

List of Figures

1	Optical and radio telescopes used by the author for this work	16
1.1	The open star cluster NGC 6520 and the dark nebula Barnard 86	19
1.2	IC 349 or Barnard's Merope Nebula located in the Pleiades	20
1.3	V838 Monocerotis and <i>The Starry Night</i>	24
1.4	A montage of images of planetary nebulae made with the HST	26
2.1	Transmission curves for on- and off-band $H\alpha$ and $O\text{ III}$ filters	33
2.2	Transmission curves for on-band $H\alpha$ and $O\text{ III}$ filters.	34
2.3	Transmission curves for on-band $H\alpha$ filter from NTT spectra	36
2.4	Schematic layout of EMMI instrumentation	37
2.5	PNe centre positions on CCD array	38
2.6	Continuum subtraction for M2-10 using $H\alpha$ on- and off-band filters	39
2.7	Distribution of observed PNe relative to the Galactic plane	40
2.8	Simplified schematic of the light path from filter to CCD array	42
3.1	$H\alpha$ restored image plots with contour levels	47
3.2	Comparison of $H\alpha$ and $O\text{ III}$ angular diameters θ_{line}	50
3.3	Comparison of $H\alpha$ angular diameters θ_{mean} and θ_{rest}	50
3.4	The outflow features of He2-104 (PN G 315.4+09.4)	51
3.5	$H\alpha$ image plots with contour levels	53
3.6	$H\alpha$ images compared to $H\alpha$ contour plots	56
3.7	<i>Squares with Concentric Rings</i> by Wassily Kandinsky	57

LIST OF FIGURES

4.1	Determination of maximum H α flux level from PN radius	64
4.2	Example of N II contribution to H α flux	64
4.3	Distribution of $\Delta F(\text{H}\alpha)$ between observed and catalogued H α flux . .	66
4.4	Comparison of ΔF (H α and O III) with observation time	67
4.5	Comparison of $\Delta F(\text{H}\alpha)$ with angular diameter θ_{line}	68
4.6	Comparison of $\Delta F(\text{H}\alpha)$ with H α filter transmission coefficient	69
4.7	Comparison of $\Delta F(\text{H}\alpha)$ with radial velocity	69
4.8	Comparison of observed and catalogued H α and O III flux values . . .	70
5.1	Interstellar extinction, A_{λ} , as a function of wavelength, λ	79
5.2	Comparison of observed and catalogued H α extinction values	84
5.3	Comparison of R_V and observed H α extinction values	85
5.4	Comparison of ΔR_V and observed H α extinction values	86
5.5	Comparison of observed R_V with catalogue S_V values	87
5.6	Comparison of R_V with Galactic distribution for Bulge subset B objects	88
5.7	Comparison of R_V calculated from observed and catalogue H α extinction	88
5.8	Comparison of H α extinction from observed and catalogue $S_V/\text{H}\alpha$. .	89
5.9	Comparison of H α extinction from catalogue $S_V/\text{H}\alpha$ and H $\alpha/\text{H}\beta$. . .	89
6.1	Size distribution for a Greenberg dust model	97
6.2	(a) Absorption, scattering and extinction Greenberg cross-sections, (b) Calculated values for R_V for a Greenberg dust model	98
7.1	The Eagle Nebula (M16), comprising cold gas and dust	104
8.1	Location of molecular clouds EC2 and EC1 on the Galactic plane . .	110
8.2	Map and image of EC2 showing MR1 and seven red NIR sources . . .	111
8.3	Optical and CO images of the Milky Way towards EC2 and EC1 . . .	113
8.4	CO maps of EC2 showing observed positions A through K	116
8.5	EC2 spectra observed at the ARO 12m Feb-June 2002 position A . . .	118
8.6	EC2 spectra observed at the MPIfR Effelsberg 100m position A . . .	120

8.7	EC2 spectra observed at the JCMT 15m June 2004 position A	121
8.8	Map of EC1 showing observed positions Q through Z	122
8.9	^{13}CO maps of EC1 showing ARO 12m April 2004 intensities	123
8.10	Plot of the OSO 20m gain-elevation dependence	125
8.11	EC1 spectra observed at the ARO 12m April 2004 positions S and T .	126
8.12	EC1 CO spectra observed at the ARO 12m Mar 2005 pos. S, T, U, W	127
8.13	EC1 spectra observed at the OSO 20m May 2005 positions P and R .	128
8.14	JCMT 15m May-July 05 combined contour map of CO 2–1 intensities	134
8.15	JCMT 15m May-July 05 maps of CO centred on position <i>EC2MAP1</i> .	135
8.16	JCMT 15m May-July 05 maps of CO centred on position <i>EC2MAP2</i> .	136
8.17	IRAM 30m Oct-Nov 2005 1.2 mm dust map <i>EC2DUSTIA</i>	139
8.18	CO 2–1 intensity contours overlaid on 1.2 mm dust map	140
9.1	Telescope beam sizes centred on EC2 position A	142
12.1	Agreement factor varying over time for Models 1–4 (A_V and CRI) . .	189
12.2	Agreement factor varying over time for Models 2, 5–7 (UV field) . . .	189
12.3	Agreement factor varying over time for Models 2, 8–10 (abundances)	190
12.4	Agreement factor varying over time for Models 2, 11–13 (increased S)	190
12.5	Agreement factor varying over time for Models 2, 14–16 (depleted N)	191
12.6	Fractional abundances varying over time for Model 2	191
12.7	Fractional abundances varying over time for Model 4	192
12.8	Fractional abundances varying over time for Model 6	192
12.9	Fractional abundances varying over time for Model 7	193
12.10	Fractional abundances varying over time for Model 8	193
12.11	Agreement factor for models with varying A_V and CRI	194
12.12	Agreement factor for models with varying A_V , CRI, high or low UV .	195
12.13	Agreement factor for models with varying A_V and UV or abundances .	196
12.14	Agreement factor for models with varying A_V and $n(\text{H}_2)$	197
12.15	Agreement factor for models with varying A_V and $x(\text{S})$ or $x(\text{N})$	198

