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Jets from paramagnetic electrons in superstrong fields

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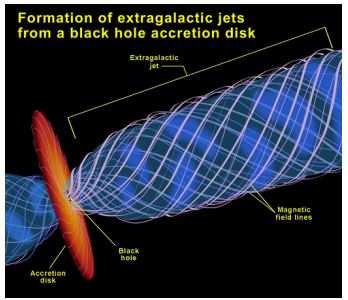
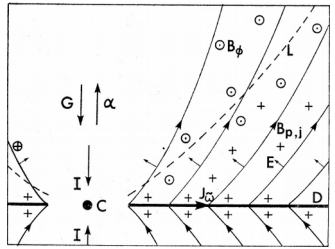
Challenges for jet models

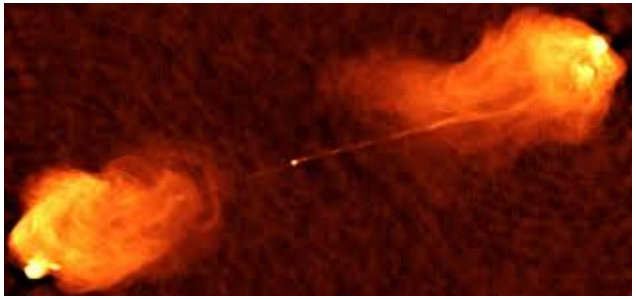
- Disks have only azimuthal, not vertical, motion; jets have *precisely* the opposite!
- Magnetic field morphology not well understood --▶
- Must be able to launch violent GRB
- Hard synchrotron and gamma spectra *far* from source: radio galaxies are really gamma-ray galaxies! (*X-rays + radio shown.*) -----▶





The proposal: connecting two factors of 10^{10}

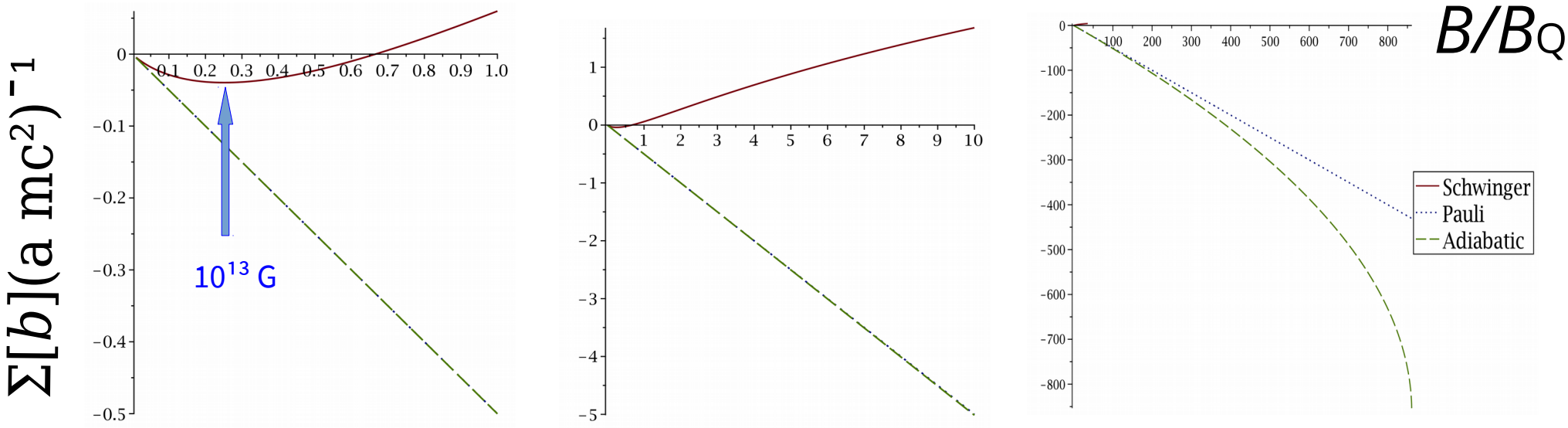
- Mpc radio jet/(10^8 M⊙ SMBH) length ratio



