VELOCITY-RESOLVED SPECTRA OF BRα AND BRγ ON IRS16 SW AND NE

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ABSTRACT. The source IRS16 has been observed with the FTS at the Canada-France -Hawaii Telescope, in July 1987 and May 1988, in an attempt of spectral resolution associated with spatial resolution. Three positions were observed with a 2.5 arcsec aperture, centered on the sub-structures SW, NE and NW. Brα and Brγ spectra were obtained at respective velocity resolutions of 210 and 140 km s^{-1}, allowing resolution of the line profiles. The detection of hydrogen emission was marginal on NW, and strong on SW and NE, showing a net velocity difference of the gas of 160 km s^{-1}. The Brα line on SW has very extended wings suggesting two components of different origin. These observations imply a difference of physical nature of the objects located in the vicinity of Sgr A*.

1. INTRODUCTION

The Galactic Center source IRS16 (Becklin and Neugebauer 1975) has been the subject of many specific studies because it is the infrared source lying nearest to the compact, nonthermal radio object Sgr A*, considered as the true center of the Galaxy. The previously reported spectroscopic analyses in the 2-4 μm region have been made with Fabry-Perot spectrometers and FTSs. They revealed the presence of broad hydrogen and helium lines (Wollman et al. 1982, Hall et al. 1982, Geballe et al. 1984), broadening interpreted as due to an outflowing gas from IRS16. For these observations, apertures integrating over the whole infrared source were used. Geballe et al. (1984) used a 4.2" beam. Hall et al. (1982) had used a 3.8" diameter entrance aperture on the interferometer, with an uncertainty on the positioning estimated to 1.5". Recent mappings with infrared array detectors have considerably improved the spatial resolution, allowing one to break the 4 $\times$ 4 arcsec infrared source into several discrete sources on the scale of 1" (Stein and Forrest 1986, Allen and Sanders 1986, Lacombe et al. 1987). IRS16 has no longer any physical meaning as an entity, and the spectroscopic observations have to be reconsidered for a proper

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understanding of the gas dynamic in the very inner region of the Galactic Center. The infrared images have provided the spatial resolution but are lacking of spectral resolution. Various attempts have been made to obtain both kinds of information, by associating a camera with a CVF (Forrest et al. 1987), a Fabry-Perot (DePoy et al. 1988) , or by making a mapping with a cold grating spectrograph (Allen et al. 1988). The following observations represent another approach to obtaining spatially-resolved spectroscopic information on IRS16. The spatial resolution has been pushed to 2.5", and a FTS used to record spectra of Brα and Brγ on three different locations within IRS16. Although the spatial resolution is not yet optimum, these observations already show striking differences between the sources, with the advantage of an improved spectroscopic resolution. The instrument offers in addition the capability of reliable radial velocity measurements, to compare the velocity of the ionized gas on various points.

2. OBSERVATIONS

The Brα and Brγ lines on IRS16 were recorded on two different runs at the Canada-France-Hawaii Telescope on Mauna Kea, using the Cassegrain FTS (Maillard and Michel 1982). The Brγ measurements were conducted on the night of July 6, 1987 through a K-band filter. Due to the lack of an appropriate narrow Brα filter, the observations at 4.05 μm had to be postponed. These were secured with the right filter, unfortunately through poor weather conditions, on the night of May 4, 1988. All the observations were obtained with a 2.5" field aperture in the dewars. An EW telescope beamswitching was made after each scan, between the two entrances of the instrument 53" apart, to subtract the residual thermal background.

2.1. Procedure of pointing

The pointing of the positions within IRS16 had to be made as accurate as possible. The bright unresolved source IRS7 was acquired first through a 1" aperture with its infrared signal. A pick-up mirror made of an uncoated pellicle plate was displaying the field on TV. A guiding box on the TV screen was centered on one of the nearby visible stars. From that initial position the pick-up mirror was exactly offset in R.A. and decl. of the differences, with the opposite sign, between IRS7 and the discrete sources within IRS16, taken from the infrared map of Lacombe et al. (1987). The telescope was then immediately recentered by moving back the guiding star. With this procedure the offsetting is very accurate ($\pm$ 0.006"). The remaining error is equal to the uncertainty on the initial centering of IRS7 ($\pm$ 0.25"). The FTS working at the Cassegrain focus, there is no field rotation during the observations. The map is reproduced in fig. 1, with the circles indicating the three positions on which the 2.5" aperture was successively placed: SW, NE, NW.

