

*Spatially resolved spectroscopic studies  
of planetary nebulae and their halos*

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## ⇒ **Observations** ⇐

Selected objects, instrument setup

## **Results**

Binning, Surface Brightnesses, Temperatures, Densities

## **Modeling – understanding the observations**

Using 1D **time-dependent** ionization models

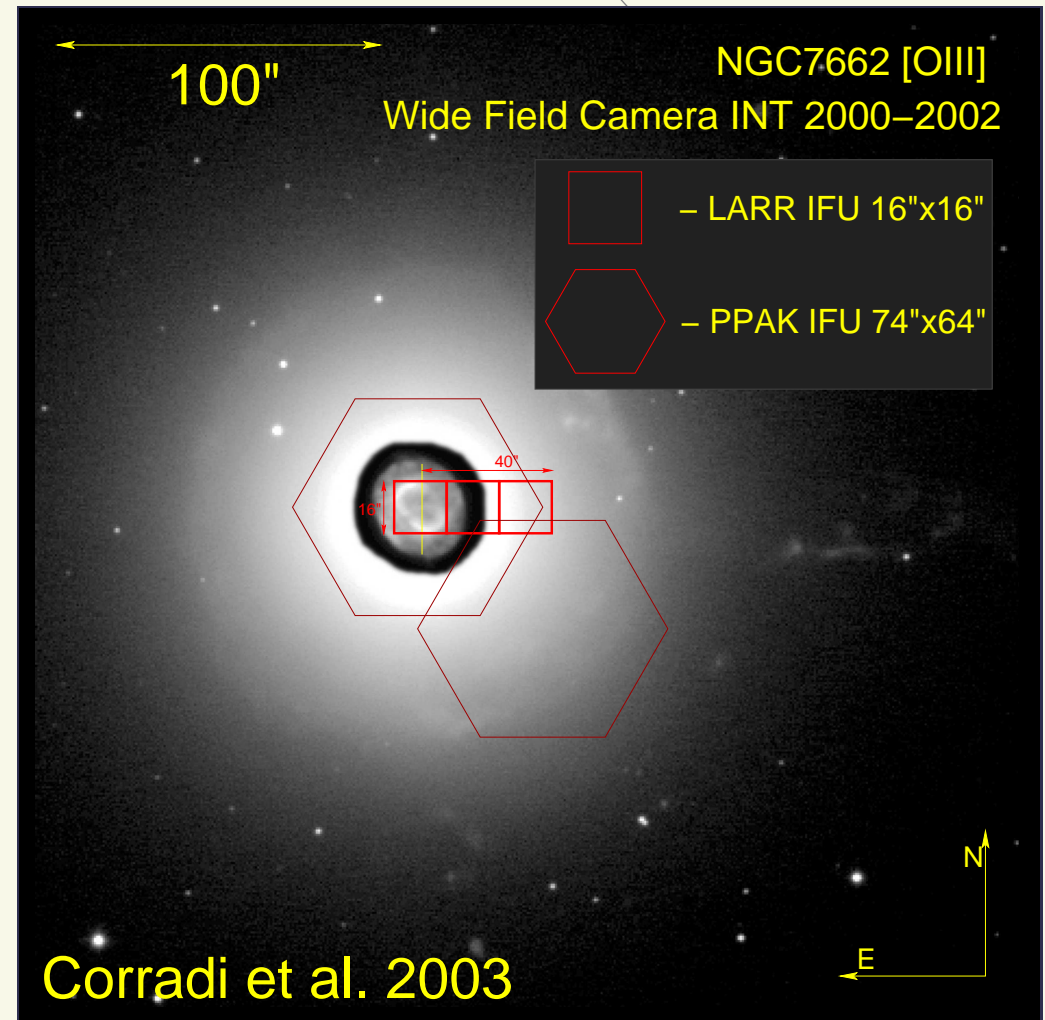
## **Conclusions**

# Observed planetary nebulae with a halo – PMAS + Calar Alto 3.5m

Object: NGC7662

- Size: shell: 25", halo: 140"
- Date and run of observation: 09.09.2005, run48, backup target
- Grating, IFU & wavelength r.: V600, 1.0" Lens array, 3490–5150 Å

IFU – Integral Field Unit  
Covers an extended two-dimensional surface



# Presentation – overview

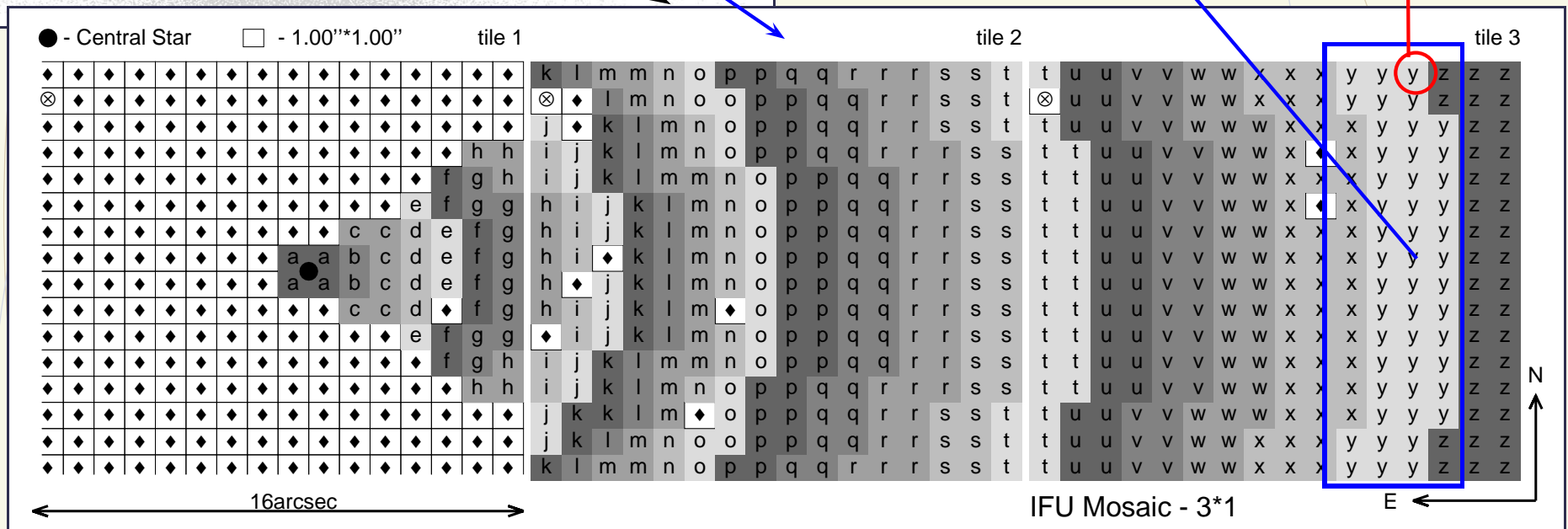
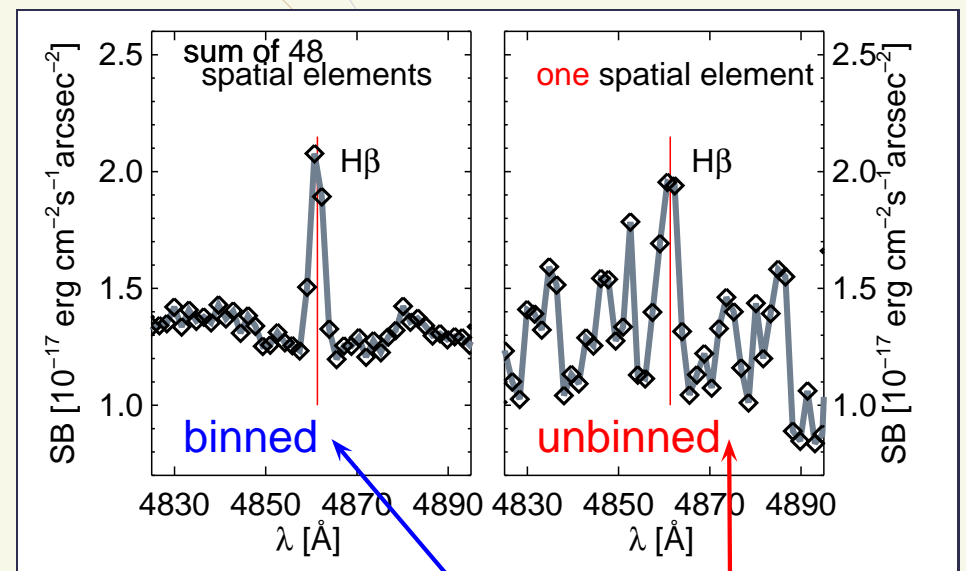
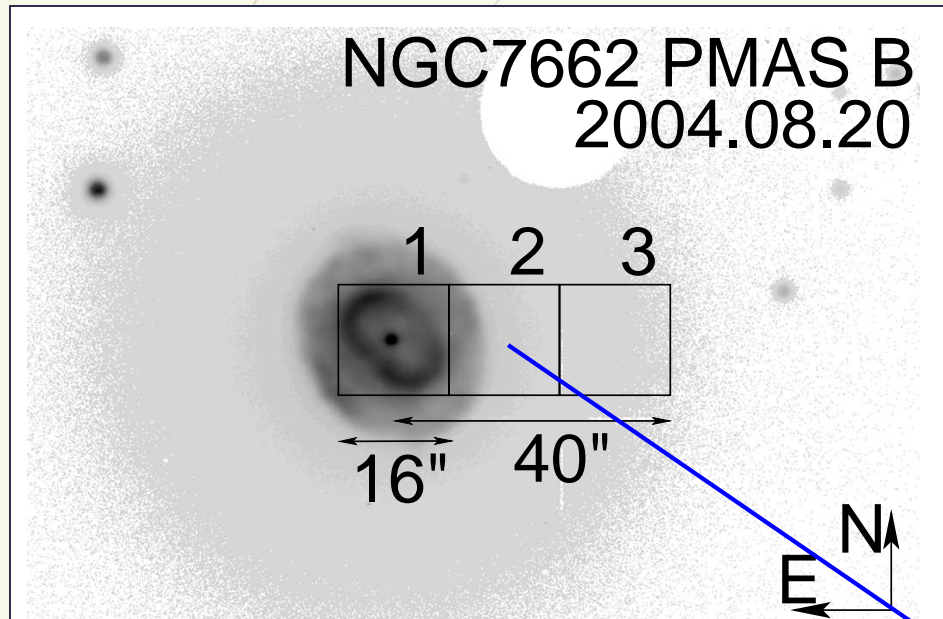
Observations

⇒ **Results** ⇐

Modeling

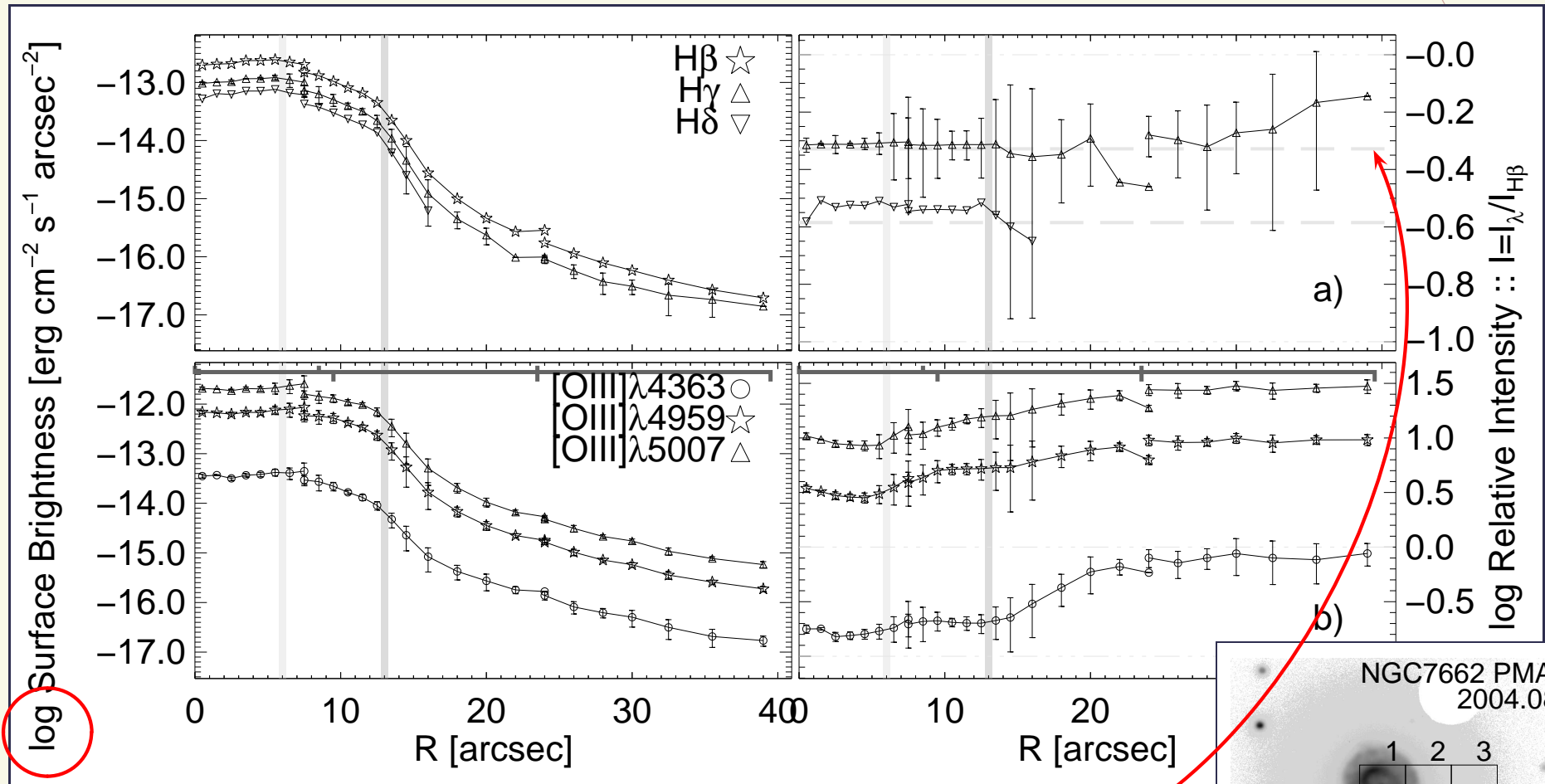
Conclusions

# NGC7662 – “Blue Snowball Planetary Nebula”



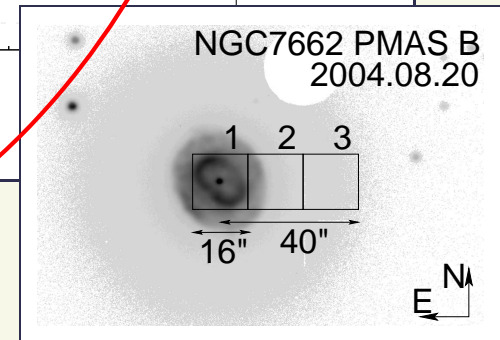
# NGC7662 – “Blue Snowball Planetary Nebula”

