A SCHMIDT–KENNICUTT LAW FOR STAR FORMATION IN THE MILKY WAY DISK

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ABSTRACT

We use a new method to trace backward the star formation history of the Milky Way disk, using a sample of M dwarfs in the solar neighborhood that is representative for the entire solar circle. M stars are used because they show Hα emission until a particular age, which is a well-calibrated function of their absolute magnitudes. This allows us to reconstruct the rate at which disk stars have been born over about half the disk’s lifetime. Our star formation rate (SFR) agrees well with those obtained by using other independent methods and seems to rule out a constant SFR. The principal result of this study is to show that a relation of the Schmidt–Kennicutt type (which relates the SFR to the interstellar gas content of galaxy disks) has pertained in the Milky Way disk during the last 5 Gyr. The SFR we derive from the M dwarfs and the interstellar gas content of the disk can be inferred as a function of time from a model of the chemical enrichment of the disk, which is well constrained by the observations indicating that the metallicity of the Galactic disk has remained nearly constant over the timescales involved. We demonstrate that the SFR and gas surface densities over the last 5 Gyr can be accurately described by a Schmidt–Kennicutt law with an index of $\Gamma = 1.45^{+0.22}_{-0.09}$. This is, within statistical uncertainties, the same value found for other galaxies.

Key words: Galaxy: evolution – Galaxy: formation

Online-only material: color figures

1. INTRODUCTION

Tracing the star formation history (SFH) in galactic disks is a crucial aspect of understanding their evolution. Determination of a detailed SFH is practically only possible in the disk of the Milky Way, and various methods have been developed to do so. The most common method, introduced by Twarog (1980), is to model the color–magnitude diagram (CMD) of stars in the solar neighborhood. Model CMDs are computed by adopting an initial mass function (IMF), a metallicity–age relation, and sets of isochrones, and iterating the SFH until computed CMDs match observations (Hernandez et al. 2000; Bertelli & Nasi 2001; Vergely et al. 2002; Cignoni et al. 2006). Rocha-Pinto et al. (2000) used the chromospheric emission intensity in the Ca H and K absorption lines in the spectra of F and G stars. However, due to stellar activity cycles, metallicity effects, and other complications, chromospheric emission dating can become very uncertain (see Feltzing et al. 2001 for a full discussion). A third method, described by Noh & Scalo (1990), is based on the luminosity function of white dwarfs, which preserves details of the SFH. Lada & Lada (2003) have demonstrated that a very considerable fraction of the field star population in the Milky Way disk might have been formed in open clusters. These dissolve on fairly short timescales due to dynamical effects (de la Fuente Marcos & de la Fuente Marcos 2004) so that, even though only a small percentage of the stellar population is actually found in open clusters, the SFH of open clusters might be indicative for the overall SFH of the Galaxy. However, since open clusters are typically young, this method can be used to study the SFH only over the last Gyr of the evolution of the Galactic disk. Despite differences in the details, the broad result of these studies is that the star formation rate (SFR) has been declining slowly for the last 5 Gyr, prior to which it was rising slowly, and has been punctuated by bursts of star formation from time to time.

In this study, we analyze a sample of M dwarfs, whose spectra show Hα emission (dMe), which we have drawn from the Fourth Edition of the Catalog of Nearby Stars (CNS4; Jahreiß 2009). Like chromospheric Ca H and K emission, Hα emission is related to magnetic activity in the stars, which is in turn regulated by their internal constitution, and in particular by the depth of their convection zones (West et al. 2007). Hawley et al. (2000) have demonstrated, using M dwarfs in nearby open clusters, that the period in which the stars show Hα emission is (among other stellar properties) closely correlated with their absolute magnitudes, and ranges from about $10^{7.5}$ yr at absolute V-band magnitude $M_V = 6$ to some $10^{9.7}$ yr at an absolute magnitude of $M_V = 13$. After these timescales, the Hα emission essentially switches off. We have utilized this effect to reconstruct the SFH of the Galactic disk in a new, independent manner.