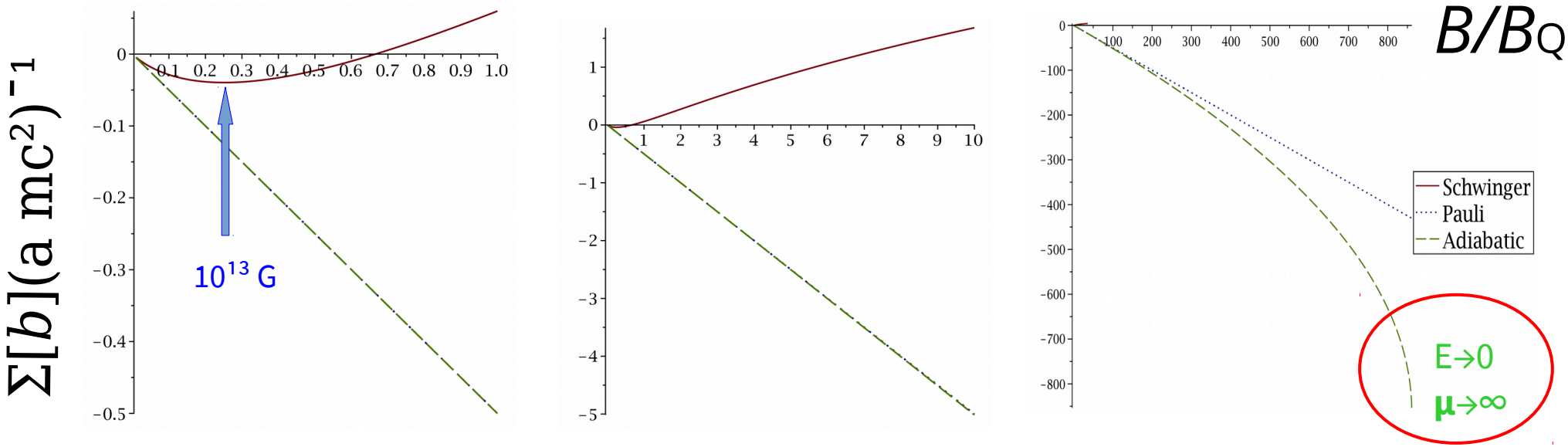
(Cyg. A image: Carilli/Perley)

- electron a= (g-2)/2 ~ α/(2 π) known to better than 10 digits

Shift in electron mass in a B field



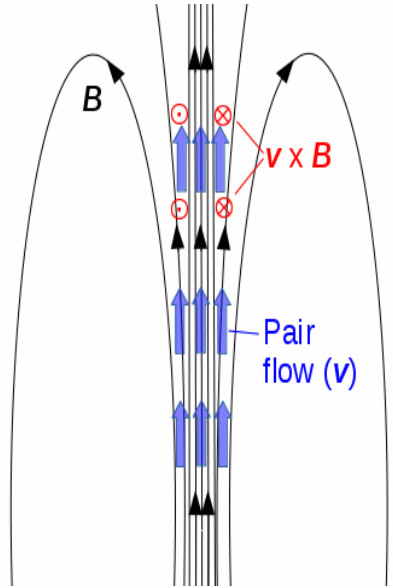
Shift in electron mass in a B field



Schwinger's calculation predicts all nonlinear terms diverge at B=0, due to infrared photon exchange (this should be considered unphysical!) Corrected calculation *should* preserve **μ**·E (adiabatic invariant).

Consequences of a linear decrease of m^2

- Fields above 3.8 x 10^{16} G *unstable*! Decay into massless and strongly magnetized pairs, shot out along field lines.
- ***B*** increases but ***H*** decreases in beam, lowering ***B*·*H***. Entropy created, so beams are energetically favored.
- Pair—photon plasma should have a *superconducting* component and normal component -- trapping flux as ***M*** decreases as beam exits jet core region.