The radial surface brightness for selected lines



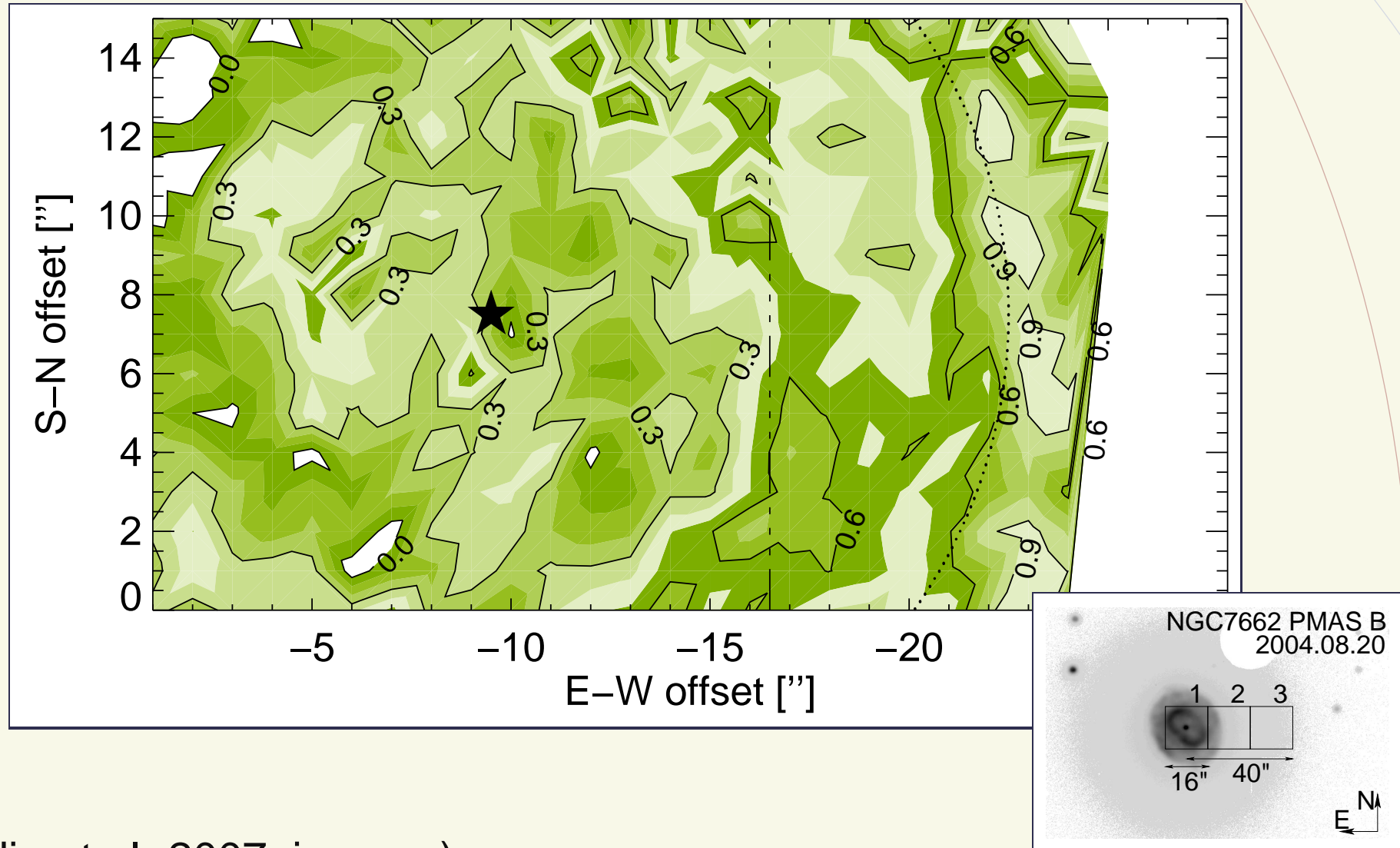
Recombination theory  $I(H\gamma)/I(H\beta)$

(Sandin et al. 2007, in prep.)



# NGC7662 – “Blue Snowball Planetary Nebula”

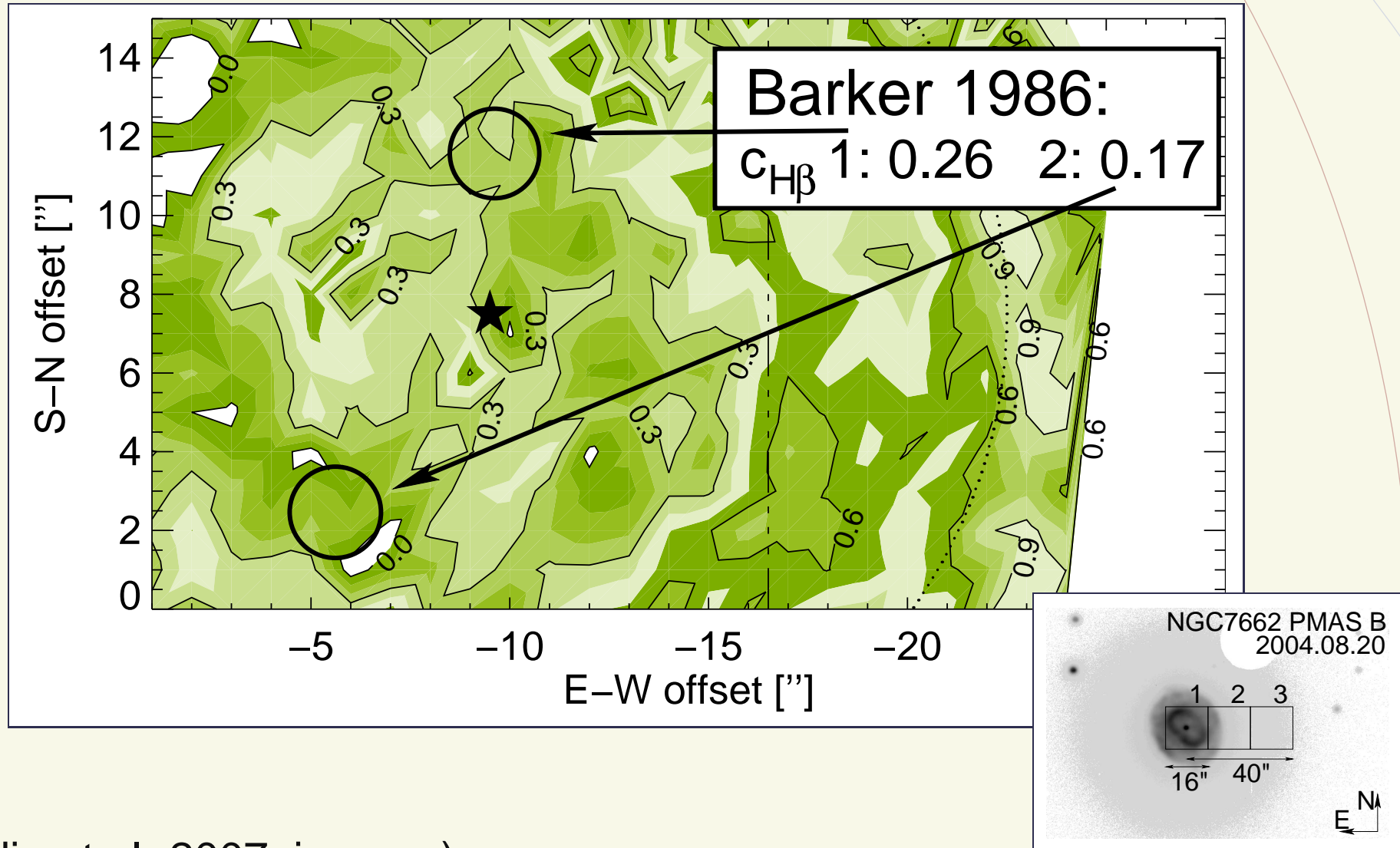
The radial surface brightness for selected lines and  $c_{H\beta}$



(Sandin et al. 2007, in prep.)

# NGC7662 – “Blue Snowball Planetary Nebula”

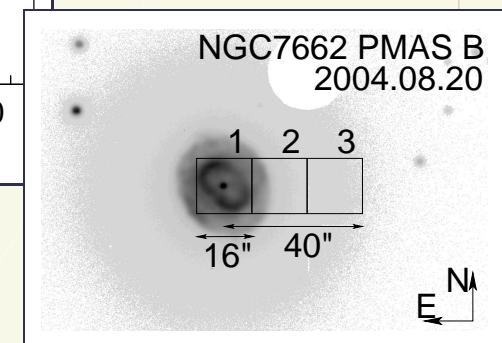
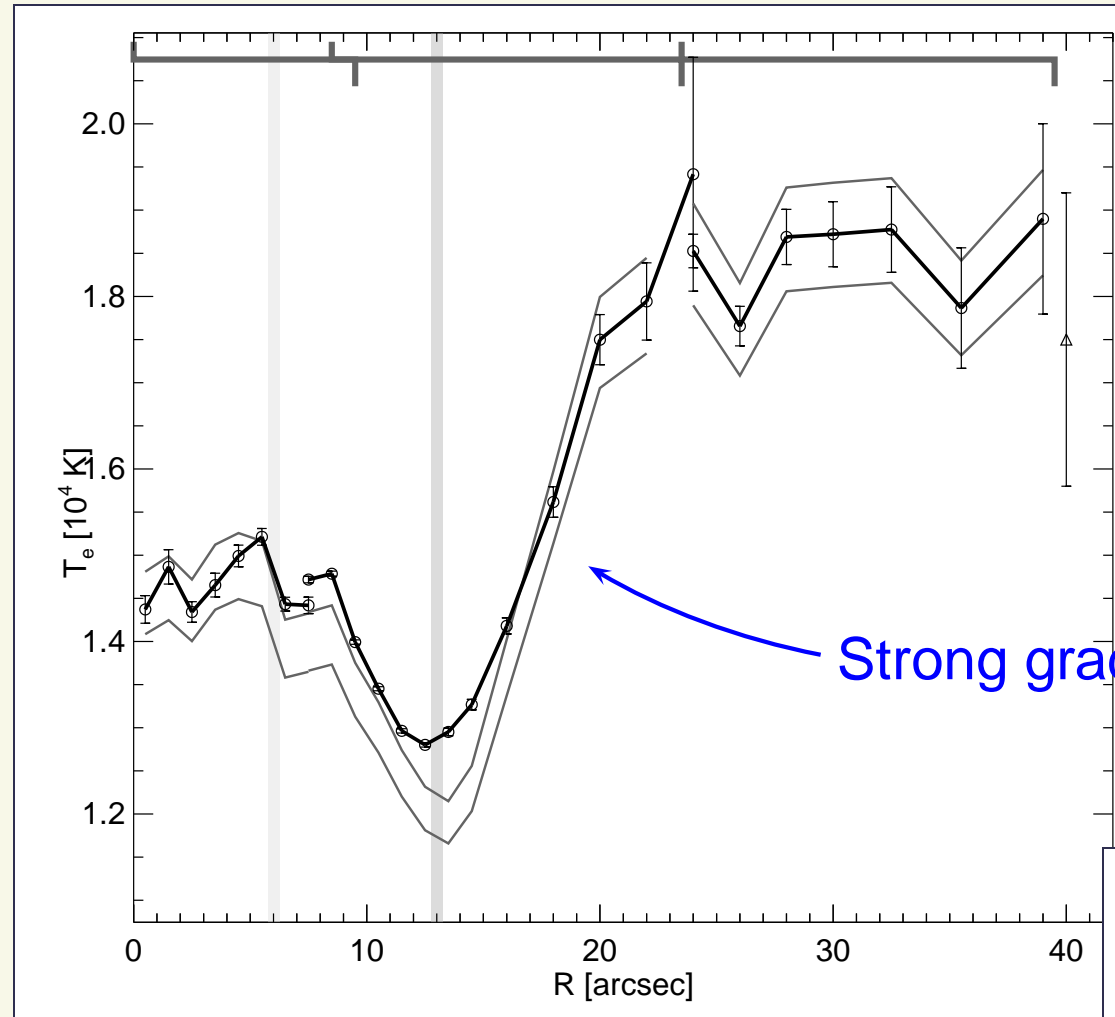
The radial surface brightness for selected lines and  $c_{H\beta}$



(Sandin et al. 2007, in prep.)

