Fe Kα excitation by electron impact

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&

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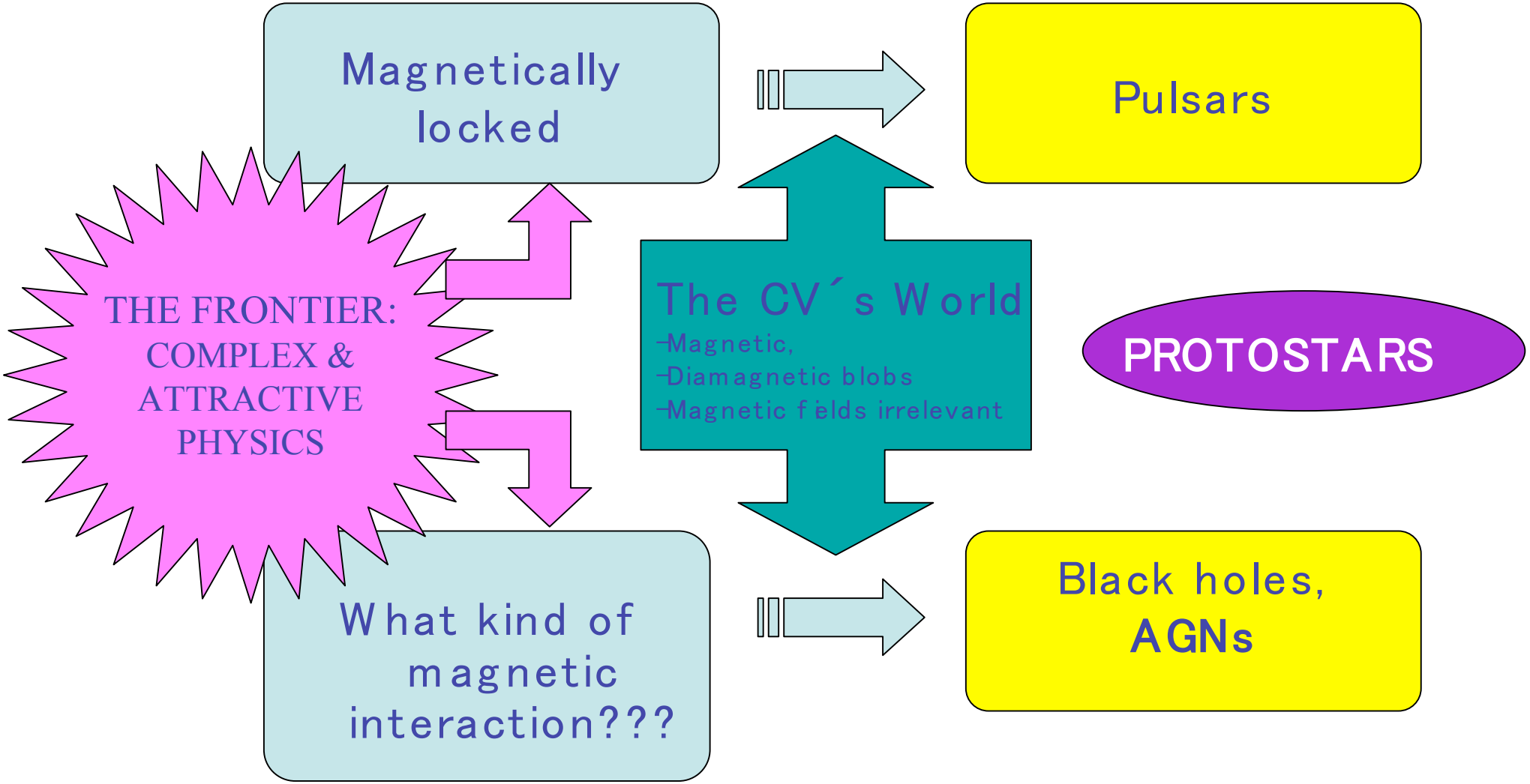
MENU

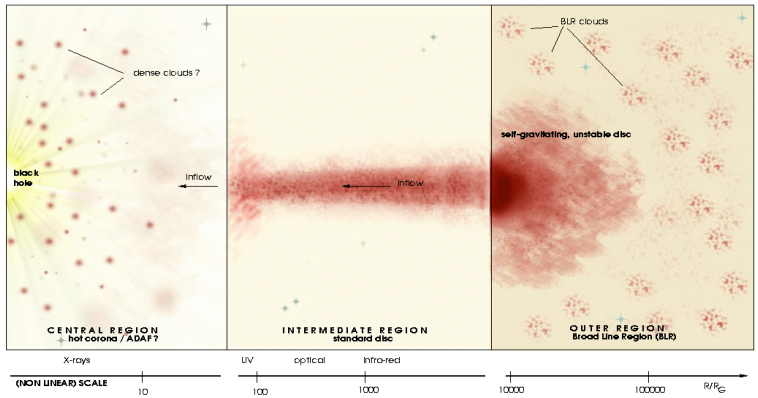
1. Accretion disks & generation of electron beams
2. Interaction of electron beams with matter
3. The numerical Lab
4. Results & Interpretations
5. Conclusions

