X-Ray Polarization from Accreting Black Holes

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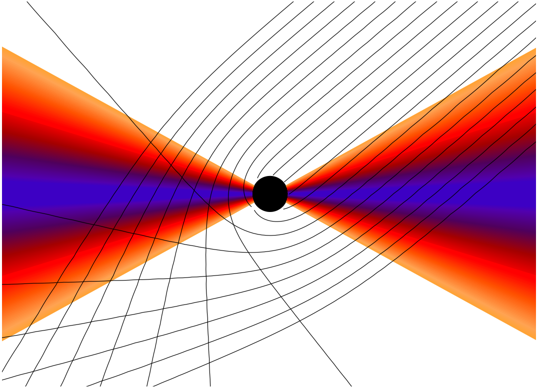
Outline

- Ray-tracing in Kerr metric: two paradigms
- Description of model
    - Steady-state thin disk
    - Hot corona
    - Polarization
- Results

Observer-to-Emitter

The "traditional" paradigm traces photons along geodesic paths from a distant observer to the disk

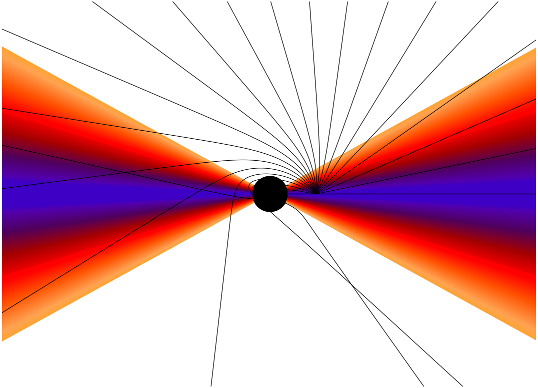


cf. Schnittman, Krolik, & Hawley (2006)

Noble et al. (2007)

Emitter-to-Observer

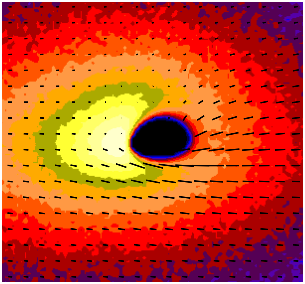
To include scattering effects and return radiation, we trace the photon paths from the emission region to the observer



cf. Schnittman (2005; 2008)

Transport of polarization vectors

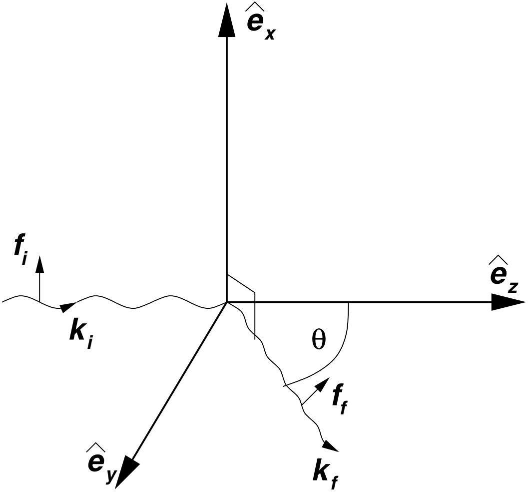
- Polarization vector is space-like and normal to wave vector: $\mathbf{f} \cdot \mathbf{k} = 0$ and $\mathbf{f} \cdot \mathbf{f} = 1$.
- Walker-Penrose constant of motion $\kappa_{\rm PW}$, conserved along null geodesics, gives remaining components of $\mathbf{f}$. (Connors et al. 1980)
- Emission from scattering-dominated atmosphere is polarized parallel to disk surface. (Chandrasekhar 1960)



The thermal seed photons come from a relativistic thin disk

- disk parameters:
  - BH mass M
  - BH spin a/M
  - accretion rate $\dot{M}/\dot{M}_{\rm Edd}$
  - emissivity (Novikov-Thorne vs. power-law to horizon)
- corona parameters:
  - temperature, density profile $T_c(r)$, $\rho_c(r)$
  - optical depth to Compton scattering $\tau_{\rm es}$

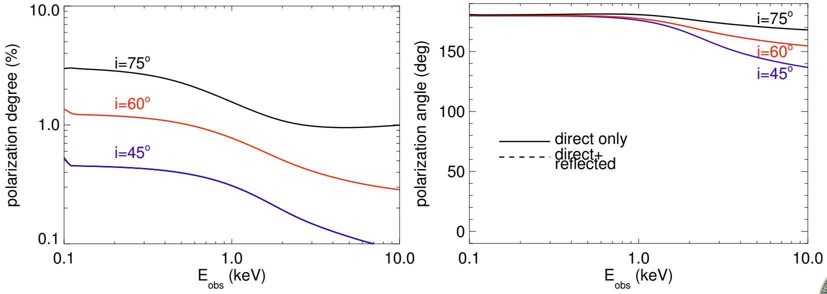
Thompson scattering of polarized photons



