Hydrogen line ratios in the Seyfert galaxy NGC 4151

M. Srinivasa Rao
Indian Institute of Astrophysics
Koramangala, Bangalore

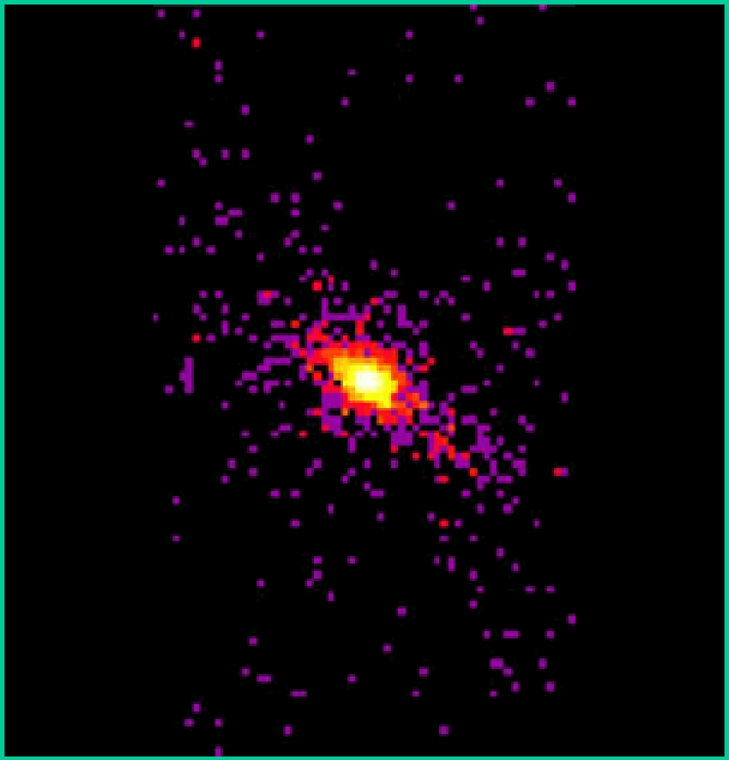
Collaborator:
Prof. Mika Juvela
Helsinki University Observatory
Finland

Plan of Presentation:

- About Seyfert galaxy
- Introduction to the problem
- Description of the method

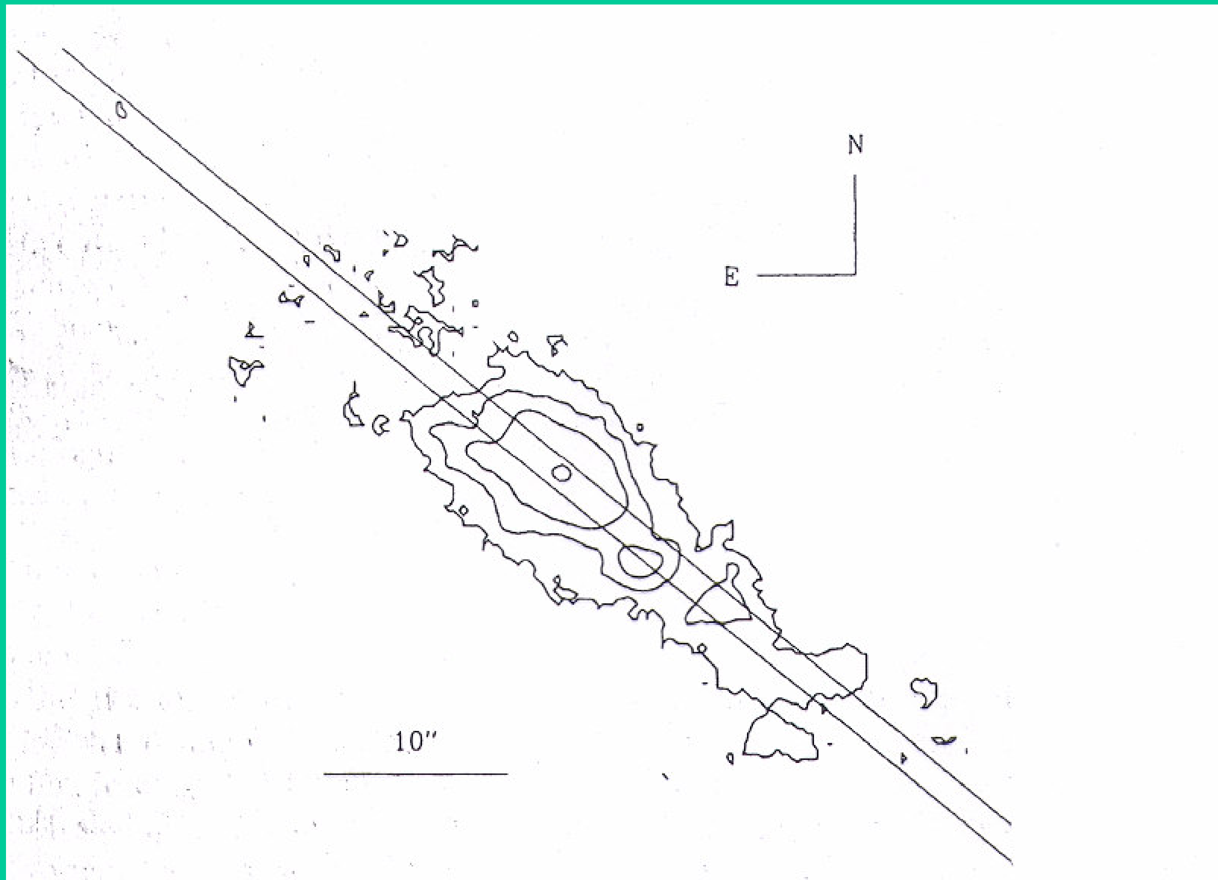
Seyfert Galaxy:

