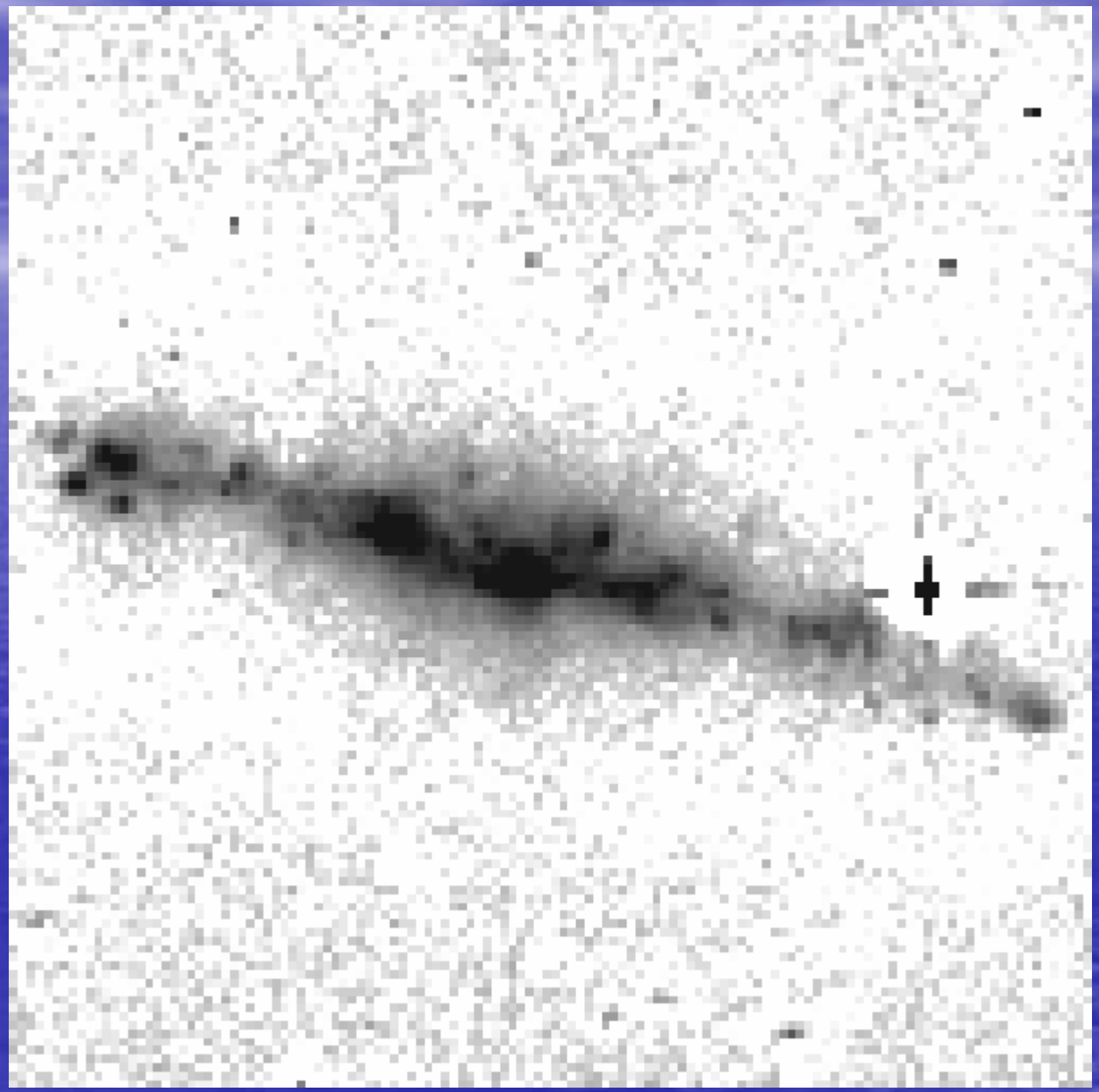
A Geometrical View of the Diffuse Ionised Gas (DIG)

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NGC 7426
showing an extended diffuse extraplanar gas *(Rossa & Dettmar 2003)*



BASIC PHYSICAL PROPERTIES (*Reynolds 1991, 2003*)

- Diffuse medium ($n_e \sim 0.1$ cm^{-3})
- $T_e \sim 6000 - 10\,000$ K (no direct estimate)
- H^+ scale height ~ 1 kpc (WHAM observations)
- Accounts for 90% of ionised gas in the solar vicinity
- Power input requirements < disc massive stars

In external edge-on spiral galaxies, the H^+ layer extends up to several kpc over the midplane (NGC 891, NGC 5775) *Dettmar 1990, Rand, Kulkarni & Hester 1990*

OUR OBJECTIVES ARE TO…

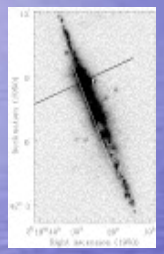
- Reproduce the maximum observed values of emission line intensity ratios.
- Reproduce their observed trends with increasing height.
- Understand the relationship between these intensity ratios, Hα emission and electron density
- Understand what is going on with the gas electron temperature
- Give, for the first time, a physical meaning to these properties and determine the hidden nature of the DIG

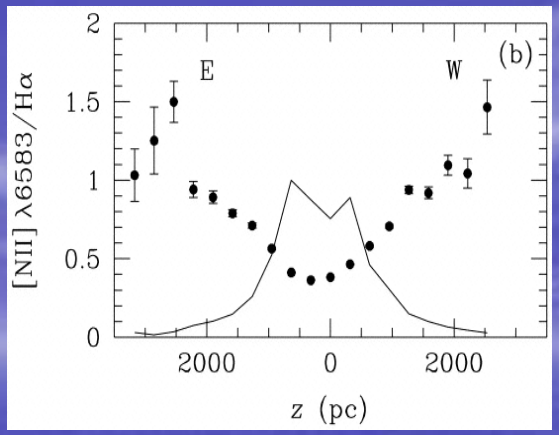
Why?

