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Faculty of Science
Institute for Astronomy and Astrophysics

Spectral Modeling of AM CVn stars

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Overview

- Modeling of NLTE Accretion Disks
- Non-Stationary vs. Stationary Disks
  → structure
  → spectra
- Preliminary results
- Future Prospects

Modeling of NLTE Accretion Disks

Accretion Disk Code

- Assumptions:
  → geometrically thin α-disk (Shakura & Sunyaev 1973)
  → axial symmetry
- Division of disk in concentric rings
  → plane-parallel radiating slides
- Calculate vertical structure and synthetic spectrum
  → with AcDc (Accretion Disk Code, Nagel et al. 2004)

Modeling of NLTE Accretion Disks

Effective Temperature

$$T_{\mathrm{eff}} = \left[\frac{3GM_1\dot{M}}{8\pi\sigma R^3} \left(1 - \sqrt{\frac{R_1}{R}} \right) \right]^{1/4}$$

- Radial distribution of effective temperature
- Stationary model

Column mass depth

$$m(z) = \int_z^\infty \rho(z')\,\mathrm{d}z'$$

- Relationship to geometrical depth

Modeling of NLTE Accretion Disks

Modeling

- Equations of radiative equilibrium
- Equations of hydrostatic equilibrium
- NLTE Populations numbers of the atomic level
- Radiation transfer equation
- Particle number and charge conversation

Modeling of NLTE Accretion Disks

Input

- Mass and radius of central object
- Mass-accretion rate
- Radial extension of accretion disk
- Reynolds number
- Chemical abundance
- Atomic data
- Irradiation

Stationary vs. Non-Stationary

SDSS J141118.31+481257.6

- Long-period AM CVn star
- Low mass-transfer rate system
- Orbital Period: 46 ± 2 minutes
  (Groot et al. 2007)
- Mass of central object: 0.9 solar masses
- Radius of central object: 6720 kilometer

→ mass-radius-relation

Stationary vs. Non-Stationary

Features of Stationary Disks

- Constant mass-accretion-rate all over the disk

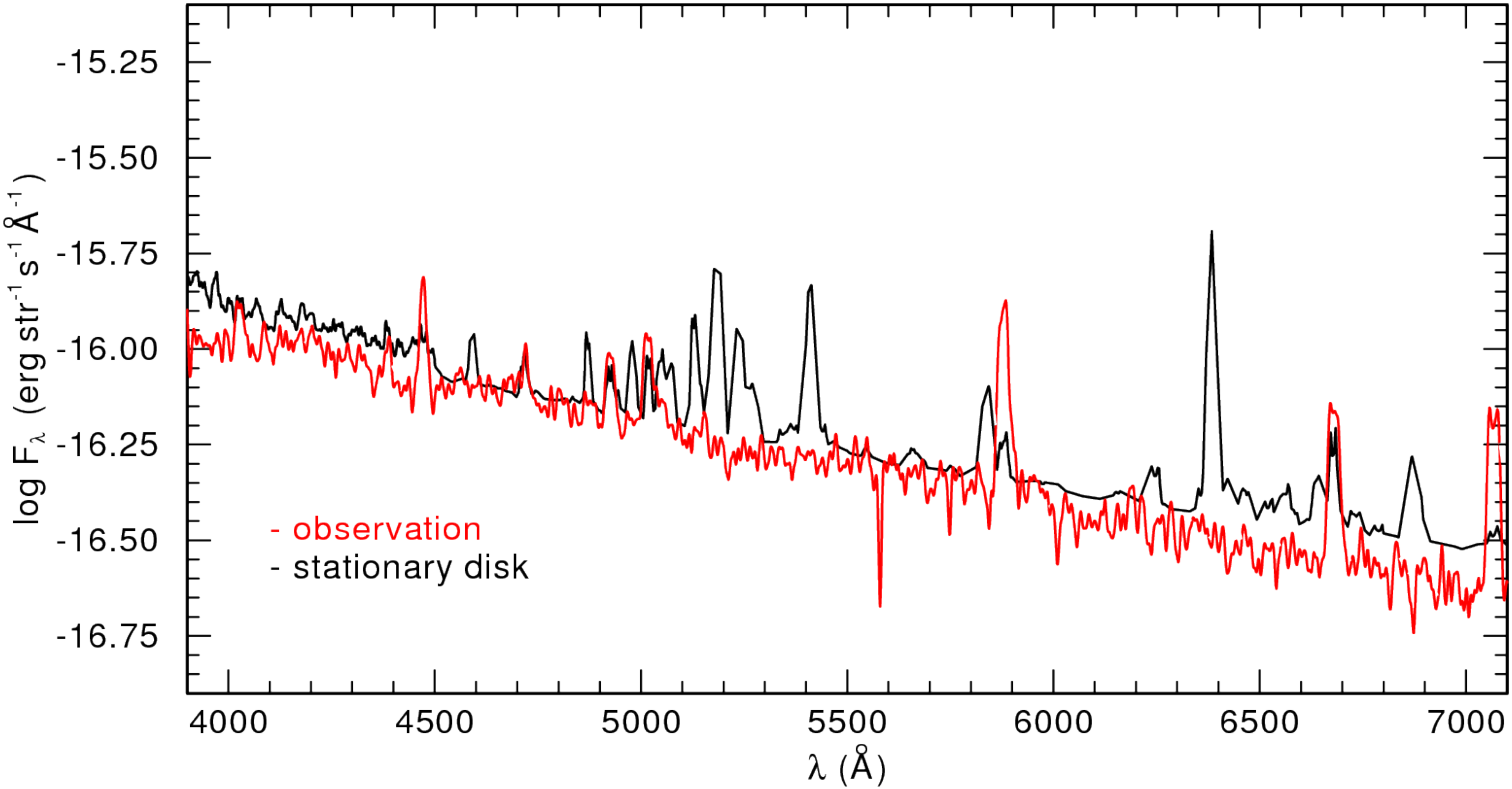
  → higher temperature to the innermost rings