LIST OF FIGURES

13.1	Detail of SN remnant GSH 138–01–94 in relation to EC2	202
A.1	Additional H α image plots with contour levels	208
B.1	Telescope beam sizes centred on EC2 positions A and K	211
B.2	JCMT 15m May-July 05 map of CO 2–1 centred on pos. <i>EC2MAP1</i> .	212
B.3	JCMT 15m May-July 05 maps of CO 2–1 centred on pos. <i>EC2MAP1</i>	213
B.4	JCMT 15m May-July 05 map of CO 3–2 centred on pos. <i>EC2MAP1</i> .	214
B.5	JCMT 15m May-July 05 maps of CO 3–2 centred on pos. <i>EC2MAP1</i>	215
B.6	JCMT 15m May-July 05 map of ^{13}CO 2–1 centred on pos. <i>EC2MAP1</i>	216
B.7	JCMT 15m May-July 05 maps of ^{13}CO 2–1 centred on pos. <i>EC2MAP1</i>	217
B.8	JCMT 15m May-July 05 map of ^{13}CO 3–2 centred on pos. <i>EC2MAP1</i>	218
B.9	JCMT 15m May-July 05 maps of ^{13}CO 3–2 centred on pos. <i>EC2MAP1</i>	219
B.10	JCMT 15m May-July 05 map of C ^{18}O 2–1 centred on pos. <i>EC2MAP1</i>	220
B.11	JCMT 15m May-July 05 maps of C ^{18}O 2–1 centred on pos. <i>EC2MAP1</i>	221
B.12	JCMT 15m May-July 05 map of CO 2–1 centred on pos. <i>EC2MAP2</i> .	222
B.13	JCMT 15m May-July 05 maps of CO 2–1 centred on pos. <i>EC2MAP2</i>	223
B.14	JCMT 15m May-July 05 map of CO 3–2 centred on pos. <i>EC2MAP2</i> .	224
B.15	JCMT 15m May-July 05 maps of CO 3–2 centred on pos. <i>EC2MAP2</i>	225
B.16	JCMT 15m May-July 05 map of ^{13}CO 2–1 centred on pos. <i>EC2MAP2</i>	226
B.17	JCMT 15m May-July 05 maps of ^{13}CO 2–1 centred on pos. <i>EC2MAP2</i>	227
B.18	JCMT 15m May-July 05 map of ^{13}CO 3–2 centred on pos. <i>EC2MAP2</i>	228
B.19	JCMT 15m May-July 05 maps of ^{13}CO 3–2 centred on pos. <i>EC2MAP2</i>	229
B.20	JCMT 15m May-July 05 map of C ^{18}O 2–1 centred on pos. <i>EC2MAP2</i>	230
B.21	JCMT 15m May-July 05 maps of C ^{18}O 2–1 centred on pos. <i>EC2MAP2</i>	231
C.1	CO map of EC2 showing ARO 12m Feb-June 2002 pos. A, B and C .	233
C.2	EC2 position A: spectra observed at the ARO 12m Feb-June 2002 . .	234
C.3	EC2 position B: spectra observed at the ARO 12m Feb-June 2002 . .	238
C.4	EC2 position C spectra observed at the ARO 12m Feb-June 2002 . . .	239

