Synchrotron Image of a GRMHD Jet

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Introduction

Future sub-mm VLBI observation of M87 by Event Horizon Telescope (EHT) or Greenland Telescope (GLT) Project on event horizon scale will provide an unique opportunity to investigate the formation mechanism and environment of black hole relativistic jets. However, the uncertain of electron properties make the prediction of the jet imaging very challenging. How to consider this issue properly is an important science topic. Base on a semi-analytical GRMHD jet model, ray-tracing in Kerr metric, and general relativistic radiative transfer, in this poster we present a preliminary study of how jet synchrotron image varies with different electron properties.

Model Setup

◎ a/M (dimensionless black hole spin parameter): 0.9

◎ Inclination angle: 20 degree

◎ Field angular velocity: half of angular velocity of the event horizon

◎ Jet dynamics: the four momentum of the GRMHD flow is obtained by solving the wind equation along Blandford-Znajek parabolic field lines, by assuming the outward energy flux is continuous through the inflow and outflow region (right figure); since the outflow has no fast surface, we pick the outflow which has minimum energy to extend to 800 GM/c^2

◎ Magnetic field: scaled from the solution of the wind equation, with a typical strength ~5 Gauss

◎ Thermal electrons properties: (non-thermal electrons follow relativistic Maxwellian distribution and contribute to thermal synchrotron emission)

★ temperature: $kT_e/m_ec^2=2$

★ spatial distribution: $\mathbf{n_{th}= n_0 \exp[-r_c^2/(2a^2)] \exp[-r^2/(2b^2)]}$, where $n_0=10^7$, r_c is the cylindrical radius

◎ Non-thermal electrons properties : (non-thermal electrons follow power-law energy distribution and contribute to non-thermal synchrotron emission)

★minimum Lorentz factor: 50

★ maximum Lorentz factor: 10^5

★ power-law index: -3.5

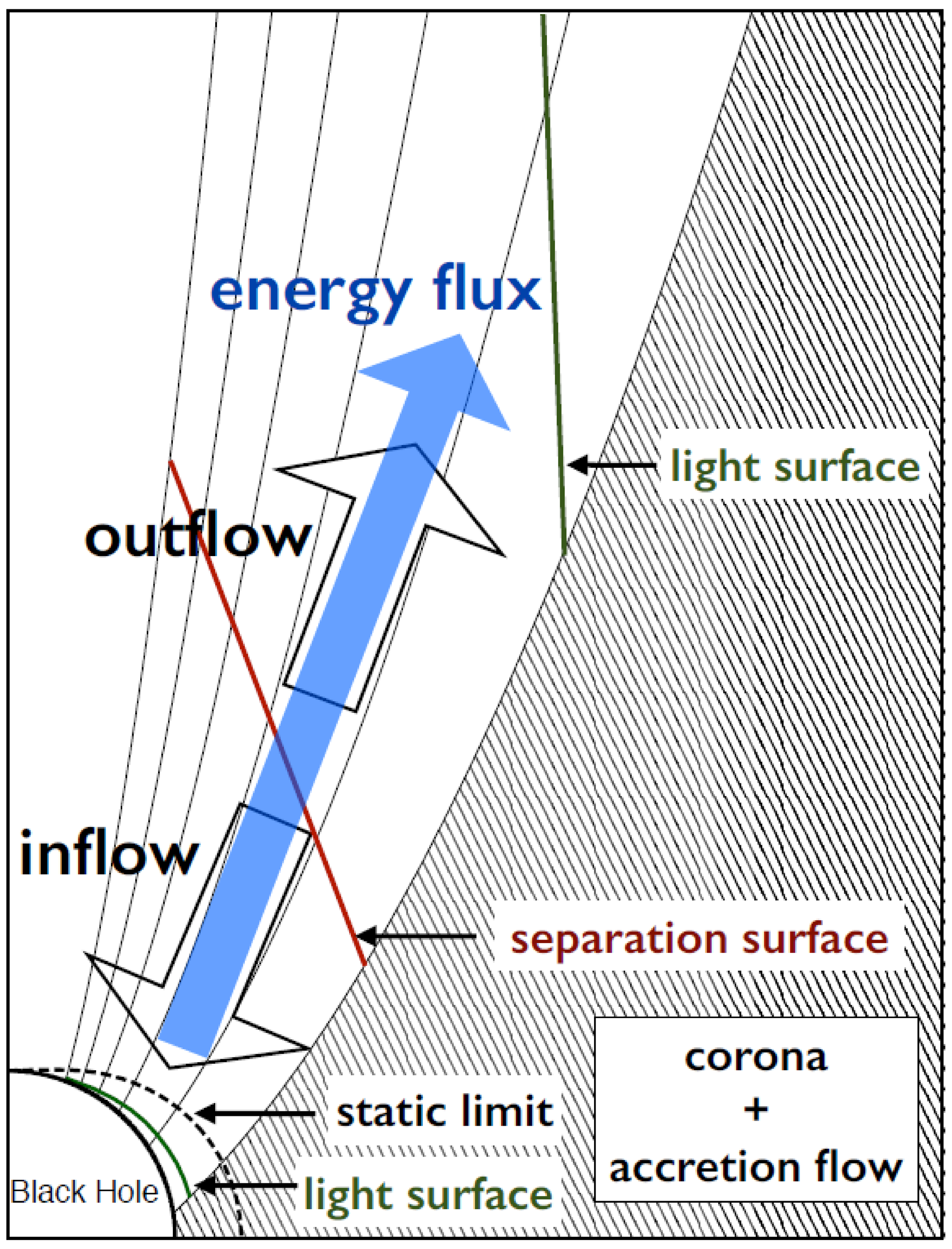
★ spatical distribution: $\mathbf{n_{nth} = f\, n_{th}}$

