Planetary Nebula : NGC 2022

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Received ____________; accepted ____________

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ABSTRACT

We present, for the planetary nebula NGC 2022, the results of spectral-line flux mapping extracted from long-slit spectra taken with the 2.56 m Nordic Optical Telescope, in the Observatorio del Roque de los Muchachos, Spain. Two-dimensional emission-line images for the entire nebula are created using data from only half of the nebula, and are used to derive fluxes for 19 lines. We also create the Hα/Hβ extinction map, the [SII] and [Ar IV] line ratio density maps, and the [OIII] temperature map of the nebula. The total Hβ flux is compared with values obtained by other authors. With these results we are ready to begin modelling the nebula with a 3-D photoionization code, which will allow us to determine the distance to NGC 2022.

Subject headings: Planetary Nebulae: individual(NGC 2022)

1. Introduction

Planetary nebulae are expanding gaseous envelopes of enormous size wtih a high temperature star in the center. This is the stage between AGB and white dwarf in the evolution of low-mass stars. They have different shapes and structures. In this paper we are working with NGC 2022 a planetary nebula classified as elliptical in shape (Pottasch et al. 2005; Stanghellini et al. 1993).NGC 2022 is a very symmetric object located in Orion, 11 ° above the Gallactic plane and has a diameter of approximately of 27 ″.
Monteiro et al. have been doing research in PNe using 3-D photoionization models in order to determined physical properties and different parameters of this objects. One parameter, distance, remains difficult to mesuare, and is a crucial problem in the study of PNe. For NGC 2022 there are different values for distance. From eleven distinct values for the distance, the minimum and maximum values are 1.3 kpc and 4.65 kpc respectively and the statistical distance is 2.32 ± 0.87 (Strasbourg-ESO catalog of Galactic PNe 1992). The distance is an important parameter for determing other properties of PNe, e.g. luminosity, and it must be accurately determined. In this paper we start with the calculation of the fluxes of the strongest lines obtained from the spectra of NGC 2022 using algorithms running in IDL provided by Monteiro and addapted for our data. All the procedure is explained in section 2.

2. Observations and Data Reduction

All of our observations were taken with the Nordic Optical Telescope (2.56 m), in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias, La Palma, Spain on 2005 October 29. The seeing conditions during the observing run were 1.1″.
The 10 s exposure Hα(λ =656.2 nm) image of NGC2022 is shown in Figure 1. We can

easily see that the nebula is point-symmetric, because of the two blobs that have simmilar intensities in each part of the nebula, and it does not have a complex morphology. Also, in Figure 1, we show our 7 slit positions. Note that we obtained line intensity profiles for only one half of the nebula by taking 300s exposures at each of several parallel long-slit positions across the nothern half of the nebula. The slit was $1.3''$, and our slit positions are spaced every 2 $''$. However, one of the slit positions was not observed, so we computed an average of the two adjacent slit spectra for the missing slit, $6''$ from the central star.

Using IRAF reduction packages, each slit was reduced with standard procedures for long-slit spectroscopy, obtaining the spectra shown in Figure 2. The wavelength calibration was applied to the two-dimensional images by using the tasks FITCORDS and TRANSFORM after identifying and reidentifying the spectra. The flux calibration of the spectra was done with a standard star spectrum obtained with a wider slit ($2.5''$), in order to obtain more flux, and minimize lost flux from the star.

2.1. Full Nebula Image Construction

Using the same method used by Monteiro et al.(2004,2005) for obtaining emision-line images (flux maps) and using the same algorithm (Park & Schowengerdt 1983; Rifman & McKinnon 1993) to combine and interpolate the integrated flux profiles we create emision-line images for each line of the spectra obtained, this is shown in Figure 3. Since the data were taken from half of the nebula, the other half was reconstructed with this algorithm by repeating the data that we already had. The observed half was rotated about the N-S axis and flipped about the E-W axis to form the southern half of the nebula.

In Figure 4 the Hα flux map for the entire nebula is shown with overlay of our Hα image. Note that the contour lines fit well even though the data from one half of the nebula was missing.

3. Observational Results

Just as we did with Hα, we create images of the 19 strongest lines found in the NGC 2022 spectra. In Figure 5 we show the most important. These images are corrected for the effects of interstellar extinction using the Hα/Hβ ratio map. The logarithmic correction constant was calculaed pixel by pixel using a theoretical value Hα/Hβ = 2.87 (Osterbock 1989) and the reddening curve of Seaton (1979). The correction for atmospheric extinction effects was also applied. The same procedure was performed, for diferent nebulae, by Monteiro et al.(2004,2005).