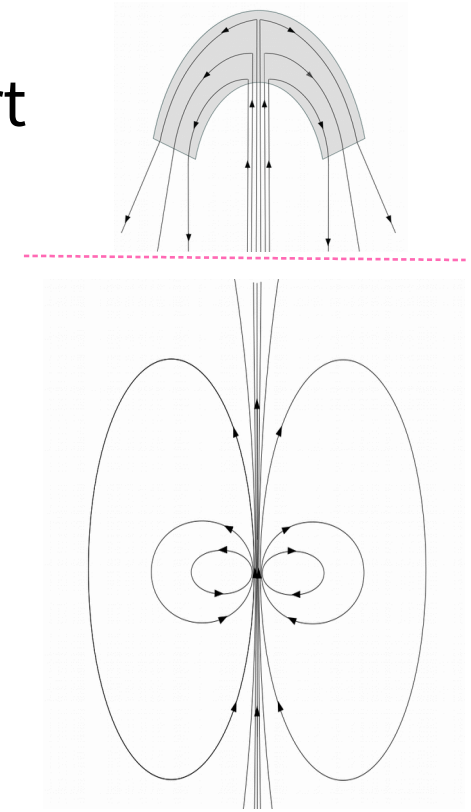


Properties of a supercritical field, and model

- Collimation I: pair creation kinematics gives zero photon and pair mobility perp. to ***B***; infinite mobility parallel!
- Pair and photon creation/annihilation in local balance (similar to 95 Thompson/Duncan magnetar "fireball" model) … but now ALL photons are above pair threshold!
- As pairs regain mass, can't keep up with photons in beam front. Leads to massive annihilation *and subsequent GRB!*
- Field lines strive to be absolutely straight. Photons, Alfven & magnetosonic waves, toroidal components all lose energy to pair creation in field held at critical (= *stable jet core*).

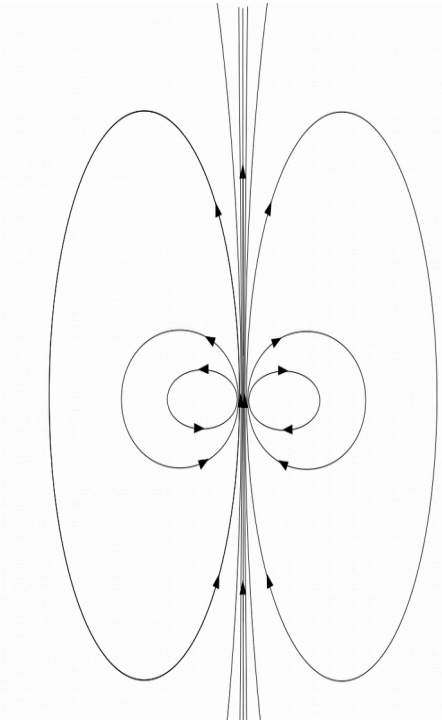
Poloidal field: dipole + “leaky” solenoid

- Retaining paramagnetic moment allows for transport of magnetic energy from source to large distances
- Collimation II: superconducting pairs with over-magnetic pressure will straighten field lines as they go –---> beam field is that of a solenoid!
- No emission from core of beams. Synchrotron goes from X-ray to radio radially outward from core. (Beam ***B*** strength in white dwarf – pulsar range)

