PART II

EVOLUTION OF THE CENTRAL PARTS OF THE GALAXY

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ABUNDANCES AND CHEMICAL EVOLUTION OF THE GALACTIC CENTER

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ABSTRACT

From observations of the galactic center using various techniques radioastronomy, millimeter waves (molecules) - infrared and gamma rays, the interstellar matter of this region appears to have been strongly processed into stars : the gas density is much lower than in the solar neighbourhood. From CO measurements one knows that there are many molecular clouds such as SgrB2 where stars are forming now. From IR measurements, there are some indication that low mass stars are relatively more numerous in such regions than in the external regions of the galaxy. Finally the heavy element abundances show three important features (i) the possibility of strong enhancements in elements such as N and in a less extent O and Ne (the so called abundance gradients). (ii) Some specific enhancements of isotopes such as ^{13}C, ^{14}N and also ^{17}O relative to ^{12}C, ^{15}N and ^{16}O (iii) Deuterium seems to have a lower abundance than in other parts of the galaxy such as the solar neighbourhood. Simple models of chemical evolution have been designed to account for such features and are rewiewed here.

I - INTRODUCTION

The galactic center is a complex region which is rather difficult to study : First, the large amount of dust on the line of sight is such that the optical observations are not the best way to study the galactic center. Fortunately as it will be reminded here, gamma rays, infrared millimetric and centimetric techniques provide now a large amount of information on this region : A summary on the present knowledge on the morphology of the galactic center is given in Section II. There is some ambiguity in defining the galactic center : some authors especially the radio and the infrared astronomers would give a rather restricted definition of the galactic center. They would limit it to the Sgr A West region. Those who are performing very long base interferometry (VLBI) observations (Lo et al 1975 and Kellermann et al 1977) are able to detect a central point less extended than the solar system. Those of us who are interested in modeling the evolution of such regions are indeed less strict and would define the central parts as those included within few hundred parsecs. This more extended definition will be used in this review.

For modeling the evolution of the galactic center one needs to know

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not only the gas density but also the relative proportion of low mass and high mass stars : low mass stars are long lived and end up their lives as planetary nebulae : they can be important in modifying the CNO abundances by favouring the production of ^{14}N and ^{13}C relative to ^{12}C and ^{16}O for instance. High mass stars ($M > 5M_\odot$) are short lived, end up their evolution as supernovae and are considered as the progenitors of "primary" elements such as ^{12}C*, ^{16}O and Fe. The purpose of the models of chemical evolution is to account for the variation of the elements abundances. In section III, I summarize the present information coming from observations and relevant to the evolution models. Finally in section IV, our current evolution models built up to account for the central region of the galaxy are described and discussed. This review on the galactic center is far from complete. The reader interested on the recent developements regarding these complex regions is not only referred to the previous review of Sanders (this colloquium) but also to Mezger (1974) and especially the very complete review of Oort (1977).

II - THE MORPHOLOGY OF THE GALACTIC CENTER

The morphology of the galactic center is mainly approached by the radio astronomy techniques mainly on millimetric and centimetric wavelengths, and by the infrared astronomy (with λ from 2 to a few hundred μ). The search for gamma rays coming from the galactic center appears also very promising.

1) - The radio astronomy techniques provide the following information :

- Strong continuum radio sources can be found in surveys made at different frequencies (see fig 1 from Downes et al 1965 performed at 8.0 Gc/s). These strong radio sources are generally thermal sources i.e. large HII regions (fig 1). It is well known that dust and molecular clouds are associated to these HII regions.

There exist also non thermal radio sources which can be considered to be supernovae remnants. One of them is described in the work of Ekers et al 1975 who give the highest resolution (10.3 x 1.7 pc) existing map of the non thermal radio source Sgr A East, close to the thermal source Sgr A West which is considered to coincide with the galactic nucleus itself (fig 2).

In the central source itself Sgr A West, surveys made by very long base interferometry techniques (VLBI) by Lo et al 1975 and by Kellerman et al 1977 show clearly a VLBI source which has a dimension of at

*the case of carbon might be more complicated than that what was thought before : Peimbert (this colloquium) indicates that C could be significantly produced in ejectae of planetary nebulae.

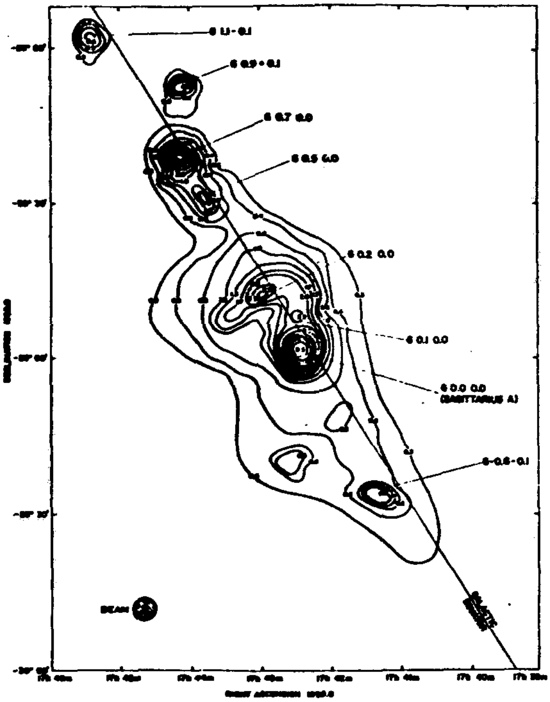

Fig. 1 Galactic center region at 8.0 Gc/s (Downes et al 1965) Contours units represent antenna temperature. Nomenclature for the sources in galactic coordinates is indicated. G.07 - 0.0 is also SgrB2.

most 10^{15} cm. Its luminosity ($L \sim 10^{33}$ ergs/sec) is still 10^{7} times smaller than that the luminosity of corresponding central sources of other galaxies. The nature of this VLBI compact source is still mysterious· several expanations have been proposed:either it could be a supernovae remnant at the very beginning of its evolution or a black hole. Arguments against the last possibility are presented by Ozernoy (this colloquium).

