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BINARITY AND OVERESTIMATION OF THE STELLAR CLUSTER VELOCITY DISPERSION

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RESUMEN

Usando las facilidades instrumentales de GMOS en Gemini Sur que permiten obtener unos treinta espectros de forma simultánea, pudimos investigar la presencia de binarias espectroscópicas en el cúmulo ionizante de 30 Doradus. Esto permite analizar el impacto que los movimientos orbitales debidos al par binario tendrán en la medición de la dispersión de velocidades medidas a partir de una sola exposición y la consecuente determinación de la masa dinámica del cúmulo.

ABSTRACT

Making use of the multiplexing facilities of Gemini Multi Object Spectrograph (GMOS) we were able to investigate the presence of binary stars within the ionising cluster of 30 Doradus. This issue turns out to be crucial to analyse the impact that the orbital motions within a spectroscopic pair can have on the stellar velocity dispersion measured in a single snapshot and consequently on the dynamic mass determination.

Key Words: binaries: spectroscopic — stars: early-type — stars: kinematics

In this contribution we present a new set of observations of the ionising cluster NGC 2070 obtained with the Gemini Multi Object Spectrograph (GMOS) at Gemini South. These comprise multi object optical spectroscopy of 50 early-type stars observed at three different epochs. The aim is to detect spectroscopic binary stars from variations in their radial velocities. Observations were performed as part of the Proposal GS-2005B-Q-2 using two multislit masks. Targets within each mask were selected from a previous imaging run with GMOS according to their spectral types as determined and compiled in Bosch et al. (1999). The instrument was set up with the B1200 grating centred at about 4500 Å which yields a resolution of 0.25Å per pixel at the CCD.

We checked for the presence of zero-point errors in our radial velocity determinations using the nebular emission lines present everywhere in this star forming region. The differences for the radial velocities obtained on different nights for the nebular spectra are negligible ($\Delta V_{neb} = -0.89$, $\sigma_{neb} = 3.1$ km s^{-1}), which suggests that there is no systematics introducing spurious variations among stellar radial velocities.

Radial velocities were derived measuring absorption line profiles with the aid of the `ngaussfit` task within the STSDAS/IRAF package, following a similar procedure as the one described in Bosch et al. (2001). This allowed us to derive individual radial velocities for each spectral line. Stellar radial velocities were derived using the best set of lines available, according to the star's spectral type.

The complete set of radial velocities determined for the sample stars is listed in Table 1. Stars are labelled following the nomenclature by Parker (1993) and data columns include average radial velocity (and its uncertainty) for each epoch. The errors listed in Columns 3, 5 and 7 in Table 1 correspond to the standard deviation in the estimation of the average from the set of available lines, while the one listed in Column 8 is the standard deviation of stellar radial velocity among different epochs.

With the radial velocities available at different epochs we can then simply check for the presence of variations with time. To quantify this, we follow the standard procedure of comparing the dispersion about the average radial velocity for each star with the average uncertainty in the determination of each radial velocity. Following Abt et al. (1972) procedure, we therefore calculate the "external" to "internal" velocity dispersion ratio ($\sigma_{\rm E}/\sigma_{\rm I}$). Radial velocity variables can then be easily flagged out as they show $\sigma_{\rm E}/\sigma_{\rm I}$ above 3, which is analogue to say that the variation in radial velocity is 3 times larger than the expected uncertainties.

Table 1 shows that 19 out of 46 stars show radial velocity variations. Adding stars that show variation of their absorption line profiles from epoch to epoch, our sample rises up to 27 out of 52 stars ($\sim$ 50%).

