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Galactic Hα emission line studies using DEFPOS at the TÜBİTAK National Observatory

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Abstract: Hα spectral line (6563 Å) profiles of eight northern H II regions in our galaxy (Sh2-25, Sh2-131, Sh2-237, IC 434, IC 1318, NGC 1982, NGC 6543, and NGC 6611) have been obtained using the Dual Etalon Fabry–Pérot Optical spectrometer (DEFPOS) with a 4' field of view, located at the coudé focus of the 150 cm RTT150 telescope at the TÜBİTAK National Observatory (TUG, Antalya, Turkey). Observations were carried out during the nights of 25–27 December 2015 and 6–7 June 2017 with different long exposure times ranging from 900 s to 3600 s. These spectra provide information about the local standard of rest (LSR) velocities, the full width at half maximum (FWHM), and densities of the sources. The LSR velocities and the FWHM of the Hα emission lines were found to be in the range of –50.31 km/s to 27.57 km/s and 34.88 km/s to 44.54 km/s (mean FWHM: 37.19 km/s), respectively. The NGC 6543 (Cat's Eye Nebula) is the faintest one (75.06 R), while the NGC 1982 H II region is brightest source (38,477.3 R). The LSR velocity and the FWHM results of the DEFPOS/RTT150 system were compared with the data by several authors given in the literature and the results of DEFPOS data were found to be in good agreement with data given in the literature. Since there is not enough information on LSR velocities and intensities of such galactic sources with low angular size in the literature, we believe that this spectrometer will provide a powerful tool for the study of diffuse ionized gas and these new results may have significant contributions to the literature. In the future, we are planning to prepare Hα maps with the 4' field of view of some diffuse ionized emission sources selected from VTSS and WHAM Hα maps with large fields of view.

Key words: ISM: H II regions, emission nebulae, planetary nebulae, open clusters, techniques: spectroscopic, Fabry–Pérot, radial velocities, line widths

1. Introduction

The region between the stars in the Milky Way, so-called interstellar medium (ISM), is filled with a dilute mixture of dust grains, molecules, atoms, charged particles, and magnetic fields. This complex medium with very low density plays a central role in the cycle of stellar birth, death, and the evolution of galaxies [1–3]. Understanding its physical properties and dynamical behavior has therefore a vitally important role. The gas in the ISM is photoionized by the ultraviolet radiation from hot massive stars of spectral types O and B. The spatial distribution of O stars in the solar neighborhood supplies the required ionizing radiation to produce the observed galactic ionized gas [4,5]. The gas in the ISM is composed almost entirely of hydrogen (90%), helium (10%), and other heavier elements than helium (0.1%). The dominant hydrogen gas clouds are found in ionized (H^+), neutral (H^0), and molecular (H_2) forms in the ISM [2]. The H II regions (the so-called ionized bubbles

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or Strömgren spheres) in the ISM are regions of ionized hydrogen (H^+) gas surrounding luminous hot massive stars having O and B spectral types and consist of a cloud of hot plasma of ionized hydrogen at about 10^4 K [2,3,5–8].

Today, we know that extensive quantities of ionized hydrogen exist in the Milky Way. This gas is generally referred to as diffuse ionized gas (DIG; also commonly referred to as warm ionized medium or the Reynolds layers) [9]. The DIG is known to be a major yet poorly understood component of the ISM and consists mostly of a mass of the ionized ISM. From interstellar emission lines and pulsar dispersion measurements, this ionized medium with a low electron density of 0.15 cm^{-3}, a warm temperature of 10^4 K, and a scale height of 1.0–1.5 kpc (1 pc = 3.086 $\times$ 10^{13} km), placing half of the gas outside z = 0.6 kpc, fills approximately 20% of the volume of the ISM within a 2-kpc-thick layer near the Galactic midplane and has a mass surface density equal to 1/3 that of neutral hydrogen [2,4,8–14]. In recent years, significant information about the distribution and kinematics of the DIG gas has been obtained through the study of the faint optical emission lines, especially at Hα [15–22]. The physical properties of the DIG in the our galaxy, such as ionization state, electron temperature, and scale height, were studied in detail in [18].

This paper presents the results of a study of local standard of rest (LSR) velocity, full width at half maximum (FWHM), and intensity in eight northern H II regions observed in the Milky Way using the Dual Etalon Fabry–Pérot Optical spectrometer (DEFPOS). The LSR velocity, FWHM, and intensity values were deduced from Hα line profiles of galactic H II regions obtained with DEFPOS and then were compared with some available data in the literature.