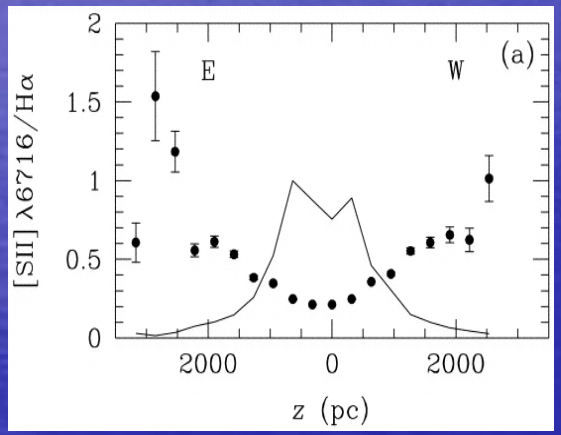
- Pure photoionisation models fail to explain the observed trends (constant [SII]/[NII] and [OIII]/Hα) Notice on models!!!
- Composite photoionisation-shocks cannot explain [SII]/[NII]
- Proposed solution *(Haffner, Reynolds & Tufte 1999; Otte, Gallagher & Reynolds 2002)* : « The electron temperature seems to increase with increasing distance from the midplane of the galaxies. This is not necessarily caused by an additional source of ionisation, but by an additional heating mechanism that does not ionise the diffuse gas »

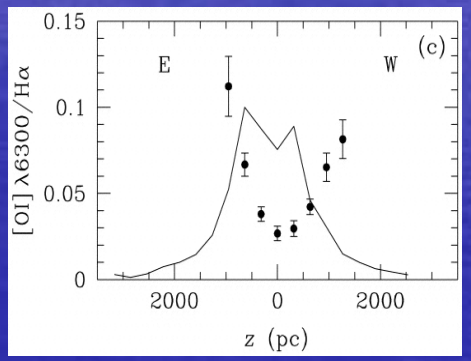
How?

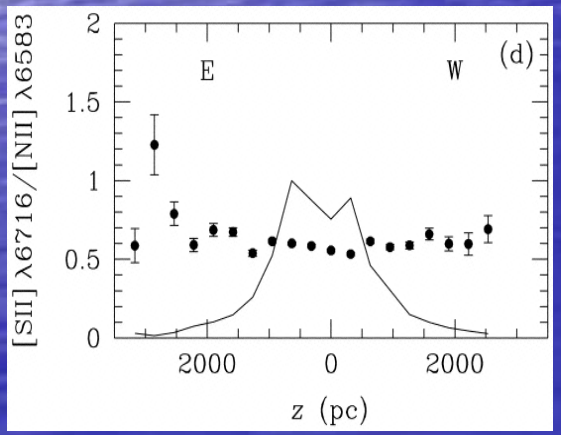
Observed trends for emission line intensity ratios with increasing height from the Galaxy plane (NGC 891; *Rand 1998*)