In galaxy evolution studies, the SFR is commonly expressed as a “Schmidt–Kennicutt” power-law function of the surface density of the interstellar gas, even though the physical processes leading to this relation are not yet fully understood (see Schaye & Dalla Vecchia 2008 for a discussion of the various concepts). A relation between the SFR and the density of interstellar gas raised to some power was first suggested by Schmidt (1959) in order to explain that the vertical scale height of young stellar populations in the Galactic disk is smaller compared with that of the interstellar gas. This relation was later modified by Kennicutt (1989, 1998) who correlated the SFR observed in other spiral galaxies with the surface densities of their interstellar gas either in concentric rings around the centers of the galaxies or averaged over their entire optical disks. The SFRs and gas surface densities of the galaxies studied by Kennicutt (1989, 1998) are based on present day states of the disks. Similarly Boissier et al. (2001) have derived a Schmidt–Kennicutt relation for the disk of the Milky Way based on its present day gas content. They correlated the radial density
distribution of the interstellar gas in the Galactic disk with the radial variation of the disk’s present day SFR, finding a relation which is steeper than the original Schmidt–Kennicutt relation for other galaxies. What we address here is whether the Schmidt–Kennicutt law also holds true in the disk’s evolution in the past, particularly over the last 5 Gyr or so. The M dwarfs permit us to track the SFH, and we use the chemical enrichment history of the Galactic disk to reconstruct its gas surface density over time.

Our paper is organized as follows. In Section 2 we describe our data. In Section 3, we derive the SFH, and in Section 4, we try to establish a Schmidt–Kennicutt law for earlier epochs of Galactic evolution. The conclusions are summarized in the last section.

2. DATA

Our basic sample consists of 1453 M dwarfs extracted from the CNS4 which are within 25 pc from the Sun. Two hundred and ten of them are classified as dMe. The emission strength data come from the Palomar/Michigan State University (MSU) Nearby-Star Spectroscopic Survey (Reid et al. 1995; Hawley et al. 1996). This survey was based on an earlier version of the Catalog of Nearby Stars (Gliese & Jahreiß 1991). The dMe are binned into half-magnitude intervals of absolute magnitudes from $M_V = 8.75$ to $M_V = 12.75$ mag and are shown in Figure 1 together with star counts in the CNS4 of all M dwarfs of the same absolute magnitudes. The latter were restricted to that sample on which the Palomar/MSU Nearby-Star Spectroscopic Survey is based. Since we want to concentrate here on the thin disk of the Milky Way, we only use stars with vertical $W$ velocities with $|W| \leq 50$ km s$^{-1}$ (Nordström et al. 2004).

To assess the completeness of our sample, we have determined the cumulative number of stars as a function of distance from the Sun. These are shown in Figure 2 on double logarithmic scales. In a spatially homogeneous sample the cumulative number of stars grows in proportion to $r^3$. This is indicated as solid lines with a slope of 3 in the logarithmic diagram.

As can be seen from Figure 2 our samples become seriously incomplete beyond 15 pc of the Sun (this was demonstrated already by Jahreiß & Wielen 1997 with a preliminary version of the CNS4), but this incompleteness has only a small effect on the method we use, which depends on the relative numbers of stars with and without Hα emission, and furthermore such stars have almost the same likelihood of being in the source catalog. This can be quantified as follows. Figure 2 indicates that the dMe are undersampled compared to the entire sample of M dwarfs. For example, within a radius of 25 pc from the Sun, 53% of nearby M dwarfs in the magnitude range that we consider here are cataloged in the CNS4, and 44% of the dMe in this range are also cataloged. To reach a completeness level that is the same as that in the complete sample at this distance (25 pc) implies that some 43 dMe are missing from the CNS4.