# NGC7662 – “Blue Snowball Planetary Nebula”

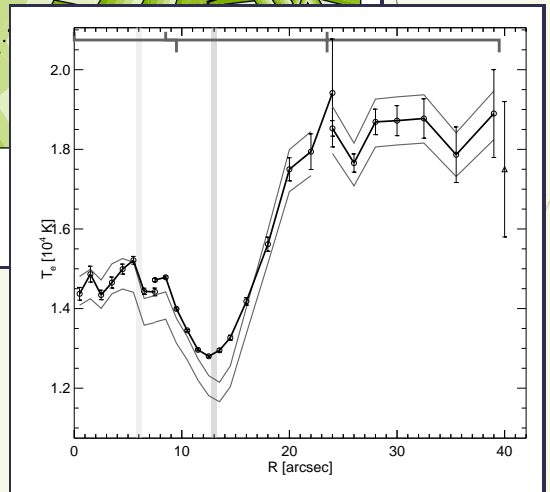
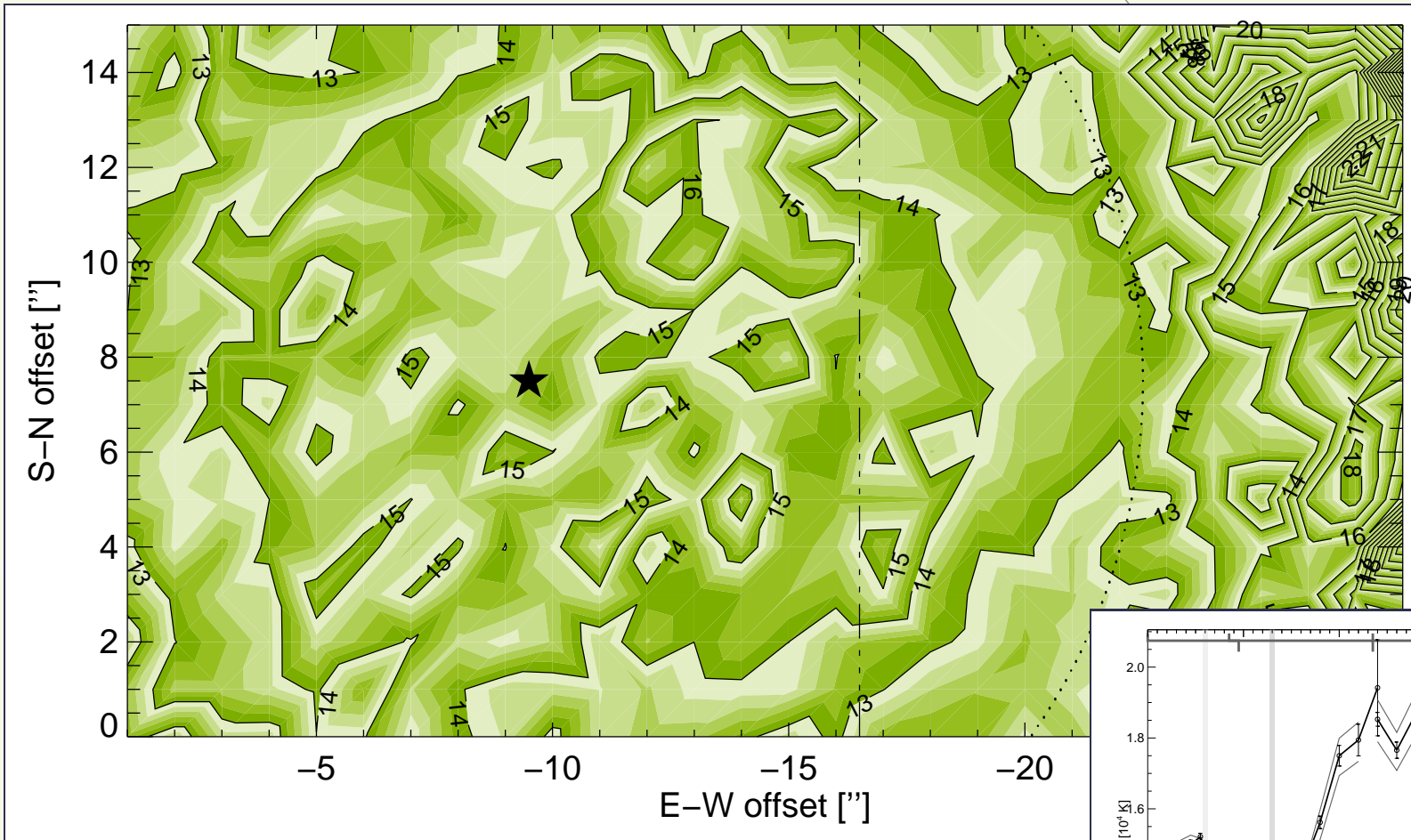
## The radial electron temperature



(Sandin et al. 2007, in prep.)

# NGC7662 – “Blue Snowball Planetary Nebula”

Compared with a 2D [OIII] temperature map



(Sandin et al. 2007, in prep.)

# NGC7662 – “Blue Snowball Planetary Nebula”

Compared with a 2D [O III] temperature map – with an overlay

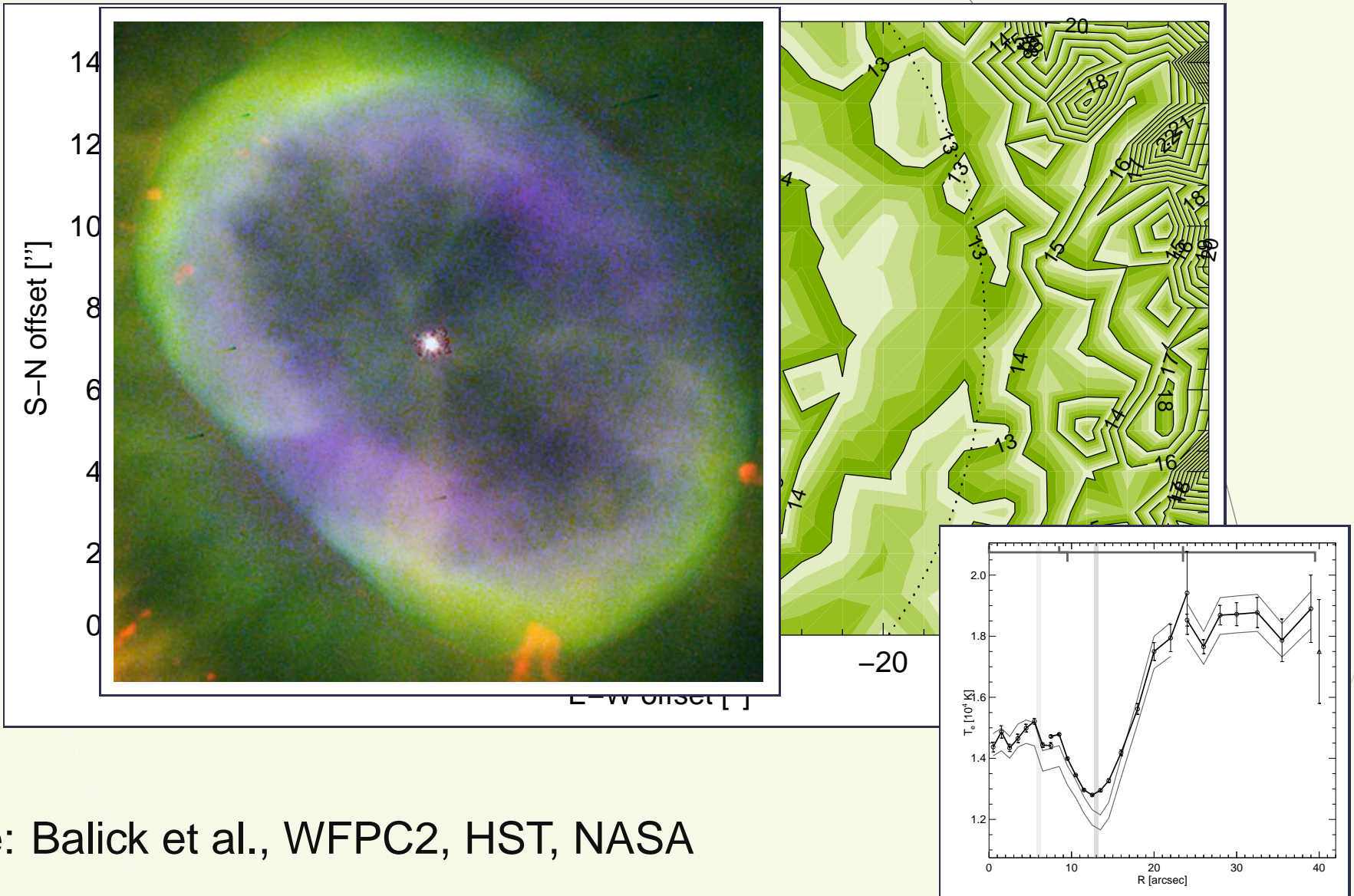
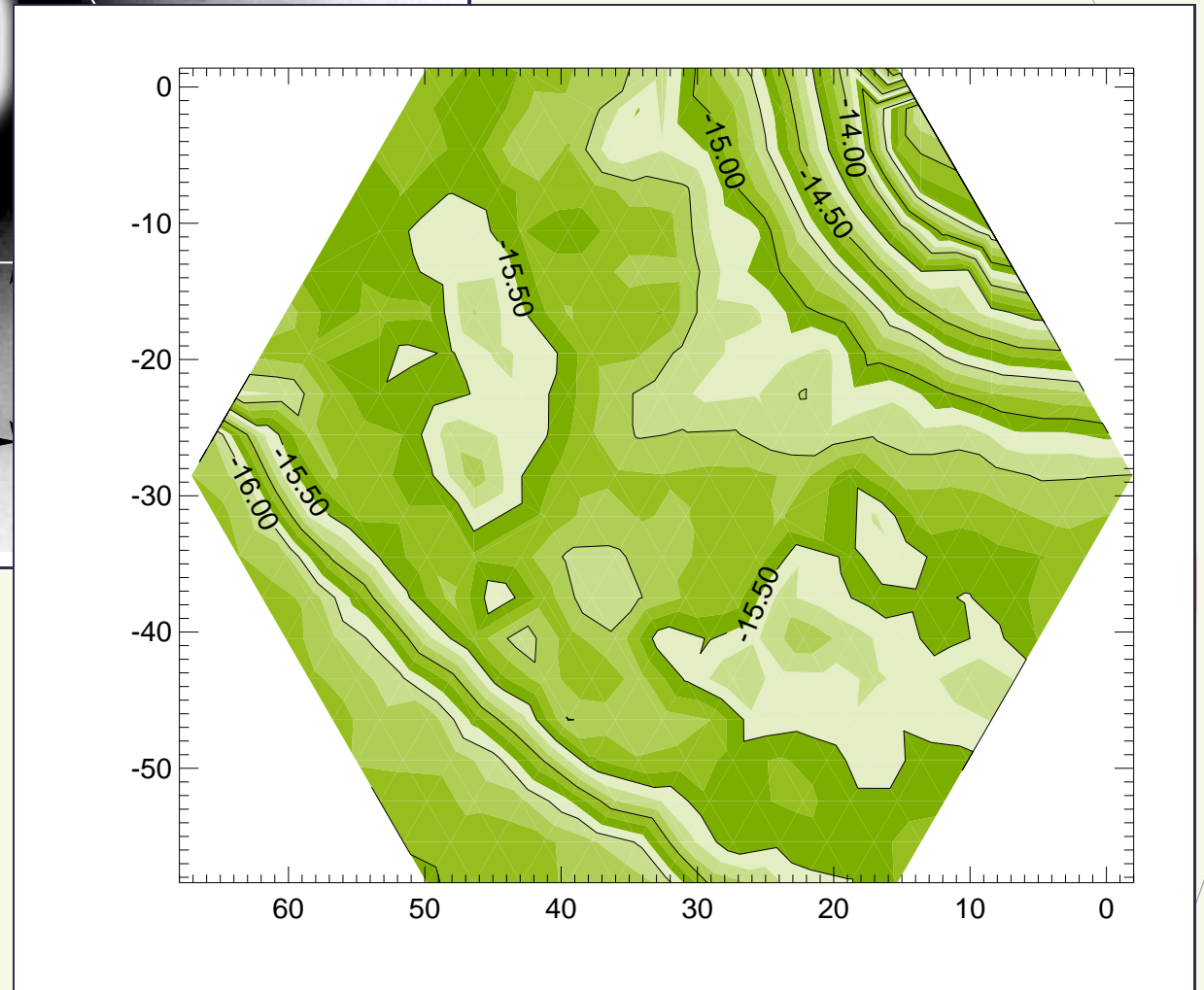
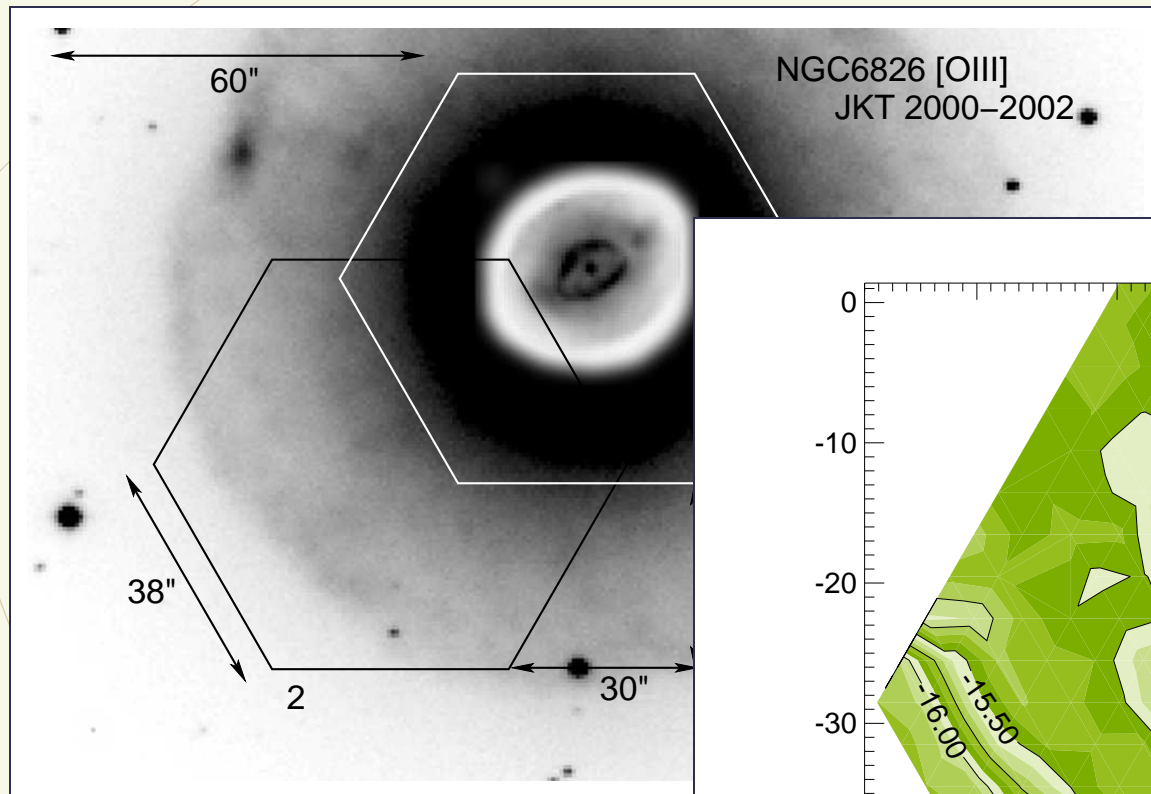