LIST OF FIGURES

D.1	CO map of EC2 showing ARO 12m Nov 02 & Feb 03 pos. A and H .	241
D.2	EC2 pos. A: DCO ⁺ , H ¹³ CO ⁺ obs. at the ARO 12m Nov 02 & Feb 03 .	242
D.3	EC2 pos. H: CS, DCO ⁺ obs. at the ARO 12m Nov 02 & Feb 03 . . .	244
E.1	CO map of EC2 showing ARO 12m April 2004 positions A and D . .	247
E.2	EC2 positions A and D: spectra observed at the ARO 12m April 2004	248
F.1	CO map of EC2 showing JCMT 15m June 2004 positions A and B . .	251
F.2	EC2 position A: spectra observed at the JCMT 15m June 2004	252
F.3	EC2 position B: spectra observed at the JCMT 15m June 2004	254
G.1	CO maps of EC2 showing ARO 12m Feb-Mar 05 pos. A, B, C, D, E, F	255
G.2	EC2 position A: C ₂ D spectra observed at the ARO 12m Feb-Mar 2005	256
G.3	EC2 position A: DCN spectra observed at the ARO 12m Feb-Mar 2005	258
G.4	EC2 position A: H ¹³ CO ⁺ spectra obs. at the ARO 12m Feb-Mar 2005	260
G.5	EC2 position A: HDCO spectra obs. at the ARO 12m Feb-Mar 2005 .	262
G.6	EC2 position A: CO spectra observed at the ARO 12m Feb-Mar 2005	264
G.7	EC2 position B: CO spectra observed at the ARO 12m Feb-Mar 2005	266
G.8	EC2 position C: CO spectra observed at the ARO 12m Feb-Mar 2005	268
G.9	EC2 position D: CO spectra observed at the ARO 12m Feb-Mar 2005	270
G.10	EC2 position E: CO spectra observed at the ARO 12m Feb-Mar 2005	272
G.11	EC2 position F: CO spectra observed at the ARO 12m Feb-Mar 2005 .	274
H.1	CO map of EC2 showing MPIfR 100m positions A, B and C	275
H.2	EC2 pos. A: obs. at MPIfR 100m Dec 2002, May 2004, Nov 2005 . .	276
H.3	EC2 pos. B, C: obs. at MPIfR 100m Dec 2002, May 2004, Nov 2005	278
I.1	CO map of EC2 showing ARO 12m Dec 05-Jan 06 positions A, G, H	281
I.2	EC2 pos. A, G, H: HCO ⁺ spectra obs. at the ARO 12m Dec 05-Jan 06	282
I.3	EC2 pos. A, G, H: HCN spectra obs. at the ARO 12m Dec 05-Jan 06 .	284
I.4	EC2 pos. G, H: C ₂ H spectra obs. at the ARO 12m Dec 05-Jan 06 . . .	286

LIST OF FIGURES

I.5	EC2 pos. G, H: DCN/DCO ⁺ spec. obs. at the ARO 12m Dec 05-Jan 06	288
I.6	EC2 pos. A, G: ¹² CO spectra obs. at the ARO 12m Dec 05-Jan 06 . .	290
J.1	CO map of EC1 showing ARO 12m April 2004 positions Q to Z . . .	293
J.2	EC1 position S: CO spectra observed at the ARO 12m April 2004 . .	294
J.3	EC1 position S: CS, SO spectra observed at the ARO 12m April 2004	296
J.4	EC1 position S: HCN, DCN spectra obs. at the ARO 12m April 2004	298
J.5	EC1 position S: HCO ⁺ , DCO ⁺ spectra obs. at the ARO 12m April 2004	300
J.6	EC1 position T: CS, SO spectra observed at the ARO 12m April 2004	302
J.7	EC1 position T: C ¹⁸ O, C ₂ H, CH ₃ OH obs. at the ARO 12m April 2004	304
J.8	EC1 position T: HCN, HNC, CN obs. at the ARO 12m April 2004 . .	306
J.9	EC1 position T: HCO ⁺ , DCO ⁺ , N ₂ H ⁺ obs. at the ARO 12m April 2004	308
J.10	EC1 positions Q, U, Z: spectra observed at the ARO 12m April 2004 .	310
J.11	ARO 12m April 2004 maps of ¹³ CO spectra centred on position S . .	312
J.12	ARO 12m April 2004 FB11 maps of ¹³ CO centred on position S . . .	313
J.13	ARO 12m April 2004 FB21 maps of ¹³ CO centred on position S . . .	314
J.14	ARO 12m April 2004 MAC11 maps of ¹³ CO centred on position S . .	315
K.1	CO map of EC1 showing ARO 12m March 2005 positions S to Y . .	317
K.2	EC1 position S: CO spectra observed at the ARO 12m March 2005 . .	318
K.3	EC1 position T: CO spectra observed at the ARO 12m March 2005 . .	320
K.4	EC1 position U: CO spectra observed at the ARO 12m March 2005 .	322
K.5	EC1 position V: CO spectra observed at the ARO 12m March 2005 . .	324
K.6	EC1 position W: CO spectra observed at the ARO 12m March 2005 .	326
K.7	EC1 position X: CO spectra observed at the ARO 12m March 2005 .	328
K.8	EC1 position Y: CO spectra observed at the ARO 12m March 2005 . .	330
K.9	EC1 positions V, X, Y: additional CO spectra at lower velocities . . .	332
L.1	CO map of EC1 showing OSO 20m May 2005 positions P and R . . .	335
L.2	EC1 position R: spectra observed at the OSO 20m May 2005	336

LIST OF FIGURES

L.3 EC1 position R: spectra observed at the OSO 20m May 2005 338

L.4 EC1 position P: spectra observed at the OSO 20m May 2005 340

M.1 CO map of EC1 showing MPIfR 100m Oct-Nov 05 positions P and R 341

M.2 EC1 pos. P and R: spectra observed at the MPIfR 100m Oct-Nov 2005 342

O.1 Comparison of agreement factor for models with different weightings 349

LIST OF FIGURES