Molecular gas in the central parsec through regularized 3D spectroscopy

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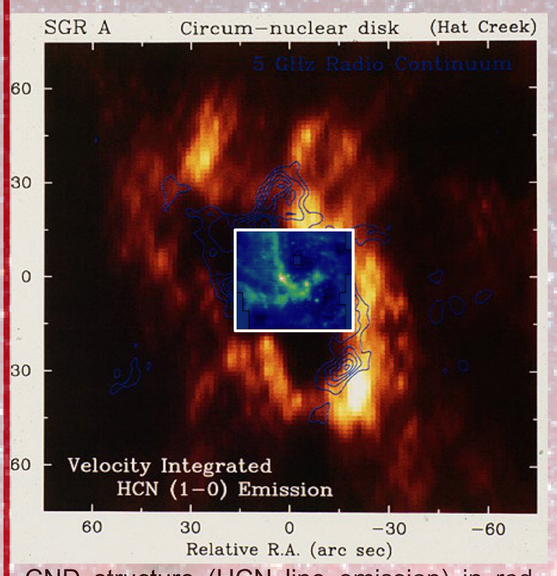
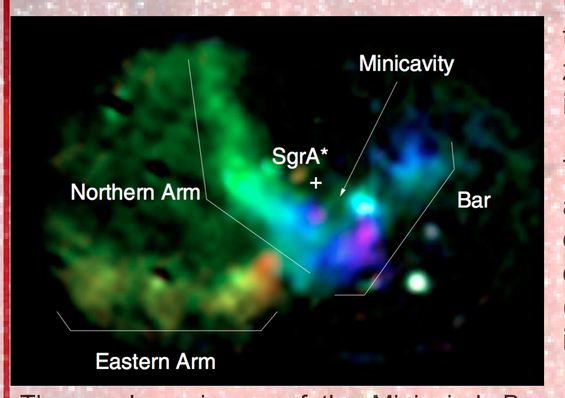
1 - INTRODUCTION

In the central parsec of the Galaxy the environment of the black hole presents, besides the star cluster, **two** different **gas structures**:



CND structure (HCN line emission) in red, Minispiral pattern in blue. In the white square the field of view of our data is represented. (Credit: Leo Blitz, University of Maryland)



Three colours image of the Minispiral, Brγ emission (Paumard *et al.* (2004)).

Circumnuclear Disk (CND)

An **asymmetric** structure (~7pc of length in the south-West direction, ~3pc in the opposite direction) in **circular rotation** (~20 – 50 km/s) around the centre (SgrA*). The CND is composed of **molecular gas clouds** and its **inner cavity** is **ionised** (~1pc from SgrA*). Its origin is not clear: the asymmetry suggests that it is **unstable**, thus it is possibly either a young, not jet circularised structure or an old, recently perturbed, one. It can represent a privileged star formation area.

Inside the CND there is an ionised region and evolved massive stars, responsible for the inner cavity ionisation.

Minispiral (Sgr A West)

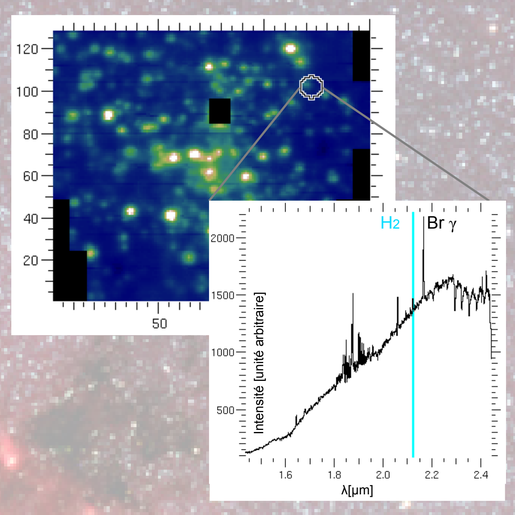
This **spiral structure** (in projection) centered on the central black hole (the central 2 pc) represents the ionised border between high/low density zones. It is dominated by the emission from **gas ionised** by young central stars.

