RECURRENT STARBURSTS OR INTERMITTENT STARBURST/AGN PHENOMENA AT THE GALACTIC CENTER ?

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Abstract. Recently, I summarized arguments, both old and new, that the Galactic center has experienced a starburst in a recent past (Ozernoy 1994a). Here I propose a likely mechanism – collisions between giant molecular clouds – that might induce (recurrent) starbursts. Taken together, these two approaches seem to indicate that the history of the central part of our Galaxy can be described as recurrent starbursts or intermittent Seyfert activities/starbursts.

1. The Problem

Analyses of recent data on the 10 KeV gas in the central 200 pc and on star formation history at the Galactic center both make a starburst episode very likely in the recent past (Ozernoy 1994a). Here I address an issue what a mechanism could trigger such a starburst.

2. Collisions between the GMCs as a Mechanism for Recurrent Starbursts

Giant Molecular Cloud Collisions. There are about 200 giant molecular clouds (GMCs) in the inner kiloparsec of the Galaxy, each containing 10^5

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to 10^6 $M_\odot$ of gas, usually on the verge of gravitational instability (Jog & Solomon 1984). Many of these clouds have peculiar velocities which deviate significantly from circular orbits around the Galactic center, with radial motions that are comparable to the circular velocity (*e. g.* Heiligman 1987). Having highly elongated orbits and a low angular momentum, those molecular clouds should experience mutual collisions. The average time interval between two successive collisions is $T_c = 2\pi/\omega_c = 2\left(a^2 n_c \sigma_v\right)^{-1} \simeq 2 \cdot 10^8$ yr, where $\sigma_v \simeq 30$ km/s is the radial velocity dispersion of GMCs whose typical radius is $a = 20$ pc, and the spatial density is $n_c \simeq 10^{-6}$ pc^{-3}. Despite the presence of magnetic fields in the clouds, the collisions of GMCs turn out to be highly dissipative.

GMC Collisions As Triggers for Star Formation at the Galactic Center. A single collision between two GMCs gives rise to the dissipation of a substantial part of the angular momentum of each of the clouds; as a result, they end up on much lower orbits. Furthermore, after the collision and dissipation of internal turbulent motions the clouds become gravitationally unstable, they could fragment and experience star formation. Therefore, a "wave of star formation" could start at comparatively large distances from the Galactic center and gradually propagate towards the center, accompanied by the fall of the remnants of the clouds onto the center.

The presence at the Galactic center of a rotating molecular circumnuclear ring, which extends between 1 and 10 pc in radius, could be considered as evidence for a recent collision between the molecular clouds in the central several tens of parsecs. The ring whose mass is estimated between 10^4 to 10^5 $M_\odot$ (Genzel et al. 1994) seems to be what is left after a comparable mass, which had its angular momentum dissipated by the collision, fell into the central parsec. Short-lived spurs like *O*I/dust ridge between the Eastern and Northern arms in Sgr A West ("the Tongue") might be one of manifestations of this collision.

A Recent Starburst. The latest starburst within the central parsec has involved no more than $\sim 4 \cdot 10^5$ $M_\odot$ (Tamblyn & Rieke 1993), which is just what is expected to be involved in a star formation process resulting from a GMC collision. Tamblyn & Rieke have found the age of the starburst to be 7 – 8 Myr and an average SN produсtion rate to be 1 SN/7 $\cdot\, 10^4$ yr. The latter implies more than 100 SN during the entire starburst, which is marginally consistent with what is required to produce the bubble of ultra hot gas (Ozernoy 1994a). Sgr A East which has been interpreted as a product of a SN explosion might be a part of that starburst provided that the SN exploded into a progenitor bubble created by a wind (Mezger *et al.* 1989).