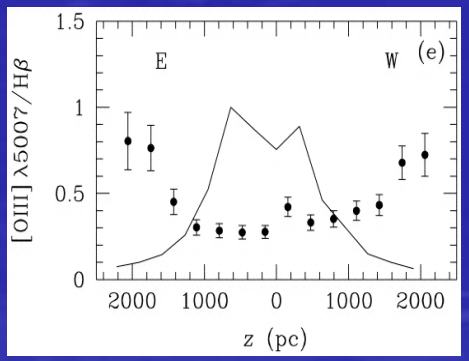




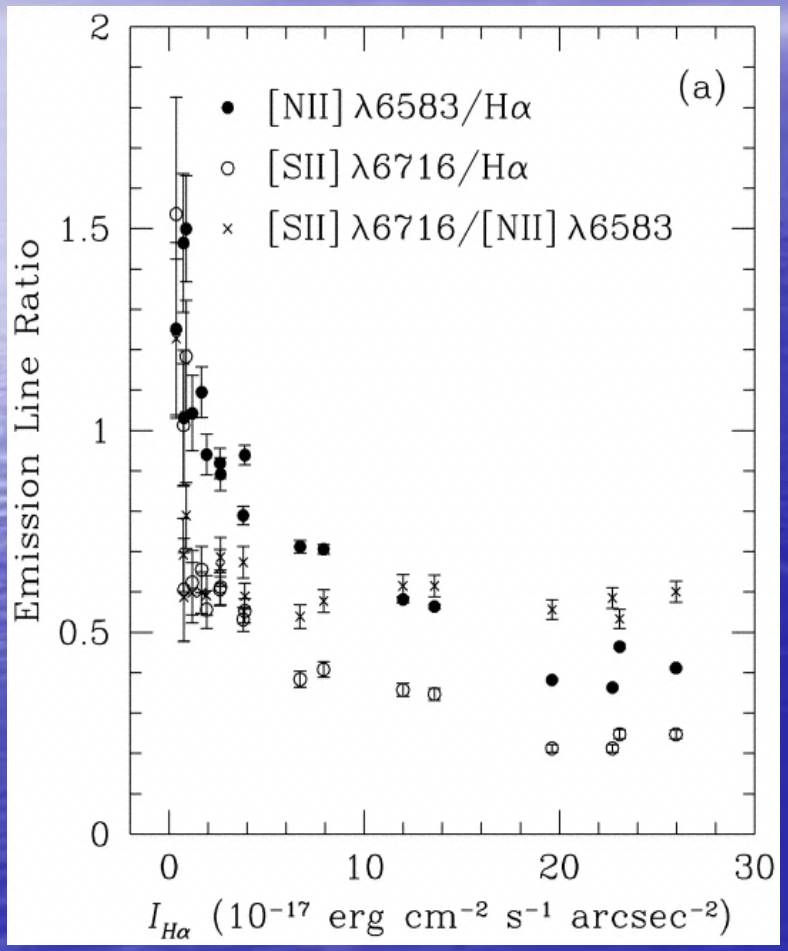


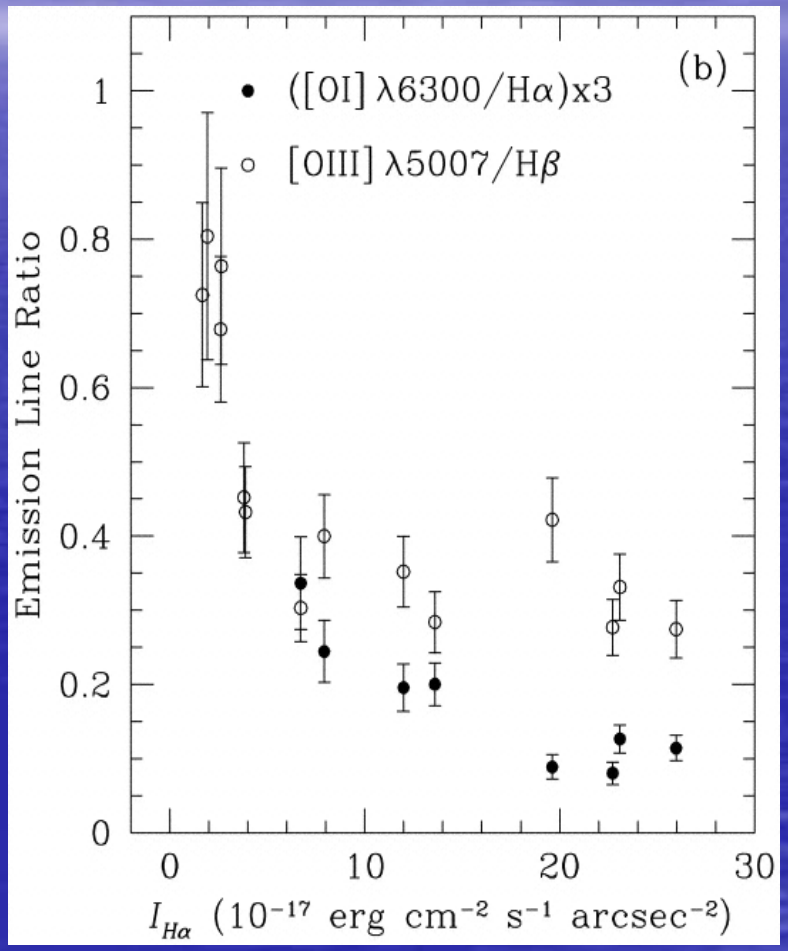


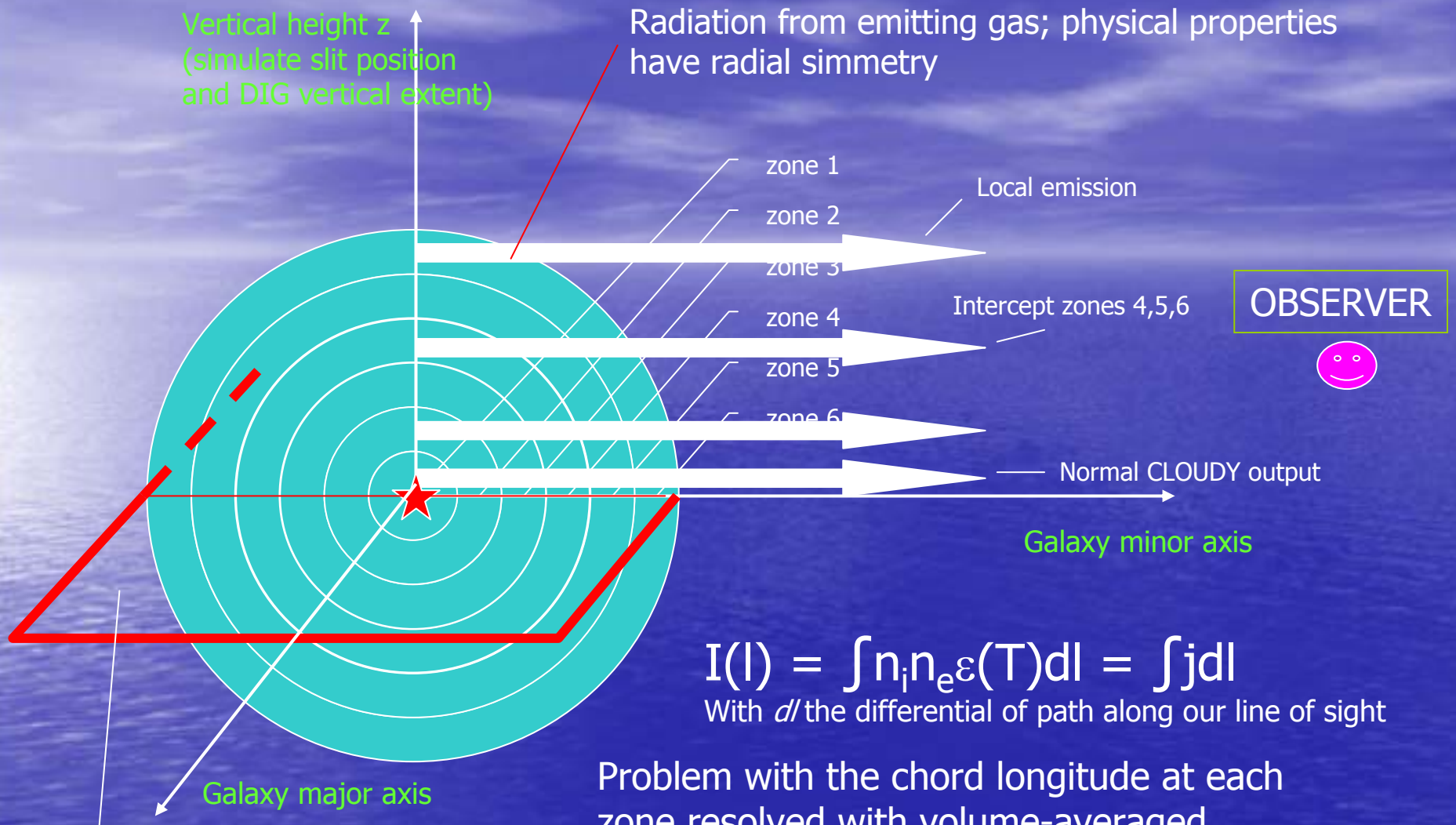




Behaviour of the emission line intensity ratios With Hα surface brightness (NGC 891; *Rand 1998*)







$$I(l) = \int n_i n_e \varepsilon(T) dl = \int j dl$$

With *dl* the differential of path along our line of sight

Problem with the chord longitude at each zone resolved with volume-averaged line emissivities in CLOUDY.

$$(I_2/I_1)_{Z_K} = (\Sigma^n_{i=k}(\int_{r_i}^{r_{i+1}} j_{2i}\, dV)) / (\Sigma^n_{i=k}(\int_{r_i}^{r_{i+1}} j_{1i}\, dV))$$

Input parameters for models

- ST99 Cluster models ($M_{cluster} = 10^6\ M_\odot$) with a Salpeter IMF (0.8 to 120 $M_\odot$) and Pauldrach/Hillier stellar atmosphere models.
- Typical hardness for the ionising radiation:

  Q(He)/Q(H) = 0.10; 0.14; 0.18; 0.21; 0.24
- Local ionisation parameter: log U = -2.0 and -4.0 in 0.25 dex interval ---------- constant density and exponential hydrogen density models
- Gas oxygen abundances parametrised by Z (metal content). Z = 0.10 to 1.20 in 0.10 dex intervals

Digging in the … fit!!

Statistical fit to choose best fitting models

- χ^2 method computed for each intensity line ratio
- χ^2 method computed globally for all ratios (sum of individual χ^2).
- Confidence levels for adjacent models (*ongoing*)

Physical constraints: Strömgren sphere concept

- Seek maximum value in observations and adjust the maximum value of model (allow tolerance in vertical DIG extent) → PROBLEMS: sudden fall in ionization, is that the case in observations? Real DIG extension?