The different sampling rates are almost certainly due to the fact that the M dwarf sample in the CNS4 is biased toward high proper motion stars. dMe at the bright end of the luminosity function are very young and have low space velocities. Thus it is very plausible that they are undersampled compared to the entire M dwarf sample. Indeed, Hawley et al. (1996) have shown that the velocity dispersions of the dMe are significantly smaller than the mean velocity dispersions of M dwarfs in the CNS4. We discuss possible consequences of the effect for our results below.

We note that dMe frequently seem to be the members of binary or multiple systems. Sixty three percent of the dMe of our sample are flagged as binaries in the CNS4, whereas only 28% of the M dwarfs without Hα emission are flagged. However, we do not attribute any significance to these numbers, because the degree of completeness of the identification of binaries in the CNS4 is not known. In a systematic study, Fischer & Marcy (1992) found that 42% ± 9% of M dwarfs in the solar neighborhood are binaries. Unresolved binarity might occasionally shift a star in our sample from the one half-magnitude bin into a neighboring bin, but we expect no systematic effects as a consequence.
Next, we calculate the limiting age \( t_{\text{limit}} \) of the stars in each magnitude bin, using the calibration of Hawley et al. (2000),

\[
M_V = -16.75 + 3.06 \log_{10}(t_{\text{limit}}).
\] (1)

SFRs are usually reckoned in terms of surface density per time interval, whereas our sample is confined to within 25 pc of the Sun and samples volume density. To correct our sample from volume to surface density, we note that in the disk’s vertical gravitational potential, the vertical scale height of stars is known to depend linearly on their vertical velocity dispersion. We have multiplied the numbers of M dwarfs in each magnitude bin by the \( W \) velocity dispersion of stars with the same typical ages to obtain the surface density of stars of that age, \( N'(M_V) = N(M_V) \cdot \sigma_W(t) \). For the latter, we have adopted the values given for groups 6d, 6c, 6b, 6a, and groups 5–2 in Table 4 of Jahreiß & Wielen (1997).

Our derivation of the SFH thus relies on the frequency of M dwarfs observed in the solar neighborhood and is corrected to be representative for a cylinder at the position of the Sun and perpendicular to the Galactic plane. However, the local volume actually samples stars from much more distant parts of the Milky Way. At the solar annulus, the orbital period around the Galactic center, \( p = 2\pi/\Omega_0 \), where \( \Omega_0 \) denotes the angular velocity of the local standard of rest, is \( p = 2\pi/220 \text{ km s}^{-1}/8 \text{ kpc} = 2.3 \times 10^8 \text{ yr} \). This means that stars with ages of the order of \( 10^9 \) yr can reach the solar neighborhood from the other side of the Galaxy. This effect is enhanced by the epicyclic motions of the stars. The typical sizes of the epicycles can be estimated from the velocity dispersions of the stars \( \sigma_R \) in the radial and \( \sigma_V \) in the azimuthal directions, respectively, with the relations (Wielen 1982)

\[
\sigma_R = \sqrt{\frac{\sigma_U^2}{-4\Omega_0 B} + \frac{\sigma_V^2}{4B^2}} \quad \text{and} \quad \sigma_\phi = \sqrt{\frac{\Omega_0}{-B}} \cdot \sigma_R. \tag{2}
\]

\( B \) denotes the second Oort constant. If we assume a flat Galactic rotation curve, \( B = -\frac{1}{2}\Omega_0 \), and use again the velocity dispersions given in Table 4 of Jahreiß & Wielen (1997), we find, for stars with ages \( \tau = 0.2 \text{ Gyr}, \sigma_R = 240 \text{ pc} \) and \( \sigma_\phi = 340 \text{ pc}, \) rising to \( \sigma_R = 1.1 \text{ kpc} \) and \( \sigma_\phi = 1.6 \text{ kpc} \) for stars with a mean age of \( \tau = 2.3 \text{ Gyr} \), which correspond to our oldest age bin. Thus we sample dMe in a ring around the Galactic center with a width of about 1–2 kpc, which we term “the solar circle.”

