Spatially-Resolved study of planetary nebulae with Seimei/KOOLS-IFU; the case of IC2165

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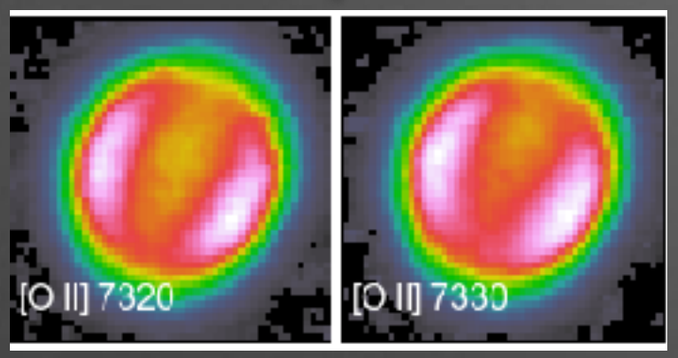
This work is based on NAOJ open-use time and Kyoto U. time

Backgrounds

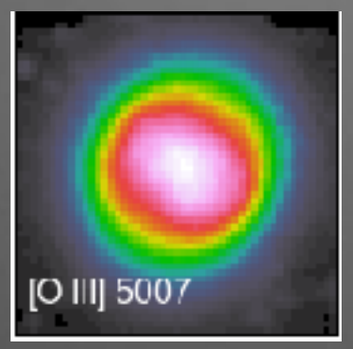
Case of planetary nebula (PN) IC418 w KOOLS-IFU

O^+/H^+



+

O^{2+}/H^+

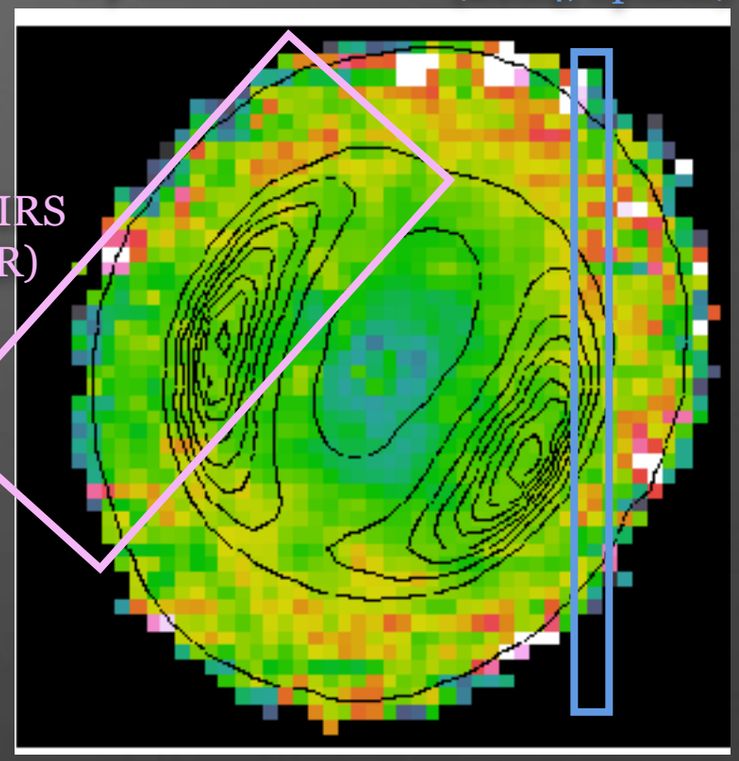


=

O/H

Sharpee et al. (2004, optical)

Spitzer/IRS (mid-IR)



- The measured abundances determined only from spectroscopic data of a single narrow-slit exposure DO NOT represent the average abundances PN. For example, Spitzer/IRS mid-IR vs. Sharpee et al. (2004).
- Elemental abundances are NOT Uniformly distributed within dusty nebula, due to nucleosynthesis history, traps by dust grains/molecules, ionization, mass-loss wind…

To fully understand PNe and obtain the representative abundances, spatially-resolved spectroscopy is necessary! IFU instruments have advantages over slit-scan!

Aims of this study

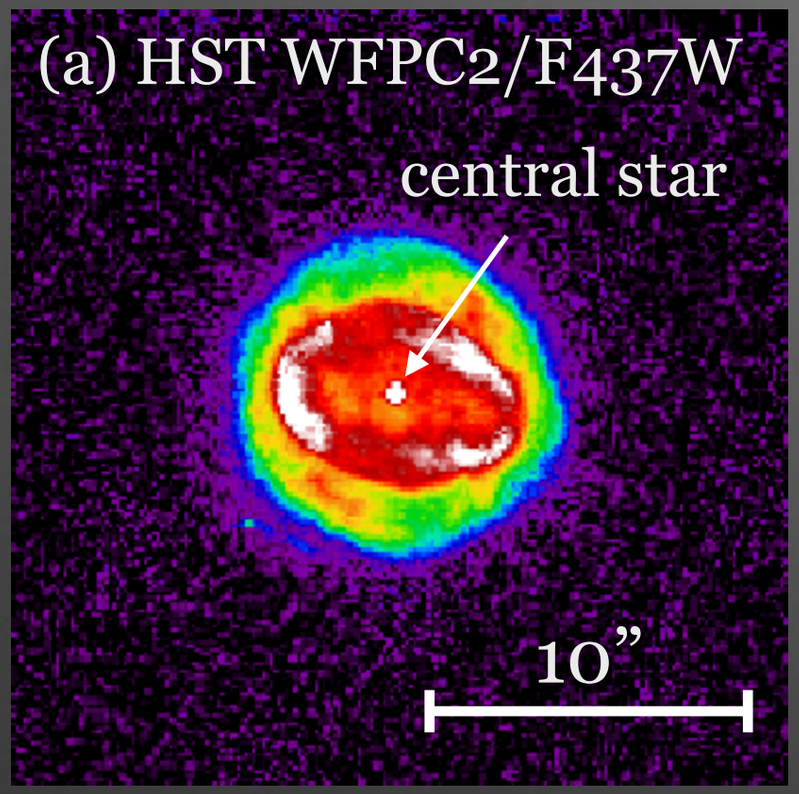
We study Galactic PNe using Seimei/KOOLS-IFU and archive data in multiwavelengths for investigation into