2. Observations and data analysis of the spectrometer

Since Fabry–Pérot spectrometers have high throughput, providing a high signal to noise ratio (S/N) and high spectral resolution, they are well suited for studies of Hα emission lines from the DIG [1,18,23,24]. Therefore, DEFPOS was developed to measure the Hα emission line from spatially extended emission sources such as H II regions, planetary nebulae, open clusters, and supernova remnants in the our galaxy within the 200 km/s (4.4 Å) spectral window. The spectrometer, located in the coudé exit of the 150 cm RTT150 telescope (*f/48*) at the TÜBİTAK National Observatory (TUG, Antalya, Turkey) in 2007, has obtained many galactic Hα emission lines from the DIG [20,21,25,26]. The DEFPOS system consists of a 7.5 cm dual etalon, a narrow band Hα filter (FWHM 15 Å), and a 2048 $\times$ 2048 CCD camera with pixel size of 13.5 μm. The CCD camera has more than 90% quantum efficiency (QE) at Hα. The spectrometer has a field of view of 4' and resolving power of 11,000 (30 km/s: FWHM of the instrumental response function). Detailed information about the design of DEFPOS, the intensity calibration, and the data reduction procedure can be found in [21,25,26] .

The eight H II regions, which are bright sources in the Milky Way, were selected to achieve an adequately high S/N ratio. The observations of north galactic Hα emission were carried out with DEFPOS on 25–27 December 2015 and on 6–7 June 2017 at the TUG RTT150 telescope with different long exposure times ranging from 900 s to 3600 s. During the analysis of the DEFPOS data, the standard CCD data reduction technique including bias, dark, and flat field corrections was used for each individual CCD image and then cosmic rays and unwanted reflections due to the optical system were removed from galactic data. Tracking correction was not used during the observations. The reduced CCD images were then converted to one-dimensional Hα line profiles with 50 data points in each row by implementing an annular ring-summing procedure (see Figures 1 and 2). The annular ring-summing procedure is the property of equal area annuli corresponding to equal spectral intervals

[18,27–29]. This two-dimensional Hα line spectrum provides detailed information about physical conditions of the gas (e.g., the distribution and the kinematics) obtained from the H II regions in the ISM [9]. An example of the data reduction and the annular ring-summing procedure applied for DEFPOS data is given in Section 3.1.

The center of the North America Nebula (NAN: NGC 7000) within a 4' area $\alpha = 20^h\ 58^m\ 04^s.0$, $\delta = 44^\circ\ 35'\ 43''.0$ (2000), was used for intensity calibration of all galactic data. The value of Hα surface brightness of this region in Rayleigh (R) units was estimated to be 900 R [1R $= 10^6/4\pi$ photons cm^2 sr^{-1} s^{-1} at Hα] in [30]. Three or four Hα spectra were taken with different exposure times during the observation nights. Finally, using the data obtained from this selected region of NGC 7000, the galactic data in analog to digital units (ADU) were converted to intensity in units of R.

3. Results and discussion

The eight northern H II sources observed with DEFPOS are listed in Table 1. These galactic Hα sources are from H II regions, planetary nebulae, and open clusters. Column 1 and column 2 give the data set number and the name of the H II region, beginning with the Sharpless catalog name (Sh2: Sharpless 1959) [31], NGC, and IC numbers. Columns 3 and 4 present the coordinates (α, δ) of each source in epoch 2000. The names and spectral types of the central stars that ionize their surrounding gas to create the H II regions are listed in the fifth and sixth columns, respectively. The stars listed in the fifth column are young OB stars and they are the ionization sources of H II regions. The distances (kpc) to the H II region, angular diameter (arc-minute: ') of the H II region, and alternative names of each source taken from the literature are given in columns 7–9, respectively.

The eight galactic CCD images used in this study were converted to two-dimensional line profiles using an annular summing technique as given in Figure 1. In Figure 1, the spectra are plotted as intensity values in units of R (km/s) against radial velocity (V_{LSR}) with respect to the LSR in units of km/s. We assumed the Sun to be moving at 20 km/s toward $\alpha_{2000} = 18^h\ 03^m\ 44^s$, $\delta_{2000} = 30^\circ\ 03'\ 12''$ (2000) [32]. The observed values of Figure 1 are given by filled circles. Each filled circle represents a 4 km/s spectral resolution element, and the solid line represents the best theoretical Gaussian fit to the observations. The vertical dashed line for each individual datum represents the differences between the center of the spectrum and its fit position of the LSR [20,21].

