

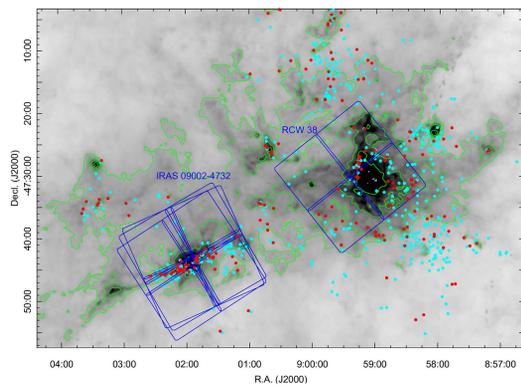
IRAS 09002-4732: A Laboratory for the Formation of Rich Stellar Clusters



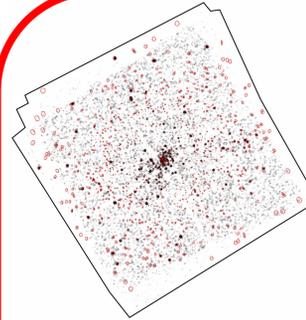
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IRAS 09002-4732 is a poorly studied stellar cluster associated with a several-parsec long molecular filament. Deep Chandra observations combined with optical/infrared surveys have revealed a very young and rich stellar population, twice that of the Orion Nebula Cluster. Most stars reside in a compact, dense, elliptical cluster, but a minority reside along the molecular filament. Inferred cluster properties including extreme youth, richness, possible age gradient, and dearth of massive stars are consistent with astrophysical models of cluster formation in clouds that involve the hierarchical formation and merging of groups in molecular filaments.



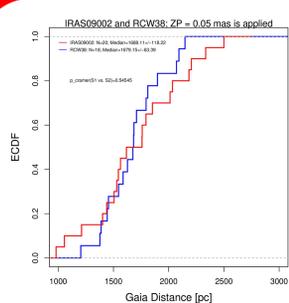
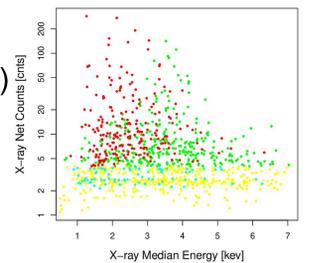
Herschel-SPIRE image of **5-40 pc long Vela molecular filamentary cloud** structures associated with the **IRAS 09002-4732** and nearby **RCW 38** star forming regions. The latter is part of our large MYStIX project [3]. Spitzer-selected **young disk** protostars (red) and Class II stars (cyan) are overplotted [9].



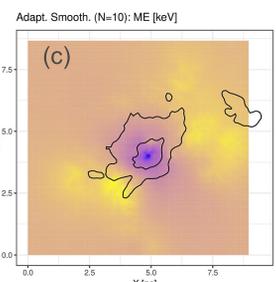
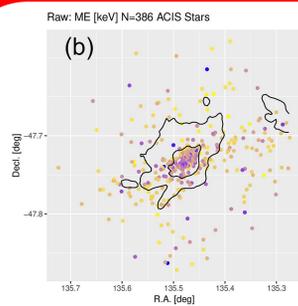
Smoothed, low-resolution, ACIS-I image of IRAS 09002-4732. Exposure time is 100 ks. ACIS Extract [1] identifies and characterizes **1034 X-ray point sources**, many of which are extragalactic contaminants.

X-ray color-magnitude diagram:

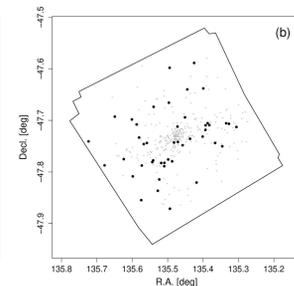
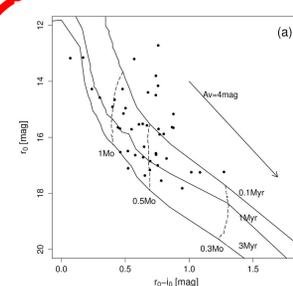
300 ACIS sources with VPHAS+, Gaia, 2MASS, and Spitzer matches (red, cyan) plus 86 without matches spatially concentrated in the cluster center (some of the greens) plus 55 non-ACIS Spitzer disk stars, totaling **441 observed young stellar objects**.



For about 40 IRAS 09002-4732 and RCW 38 young stars with errors on Gaia parallaxes < 0.1 mas, the median Gaia distance is around **1.7 kpc**.