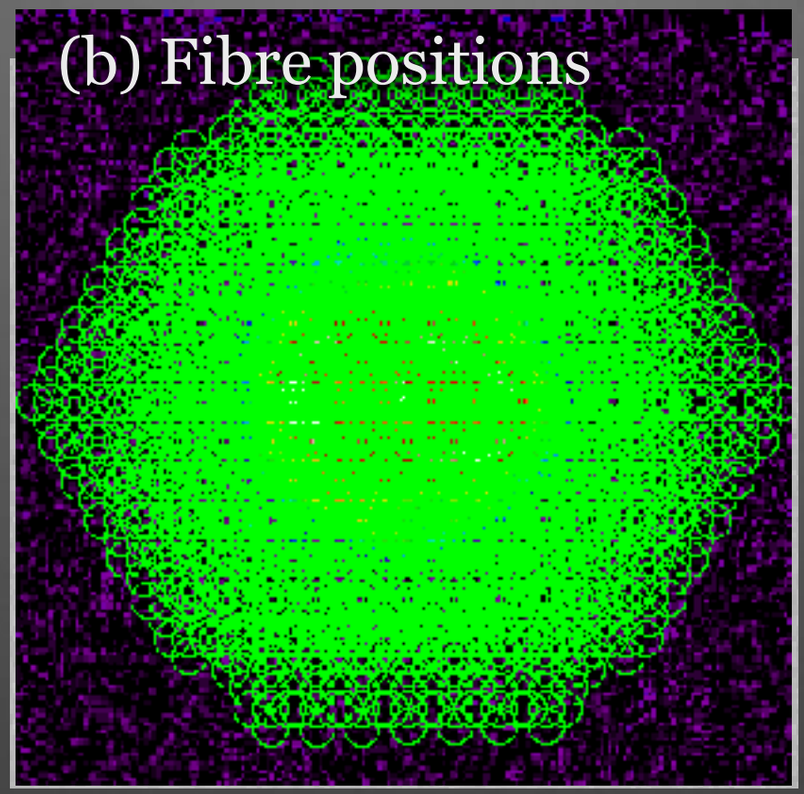
(I) spatial distributions of dust extinction, electron densities/ temperatures, and ionic/elemental abundances

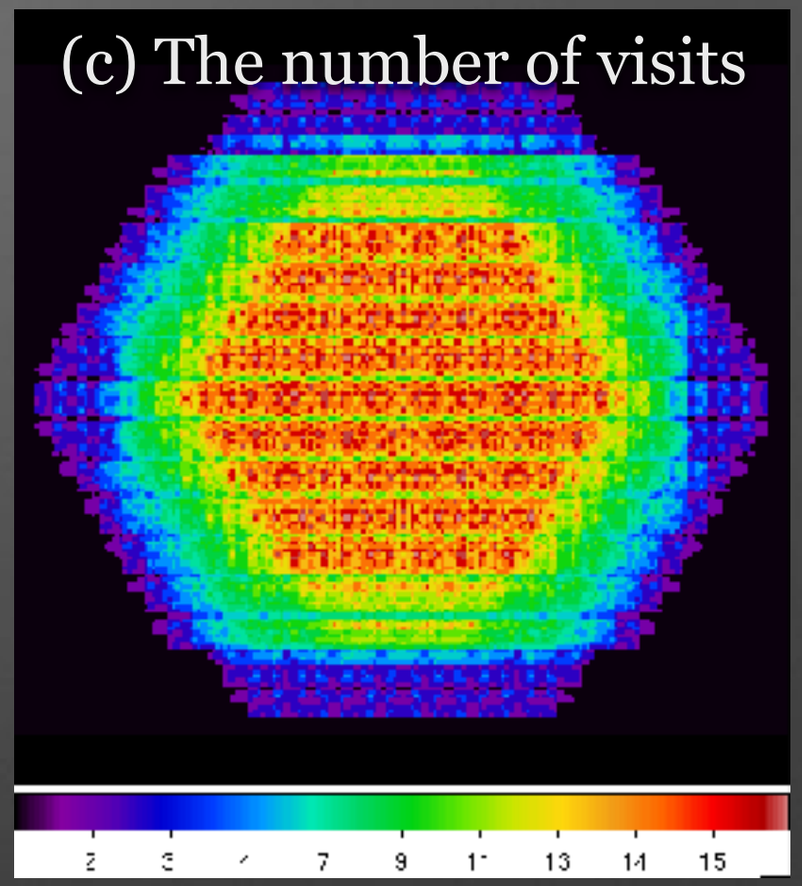
(II) spatial distributions of gas/dust masses and gas-to-dust mass ratio by combing use of IR data

(III) evolutionary history of the progenitors by comparing observed quantities with theoretical AGB model

