Galactic Molecular Clouds : Their Place in the Galaxy

L J Summers – lsummers@astro.ex.ac.uk
www.astro.ex.ac.uk/people/lsummers

Abstract

Using data from FCRAO observations of the outer galaxy, the variation with age of the mass of gas associated with stellar clusters is investigated and preliminary results and findings are discussed. I present an improvement on the previous work by Leisawitz et al (1989) and find that the age of a stellar cluster is inversely related to the mass of probably associated molecular material.

Introduction

Any study of the formation of the Universe must include many facets of research progressing from the formation of galaxy clusters through the aggregation of galaxies which in turn are aggregations of stars. Therefore star formation is the keystone in the Universe's evolutionary arc. Any study of star formation (SF) and the timescales involved must include understanding of Galactic Molecular Clouds (GMCs). Sites of all known star formation occur within GMCs, hence where ever there are Stellar Clusters (SCs) one may assume that GMCs are residual within them[1].

Theory

Galaxy morphology plays an important role in governing SF, with the main sites of SF occurring within the spiral arms of S-type galaxies. The flow of GMCs through the shock-fronts in the spiral arms cause perturbations within the clouds allowing macroscopic over-densities to facilitate gravitational collapse into young stellar objects (YSOs)[2]. Previous works[3] found there to be an inverse relation between mass of the associated molecular gas and the age of the SC, see figure 1.

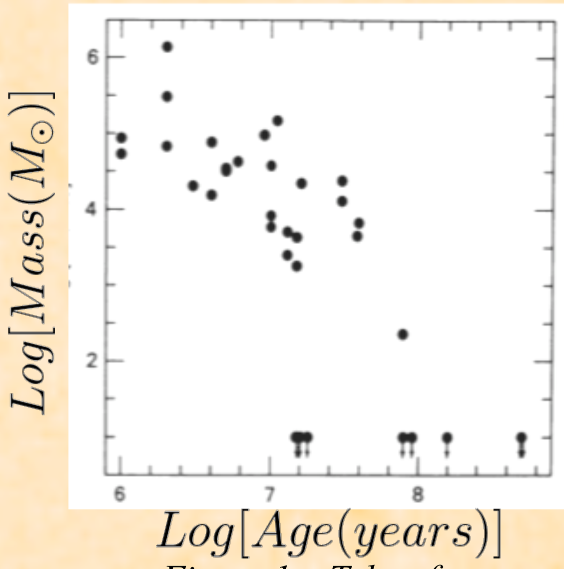

Figure 1 – Taken from Leisawitz et al (1989)

There are now higher resolution data available, so the aim of this work is to revisit the attempt of Leisawitz et al (1989) using the J(1->0) transition of ^{12}CO improve upon the results obtained. CO is used as a tracer for H_2 since the CO aggregates in a similar way to that of the H_2. However, the CO may only be used to probe low density environments (n_{H_2}<3x10^{4}cm^{-3}) because above this limit, the CO molecules suffer from gas-phase freeze-out[4]. In the low density limit, the rotational levels of CO are progressively increases with density.

Methodology

The FCRAO data cubes are defined by a 3-dimensional parameter space in (l,b,V_{LSR}), the Hydrogen mass is then calculated using an X-factor method utilising intensity of ^{12}CO data . Future iterations of the work will use the ^{13}CO isotope. Analysis of ^{12}CO and ^{13}CO together can give more reliable masses through estimation of the excitation temperatures and opacities of these isotopes.

To identify the associated Hydrogen content for each of the stellar a set of two loci, one of radius 25pc and the other being the cluster size with the SC centered at the focus, will initially be used. The upper limit locus is defined by Leisawitz et al. as the point at which gas has a low probability of being associated with the SC.