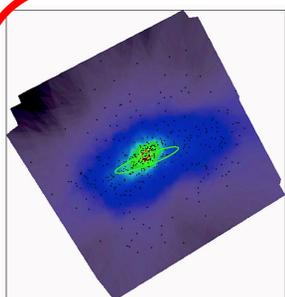


Strong **spatial gradient in X-ray median energy** (surrogate for absorption). Central cluster has $A_V \sim 50$ mag; stars in periphery have $A_V < 5$ mag.



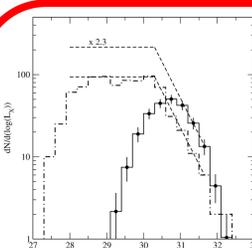
Stellar ages are derived in 2 ways: Age_{JX} [5] and through VPHAS+ color-magnitude diagram.

Both methods produce consistent median **ages of 0.8 Myr** across the region (based on the time scale of [10]).



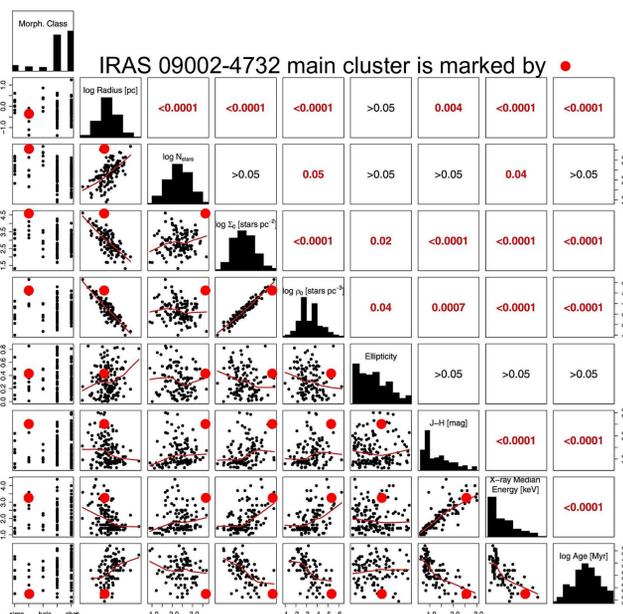
The spatial distribution of young stars in IRAS 09002-4732 is fit by the mixture model composed of

multiple isothermal ellipsoidal clusters [7]. This produces **2 sub-clusters**: a rich, compact, elliptical cluster, and a highly elongated component coincident with the 8-pc long molecular filament.



Stellar X-ray luminosities are produced using the non-parametric XPHOT method [4]. Comparison of X-ray luminosity functions between IRAS 09002-4732 and Orion Nebula Cluster (ONC) yields the total stellar population of **~6000 stars**, more than twice that of ONC. This requires a few early type O stars; but only one O7 star, surrounded by a small ultra-compact HII region, is observed near the cluster center of IRAS 0902-4732 => **deficient in massive stars**.

Multivariate Comparison with the MYStIX Clusters [8].



Among ~150 MYStIX stellar clusters, IRAS 09002-4732 is one of the **youngest, richest, densest, and highly absorbed**. It is a **rare case** where a very rich cluster is captured in its early evolutionary stage, still forming today in a large molecular filament.

- Presence of two cluster components (main central and elongated filamentary), spatial gradient in X-ray median energy, the youth of the ionizing O7 star associated with the small ultra-compact HII region (~ 10000 yr), deficiency in massive stars => all these results suggest **possible cluster age gradient** [6] and **current active star formation in the central core**, which support the model of **slow, hierarchical** [11] rather than rapid, monolithic [2] cluster formation.
- The observed extreme star density of the cluster core suggests efficient dynamical N-body interactions that should lead to ejection of numerous high-velocity **runaway stars**.

[1] Broos et al. 2010, ApJS, 209, 32; [2] Elmegreen 2000, ApJ, 530, 277; [3] Feigelson et al. 2003, ApJS, 209, 26; [4] Getman et al. 2010, ApJ, 708, 176; [5] Getman et al. 2014, ApJ, 787, 108; [6] Getman et al. 2018, MNRAS, 477, 298; [7] Kuhn et al. 2014, ApJ, 787, 107; [8] Kuhn et al. 2015, ApJ, 812, 131; [9] Povich et al. 2013, ApJS, 209, 31; [10] Siess et al. 2000, A&A, 358, 593; [11] Vazquez-Semadeni et al. 2019, MNRAS, 490, 3061.