Seyfert galaxies are first described by Carl K. Seyfert in 1943. These are a type of active galaxies. They are Spiral galaxies with extremely bright nuclei. The luminosity of Seyfert galaxies are range from 0.1 to 10 times the luminosity of our galaxy. About 2% of spiral galaxies are Seyfert galaxies. The spectra of these galaxies are characterized by emission lines from highly ionized gas. In some cases, the emission lines are broadened by random motions up to 10,000 Km/Sec.



Type 1	Type 2
Emission line spectra in their nuclei is very broad suggesting that gas velocities are 1000 Km/Sec (This is observed directly) (BLR)	Emission line spectra in their nuclei is much narrower, which suggest that gas moves very slowly. (this is observed through accretion disc)(NLR)

Another class of galaxies have been identified whose emission line FWHM are less thank 30 Km/sec and are called Extended Narrow Line Region (ENLR).These regions are more extended spatially than the NLRs and have much smaller velocity dispersion.



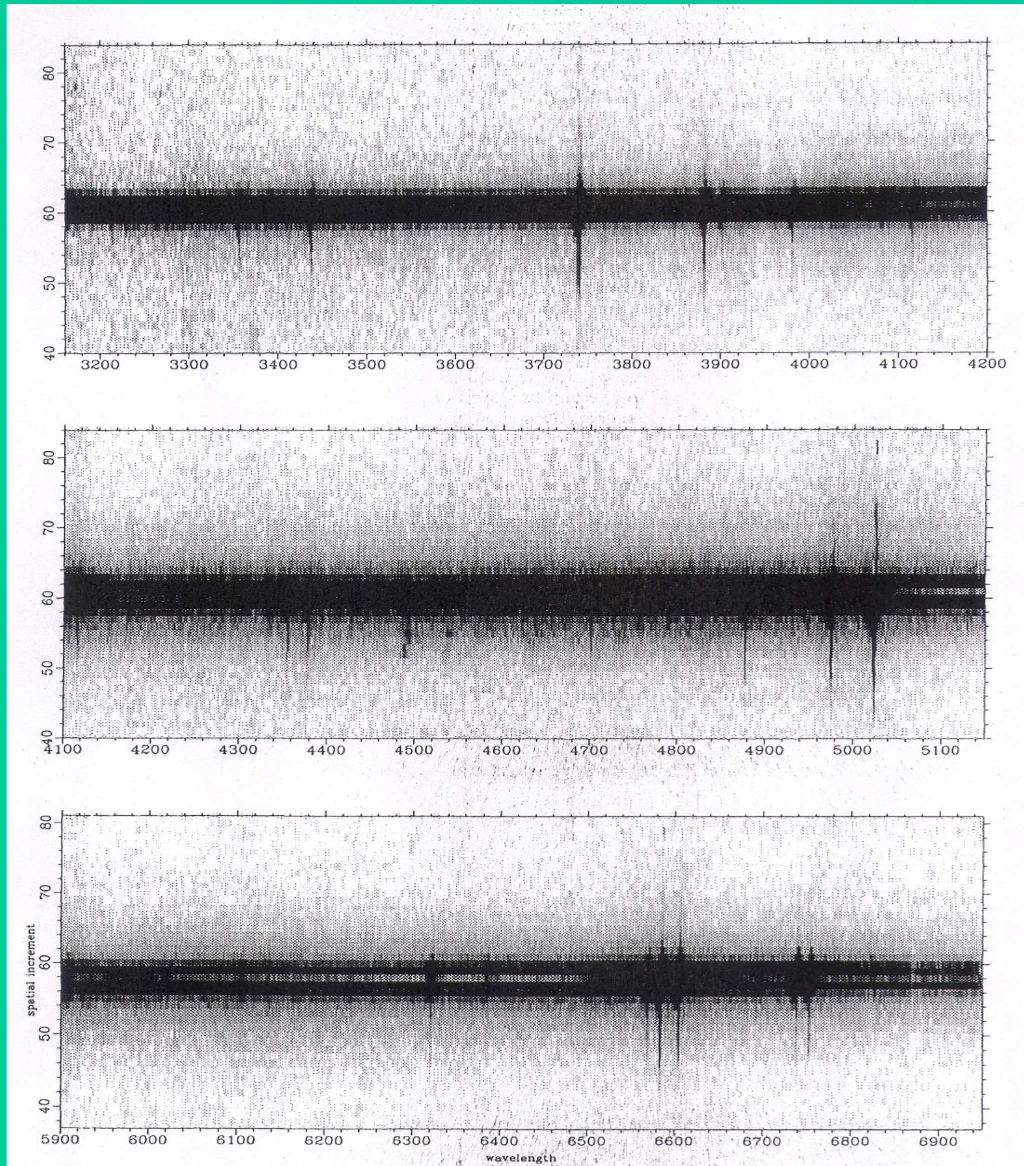
A sketch map of ENLR showing slit orientation. The innermost contour marks the nucleus. It contains several bright knots forming elongated structure oriented at a position angle~50^0 with south-west side is brighter.

