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## Using high resolution mm and X-ray images to constrain distance to black hole 4U1630-47 and the molecular clouds in the line of sight

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We report new constraints on the distance to 4U 1630–47 by analyzing its dust scattering halo (DSH) using high-resolution X-ray (Chandra) and millimeter (APEX) observations. DSHs, produced when X-rays scatter off interstellar dust, encode information about both the source distance and the distribution of intervening material. Previous distance estimates for 4U 1630–47 (4.9 kpc and 11.5 kpc) remained uncertain due to limited-resolution molecular gas maps. Accurate distance measurements are especially important for this source due to its surprisingly high X-ray polarization amplitude.

We developed a new methodology combining a machine learning approach to reconstruct the 3D distribution of molecular clouds from APEX data with synthetic DSH image modeling based on X-ray flux measurements. By fitting both radial and azimuthal profiles of these synthetic halos to Chandra observations, we simultaneously constrained the source distance and identified the near/far distances of the intervening molecular clouds.

Our analysis still favors a distance of 11.5 kpc, rejecting a 13.6 kpc solution—despite its lower  $\chi^2$  fit—because it would produce a bright halo feature beyond the observed field of view. The 4.9 kpc estimate was also ruled out due to poor fit quality and inconsistencies in cloud positioning. The primary source of uncertainty remains a systematic  $\sim 1$  kpc error associated with molecular cloud distance estimates.

### Affiliation

Sabanci University

**Author:** KALEMCI, Emrah (Sabanci University)

**Co-authors:** Mr ABBASI, Ahmed Abdullah (Sabanci University); Mr SARACYAKUPOGLU, Atakan (Sabanci University); Mr BAHCECI, Batuhan (Sabanci University); Mr OZTABAN, Efe (Sabanci University); Mr VON NUSSBAUM, Enno (TU Munchen); Prof. MILLER-JONES, James (Curtin University); Dr TOMSICK, John A. (UC Berkeley); Dr DIAZ-TRIGO, Maria (ESO); MACCARONE, Thomas (Texas Tech University); Dr STANKE, Thomas (MPE)

**Presenter:** KALEMCI, Emrah (Sabanci University)

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