Mapping observations towards IC2165 w Seimei/KOOLS-IFU







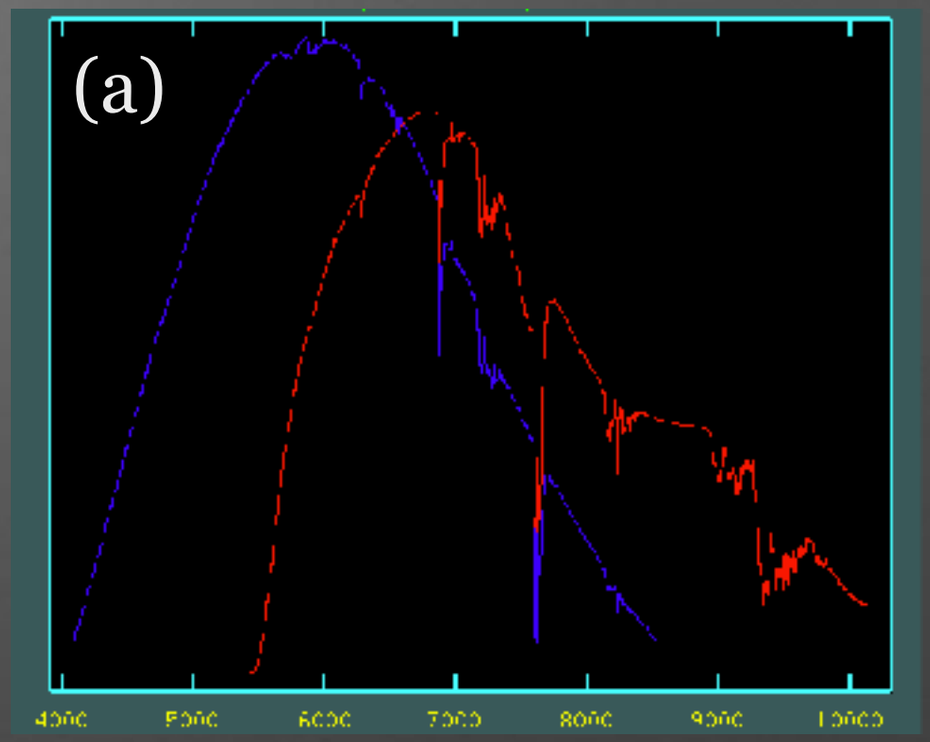
- We observed IC2165 (panel a) using the VPH-Blue and Red grisms, covering 0.4-1 μm under clear/stable sky; 4.5-5.2 °C in outside temperature, 76 – 78 % in relative humidity, and 985.5 hpa in pressure.
- We took a single 60s exposure on each 25 dither position (panel b).
- Exposure map (panel c) indicates that we took (13-18) x 60 sec exposure toward the nebula and central star.

Data Reduction

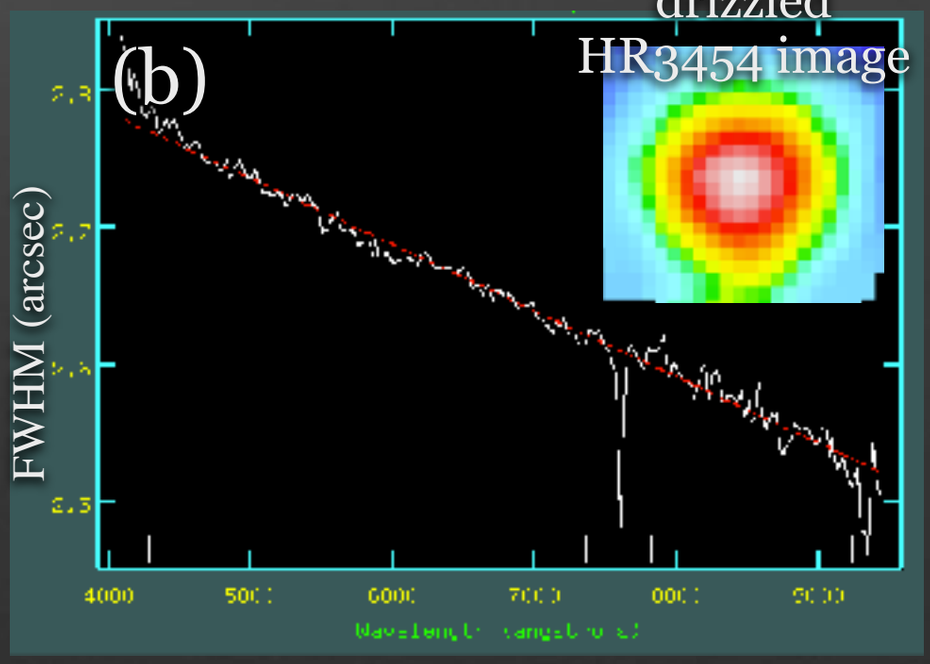
We improved following points;

- Displacements in spatial owing to atmospheric dispersion
- Issues on flux calibration database (e.g., magnitude, blue and red spec connection with forcefully removing absorptions in the blue spec, and less data in near-IR, etc) and also telluric removal (panel a)
  - By comparison of the modelled with the observed spectra, we obtained sensitivity/telluric removal function.
  - As a bonus, the issue on transition probabilities of [S III]9068/9530Å was gone.
- FWHM versus wavelength relation (panel b)
  - Now, we can safely compare other spec, e..g., Spitzer（PSF~3”), IUE（PSF~4.1”）with KOOLS spec!
- Further correction factor (1.048) by comparing with the KOOLS-PSF *convolved* HST F547M image
- Richardson-Lucy (RL) deconvolution
- Others
  - De-stripe residual bias pattern （ref. the Messenger, vol. 70, p. 82-84)

