What aspect of star formation will we address in this work?

What is star formation rate?

How does triggered star formation work?

How is triggered star formation and star formation rates useful in understanding star formation process? (triggered star formation not addressed in this paper)

Elmegreen 1998

Our study will focus on triggered star formation within NGC 281 and attempt to determine the type(s) of star formation that are occurring. Most star formation begins due to spontaneous processes on a galactic scale, but triggered star formation takes over and extends the star formation process according to Elmegreen 1998 (Elmegreen, B. G., 1998, Origins, ASP Conference Series, Vol. 148, p.150). The presence of dense or compressed gasses is necessary for all star formation. If there is enough mass/density, gravity alone will produce a star. If conditions are not sufficient for free fall, an outside source of energy is necessary to trigger the formation of a star.

Observations of types of triggering are organized into three categories; small scale triggering which consists squeezing from all sides of existing dense areas, intermediate scale triggering which consists of pressure from one direction that moves through an existing area of density creating a wave front of density that produces stars, and large scale triggering which consists of gas around the source of pressure (OB star?) collecting and becoming dense enough to produce stars in an expanding bubble around the source.

In this paper, Elemegreen refers to NGC 281 as being categorized as an area of small scale triggering with star formation in dense globules. Within the category of small scale triggering it seems that we would be concerned with H II ionization or “formation and collapse of globules in filaments”.

In an H II region around an OB star it is believed that an H II ionization front engulfs areas of high density, but it is uncertain whether these areas of star formation were actually triggered by compression from the H II region or whether the ionization exposed stars that already existed within the density. The paper does not discuss the actual age and distribution of these protostars, but I would think that this would be an area of our study. He also discusses the possibilities of super nova or stellar winds, but I do not believe they apply to our region. Calculations of the pressure necessary for triggering (Pmax) considering mass, speed, size and magnetic field is discussed in great detail but I don’t

think this will be part of our work?

Another possibility is star formation within filaments of dense globules possibly formed due to magnetic fields. Filaments with insufficient magnetic field strength will collapse leading to unstable dense globules which produce stars. Again there is not a lot of detail, but the distribution of stars created via filaments would result in distribution of protostars dependent on the size of the filament.

The paper points out that all of the following should be considered in triggered star formation; internal motions, turbulence, magnetic waves, fragmentations, heating and cooling ionization.

Evans et al. 2009

Evans et al. 2009 studied 5 large nearby clouds ( 15.5 sq deg) for Young Stellar Objects “from molecular cores to planet forming disks” (abbreviated c2d) using primarily Spitzer data. Spitzer data from 3.5 to 160 microns was used in addition to 2MASS, optical data, spectral type information, 1.1 mm using Bolocam on the Caltech Submillimeter Observatory. This study only allowed for YSOs that were detected in all Spitzer IRAC bands (3.6 – 8.0 micron) and Spitzer MIPS 20 micron and showing an infrared excess. This only allows for YSOs through Class II and the beginning stages of Class III as infrared excess diminishes in Class III. This method also misses very young YSOs that are deeply embedded, with the majority of their emissions coming from their dense cloud at much longer wavelengths. Our Herschel data will deal with these longer wavelengths, finding these younger YSOs but in a different region.

YSOs were classified using several methods with results as detected and corrected for reddening from interstellar medium. The slope, alpha, of the infrared excess (IRx) seen in the Spectral Energy Distribution (SED) between 2 and 20 microns was calculated. In general greater slopes indicated more IRx and therefore younger stars. Bolometric temperature (Tbol), the temperature of the peak emission temperature of the SED was also used, the lower the Tbol, the longer the peak wavelength, the younger the star. The uncertainty for Tbol was high for the more embedded stars as Spitzer beam size at these longer wavelengths resulted in increased source confusion (multiple sources included in one detection). Color-Color diagrams were also used to show the degree of reddening at various wavelengths.

Connections between these classifications and the physical properties of each phase was discussed as well as YSO distribution or clustering and comparison to star formation models, but this is getting long and I need to get to Babar’s questions.

The clouds in this study were found to produce YSOs at a Star Formation Rate (SFR) of 290 solar masses every million years which is which is much lower than the predicted rate for “free fall” formation (gravitation collapse/non-triggered) (Why so much lower?) Star formation rate (SFR) is a measurement of stars being born in terms of mass per unit time and is also considered in terms of SFR per unit area. The number of Young Stellar Objects (YSOs) in an area is literally multiplied by the assumed mean mass of 0.5 solar mass and divided by the assumed life of a YSO through Class II of 2 Myr to get SFR. They stopped at Class II in this study because they only allowed YSOs to be considered if they still had an IRx, Class III have begun to lose or have lost their IRx. This is further divided by the area in parsecs (pc) of the cloud to get SFR/area. From this we can calculate the star formation efficiency (SFE), a ratio of the mass of the YSOs (SFR) to the mass of the cloud (including the mass of the YSOs). *But I don’t understand how we can mix SFR which is in units of mass/time with the mass of the cloud.* We can also determine how long the cloud can keep producing stars called the depletion time (tdep), the mass of the cloud divided by the SFR. *These units make more sense.*

SFR are useful in understanding star formation process because looking at the mass of stars being born in the assumed 2 Myr time period, and then looking at the percentage of each class that makes up those stars leads us to an estimation of how much time stars spend in each of these classes. This does not, however, take in to account the possible effects of higher or lower mass on the time a star spends in a particular class. In this study SFR and YSO classifcation using several methods (infrared excess, bolimetric temperatures, color-color diagrams), and the assumption that the cloud has been producing stars for longer than the time a star spends as a YSO, the time stars spend in each class was determined. These calculations were made assuming continuous flow from conception through Class II. Lifetimes (median or half life) found were; Class I 0.54 Myr (longer than estimates), Class 0 SED class 0.16 Myr (longer than estimates). YSOs are concentrated in dense cores with high extinction, extinction (loss of luminosity due to interstellar dust) correction reduce numbers to 0.44 Myr and 0.10 Myr respectively. These high extinction areas also make the correlation between traditional classes and the physical stage the YSO is actually in less certain. In this study, Ophiuchus in particular had a dense core and high level of extinction which effect the results (need to find out how and why) The stars were found to be primarily in clusters, 54% in dense clusters 91% in dense or loose clusters and only 9 % randomly distributed.

Mass surface density and the comparision to Kennicutt Relations does not fall under Babar’s questions and may be outside of our scope, but this paper says that Kennicutt’s work would predict a much lower rate of star formation for these regions, but this work was done on extragalactic structures where matter is more diffuse.