3. STAR FORMATION HISTORY

The surface densities determined in the previous section depend on how far back the past SFH has been sampled, but are also weighted by the Main Sequence luminosity function \( \Phi_{ms}(M_V) \), i.e., the relative frequency distribution of stars as a function of absolute magnitude. Since M dwarfs are so long-lived, their luminosity function can be safely assumed to be unchanging with time. As is customary practice in studies of the SFH we assume that the SFH has been the same for all M dwarfs in our sample irrespective of the mass (they have masses in the range 0.7–0.2 \( M_\odot \); Henry et al. 1993). Below we compare our results with SFHs determined with other stellar types. The numbers \( N'(M_V) \) determined above can then be interpreted as

\[
\frac{N'_H(M_V)}{N'_\text{tot}(M_V)} \propto \frac{\Phi_{ms}(M_V) \cdot \int_{T}^{T_{\text{limit}(M_V)}} \Sigma_\star(t) \, dt}{\Phi_{ms}(M_V) \cdot \int_{0}^{T} \Sigma_\star(t) \, dt} = \frac{\Sigma_\star(T) - \Sigma_\star(t)}{\Sigma_\star(T)}, \tag{3}
\]

where \( T \) is the present age of the Galactic disk, for which we adopt a value of \( 10^{10} \) yr, and where \( \Sigma_\star(t) \) and \( \Sigma_\star(T) \) denote the surface density of the stellar disk and the SFR, respectively, at the epoch \( t = T - t_{\text{limit}}(M_V) \). Equation (3), we have assumed that the surface density of stellar disk was initially \( \Sigma_\star(0) = 0 \). Thus the ratio \( N'_H(M_V)/N'_\text{tot}(M_V) \) allows us to determine \( \Sigma_\star(T) - \Sigma_\star(t) \), which represents the SFH of the disk as a function of time \( t \) relative to the current stellar surface density \( (t = T) \). This is shown on logarithmic scale in Figure 3. The vertical error bars reflect only Poisson errors. The horizontal error bars have been estimated by the scatter of the calibration data points around the linear \( M_V - \log(\text{age}) \) regression line of Hawley et al. (2000). The calibration is based on five open clusters in which the authors have determined the limiting \( M_V \) of the dMes. The ages of the clusters are somewhat uncertain. To their oldest cluster, M67, Hawley et al. (2000) assign an age of 5.4 Gyr, whereas other determinations find 4 ± 0.5 Gyr (Dinescu et al. 1995; Mamajek & Hillenbrand 2008). The ages of the younger clusters used by Hawley et al. (2000) like the Hyades or the Pleiades with ages of 625 and 130 Myr, respectively, are uncertain on the order of 10 Myr (Mamajek & Hillenbrand 2008). We have fitted to the data in Figure 3 in the range of disk age \( t = 5–10 \text{ Gyr} \) a relation of the form

\[
\Sigma_\star(t) = \Sigma_\star(0) - \alpha t^{-\beta}, \tag{4}
\]

and find an index of \( \beta = 2.2^{+0.7}_{-0.6} \). The SFR is then given by

\[
\Sigma_\star(t) = \alpha \beta t^{-(1+\beta)}, \tag{5}
\]

a relation which declines with time. As can be seen from Figure 3, a constant SFR does not fit the data.

As described above, the ratios \( N'_H/N'_\text{tot} \) have to be corrected upward due to the relative undersampling of the dMe. This
affects mainly the younger, bright dMe as they have low space velocities. In our view this explains the irregular pattern of $N_{dMe}′/N_{tot}$ ratios at $t = 9$ and 9.3 Gyr. Shifting the latter up to the fitting curve in Figure 3 would require some 39 additional stars. This is almost precisely the number of stars we have estimated above that needed to be added to the dMe sample so that it reaches the same level of relative completeness as the entire M dwarf sample. As can be seen from Figure 3 such a correction leads to an even better fit of Equation (4) to the $N_{dMe}′/N_{tot}$ data.