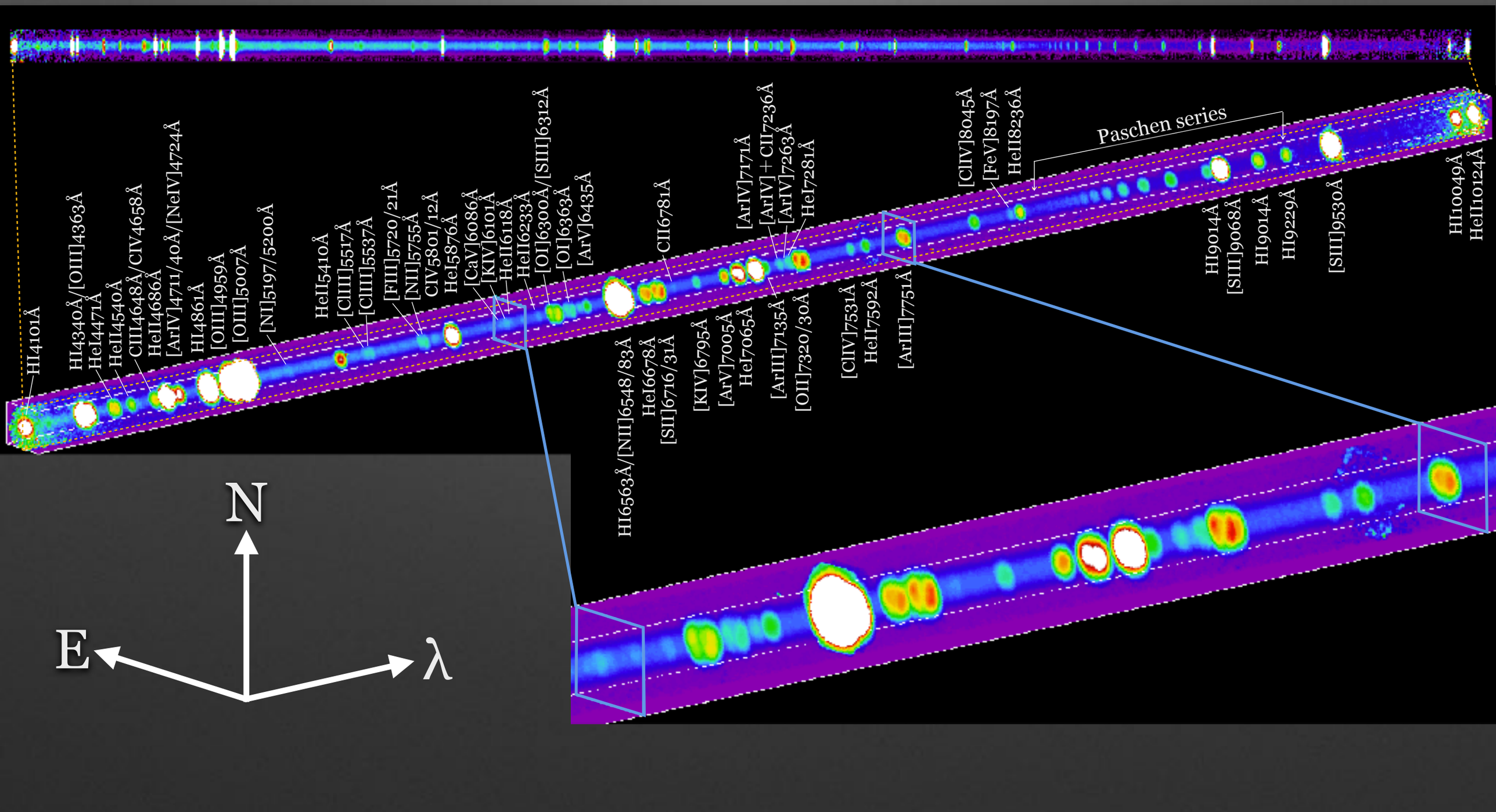
sens. function



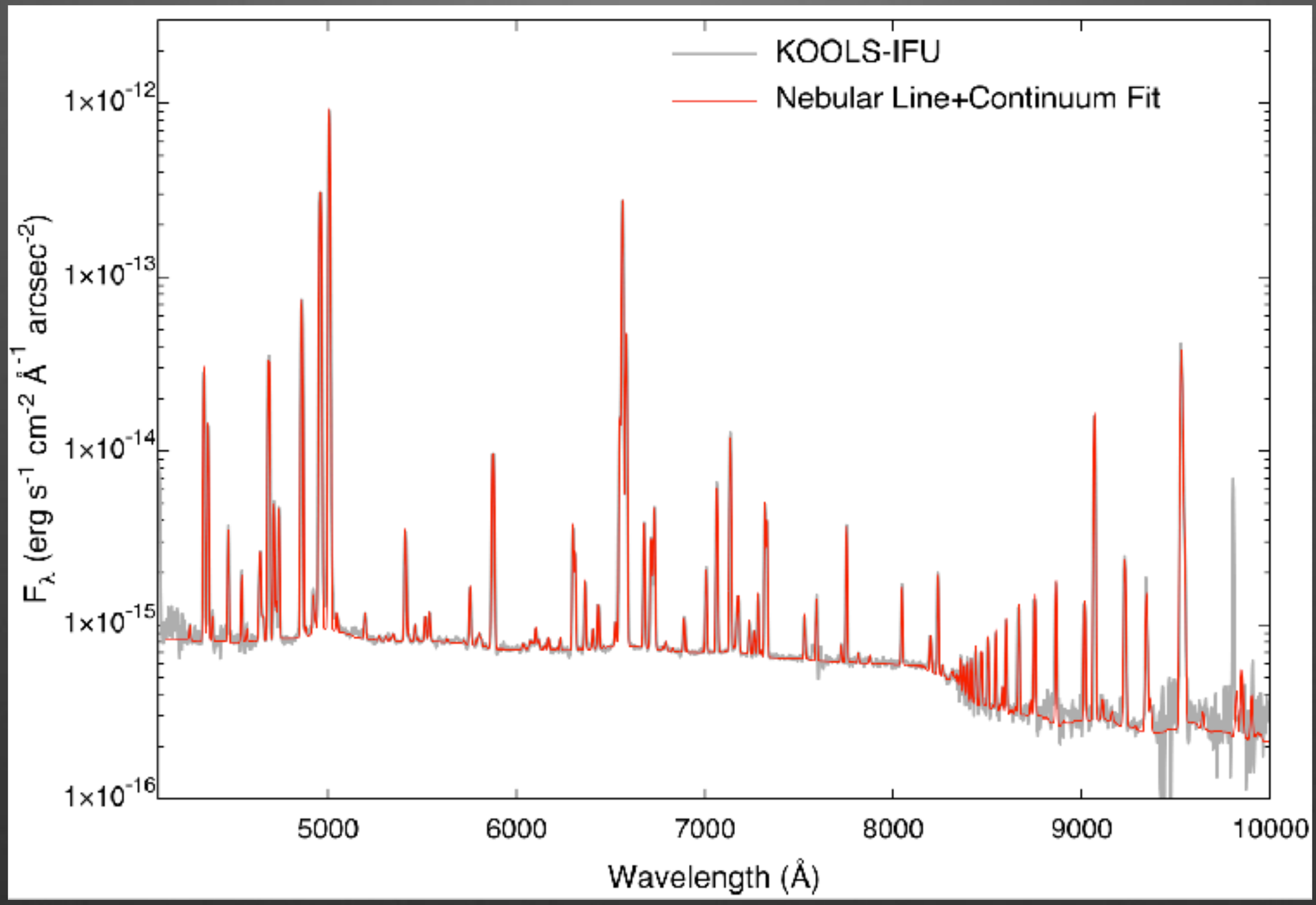
drizzled HR3454 image



KOOLS-IFU 0.4-1μm
RA-DEC-λ CUBEDATA of IC2165