Radio astronomy measurements in the 21 cm allow to survey the atomic hydrogen, the recombination lines survey the HII regions, finally with the 2.6 mm line from CO the molecular hydrogen distribution can be indirectly determined. The reader is referred to Burton (1976), Oort (1977), Bania (1977) who give the availbable information on the distribution of gas in the galactic center. A few remarks can be made regarding this distribution :

i) the volume density of HI remains constant when one goes towards the

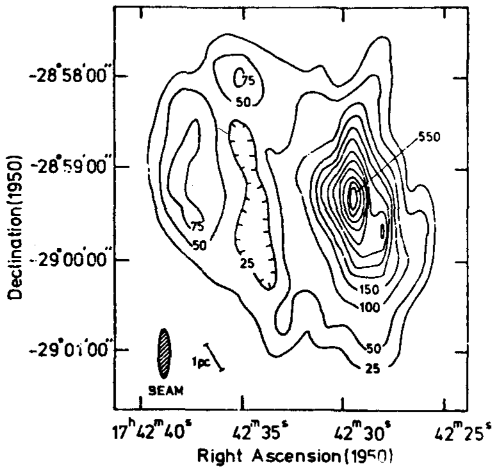

Fig.2 Map of the 6cm radio emission from the galactic center with a beam of 6" x 34" half power width, constructed from a combination of observations at Westerbork and Owens Valley. (Ekers, et al 1975). The strongly concentrated source on the right is Sagittarius A West. It coincides with the galactic center. The left-hand source is Sgr A East It lies at 1'8, or 5 pc, from the centre. The line indicating the scale is parallel to the galactic plane.

central regions while the total mass density (in volume) increases.
ii) on the contrary, the ionized, and from CO the molecular hydrogen distribution is more concentrated like the gamma rays.
iii) the position and the width of the recombination lines provide the velocity distribution and the internal velocity dispersion of the HII regions and then allows the determination of the mass distribution in the galactic center (as outlined in the next section). The lines of HI, CO and other molecules provides a similar kind of data.

Many molecular surveys of the galactic center have been performed : CO provides indirectly not only the mass but also temperature distribution of cold and dense clumps of gas. The SgrB2 (G 0.7 - 0.0) region appears to be a very important molecular cloud : such dense clouds are assumed to be the site of intense star formation (To achieve this process important compression effect should obviously take place). In fact the densest parts of the molecular clouds contain OH-H_2O masers which indicate the existence of very dense and small clumps inside the molecular clouds themselves and are generally believed to be be associated to proto-stars.

About 45 molecules have been discovered mainly in the galactic center (see eg the review of Zuckermann 1977) A few of them like CO, CS HCN, H CO, HC_3N can be used as good probes to obtain isotopic ratios of such regions.

2) The galactic center has been also thoroughly surveyed in the <u>infrared</u>.

Very detailed maps from 2μ up to a few hundred μ have been provided in particular by the Caltech group: Becklin and Neugebauer 1968, 1975 and very recently Gatley et <u>al</u> 1977 (see figs 3,4)

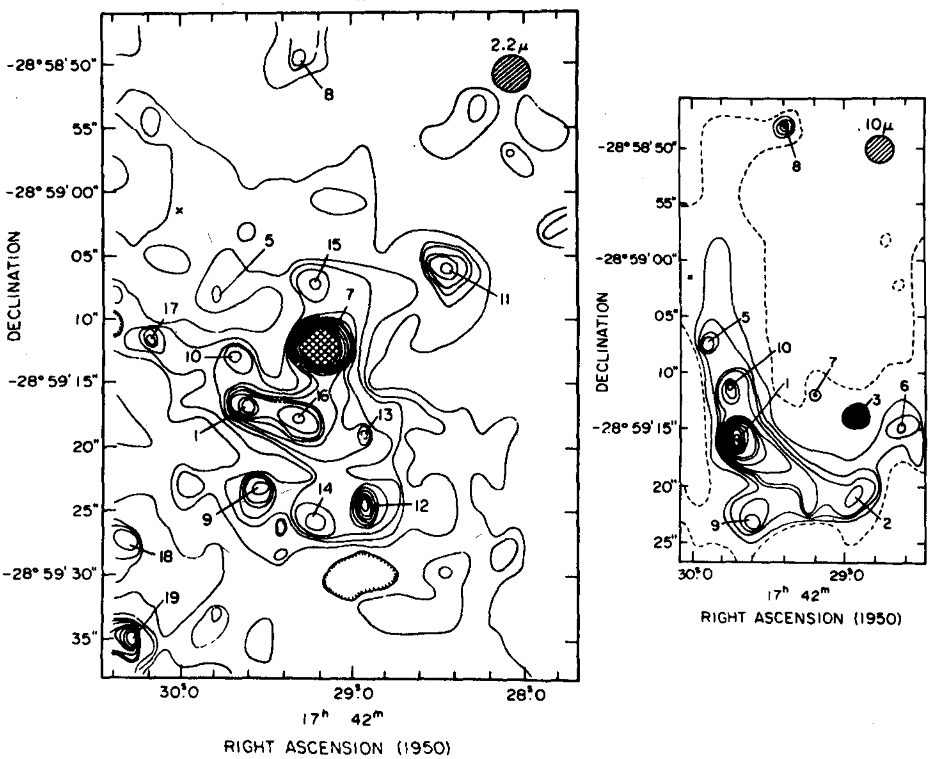

Fig. 3 and 4 Contour maps of the radiation 2.2 and 10 μm wavelength in the infrared core (Becklin and Neugebauer, 1975).

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These maps show in particular that SgrA West coincides with the strongest 2.2μ source (IRS 16 in the Becklin Neugebauer 1975 map).

