Virtually no progress has been made over the past half-century in establishing a distance scale to clouds and pre-main sequence (PMS) stellar clusters in the Galactic disk. Unless a clear main sequence is present, distance estimates can be very uncertain. We suggest that Chandra studies have found a new, potentially accurate, distance estimator based on the recent discovery that the shape of X-ray luminosity functions (XLFs) of PMS clusters is lognormal with a narrow dispersion and appears to be the same in all clusters. The XLF is low at high-Lx due to the steep Salpeter IMF, and turns steeply down at low-Lx due to a convolution of the flattening IMF combined with a poorly-understood Lx-mass correlation. The XLF thus provides a new standard candle for PMS cluster distance estimates. This poster shows the data underlying this argument (e.g. Orion Nebula Cluster, IC 348 and NGC 1333), estimates of the expected precision of the distance estimates, and outlines a proposed application to the LkHa101 = NGC 1579 cluster.

**ABSTRACT**

We have proposed a Chandra ACIS exposure of LkHa101 to measure the X-ray source counts and derive its distance from the XLF. Its distance should be estimated to about +/-100 pc precision.

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**Stellar X-rays**

Stellar X-rays arise from magnetic reconnection events and thus trace the MHD of stellar interiors and environments.

- X-ray emission, often dominated by high-amplitude flares, in pre-MS stars is elevated ~300-fold over MS stars.
- Pre-MS X-ray emission is ubiquitous and is insensitive to the presence or absence of a circumstellar disk. The origins of the magnetic fields (saturated or convective dynamo?), and the empirical correlation between Lx and stellar mass L, are poorly understood.

A convolution of the power-law Lx-M correlation with the curved stellar IMF produces a strongly peaked X-ray luminosity function when an ensemble of stars is observed.

**Chandra Studies of Young Stellar Clusters**

Chandra studies of pre-MS stellar clusters find that their X-ray luminosity functions are lognormal in shape with narrow dispersion. This arises from a convolution of the curved IMF and a Lx-Mass correlation. The peak of a cluster XLF is thus a standard candle useful for distance estimates.

**Fig. 1. - Yohkoh image of the X-ray Sun.**

**Fig. 2. - Chandra study of a rich young stellar cluster. Orion Nebula Cluster, D = 450 pc, Chandra Orion Ultradeep Project (COUP). Central region (4' x 4') of 850 ks ACIS exposure. Red = unabsorbed, Blue = embedded. 1616 sources with sensitivity log Lx,lim = 27.0 erg/s (Getman et al. 2004).**

**Fig. 3. - Chandra study of a sparse young stellar cluster. NGC 1333 cluster, D = 320 pc. Full field 38 ks ACIS exposure, 127 sources of which, 77 are YSOs. Log Lx,lim = 28.0 erg/s for low-Av sources. (Getman et al. 2002).**

**Fig. 4. - Cluster XLFs appear to be universal. NGC 1333 (77 stars): Getman et al. 2002; IC 348 (168 stars): Preibisch & Zinnecker 2002; ONC (1508 stars, COUP data truncated at logLx<31.5). All X-ray luminosities here are 0.5-8 keV corrected for absorption.**

**Fig. 5. - Orion Nebula Cluster XLF with lognormal fit. Fitted Gaussian: log Lx = 29.5 erg/s, σ = 0.9. Chandra Orion Ultradeep Project sample, 1528 sources with absorption corrected 0.5-8 keV luminosities (Getman et al. 2004).**

**Simulated X-ray Source Counts from the XLF**

<table>
<thead>
<tr>
<th>Distance (pc)</th>
<th>400</th>
<th>710</th>
<th>1270</th>
<th>2250</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limiting Lx (erg/s)</td>
<td>28.0</td>
<td>28.5</td>
<td>29.0</td>
<td>29.5</td>
<td>30.0</td>
</tr>
<tr>
<td>5 - 50 photons</td>
<td>22%</td>
<td>46%</td>
<td>60%</td>
<td>76%</td>
<td>86%</td>
</tr>
<tr>
<td>50 - 500 photons</td>
<td>46%</td>
<td>42%</td>
<td>34%</td>
<td>22%</td>
<td>14%</td>
</tr>
<tr>
<td>500 - 5,000 photons</td>
<td>28%</td>
<td>12%</td>
<td>6%</td>
<td>2%</td>
<td>0</td>
</tr>
<tr>
<td>5,000 - 50,000 photons</td>
<td>4%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

We have simulated the X-ray source counts (logN - logS curve) for a hypothetical cluster assuming the universal lognormal young cluster XLF. The top rows show the limiting distance and X-ray sensitivity for a cluster observed with Chandra ACIS for 100 ks exposure. The bottom rows give the percentage of sources seen in broad flux (5-50 photons, etc.).

**How to Find the Distance to a YSO Cluster**

Suppose one observes a cluster at D = 1000 pc with Chandra/ACIS for 25 ks, giving an intrinsic limiting sensitivity (correcting each source for absorption) of log Lx,lim = 30.0 erg/s. Suppose one detects 100 sources. From the simulation below, 86 sources will be in the faintest 5-50 count bin, 14 sources would have 50-500 counts, and no source would have >500 counts.

If the same cluster was at a distance of 330 pc where the limiting sensitivity = 29.0 erg/s, 60 sources would have 5-50 counts, 34 sources would have 50-500 counts, and 6 would have 500-5,000 counts. This logN - logS distribution is dramatically different from the 1000 pc simulation above.


**LkHa 101 = NGC 1579 cluster**

The 'isolated' Herbig AeBe star LkHa 101, one of the brightest near-IR stars in the sky, is heavily obscured (AV > 9). HAeBe stars are typically surrounded by sparse clusters, 10 < N < 100 (Testi et al. 1999). LkHa101 shows >100 JHKL YSOs (Aspin & Barsony 1994). ROSAT detects ~20 sources (Zinnecker & Preibisch 1994).

The distance to LkHa101 is controversial:

- Related to Tau-Aur, D = 140 pc (Herbig 1956)
- MS fitting of two B3-B5 stars, D > 800 pc (Herbig 1971)
- Weak-lined Tauri radio source luminosity function, D = 140 pc (Stine & O'Neal 1998)
- IR interferometry of LkHa 101 binary orbit, D ~ 340 pc (Tuthill et al. 2002)

If it lies within ~200pc, it would join Tau-Aur, Oph, CrA, as one of the nearest rich young stellar clusters.