Evolution of Dust in the Orion OB1 Protoplanetary Disks

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Summary

Determining the timescales for gas accretion and dust growth and settling requires samples of objects at ages 1 to 50 Myr. We present evidence of dust evolution in Orion OB1 disks, spanning the age range ~4-10 Myr. Our results support the notion of two characteristic timescales for disk dissipation: the mean disk lifetime and the time for the transition from optically thick to optically thin or no inner disk. We also find clear evidence of accretion even at 10Myr. The IRAC photometry reveals a population of transition objects with signatures of inner disk clearing. Our results suggest a short (< 1 Myr) timescale for the dissipation of the inner few AU in protoplanetary disks, and a rapid stopping of disk accretion in this transition phase.

The Orion OB1 Survey

We are carrying out a large scale optical photometric and spectroscopic survey of ~180 deg^2 in the Orion OB1 Association (d~400pc), to map and study the low-mass pre-main sequence stellar population with ages ~1-10 Myr. In an area of ~60 deg^2 we have identified >1000 T Tauri stars. Our ground-based observations provide us with a reliable characterization of stellar properties (T_{eff}, L, mass, age, disk accretion rates).

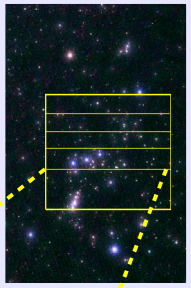

Figure 1. The total extent of the Orion OB1 survey (yellow lines). Each strip indicates the scans of the QUEST Mosaic CCD camera on the Venezuela 1m Schmidt telescope.

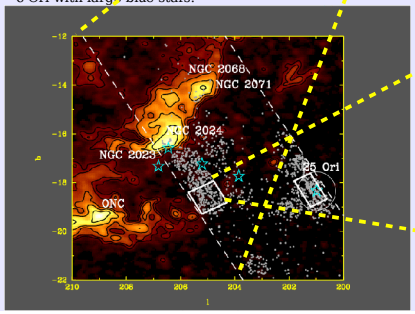

Figure 2. The ~60 deg^2 region spanning Ori OB1a and 1b, plotted over the ^{12}CO emission map. The two IRAC fields are indicated by square boxes; a 1.2 deg circle marks the 25 Ori cluster. The new low-mass members are indicated by small dots; the three Orion belt stars and σ Ori with large blue stars.

Ground-based IR observations

Using Stelircam on the 48inch SAO telescope and OSCIR on Gemini South we observed six OB1 stars at L, 10μm(N) and 18μm. K magnitudes are from 2MASS. In Fig.4 we plot their K-L vs K-N colors and compare with Taurus (~1-2 Myr). We also indicate the location of the Taurus accreting star (Classical T Tauri star, CTTS) LkCa 15, whose SED suggests significant grain growth and settling (Calvet et al. 2005, AJ, 129, 935)). In spite of the small number of objects, there is indication that the Ori OB1 stars tend to populate the gap between accreting CTTS and Weak line TTS with photospheric colors. This suggests that as early as ~4 Myr considerable grain growth and/or settling has taken place.

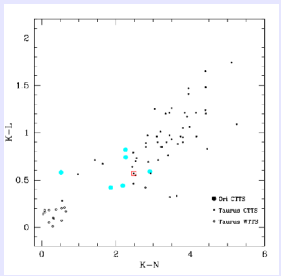

Figure 4

IRAC observations of Ori OB1 PMS stars

We have obtained Spitzer/IRAC observations of two regions in Ori OB1 (Fig.2), one in the ~4 Myr old OB 1b region and the other in the ~10 Myr old cluster 25 Ori. These two fields contain 345 stars, a large and well characterized sample to study the early evolution of dusty disks.