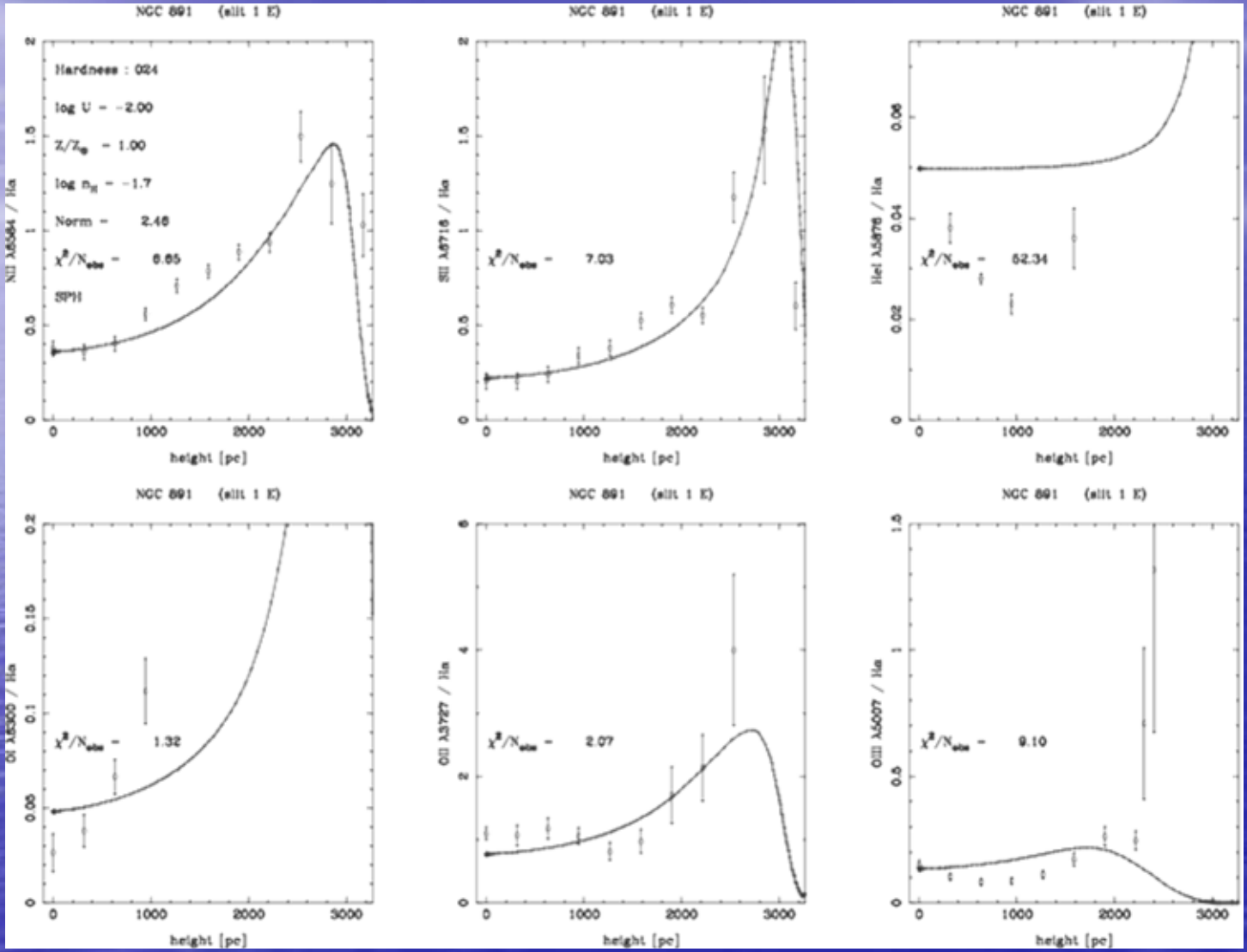
Results

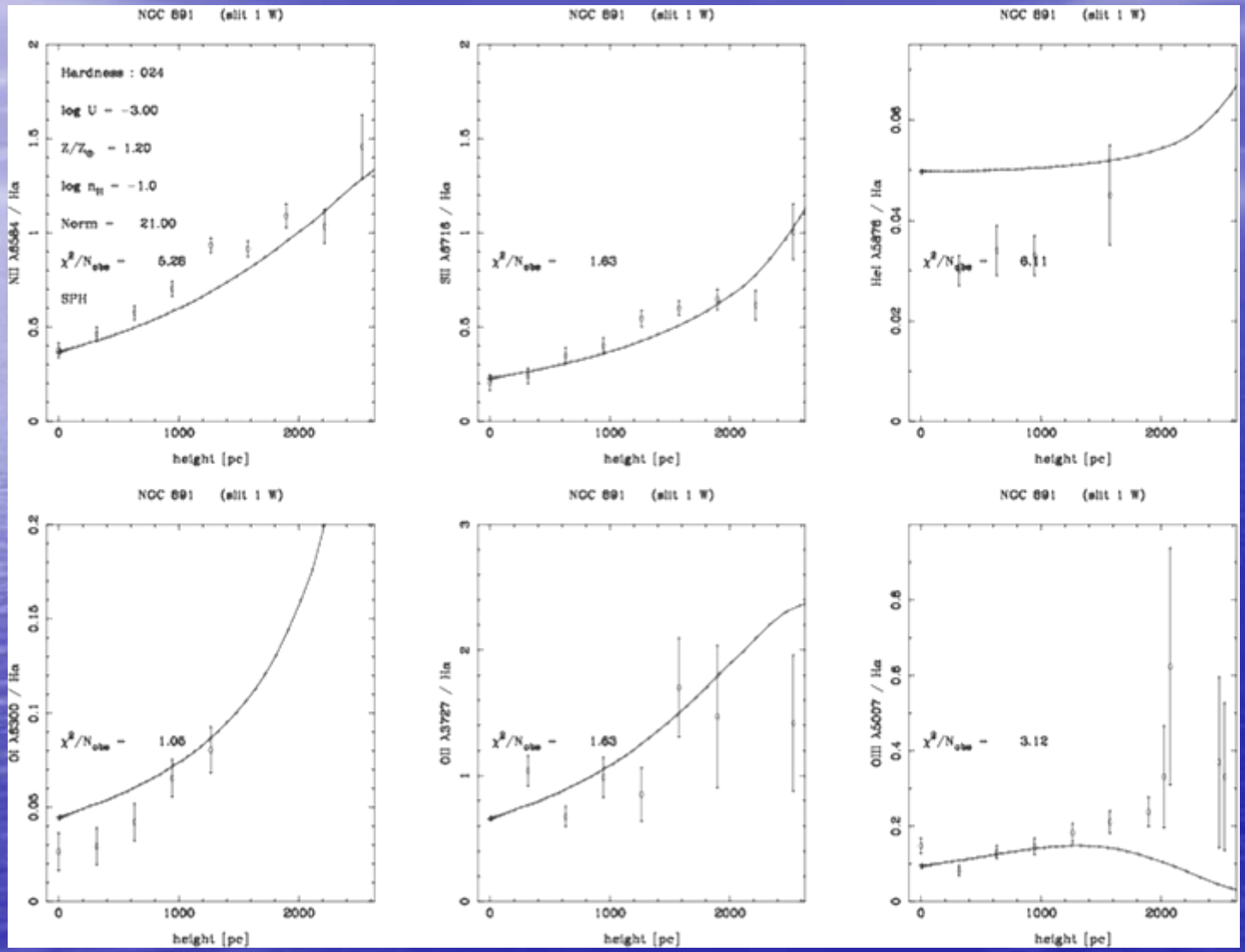
- Constant density models can reproduce both the maximum values and the observed trends in emission line intensity ratios.