The physics of accretion-outflow

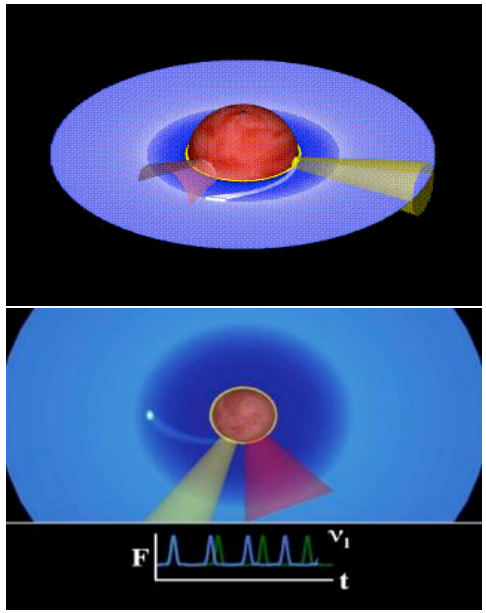


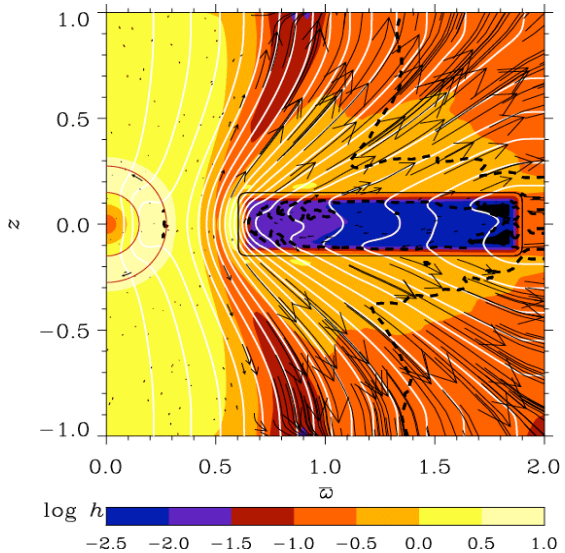
1. Accretion disks & the generation of electron beams