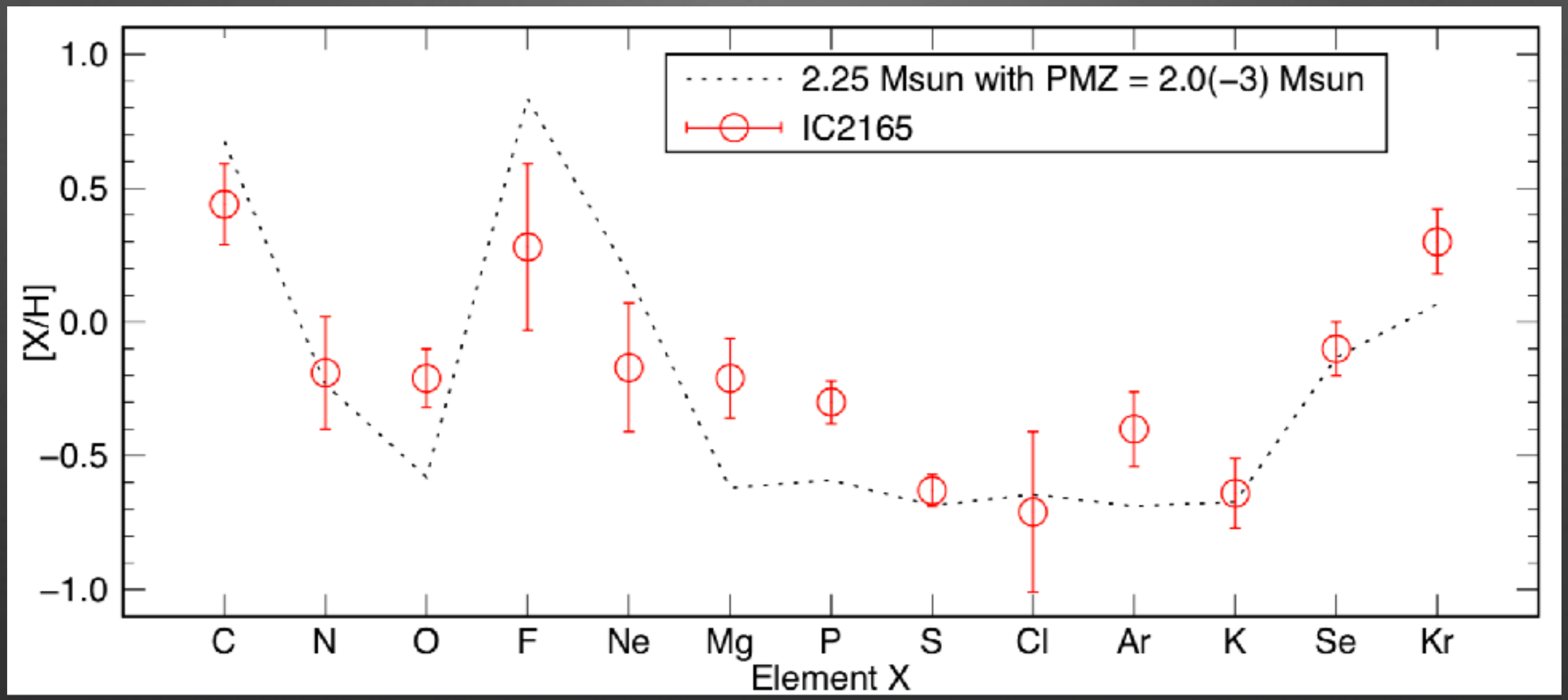


Spectra Fitting



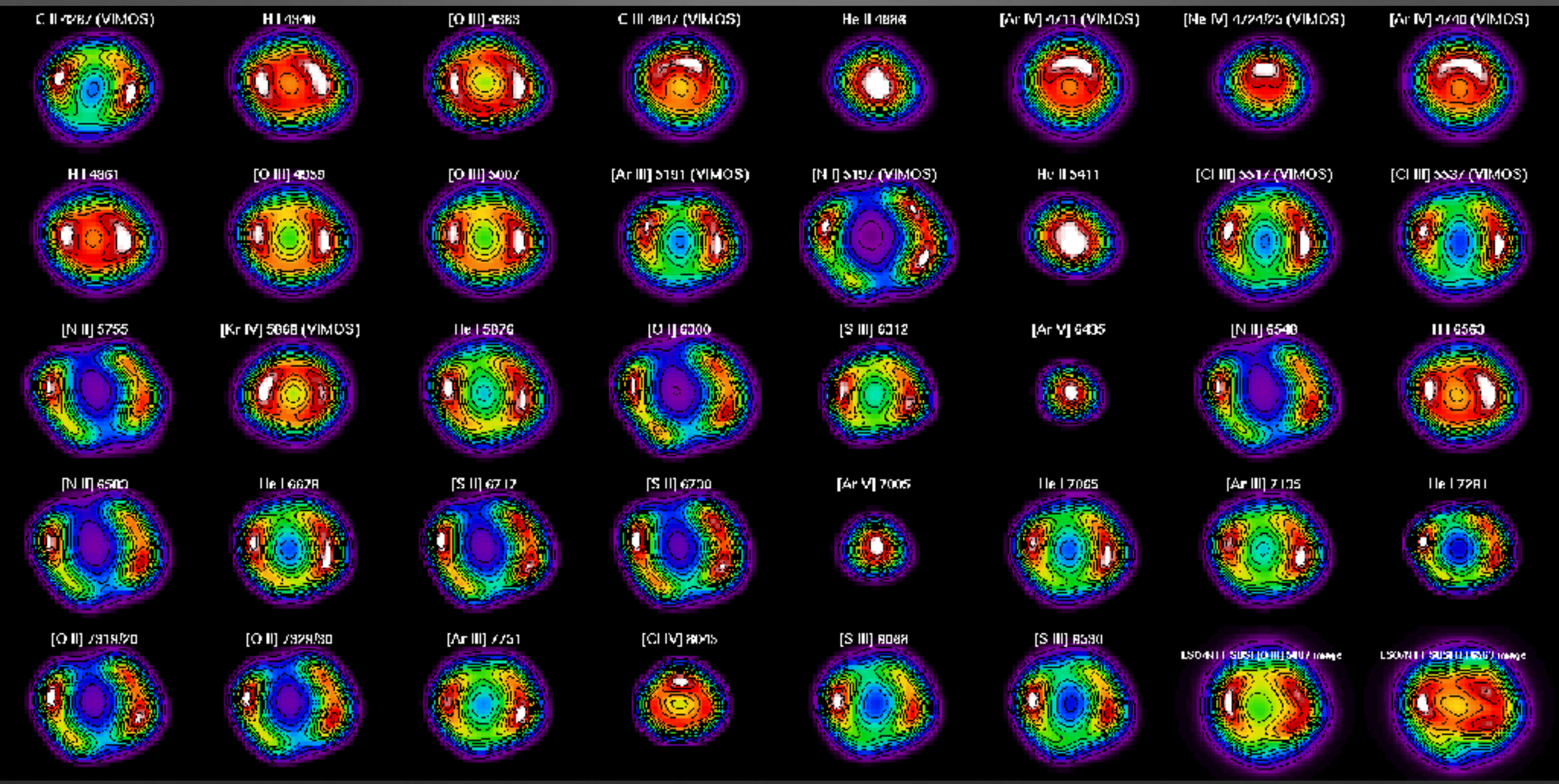
- We employ Multiple Gaussian Fitting for the 1-D spectra at every spaxel.
- We detect/identify 105 emission lines in 4300-10200 Å.

Nebular abundance analysis based on the 1-D KOOLS, IUE, Spitzer spectra



Emission Line Maps

Final FWHM~1.2”