The final corrected and integrated (19 lines) fluxes we obtained are shown in Table 1, along with error for each line and the observed (not de-reddened) uncorrected flux. The value for log(Hβ) was -11.6015, so the total flux for Hβ is 2.503×10^{-12} erg cm^{-2} s^{-1}. A comparison of the results of the log(Hβ) value from different authors is shown in Table 2.

3.1. Gas Density and Temperature

Temperature and density maps were created from the corrected maps of [OIII] (436.3 nm/500.7 nm) and [SII](673.1 nm/671.7 nm) and [ArIV](474.0 nm/471.1 nm) lines, respectively. They are shown in Figures 6, 7 and 8. We used the method described in Monteiro et al. (2004) to obtaine these maps. The values for density will not be used for running the models because the accuracy of this values is poor resulting from the faintness of this lines.

We will search for the values for density and temperature to input into the model so that we will have more accurate results .

4. Conclusions

We present spectrophotometric maps of NGC2022. The value for the Hβ flux was compared to the values from the literature, in Table 2, and our value is consistent with previous findings.

Now, we are ready to run the photoionization model that will allow us to accurately determine the distance to NGC 2022. We have the fluxes for each emission line found in the spectrum and the flux maps for each. Later we can compare the outputs from the model with our results and obtain the distance.

4.1. Future work

The determination of distances to nebulae remains a big problem in the study of PNe. That is why one of the objectives of this work is to accurately determine the distance to NGC2022 as an addition to the work that has been done by Monteiro et al.

The details of the method used by Monteiro et al. are discussed in an apendix of one of his papers (Monteiro et al. 2005, 2004), basically they used an improvement of the astrophysical method for determing distance (Gurzadyan 1997). In the Astrophysical method, the distance is defined by

$$d = 2.4 \times 10^{25} \frac{F(H\beta)}{n^2 \theta^3 \epsilon} \tag{1}$$

where $F(\mathrm{H}\beta)$ is the Hβ flux in ergs cm^{-2} s^{-1}, n is the electron density in cm^{-3}, θ is the observed angular extent of the nebula and ϵ is the so-called filling factor, which is the fraction of the nebular volume that is emitting(it contains ionazed gas). We do not need the filling factor because we are going to determine the 3-D structure of NGC2022 and for this reason our method is more accurate.

I would like to thanks to Hugo Schwarz and Joey Richards. It was a pleasure working with you. Gracias por la experiencia, hicieron mi verano como nunca lo habria imaginado, ẗrabajandoën CTIO. Hektor Monteiro, even though we have never met, thanks for your help, it has been crucial to my progress. Stella, thanks for the opportunity of being here and the observing run was a great experience. Thanks to all the REUs for making me happier every day at dinner with your inappropiate ÿokes.̈