2.2. Resolution

The resolution on Brγ corresponds to a velocity resolution of 140 km s^{-1}, better by a factor 1.5 than the resolution previously obtained by Hall et al (1982) over the whole source. The integration time on each position was of the order of 1 hour. The Brα filter has a 32 cm^{-1} bandwith, allowing to obtain the line profile plus a little of the continuum. The useful duration of each integration was about 5 minutes. The resolution obtained is equivalent to 210 km s^{-1}, which is a factor 3 higher than the mapping of this line by Geballe et al. (1984) or Allen et al. (1988).

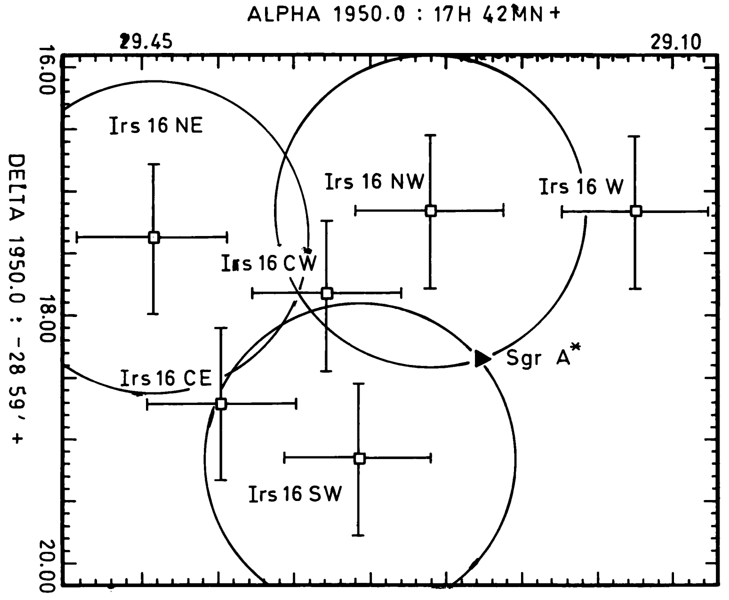

Fig.1: Positions of individual sources in IRS16 from the K-band map of Lacombe et al (1987). The circles represent the aperture size (2.5") centered at each position observed with the FTS. The location of Sgr A is from Forrest et al (1987).*

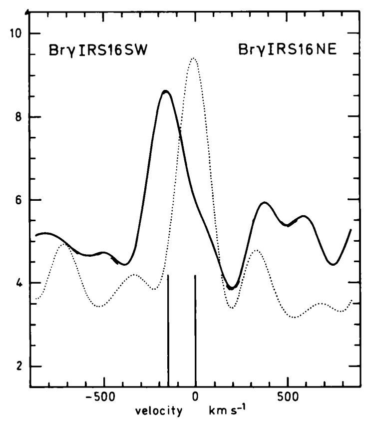

Fig.2 Velocity profiles of Brγ on IRS16 SW and NE showing the difference of radial velocity of the ionized gas between the two sources.

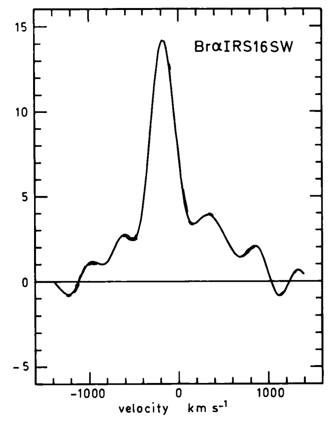

Fig.3 Velocity profile of Brα on IRS16 SW: combination of a narrow (280 km s^{-1}) and a broad profile (velocity extent 2400 km s^{-1}), redshifted relative to the peak.

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3. SUMMARY OF RESULTS

The final data are represented by 6 spectra: 2 for each source. A coarse analysis revealed several striking differences between each position:

3.1. The hydrogen lines Brα and Brγ are detected on NE and SW

More precisely, a comparable continuum is detected on all points but Brγ does not emerge from it at the NW position, and Brα is marginally seen.

3.2. The lines on NE and SW do not have the same radial velocity

The hydrogen emission on SW is blueshifted with respect to the emission on NE. A comparable difference can be measured between the two points in Brα and Brγ: 158 $\pm$ 4 km s^{-1} and 154 $\pm$ 4 km s^{-1} (fig. 2). The reproducibility of the two measurements done independently, almost one year apart, gives confidence on the quality of the pointing. The LSR velocity of the ionized gas for each component is: -152 $\pm$ 4 km s^{-1} (IRS16 SW) and +9 $\pm$ 4 km s^{-1} (IRS16 NE).