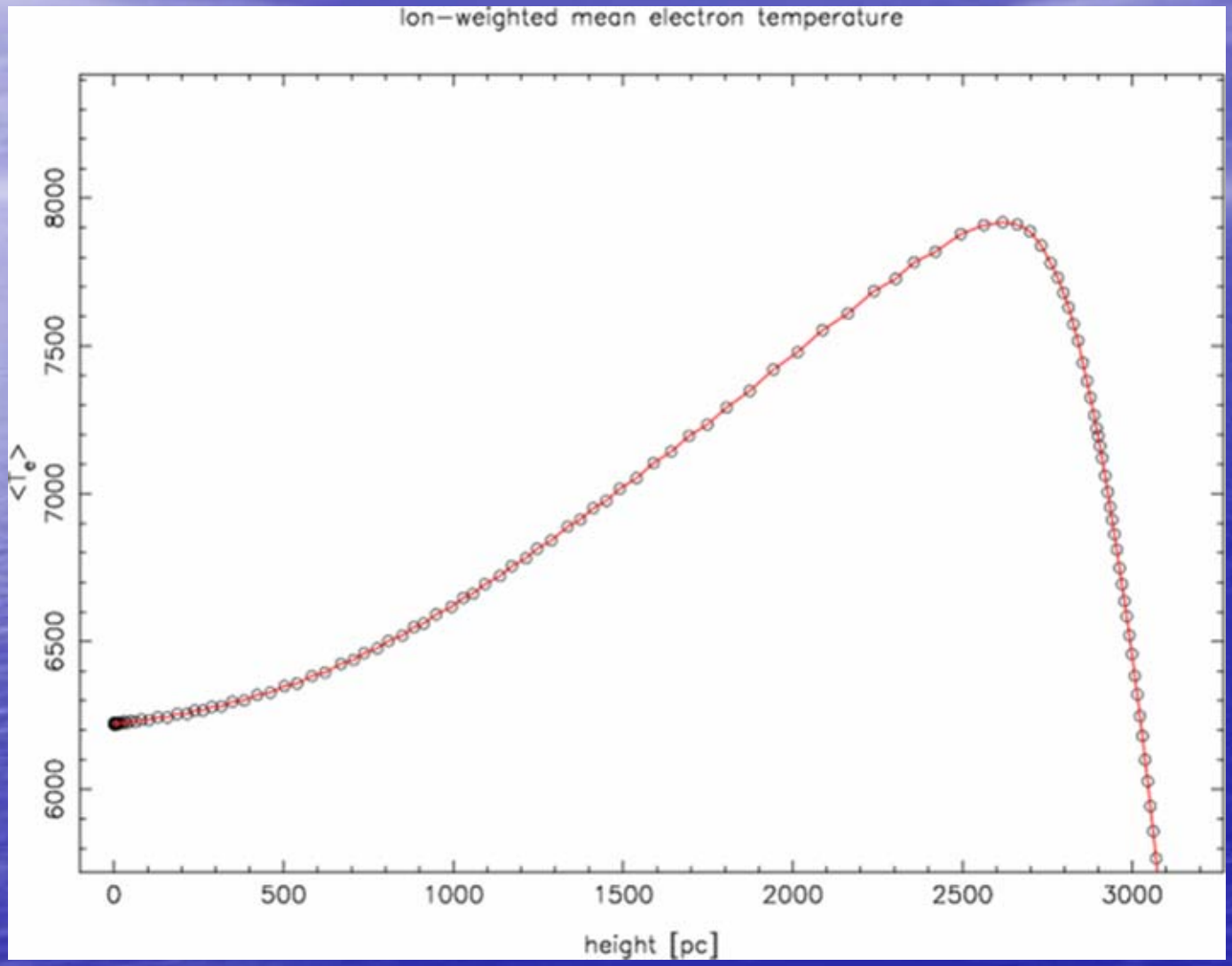
→ The goal is to reproduce the observed trends with exponential density models where scale heights are available (NGC 891, NGC 5775, UGC 10288) *(ongoing)*

