The mysterious high galactic latitude cometary globule (CG) CG12 has been observed with the ACIS detector on board the Chandra X-ray Observatory. We detect 128 X-ray sources, of which a half are likely young stars formed within the globule's head. We make unobscured OB types (e.g. Reipurth 1983). The figure shows the galactic distribution of Bok globules in southern sky from Bourke et al. (1995). The Vela annulus denotes the Gum Nebula. CG12 (red) is one of the few globules located at high-galactic latitude.

The existence of any star forming dark cloud at Galactic location (l,b)=(316,21) is unusual, and the cometary structure of CG12 in such an isolated environment is even more mysterious. There are no reported luminous OB-type stars at even higher latitudes to produce the head-tail morphology with its tail pointing towards (not away from) the Galactic plane. The aim of this project is to identify the poorly known young stellar population of the globule and study its spatial, age, dynamics properties using Chandra X-ray and ancillary ONIR data, and further provide better insights into the origin of CG12.

Method: The current project combines four X-ray observations of the globule, one primary field (I in the Figure) with 31 ks exposure directly at the globule's core and three secondary fields (II, III, and IV) with 3 ks exposures positioned contiguously to the north and west of the core. We detected 128 X-ray point sources. Schematic representation of their X-ray source properties in four dimensions (R.A., Dec., median energy, and count rate) is overlayed on the optical DSS image covering 1.8x1.8 square degrees of the CG12 neighborhood. A dark molecular cloud (outlined by grey contours) lies in the head of the globule, and is superposed by three optical reflection nebulae (magenta contours) illuminated by B-type members of the region. Of the 128 X-ray source; we identified a previously unknown population of X-ray-Tau members (red and some of the green, orange, and cyan circles in Figure). Most are unobscured but some lie inside the cloud. Three protostars embedded in the molecular cloud cores are detected, one of which is newly reported (blue circles within the molecular cloud contour). We establish that the remaining ~70 X-ray sources (most of blue, and some cyan and green circles) are likely contaminants, mostly extragalactic. Source X-ray median energy is color-coded as follows, (keV): [0.5-1.4], [1.6-2.0].

Results: ONIR properties. While accurate classification of the Chandra sources must await our upcoming optical spectrophotometric measurements and accepted Spitzer-IRAC observation, the nature of the sources with known ONIR photometry can be estimated from the presented ONIR diagrams. Most are unidentified or lightly obscured (Av < 2 mag), with positions in the color-magnitude diagram consistent with low-mass 0.2-0.7 M_☉ PMS stars. A wide spread of ages, ranging from <1 to 20 Myr, is seen. Roughly 9-15% of T-Tauri stars possess inner Ks-band disks. Comparing with three other unique sparse clusters we infer that the CG12's disk fraction is lower than that in 0-2 Myr Taurus cloud and higher than that in 17-23 Myr LCC/UCL Sco-Cen subgroups, and roughly similar to that in 8-9 Myr eta Cha cluster. By comparing the observed proper motions of the CG12 stars to a simulated sample of nearby (<1 kpc) field stars from the Besançon stellar population model we also infer that CG12 stellar motions can be attributed entirely to the established motions in the Galactic disk with no evidence for peculiar space motions (graph not shown).

Results: Triggered star formation. Process of radiation-driven implosion (RDI) in molecular globules was originally studied through analytical models for spherical clouds (Bertoldi 1989) and 3-dimensional hydrodynamical calculations (Lefloch & Lazareff 1994, 1995). Recent 3-dimensional calculations of RDI processes in molecular globules, including self-gravity, heating, and cooling, are presented by Kessel-Deynet & Burket (2003) and Miao et al. (2006). The characteristic timescale for producing cometary morphologies and inducing gravitational collapse is 0.1-0.5 Myr (see the Figure). The broad age spread found in CG12 is inconsistent with the rapid timescale (<10^6 yr) predicted by simple triggered star formation models of CGs. However, more complex models of shock triggered star formation might explain the age distribution of CG12 stars. Two possibilities can be considered. First, RDI simulations producing only brief durations of star formation modelled only small globules with initial sizes <1 pc typical for known bright rimmed clouds (Sugitani et al. 1991) with volumes much smaller than the initial size of the atypically large CG12 cloud. The RDI shock front may thus take millions of years to propagate through the whole CG12 cloud during which distributed molecular cores could be compressed, triggering localized star formation at different times. Second, unlike triggering by the continuous flux of photoevaporating ultraviolet light from OB stars in Hill regions, the triggering of CG12 could arise from a sequence of distinct episodes separated by millions of years. These triggers could be the shocks of distinct supernova from a massive OB association. Astronomical evidence for these scenarios is discussed below.

Results: Distance. The distance to CG12 is controversial, with estimates ranging from 400 to 550 pc. By comparing the observed proper motions of the CG12 stars to a simulated sample of nearby (<1 kpc) field stars from the ONC we infer that a dozen expected early O-B3 type members are missing. These could be the relics of a massive binary system that has undergone SN explosion.

Results: Star Formation Efficiency. Assuming the Galactic field IMF for the unobscured YSO population of CG12, we estimate a total population of ~80 stars associated with CG12 with masses ~0.2 M_☉. The star formation efficiency of the globule is in the range 15-35%, typical for active star forming regions, but above that seen in smaller molecular globules with star formation triggered by UV shock fronts.