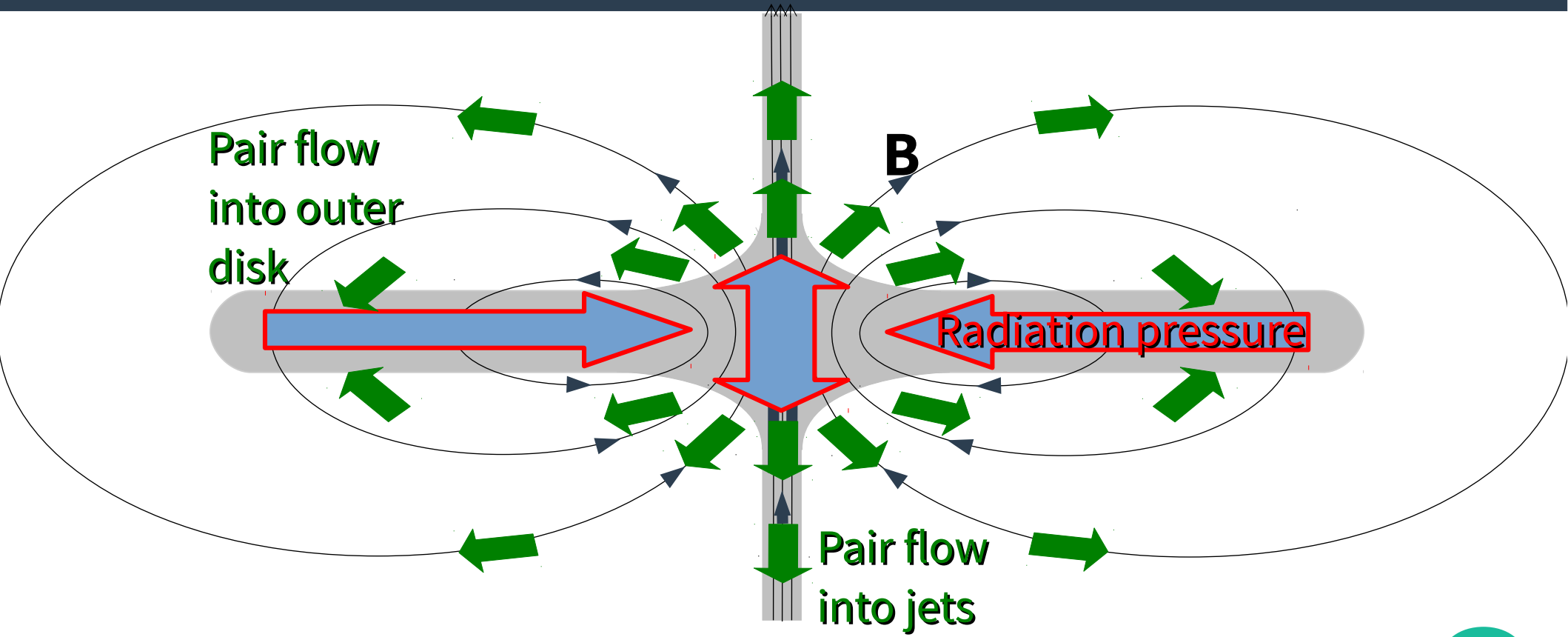


AGN model: Kerr-Newman hole at threshold B

- K-N holes may not instantly discharge, due to conducting magnetosphere! (Lyutikov & McKinney)
- Feeding: can come from ***B***, photons, mass accretion, and other disturbances all putting energy into jets
- Also can be engine of micro-quasars
- Galactic center: MeerKAT images (linear poloidal structures), Fermi bubbles, X-ray chimneys consistent with proposed field morphology!