3.3. Brα and Brγ lines have different widths

The respective FWHMs are 280 $\pm$ 5 km s^{-1}, and 260 $\pm$ 5 km s^{-1} for Brα on SW and NE, while 205 $\pm$ 5 km s^{-1} and 183 $\pm$ 5 km s^{-1} are measured for Brγ at the same positions (fig. 2). The profiles on SW are slightly broader than on NE. However, these values are significantly bigger than the limits of resolution used for each spectrum, and therefore the profiles can be considered as velocity- resolved.

3.4. The Brα profile on SW is composite

From fig. 3, where the slope of the continuum has been subtracted, it can be seen that Brα measured on this position is made of the sum of two profiles: a "narrow profile" with the FWHM reported above (280 km s^{-1}), and a much broader profile. Its wings have a velocity extent of 2400 $\pm$ 200 km s^{-1}. The broad component is not centered on the narrow one. Its mean velocity is roughly coincident with the value measured on NE. No similar profile is detected on NE.

4. DISCUSSION

The previous spectroscopic analyses of Brα and Brγ on IRS16 reported a FWHM of 240 km s^{-1} for Brγ (Hall et al. 1982) and 700 km s^{-1} for Brα (Geballe et al. 1984). For each component we measure a narrower FWHM and a velocity difference of $\simeq$ 160 km s^{-1}. Consequently, an integration over these two components would have given a Brα line of $\sim$ 440 km s^{-1} and a Brγ line of $\sim$ 350 km s^{-1} (FWHM), with a mean LSR velocity of $\sim$ -80 km s^{-1}. In Geballe's measurements the FWHMs, given without deconvolution, are measured with a resolution of 550 km s^{-1}. That is consistent with the decomposition on two distinct profiles we observe. On the other hand, the full width at the 3% level of 2100 km s^{-1} reported by the same authors is consistent with the velocity extent we measure on SW. However, they cannot detect a composite profile. On Brγ, the LSR velocity of -25 km s^{-1} reported by Hall et al. should result also from a partial averaging between the sources. In the same paper is reported the detection of a broad 2.06 μm helium line, which has a profile quite comparable to the broad component we detect for Brα on the SW source. We did not yet analyse our K -band spectra to measure this helium line on the three positions. We can only state that it is not prominent.

Assuming that the width of the helium line is confirmed, the broad hydrogen emission component seen on SW and the helium line may be connected. Their width is comparable to that of the broad emission lines seen in the nuclei of Seyfert galaxies. They are attributed to flow patterns in the ionized gas. However, the much narrower component on top of should have a different origin. In addition, the central velocity between the broad and the narrow component is different. The narrow component is comparable to the one detected on NE, and looks more like the recombination lines from young stars. This hypothesis was ruled out by the integration over the whole IRS16 source, leading to profiles which were too broad to be attributed to stellar lines. The 180 km s^{-1} (FWHM) of Brγ is consistent with the width measured for the same line on young emission-line objects. Forrest et al. (1987), in their mapping of the inner parsec of the Galactic Center with a 1.3 % spectral resolution CVF, centered on Brα, noted "unusual" Brα sources, from the fact they were concentrated, and had no counterpart in the 5 or 15 GHz radio maps. The brightest Brα source of this type is almost coincident with the 2.2 μm IRS16 NE source. The strong, narrow Brα and Brγ emissions we detect on this point, associated with a weak radio source, strengthens the argument for the association of a young hot star with a dense ionized wind for IRS16 NE. The source NW should be more evolved from the absence of hydrogen emission. However, it has near infrared colors consistent with a hot star and then might be a Wolf-Rayet star. These stars are hydrogen deficient. The broad component seen on SW only, makes this point particularly interesting. There, we might have in the same line of sight a hot star seen by the narrow recombination lines, and a flow related to the nearby massive object: Sgr A*.

Our conclusions can be only preliminary, our spatial resolution is not yet high enough, and we do not avoid the confusion with several point-like sources (fig. 1). However, these results show significant differences between the sources originally revealed by the K- band imagery of IRS16. With the same technique the spatial resolution should be pushed to 1.5 arcsec to limit the source confusion, without the risk of too much seeing fluctuations. Then, more points could be separated and confirm the concentration of young stellar objects in the inner part of the Galactic Center.

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