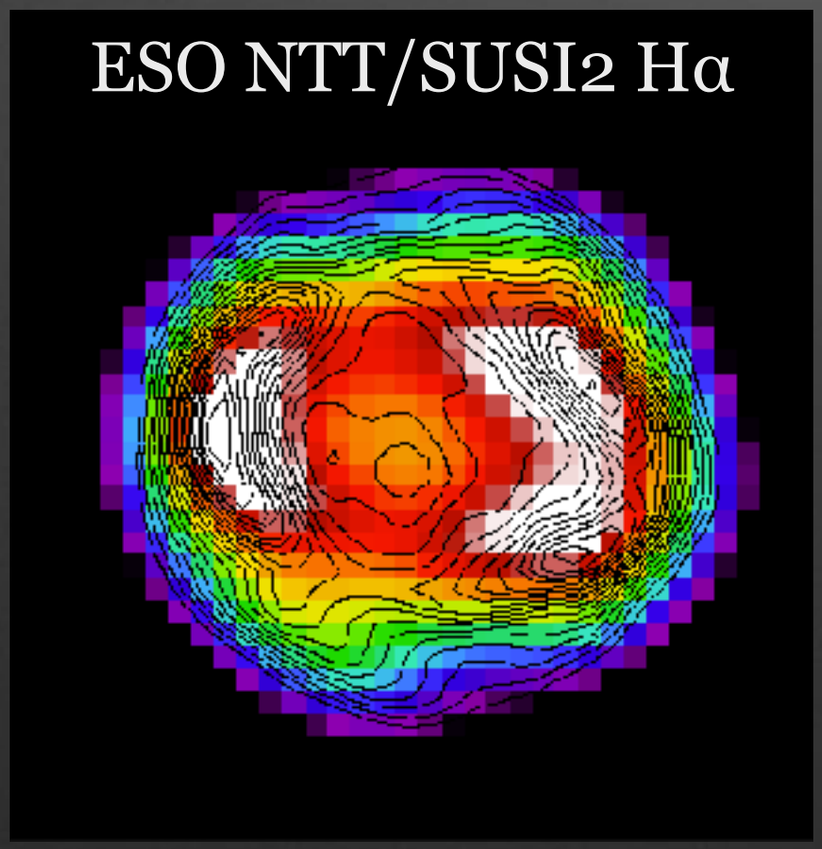


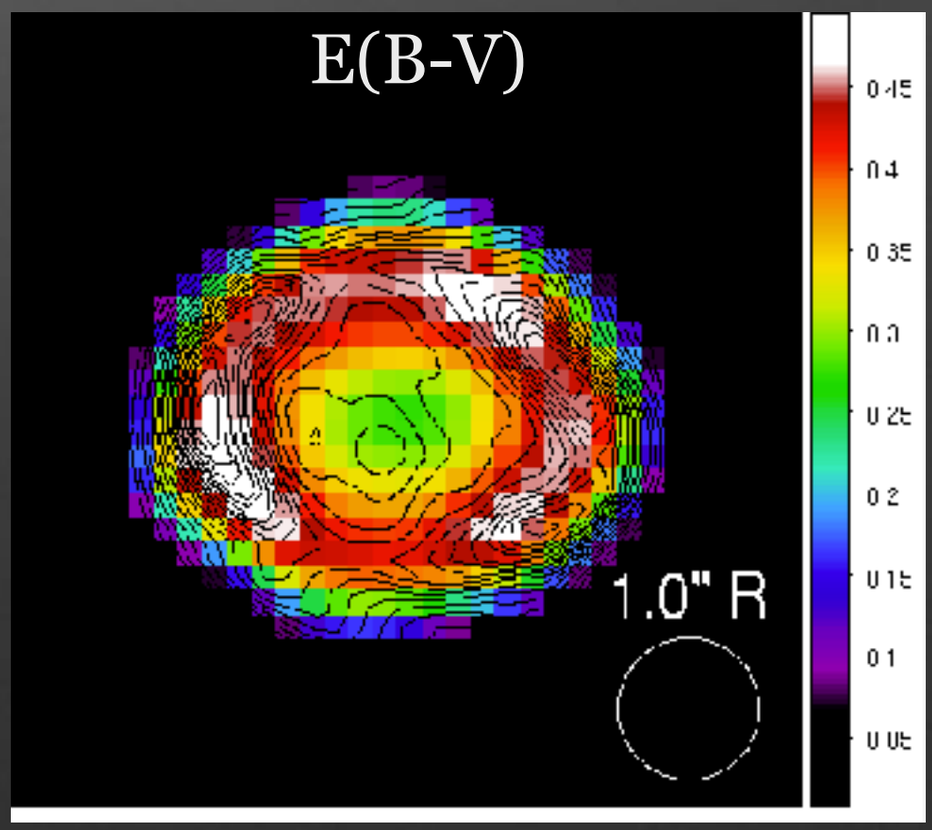
Extinction Map as an indicator of dust distribution

By comparison between observed F(Hγ, 6 Paschen lines)/F(Hβ) and the theoretical ones as follows;

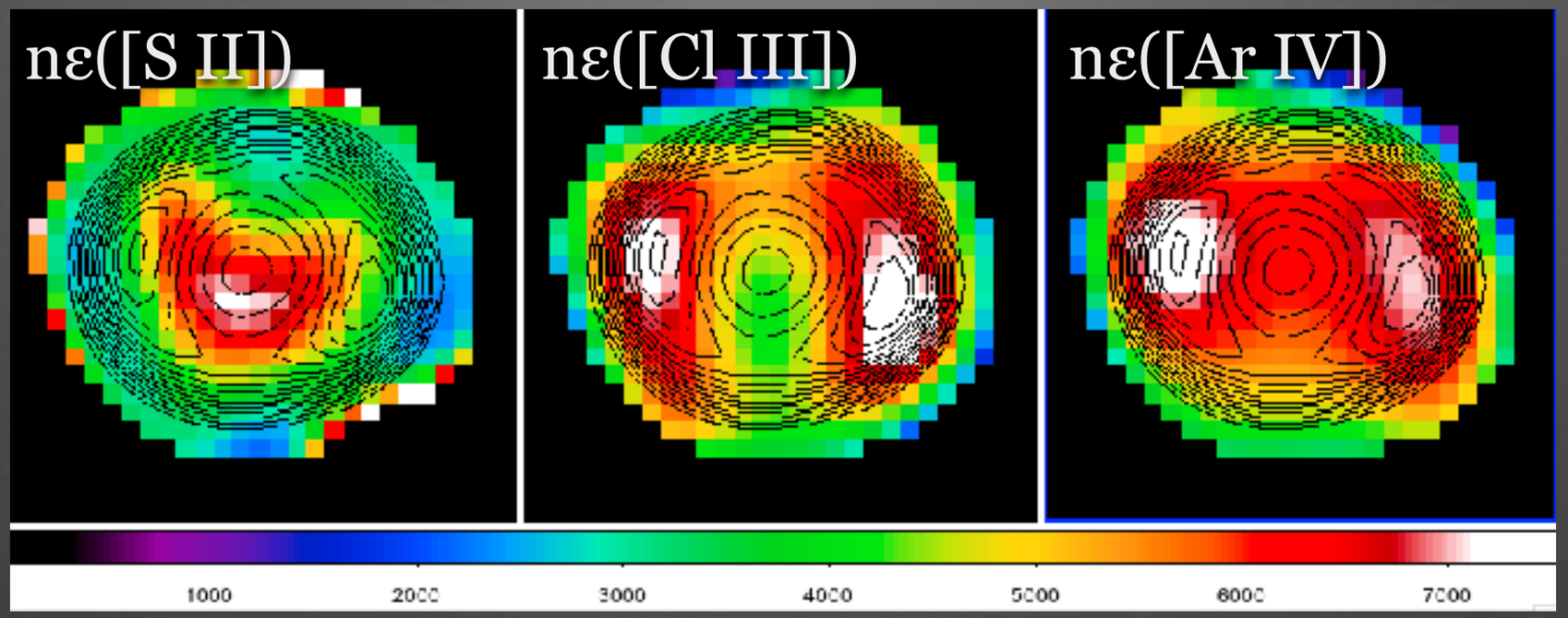
- step1: correct line fluxes with a constant c(Hβ) value; c(Hβ)=1.45E(B-V) with Rv=3.1 and CCM reddening function
- step2: calculate Tε/nε values in each pixel using diagnostic line ratios
- step3: compute theoretical H I lines to Hβ ratio values (as a functions of Tε/nε) in each pixel
- step4: compare the observed HI lines to Hβ ratios with the theoretical values calculated in step3. Thus, c(Hβ) was obtained.
    - Iterate steps1-4 4 times.