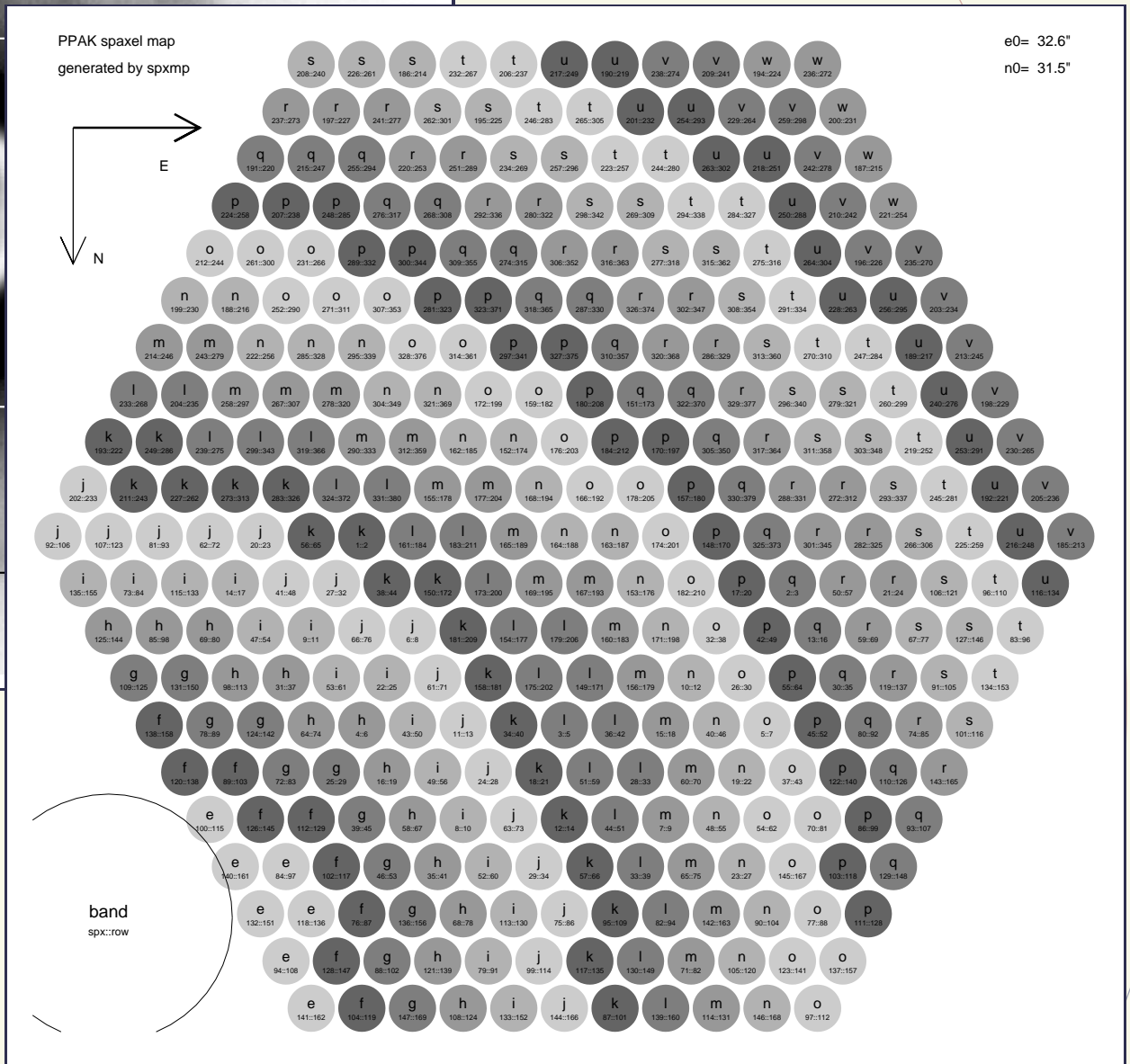
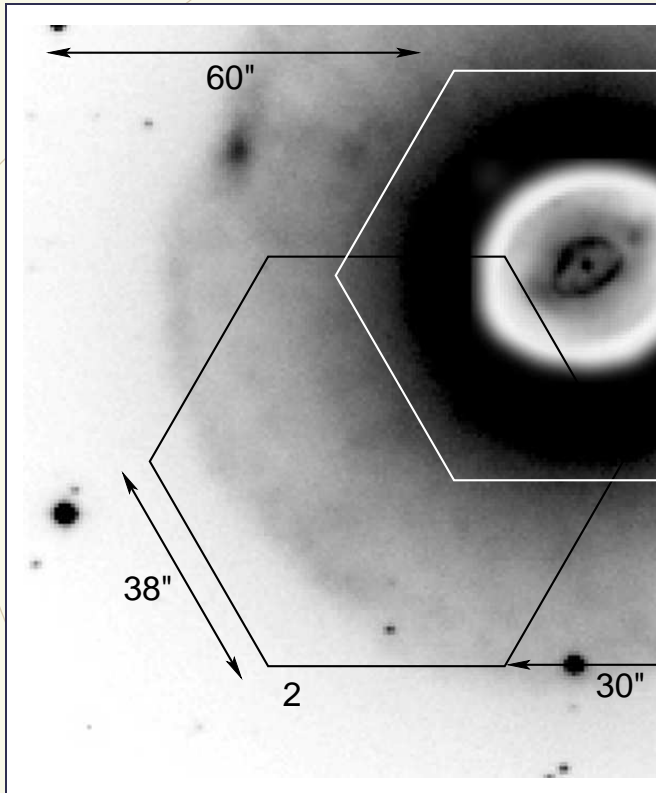
Image: Balick et al., WFPC2, HST, NASA

# NGC6826 – “Blinking Eye Nebula”



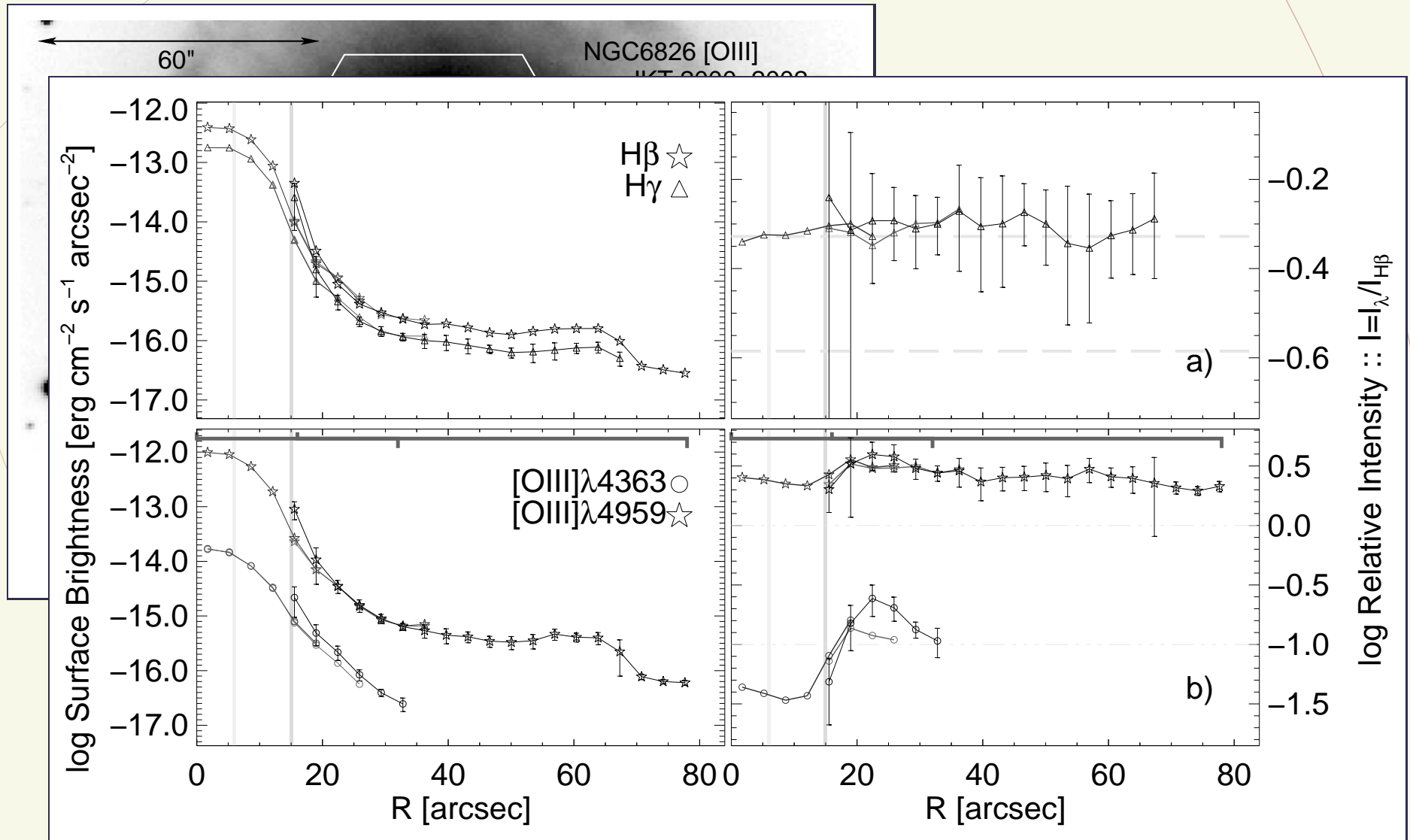
Surface brightness  
map of [OIII]  $\lambda$  4959  
(Sandin et al. 2007,  
in prep.)

