Feedback from the environment on protoplanetary disks evolution in Cygnus OB2

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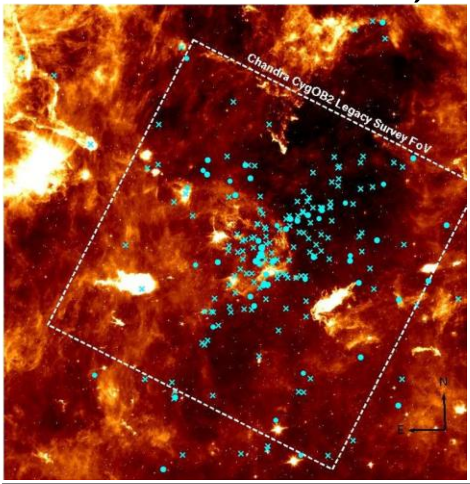


1) The Chandra Cygnus OB2 Legacy Survey

Cygnus OB2 is the closest massive association to our Sun (~1400 pc [1]) hosting hundreds massive stars (among which 2 O3 stars, about 10 B supergiant such as CygOB2 #12 and 3 WR stars [13]) and thousand low mass stars both with and without disks ([2][3]), thus being the best target to study how the environment affects the evolution of protoplanetary disks by:

1) Disk photoevaporation externally induced by intense Far UV and Extreme UV radiation field [4]
2) Gravitational interaction with low mass members during close encounters [5]

This was one of the main motivations of the Chandra Cygnus OB2 Legacy Survey, a 1.03 Msec Chandra/ACIS-I observation of the 0.5 square degree area centered on CygOB2 [6].

A total of 7924 X-ray sources are detected and validated [7], among which 5022 are classified as members [8]. The list of candidate members is completed with 1843 optical-infrared sources classified as disk-bearing members of the association [2].

Fig. 1— Spitzer/IRAC [8.0] image of the Cygnus OB2 area. With the ACIS-I field, are illustrated the positions of known O stars (filled circles) and B stars (crosses).

2) Disk fraction vs. local UV flux

We observe a decline of disk fraction with the intensity of the local FUV and EUV fluxes estimated by projecting and summing emission from all O and WR stars. We verified that this is not due to: a) inside-out sequence of star formation, b) 2D projection, c) incompleteness of X-ray, optical, or IR data [9]

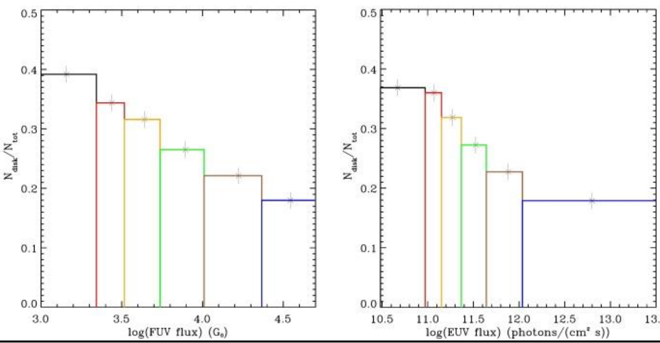
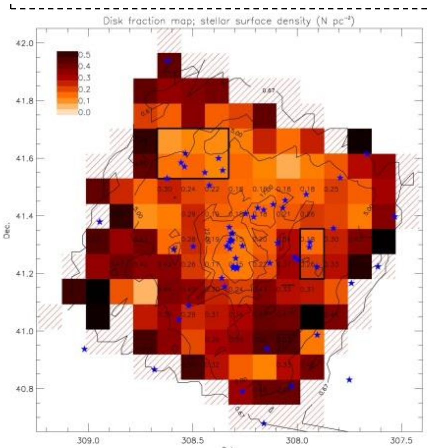


Fig. 2— Variation of the disk fraction with the local EUV (right panel) and FUV fields (left panel). The bin size is fixed to have the same amount of class III sources in each bin



3) Disk fraction vs. stellar density

The disk fraction also decreases with the increase of the local surface stellar density, but regions at high stellar density are also those with more intense local UV field. To understand if stellar density in CygOB2 is high enough to result in significant disks destruction by close encounters, we calculated the local stellar density in simulated 3D configurations of the association adopting a SPH approach [11] and fixed 3D binning, correcting for the mass incompleteness of our catalog. The derived stellar density is low and result in only 15% of members having about 1% chance for close encounters in 1Myr [10]. The chance is smaller for the remaining 85% members. We conclude that in sparse associations such CygOB2 disks are not affected by close stellar encounters.

Fig. 3— Map showing the spatial variation of the disk fraction. The overplotted contours mark the local stellar surface density. The contour levels are: 0.7, 5, 17, 22, and 33 N/pc^2.

4) Disk fraction vs. mass loss rate induced by EUV photons

We find that in most of the association, disk photoevaporation is driven by EUV photons. The expected mass loss rates calculated as in [12] due to the observed local EUV fluxes, range from $1.5\times10^{-8} M_\odot$/yr to $3.9 \times 10^{-7} M_\odot$/yr across the entire field. Such values are capable of dissipating a disk with a typical mass of $0.05 M_\odot$ in 3.3 and 0.1Myrs, respectively. For comparison, a mass loss rate larger than $1.5 \times 10^{-8} M_\odot$/yr is induced by Θ^1 Ori within 0.44 pc. So why do we still observe a rich disk population in CygOB2? The attenuation of EUV photons by residual intra-association material likely reduces the real mass loss rates. There is evidence for the presence of such residual material and the associated extinction is more efficient at larger distances from the central cluster of OB stars. We calculated that realistic dust and gas absorption in the association can result in significant attenuation of incident EUV photons and account for disks dissipation timescales in the outskirts of the association larger than the age of its stellar population.

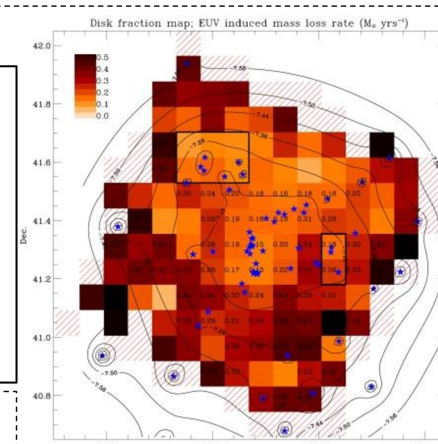


Fig. 4—Map showing the spatial variation of the disk fraction. The overplotted contours mark the expected mass-loss rate due to the EUV photons. The label shows the values of log ($\dot{M}$) in units of $M_\odot yr^{-1}$.

References: [1] Rygl et al. 2012; [2] Guarcello et al. 2013; [3] Wright & Drake 2009; [4] Störzer & Hollenbach 1999; [5] Clarke & Pringle 1993; [6] Drake et al. in prep.; [7] Wright et al. 2014; [8] Kashyap et al. in prep.; [9] Guarcello et al. 2016; [10] Clarke & Pringle 1991; [11] Whitworth et al. 1995; [12] Adams 2012; [13] Wright et al. 2015