Finally, we fix the jet dynamics, and computed the jet synchrotron image with varied (f, a, b):

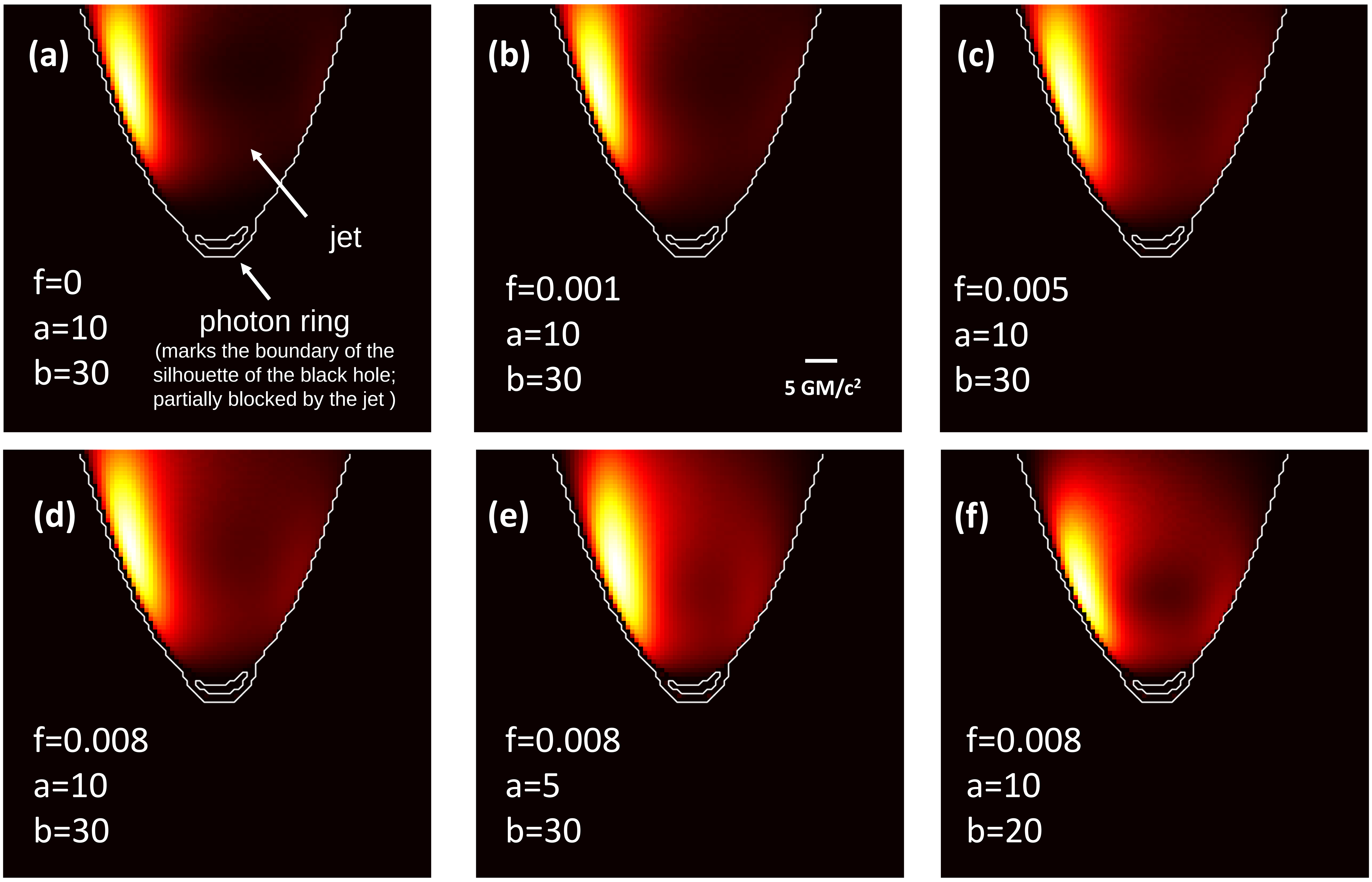
f: related to the mixture of thermal and non-thermal electrons

a: related to the electron distribution in r_c(cylindrical radius)-direction

b: related to the electron distribution in r-direction



Schematic illustration of a Poynting flux dominated (PFD) GRMHD flow surrounded by the accretion flow and its corona. The black hole rotational energy is extracted by the inflow . By assuming that the energy flux is continuously propagate outward in both inflow and outflow region, the outflow property is constrained by the inflow (Pu et al. 2015 ApJ 801, 56).



Preliminary Results

The above images shows the resulting 230 GHz (1.3mm) image of different parameter (f, a, b) with a scale of 64 x 64 GM/c^2. For all figures, the color shows square-rooted scaled flux. For all cases, the approaching (left) side of the jet is much brighter than the receding (right) side. The resulting jet image is sensitive to the mixture of thermal and non-thermal synchrotron (related to the parameter "f"; see **(a)**-**(d)**). Comparison between **(d)** and **(e)** shows how the jet image changes when the electron distribution is closer to the axis (corresponding to a smaller value of "a") . Comparison between **(d)** and **(f)** shows how the image changes when the electron distribution is closer to the black hole (corresponding to a smaller value of "b"). While here we use an phenomenological approach to demonstrate how the resulting jet image is sensitive to the population of thermal and non-thermal electron, a more sophisticated approach is ongoing. In addition, the observed spectra can provide further constraints for what we may observed in future sub-mm VLBI observation of M87.