# NGC6826 – “Blinking Eye Nebula”



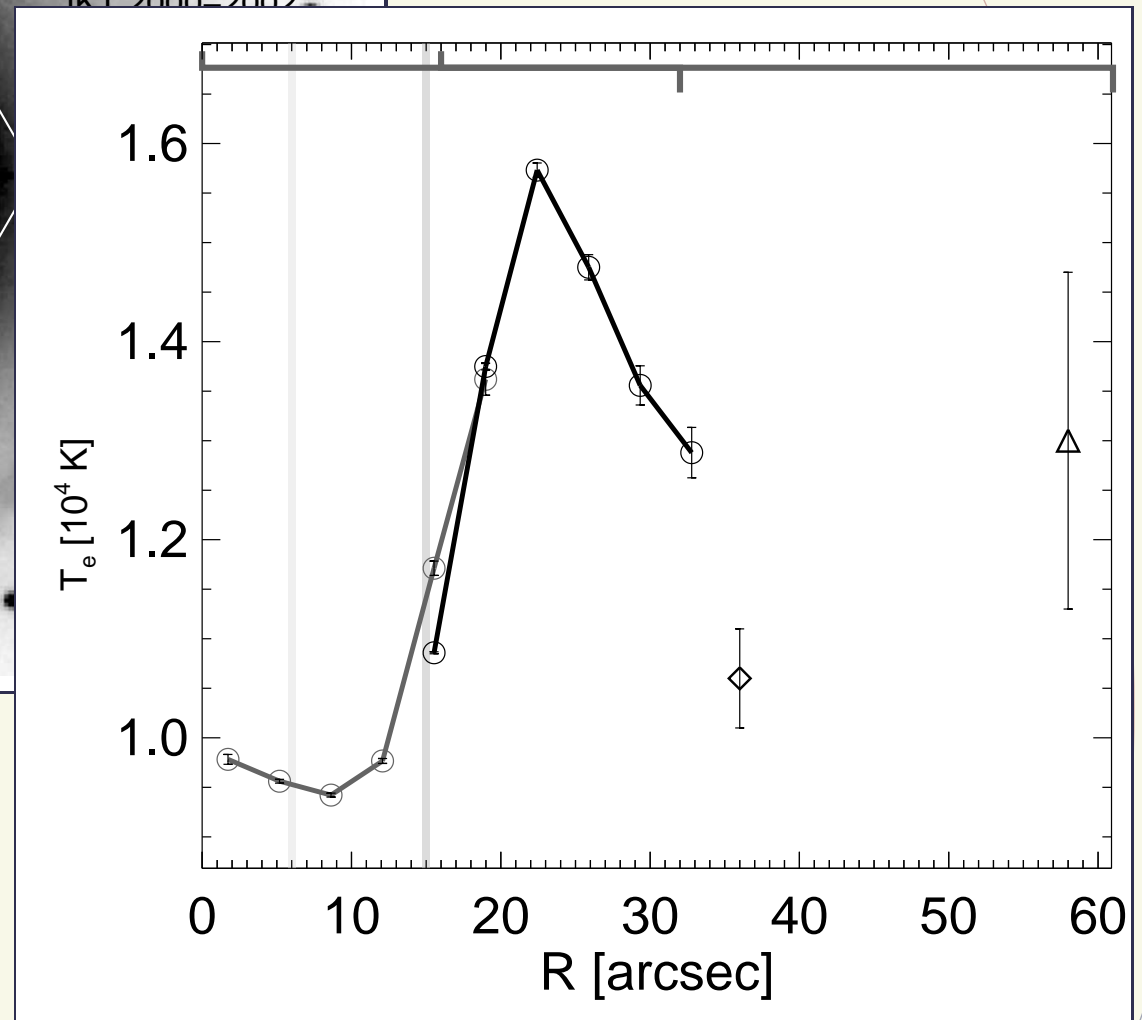
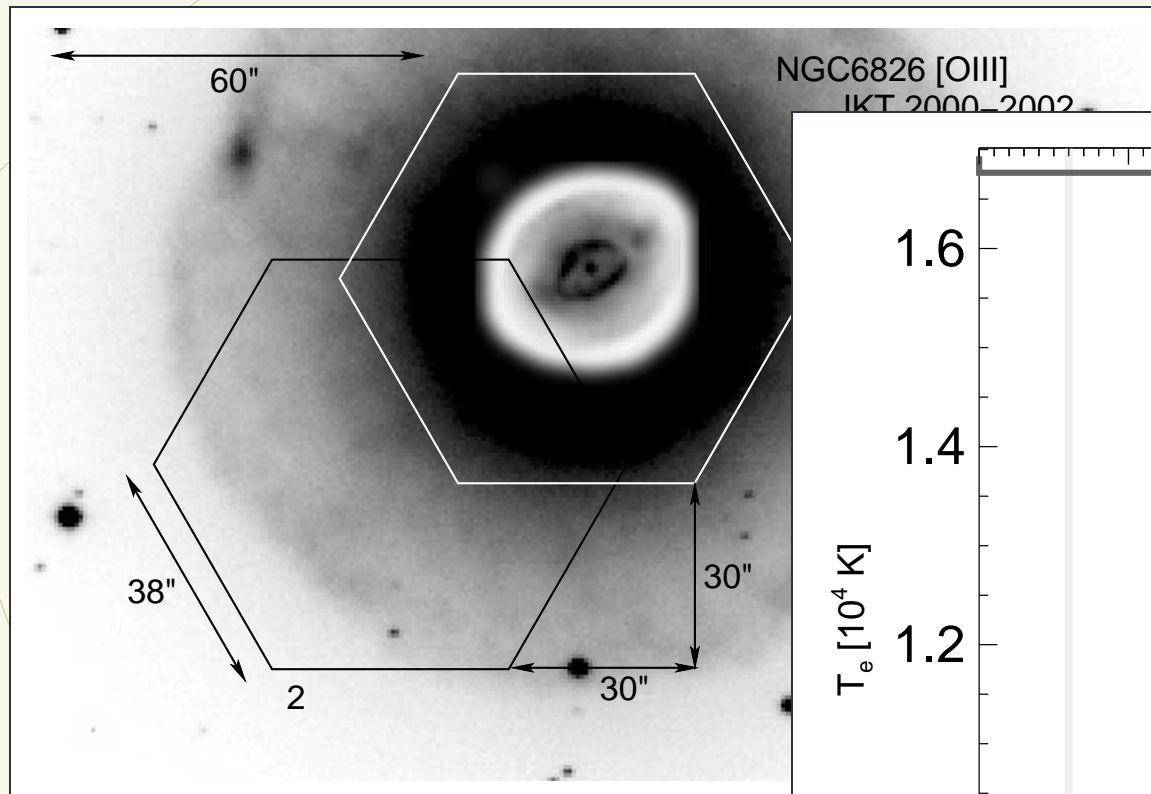
PPAK binning map  
(Sandin et al. 2007,  
in prep.)

# NGC6826 – “Blinking Eye Nebula”



(Sandin et al. 2007, in prep.)

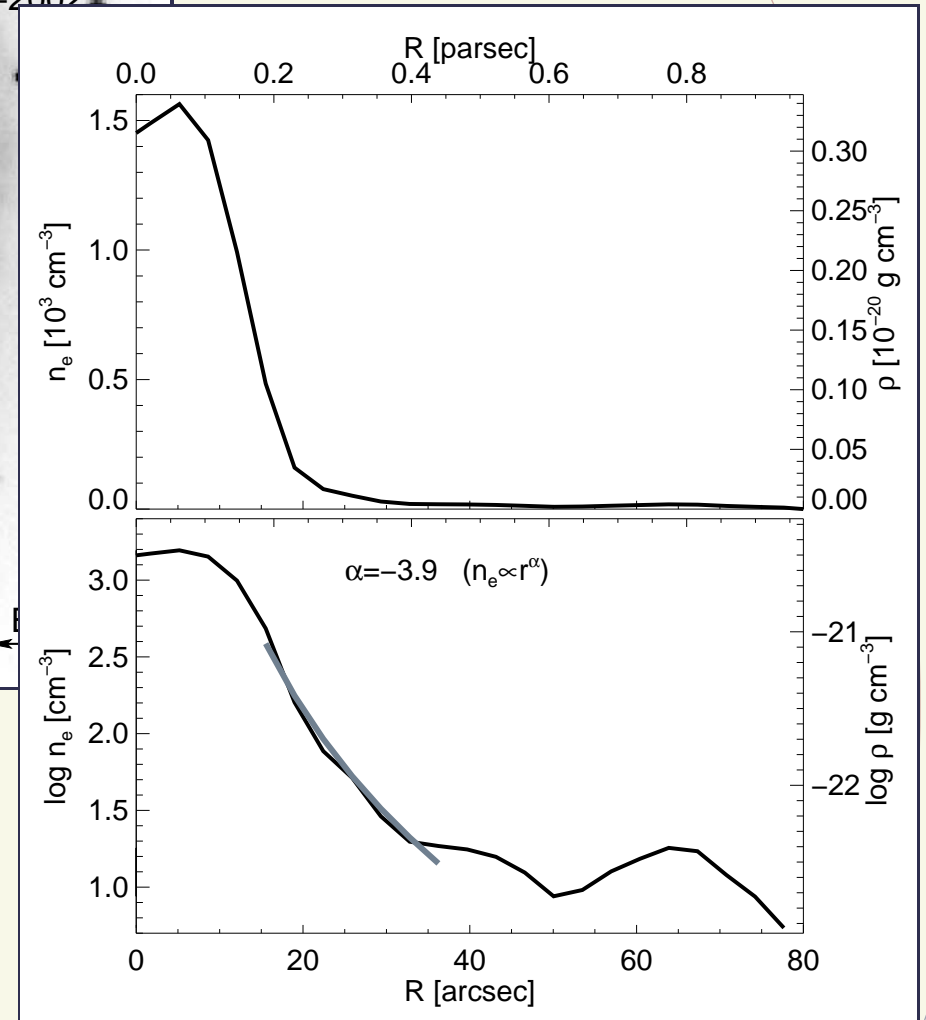
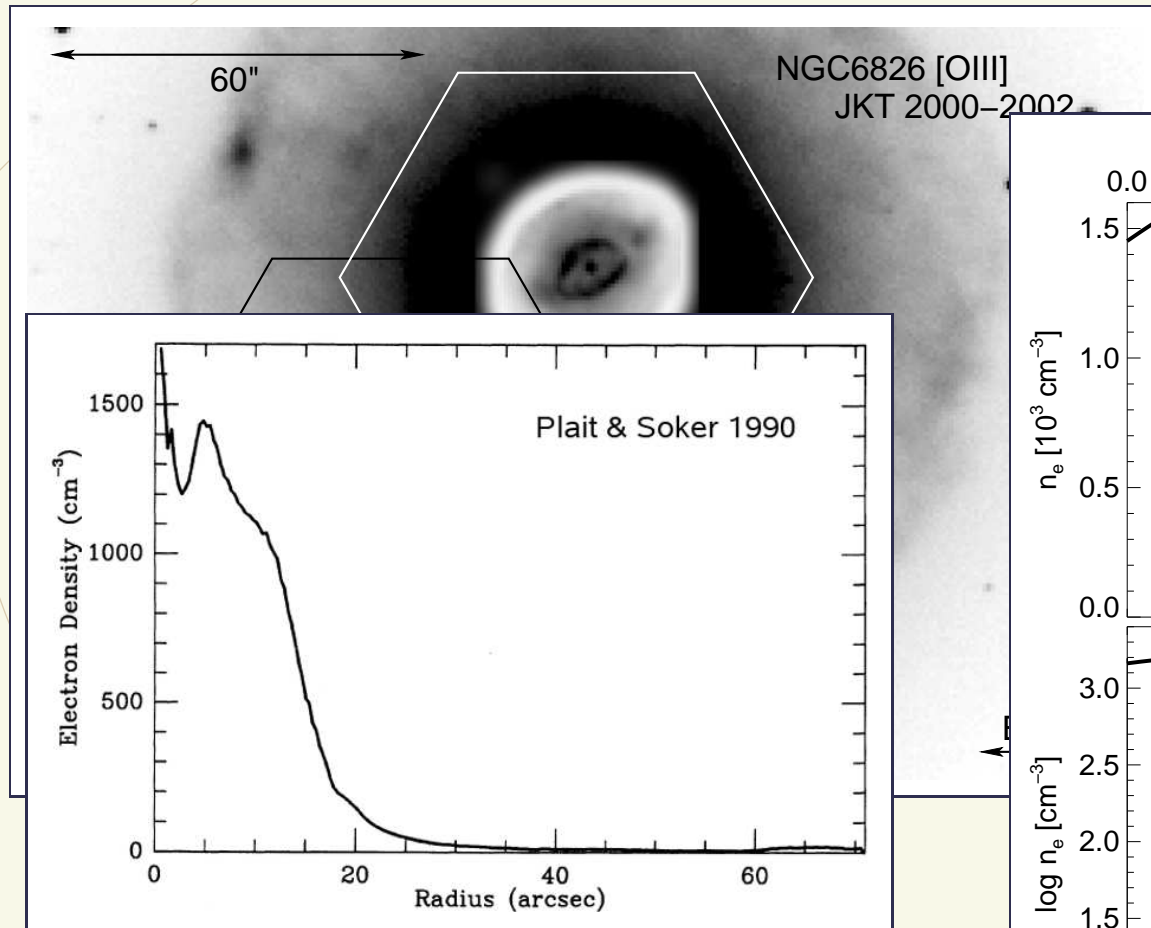
# NGC6826 – “Blinking Eye Nebula”



Radial temperature structure

(Sandin et al. 2007, in prep.)

# NGC6826 – “Blinking Eye Nebula”



Radial  $n_e$  structure  $\Rightarrow d = 2.5 \text{ kpc}$   
(Kudritzki et al. 2006:  $d = 2.6 \text{ kpc}$ )

(Sandin et al. 2007, in prep.)