The V_{LSR} velocity, the FWHM, and the intensity of the Hα emission line from eight north galactic Hα sources listed in Galactic H II region catalogs were determined and results are summarized in Table 2. In Table 2, the first and second columns give the data set number and the name of the sources observed by DEFPOS, similar to Table 1. The third and fourth columns give the observation date and exposure time for the data, respectively. The velocities, FWHM, and intensities for each of the 8 regions are given in the remaining three columns. All galactic Hα observations discussed in the next subsections have been compared with data from the literature.

3.1. H II region Sh2-25 (M 8)

Sh2-25 (Lagoon Nebula: M 8, NGC 6523, LBN 25, W 29) is one of the closest and brightest H II regions in the constellation Sagittarius of our galaxy. The Sh2-25 region is a bright nebula (NGC 6523) combined with a bright open galactic cluster (NGC 6530). The energy source of this region is ionization from high-energy photons emitted from a nearby hot star. The Sh2-25 nebula is estimated to have an apparent magnitude of 6'.0

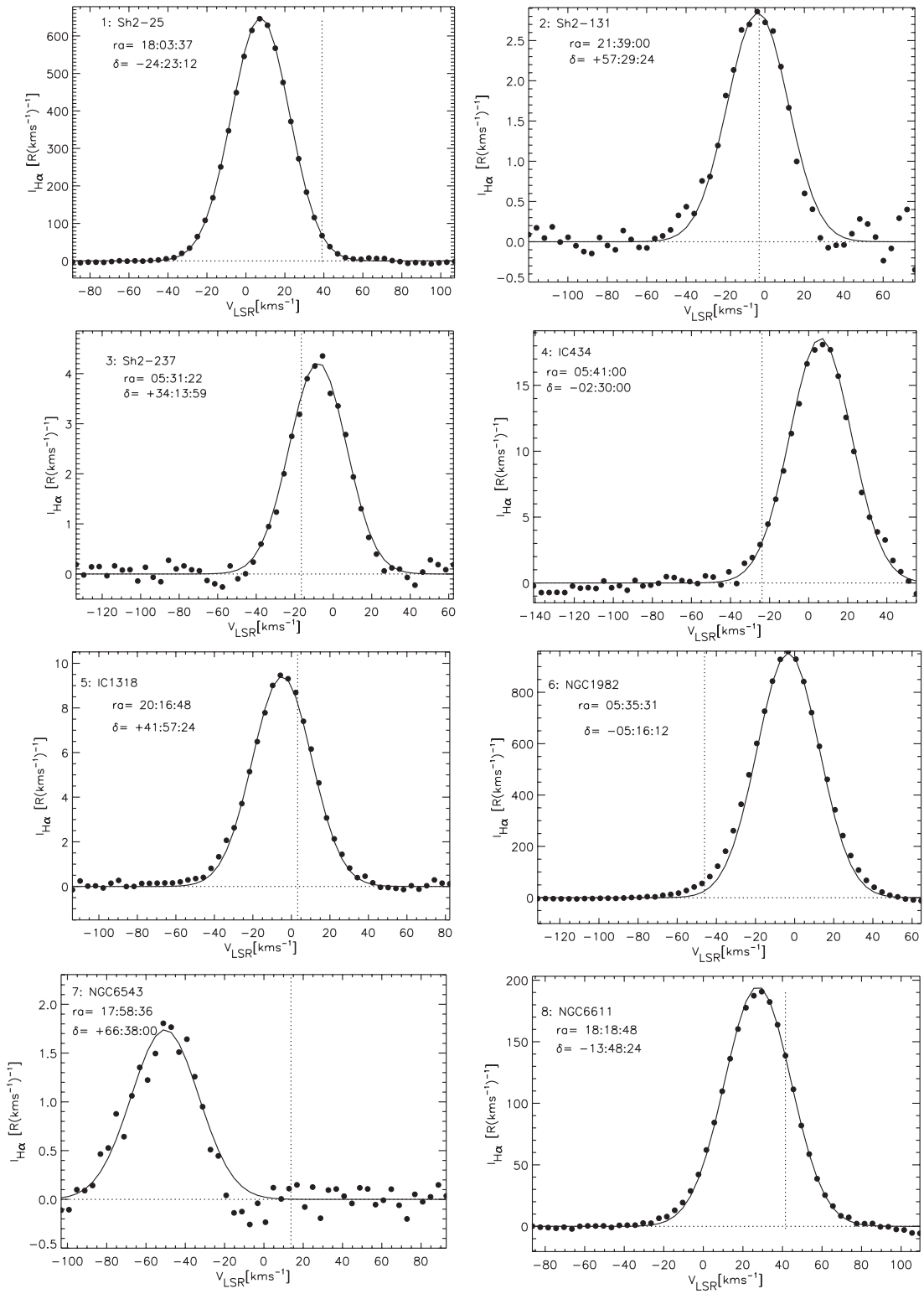

Figure 1. Eight Hα spectral line profiles selected from different northern H II regions in our galaxy are plotted as intensity vs. LSR velocity. Object names and their equatorial coordinates are given in the upper left of each individual panel.