The outcome of these important measurements can be summarized as follows :

i) IR measurements provide a better knowledge of this region than optical ones because a large amount of dust on the line of sight absorbs completely the optical radiation (Av$\sim$27 magnitudes)

ii) From surveys made at different wavelengths one can obtain several different pieces of information : surveys made at short wavelengths ie. at 2μ allow to sample the strong stellar sources. They provide some information on the distribution of the red giant stars which are the main contributors to the luminosity at this wavelength. In particular, the galactic center itself (Sgr A West) appears to be a strong stellar source. At 10μ the hot dust ($\sim$ 300K) in planetary nebulae, HII regions or circumstellar envelopes appear to be most important sources. Finally the radiation seen between 30 to 100 is mainly due to thermal reemission by dust at T$\sim$30 K of the stellar radiation coming from hot O and B stars and absorbed by it. Figure 5 shows a map obtained at 100μ by

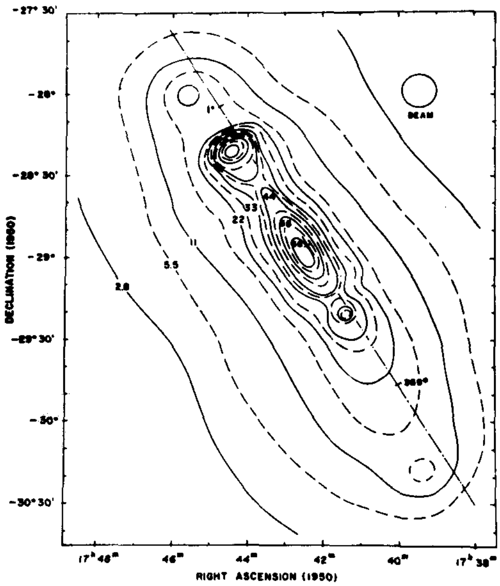

Fig.5 Contour map of the galactic center region at 100μ. The contour intervals are given in units of 10 ergs sec^{-1} μ^{-1}sterad^{-1}. The observed coordinates have been adjusted to fit the radio position of Sgr A. The galactic equator (b^{II} =0) is indicated by a broken line Notice the similitude with fig.1 (from Hoffmann et al 1971).

Hoffmann et al 1971, quite similar to the radio map of fig.1 These two maps show in particular the actual center of the galaxy G.0.0 - 0.0 (or Sagittarius A) and the largest HII region-molecular cloud complexes of our galaxy (Sagittarius B2 or G 0.7 - 0.0). The strong 100 sources coincide with the radio sources. Furthermore as noted by Gatley et al 1977 the dimension of Sgr A increases with λ for $\lambda > 10\mu$ which means that the far IR radiation is in thermal equilibrium and is not due to non processes such as synchrotron radiation. An important point made by Gatley et al 1977 is that the amount of dust relative to gas present in the galactic center itself does not seem to be larger than in external regions. This point could give some support to the idea that the amount of dust is roughly proportional to the amount of gas available.

Before leaving the IR measurements, one should note that observations in the Ne II fine-structure line at 12.8μ has been used in particular by Wollman et al 1976 and Wollman 1976 to show the presence of a highly ionized region inside Sgr A West within 0.4 pc from the center. This measurement is quite consistent with the results of radio recombination lines studies in this region (Pauls et al 1974).

3) High energy gamma rays have been observed by SAS II (see Fitchel et al 1975 by COS B (Caravane collaboration) in the galactic center. These fluxes can provide some indication on the cosmic rays fluxes themselves and therefore on their sources i.e. the supernovae (or massices stars). The use of observations will be developed in § IV to try to understand the deuterium abundance in the galactic center.

III - OBSERVATIONS RELEVANT TO THE EVOLUTION MODELS OF THE GALACTIC CENTER

At it will be seen in the next section, three different types of observations are needed to build up evolution models of a given region of the galaxy: one should know 1) the mass distribution, in particular the ratio between the gas density and the total mass density 2) the stellar distribution namely one should have at least an indication on the relative number of low mass stars and high mass stars 3) the elemental abundances and also some isotopic ratios if possible.

The total mass is derived from dynamical properties. The mass of the nucleus itself (Sgr A West) has been derived by Pauls et al(1974) from the width of the radio recombination lines using the virial theorem. The mass distribution in the whole region has been deduced by Sanders and Wrixon 1973 from a rotation curve obtained from CO observations.

The mass of gas can be estimated from CO measurements one assumes that 10 to 20 % of C is in the CO phase and also that C/H is solar (which are rather rough assumptions see eg Thaddeus 1977) one can deduce the amount of gas in the form of molecular hydrogen which is assumed to represent most of the gas. Another way to estimate the density of gas is to evaluate the amount of dust present inside the central regions (this can be done either by measuring the reddening of the visible or the IR light or by estimating the mass of dust in the far IR sources (these far IR sources are assumed to correspond to the emission of dust heated by the nearby hot stars). It one makes the assumptions that the ratio dust to gas remains constant within the whole galaxy (assumption supported by the recent observations of Gatley et al 1977) one might then deduce the gas density. The ratio gas density to total density in central regions is listed in Table 1. The above remarks do show how inaccurate is the determination of the gas density : measurements of CO and the amount of dust present in the galactic center can provide very different estimates of this parameter depending strongly on the assumptions that one should make.

2) the stellar distribution namely the comparison between the rate of deaths of low mass stars (generally classed as planetary nebulae) and the rate of supernovae explosions are listed also in Table 1. The rate of formation of planetary nebulae (which can be related to the rate of death of low mass stars) can be estimated by looking for IR sources having features similar to these objects. Becklin and Neugebauer (1975) assume that five 10μ sources close to the galactic center can be good planetary nebulae candidates (ie IRS 7,11, 12, for example). This comparison however is questioned now because these sources are far more intense than ordinary planetary nebulae such as NGC 7027. The supernovae explosions leave a supernovae remnant which appear to be a strong non thermal radio source. Three or four non thermal sources can be classed as supernovae remnants; Sgr A East (after Ekers et al 1975) G 1.05 - 0.1 and G 359.4 - 0.1 listed by Downes 1974. The origin of the VLBI sources is still a problem. In this method which attempts to deduce the rate of high mass stars by counting the non thermal radio sources one assumes that the supernovae remnants have the same life time which is a very questionable hypothesis.