Introduction: Penston (1990) observed the extended narrow line region (ENLR) of NGC 4151 and gave the line ratios from which they have derived the electron density, temperature and other physical parameters. (For data reduction they used FIGARO software on the La Palma Data Reduction VAX 8300)

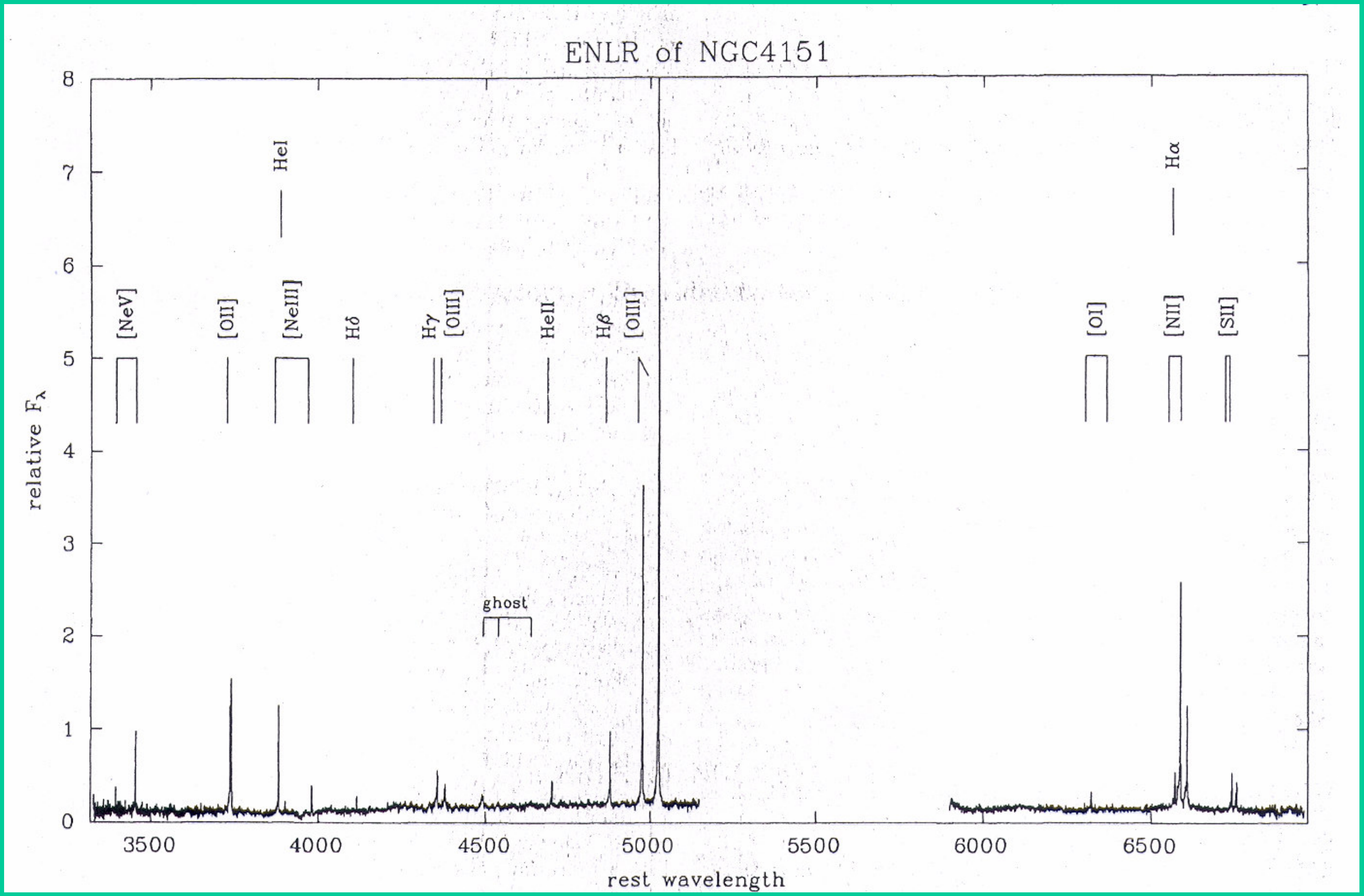
Line ratios of different lines are (photo ionization models by power law spectra)