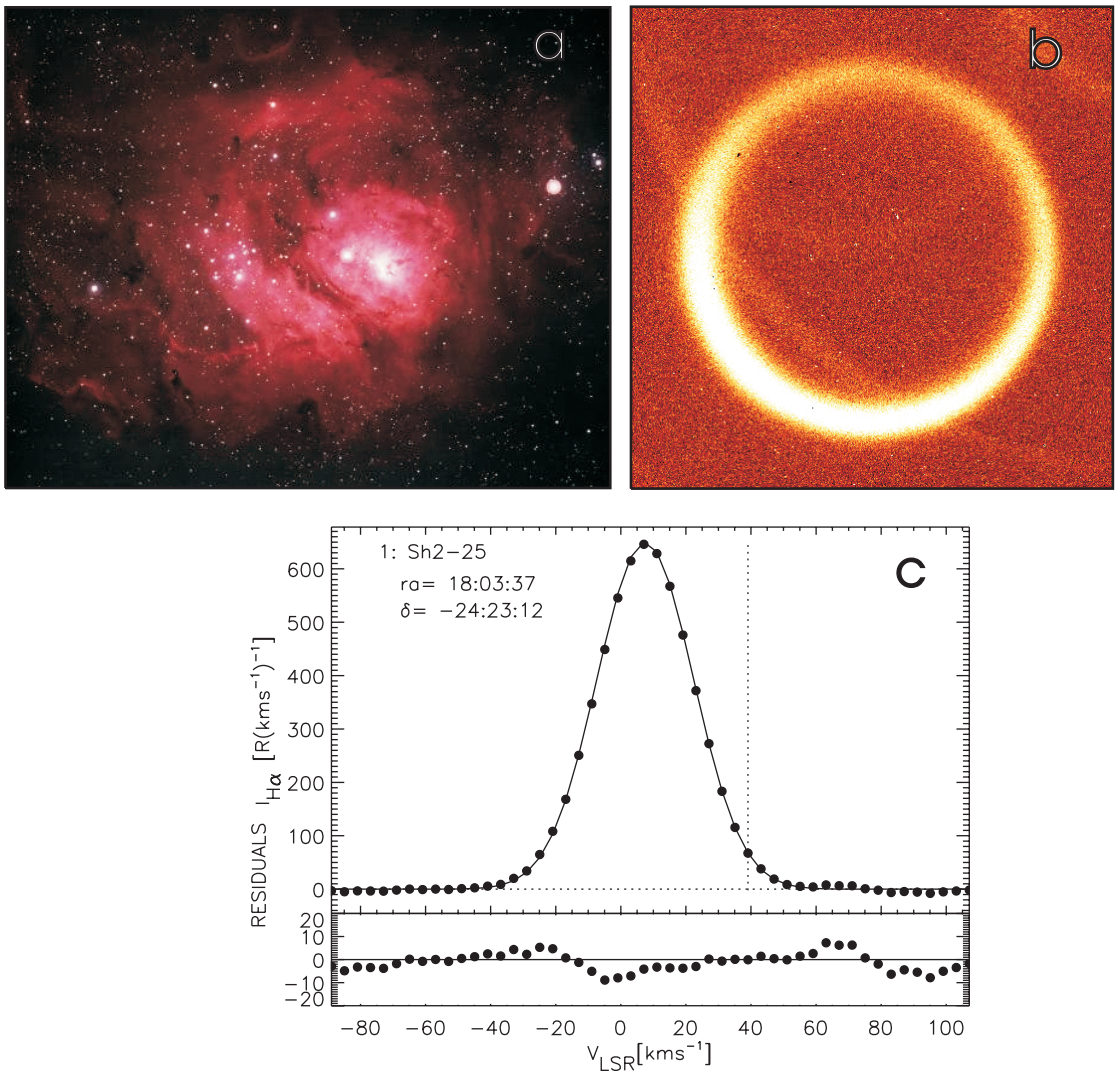

Figure 2. a) A photograph of Sh2-25 (M 8): H II region. b) A raw CCD Fabry–Pérot image from the observation of this nebula within the 4' beam. The observation was taken on 6 June 2017. The interference pattern is imaged onto a 1.0 cm^2 region of the CCD chip. c) Line profile after the annular-summing procedure. The top panel shows the spectra, and the residuals of the fit are plotted in the bottom panel. More detailed information about the figure can be found in the text.

and apparent dimensions of 90' at a distance of 1.8 kpc from the Earth [33–35]. The M 8 nebula is ionized by the O4 V star 9 Sgr and HD 165052 (O6.5 V) [33,36] and has a very young open cluster, NGC 6530, as well as a compact H II region [36].