  → lower temperature to the outermost rings

- Changing effective temperature

  → hot midplane for the innermost rings

Stationary vs. Non-Stationary



Stationary vs. Non-Stationary

Features of Non-Stationary Disks

- Changing mass-accretion-rate

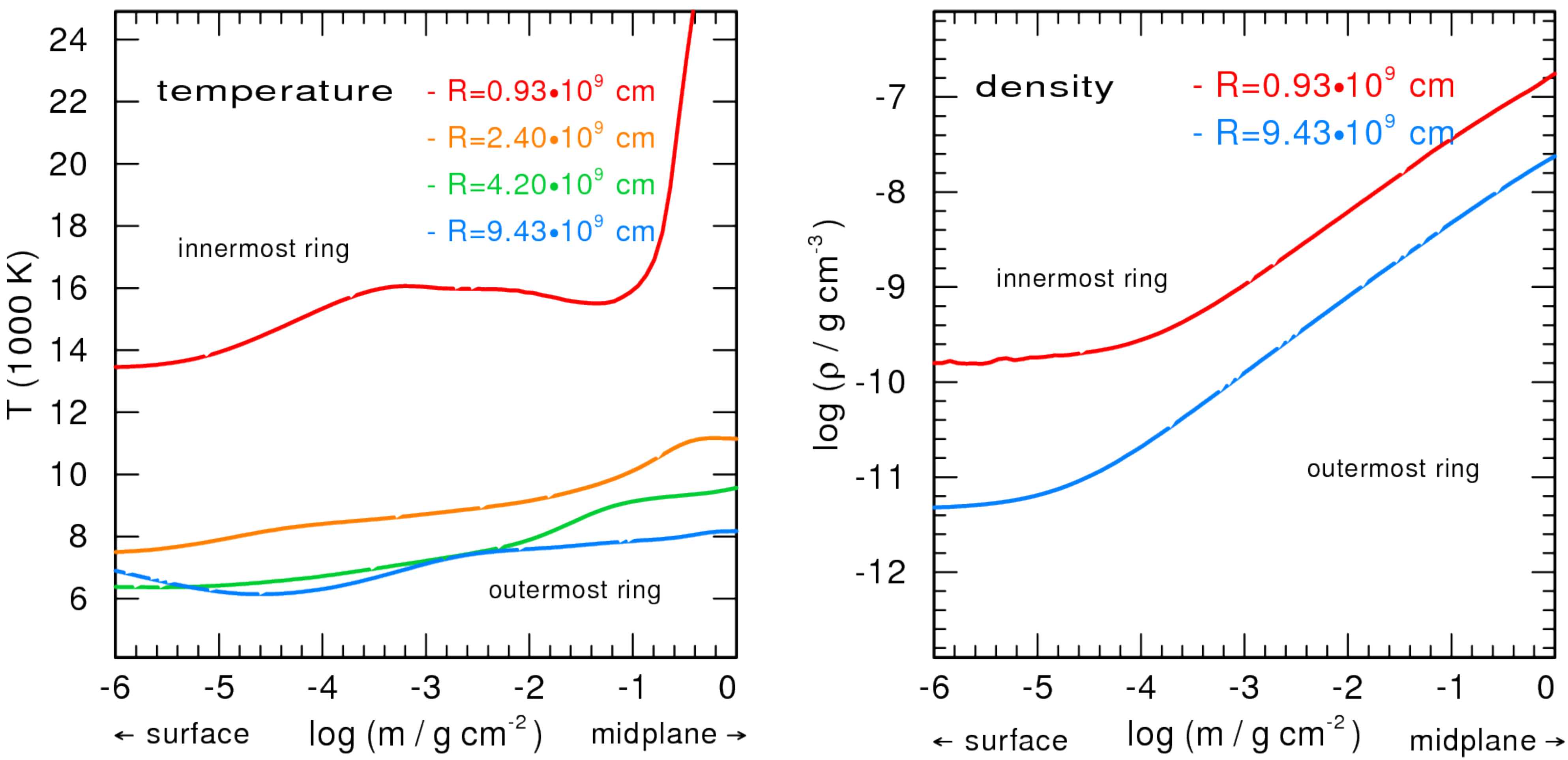
  → low mass-accretion at the inside

  → high mass-accretion at the outside

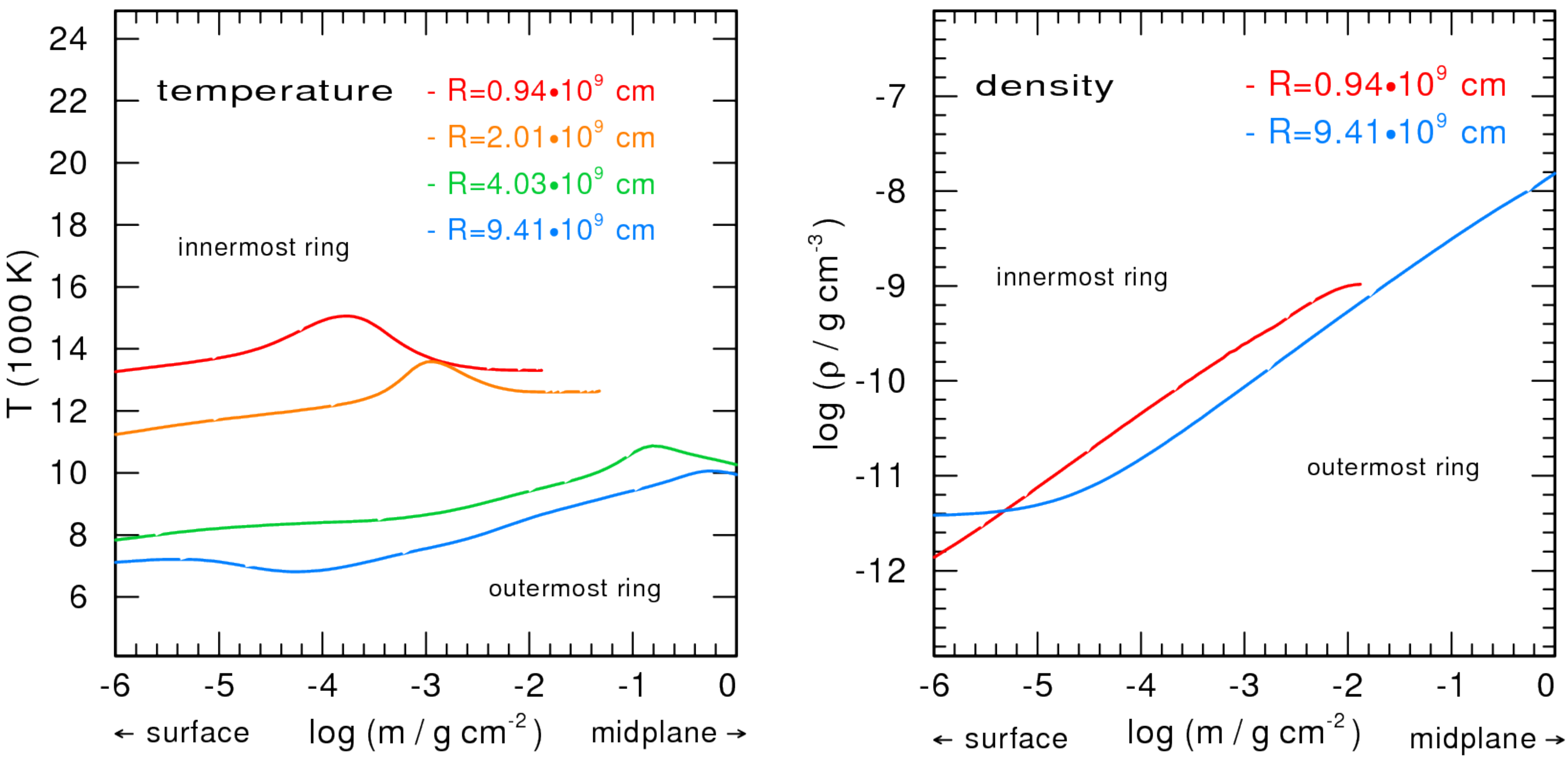
- Equal effective temperature all over the disk