Objects within the spiral arms are subject to shock. This work concentrates on the Perseus Spiral Arm, assuming a flat rotation curve. The shock causes objects subject to this effect to experience a step in observed velocity, i.e. deviates from the model of circular motion. The position of the Perseus Arm varies with longitude, for this work I use the 4-arm model as defined in Hou et al 2009. The position of the spiral arms within the Galaxy obey a polynomial form of a logarithmic spiral, due to the variation of pitch angle along the arms;

$$ln(r) = a_i + b_i\theta + c_i\theta^2 + d_i\theta^3$$

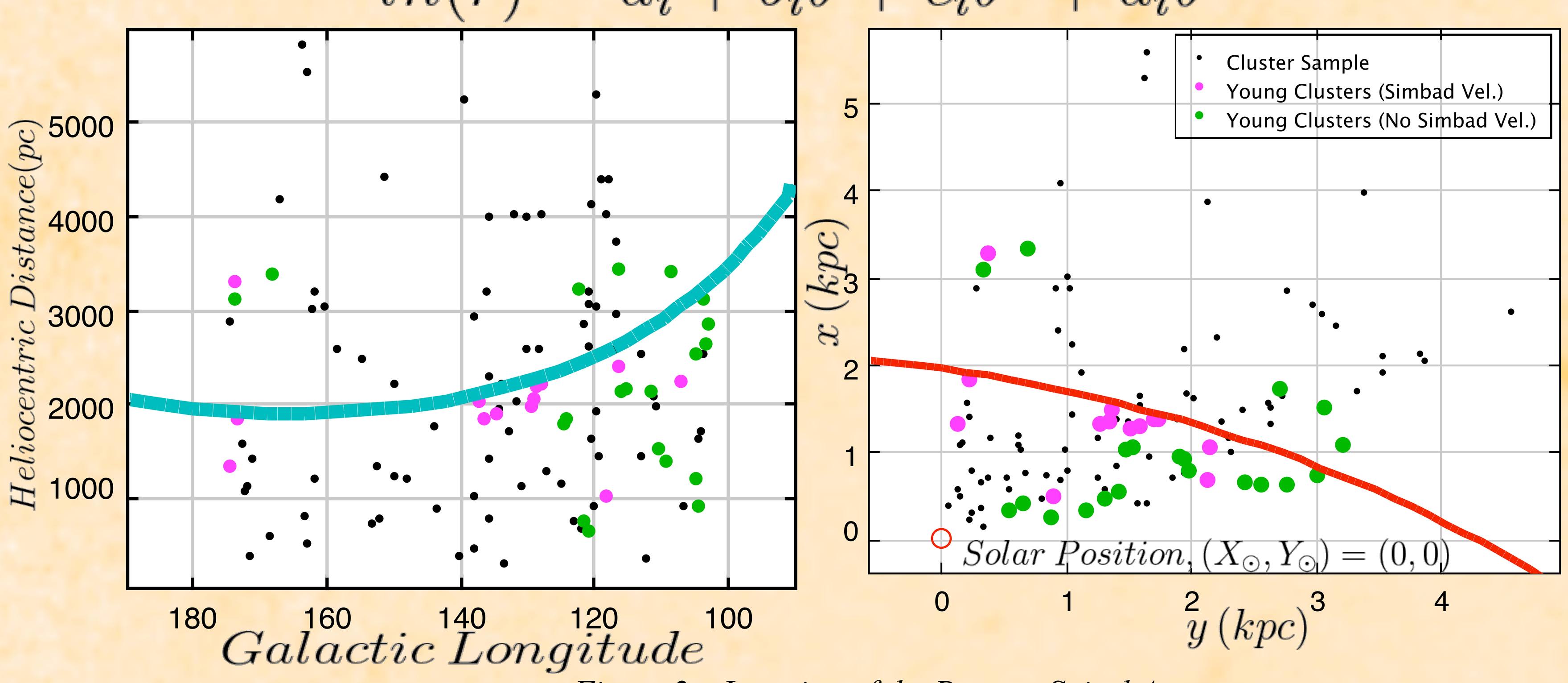

Figure 2 – Location of the Perseus Spiral Arm

The spiral arm is not considered to be a discrete line through the plane of the galaxy instead it is an extended band following this central line.