The rate of supernovae explosions could also be indirectly approached by the observations of high energy gamma rays such as those undertaken with SAS II and now with COS B which could provide in the future an estimate of the cosmic ray fluxes and then some indication on the rate of supernovae. Finally one can estimate the population of high mass stars (hot O-B stars) by observing the radio thermal continuum emission which allow to evaluate the flux of Lyman photons needed to ionize the hydrogen and then the number of O and stars needed to release these fluxes of Lyman photons (see eg Mezger ans Smith 1976).

3) There are very few elemental abundances which can be directly measured in the central regions : For instance Mezger and Smith (1976) indicate that helium can be somewhat enhanced in the central regions compared to its canonical abundance. This belief is based but not proved by the recent measurements and comparisons of the hydrogen and helium recombination lines. By noticing that the H II regions in the center of our galaxy are generally somewhat colder that external H II regions and noting that the main cooling agent is oxygen , Churchwell and his associates claim that there should be some gradient of oxygen which should be more abundant in the galactic center than in external regions. From the 12.8μ line coming the recombination of the Ne II, Aitken et al (1976) think that Ne could have an abundance between its solar value to three times this value. Finally there are indirect evidence of a strong gradient of nitrogen coming from all the measurements or estimates made

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TABLE 1

	Galactic Center	Solar neighborhood
GAS/TOTAL MASS	(7-70) 10^{-4} *	0.05 - 0.15
SUPERNOVA RATE per total mass ($M_\odot$ yr^{-1})	(2-15) 10^{-14}	(2-8) 10^{-13}
per unit of gas mass ($M_\odot$ yr^{-1})	(0.2-8) 10^{-10}	(1-8) 10^{-12}
PLANETARY NEBULAE per total mass ($M_\odot$ yr^{-1})	(0.7-6) 10^{-11}	(0.5-2) 10^{-11}
per unit of gas mass ($M_\odot$ yr^{-1})	(0.7-30) 10^{-8}	(0.3-2) 10^{-10}

* These figures coming from Audouze et al 1975 are based on the total mass estimated by Sanders and Lowinger (1973) inside a radius of 600 pc and for a mass of gas between 10^7 to 10^8 $M_\odot$ (see eg Scoville et al 1974). Bania (1977) gives a mass of gas of 3.5 to 7 10^8 $M_\odot$ ($m_g / m_{TOT} < 5\ 10^{-2}$) which we consider as a strict upper limit for reason linked to the very uncertain conversion of the observed CO line intensity into H density.

in nearby spiral galaxies.

Finally, progress has been made recently in the determination and the knowledge of some important isotopic ratios in the galactic center. (see in this context the series of papers published by the Bell Lab and quoted in table 2). The galactic center is a good place to look for molecular isotopic ratios because of the presence of large molecular clouds such as Sgr B2 and Sgr A. From table 2 one sees that i) If deuterium is present in the galactic center, its abundance is much lower than in other parts of our galaxy ii) There is appreciable enrichement in ^{13}C relative to ^{12}C, ^{14}N relative to ^{15}N, ^{17}O relative to ^{18}O. These relative enrichements can be tentatively interpreted

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TABLE 2.

Isotopic determinations in the galactic center (Sgr A and Sgr B2)

Molecular ratio	Reference	(1) GC value (2) solar system value
$^{12}C^{18}O/^{13}C^{16}O$	Wannier et al 1976a	(1) 0.070 (2) 0.178
$C^{17}O$ / $C^{18}O$	Wannier et al 1976b	(1) 0.29 (2) 0.186
$^{13}C^{32}S/^{12}C^{34}S$	Wilson et al 1976	(1) 0.60 (2) 0.26
$HC^{15}N/H^{13}CN$	Linke et al 1977	(1) SgrA 0.08 ± 0.017 (1) SgrB2 0.037 ± 0.020 (2) 0.327
DCN / $H^{13}CN$	Penzias et al 1977	(1) SgrB2 0.018 ± 0.012 (taking into account saturation effects) (2) 0.18
$H^{13}CC_2N/HC_3N$ $HC^{13}CCN/HC_3N$ $HC_2{}^{13}C/N HC_3N$	Churchwell et al 1977	(1) 21 ± 3 (1) 56 ± 10 (1) 56 ± 10 (2) 89

in evolution models reviewed in the next section.

IV - EVOLUTION MODELS FOR THE GALACTIC CENTER

The description of the central regions of our galaxy which appear to be of a very complex nature can therefore be summarized as follows :

1 - The density of the gas is much lower ($m_g/m_{TOT} < 10^{-3}$) than in external regions such as the solar neighbourhood.
2 - Then is some indication that the death rate of low mass stars ($M_\odot < 5$) compared to that of large mass stars ($M_\odot > 5$) is much larger in these regions than in the solar neighbourhood (table 1).
3 - The chemical composition appears to be also different : the overall metal abundances should be enhanced as in the central regions of nearby galaxies - elements such as ^{13}C and ^{14}N and in a less extent ^{17}O should have also a higher abundance than in other regions while deuterium seems to have a lower abundance.