Observations & Data reduction

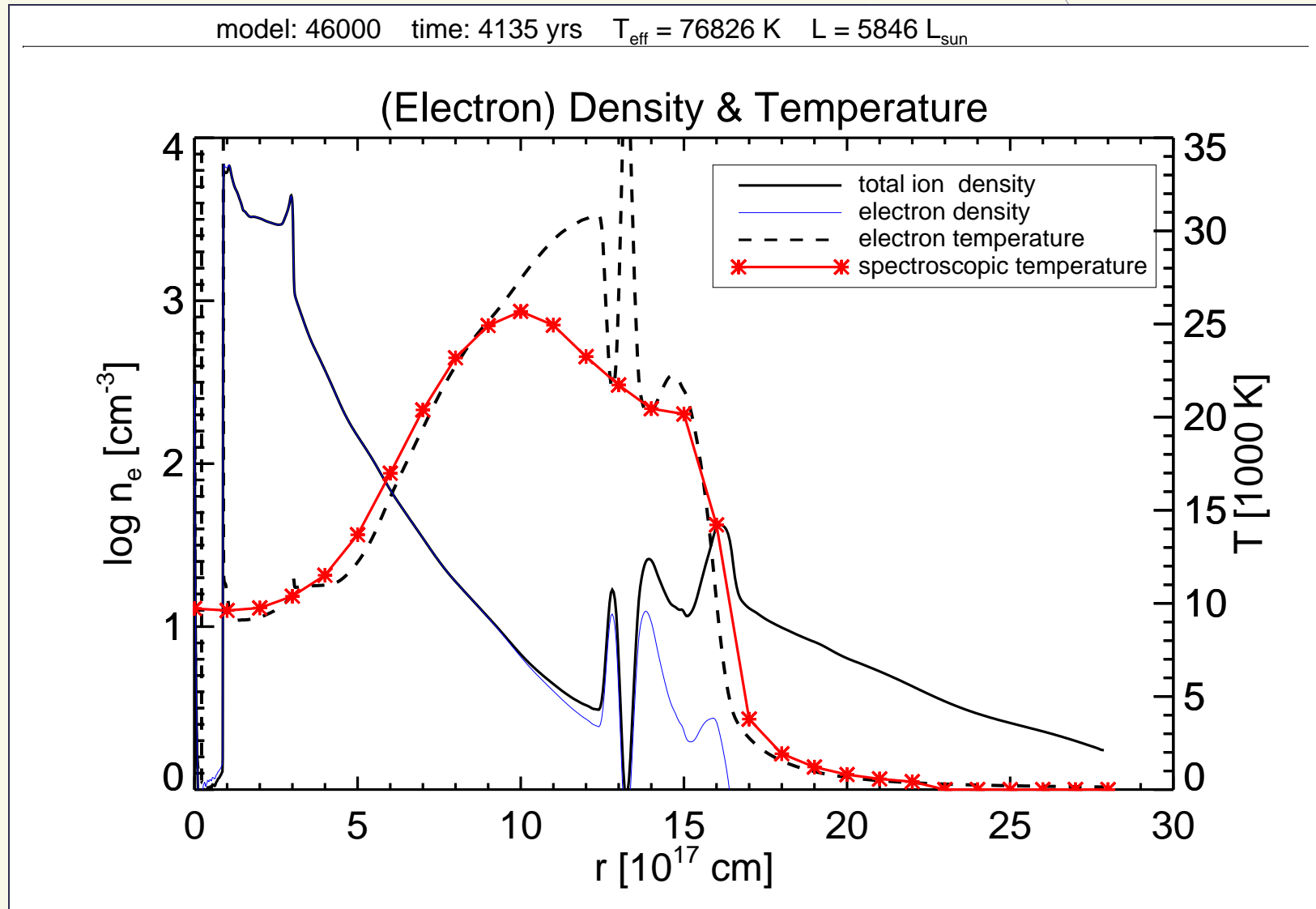
Results

⇒ **Modeling** ⇐

Conclusions

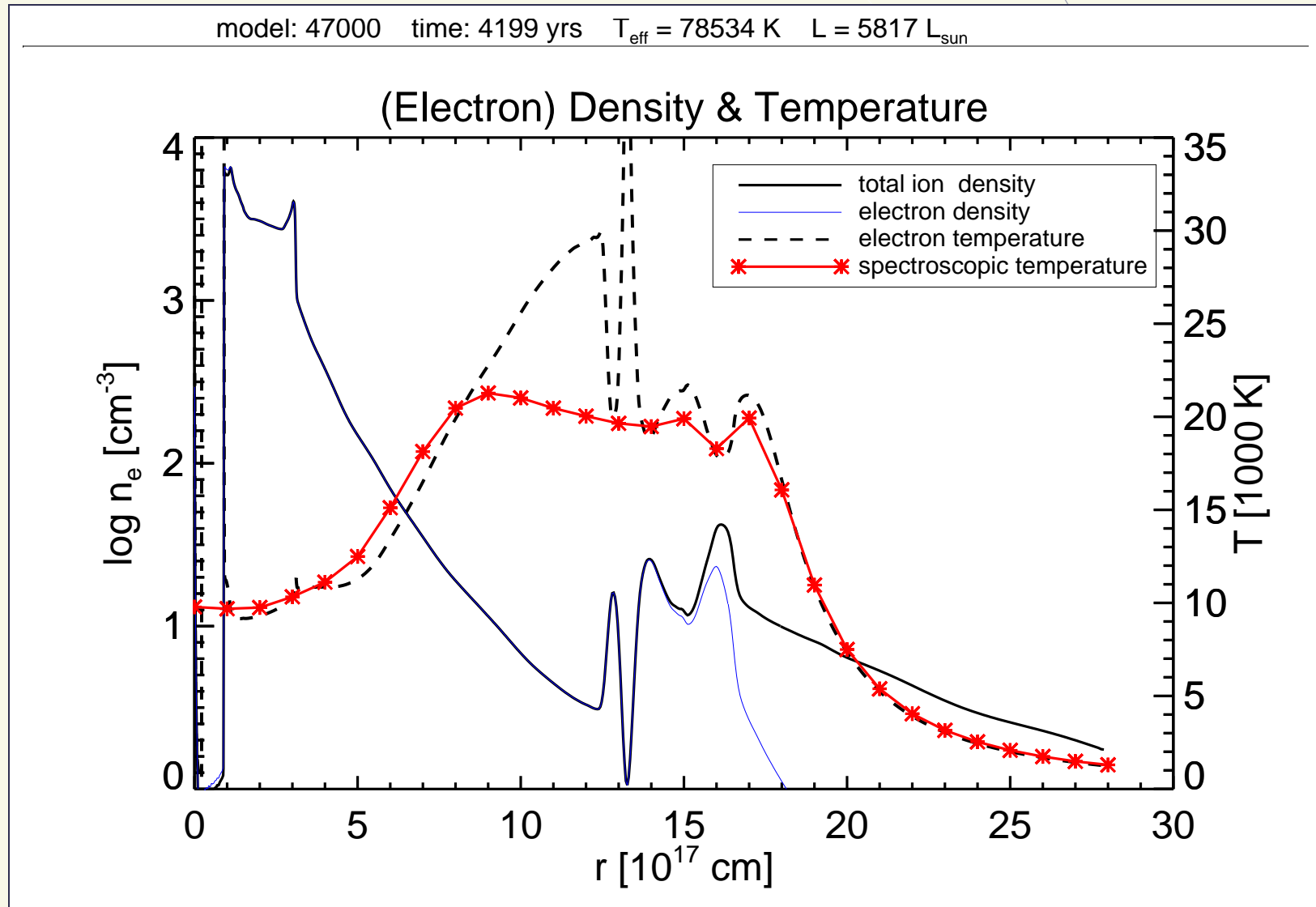
# Interpreting observations – modeling

## Temporal series illustrating the traversal of the ionization front – 1/3



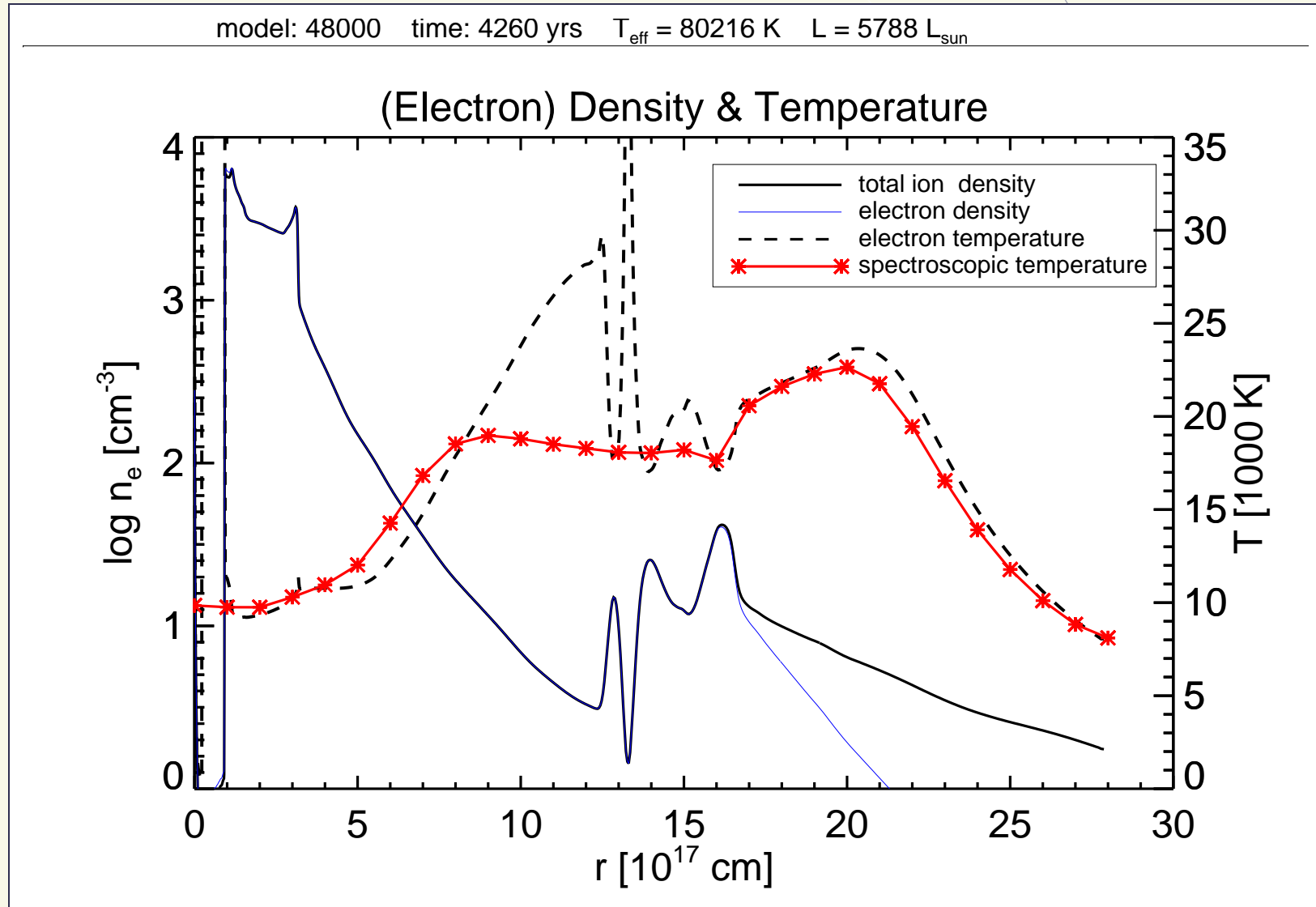
# Interpreting observations – modeling

## Temporal series illustrating the traversal of the ionization front – 2/3



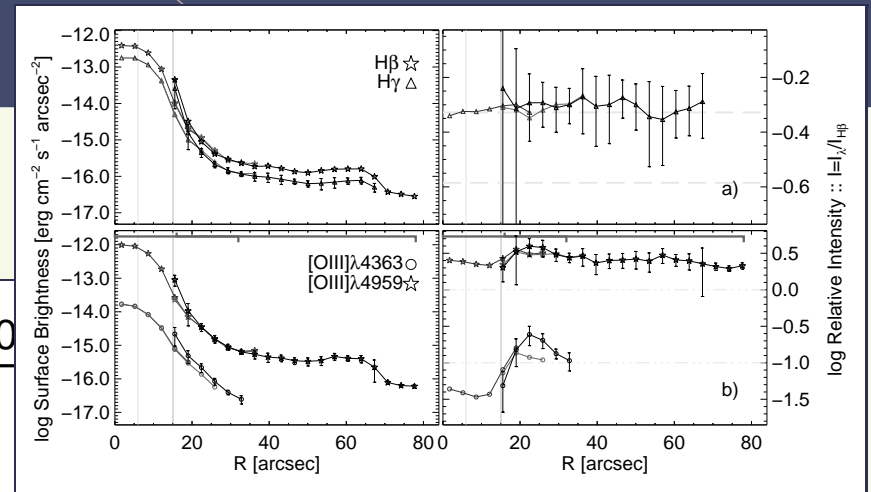
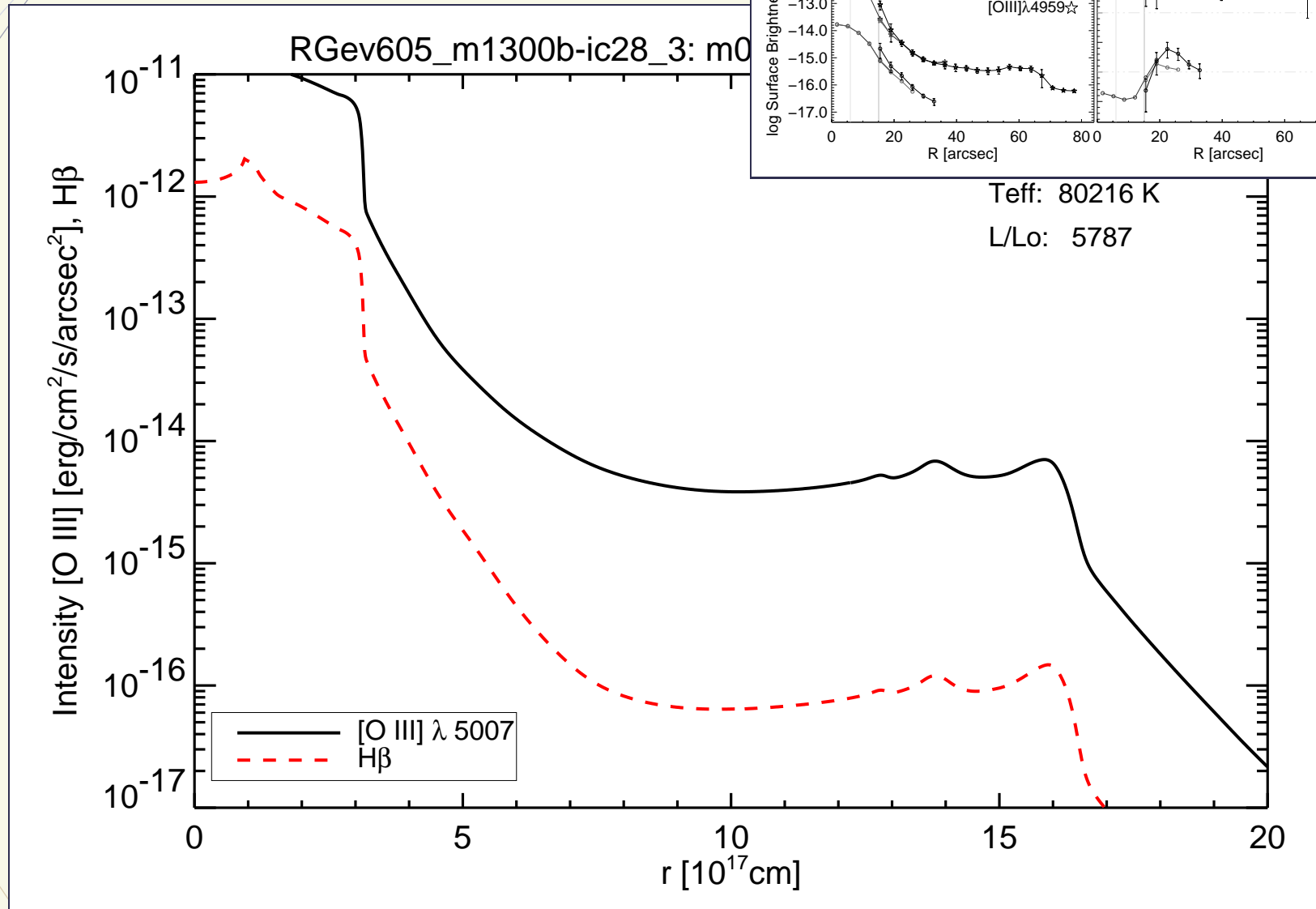
# Interpreting observations – modeling