SCs within this bound region are subject to a Δv shift in velocity. This then places the SC in the correct position in (l,b,V) space. Using this estimate of the V_{LSR} for the clusters, the cluster positions can be inserted into parameter space and the associated CO clouds identified

Preliminary Results

Figure 3, below, shows the variation in associated mass of three stellar clusters with their age. It can be seen the younger cluster (BK 59) has the most associated CO, with the oldest (NGC 1960) having the least. Age decreases from left to right. The brightness scale of the background is normalised for the three CO images. The red and green locus represents the cluster radius and a fixed radius of 25pc as represented in parameter space respectively.

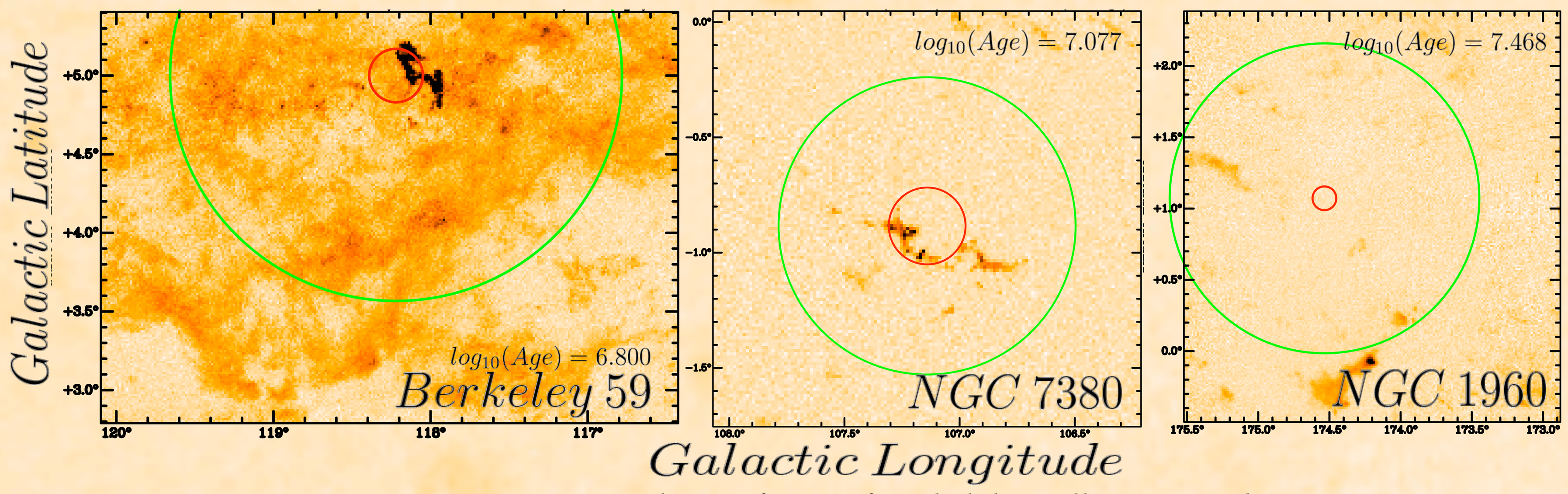

Figure 3 – Variation with age of mass of probabilistically associated CO.

The correlation between this work and that of Leisawitz is clearly seen in, not only, the above figure, but also in figure 4 which has been extended to encompass all SCs with Simbad confirmed velocities.