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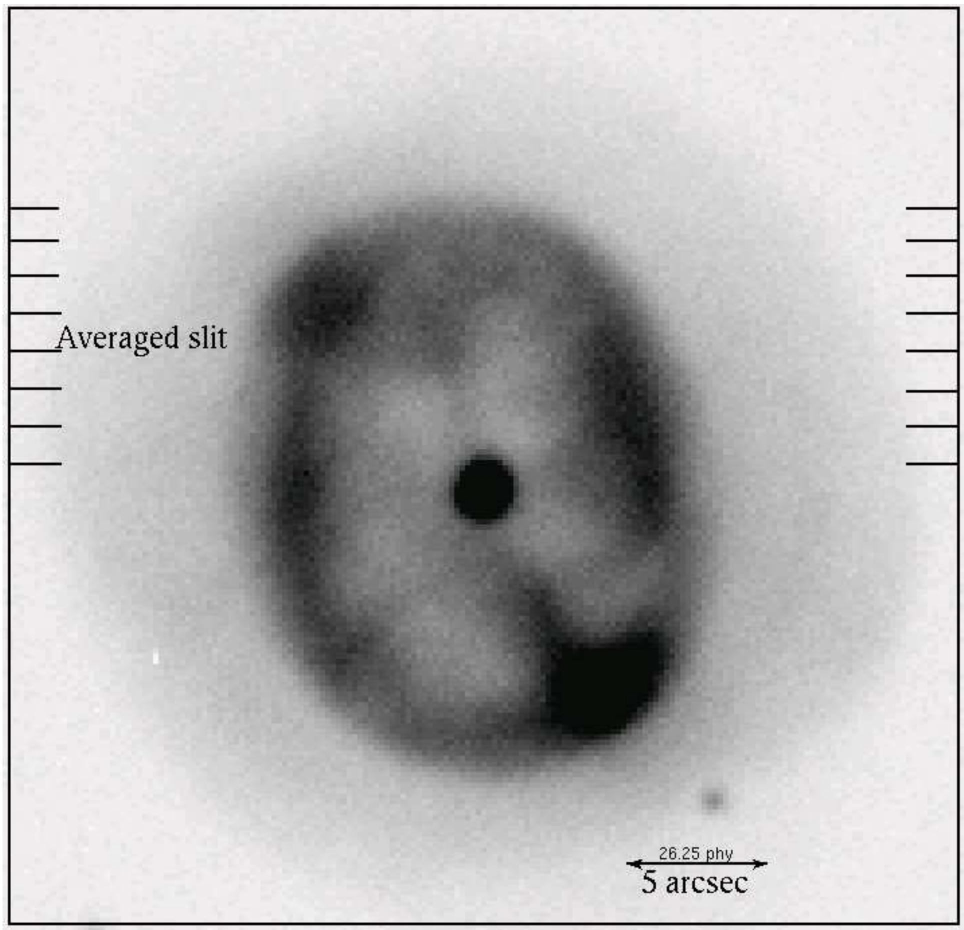

Fig. 1.— H α image of NGC2022 showing the 8 slit positions including the averaged slit. This image was taken with the Nordic Optical Telescope, La palma, Spain.

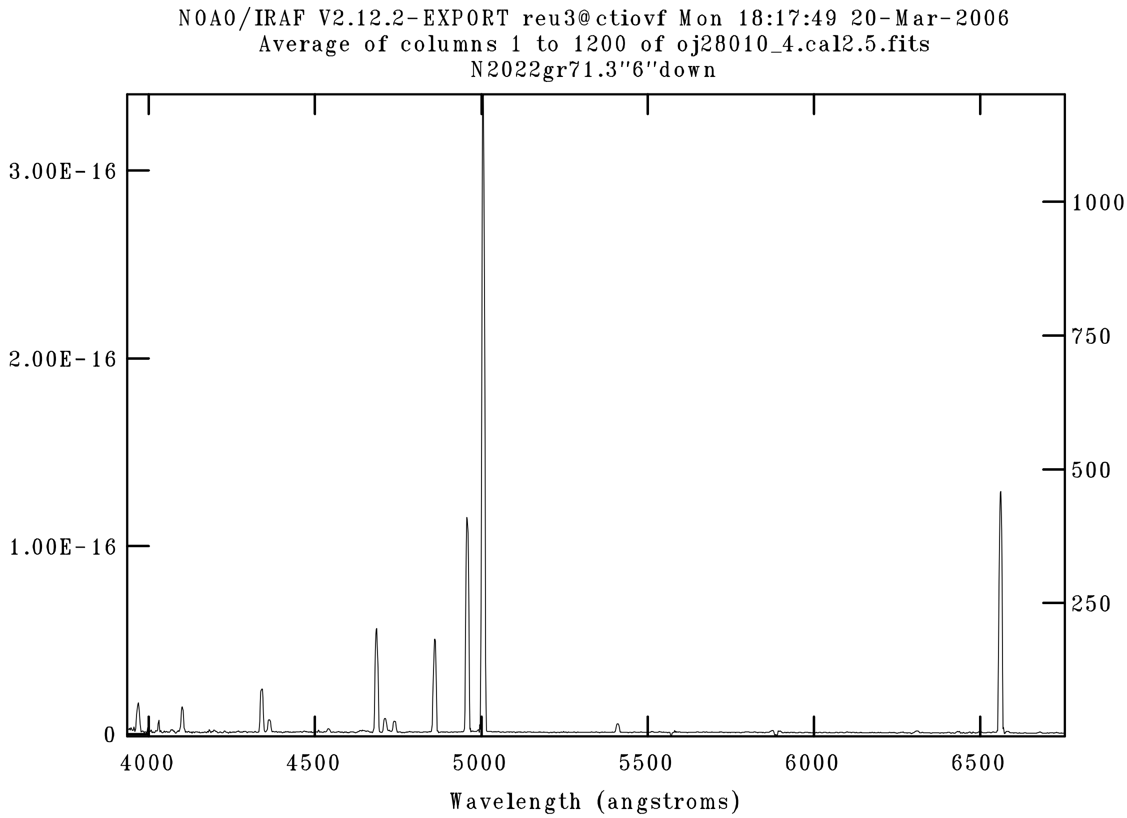

Fig. 2.— NGC 2022 final spectrum for one column of one slit.