Interacting Binaries

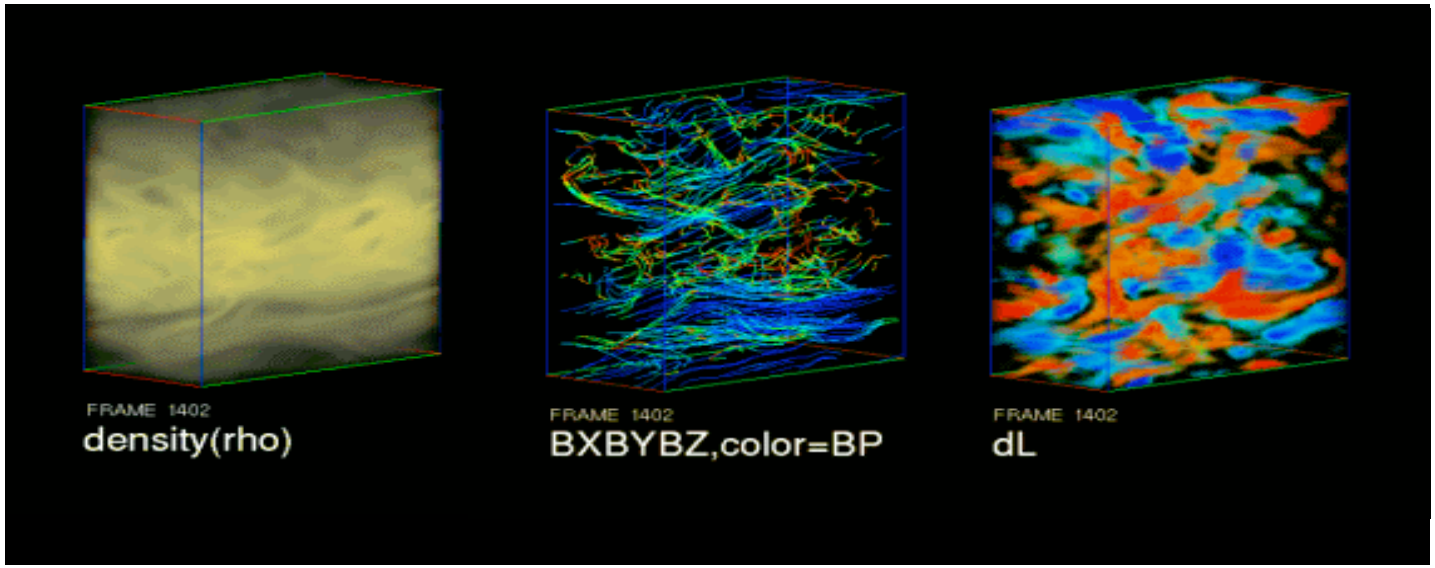


AGNs





T Tauri Stars



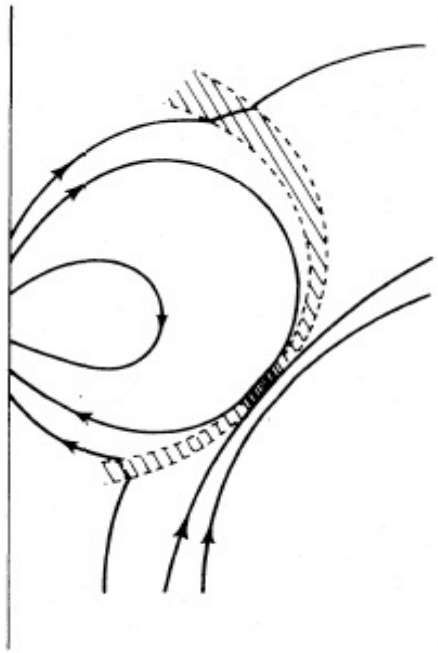
Hawley, 2003

…of ***magnetized*** *accretion disk undergoing the MRI …*

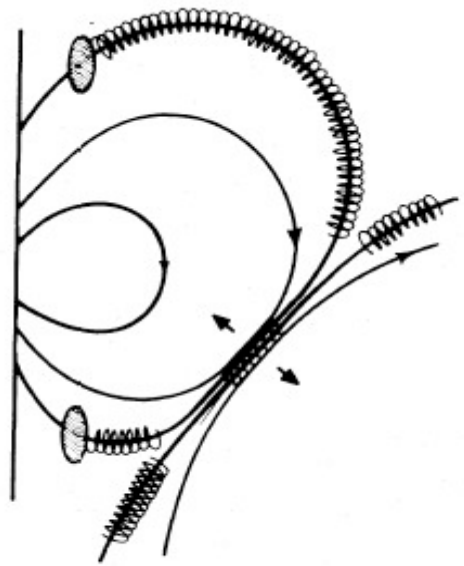
Cosmic ray and X-ray

Reconnecting magnetic fields will accelerate the electrons and heat the plasma

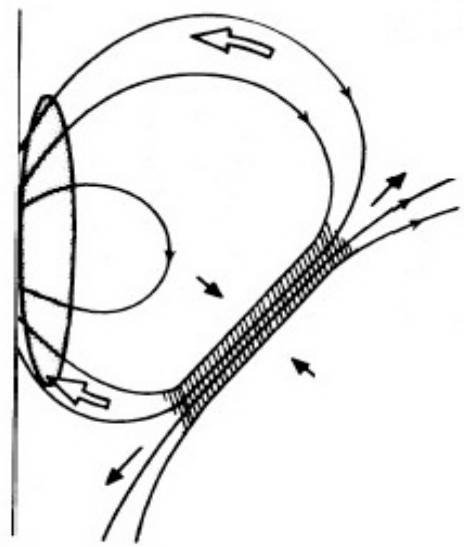
Heating by radiation from shock waves



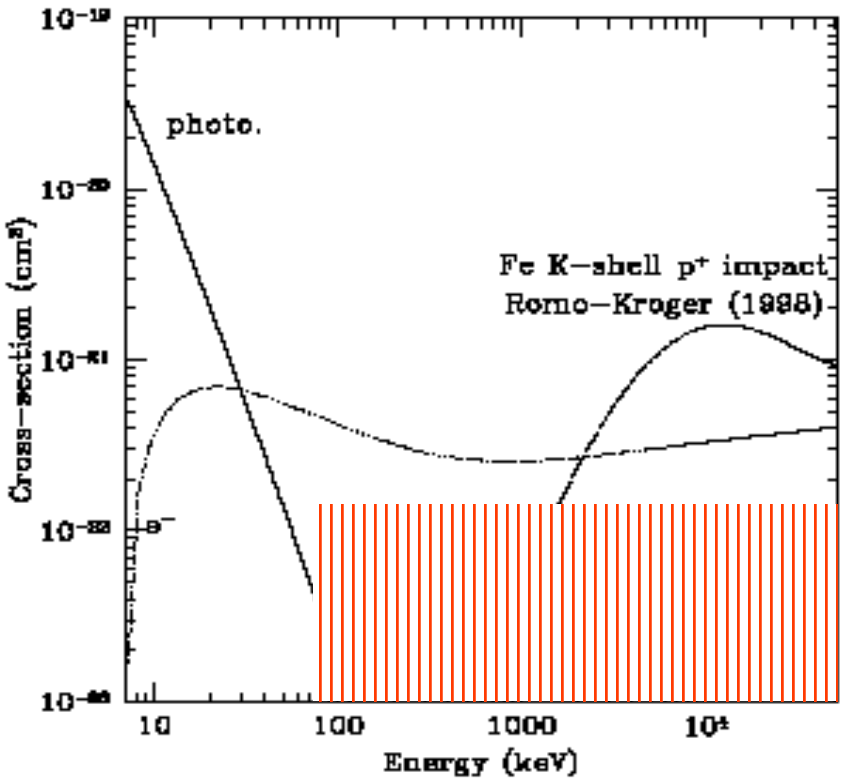
Turbulence Onset: Electric fields accelerate particles