Inhomogeneities in the eventual products of GMC collisions unavoidably give rise to non-uniform dissipation and fragmentation processes and, as a

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result, to non-coeval star formation. Different ages of stars which originated in different sites of the same starburst may explain why the estimates of the Galactic center starburst are somewhat contradictory. SN explosions can also occur non-instantaneously in different places. This might explain the existence, along with the 150-pc expanding molecular ring, of two other large-scale structures ("40-pc molecular ring" and the "20-pc barrel") with kinetic energies of 10^{52-53} ergs and the age of 10^{5-6} yr (Tsuboi *et al.* 1989).

Collisions of GMCs as a Mechanism for Recurrency of Starbursts. The time between two successive GMC collisions, $T_c \simeq 200$ Myr, defines the characteristic time interval of starburst reccurency. A possibility of repeating starbursts at the Galactic center has been envisioned by Loose *et al.* (1982) who considered evolution of a massive gaseous cloud into stars and found that, due to feedback from SN explosions, the star formation process stops and could be repeated, after some (non-specified) dissipation of turbulence induced by supernovae, on the time scale of several hundred Myr. The GMC collisions considered above offer a natural mechanism of dissipation necessary to make the starbursts repetitive.

3. Why Starburst(s), and not AGN Event(s) ?

Oort (1977) was the first who summarized evidence in favor of explosive phenomena at the Galactic center. Could those events be interpreted in terms of a compact 'monster' such as a black hole believed to operate in active galactic nuclei (AGN) ? To answer this question, a careful examination of various phenomena associated with the black hole concept needs to be done. In particular, several different methods have been employed to evaluate or constrain the black hole mass (for detail, see Ozernoy 1994b and refs. therein). The derived upper limits seem to be too small ($\ll 10^6$ $M_\odot$) to allow the black hole to serve as an 'engine' for a Seyfert galaxy at the Galactic center.

The lack of an appropriate mass for the 'engine' is not the main reason why our Galaxy is currently not a Seyfert one. Neither is there insufficient mass supply in the central part of the Galaxy: the mass flux into the central parsec is estimated to be $\sim 10^{-2}$ $M_\odot$ yr^{-1}(*e.g.* Blitz *et al.* 1993, Genzel *et al.* 1994) which, paradoxically, is rather large even on AGN scale. However, the lion's share of this flux is not going to 'feed the monster' (whatever it is), otherwise it would result in accretion luminosity much exceeding the available upper limit. The main reason is the presence of the *wind from IRS 16 and He I stars* in the central parsec, which prevents the accretion rate from being as high as the inflow rate. If a recent starburst at the Galactic center is responsible for the formation of these stars (Tamblyn & Rieke 1993), then the starburst and an AGN-type activity are anti-correlated

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here.

Such a prevention of a Seyfert-type activity could not last longer than the life-time of the wind-creating massive stars, *i. e.* several Myr. After that, the total accretion luminosity of Sgr A* would be as high as $L \simeq 5 \cdot 10^{43}$ erg/s, provided that the inflow rate were kept the same as the current one. (The current mass flux onto the galactic nucleus, however, might be just a transient phenomenon responsible for feeding the starburst). This power does not depend upon the value of Sgr A* mass unless it is smaller than $4 \cdot 10^5$ $M_\odot$ (for this mass, $L \simeq L_{\rm Edd}$).

It remains to be seen whether or not the Galactic center has experienced such a Seyfert-type activity in the distant past. Meanwhile the evidence summarized above demonstrates that, in the recent past, the Galactic center has passed through a starburst. It is worth emphasizing that the energy production by supernovae averaged over time during the starburst phase was as high as $\sim 3 \cdot 10^{42}$ erg/s, which is comparable with the above accretion luminosity, especially if $L \ll L_{\rm Edd}$.

4. Conclusions: AGN/Starburst Dilemma

To sum up, the main conclusions of the present paper are the following:

- Rather than being a 'dormant' version of an AGN, the Galactic nucleus seems to be a scaled-down version of a starburst nucleus.
- There are reasons to believe that the starbursts at the Galactic center are recurrent. Intermittence *starburst/AGN* seems possible but the expected level of non-thermal activity would be not too spectacular.

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