The CND (molecular) and the Minispiral (atomic and ionized) are physically and morphologically different but **both are of the same nature** (made of clumps) and presents a **spatial coincidence** (the Western arm of Sgr A West lays onto the inner border of the CND)

↳maybe they have **common or related origins.**

To understand the origin and dynamics of these structures, in particular the transition between the two, we have **investigated the presence of molecular gas (H_2) in the inner part of the CND, where the ionized Minispiral lies** (for example in the shadow corner, in the transition zone or in the line of sight).

2 - DATA



Spectro-imagery data

We dispose of spectro-imagery data taken by SPIFFI (SPectrometer for Infrared Faint Field Imaging), the VLT spectrometer SINFONI without adaptive optics. The FoV is of 36" x 29" and the resolution R = 1500 in the NIR.

Spectral range covers two H_2 lines (2.122 μm and 2.223 μm) and the Brγ line of the H I spectrum (2.166 μm). Also a Fe III feature (2.218 μm) has been observed.

This data set have been obtained thanks to the collaboration with S. Gillessen, MPE.

3 - REGULARIZED 3D SPECTROSCOPY

To analyse data we want to create **maps of physical parameters** (line intensity, radial velocity and width). Usually the approach is to fit the spectrum of each spatial pixel, but, if the signal to noise is not good enough the resultant noisy image can't be safely smoothed (risk of fitting a wrong spectral feature because of a noise spike).

Instead we implemented a **new method which consists on a regularized three-dimensional fit**, the **estimator to be minimized** being:

$$\varepsilon(a_1,...,a_n) = A \cdot \underbrace{\sum_{\alpha,\delta,\lambda}((D-M_3)\cdot W)^2)}_{\text{weighted } \chi 2} + B \cdot \underbrace{\sum_{i=1}^{n} R_i(a_i)}_{\text{regularisation}}$$

The regularization is a ***I1I2 algorithm,*** developed in Mugnier 2004 and coded in Yoda software by D. Gratadour. Such term **disfavours random variations** of the maps (noise) but still allows quick and coherent variations.

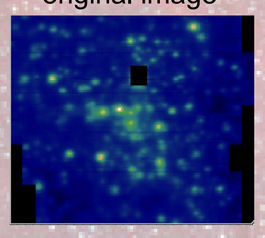
The two constants (A and B) are meant to manage the scale between the two terms.

Thanks to this approach, data with low signal to noise weigh less, spatial resolution is conserved and edge effects minimized.

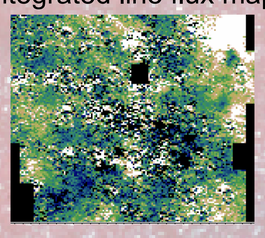
4 - REGULARIZED 3D SPECTROSCOPY: application

The **regularisation should not penalise the fit** (for example we want to avoid the procedure to push towards maps which are too smoothed) but just trigger it. Roughly speaking, in SPIFFI data the *I1I2* contribution can be reduced to few percent of ε.
This leads to convergent results which are moreover independent from the fit initial guess.
An example of the application of this method to our data:

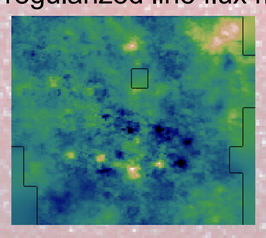
original image



integrated line flux map



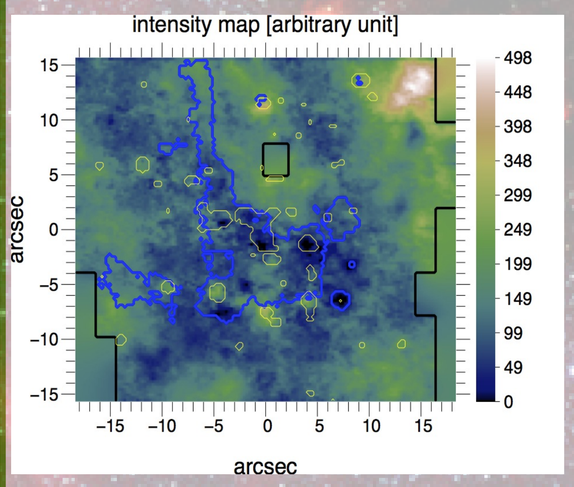
3D regularized line flux map



There are still some problems on the continuum evaluation, mostly because of Wolf-Rayet stars.