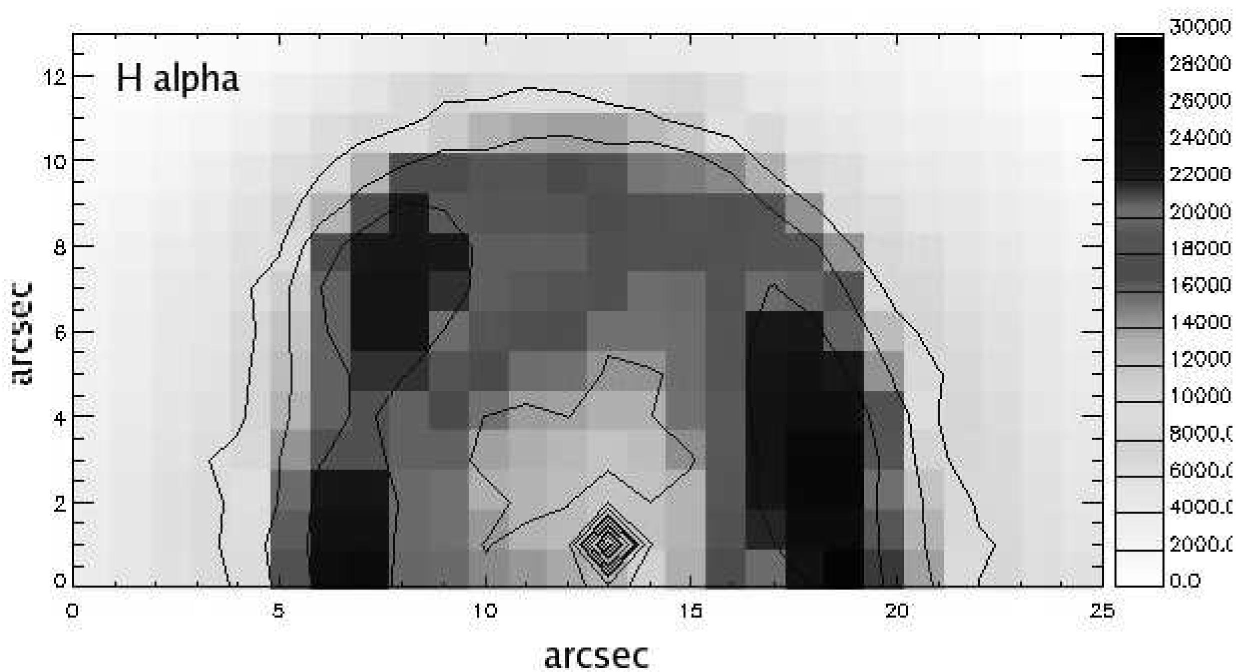

Fig. 3.— Hα flux map constructed with the data, overplotted with contour lines of the Hα image.

