Spiral-arm star formation in Cygnus OB2

N.J. Wright1, J.J. Drake1, J.E. Drew2, J.S. Vink3, and the Chandra Cygnus OB2 Legacy Survey Team
1. Harvard-Smithsonian Center for Astrophysics, 2. University of Hertfordshire, 3. Armagh Observatory
e-mail: nwright@cfa.harvard.edu website: www.cygob2.org

Introduction
Cygnus OB2 is our nearest massive OB association (d=1.3kpc), and with a mass of $\sim 3 \times 10^5 \ M_\odot$ [1] is one of the largest young clusters in our Galaxy. Its size and proximity make it a vital bridge between studies of Orion and other nearby star forming regions, and the distant super-star clusters seen in other galaxies.

Its location in the giant molecular cloud (GMC) Cygnus X, where star formation is still ongoing, also makes it relevant for an understanding of the formation, evolution and eventual disruption of GMCs. These massive structures (e.g. Cygnus X has M $\sim 10^7 \ M_\odot$ [2]) are the dominant mode of star formation in the spiral arms of galaxies and are vital if we are to obtain a global understanding of star and galaxy formation.

The Chandra Cygnus OB2 Legacy Survey
Studies of Cyg OB2 have the potential to address many questions:
- What determines the lifetime of a typical GMC?
- Do massive OB associations form bound open clusters or disperse into the field population?
- What is the influence of massive stars on nearby star formation through disruption and triggering?
- How do the stellar populations (e.g. the initial mass function and protoplanetary disk fractions) in these regions differ from those in smaller star-forming regions?

To address these questions, and to build up a comprehensive understanding of the mass, spatial extent, and dynamics of the region that are necessary for a complete census of our Galaxy’s massive clusters and OB associations, we are undertaking a 1 sq. deg. Chandra survey of the region (Figure 1, above right) [3]. The survey utilises the elevated X-ray emission of young stars to identify them against the Galactic foreground population and our depth of 120ks will allow sources down to 0.5 M $\odot$ [3] to be detected.

Complementary deep optical, near-IR, Spitzer mid-IR, and Herschel far-IR photometry will allow the stellar and circumstellar properties of the detected sources to be characterised. This will provide an unparallel census of the stellar population in Cyg OB2, including spectral types, coronal properties and variability, circumstellar disk properties and accretion diagnostics from Ha photometry.

The Chandra Cygnus OB2 Legacy Survey collaborator includes scientists from the Harvard-Smithsonian Center for Astrophysics, Palermo Astronomical Observatory, the University of Hertfordshire, Exeter University, Armagh Observatory, Observatoire de Bordeaux, Univ.-Sternwarte München, University of Southampton, University of Wyoming, Instituto de Astrofísica de Canarias, University College London, Warwick University, Imperial College London, University of Toledo, the National Radio Astronomy Observatory, CEA/Saclay, University of Liege, Observatorio Astronomico of La Plata and the Centre d'Etude Spatiale des Rayonnements.

Results from two existing Chandra fields
A preliminary study based on two existing Chandra fields in the center of the Cygnus OB2 association was performed, combining ~1700 X-ray detections with optical and near-IR photometry [4].

These were used to estimate integrated ages by fitting pre-MS isochrones (Figure 2, right) with ages of 3.5 and 5.25 Myrs for the two fields, both with considerable spreads around the isochrone. These ages are in contrast with the accepted age of 2 Myr for Cyg OB2 based only on the presence of known O-type stars.

We argue that the combination of these ages and the presence of O-type stars as young as 1 Myr [5] suggests a considerable age spread in Cyg OB2. This may be due to either continued star formation within the GMC, or multiple separate bursts.

Figure 1. Ha image of the Cygnus region (2.67 x 2.85 deg) showing the exposure map of the Chandra Cygnus OB2 Legacy Survey (full red = 120ks). The two fields used for the preliminary study are shown as white squares.

Figure 2. Near-IR color-magnitude diagram with 3.5 Myr pre-MS isochrone fitted.

Figure 3. Near-IR color-color diagram with Type I (large dot), II (crosses) and III (small dot) sources shown.

Figure 4. Mass functions for sources in the two fields and fits made within the completeness limits (excluding A/late-B stars that do not give off X-rays).

Circumstellar disks
The fraction of sources with circumstellar material was estimated as a function of the presence of near-IR excesses (Figure 3, right). This low disk fraction for a previously-believed 2 Myr association had been suggested as evidence for rapid disk photoevaporation in the presence of multiple OB stars. However, we suggest that these fractions are not abnormal if a significant fraction of sources in Cyg OB2 are older than previously thought. A disk fraction of 5-10% is standard for a population of age ~5 Myr [6].

The initial mass function
Using masses derived from existing spectroscopy and near-IR photometry we estimate stellar masses for all sources and plot mass functions (Figure 4, left). Power-law fits exhibit a slope $\gamma = -1.09$, in agreement with a universal IMF [7]. At higher masses we find that the mass function steepens significantly, an effect we suggest is due to evolutionary losses of the most massive members of the association and not an inherent property of the initial mass function.

Conclusions
From a study of two Chandra fields in Cyg OB2 we find evidence for an older generation of star formation with an age ~5 Myr. Taking this into account, the observed stellar properties such as mass functions and disk fractions agree with those found locally. We therefore conclude that large-scale spiral-arm star formation in GMCs like Cygnus X does not produce significantly different stellar populations than in local regions. The recently completed Chandra Cygnus OB2 Legacy Survey will greatly improve these results and will address many questions regarding the formation and dynamical evolution of massive OB associations in GMCs.

References