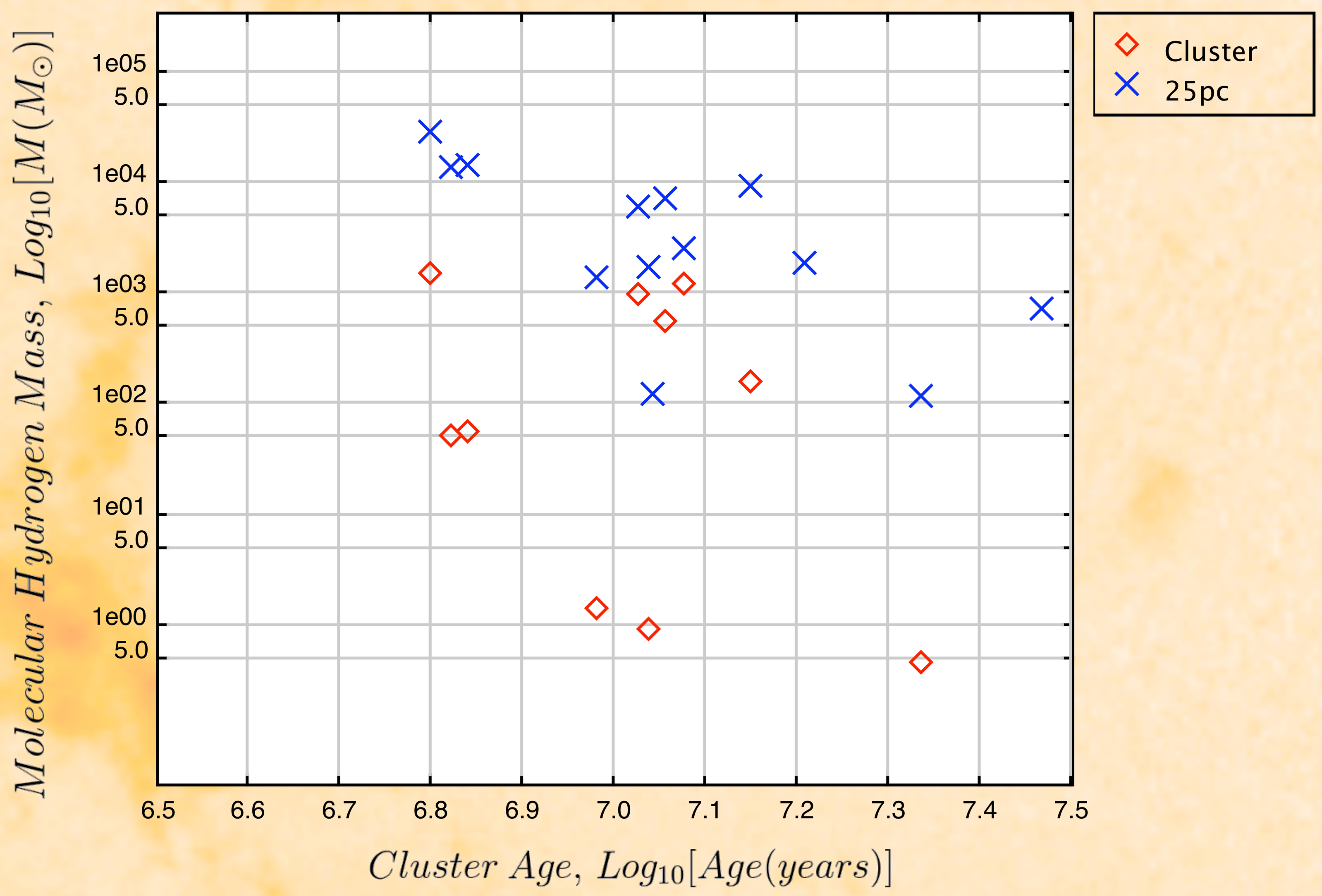

Figure 4 - Preliminary results using Simbad confirmed Velocities.

Figure 4 shows the relation between the mass of probably associated gas with the log_{10}(Age) of the cluster. For the age range represented above, the results present a negative correlation for both the cluster size and 25pc locus. The complete data sample available for analysis contains a total of 114 clusters, which is a three-fold improvement in sample size included in previous works[3].

Further Work

The first modification will be to define a series of integration radii, so that the variation of the mass can be observed, initial findings suggest dM/dt decreases for increasing R. This will give information as to the evolutionary path of the associated mass over time, also, it would yield information as to the background of the environment in which the clusters reside. I also hope to be able to map (x,y,z,V_z) for clusters as they traverse the spiral arm.

References

1) Glover S. C. O. and Mac Low M. M., 2007, ApJ, 659, 1317
2) Roberts W. W., 1972 ApJ 173, 259
3) Leisawitz D., Bash F. N. and Thaddeus P., 1989, ApJS, 70, 731
4) Bergin E.A and Tafallaa M. 2007, ARAAA Vol. 45: 339-396
5) Hou L.G., Han J.L. and Shi W.B , 2009, arXiv0903.0721