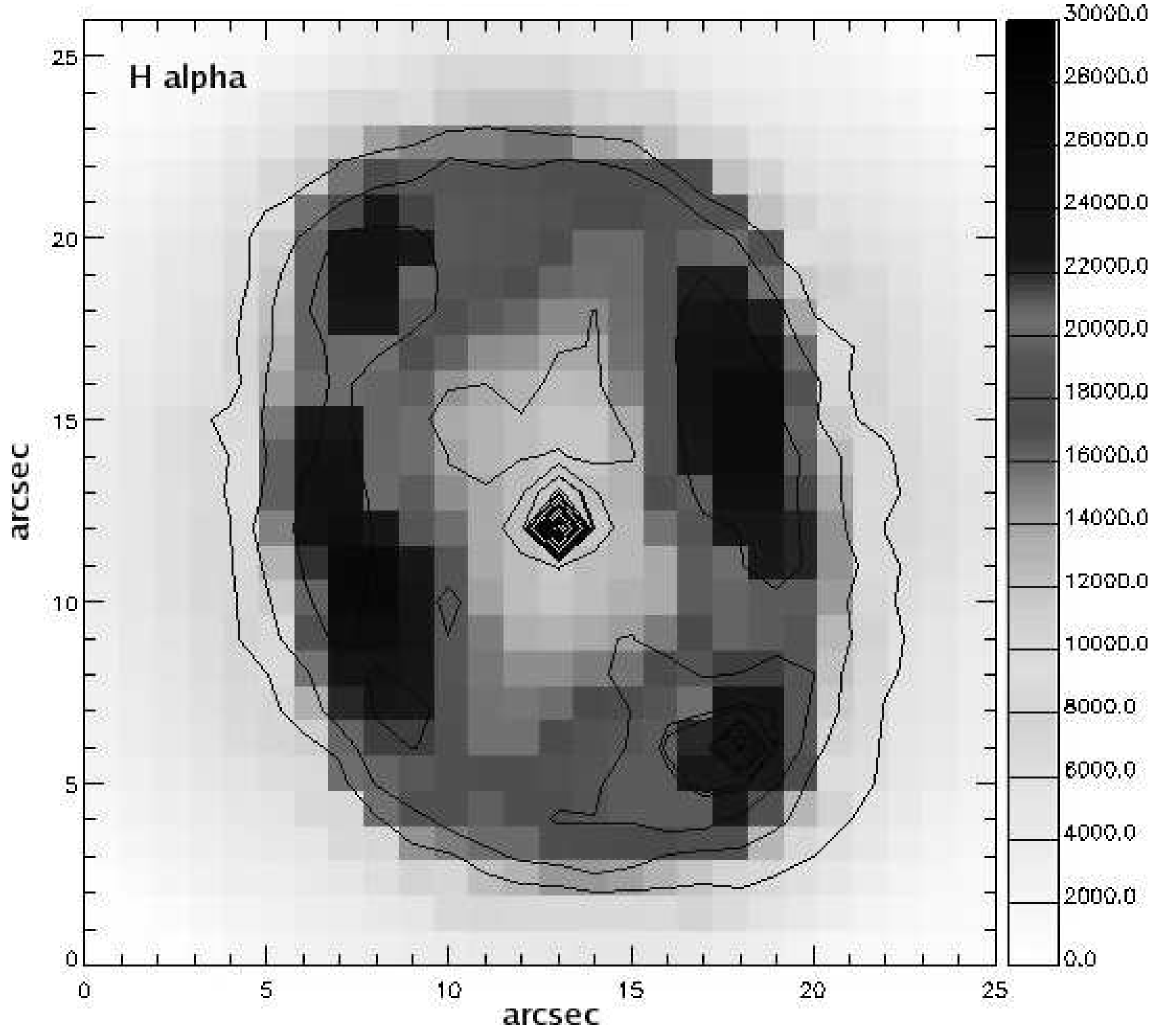

Fig. 4.— Hα flux map for the entire nebula constructed using the flux map obtained before (half of the nebula).