Reconnection: particles are conducted to the chromosphere

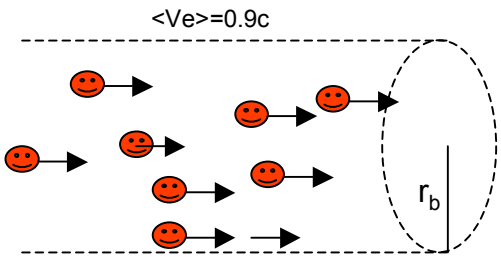


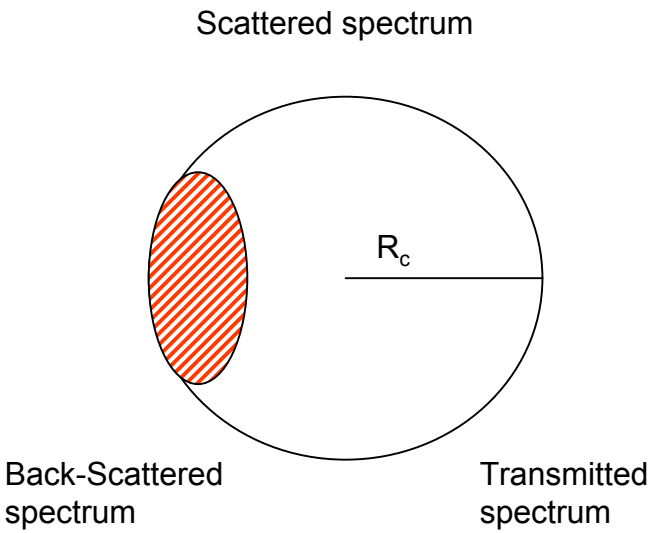
Interaction of electron beams with matter

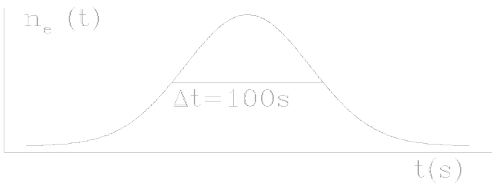


- If ε<100keV, $\sigma_{ph} >> \sigma_{el}$
- If ε<100keV, $\sigma_{ph} << \sigma_{el}$

The numerical Lab







$r_b = 3\ 10^{12}cm$
$R_c = 3\ 10^{12}cm - 10\ 10^{12}cm$
$n_c = 10^{11}cm^{-3}$
Solar abundances
Electron energy distribution:
maxwellian relativistic

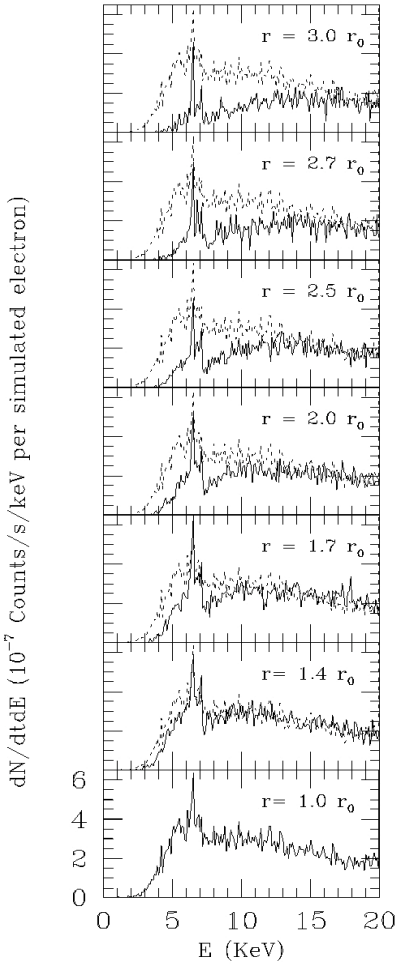
H, He, O, C, Ne, N, Mg, Si, Fe, S

The propagation of a high energy particle generates a cascade of secondary particles: a shower

Numerical treatment: Montercarlo code in PENELOPE (www.iaea.org)

Relation with the depth of the cloud ($n_e = 10^{11} cm^{-3}$)

Transmitted X-ray

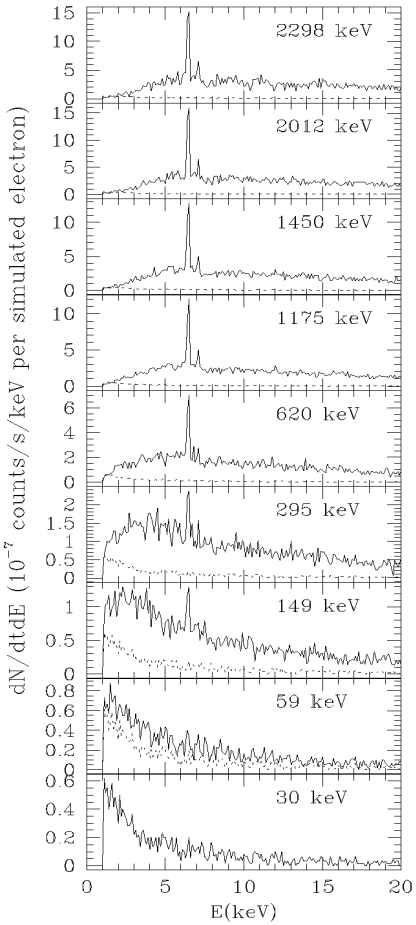


"Soft" electron beams will be absorbed and the output X-ray spectrum will depend on:

- The gas column
- The relative orientation with the observer

ΔR (10^{12}cm)	N_H(1.25 10^{24} cm^{-2})
3	0.48
4	0.64
5	0.80
6	0.96
7	1.12
8	1.28
9	1.44
10	1.60

Back-Scattered X-ray

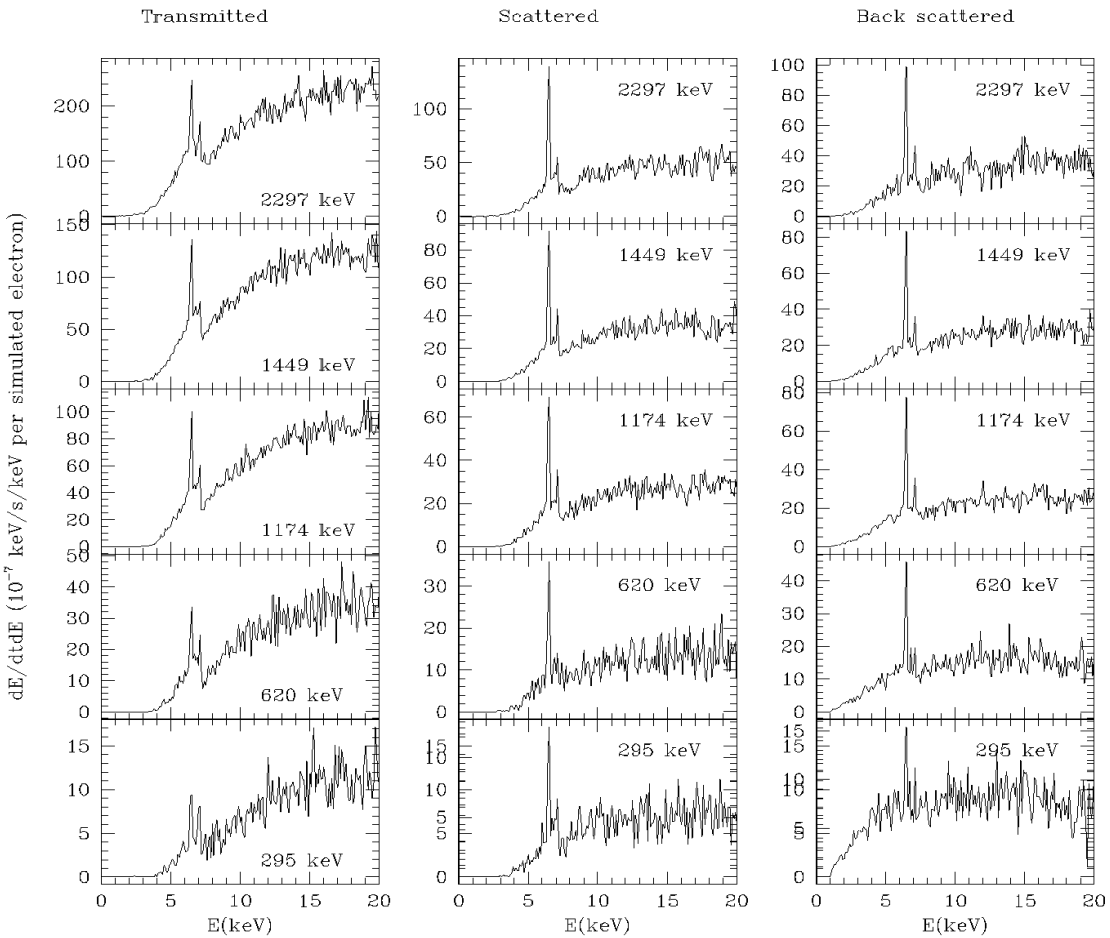


Gómez de Castro & Antonicci 2004

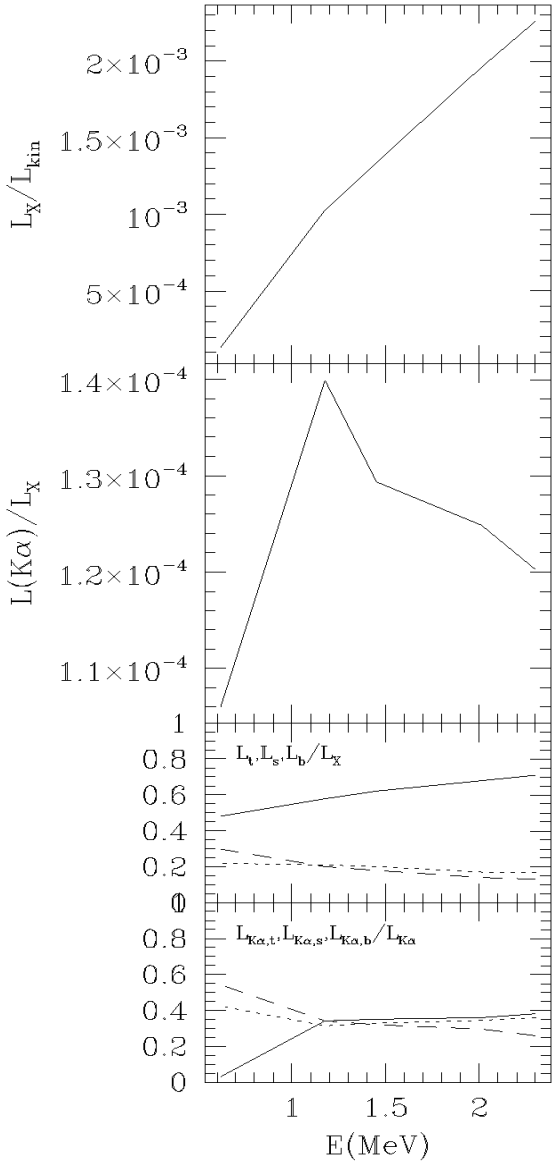
4.Results & Interpretation

<u>Relation with the electrons energy</u>

- E<100keV, electrons are rapidly absorbed, X-ray radiation only from the hot-spot.
- E≈2.2MeV, 99.7% of the electrons reach the rear of the cloud.



Rc =6 10^{12} cm

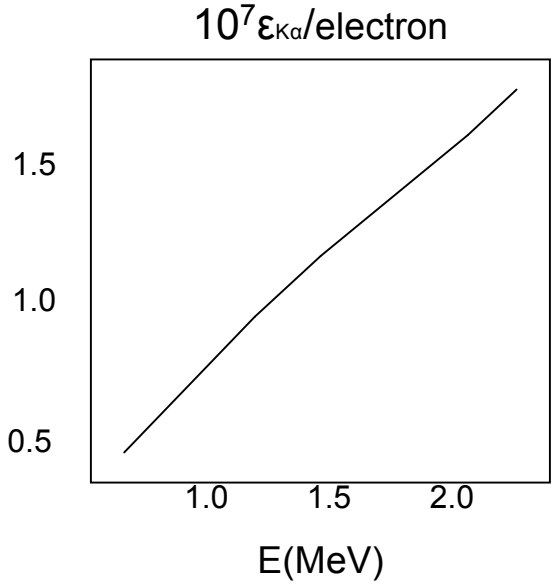


The kinetic energy is spent into:

- X-ray continuum radiation (0.1 %)