A few evolution models have been proposed by our group (Audouze et al 1975, 1976, 1977, Vigroux et al 1976) regarding these central regions. As nearly all the investigators who have dealt with such a problem, we have used rather simple and crude approaches, the reason being that it is only possible to sketch this complex region. In our model which is exposed in Vigroux et al 1976 assume that at the time of its formation the galaxy consisted in a clump of metal free gas. The rate of star formation at a given is proportional to the density of gas present at this time : $\frac{dS}{dt} = -\frac{d\sigma}{dt} \propto \nu\sigma$

where ν is a parameter which depends on the considered region and is obviously related to the time scale of gas processing into stars . This parameter is larger in the galactic center to take into account the fact that it is a highly processed region ($\nu \geq 2$ with the time expressed in 10^9 years units compared to $\nu \sim .2$ - .3 for the solar neighbourhood.)
The important feature of the model is that one does use the instant recycling approximation which does not apply at all to highly processed regions such as the galactic center. The equations describing the evolution of the gas density and of the element abundances are

$$\frac{d\sigma}{dt} = -\nu\sigma + \int_{m(t)}^{m_{max}} \frac{E(m)}{m}\,\psi(m)\,\nu\,\sigma(t-\tau_m)\,dm + \delta$$

$$\frac{d\sigma_f}{dt} = -\nu\sigma_f + \int_{m(t)}^{m_{max}} \psi(m)\,A_f(m)\,\nu\,\sigma_f(t-\tau_m)\,dm + \delta_f$$

In these equations ψ(m) is the normalized initial mass function (IMF) : $\psi(m) = \zeta(x-1)m^{-x}$: that is the classical Salpeter law

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with $\zeta = 0.25$ which represents the mass fraction corresponding to stars of mass $M > 1\ M_\odot$ and the exponent x such that $1.3 < x < 1.8$; m is the life time of a star of mass m ($\tau_m \sim 12 \times 10^9 / m^3$ years) E(m) is the whole mass fraction returned by a star of mass m (expressed in solar mass units) at the end of its evolution and Af (m) is the mass fraction of the element f released by such a process. The mass fractions δ and δ_f correspond to the enrichement in gas or in the element f due to the infall of external gas.

The model has been used to account for the evolution of the gas, the rate of material ejected by low and by high mass stars and for the evolution of elements such as deuterium and C,N,O isotopes. In the particular case of deuterium which is destroyed in the stellar interiors the equation describing its evolution reduces to $d\sigma_D/dt = -\nu\sigma_D + \delta_D$

The outcome of this model is the following :

1) The evolution of the gas density with time in the absence of infall is presented in fig.6. It is important to notice the change of slope of σ(t) for models featuring the central regions : one can see that the amount of gas available becomes larger than that obtained by instant recycling models for a given ν: this is because the central regions are presently replenished into gas coming from low mass stars. This important discrepancy between our model and the instant recycling approximation calculations show clearly their limitation.

2) the ejected mass coming from low mass stars becomes more important than that coming from high mass stars after times as short as a few 10^8 years (while this time is $\geq 2\ 10^9$ years in less central regions) (see fig.7)

3) Regarding the deuterium, although its abundance in the center appears to be smaller than in other regions of the galaxy ($D/H \leq$ a few 10^{-6} instead of $D/H \sim 2\ 10^{-5}$ according to the measurements of Penzias et al 1977), it cannot be as small as $D/H \sim 10^{-12}$ which is the solution of the simple equation $d\sigma_D/dt = -\nu\sigma_D$ with $\nu \sim 2\ (10^9\ \text{years}^{-1})$ To account for its abundance one has been led to propose two possible explanations. (Audouze et al 1976).

a) Either deuterium has a cosmological origin and is continuously replenished by infall of external gas (this gas coming either from the halo or possibly also from other regions of the disk.)
In these conditions $D/H \sim 10^3\,\delta\,(\frac{D}{H})_{cosm.} \leq 0.2\,(\frac{D}{H})_{sol.\ neighb.}$

This is indeed quite sufficient to explain the Penzias et al (1977) measurements of the DCN/HCN ratio in Sgr A and Sgr B2.

b) Or deuterium can be produced by the spallation of the interstellar gas by the cosmic rays which are assumed to be generated by the supernovae. It is known that this process cannot account for the deuterium production in the solar neighbourhood (see eg Meneguzzi et al 1971).
There are however two possibilities which speak in favour of such a production in the central regions of the galaxy :
(i) The rate of supernovae is higher in such regions therefore favouring the production of larger fluxes of galactic cosmic rays (ii) As noticed already by Meyer (1974) the production of D by spallation can be

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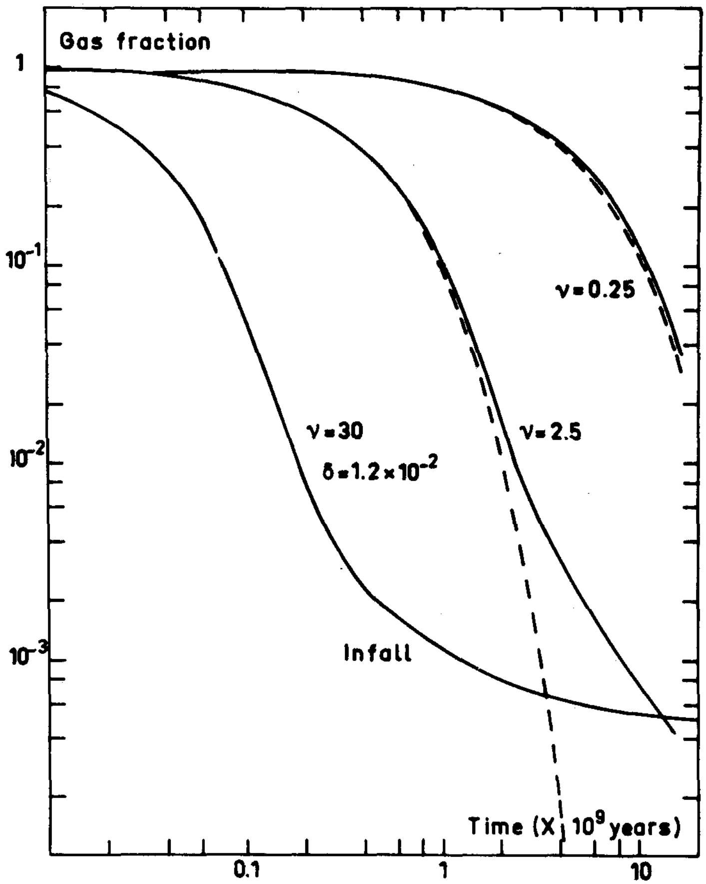

Fig. 6. Evolution of the gas fraction for the solar neighbourhood (ν~0.2-0.5) where σ~0.1 at t~10^{10} years and the galactic center (ν~2) where σ~5 10^{-4} at t~10^{10} years. Dashed lines represent the gas evolution when calculations are made with instant recycling : notice the rather important discrepancy when ν~2. The curve labelled infall shows the gas evolution for ν=30 and δ=1.2$10^{-2}$ $M_{\odot}/M_{\odot}$ per 10^9 year : Infalling material sets a limit for at large times (from Vigroux et al 1976).

