Mem. S.A.It. Vol. 88, 790

Memorie della

Young stellar objects & photoevaporating protoplanetary disks in the Orion's sibling NGC 1977

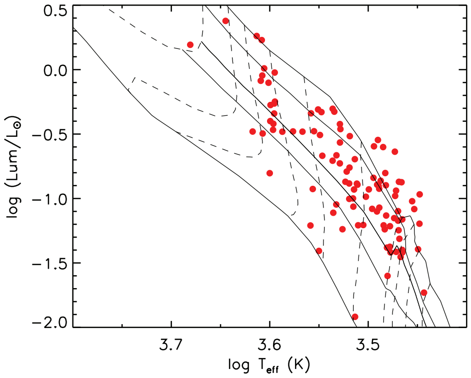
J. S. Kim[1], M. Fang[1], C.J. Clarke[2], S. Facchini[3], I. Pascucci[4], D. Apai[1], and J. Bally[5]

[1] Steward Observatory, University of Arizona, 933 N. Cherry Ave., Tucson, AZ 85750, USA
e-mail: `serena@as.arizona.edu`
[2] IoA, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK
[3] MPE, Giessenbachstrasse 1, D-85748 Garching, Germany
[4] LPL, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721, USA
[5] CASA, University of Colorado, CB 389, Boulder, CO 80309, USA

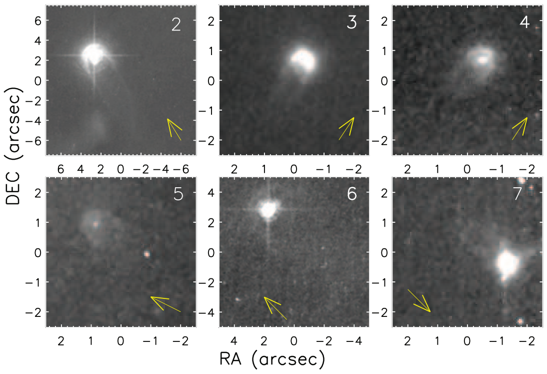
Abstract. We present young stellar population in NGC 1977, Orion Nebula's sibling, and the discovery of new photoevaporating protoplanetary disks (proplyds) around a B star, 42 Ori. NGC 1977 (age$\lesssim$2 Myr) is located at ~30′ north of the Orion Nebula at a distance of ~400 pc, but it lacks high mass O stars unlike in Orion Nebula Cluster (ONC). Nevertheless, we have identified seven proplyds in vicinity of its most massive star, 42 Ori (B1V). The proplyds show cometary Hα emission in HST images, with clear ionization front and tails evaporating away from 42 Ori. These are the first proplyds to be found around a B star, while previously known proplyds were found near O stars. The FUV radiation impinging on these proplyds is 10-30 times weaker than that on the proplyds in ONC. We find that observed proplyd sizes are consistent with a model for photoevaporation in weak FUV radiation field. We briefly discuss one of the interesting YSOs found in this lesser-known star forming region in Orion, NGC 1977.

YSOs and Proplyds in NGC 1977

The Orion complex contains active star forming regions in the solar neighborhood providing diverse star forming environments with ages ranging from <1 Myr to 10 Myr. This complex provides excellent laboratories to study key questions in star formation, e.g., initial mass function, disk evolution and star formation history. The Orion Nebula (M42, NGC 1976) is one of the best studied star forming region. We present our findings of interesting young objects in its lesser-known sibling, NGC 1977, located at ~30′ north of ONC, at about the same distance (d~414 pc). NGC 1977 provides us unique environment, since it is in a milder radiation field and lower stellar density environment than the ONC despite their similar ages. Using multi-wavelength data from X-ray, optical to infrared, and optical spectroscopy we identified young stellar population in NGC 1977. In Fig. 1a we show an H-R diagram of spectroscopically confirmed YSOs in NGC 1977 (Fang et al., in prep.). The isochrones and tracks in the figure are from Baraffe et al. (2015). Our preliminary analysis suggests that the ages of the YSOs in NGC 1977 is $\lesssim$2 Myr.



(a) H-R diagram of YSOs



(b) *Proplyds*

Fig. 1: (a) H-R diagram of YSOs in NGC 1977 (Fang et al. in prep.). The isochrones and evolutionary tracks are from Baraffe et al. (2015). Isochrones shown in the panel are 0.5, 1, 3, 6, 50 Myr and the evolutionary tracks are 0.04, 0.08. 0.1, 0.2, 0.4, 0.6, 0.8. 1.0, 1.4 M$_\odot$. (b) Six of the 7 proplyds in NGC 1977 (Kim et al. 2016). Yellow arrows indicate the direction toward 42 Ori. Proplyds 4 and 5 show resolved disks of sizes 50-70 au, and the central objects are likley very low mass sub-stellar objects.

Proplyds are unique objects to study the effect of external radiation on circumstellar disks, since they provide direct evidence of external UV radiation interacting with disks around YSOs. Their cometary morphology clearly points to the responsible ionizing source. Proplyds are rarely found, and until recently all proplyds were found around O stars, mostly in ONC. However, we have found proplyds in milder FUV environment. The highest mass member in ONC is an O star, θ^1Ori C (O6.5V). However, the highest mass star in NGC 1977 is a B star, 42 Ori (B1V). Compared to θ^1Ori C, the surroundings of 42 Ori have at least 10−30 times lower FUV field, yet we have identified 7 photoevaporating proplyds (Fig. 1b, see Kim et al. 2016). These proplyds are ~0.04-0.27 pc away from 42 Ori, and the radii of the offset ionization fronts in our sample are ~200-500 au. Two of the proplyds shown in Fig. 1b (# 4 & 5) have resolved central sources that we associate with disks of radii 50−70 au. These two proplyd hosts are found to be very low sub-stellar mass objects (Kim et al. 2016; 2017 in prep.). The observed proplyd sizes are consistent with our models for FUV photoevaporation in weak FUV radiation fields using photoevaporation mass loss rate of

$10^{-9} - 10^{-8} M_{\odot}\ yr^{-1}$ (Facchini et al. 2016). Kim et al. (2016) discuss more details on observations and modeling of these proplyds.

Other Interesting YSOs: In NGC 1977 there are numerous interesting YSOs including unique jets and outflow sources. Bally et al. (2012) discovered a unique *spindle*-like structure around a solar mass young star, Parenago 2042, and its pulsed, bent jet that was discovered in HST cycle 18 images. The *spindle* shows an arcs surrounding the western side of the young star illuminated by external ionization by 42 Ori. The innermost, largest arc traces the ionized edge of a 500 au disk with a 170 au gap (see Bally et al. 2012).

References

Bally, J., et al. 2012, ApJ, 756, 137
Baraffe, I., et al. 2015 A&A, 577, 42
Facchini, S., et al. 2016, MNRAS, 457, 3593
Kim, J. S., Clarke, C. J, Fang, M., & Facchini, S. 2016, ApJ, 826, L15