  → different rings look alike

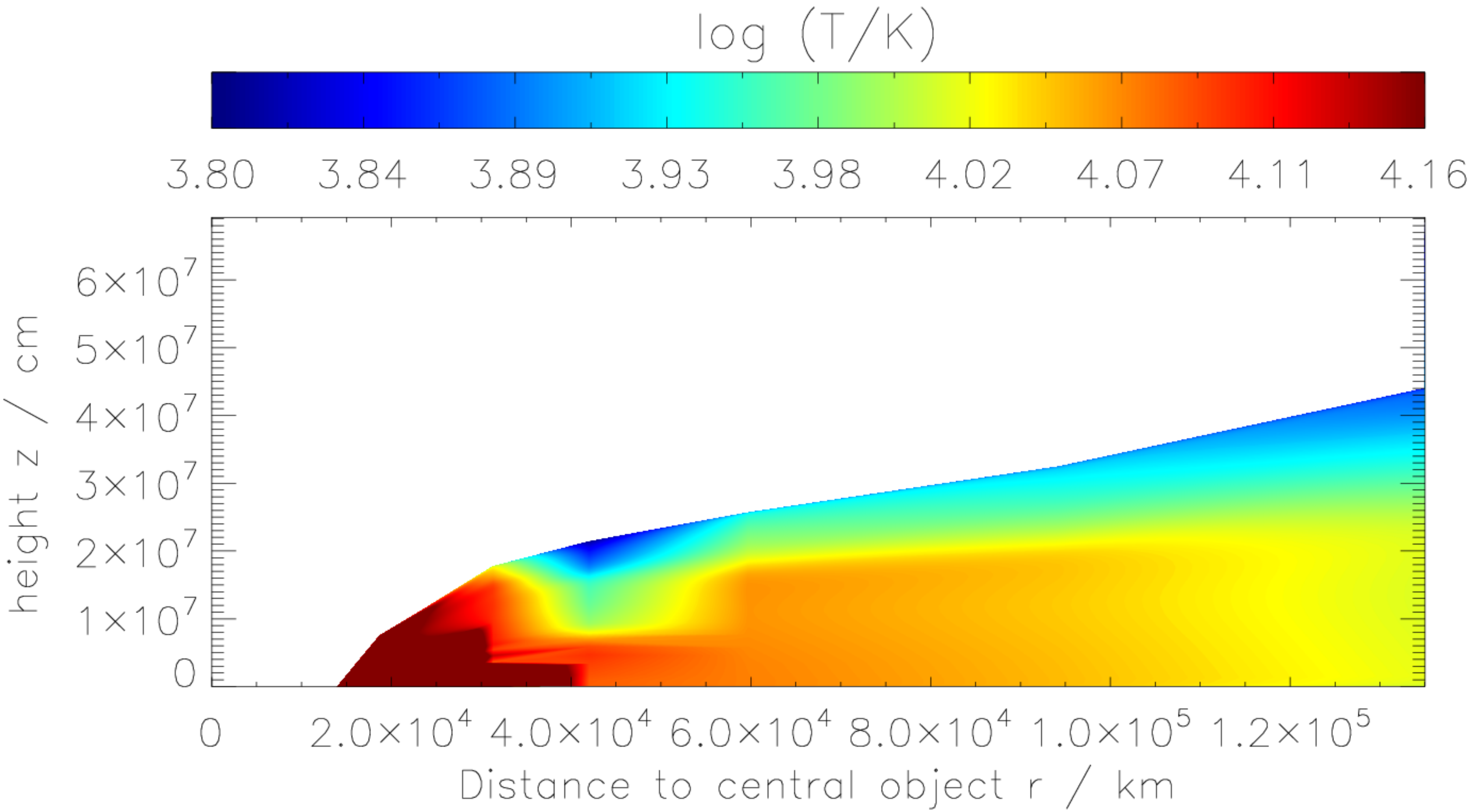
SD vs NSD: Structure



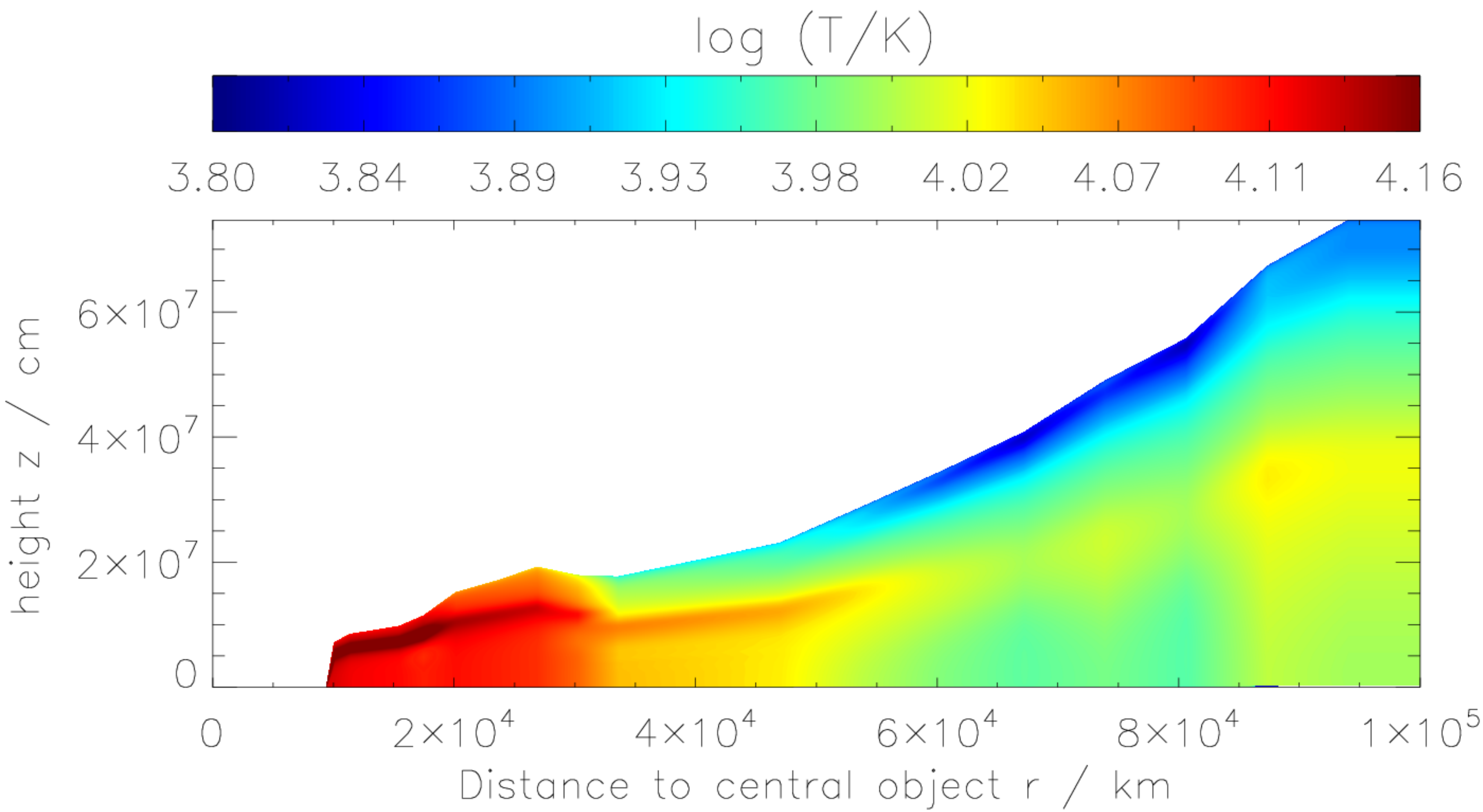
SD vs NSD: Structure



SD vs NSD: Structure



SD vs NSD: Structure



SD vs NSD: Structure

Comparison radial structure

- Stationary Disk:

→ hot midplane

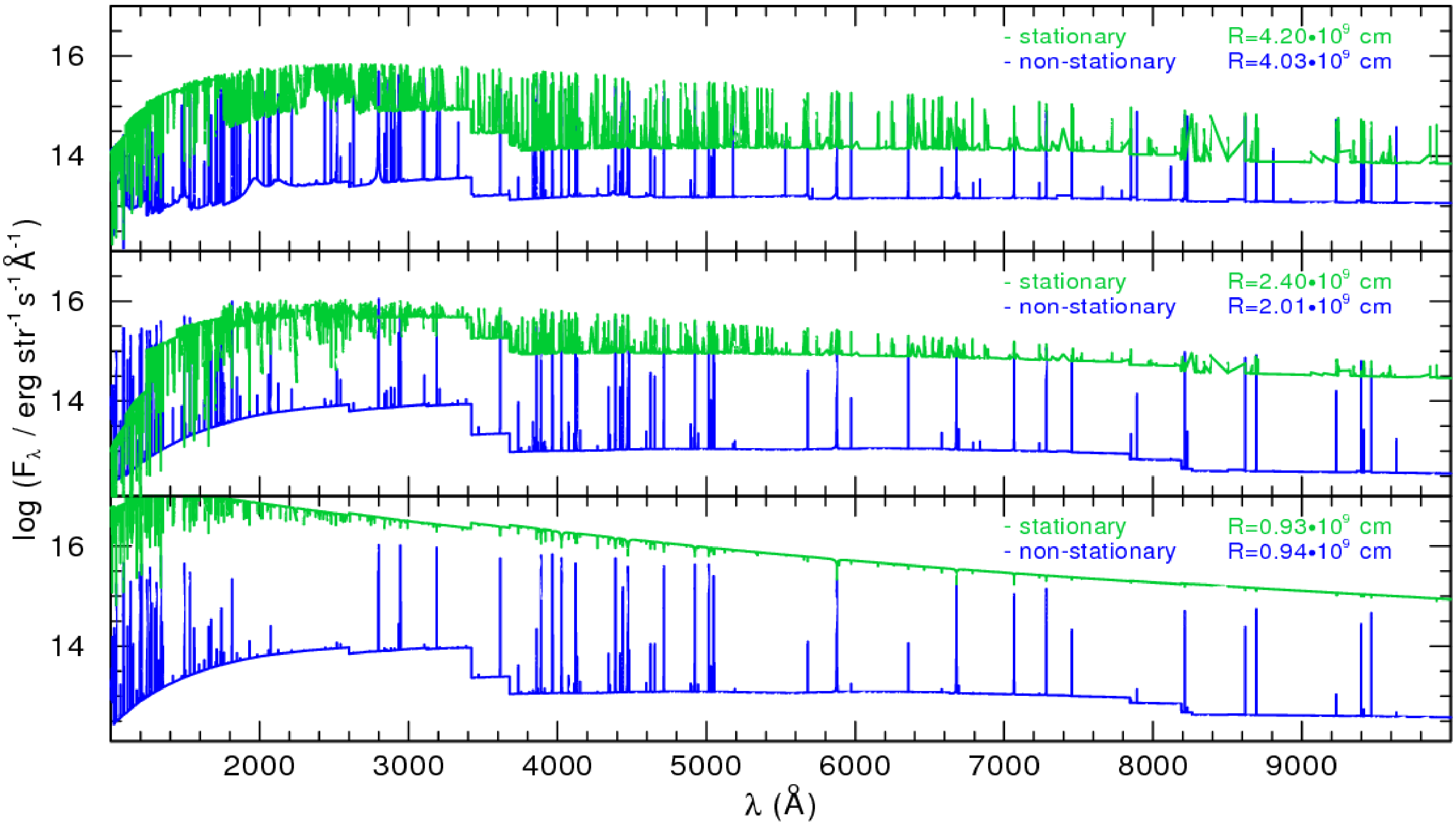
→ higher temperatures to the innermost rings