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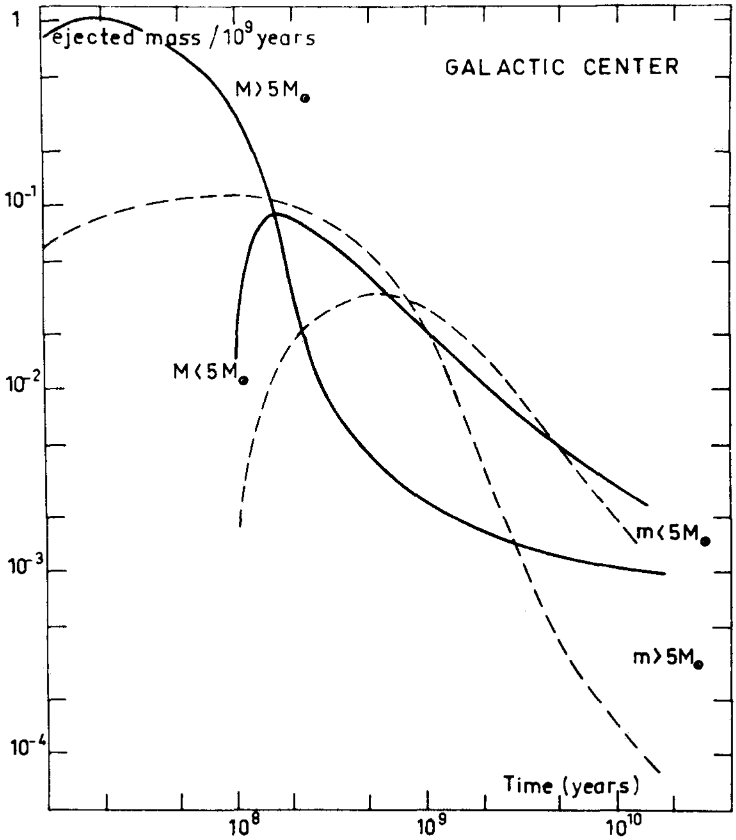

Fig. 7. Mass fractions ejected from low mass stars ($M<5M_\odot$) and high mass stars ($M>5M_\odot$) in the galactic center. Dashed line : $\nu = 2.5$, $\delta = 0$; solid line $\nu = 30$, $\delta = 1.2\ 10^{-2}\ M_\odot/M_\odot$ per 10^9 year. Notice that infall and large values of ν do not affect significantly the mass fraction ejected by low mass stars but modify the mass fraction ejected by large mass stars proportionally to ν(from Vigroux et al 1976).

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increased by factors up to $\sim$100 if the energy spectrum of the galactic cosmic rays is particularly rich in low energy particles (spectrum in power of the kinetic energy instead of spectrum in power of the total energy).

If D is produced by cosmic rays one can write:

$$\left.\frac{D}{H}\right)_{G.C.} = a . b \left.\frac{D}{H}\right)_{sol.\ neighb.}$$

a is the factor describing the increase of the cosmic ray flux due to a larger rate of supernovae in the central regions and the parameter b is related to the shape of the energy spectrum of the cosmic rays. There is some indication that the cosmic-ray intensity in the center can be larger by factor ranging up to 10 : As shown by Wolfendale and Worrall (1976) and by Puget (1977) the parameter a can be estimated (within a factor 2) 1) by using the total mass of gas, we took 5 10^7 M$_\odot$ within a radius of 350 pc from Scoville et al 1974 2) by using the estimate of the flux of high energy gamma rays (E $>$70 MeV) performed by Fitchel et al 1975 from the measurement made with the SAS II experiment : Φ_γ = 6.7 10^{-6} cm^{-2}sec^{-1} within a few degrees from the center. If one makes the reasonable assumption that the ratio between the flux of cosmic ray electrons and that of the cosmic ray protons remain constant within the galactic disk one can estimate the flux of the high energy gamma rays which can be produced in the solar neigbourhood : the high energy gamma rays come mainly from the p + p $\rightarrow \pi \rightarrow \gamma$ reactions, and from the inverse compton and bremsthrallung processes.

The Wolfendale and Worrall 1976 and Puget 1977 estimates gives $\left.\Phi_\gamma\right)_{sol\ neighb} = 8.7\ 10^{-7} cm^{-2} sec^{-1}$ which means that $a = 6^{+6}_{-3}$ can be deduced from the gamma rays observations in particular if the Haymes et al 1975 measurements are confirmed[1].

Therefore $$\left.\frac{D}{H}\right)_{G.C.} \sim (1\text{-}10)(3\text{-}30) \left.\frac{D}{H}\right)_{sol.\ neighb.}$$

In summary to explain the presence of deuterium in the galactic center, since this region has been highly processed into stars, deuterium must have been replenished either by spallation processes or by accretion of matter coming from external region within the last 5 x 10^9 years.