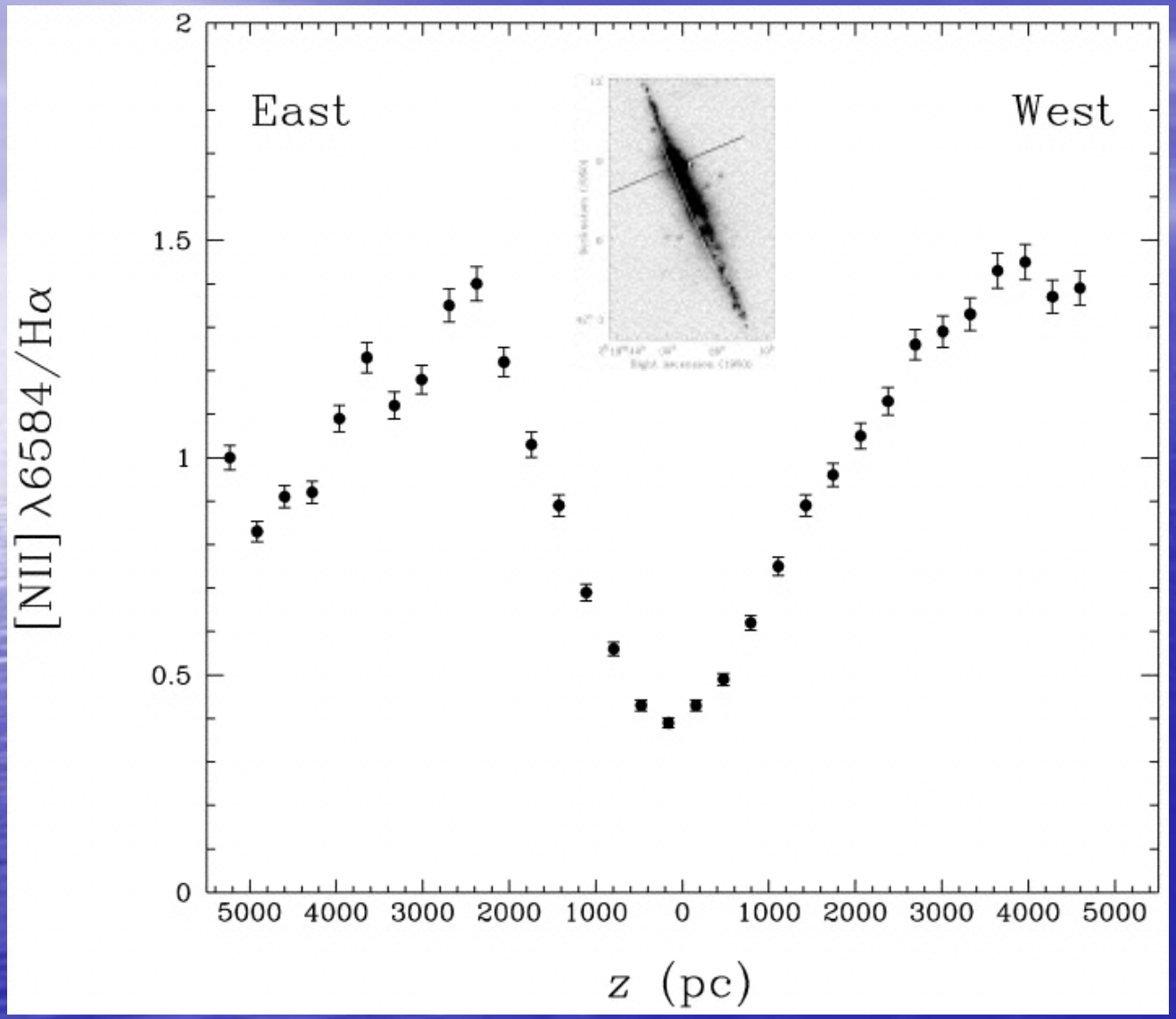
- The increase in electron temperature is expected from the alteration of the radiation field with increasing optical depth.
- This, together with the adopted geometry and the exponential dependence for the hydrogen density, explains the boost-up in the emission line ratios with increasing distance from the source and the decrease in the Hα intensity.

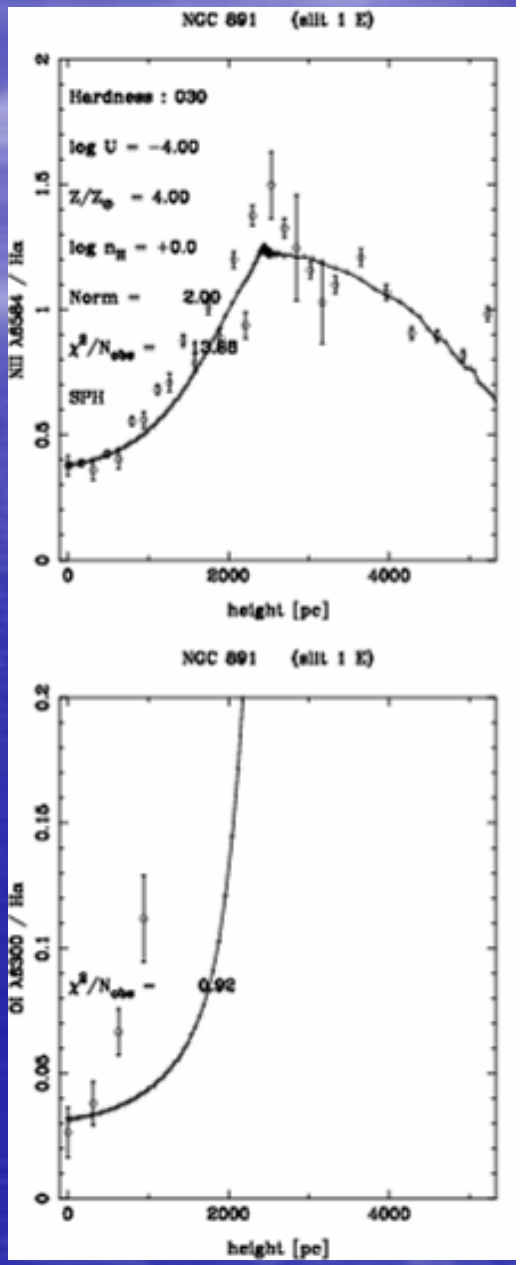
$$j(f) \alpha n_i n_e e^{-(\chi/kT)} T^{-0.5} \quad // \quad j(r) \alpha n_p n_e T^{-m}$$