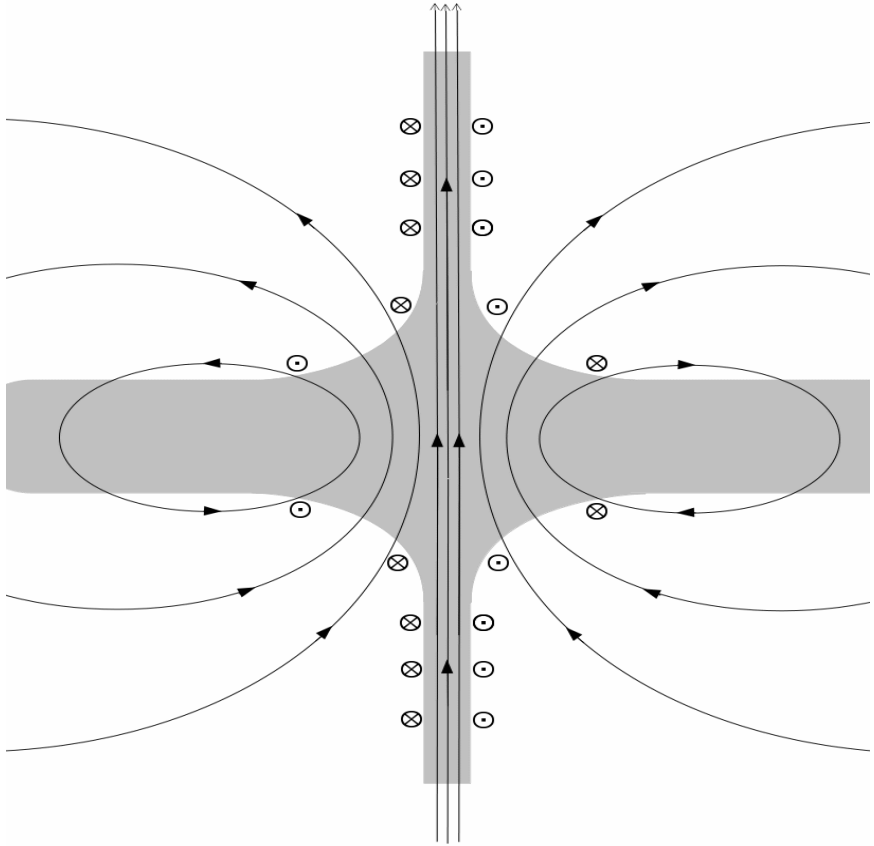


Pairs in a hollow torus "turbocharge" disk-fed engine – gives super-Eddington accretion rates!



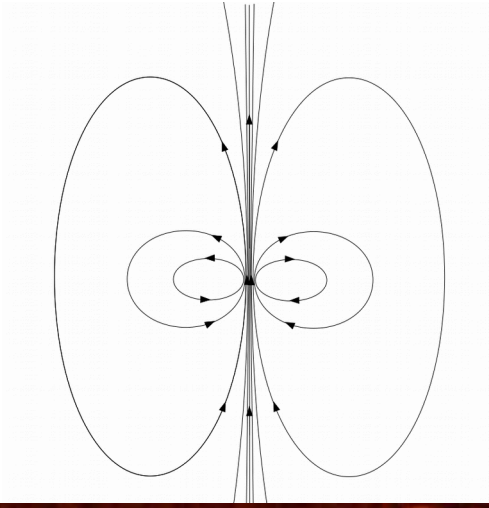
Collimation III: skin effect from entrained baryonic disk

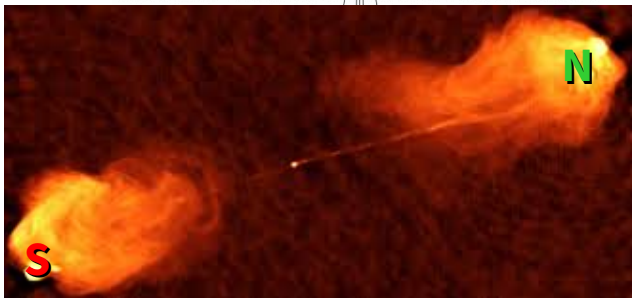
Thermoelectric “skin” near strong fields, made of electrons. ***S*** shown as vectors into/out of page. Drives currents that collimate flow into beams.



Summary

- Jets and GRBs may be a simple consequence of a maximum field strength
- Even if theoretical premise in doubt, observations give compelling support
- Model shows promise in clearing major challenges AND aids SMBH growth. (*FRBs? Giant pulses? Maybe...*)
- More predictions: toroidal components *not* large-scale, additional hard neutrinos from exactly HALF of blazars!





Thank you! Questions?

Special thanks to: I.G. Avramidi