- Fe Kα emission (0.01%)
- GAS HEATING!

Only 1% of the incident electrons with kinetic energy 2MeV reach the back of a 6 10^{12} cm cloud and their average energy is degraded to 1.44 MeV

$$< \varepsilon_{K\alpha}(E) >= \frac{L_{K\alpha,t} + L_{K\alpha,b} + L_{K\alpha,s}}{4\pi}$$



$$F_{K\alpha}\left(\frac{counts}{s\cdot cm^2}\right) \geq 1.04\cdot 10^{-56} N_e \left(\frac{d}{1Mpc}\right)^{-2}$$

Thus, for electrons with mean kinetic energy 1MeV, Ne≈3.1 10^{54} -2.49 10^{55} to reproduce the MCG-6-30-15 counts (narrow and broad component, respectively)

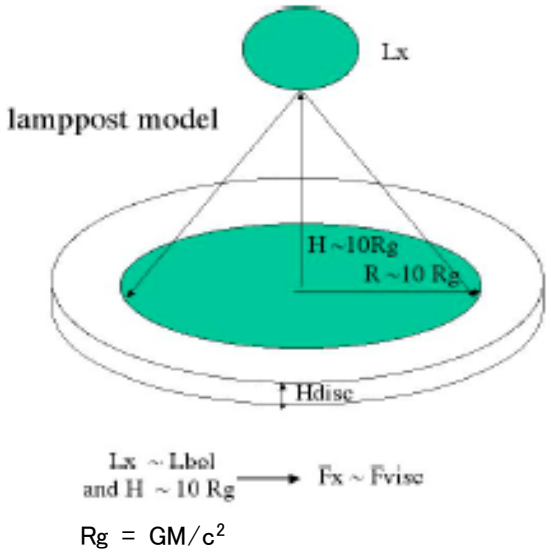
The kinetic luminosity of the electrons (assuming 100 s injection time):