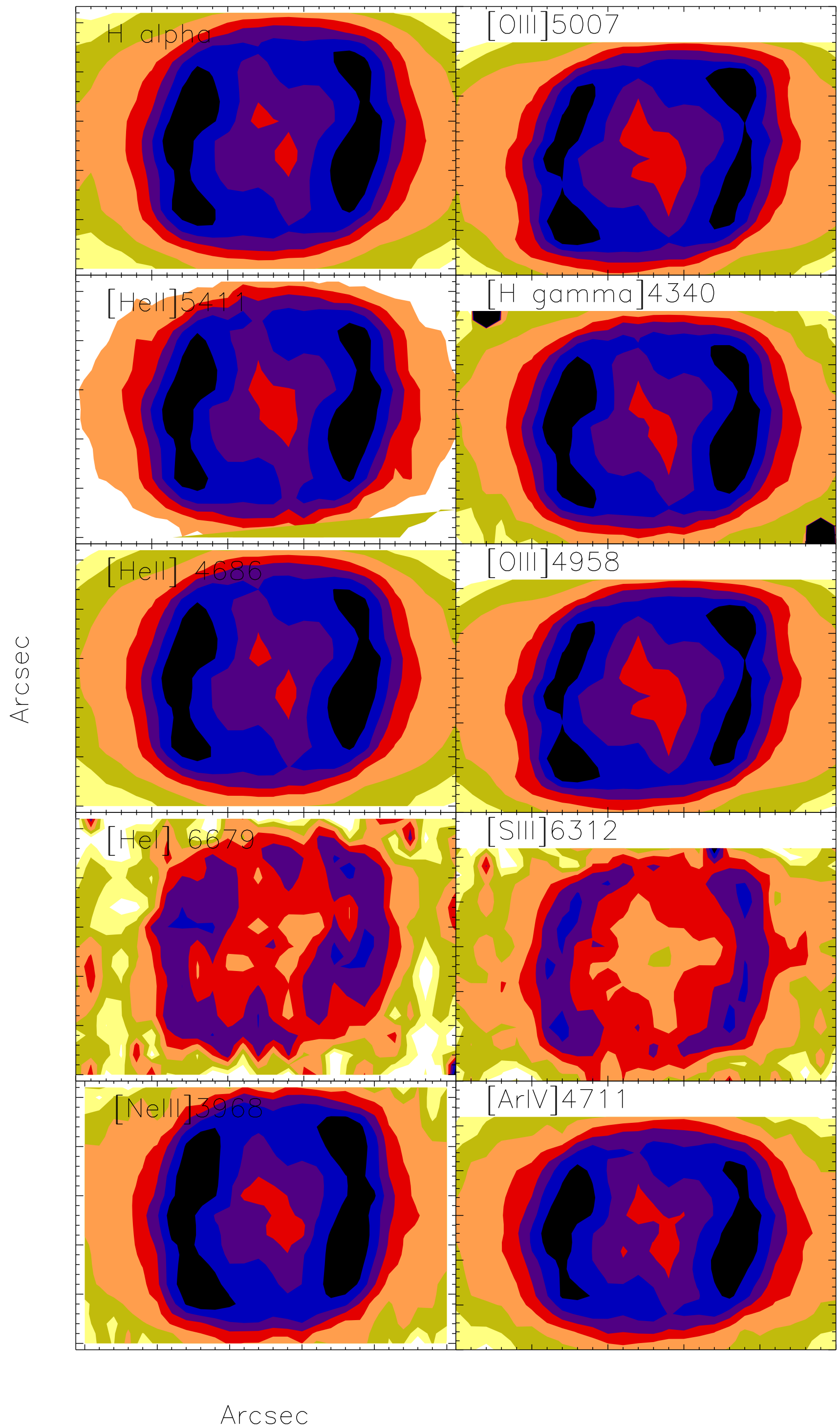

Fig. 5.— flux map of the strongest lines in the NGC 2022 spectrum.