Figure 5 shows the IRAC color-color diagrams. WTTS, those without signatures of ongoing accretion, are indicated with open circles. Solid red dots mark CTTS. We removed objects with indications of contamination by PAH emission. The colors of the transition disk, 2 Myr old, systems CoKu Tau 4, GM Aur, and the 10 Myr old TW Hya are indicated. The solid boxes marks the locus of Taurus colors. The dashed-line box marks the locus of the D'Alessio et al. 2005 (RMxAA, 41, 61) models. Initial results from the ground-based IR photometry are dramatically confirmed by the Spitzer data. The Ori OB1 populations bridge the gap between 1-2 Myr old objects and diskless stars with photospheric colors.

Figure 3. IRAC Orion OB1b field color composite: 3.8micron=blue, 5.8micron=green, 8micron= red.

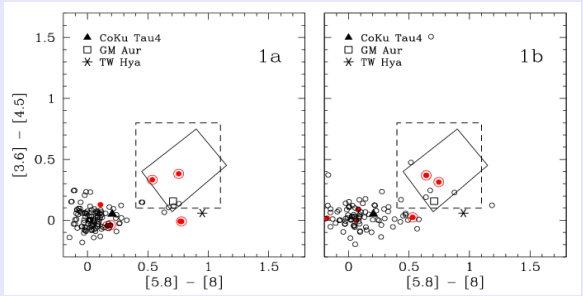

Figure 5

Using the location of well-known transition objects, we define the locus of transition disks as [5.8]-[8] > 0.2, [3.6]-[4.5] < 0.1. We find that the fraction of transition disks in OB 1b (4 Myr) is 14% and in OB 1a (10 Myr) is 7%. Using these fractions and the age of the regions, we infer that the timescale for the transitional disk phase is rather short, < 1Myr. Also, only a small fraction (~1%) of the transition disks are still accreting, similar to the results for the 4 Myr cluster Tr 37 (Sicilia-Aguilar et al. 2005, AJ, 130, 188). Thus, our findings support a rapid shut off of accretion during the transition phase, consistent with predictions of photoevaporating disks by Clarke et al. (2001, MNRAS, 328, 485).

Stellar properties of the OB1 low-mass population

In Fig.6 we show the H-R diagrams for over 1000 new T Tauri stars, using the Siess et al. (2000, A&A, 358, 593) evolutionary tracks. Dashed lines indicate isochrones for 1, 3, 10, 30 Myr and the ZAMS. Red circles represent WTTS, while cyan dots indicate acrreting members (CTTS). There is considerable spread but clearly the OB1a region is older than OB1b. We find ages of ~10 Myr for 1a and ~3-5 Myr for 1b.

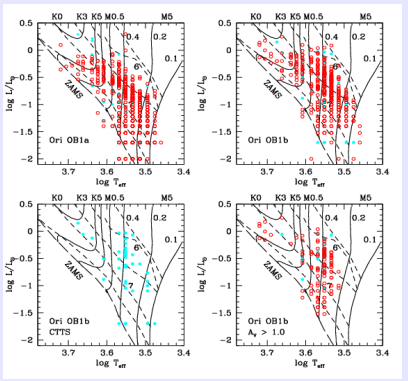

Figure 6

Disk accretion

We used U-band photometry obtained at the SAO 48inch telescope and the Gullbring et al. (1998, ApJ, 492, 323) calibration to derive excess emission and disk accretion rates for 59 stars in Ori OB1. In Fig.7 we show the dM/dt vs age diagram. Disk accretion rates in Orion are consistent with those of other regions, and show a steady decline with age consistent with viscous evolution. If we estimate the fraction of accretors in each sub-association as the fraction of CTTS, we find that in OB1a 82/634 (~13%) are accreting, while only 40/731 (~5%) are accreting in OB1a at 10 Myr.

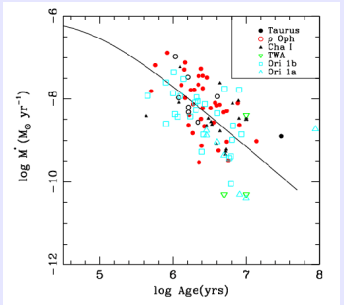

Figure 7