

**In fond memory of**

**my granny Parvathamma**

**.....who funded my Amateur Astronomy**

# **Near Infrared Investigations on Regions of Star Formation**

**A Thesis Submitted to  
The Gujarat University  
for**

**THE DEGREE OF DOCTOR OF PHILOSOPHY  
in  
PHYSICS**

**by**

**M. S. Nanda Kumar**

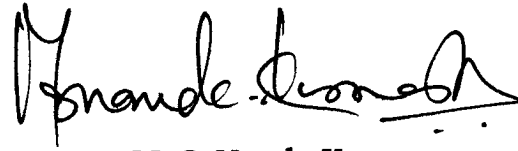
**पुस्तकालय THE LIBRARY  
भौतिक अनुसंधान प्रयोगशाला  
PHYSICAL RESEARCH LABORATORY  
नवरंगपुरा, अहमदाबाद-380 009  
NAVRANGPURA, AHMEDABAD-380 009  
भारत / INDIA**

**PHYSICAL RESEARCH LABORATORY  
NAVRANGPURA  
AHMEDABAD 380 009  
INDIA**

**September 1999**

## **CERTIFICATE**

I hereby declare that the work presented in this thesis is original and has not formed the basis for the award of any degree or diploma by any University or Institution.



**M. S. Nanda Kumar**

**(Author)**

**Astronomy and Astrophysics Division  
Physical Research Laboratory  
Navrangpura  
Ahmedabad - 380 009  
India**

**CERTIFIED BY**



**Prof. B. G. Anandarao**

**(Thesis Supervisor)**

**Professor  
Astronomy and Astrophysics Division  
Physical Research Laboratory  
Navrangpura  
Ahmedabad - 380 009  
India**

# Contents

Acknowledgements . . . . .	iv
<b>1 Introduction</b>	<b>1</b>
1.1 Star Formation and Near-IR Astronomy . . . . .	1
1.2 Basic Physics of Star formation . . . . .	3
1.3 Observational aspects of star forming regions . . . . .	7
1.3.1 Molecular clouds, clumps and cores . . . . .	7
1.3.2 Protostars and T Tauri stars . . . . .	9
1.3.3 Jets & Outflows from YSO's . . . . .	12
1.3.4 Disks and Unified models . . . . .	15
1.3.5 Pre-Main-Sequence Companions . . . . .	16
1.4 References . . . . .	17
<b>2 Observations and data reduction</b>	<b>20</b>
2.1 The Near-Infrared Sky . . . . .	21
2.2 PRL Near Infrared Camera: PRLNIC . . . . .	22
2.2.1 Camera Operating Software . . . . .	25
2.3 Black Magic for the Black Box: PRLNIC . . . . .	26
2.3.1 The Problem . . . . .	26
2.3.2 The Solution . . . . .	27
2.4 Observation and Data Reduction Procedures . . . . .	28
2.4.1 Imaging Mode . . . . .	28
2.4.2 Spectroscopy . . . . .	31
2.5 Future efforts . . . . .	33
2.6 References . . . . .	36
<b>3 Cold Disk Structures in Protostellar Envelopes</b>	<b>37</b>

3.1	Introduction . . . . .	37
3.2	The L43 dark cloud . . . . .	38
3.2.1	The CO outflow in L43 . . . . .	39
3.2.2	L43 dense core . . . . .	41
3.3	RNO 90: A T Tauri Star in L43 . . . . .	43
3.4	Shocked molecular hydrogen from RNO 91 . . . . .	45
3.4.1	Observations and Data Reduction . . . . .	46
3.4.2	Results . . . . .	47
3.4.3	Discussion . . . . .	50
3.5	RNO 91 disk/outflow . . . . .	53
3.6	Future Work . . . . .	58
3.7	Summary and Conclusions . . . . .	60
3.8	References . . . . .	61
<b>4</b>	<b>Warm and Hot Disk Structures in Protostellar Envelopes</b>	<b>64</b>
4.1	Introduction . . . . .	64
4.2	The Sample Set . . . . .	65
4.3	Infrared Spectroscopy of YSO's . . . . .	66
4.4	Results and Discussion . . . . .	68
4.4.1	FS Tau . . . . .	70
4.4.2	DG Tau . . . . .	72
4.4.3	GM Aurigae . . . . .	73
4.4.4	DL Tau . . . . .	74
4.4.5	DO Tau . . . . .	75
4.4.6	CY Tau . . . . .	75
4.4.7	V836 Tau . . . . .	75
4.5	Conclusions . . . . .	76
4.6	References . . . . .	77
<b>5</b>	<b>L1340 : A star forming cloud</b>	<b>79</b>
5.1	Introduction . . . . .	79

5.2	Observations and Data Reduction . . . . .	80
5.3	L1340 cloud and the Cohen's objects . . . . .	81
5.3.1	RNO7 . . . . .	82
5.3.2	RNO8 . . . . .	83
5.3.3	RNO9 . . . . .	84
5.4	New Herbig-Haro Objects in L1340 . . . . .	95
5.4.1	HH487 . . . . .	96
5.4.2	HH488 . . . . .	96
5.4.3	HH489 . . . . .	98
5.5	Conclusions . . . . .	105
5.6	References . . . . .	106
<b>6</b>	<b>A Near Infrared Imaging Fabry-Perot Spectrometer</b>	<b>107</b>
6.1	Introduction . . . . .	107
6.2	The Fabry-Perot Interferometer . . . . .	108
6.3	Imaging Fabry-Perot Spectrometers . . . . .	110
6.3.1	Scanning and phase correction . . . . .	111
6.3.2	Wavelength Calibration . . . . .	113
6.4	Astronomical Observations with an IFPS . . . . .	114
6.5	Telecentric Configuration . . . . .	115
6.6	Telecentric vs Classical Configuration . . . . .	116
6.7	PRL Infrared FP Etalon . . . . .	117
6.7.1	Characterization . . . . .	118
6.7.2	Tuning of the FP . . . . .	119
6.8	Observations and data analysis . . . . .	120
6.9	High-Resolution Spectrophotometric Imaging in Emission Lines - NIRFPS as a Tunable Filter . . . . .	122
6.10	References . . . . .	124
	<b>Epilogue</b>	<b>125</b>
	List of Publications . . . . .	128

For Full text Please Contact

To

Author