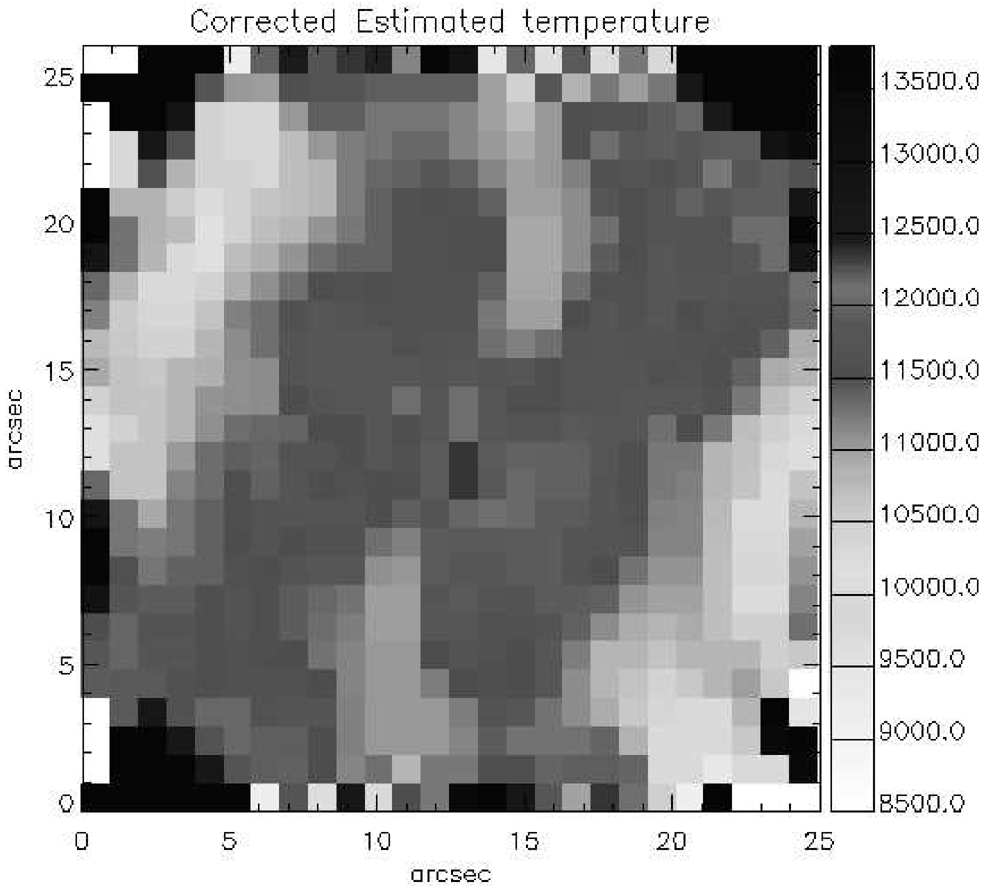

Fig. 6.— Temperature map obtained with [OIII] (436.3 nm/500.7 nm) lines.

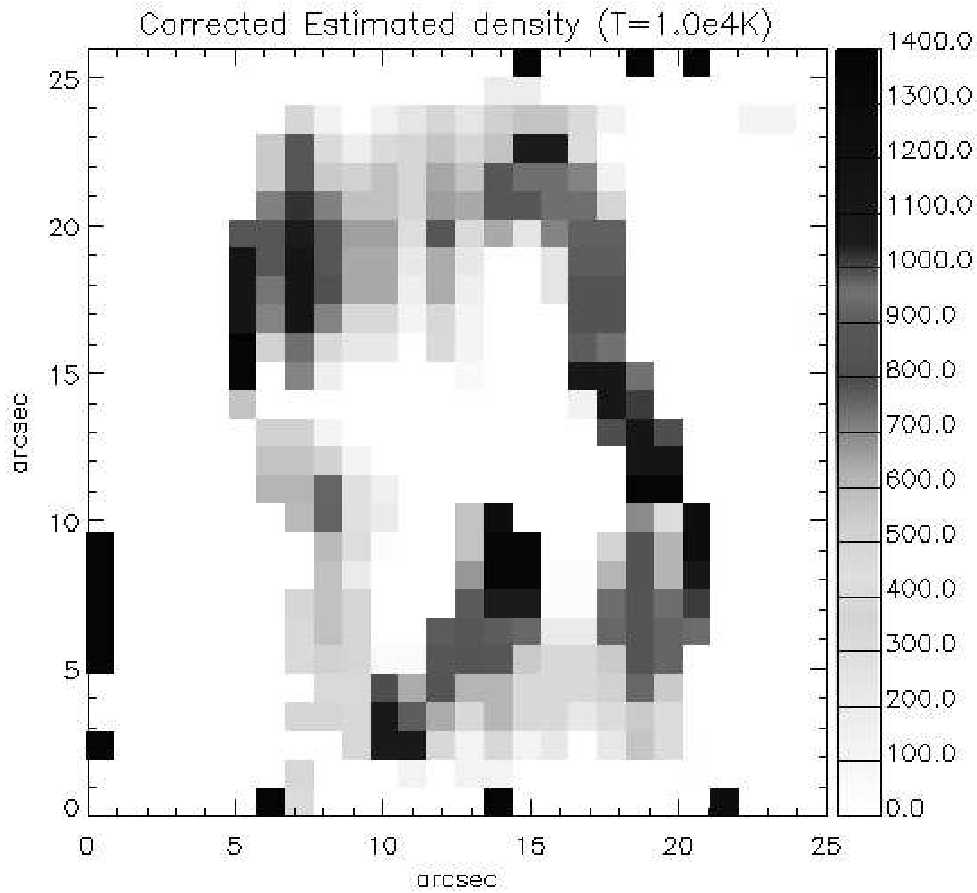

Fig. 7.— Density map obtained with [SII] (673.1 nm/671.7 nm) lines.

