The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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Observational signature of tidal disruption of a star by a massive black hole

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Abstract. We have modeled the time-variable profiles of the Hα emission line from the non-axisymmetric disk and debris tail created in the tidal disruption of a solar-type star by a $10^6\ M_\odot$ black hole. We find that the line profiles at these very early stages of the evolution of the post-disruption debris do not resemble the double peaked profiles expected from a rotating disk since the debris has not yet settled into such a stable structure. The predicted line profiles vary on fairly short time scales (of order hours to days). As a result of the uneven distribution of the debris and the existence of a "tidal tail" (the stream of returning debris), the line profiles depend sensitively on the orientation of the tail relative to the line of sight. Given the illuminating UV/X-ray light curve, we also model the Hα light curve from the debris.

1. Light Curves and Emission Line Profiles From the Tidal Debris

Simulations of tidal disruption of a star were carried out using a three-dimensional, relativistic, smooth-particle hydrodynamics code (Laguna et al. 1993), to describe the early evolution of the debris during the first fifty to ninety days. We have used the photoionization code CLOUDY (Ferland 1996) to calculate the physical conditions and radiative processes in the debris. To obtain the observed profile from the relativistic debris, confined to a plane, in the weak field approximation we have followed the line profile calculations by Chen & Halpern (1989) and Eracleous et al. (1995).

Once bound debris starts to rain down on the black hole it is expected to cause the initial rapid rise in the emitted UV/X-ray light curve and steady decay with the power low index of $-5/3$ later on (Rees 1988). The UV/X-ray flares from the central source illuminate the debris, the photons get absorbed, and some are re-emitted in the Balmer series Hα line. We have modeled the Hα light curve and emission line profiles in the period immediately after the accretion rate onto the black hole became significant. The main features of the Hα light curve are an initial rise followed by a decline, with superposed fluctuations. The decay rate of the Hα light curve is determined by the decay rate of UV/X-ray light curve, and the debris expansion and redistribution rate.

Our model predicts prompt evolution of the profile shapes on the time scales of hours to days, as shown in Figure 1. The line profiles can take a variety of shapes for different orientations of the debris relative to the observer. Due to the very diverse morphology of the debris, it is almost impossible to uniquely match the multi-peaked profile with the exact emission geometry. Nevertheless, the profile widths and shifts are strongly indicative of the velocity distribution and the location of matter emitting the bulk of the Hα light. The profile shapes do not depend sensitively on the shape of the UV/X-ray light curve illuminating the debris. They strongly depend on the distance of the emitting material from the central ionizing source, which is a consequence of the finite propagation

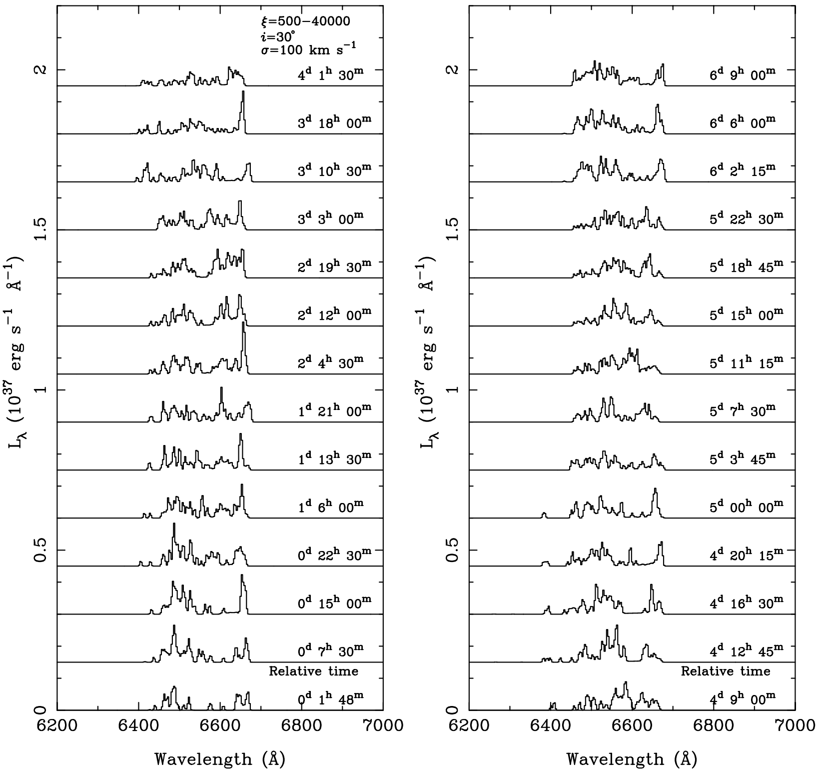

Figure 1. Sequence of Hα profiles emitted from the debris region $\xi \in (500, 40\,000)$ (in units of MG/c^2) over period of 6 days. The relative time from the beginning of the accretion phase onto the black hole is marked next to each profile. The inclination of the debris plane and the velocity shear are as marked on the figure.

time of the ionization front and the redistribution of the debris in phase space. If X-ray flares and the predicted variable profiles could be observed from the same object they could be used to identify the tidal disruption event in its early phase.

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