These H I lines are not contaminated with He II lines, which are removed out by employing similar technique, of course.





Electron Density (nε) and Temperature (Tε) maps



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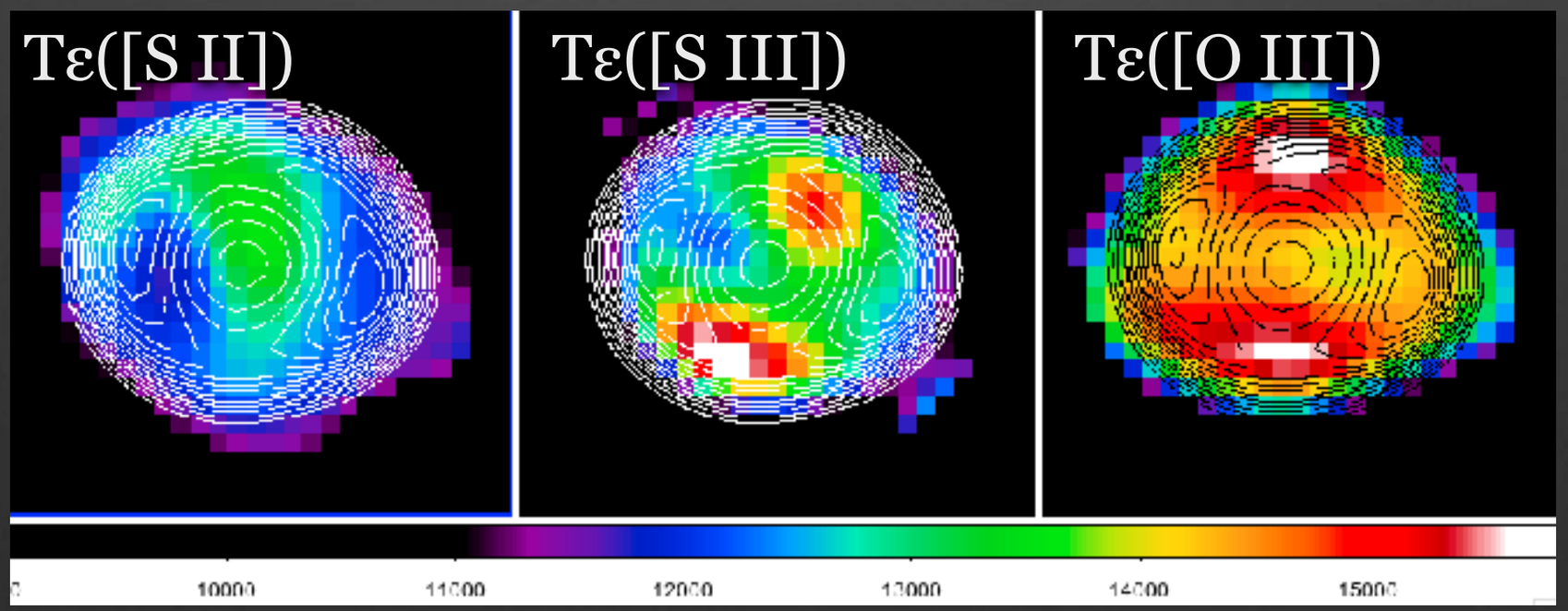

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Progress and Future Plan

- ✓ Abundance analysis based 1-D spectra taken by IUE, KOOLS, VLT/VIMOS, and Spitzer (done)
- ✓ KOOLS and VIMOS 2-D emission line image reconstruction (done)
- ✓ 2-D Extinction and Tε/Nε maps (done)
- ✓ Ionic/Elemental abundance maps (doing)
- ✓ Construct 3-D structure using VIMOS PV-maps
- ✓ Construct 3-D photoionisation model
- ✓ Simulate atomic gas emission lines in mid-IR based on the obtained Tε/Nε and ionic abundance maps

I hope KOOLS with auto-guider will provide Spectacular data!