## Temporal series illustrating the traversal of the ionization front – 3/3



# Interpreting observations – modeling

## Surface brightness curves



# Presentation – overview

Observations

Results

Modeling

⇒ **Conclusions** ⇐

# Conclusions

- Binning of spatial elements  $\Rightarrow$   
increases S/N of weaker lines  $\Rightarrow$   
**allows observations of a weak halo**

... Ideally, one would like a spectrograph having thousands of input apertures which can be configured to a packed array of several hundred per side to sample the sky at arc-sec intervals...

Jacoby, Quigley, and Africano 1987, PASP 99, 672–685

- Hot halos require **time-dependent models** to explain the physical structure
- Final mass loss rates are time-dependent

Project: Part of XPN project [<http://www.aip.de/groups/xpn/>]



## Future prospects – upcoming related tasks & projects

- Calculation of abundances – where possible,  $T_e$  and  $n_e$  necessary
- Physical structure of galactic disk PNe halos  
Sandin et al. 2007, in preparation
- Reduction & analysis of **halo** PNe – physical structure  
6 out of 11 objects are observed
- Velocities in halo & LMC PNe – VLT project

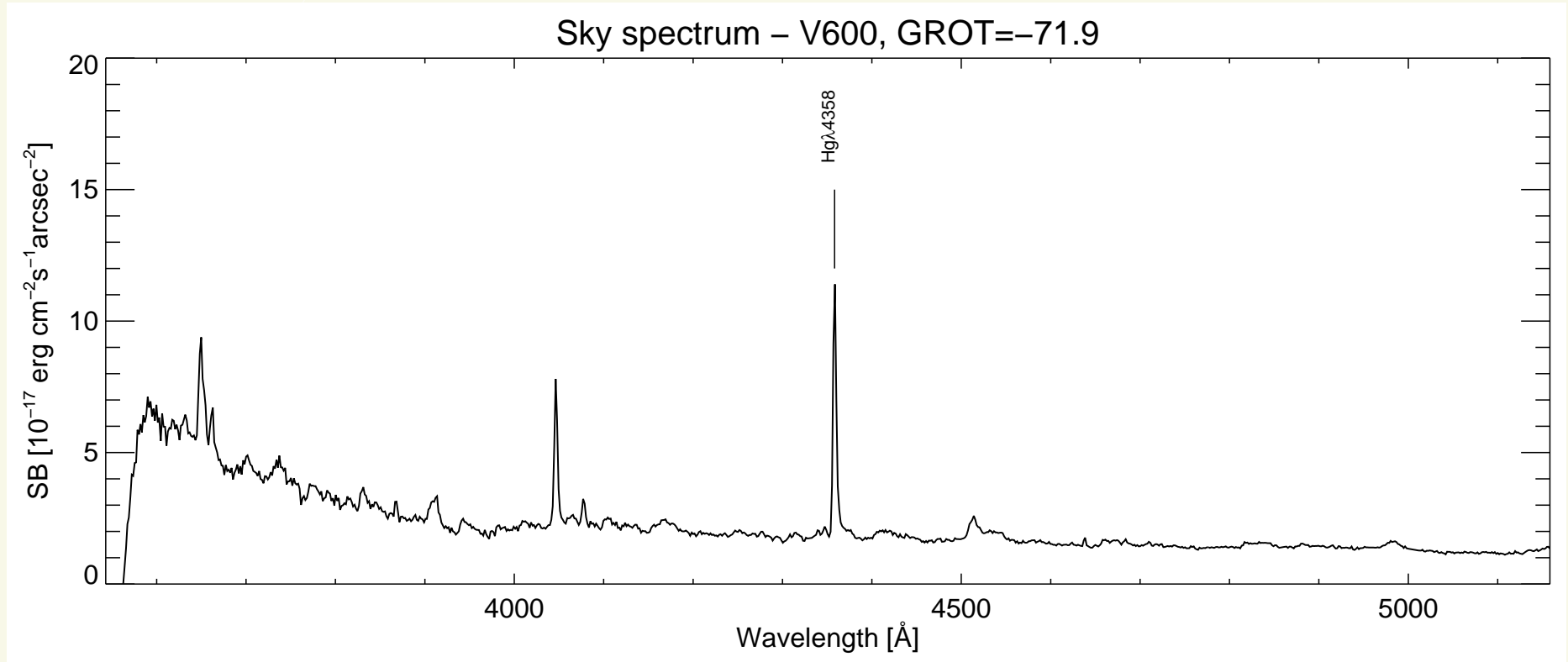
Project: Part of the XPN project

[<http://www.aip.de/groups/xpn/>]



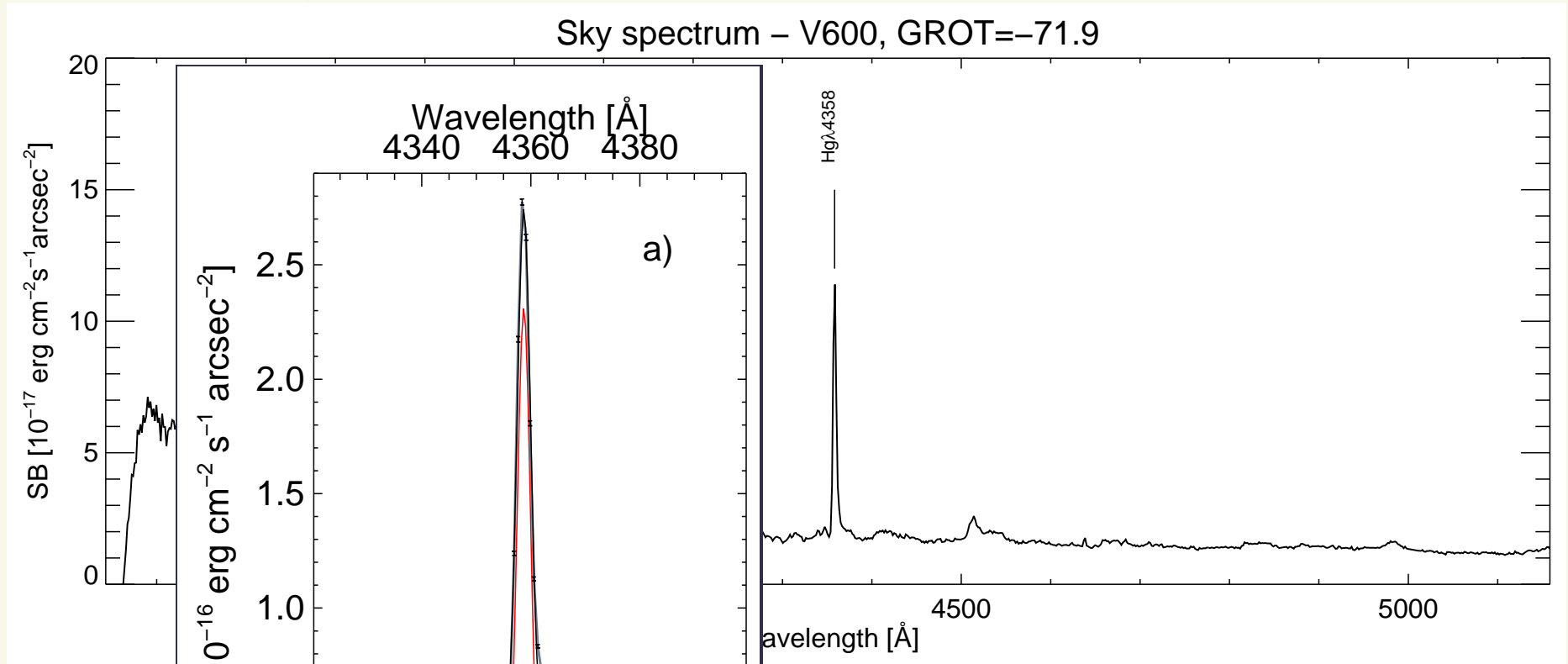
# Sky subtraction, removing sky emission lines from object data

