Hot Accretion Flows Around Black Holes

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Background

- Black Hole accretion is the primary power source in
  - Active Galactic Nuclei (AGNs)
  - Black Hole Binaries (BHBs)
- First Accretion disk model: Thin Disk
- Next model: Slim Disk
- These are both cold flows

Thin Disk

- Temperature: $10^4 - 10^7$K
- Geometrically thin
- Optically thick gas
- Radiates Blackbody-like
- Mass accretion below Eddington limit
- Ex: Luminous AGNs

Slim Disk

- Occurs when mass accretion reaches Eddington Limit
- High optical thickness
- Unable to radiate energy local, advected inward
- Luminosity becomes less than $0.1\dot{M}c^2$

Introduction of Hot Accretion Flows

- Both Slim and Thin disk are considered cold accretion flows and consist of optically thick gas
- The first hot accretion flow model was the SLE
- SLE has the high temperatures (approaching the virial temperature)
- Has two-temperature plasma with ions much hotter than electrons
- Able to explain the hard X-ray emission of some black hole sources
- SLE was shown to be thermally unstable

Advection Dominated Accretion Flows (ADAF)

- Either Hot or cold Accretion flow that is dominated by Advection
- Hot ADAF are not thermally unstable like SLE
- Examples: Sgr A* and low-luminosity AGNs (LLAGNs)
- Two variants:
  - Adiabatic inflow-outflow solution (ADIOS)
  - Convection-dominated Accretion Flows (CDAF)

Jets in Hot Accretion Flows

- Believed that hot accretion flows have strong winds and jets
- Observationally, LLAGNs are radio loud and BHBs in a hard state have radio emisions
- Jets believed weaker in cold flows
- Likely reasons:
  - Thick disks advect the magnetic field to the black hole more easily
  - Bernoulli parameter of gas is higher, enhancing winds
  - Strong winds help to collimate and stabilize the jet
- Source of energy for jet: either rotational energy of black hole or accretion disk

Disk Winds from Hot Accretion Flows

- Nonrelativistic, slow moving
- High mass loss rate
- Rate of Energy outflow less than jet

Sagittarius A*

- Outer boundary of accretion flow assumed to be $\sim 10^5 R_s \approx 0.04 \text{ pc}$
- Accretion rate at this boundary is $\sim 10^{-5} M_{sun} \text{ year}^{-1} \sim 10^{-4} \dot{M}_{Edd}$
- Extremely low luminosity $L_{Bol} \sim 2 \times 10^{-9} L_{Edd}$
- Observed spectrum does not match multitemperature blackbody spectrum for a thin disk
- Likely that a hot ADAF is around Sag A*

LLAGNs

- Vast majority of AGNs are LLAGNs
- $L_{Bol} \sim 10^{-9} - 10^{-1} L_{Edd}$
- Low luminosity implies radiatively inefficient accretion (i.e. hot)
- "Big blue bump" absent
- Two zone disks: cool, thin disk at large radii; hot accretion flow at small radii
- Truncation determined by Accretion rate

Conclusion

- Accretion Flow can be divided between two types: Cold and Hot
- Cold Accretion Flows: radiatively efficient and optically thick
  - Thin Disk model
  - Slim Disk model
- Hot Accretion Flows: radiatively inefficient and optically thin
  - SLE model
  - ADAF model
- Jets and Winds are strong in Hot Flows
- Most observed AGN including Sag A* are believed to have Hot Accretion