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X-rays Flares and Protoplanetary Disks¹

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X-ray observations of star forming regions show that magnetic reconnection flares are powerful and frequent in pre-main sequence solar-type stars. Well-defined samples in the Orion Nebula Cluster and Taurus clouds exhibit flares with peak X-ray luminosities $L_x \sim 10^{29} - 10^{32}$ erg/s, orders of magnitude stronger and more frequent than contemporary solar flares. X-rays are emitted in magnetic loops extending 0.1-10 R_* above the stellar surface and thus have a favorable geometry to irradiate the protoplanetary disk. Several lines of evidence - fluorescent iron X-ray emission line, forbidden [NeII] infrared line, and excited molecular bands - support X-ray irradiation of cold material in some young systems. Several astrophysical consequences of X-ray irradiation are outlined. As ionization fractions need only reach 10^{-12} to induce the magnetorotational instability and associated turbulence, X-rays may be the principal determinant of the extent of the viscous “active zone” and laminar “dead zone” in the layered accretion disk. X-ray irradiation may thus play a major role in planet formation processes: particle settling; meter-size inspiral; protoplanetary migration; and dissipation of the gaseous disk.

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