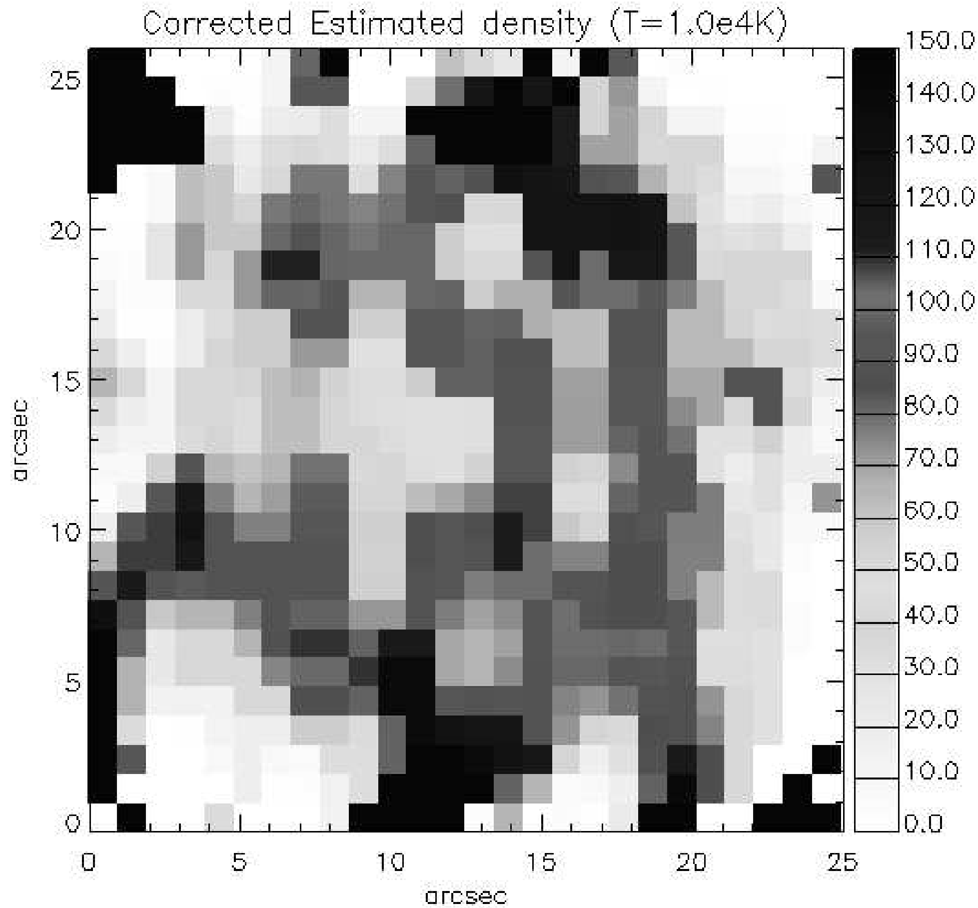

Fig. 8.— Density map obtained with [ArIV] (474.0 nm/471.1 nm) lines.

Table 1: Line Fluxes Relative to Hβ

Line (nm)	Flux	Corrected Flux	Error (%)
NeIIIλ 396.8	0.29	0.29	7
H $\delta\lambda$ 410.0	0.26	0.25	6.8
H $\gamma\lambda$ 434.0	0.47	0.47	5.5
OIII λ436.3	0.14	0.14	7.9
HeII λ454.1	0.039	0.034	11
HeII λ468.4	1.08	1.08	4.9
ArIV λ471.1	0.14	0.14	7
ArIV λ474.0	0.10	0.10	7.6
OIII λ495.8	2.22	2.23	4.6
OIII λ500.7	6.67	6.695	4.5
HeII λ541.1	0.039	0.035	7.1
HeI λ587.6	0.029	0.027	9.8
NaI λ589.5	0.018	0.016	12
SIII λ631.2	0.022	0.021	11
Hα λ656.2	2.74	2.73	4.2
NII λ658.4	0.144	0.143	6
HeI λ668.0	0.011	0.010	12
SII λ671.7	0.007	0.004	16
SII λ673.1	0.007	0.005	11

Table 2: Comparison of log(Hβ) values for NGC 2022

authors	log(Hβ)
us	-11.60
Aller et al. (1979)	-11.15
Kwitter et al. (2003)	-11.62
Pottasch et al. (2005)	-10.75
Sabbadin et al. (1984)	-11.12
Tsamis et al. (2003)	-11.13