The Sun and the stars in its vicinity are at present embedded in the “Local Bubble” of the interstellar medium (ISM), a cavity with a diameter of about 200 pc filled with hot diluted gas. The physical conditions of this gas are such that one does not expect any stars to be presently forming within it. However, the Local Bubble is quite young. Fuchs et al. (2006) have recently redetermined its age and found that it was formed about 15 Myr or less ago. The ages of the dMe in our youngest age bin are of the order of 100 Myr, so that most of them were born before the Local Bubble was formed. Our results on the SFH are therefore not affected by the presence of the Local Bubble today.

Unfortunately, we cannot derive absolute rates for the SFH using our method. However, we can estimate its magnitude roughly by observing that, according to our determination, the surface density of the stellar component of the Galactic disk’s mass grew by 20% of today’s surface density over the last 3 Gyr. Flynn et al. (2006) find a local surface density of the stellar Galactic disk of 35.5 $M_{\odot}$ pc$^{-2}$ which corresponds to a SFR of 2.4 $M_{\odot}$ pc$^{-2}$ Gyr$^{-1}$. The local surface density of interstellar atomic and molecular hydrogen is 6.5 $M_{\odot}$ pc$^{-2}$ (Dame 1993). Very interestingly, this combination of parameters places the Milky Way right on the Kennicutt (1998) relation, even though we use local disk star data, whereas Kennicutt’s data are radially averaged over the whole disk. In Figure 4, we have reproduced the data of Kennicutt (1998) and indicated the location of the Milky Way in the diagram. As can be seen from Figure 4, the Milky Way falls precisely in the region populated by similar galaxy types, i.e., Sb-Sbc.

Our determination of the shape of the SFH is consistent with other determinations of the SFH of the Milky Way disk. We compare our results in particular with the results of Cignoni et al. (2006), de la Fuente Marcos & de la Fuente Marcos (2004), Hernandez et al. (2000), Rocha-Pinto et al. (2000), and Vergely et al. (2002). The results of Hernandez et al. (2000), who modeled the CMD of stars younger than 3 Gyr, and Vergely et al. (2002), who modeled the CMD of nearby stars observed with Hipparcos, can be directly compared with our results, because they refer to column densities. In Figure 5, we show on a logarithmic scale $\Sigma_\star(t) - \Sigma_\star(t)$ as obtained in this work versus $\Sigma_\star(t) - \Sigma_\star(t)$ as constructed by integrating the SFRs determined by Hernandez et al. (2000) and Vergely et al. (2002). Short-duration star bursts in the SFR are effectively smoothed away by the integration procedure. We show in Figure 5 also a SFH determined by integrating the SFR derived by de la Fuente Marcos & de la Fuente Marcos (2004) from the age distribution of nearby open clusters. Their local number densities have been corrected to be representative for column densities by multiplying them by the vertical velocity dispersions $\sigma(\tau)$ typical for stars of the same age (Jahreiß & Wielen 1997). Similarly, we have integrated and converted the SFR found by Cignoni et al. (2006) modeling the CMD of Hipparcos stars (using the data which have been clipped in velocity space). Over the last 3 Gyr all SFHs fit excellently together. Given the totally different approaches in deriving the SFH the good agreement is, in our view, quite remarkable. As explained above, the deviation of our data 0.7 and 1 Gyr ago from the other SFHs and the fitting formula (Equation (4)) is in our interpretation due to the proper motion bias in the CNS4. This affects mainly the bright dMes with short limiting H$\alpha$ emission ages. The velocity dispersion of young stars increases with age by a factor of 3 (Jahreiß & Wielen 1997). Thus our older age bins are expected to be more complete, as they indeed seem to be. Beyond ages of 3 Gyr, the SFH determined by Cignoni et al. (2006) is consistent with the SFH derived in this work, whereas the SFH by Vergely et al. (2002) falls in that age range for unknown reasons, systematically below the two other determinations. Finally, we show in Figure 5 also a SFH obtained by integrating the SFR of Rocha-Pinto et al. (2000), which is based on nearby F and G stars dated with chromospheric emission ages. This SFH differs significantly from the other SFHs shown there and is consistent with a constant SFR (see Figure 3). With the exception of the results by Rocha-Pinto et al. (2000), the consistent picture of the disk’s SFR is that $\Sigma_\star(t) - \Sigma_\star(t)$ rises steeply as a function of look-back time $T - t$ until about 5 Gyr. We cannot resolve with our data the SFH at earlier epochs of Galactic evolution. However, the other determinations of the SFH summarized in Cignoni et al. (2006) indicate a turnover of the SFH to an apparently much reduced rate at early epochs.

