Star formation in self-gravitating disks in active galactic nuclei. I. Metallicity gradients in broad line regions

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(Submitted on 19 Jul 2011)

It has been suggested that the high metallicity generally observed in active galactic nuclei (AGNs) and quasars originates from ongoing star formation in the self-gravitating part of accretion disks around the supermassive black holes. We designate this region as the star forming (SF) disk, in which metals are produced from supernova explosions (SNexp) while at the same time inflows are driven by SNexp-excited turbulent viscosity to accrete onto the SMBHs. In this paper, an equation of metallicity governed by SNexp and radial advection is established to describe the metal distribution and evolution in the SF disk. We find that the metal abundance is enriched at different rates at different positions in the disk, and that a metallicity gradient is set up that evolves for steady-state AGNs. Metallicity as an integrated physical parameter can be used as a probe of the SF disk age during one episode of SMBH activity. In the SF disk, evaporation of molecular clouds heated by SNexp blast waves unavoidably forms hot gas. This heating is eventually balanced by the cooling of the hot gas, but we show that the hot gas will escape from the SF disk before being cooled, and diffuse into the BLRs forming with a typical rate of $\sim 1\sunmyr$. The diffusion of hot gas from a SF disk depends on ongoing star formation, leading to the metallicity gradients in BLR observed in AGNs. We discuss this and other observable consequences of this scenario.

Comments:	11 pages, 5 Figures, ApJ, Vol. 737, in press
Subjects:	**Galaxy Astrophysics (astro-ph.GA)**; Cosmology and Extragalactic Astrophysics (astro-ph.CO)
Journal reference:	Astrophysical Journal, 2011
Cite as:	**arXiv:1107.3620 [astro-ph.GA]**
	(or **arXiv:1107.3620v1 [astro-ph.GA]** for this version)

Submission history

From: Jian-Min Wang [view email]
[v1] Tue, 19 Jul 2011 03:20:46 GMT (243kb)

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