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TABLE 1

STELLAR RADIAL VELOCITIES

Id	V_r	$\sigma_{\rm I}$	V_r	$\sigma_{\rm I}$	V_r	$\sigma_{\rm I}$	$\frac{\sigma_{\rm E}}{\sigma_{\rm I}}$	Id	V_r	$\sigma_{\rm I}$	V_r	$\sigma_{\rm I}$	V_r	$\sigma_{\rm I}$	$\frac{\sigma_{\rm E}}{\sigma_{\rm I}}$
15	300.1	4.5			273.7	8.4	2.9	1063	269.5	5.8	265.3	2.1	265.9	8.3	0.4
32	283.3	5.5	271.6	2.8	261.1	3.7	2.8	1109	275.2	4.8	294.9	8.0	279.5	3.3	1.9
124	267.0	2.8	240.3	2.1	210.6	5.1	8.5	1139	257.3	4.4	267.2	7.4	260.0	2.7	1.1
171	273.7	2.0	287.5	4.5	257.8	3.9	4.3	1163	264.6	4.5	274.3	7.2	260.5	3.7	1.4
260	286.0	8.6	274.7	5.1	261.0	8.9	1.7	1218	294.1	1.3	283.6	2.7	273.0	6.4	3.1
305	269.5	9.2	269.5	5.2	249.9	5.7	1.7	1222	278.8	3.5	273.6	5.0	259.1	3.7	2.5
316	287.7	3.9	366.9	5.9	303.7	2.4	10.2	1247	249.7	8.3	264.1	3.0	249.0	15.0	1.0
485	277.3	4.3	260.1	4.6	255.7	7.5	2.1	1260	290.0	3.9	295.8	4.1	280.3	4.0	2.0
531	309.3	6.4	247.6	2.0	221.2	8.8	7.9	1339	253.7	5.3	272.7	4.1	256.0	5.4	2.1
541	240.2	5.4	276.9	6.3	273.3	1.5	4.6	1341	288.9	7.0	301.2	5.2	302.2	3.1	1.4
613	246.2	2.7	275.6	3.7	332.9	8.6	8.9	1350	266.1	3.5	269.3	6.8	255.9	6.2	1.3
649	282.6	8.6	286.3	5.8	280.2	5.6	0.5	1401	249.2	0.2	261.6	1.9	280.6	4.1	7.7
684	275.7	7.3	270.4	4.4	247.8	7.1	2.4	1468	268.2	9.0	276.1	4.8	259.9	3.1	1.4
713	239.3	3.5	317.1	6.2	299.8	3.2	9.5	1531	277.1	3.3	305.0	4.6	291.8	1.6	4.4
716	274.0	1.9	273.8	6.7	266.1	3.4	1.1	1553	268.1	2.9	241.9	5.2	231.2	7.2	3.7
747	183.4	2.1	214.9	4.6	307.4	3.9	18.2	1584			281.7	5.1	250.7	6.1	3.9
809	263.8	8.9	268.7	4.6	256.0	7.3	0.9	1604	271.9	4.9	262.2	6.9	252.0	2.6	2.1
871	275.2	6.8	272.8	5.5	268.7	7.8	0.5	1607	281.7	1.9	279.7	3.5	267.2	2.0	3.2
885	276.1	4.1	289.1	2.7	286.3	6.9	1.5	1614	275.0	0.1	294.6	3.1	277.8	5.1	3.8
905	269.5	6.1	268.4	7.5	272.1	10.7	0.2	1619	268.9	1.0	322.6	4.0	302.4	1.1	13.3
956	269.4	5.8	285.4	5.7	240.0	2.1	5.1	1729	281.3	7.9	270.8	3.4	194.2	5.5	8.5
975	297.4	2.9	288.8	2.0	266.7	5.8	4.4	1840	262.4	7.6	270.8	3.0	273.5	4.9	1.1
1022	275.3	3.2	289.8	3.8	272.1	3.9	2.6	1969	274.3	4.1	277.8	5.8	285.9	2.6	1.4
1035	287.8	10.8	278.1	6.9	263.5	7.8	1.4	1988	219.3	4.3	326.2	5.4	235.4	1.9	14.9

This detection rate is still consistent with a spectroscopic population of 100% massive binaries, when the observational parameters described in Bosch & Meza (2001) are set for our GMOS observations. The non-binary population of our sample decreases to 26 stars, still enough to calculate a representative value of the stellar radial velocity dispersion (σ_r). For our sample, we derive a value of 8.9 $\mathrm{km\,s^{-1}}$ for the actual radial velocity dispersion. This seems to confirm the suggestion by Bosch et al. (2001) based on simulations, that the large values derived for the stellar velocity dispersion were most probably due to the presence of binaries.

The radial velocity dispersion found for the 30 Doradus ionising cluster agrees, within observational errors, with the stellar kinematics expected if the cluster is virialised and its total mass is derived from the photometric plus ionised gas masses. This suggests that the stellar cluster is far from disruption and stands as a firm candidate for a future globular cluster system.

GMOS has therefore proven that MOS spectroscopy can deliver essential information using small amounts of telescope time. The analysis shown in this contribution can be extended to other stellar cluster, provided they fit on GMOS field of view. Most star forming regions in the MCs, like N159/N160 region are excellent candidates to do so.

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DISCUSSION

H. Zinnecker - The other stars you suggest to study (N159, N160) are dusty and partly obscured, so you may want to study their massive stars' radial velocity variations and velocity dispersion via infrared rather than optical multi object spectroscopy, pehaps with KMOS at the VLT?

G. Bosch - There is still a lot of ground that can be covered with optical spectroscopy, as we can derive kinematics avoiding the core dusty areas. It will be interesting though in order to analyse segregation effects, for which we will need to get closer to the core. Radial velocity determinations – and binary detections – in the infrared are at their early stages, but they will be an interesting option in the future.