A universal law for star formation

January 9 2012

An infrared image of a cluster of young stars (seen as red dots or white dots with red halos) forming in a lane of dark dust and gas amidst remnants of earlier star formation activity in the Cygnus region. Credit: NASA/JPL-Caltech/J. Hora (Harvard-Smithsonian)

(PhysOrg.com) -- Star formation is studied by astronomers not only because it produces new stars and planetary systems. It also generates copious amounts of ultraviolet light that heats dust which in turn causes the birth region to shine brightly in the infrared. Galaxies so far away, for example, that their light has been traveling for over eleven billion years have been discovered thanks to their bright infrared star formation activity.

However the observation of star formation in other galaxies tends to encompass very large volumes; in our own galaxy, by contrast, research focuses on individual star forming molecular clouds because they are much closer and so appear much larger in angular size.

A fundamental yet still only partially unresolved question is whether the same physical processes are at work in all cases. It could be, for instance, that large-scale effects in galaxies, such as inter-galaxy collisions, make their star factories completely different (on average) from those in local, relatively quiescent clouds. After all, the estimated rates of star formation in infrared galaxies are sometimes a million or more times that of local clouds.

CfA astronomers Charlie Lada and Jan Forbrich, with two colleagues, argue in a new paper that the basic processes are the same.

They examined the relationship between the rate of star formation (as determined by numbers of young stars) and the density of molecular gas in the natal regions (as determined by radio measurements of diagnostic molecules). They found good evidence that in all cases the rate of star formation, across nearly a factor of a billion, is linearly proportional to the amount of dense gas present.

Their result contradicts the earlier, more established idea that the relationship is non-linear with total gas abundance, but the authors offer a convincing explanation for why the earlier results were in error. The new paper helps to resolve the uncertainty about global star formation, and focuses future research on the question: what produces the dense gas that is responsible?

More information: Star Formation Rates in Molecular Clouds and the Nature of the Extragalactic Scaling Relations, arXiv:1112.4466v1 [astro-ph.GA] arxiv.org/abs/1112.4466

Abstract
In this paper we investigate scaling relations between star formation rates and molecular gas masses for both local Galactic clouds and a sample of external galaxies. We specifically consider relations between the star formation rates and measurements of dense, as well as total, molecular gas masses. We argue that there is a fundamental empirical scaling relation that directly connects the local star formation process with that operating globally within galaxies. Specifically, the total star formation rate in a molecular cloud or galaxy is linearly proportional to the mass of dense gas within the cloud or galaxy. This simple relation, first documented in previous studies, holds over a span of mass covering nearly nine orders of magnitude and indicates that the rate of star formation is directly controlled by the amount of dense molecular gas that can be assembled within a star formation complex. We further show that the star formation rates and total molecular masses, characterizing both local clouds and galaxies, are correlated over similarly large scales of mass and can be described by a family of linear star formation scaling laws, parameterized by f_{DG}, the fraction of dense gas contained within the clouds or galaxies. That is, the underlying star formation scaling law is always linear for clouds and galaxies with the same dense gas fraction. These considerations provide a single unified framework for understanding the relation between the standard (non-linear) extragalactic Schmidt-Kennicutt scaling law, that is typically derived from CO observations of the gas, and the linear star formation scaling law derived from HCN observations of the dense gas.

Provided by Harvard-Smithsonian Center for Astrophysics