The Hα observation with DEFPOS was made of galactic diffuse nebula M 8 ($\alpha_{2000} = 18^h\ 03^m.6$, δ_{2000} = –24° 23'.2; UT: 02:20) on the night of 6 June 2017 with 3000 s exposure time. Sh2-25 is given in Figure 2 in detail as a sample of the DEFPOS data analysis. Figure 2a shows a photograph of the Sh2-25 (M 8) H II region. Figure 2b shows the raw CCD Fabry–Pérot ring image output from the Lagoon Nebula (M 8) with DEFPOS. This 'ring image' taken on 6 June 2017 represents an Hα spectrum within the 4' diameter circular beam and

Table 1. Adopted parameters for the H II regions and their ionizing stars and references given in literature.

Data	Source	α_{2000}	δ_{2000}	Ionizing	Ionizing	Dist.	Ang. Ext.	Alter.
number		(h m)	(° ′)	star name	Spec.Type	(kpc)	(′)	Names
1	Sh2-25	18 03.6	−24 23.2	HD 165052[32] HD 164794[32] HD 164816[32]	O6.5[33,36] B0 V[33] O7[33]	1.8 ± 0.2[33,34,35]	90[34]	M 8, NGC 6523, W 29, LBN 25
2	Sh2-131	21 39.0	+57 29.4	HD 206267	O6.5 V	0.69[41,43]	170[41]	IC 1396, OCL22, Tr 37,
						0.86.1[3]		C2137+572 , CTB 105
3	Sh2-237	05 31.36	+34 14.0	BD+34°1074[42]	B0 V[49]	1.8[35]	5[35, 47,49]	NGC 1931, LBN 810,
								C 0528+342, OCl 441,
								WB89 653
4	IC 434	05 41.0	−02 30.0	HD 37468[32]	O9.5 V[32]	0.43[33,34,35]	50 l120[35,47]	Horsehead Nebula,
								Barnard 33
5	IC 1318	20 16.8	+41 57.4	HD 194093	O9.0 V[51]	1.8[51]	45 × 20[47]	DWB 82, LBN251
6	NGC 1982	05 35.5	−05 16.4	BD-5°1325[44]	B0.5 V[51]	0.4[51,54]	4.5[54]	M43
				HD 37061[54]				
7	NGC 6543	17 58.6	+66 38.0	HD 164963[58]		1.0[57]	0.41[57]	IC4677, PK96+29171,
								VV143 , WB1758+6637
8	NGC 6611	18 18.8	−13 48.4	HD 165319	O5 V[48]	1.75–2.00[60]	90[447]	M16, Sh2-49, LBN67,
								OCl54, IC4703

Table 2. Some results of the DEFPOS/RTT150 system.

Data number	Sources	Date	Exp. time (s)	V_{LSR} (km/s)	FWHM (km/s)	I $_{H\alpha}$ (R)
1	Sh2-25	6 June 2017	3000	+7.34	35.33	24,300.10
2	Sh2-131	6 June 2017	3600	–3.58	36.24	109.94
3	Sh2-237	27 December 2015	3600	–7.93	34.88	156.80
4	IC 434	25 December 2015	900	+6.02	36.46	709.54
5	IC 1318	7 June 2017	3600	–4.79	36.24	363.42
6	NGC 1982	7 June 2017	3600	–3.25	37.93	38,477.30
7	NGC 6543	27 December 2015	3600	–50.31	40.54	75.06
8	NGC 6611	7 June 2017	3000	+27.57	39.41	8081.85

covers a 200 km/s spectrum. As seen from Figure 2b, there are two weak reflections with intensities of 7% and 4.5% in the CCD image. These reflections on the raw CCD image are subtracted before the ring-summing procedure [21]. This CCD image was converted to two-dimensional line profiles after the annular-summing

procedure was employed (Figure 2c). In Figure 2c, the amplitude is represented with the vertical axis, while the LSR velocity frame in units of km/s is represented with the horizontal axis. The spectrum consists of 50 spectral elements, each corresponding to a 4 km/s spectral window (filled circles). The best-fit Gaussian emission component is represented with the solid curve drawn through the spectral elements. The residuals of the fit were also plotted at the bottom of Figure 2c to see the differences between data and fit.