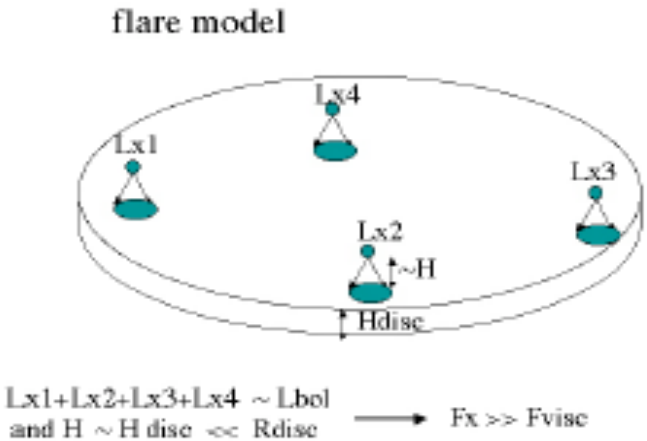
$$\log L_{KIN} = 46.8\text{-}47.7$$

The elctron kinetic luminosity measured for radio-loud AGNs (Celotti et al 97) is in this range: $45<\log L_{KIN}<48$

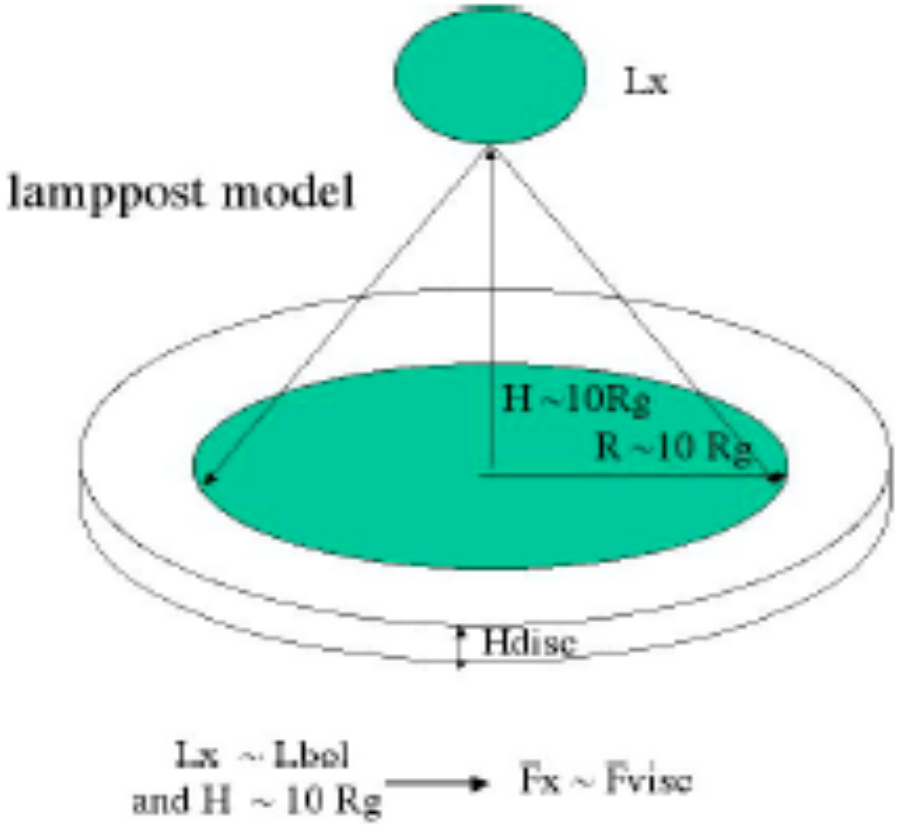
The black hole paradigma/s

(the presence of very hot plasma emitting in hard X-rays is proposed to explain the Fe Kα line emission from the inner border of the accretion disk)



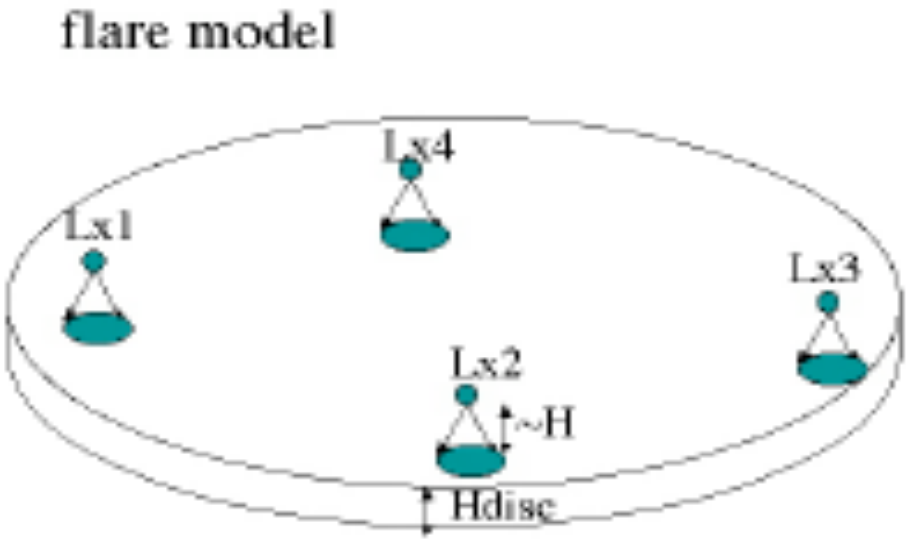


(from Collin et al 2003)