4) In Vigroux et al (1976) we have attempted to reproduce the time variation of the $^{12}C/^{13}C$, ratio as well as the gradient of the N/O ratio. We used the data regarding the $^{12}C/^{13}C$ ratio observed in evolved stars and gathered by Dearborn et al 1976. From this analysis we assumed that the enrichement in C is such that $^{12}C_i/^{13}C_f$ for stars with M$<$5M$_\odot$ and $^{12}C_i/^{13}C_f = 5$ for stars with higher masses.
The enrichement in ^{14}N in the envelope of a star (resulting from the CNO cycle reactions) is assumed to be independant of the mass of the star :

1 In a similar balloon experiment performed by Durouchoux et al (1977) the 4.4 Mev gammar ray line coming from C is not found contrary to the analysis of Haymes et al 1975.

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we adopted $^{12}C_i/(^{14}N_f-^{14}N_i)\sim 13$ in the fraction E(m) ejected by the star after its death (envelope). The results we obtained for the evolution of the C, C and N abundances in the central regions are displayed in fig.8 for the case where no infall is assumed ($\nu\simeq 2.5$ $\delta=0$)

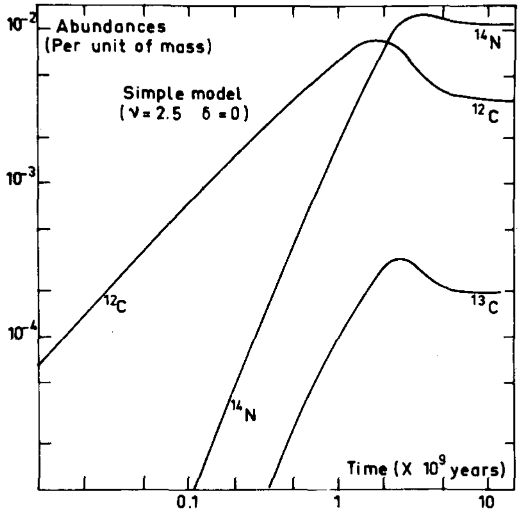

Fig.8. Evolution with time of the ^{12}C, ^{13}C and ^{14}N abundances (in mass) in the galactic center ($\nu\simeq 2.5$ $\delta=0$)

and in fig.9 for the case where one assumes some infall of external matter ($\nu\simeq 30$ (in 10^9 years)$^{-1}$ units) and $\delta\simeq 1.2\ 10^{-2}$M⊙/M⊙ per 10^9 years) A few remarks can be made on these calculations :

(i) the asymptotic value of the $^{12}C/^{13}C$ ratio is roughly equal to the value of $\beta_1 = {}^{12}C/^{13}C$ for the envelope of low mass stars if there is no infall of external gas. This is because the gas present in the central regions come mainly from the envelope of these stars.

(ii) One reproduces the gas content, the observed N/O ratio (the gradient of N) and the observed $^{12}C/^{13}C$ ratio in these regions only if the rate of infall is zero or moderate $\delta < 10^{-3}$M⊙/M⊙ per 10^9 years. In the case of a larger rate of infall such as that used in the model displayed on fig 9 the available amount of fresh accreted gas dilutes the abundances of ^{13}C and ^{14}N produced mainly in the envelope of long lived stars of low mass, while the abundance of ^{12}C remains constant : this is because this fresh gas can induce the formation of new high mass stars producing some new ^{12}C abundance together with low mass stars which will no contibute now to any increase of ^{13}C and ^{14}N because of their long life time. Therefore, if one adopts the framework of our simple model one should assume that the infall of external gas

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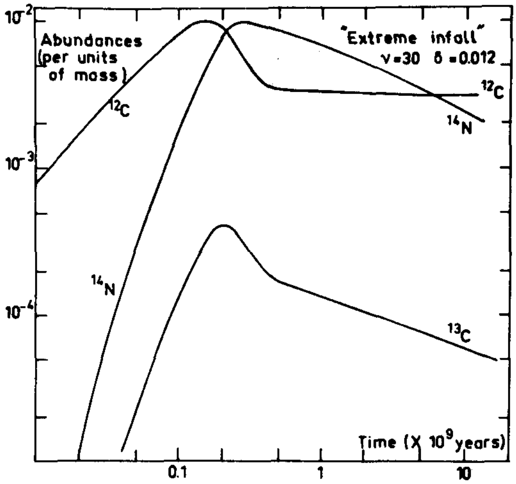

Fig.9. Evolution with time of ^{12}C, ^{13}C and ^{14}N abundances (in mass) in the galactic center (ν= 30 δ=1.2 10^{-2}M⊙/M⊙ per 10^9 year) corresponding to an extreme infall model : notice that ^{12}C reaches an asymptotic value for $t \geq 10^9$ years while ^{13}C and ^{14}N continue to decrease up to 10^{10}years (from Vigroux et al 1976).

has been small in the past. However this conclusion should be considered with some caution because we do not yet understand the dynamics of the galactic center.

5) The ratio $^{15}N^{12}C/^{14}N^{12}C$ is about ten times smaller in the central regions of the galaxy than in the solar neighbourhood and in the solar system. In Audouze et al 1977 we have attempted to understand this decrease by making different plausible assumptions on the way to form ^{15}N. These different assumptions are summarized in the table 3.

In the first assumption one assumes that ^{15}N is formed by low mass stars (M<5 M⊙). This assumption could be supported by the fact that ^{15}N is over produced by the hot CNO cycle nucleosynthesis occuring during the novae outburst (see eg Starrfield et al 1972 and recent calculation of Lazareff et al 1978). As shown in Audouze et al 1977 the spatial distribution of novae in the Andromeda galaxy give support to the idea that the novae progenitors are low mass stars. If one assumes that ^{15}N comes from objects which are distributed like low mass stars, the resulting $^{15}N^{12}C/^{14}N^{13}C$ appears to be about twice the observed value. On the other hand if ^{15}N is assumed to be produced by

TABLE 3

Typical results of the chemical evolution estimates. The reported computations are those made without infall, assuming ^{15}N destroyed during stellar processing (the assumption of non destruction of ^{15}N in stellar processes increases the ratio $^{15}N/^{14}N$ y only about 10%). In case C1 we assume $M_{ej}(^{15}N)M_{ej}(M \quad 5M_o) = 4.2\times10^{-5}$. In case C2 $M_{ej}(^{15}N)M_{ej}(^{12}C+^{16}O) = 2 \times 10^{-2}$; conclusions are not affected by making the rate of ^{15}N production proportional to that of all CNO.(*From Audouze et al* 1977).