4. SCHMIDT–KENNICUTT LAW

As Kennicutt (1998) has pointed out, the data (which we have reproduced in Figure 4) suggest a relation between the SFR and the surface density of the interstellar gas $\Sigma_\star$ of the form

$$\Sigma_\star = k \Sigma_g^\Gamma,$$  \hspace{1cm} (6)

with an index $\Gamma = 1.4 \pm 0.15$ and a coefficient $k = (2.5 \pm 0.7) \times 10^{-4} M_\odot$ yr$^{-1}$ kpc$^2$.

Let us consider the gas content of the Galactic disk as being regulated by two processes—on one hand interstellar gas is converted into stars, but on the other hand the disk accretes
primordial gas,

$$\dot{\Sigma}_g = -\dot{\Sigma}_* + \dot{\Sigma}_g^{\text{scrt}}. \quad (7)$$

The present accretion rate of gas, as inferred from infalling high velocity HI clouds is about 1 \( M_\odot \text{pc}^{-2} \text{Gyr}^{-1} \) (Wakker & van Woerden 1991), but the rate is unknown for earlier epochs of Galactic evolution. In order to constrain the amount of accreted gas we invoke constraints provided by the chemical enrichment history of the Galactic disk. In a one-zone model, the enrichment or depletion of heavy elements is described by

$$\frac{d}{dt}(Z\Sigma_g) = -Z\dot{\Sigma}_* + y\dot{\Sigma}_g, \quad (8)$$

where \( Z \) denotes the mass fraction of heavy elements. In Equation (8), we employed the instantaneous recycling approximation characterized by the yield \( y \). The Geneva-Copenhagen Survey of nearby F and G stars (Nordström et al. 2004) has shown that the metallicity of the Galactic disk has been, within statistical uncertainties, constant over most of its evolution (“flat”). In view of contradictory claims by Haywood (2006) and Reid et al. (2007), Holmberg et al. (2007) have thoroughly re-analyzed the Geneva–Copenhagen Survey and meticulously discussed all selection effects. They confirm their earlier conclusion that the age–metallicity relation is indeed flat. Assuming this to be the case, Equations (3) and (8) then imply \( \dot{\Sigma}_g^{\text{scrt}} = (y/Z)\dot{\Sigma}_* \) or

$$\dot{\Sigma}_g = -\left(1 - \frac{y}{Z}\right)\dot{\Sigma}_*. \quad (9)$$

The ratio \( y/Z \) has a value of about \( y/Z = 0.7 \) (Pagel 1997), which is another way of stating that accretion of gas is important for the evolution of the Galactic disk.

Taking the derivative of Equation (6) we find

$$\frac{d\dot{\Sigma}_*}{d\Sigma_g} = \Gamma k^T \dot{\Sigma}_g^{\text{scrt}}. \quad (10)$$

If we insert the parameterization of \( \dot{\Sigma}_* \) introduced in Equations (4) and (5) into Equations (9), and (10), this leads to

$$\log \left(\frac{d\dot{\Sigma}_*}{d\Sigma_g}\right) = \text{const}_1 + \frac{1}{\beta} \log (\Sigma_g - \Sigma_{g0})$$

$$= \text{const}_2 + \frac{1 + \beta}{\Gamma} \log (\Sigma_g - \Sigma_{g0}) \quad (11)$$

with

$$\Sigma_{g0} = \Sigma_g(T) - \left(1 - \frac{y}{Z}\right)\left(\Sigma_{*0} - \Sigma_*(T)\right).$$