Sky emission lines in important regions have to be removed



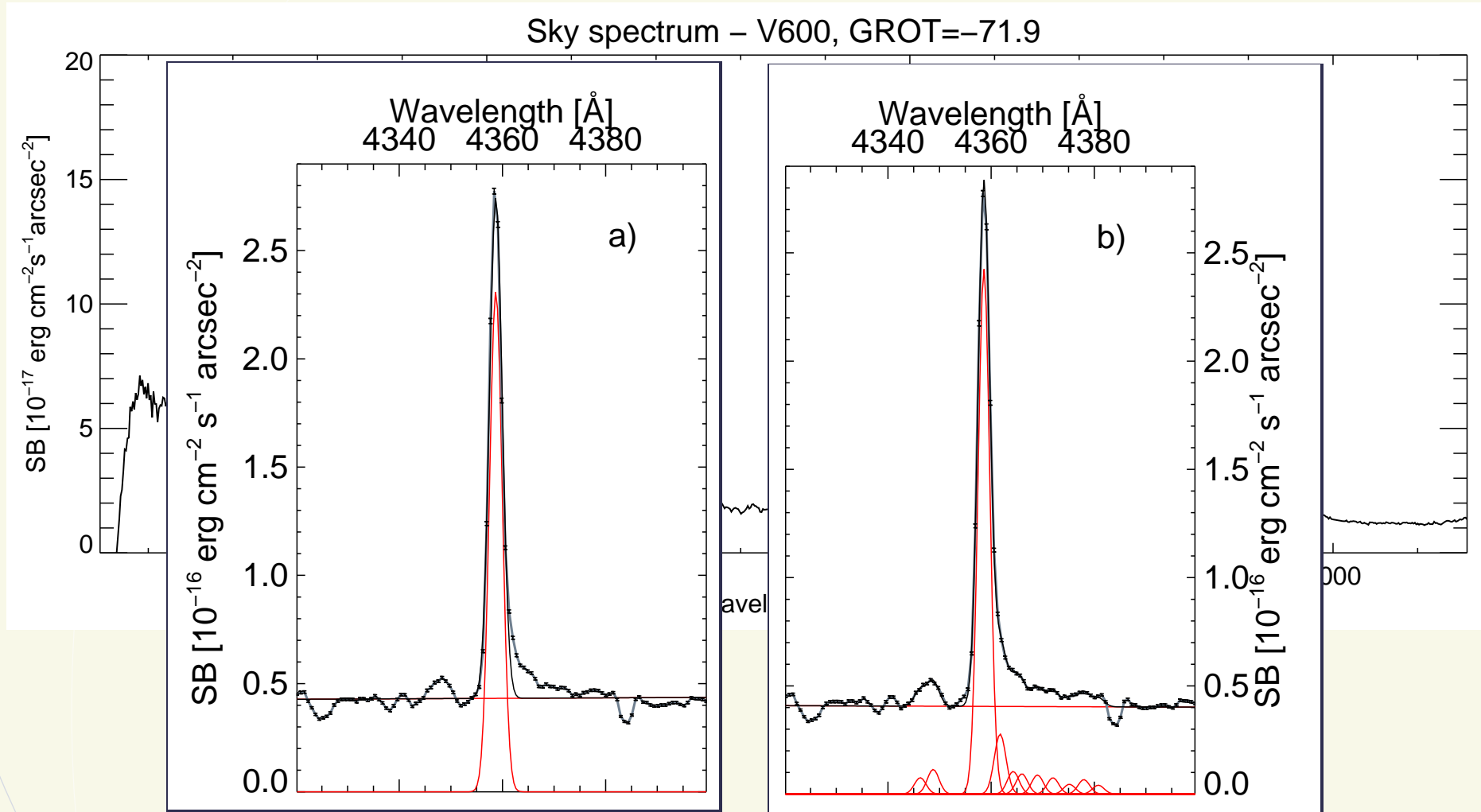
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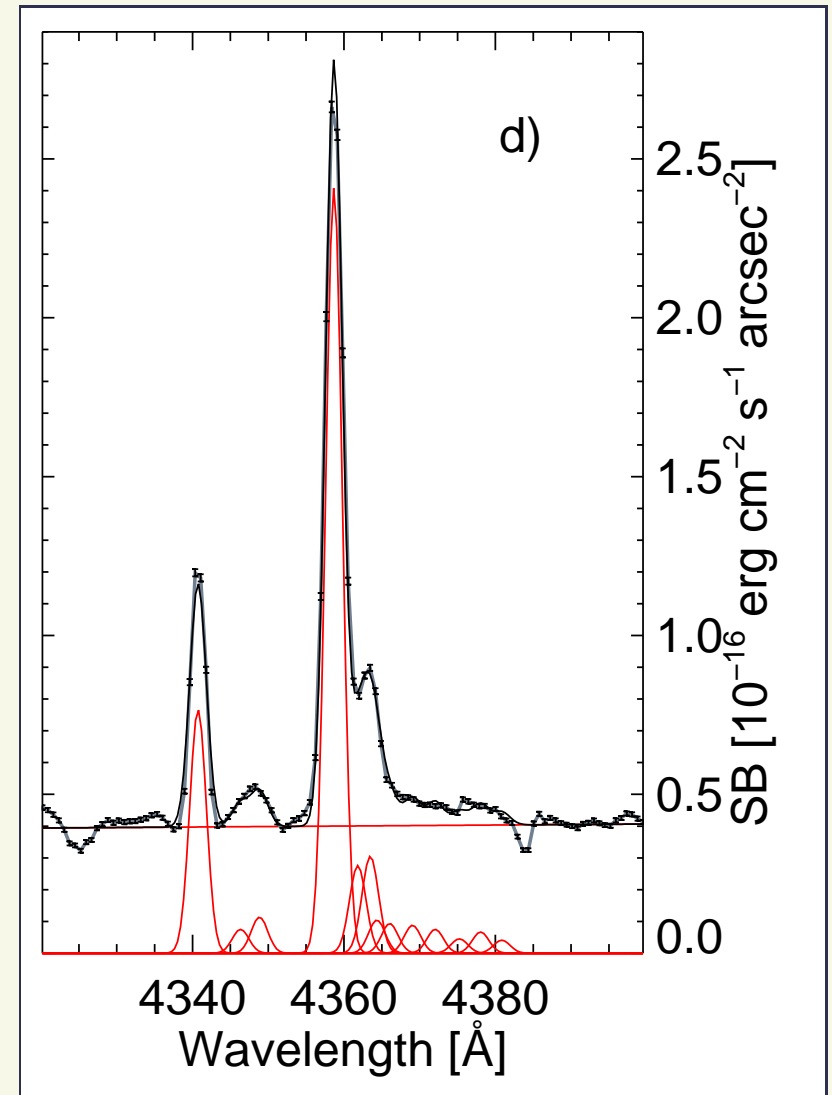
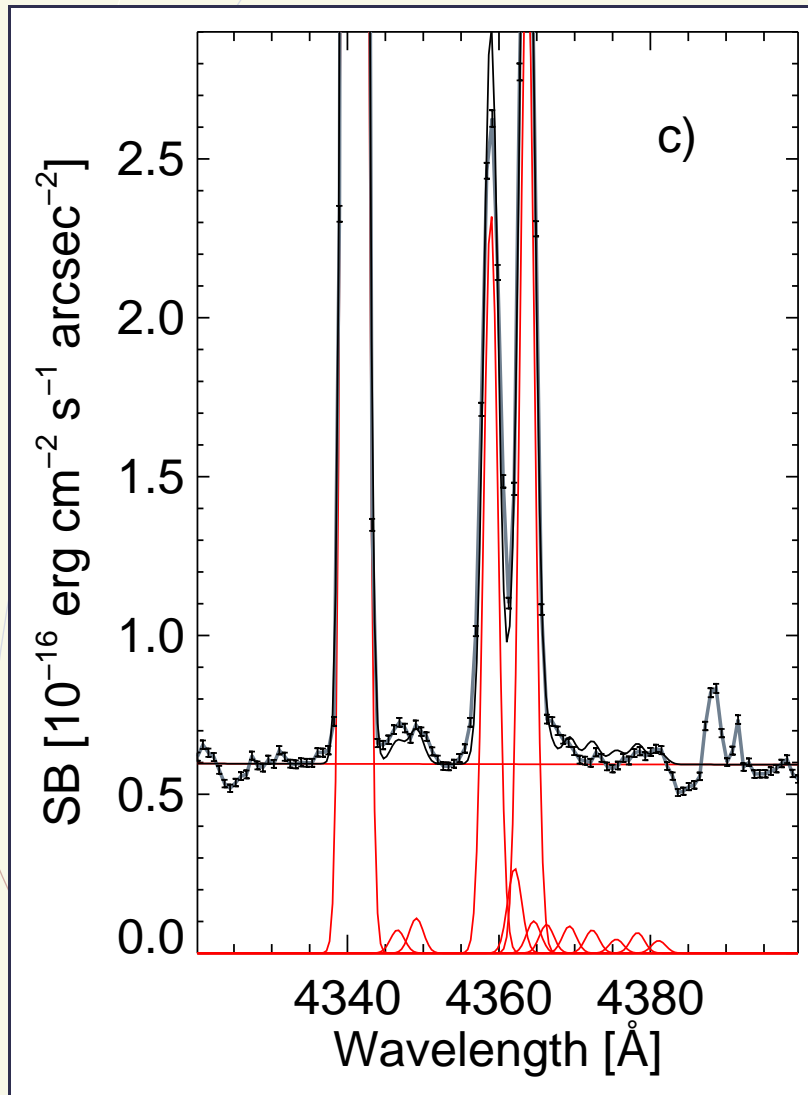
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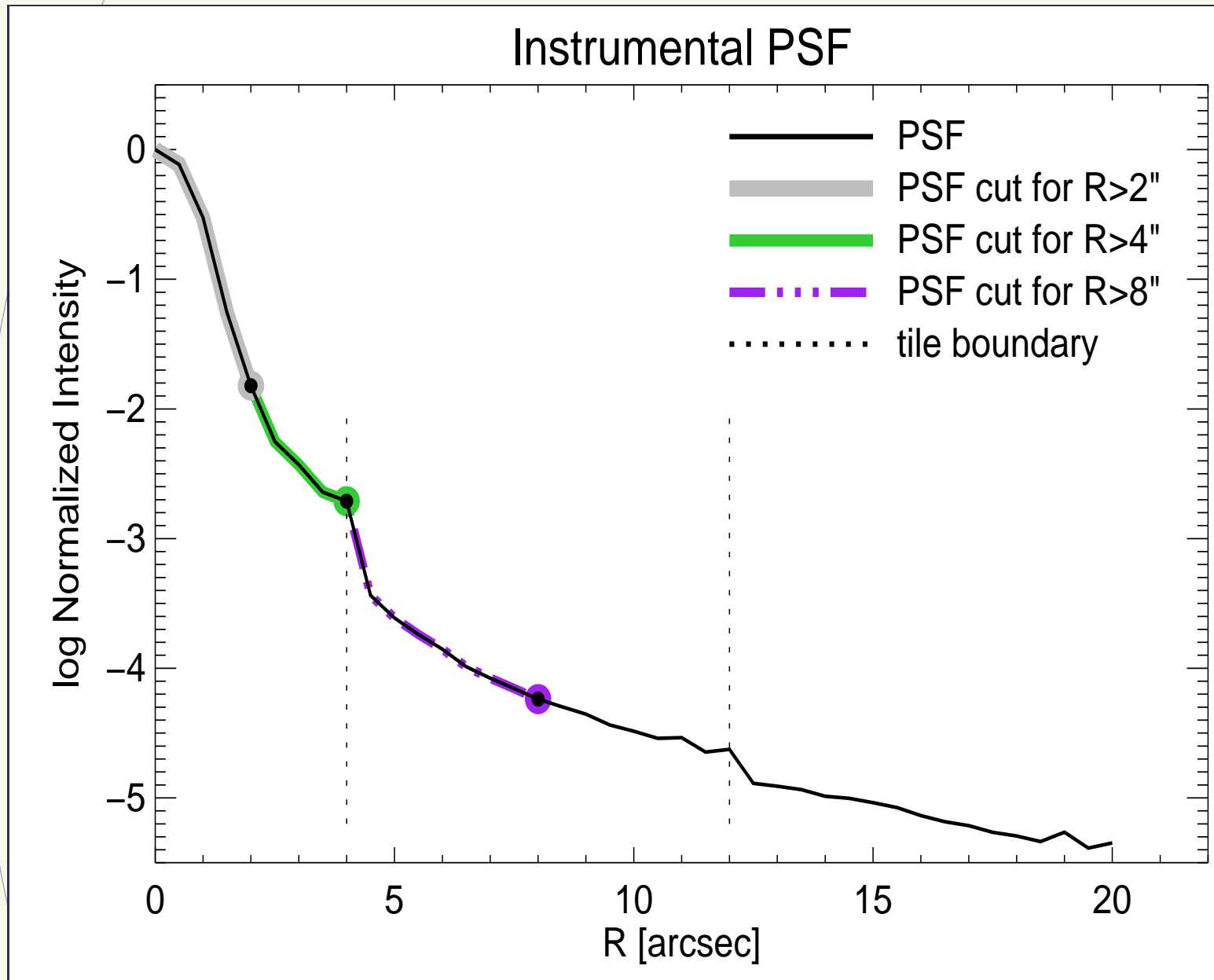


# Sky subtraction, removing sky emission lines from object data

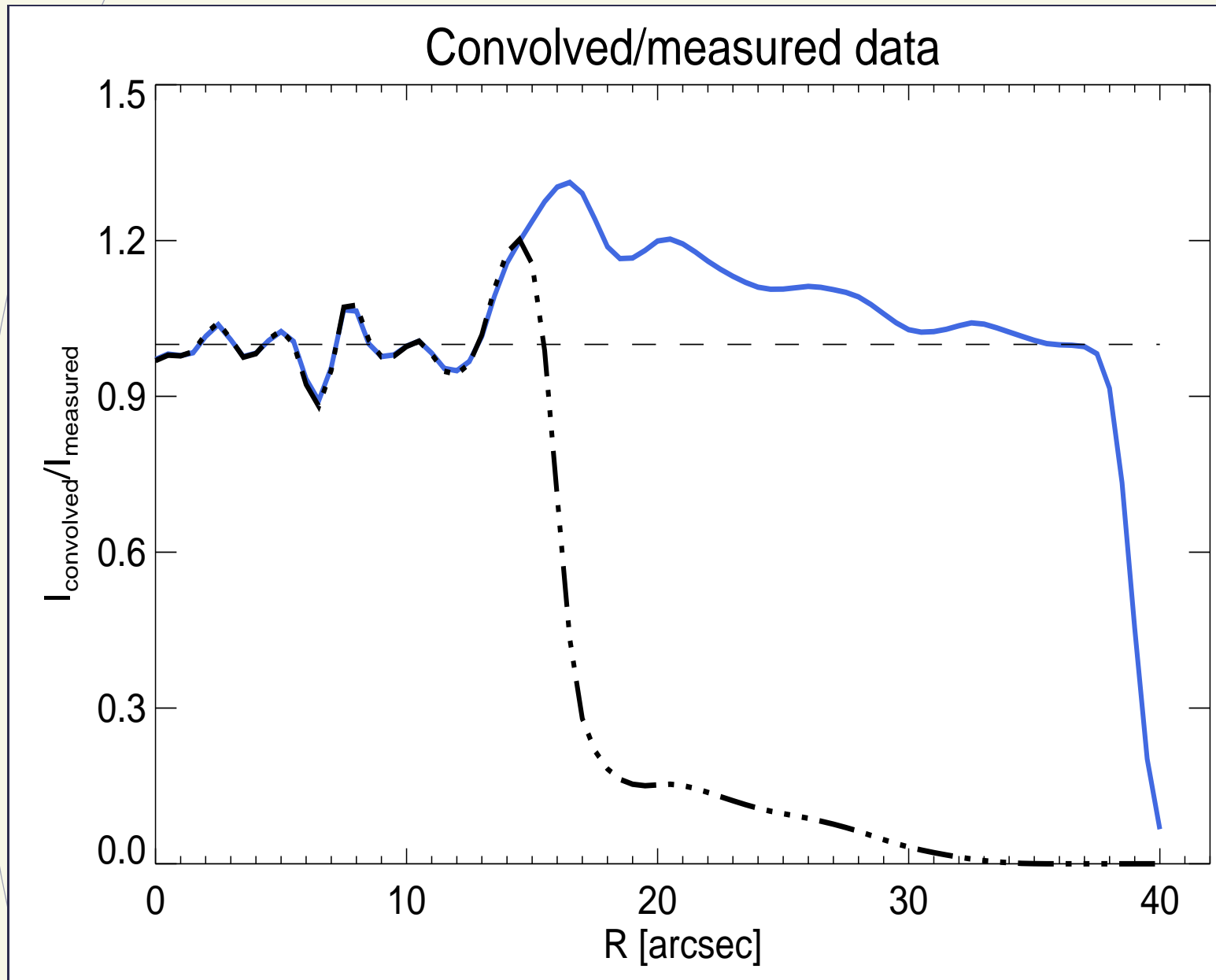
Using sky emission lines of locked relative intensity; final result



# Estimating the level of scattered light



# Estimating the level of scattered light



# Estimating the level of scattered light

