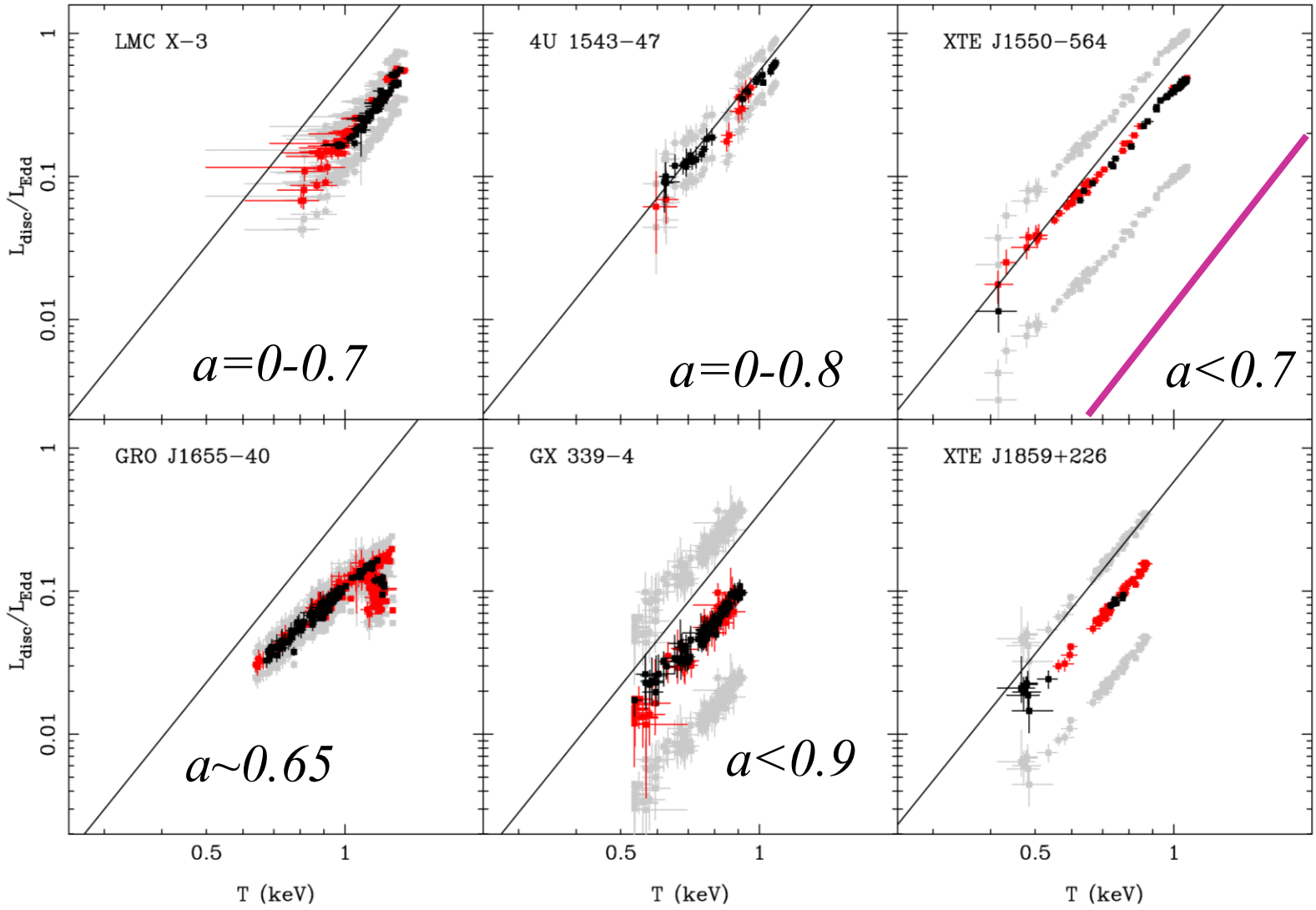

- $L/L_{Edd} \propto A T^4_{max}$
- Constant size scale – last stable orbit!! BH spin

# Disc spectra: last stable orbit

- $L/L_{Edd} \propto T^4_{max}$ (Ebisawa et al 1993; Kubota et al 1999; 2001)
- Constant size scale – last stable orbit!!



# Observed disc spectra




Done, Gierlinski & Kubota 2007