The difference between the center of the spectrum and its fit position of the LSR (see Figure 1, no. 1, and Figure 2c) is illustrated as a vertical dashed line at 39.05 km/s. Velocity of the data from the H II region is approximately 7.34 km/s with respect to the LSR velocity. The FWHM and the intensity of the Sh2-25 region were found to be approximately 35.33 km/s and 24,300.10 R, respectively. The result of LSR velocity is compared with earlier observations from different studies. For example, the radial velocity of the M 8 source was measured as –3.7 ± 7 km/s by [33], as 2.6 by [34], as 12.0 ± 1.5 km/s (V_{CO}) by [35], and as –6.0 km/s by [37]. Moreover, Lockman [38] measured velocity to be 3.9 ± 0.2 km/s and the FWHM value to be 27.7 ± 0.4 km/s. The FWHM and the radial velocity were measured to be 24.7 ± 0.1 km/s and 6.8 ± 50 km/s, respectively, by [39].

3.2. H II region Sh2-131 (IC 1396)

Sh2-131 (the Elephant's Trunk nebula: IC 1396) is a well-known diffuse shell-like H II region in Cepheus in the local arm (Orion) center at $\alpha_{2000} = 21^h\ 39^m.0$, $\delta_{2000} = 57^\circ\ 29'.4$. The source of excitation for the IC 1396 nebula is O6.5 V star HD 206267, the best member of young open cluster Trumpler 37 (Tr 37), a very young open cluster [40]. Its angular diameter and its distance are about 170' and 0.69 kpc, respectively [41–43]. The velocity of the ionized gas in this H II region was given to be about –2 km/s [44]. Patel et al. [43] carried out an extensive survey of CO emission from the IC 1396 (Sh2-131) region and found that the expanding velocity was 5 ± 1 km/s and also that the dominant source of ultraviolet (UV) radiation affecting the globules was O6 star HD 206267. We obtained the Hα spectrum with an exposure time of 3600 s toward IC 1396, a well-known H II region and active star-forming region. From the spectrum (Figure, 1 no. 2), we found that its intensity, FWHM, and LSR velocity were 109.94 R, 36.24 km/s, and –3.58 km/s, respectively. The radial velocities of IC 1396 were given by Courtes et al. [37] to be –6.5 km/s and by Georgelin and Georgelin [34] to be –3.5 km/s. Fich et al. [39] also measured the V_{LSR} and the FWHM to be 3.5 ± 0.2 km/s and 40.7 ± 0.4 km/s.

3.3. H II region Sh2-237 (NGC 1931)

The young open cluster NGC 1931 (Sh2-237, LBN 810, $\alpha_{2000} = 05^h\ 31^m.36$, $\delta_{2000} = +34^\circ\ 14'.0$), which is quite similar to the Orion Nebula (M42), lies within the glowing bright nebula NGC 1931 (Sh2-237) in the constellation Auriga [45,46]. The cluster is at a distance of 1.8 kpc, with a diameter of about 4' and an age of 10 Myr [35,45–47]. The main ionizing source of the Sh2-237 nebula is estimated to be the B0.5 star or two B2 stars [48], or the double star BD +34 1074 with a spectral class of B0 V, which is found near the brightness center of the nebula [49]. We made Hα observations of NGC 1931 (Sh2-237) with the aim of deriving cluster parameters such as FWHM, LSR velocity, and intensity. The observations of nebula NGC 193 were made on the night of 7 June 2017 with an exposure time of 3600 s. From Figure 1 (no. 3) and Table 2, the radial velocity of the nebula was measured to be –7.934 km/s relative to LSR. The FWHM and intensity values of the nebula from DEFPOS were found to be 34.881 km/s and 156.801 R, respectively. In the literature, the radial velocities

of the nebula are given to be 3.9 km/s by [34], 1.0 ± 2.0 km/s by [38], and 1.4 ± 0.4 km/s by [35]. Moreover, the FWHM values for the nebula are given to be 29 ± 4.7 km/s by [38], and to be 37.5 ± 0.2 km/s by [35].