NGC 891 (slit 1 E)
Hardness : 024
log U = -2.00
Z/Z⊙ = 1.00
log n_H = -1.7
Norm = 2.48
χ²/N_obs = 6.85
SPH
NII λ6584 / Hα
height [pc]
NGC 891 (slit 1 E)
χ²/N_obs = 7.03
SII λ6716 / Hα
height [pc]
NGC 891 (slit 1 E)
χ²/N_obs = 62.34
HeI λ5876 / Hα
height [pc]
NGC 891 (slit 1 E)
χ²/N_obs = 1.32
OI λ6300 / Hα
height [pc]
NGC 891 (slit 1 E)
χ²/N_obs = 2.07
OII λ3727 / Hα
height [pc]
NGC 891 (slit 1 E)
χ²/N_obs = 9.10
OIII λ5007 / Hα
height [pc]


NGC 691 (slit 1 W)
Hardness : 024
log U = -3.00
Z/Z⊙ = 1.20
log n_H = -1.0
Norm = 21.00
χ²/N_obs = 5.28
SPH
NII λ6584 / Hα
height [pc]
NGC 691 (slit 1 W)
χ²/N_obs = 1.63
SII λ6716 / Hα
height [pc]
NGC 691 (slit 1 W)
χ²/N_obs = 6.11
HeI λ5876 / Hα
height [pc]
NGC 691 (slit 1 W)
χ²/N_obs = 1.06
OI λ6300 / Hα
height [pc]
NGC 691 (slit 1 W)
χ²/N_obs = 1.63
OII λ3727 / Hα
height [pc]
NGC 691 (slit 1 W)
χ²/N_obs = 3.12
OIII λ5007 / Hα
height [pc]


Ion−weighted mean electron temperature
8000
7500
7000
6500
6000
<T_e>
0
500
1000
1500
2000
2500
3000
height [pc]


East
West
[NII] λ6584/Hα
z (pc)
2
1.5
1
0.5
0
5000 4000 3000 2000 1000 0 1000 2000 3000 4000 5000


NGC 891 (slit 1 E)
Hardness : 030
log U = -4.00
Z/Z⊙ = 4.00
log nH = +0.0
Norm = 2.00
χ²/Nobs = 13.88
SPH
NII λ6584 / Hα
height [pc]
NGC 891 (slit 1 E)
χ²/Nobs = 0.92
OI λ6300 / Hα
height [pc]

… therefore

The Diffuse Ionised Gas could be understood as a huge single/(collection of) Strömgren sphere/s, maintained by the ionising power of disc massive stars.

This is a first approximation to reality because we know that Stromgren spheres are theoretical artifacts!!

… interesting notes!?

- Abundance gradients?? Of course, yes.
- Nature of the gas in the DIG?? Of course, two components (metal poor and metal rich)
- Approach to 3D modelling. Mandatory.
- Application to other extended objects. Definitely, yes (liners, …)

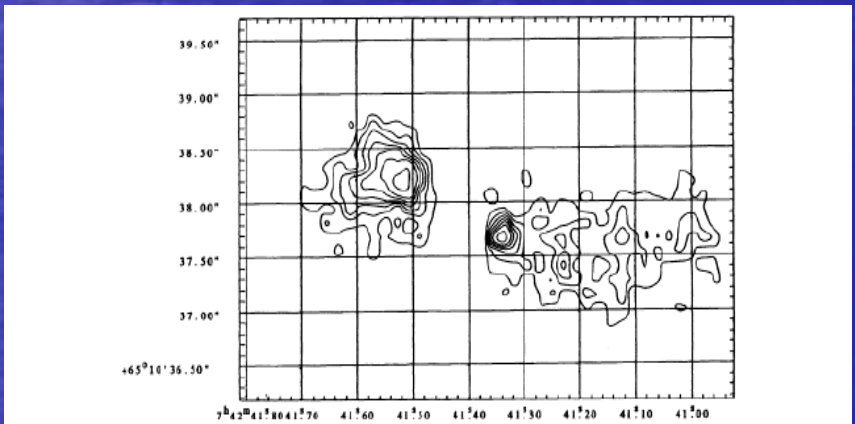


FIG. 2.—Contour plot of the [O III] emission-line region of Mrk 78. Contours levels are at 20%, 25%, 30%, 35%, 40%, 50%, 60%, 80% of the peak.