Ionization	[OIII] λ5007/H_β	Veilleux, S., and Osterbrock , D. E 1987
Excitation	[OIII] λ5007/[OII] λ3727	Baldwin, J. A., Philips, M. M., & Terlevich, R 1981
Density	[SII] λ6731/ λ6716	Osterbrock, D. E 1989
Temp	[OIII] λ5007/ λ4363	Osterbrock, D. E 1983
Reddening in NLR (H_α /H_β)		Gaskell , C. M. (1983), Gaskell, C. M & Ferland, G.J (1984)

Our aim is to compute the hydrogen emission lines in ENLR of NGC 4151 and compare with observed line ratios of Penston (1990). Clavel et al (1990, MNRAS, 246, 668) noticed significant variations of the emission lines and continuum flux in NGC 4151. The study of these ratios are adequate to investigate the ionization and physical conditions (like diagnosis of density and temp., ionization parameters and flux etc) of ENLR.



Grey scale representation of three long slit spectra of NGC 4151



Plot of Sky-subtracted spectrum. These lines are sharp and faint features such as HeI λ 3889 and [OI] λ 6364 are discernible

Table 1. Emission line ratios in the ENLR of NGC4151 Observed and corrected for a reddening of $E_{B-V} = 0.05$ ($H\beta = 100$)

Species	λ_0	Ratio Obs	Corr	Species	λ_0	Ratio Obs	Corr
[NeV]	3346	21	22	HeII	4686	38	38
[NeV]	3426	60	64	$H\beta$	4861	100	100
[OII]	3726	108	112	[OIII]	4959	435	434
[OII]	3729	136	138	[OI]	6300	25	23
[NeIII]	3869	100	104	[OI]	6364	7	7
$H\zeta$/HeI	3889	12	12	[NII]	6548	40	38
[NeIII] $H\epsilon$	3968	61	63	$H\alpha$	6563	280	265
[SII]	4072	10	10	[NII]	6584	122	116
$H\delta$	4102	16	17	[SII]	6717	56	53
$H\gamma$	4340	42	43	[SII]	6731	48	46
[OIII]	4363	24	24				

Brief description of the method: We consider the hydrogen atmosphere with lines like Lyman, Balmer, Paschen and Brackett series are used to calculate the line radiation pressure assuming 10 levels of H.

1) We have to employ Saha equation for estimating ionized H atoms
2) Boltzmann equation for calculating occupation numbers in different stages of excitation.
3) We apply non-LTE two level atom approximation to solve the line transfer for the purpose of calculating the radiation pressure in the line.
4) Finally we can derive ionized fraction of the hydrogen atoms, electron density, the population density in different stages of excitation, thermalisation parameters, radial optical depths, the radiation pressure due to combined effect of lines up to 10 levels.
5) The system of equations converge 4 to 5 iterations.

Monte Carlo calculation :

1) The dust content must be included (absorption/emission/possible emission) this is done in order to estimate the energy absorbed by the hydrogen in the selected transitions.

In brief the procedure involves three separate programs : Continuum simulation

Line simulation, Excitation solver

We use Monte Carlo simulations

Forbidden lines: Spectral lines emitted from meta stable state Or which have very low Probability of occurrence (10^{-9} - 10^{-10}).

Their particle densities are < 10^{8} cm ^{3}. Also all forbidden lines have low excitation Potentials.