3.4. H II region IC 434

The IC 434 H II region ($\alpha_{2000} = 05^h\ 41^m.0$, $\delta_{2000} = -02^\circ\ 30'.0$) is a diffuse emission nebula in the constellation of Orion with an angular diameter of 120 at a distance of 0.43 kpc [34,35,47]. The O9.5 V star Sigma Orionis (Ori: HD 37468) $0^\circ.5$ west of the region is responsible for the ionization of the nebula [33,50]. The region is famous for the spectacular Horsehead Nebula (Barnard 33: B33, $\alpha_{2000} = 05^h\ 40^m.98$, $\delta_{2000} = -02^\circ\ 27'.5$) surrounded by an emission nebula. The bright HD 37468 star ionizes hydrogen gas surrounding the dark dust clouds of the horsehead nebula. This dark dust cloud is the best known classic dark nebula and is silhouetted against a bright background of the emission nebula of IC 434. Observation of the extended H II region IC 434 was carried out with DEFPOS at Hα wavelength on 25 December 2015 (UT 01:00) with an exposure time of 900 s. Some physical parameters of the IC 434 H II region in the direction of the H II regions from analysis of the CCD image have been obtained. From Figure 1 (no. 4), the LSR velocity of the IC 434 was measured to be 6.02 km/s, while FWHM and the surface brightness were measured to be 36.46 km/s and 709.54 R, respectively. The V_{LSR} velocity of IC 434 was given by [50] to be 10.6 ± 1.4 km/s and by [32] to be 4.4 ± 1.2 km/s. The V_{CO} velocity was measured as 9.6 ± 2.1 by [35]. The radial velocity was given as 17.6 km/s by [34]. Courtes et al. [37], Miller [33], and Georgelin and Georgelin [34] also gave the radial velocity of the nebula to be 32.1 km/s, 37.1 km/s, and 10.7 ± 0.2 km/s, respectively.

3.5. H II region IC 1318

H II region IC 1318, known as the Sadr or Gamma Cygni Nebula (DWB82 and LBN251, $\alpha_{2000} = 20^h\ 16^m.8$, $\delta_{2000} = +41^\circ\ 57'.4$), is the diffuse emission H II region in the Cygnus X complex at a distance of ∼1.5 kpc. The entire nebula of IC 1318 is a group of optically visible nebula and it has three distinct visible components (IC 1318a, IC 1318b, and IC 1318c). The entire H II region is illuminated by a solitary visually obscured class O9.0 V star [51]. The distance of the nebula was estimated by [51] to be 1.8 ± 1.5 kpc using heliocentric radial velocity. The observation of this H II region was carried out with DEFPOS with exposure time of 3600 s on 7 June 2017. The mean radial velocity, FWHM, and intensity of the nebula were determined to be –4.79 km/s, 36.24 km/s, and 363.42 R as listed in Table 2. Figure 2 (no. 5) shows a spectrum of this nebula, which belongs to the Cygnus complex. The heliocentric and LSR radial velocities of this H II region were measured to be –14.8 km/s and 0.3 km/s by [51]. Courtes et al. [37] gave the radial velocity of this nebula to be –12.8 km/s. The heliocentric radial velocities and the FWHM values were given to be –17.9 ± 5.7 km/s and 52.5 ± 13.1 km/s for IC 1318c and IC 1318b, and –16.7 ± 4.7 km/s and 46.9 ± 1.7 for IC 1318c and IC 1318b by [52].

3.6. H II region NGC 1982 (M43)

The galactic NGC 1982 H II region known as M43 (De Mairan's Nebula, Companion of the Orion Nebula) is a small spherical H II region with an apparent magnitude of 9 and is a part of the Orion Nebula. The identification and Hα position of NGC 1982 is $\alpha_{2000} = 05^h\ 35^m.5$, $\delta_{2000} = -05^\circ\ 16'.4$ (2000). The wide field of view images often include the nearby low-ionization H II region M43 (NGC 1982), which lies to the northeast border of the extended Orion Nebula (M42, NGC 1976). NGC 1982 appears as a nearby circular area of emission around the exciting star HD 37061 (NU Ori) with spectral type of B0.5 V. It is a member of the Orion nebula cluster of

early type stars at a distance of about 0.4 kpc from Earth [53,54]. An exposure time of 3600 s was used for this observation. From this profile (Figure 1, no. 6) on 7 June 2017, a radial velocity of –3.25 km/s relative to the LSR was measured. The intensity and the mean FWHM of the nebula were also measured to be 38477.30 R and 37.93 km/s, respectively. The radial velocity (V_{LSR}) of NGC 1982 was given as –6.86 ± 0.3 km/s by [55] and –3.8 km/s by [56].