A comparison of the coefficients shows then that the indices are related by

$$\Gamma = \frac{1 + \beta}{\beta}. \quad (12)$$

In the previous section, we determined a value of \( \beta = 2.2^{+0.7}_{-0.6} \), which implies an index of the Schmidt–Kennicutt law of \( \Gamma = 1.45^{+0.22}_{-0.09} \). This fits, within statistical uncertainties, very well to the index observed by Kennicutt (1998) for the present day SFR in other galaxies. Apparently the SFR of the Milky Way disk was regulated by the same Schmidt–Kennicutt law over the last 5 Gyr. At earlier epochs the slope \( \beta \) was probably shallower, which would imply a larger index \( \Gamma \) for the Schmidt–Kennicutt law.

In deriving Equation (11) we have assumed an accretion rate of primordial gas that compensated exactly the metal enrichment due to star formation so that the metallicity stayed constant during the evolution of the Galactic disk, in line with the observations by Holmberg et al. (2007). But many models of the chemical enrichment history of the Galaxy predict a mild chemical enrichment of the Galactic disk over the last 5 Gyr (see Colavitti et al. 2008 for a recent discussion). This is due to less accretion than we assumed. However, our principal result on the slope of the Schmidt–Kennicutt law does not depend on the absolute amount of accreted gas. We note that a “closed-box” model with \( \dot{\Sigma}_g^{\text{scrt}} = 0 \), which is known to lead to a relative distribution of metallicities in the Milky Way disk that is quite inconsistent with observations (Pagel 1997), implies just the same relation that we found in Equation (12). Cosmological models of gas accretion onto galaxies and of the ensuing chemical enrichment history predict accretion rates which decline with time (Colavitti et al. 2008), similar to the SFR which we found for the last 5 Gyr. Thus a relation of the kind \( \dot{\Sigma}_g^{\text{scrt}} \sim \dot{\Sigma}_* \) will approximately hold and we argue that our result on the slope of the Schmidt–Kennicutt relation should be rather robust.

5. CONCLUSIONS

We have used a new method on a sample of M dwarfs in the solar neighborhood showing H\( \alpha \) emission in their spectra, to trace backward the SFH of the Milky Way disk. The M stars show H\( \alpha \) emission up until a certain age (which is a well-calibrated function of their absolute magnitudes) allowing us to reconstruct the rate at which stars have been born in the disk at the solar circle over about half its lifetime.

The SFH of the Galaxy seems to be well resolved over the last 5 Gyr using our M dwarf sample. We find that the SFR rises continuously when looking backward to 5 Gyr. This is in very good agreement with other determinations of the SFH of the Galactic disk by different methods.
In order to derive a Schmidt–Kennicutt law for the local disk, we have determined the variation of the surface density of the interstellar gas in the Galactic disk during the formation and evolution of the disk. The gas content of the disk is controlled by the competition between the star formation process, on one hand, and accretion of gas from outside the Galaxy, on the other hand. Since the latter cannot be observed directly, we had to infer the amount of accreted gas indirectly. For this purpose we have invoked the chemical enrichment history of the Galactic disk. Based on the observation that the metallicity of the Galactic disk has remained rather constant during its evolution (in particular over the last 5 Gyr) we show that the gas infall rate is proportional to the SFR. We have then correlated the SFR with the surface density of the interstellar gas and found that the correlation followed over the last 5 Gyr a Schmidt–Kennicutt law with an index of \( \Gamma = 1.45\pm0.22 \). This agrees, within statistical uncertainties, with the value of \( \Gamma = 1.4 \) found by Kennicutt (1998) for the present day SFR in other galaxies. It seems that at epochs of Galactic evolution earlier than 5 Gyr ago, stars formed at a much reduced SFR, which does not follow the Schmidt–Kennicutt law. The investigation of the reason for this change of the mode of star formation is beyond the scope of this paper, but we hope to address this question in the future.

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