To learn more about this method and its application to the CND area: *Regularized OSIRIS 3D spectroscopy at the CND ionization front* oral contribution by T. Paumard (this conference)

5 - PRELIMINARY RESULTS: H_2 intensity map



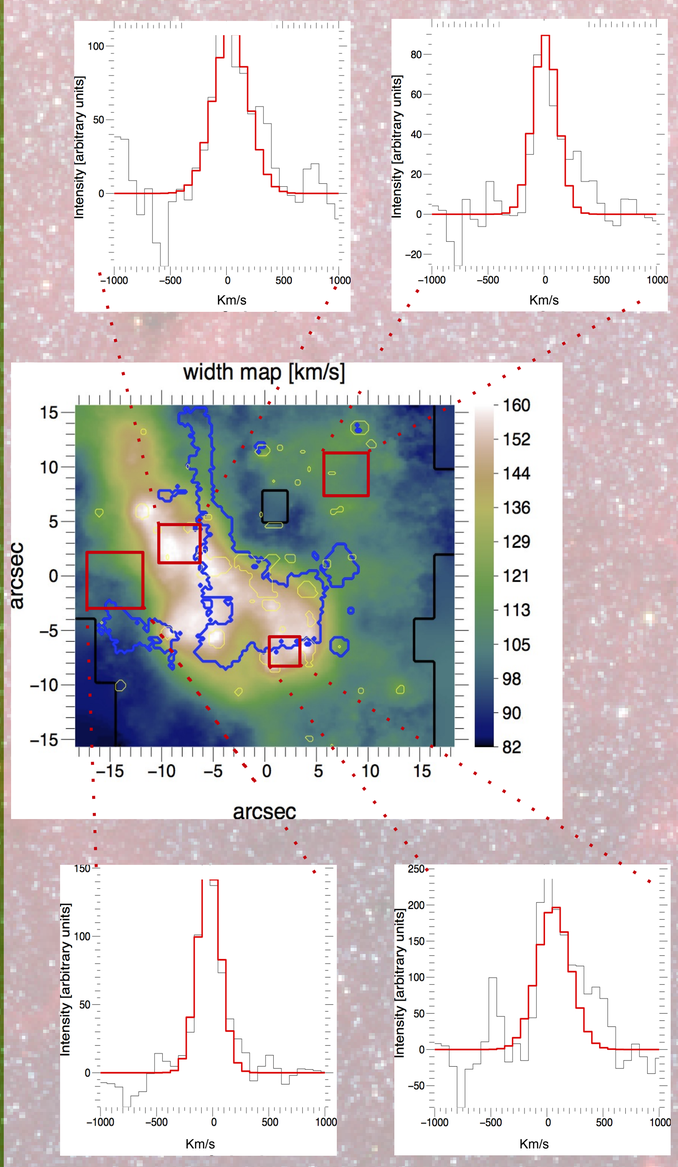
H_2 is **detected everywhere.**

In the **northern part** it is detected in the most energetic region (**distinct boundary** of the H_2 **at the Northern Arm** of the Minispiral) where it should be more unlikely for the molecular gas to resist dissociation
↳ maybe it is in the background of the Minispiral

In the **southern part** of the image
↳ it is possible that here the **CND emission** dominates

Moreover:
↳ **extinction**, associated to the ionization front traced by Brγ, could be hiding the H_2 structures

6 - PRELIMINARY RESULTS: H_2 width map



The feature that appears in this map, especially East of the Northern arm of the Minispiral, seems to suggest that the molecular gas is situated inside this arm.

This scenario is not unlikely since in this way the molecular gas would be protected by an ionization front.

Even though this interpretation is tempting, it does not explain clearly the lower part of the map (between 0 and -4 arcsec).
Moreover such structure is morphologically visible only on width maps (and not on intensity and velocity maps).

On the other hand, we are confident in the obtained width map: despite the difficulty to obtain error bars with this method, we have checked on several individual spectra (see some examples beside) that it accurately reproduces the data.

Molecular gas is detected in SPIFFI data and these preliminary results seem to indicate that it lays in the central parsec. To confirm this interpretation, and to understand if it it is located in the background of the Minispiral or inside its Northern arm further investigations are need.