	(m_{gas}/m_{total})	Observed $^{12}C^{15}N/^{13}C^{14}N$	Model B (low-mass stars) ^{15}N (per mass) 10^{-6}	Model B $^{12}C^{15}N/^{13}C^{14}N$	Model C1 (high-mass stars) ^{15}N (per mass) 10^{-6}	Model C1 $^{12}C^{15}N/^{13}C^{14}N$	Model C2 (high-mass stars) ^{15}N (per mass) 10^{-6}	Model C2 $^{12}C^{15}N/^{13}C^{14}N$
Solar system ($t=8.4 \times 10^9$ yrs)	0.23	0.33	3.7	0.29	4.2	0.33	3.8	0.31
Interstellar matter in solar neighborhood ($t = 13 \times 10^9$ yrs)	0.11	0.19 (average)	6.6	0.13	5.9	0.12	8.2	0.18
Interstellar matter in galactic center ($t = 13 \times 10^9$ yrs)	8×10^{-4}	0.026	30.	0.053	3.0	0.005	4.2	0.0079

objects which are distributed like high mass stars it is then easy to account for an $^{15}N^{12}C/^{14}N^{12}C$ ratio lower than the observed ~~upper~~ limit. Our calculations can be interpreted either by saying that ^{15}N is produced during supernovae outburst or by assuming that the novae have a distribution different from that of low mass stars. However one should note that this last hypothesis is not supported by the M31 observations.

6) For the two last point namely the comparison between the $^{13}C/^{12}C$ $^{15}N^{12}C/^{14}N^{13}C$ and N/O or N/C ratios in the galactic center and those observed in the solar neighbourhood and the solar system we have use again our evolution programs by modifying the specifications on the relative abundances of the C,N,O, isotopes released by the stellar envelopes. Instead of the specifications coming mainly from Talbot and Arnett (1973), in these new calculations we have used for the production of primary isotopes such as ^{12}C and ^{16}O the specifications presented by Arnett (1977 and this conference) based on his last nucleosynthesic models. This does not induce major changes in the results. More important is to adopt the Iben and Truran (1977) receipe to account for the ^{13}C and ^{14}N enrichement. Their requirements are based on their current redgiant models : according to their models the elements ^{14}N and ^{13}C are contributed evenly by all stars : For ^{14}N they assume that for all stars $1 < M < 9$ M⊙ 32% of the ^{12}C in the envelope is transformed into ^{14}N while 32% of ^{12}C and ^{16}O included in the envelope of heavier stars is transformed into ^{14}N. In the core of 3 to 9 M⊙ stars one assumes a full transformation of ^{12}C and ^{16}O into ^{14}N. Remember that the envelope defines the mass of the star which is rejected in the interstellar medium at the death of it and where part of primary isotopes are transformed into secondaries. The core is the rejected stellar mass enriched into primaries such as C and O for instance. For C, one assumes that 2.3 % of ^{12}C is tranformed into ^{13}C for low mass stars $m < 9M_\odot$ while this fraction goes up to 20% for $m > 9M_\odot$; one assumes also that 2/3 of the initial ^{13}C remains preserved into the star envelope.

The results obtained by this new set of specification are given in table 4. From this table one sees that the ^{14}N isotope is underproduced by a factor of about 3 to 4 compared to the results obtained with the Vigroux et al specification. This striking modification affects only ^{14}N: if ones multiplies the ^{14}N abundance by a factor 3 to 4 one reaches the same conclusions as before, as been noted independantly by Tinsley (private communication). This could mean that the ^{14}N which has been classed mainly as a secondary element (see eg. Audouze and Tinsley 1976) may have a more complicated nucleosynthetic history. Nevertheless we may have underestimated in the present calculations the enrichment into ^{14}N due to high mass stars (M > 9 Mo). This problem is still under study at the time of the writing of this paper.

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TABLE 4.

Results of chemical evolution models without infall and using the Iben and Truran (1977) and Arnett (1977) specifications. A good agreement with observations is only obtained in the high mass star hypothesis if 75% of ^{14}N to is produced by another process.

	$\frac{m_{gas}}{m_{total}}$	observed $\frac{^{12}C^{15}N}{^{13}C^{14}N}$	calculated $^{12}C^{15}N/^{13}C^{14}N$		calculated $^{12}C^{15}N/^{13}C^{14}N$	
			^{15}N due to low mass stars	^{15}N due to high mass stars	^{15}N due to low mass stars	^{15}N due to high mass stars
Solar system t=8.4x10^{9}years	0.10	0.33	1.4	1.4	0.35	0.35
Interstellar matter (solar neighborhood) (=13x10^9 years	0.04	0.19 (average)	1.1	0.8	0.28	0.20
Interstellar matter(galactic center) t=13x10^9 years)	4.710^{-4}	0.026	1.8	0.18	0.45	0.045

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V - CONCLUSION

In this review I have attempted to summarize some of the most exciting new observational data regarding the galactic center. A rapid look on the current literature (Gatley et al 1977, Bania 1977, Oort 1977 , Wollman 1976) shows clearly that many new and important observations are presently made by radio astronomers, infra red gamma rays astronomers and will provide us with very refined maps of the stellar, gaseous, molecular, atomic, and dust components of these regions. However it does not mean at all that we will be able to model up satisfactorily such active regions. After the presentation of the crude evolution models discussed in the previous section we feel that theorists should undertake now more complicated theoretical studies taking into account as properly as possible . i) the dynamics of this region ii) the still unexplained relationship between the stellar and the gaseous component and also iii) the mechanisms by which isotopes as ^{13}C, ^{14}N, ^{15}N or ^{17}O are formed and see their relative abundances modified.

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