- $\mathbf{f}_i \cdot \mathbf{k}_i = 0$
- $\mathbf{f}_f \cdot \mathbf{k}_f = 0$
- $(\mathbf{f}_i \times \mathbf{k}_f) \cdot \mathbf{f}_f = 0$
- $\delta = (X^2 + Y^2)^{1/2}$
- $\psi = \frac{1}{2} \tan^{-1}(Y/X)$

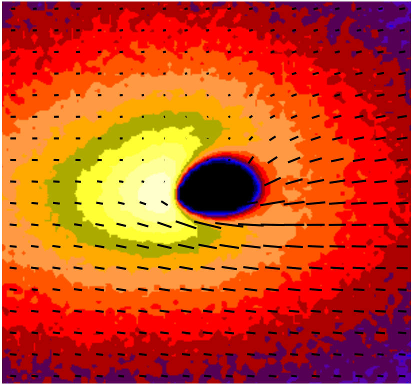
Plane polarization from a thermal disk is rotated by relativisitc beaming and lensing

$a/M = 0.9$, $R_{\rm in} = R_{\rm ISCO}$, N-T emission, $L = 0.1 L_{\rm Edd}$

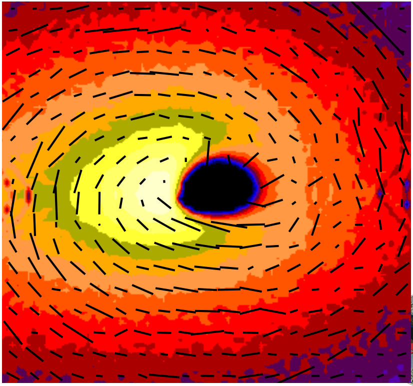


Return radiation near the BH changes the polarization signature significantly

direct only



direct+return



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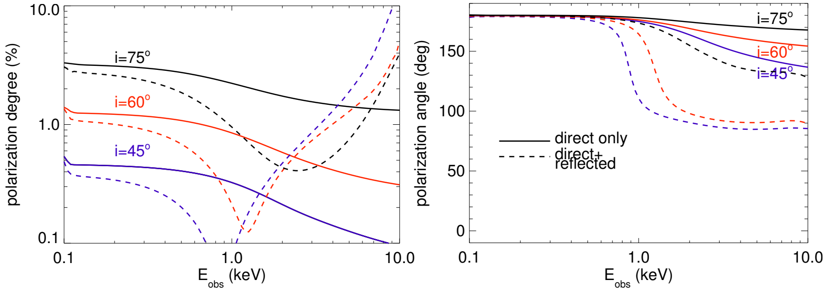
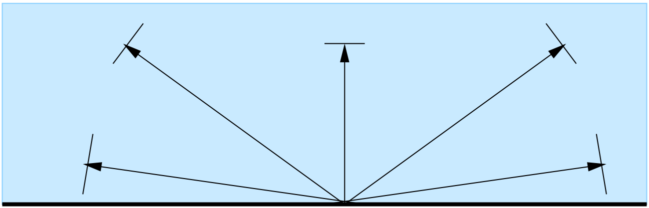
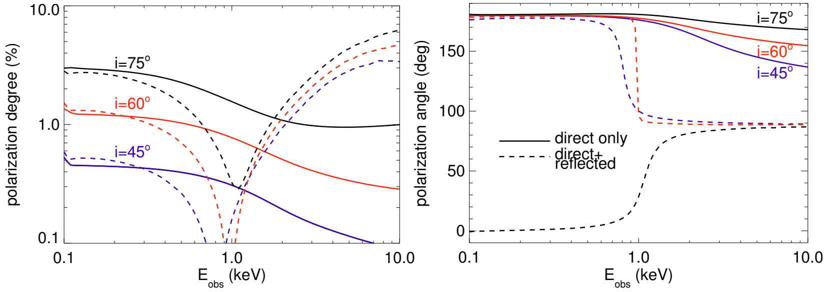


Scattering through optically thin corona rotates net polarization angle



Corona scattering preferentially changes polarization angle of high-energy photons



Applications/Future Work

- Integrated model allows us to
  - probe plunging region
  - estimate coronal properties
  - compute line emissivity profile
- Fitting observations
  - Green's function-type transfer (e.g. Magdziarz & Zdziarski 1995)
  - orthogonal basis of fitting functions to minimize parameter degeneracy
  - fold through *GEMS* response function
- 3-D numerical MHD simulations (Noble, Krolik, etc.)
  - develop realistic heating, cooling functions
  - define electron temperature everywhere
  - self-consistently calculate inverse-Compton spectrum and polarization