Star Formation Properties in Differing Galactic Environments

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Abstract: We make use of the Bolocam Galactic Plane Survey (BGPS) and the Galactic Ring Survey (GRS) to find the fraction of total gas mass in dense, 1.1mm continuum traced structures and to see how this fraction varies in relation to the proximity of large-scale structures and the local environment. We focus on a field of the Galactic Plane centred at *l*=40°, which allows for separation between spiral arm and inter-arm region.

Clump Formation Efficiency

The CFE is analogous to the star formation efficiency (SFE) in that it traces the mass of gas in dense clumps compared to the mass in the host molecular cloud.
The CFE is a measure of the following:

$$\frac{M_{clump}}{M_{cloud}} = \frac{1}{M_{cloud}} \int_0^t \frac{dM}{dt} dt$$

where dM/dt is the instantaneous clump formation rate. A high value for the CFE can indicate either a high star formation rate or a long formation timescale.

Source Distance Determination

^{13}CO J=3-2 spectra at the positions of BGPS sources, as identified from the catalogue in Rosolowsky et al. (2010), were extracted from HARP data. The peak velocity as well as its position in longitude and latitude were cross-referenced with GRS cloud catalogues (Rathborne et al., 2009; Roman-Duval et al., 2009, 2010), allowing a distance to be assigned to the source. Sources with no GRS association were assigned distances using the Galactic rotation curve of Brand & Blitz (1993).

Determining inter-arm clouds within the *l*=40° region

The *l*=40° region is host to spiral arm and inter-arm regions. The spiral arm sections are represented by two intersections of the Sagittarius arms, the far-edge of the Scutum-Centaurus tangent and the Perseus arm.
By using the model of Vallee (1995), the spiral arms are given the following equation:

$$r = 2.65 \text{ kpc } e^{(\theta+\theta_0)\tan(p)}$$

where r is the galactocentric radius, ϑ is the azimuth around the Galactic Centre with the origin located on the GC-Sun axis, $\vartheta_0 = \pi$, $3\pi/2$ and 2π for the Scutum-Centaurus, Sagittarius and Perseus arms, respectively, and p is the pitch angle.
Making use of the kinematic velocities of each cloud and inverting the distances to the GRS clouds, the galactocentric radius and azimuth of each cloud can be calculated.

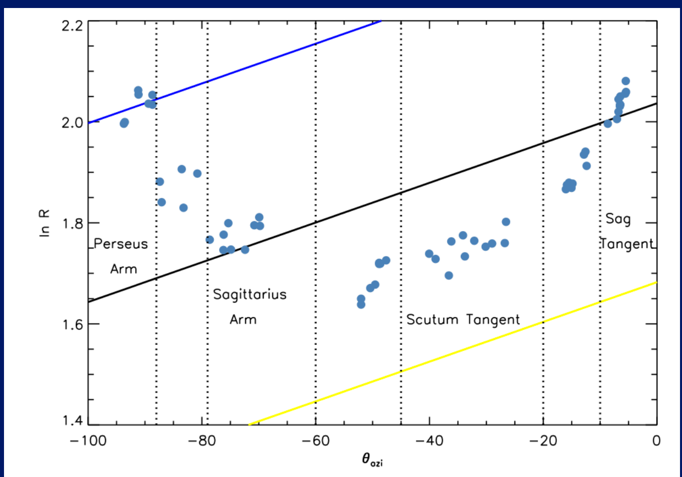

Fig.2: In (θ, ln(r)) the spiral arms are represented by straight lines, with the yellow, black and blue lines displaying the Scutum, Sagittarius and Perseus arms respectively and each point representing an individual GRS cloud

CFEs

The total CFEs, the median individual clouds and mean individual clouds for both the arm and inter-arm regions display no variation and are consistent with each other.

	Arm	Inter-Arm
Total CFE	5.47 ± 0.57 %	4.85 ± 0.68 %
Median Individual Cloud	5.57 ± 3.06 %	5.27 ± 3.31 %
Mean Individual Cloud	14.93 ± 4.81 %	16.28 ± 7.51 %

However, the Perseus arm does show an increase at the 3-σ level, compared to the other arms, with total CFEs for the Scutum-Centaurus, Sagittarius and Perseus arms 2.04 ± 0.38, 4.25 ± 0.50 and 36.27 ± 9.00 % respectively.

l=40° Region

The *l*=40° region defined as the slice of the Galactic Plane covering *l* = 37.83° – 42.50°. This longitude is located between the Scutum-Centaurus tangent (*l*≈30°) and the Sagittarius tangent (*l*≈50°), and as such, intersects the Sagittarius arm twice. This line of sight is a good region to test the comparison between spiral arm and inter-arm star formation, as multiple regions of each are observed. Spiral arm populations can be attributed to the two intersections of the Sagittarius arm, the edge of the Scutum-Centaurus tangent and the Perseus arm, with corresponding inter-arm regions between these populations.

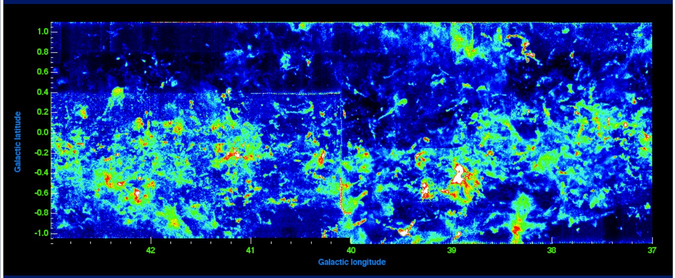

Fig.1: Integrated GRS ^{13}CO J=1-0 emission in the *l*=40° region.

Scales of Star Formation

The structure of a molecular cloud is observed to be hierarchical (Langer et al. 1995), with clouds containing clumps within which cluster sized systems form, which house cores where single stars or small multi-star systems form. As such the formation of all these objects is subject to different efficiencies which can all be measured. The formation efficiency of clouds from the ratio of H_2 to HI mass, the formation efficiency of the star forming clumps from the CFE discussed here and the formation of the cores from which stars form by the infrared luminosity-to-cloud or clump mass.
If the environment as pertaining to large-scale structure was changing the star formation process, at least one of these efficiencies should show some variation with environment. The work of Foyle et al. (2010) has shown no variation between the inter-arm and arm regions in the ratio of molecular-to-atomic gas, with the work of this study and the previous study (Eden et al. 2012) showing no variation with Galactic location in the CFE. Combining these results indicate that neither the clouds nor the clumps are formed more or less efficiently regardless of environment. However, Moore et al. (2012) found environmental variations in the infrared luminosity-to-cloud mass ratio, which implies that the large-scale structure may be changing the efficiency of the formation of stars, rather than their host structures.

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