3.7. Planetary nebula NGC 6543

NGC 6543 (also Cat's Eye Nebula; IC 4677, PK 96+29 1: $\alpha_{2000} = 17^h\ 58^m.6$, $\delta_{2000} = +66^\circ\ 38'.0$) is a bright and young planetary nebula in the northern constellation of Draco and has a complex, symmetric, and bright core of angular diameter of ∼0.41'. It is believed that planetary nebulae consist of several tenths of a solar mass of gas and dust ejected primarily during the asymptotic giant branch phase of stellar evolution [57]. The NGC 6543 nebula, having a radius of approximately 5' at a distance of 1.0 kpc [57], is known as a member of a group of planetary nebulae and the Cat's Eye having a central star of HD 164963 [58] with an effective temperature of 8×10^4 K is the bright inner core of the nebula [56]. I observed this object in 6563 Å wavelength at one selected position with DEFPOS using 3600 s exposure and I found that the LSR velocity, FWHM, and intensity of the ionized gas were –50.310 km/s, 40.54 km/s, and 75.06 R, respectively (see Figure 1, no. 7). From Table 2, the LSR radial velocity of this H II region was measured to be –50.7 km/s (V_{HEL} = –66.1 ± 0.4 km/s) by [59] and –61.1 ± 0.4 km/s by [58]. Moreover, the radial velocity of the nebula is given as –65.7 km/s in the SIMBAD Astronomical Database (http://simbad.u-strasbg.fr/simbad/sim-fbasic).

3.8. Planetary nebula NGC 6611 (Sh2-49)

The young open star cluster NGC 6611 (Sh2-49, LBN67, $\alpha_{2000} = 18^h\ 18^m.8$, $\delta_{2000} = -13^\circ\ 48'4$) is a young ($1\text{-}3 \times 10^6$ years) active star-forming region in the Sagittarius spiral arm and is located at a distance of approximately 1.75–2.00 kpc from the Sun [60,61]. The NGC 6611 cluster, formed from an interstellar cloud of gas and dust, is responsible for the radiative energy incident on the molecular cloud complex around diffuse emission Eagle Nebula (IC 4703: M16 and Sh2-49) and consists of very hot young stars of spectral type O6 imbedded in the molecular cloud W37. NGC 6611 contains four early O type stars in the cluster (∼2–3 Myr), and a B2.5I (BD∼13 4912) star (∼6 Myr) [60–62]. We used DEFPOS to study the young cluster NGC 6611 and measured the Hα spectrum from this direction on 7 June 2017 with exposure time of 3000 s. Some important kinematic structures in the direction of NGC 6611 from analysis of the CCD image are presented in Table 2 and in Figure 1 (no. 8). The LSR velocity was measured to be 27.57 km/s. The mean FWHM and the intensity of the nebula were also measured to be 39.41 km/s and 8081.85 R, respectively. Georgelin and Georgelin [34] and Rieu and Pankonin [63] gave the LSR velocity (V_{LSR}) of the planetary nebula to be 26.5 km/s. The mean radial velocity of cluster NGC 6611 was measured as 10 ± 8 km/s from the Doppler shift of some hydrogen Balmer lines by [64].

4. Conclusions

In this study, a 7.5 cm dual etalon Fabry–Pérot spectrometer (DEFPOS) located at the coudé exit of the 150 cm (*f/48*) RTT150 telescope at the TUG National Observatory with a field of view 4' in diameter at a spectral resolving power of 11,000 [21] was used to obtain some kinematics of the northern eight H II regions in the our

galaxy (Sh2-25, Sh2-131, Sh2-237, IC 434, IC 1318, NGC 1982, NGC 6543, and NGC 6611). A 2048 × 2048 Andor iKon-L 936 camera, which has active pixel arrays with pixel size of 13.5 μm and has more than 90% QE at Hα, was used to obtain the ring image from Fabry–Pérot etalons. Data including the intensities, FWHM, and LSR velocities of Hα emission from the selected eight ionized hydrogen sources were acquired on 25–27 December 2015 and 6–7 June 2017. Results were listed in Table 2 and in Figure 1 and then were compared with previous works [33–35,37–39] (see Section 3).

We conclude our work with some points as given below.

Observations were made with long exposure times that ranged from 900 s to 3600 s.

The Hα line profiles in our observations have a Gaussian shape for all H II regions in our galaxy.

The LSR velocities of the Hα emission lines were found to be in the range of –50.31 to 27.57 km/s.

The half-widths of the line profiles were found to be in the range of 34.88 to 44.51 km/s (mean: 38.055 km/s).

The intensity values of the H II sources were found to be in the range of 75.06 R (the faintest planetary nebula: Cat's Eye Nebula: NGC 6543) to 38,477.3 R (Galactic NGC 1982 H II region, which lies to the northeast border of the extended Orion Nebula).

The radial velocities and the half-widths of the northern galactic H II regions determined from our DEFPOS measurements are in good agreement with measurements by other authors as mentioned in Section 3. We believe that our spectrometer will provide a powerful tool for the study of diffuse ionized gas. In the future, we are planning to prepare Hα maps with the 4' field of view of some diffuse ionized emission sources selected from VTSS and WHAM Hα maps with large fields of view.

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