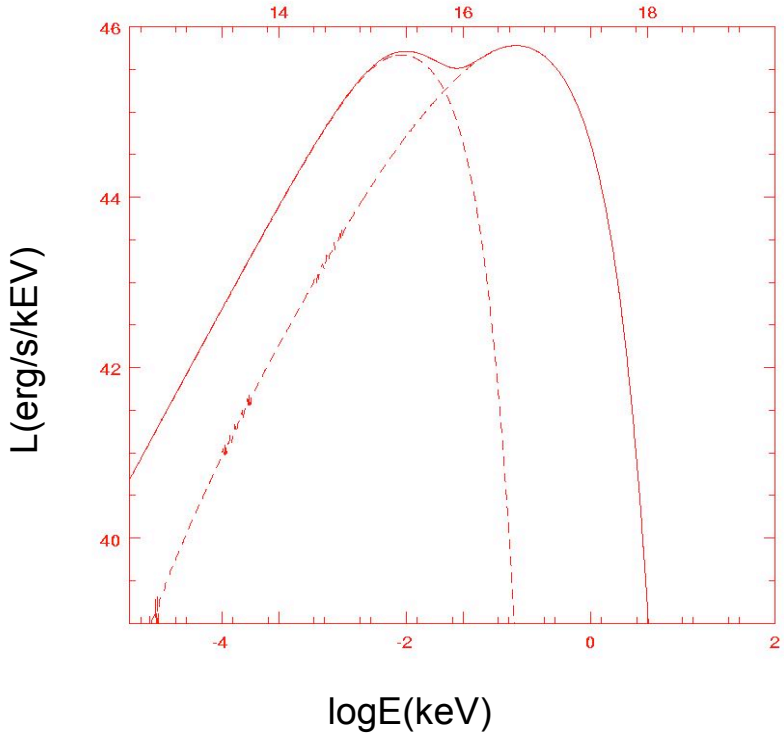
If electrons are produced at large heights above the disk the electrons are braked to non-relativistic speeds before reaching the disk (τ~700s) by Inverse Compton scattering

$$\frac{dE}{dt}\left(\frac{erg}{s}\right) = 2.23\cdot 10^{-9}\left(\frac{r}{20Rg}\right)^{-2}$$



Relativistic electrons are able to reach the disk at high speeds.

The effect of 10^{54}, 1 MeV electrons on the accretion disk continuum



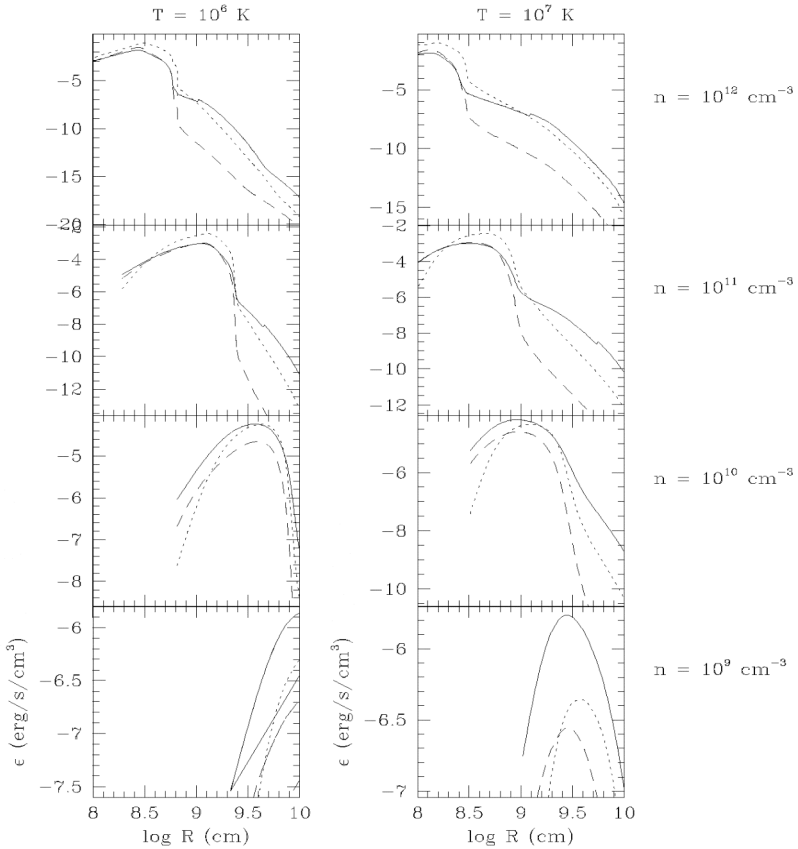
5.CONCLUSIONs

1. Flares cannot be discarded in magnetized accretion disks
2. Electron beams should also be considered as flare outputs and contributors to X-ray radiation (impact with the disk)
3. How are outflows generated? May ambient fields play a role in channeling the outflow?
4. Ionization by electron impact goes as Z^2 while photoionization goes as Z^5, to be taken into account in abundance determinations.

The grid of models will be available soon in our web

You are invited to use it for your modeling

Heating of the “circumflare” material by X-ray



Close to the disk, at high density, forbidden (UV) line emission is produced in a thin cocoon around the X-ray emission regions.