- Non-Stationary Disk:

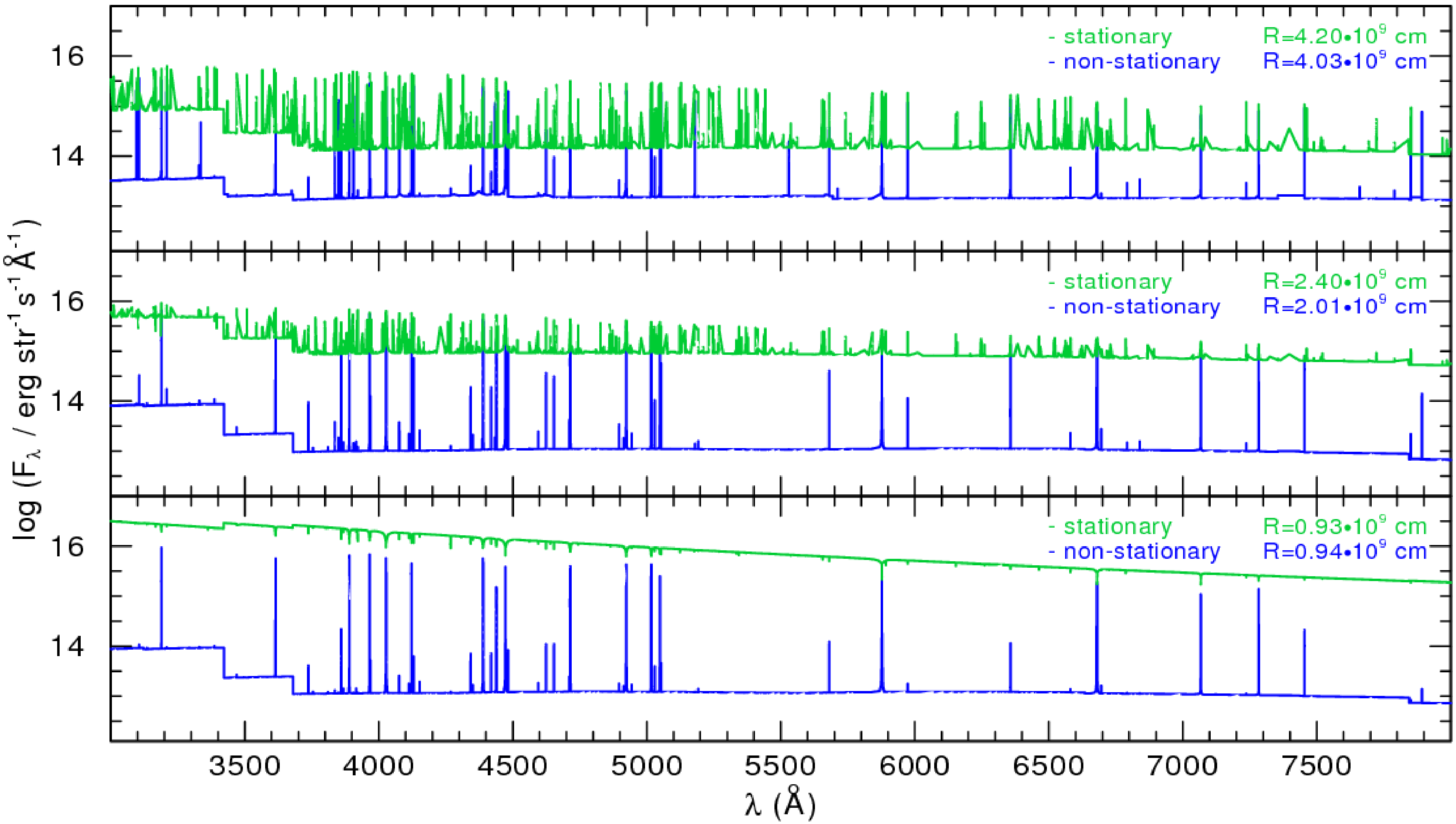
→ characteristic vertical temperature structure

→ lower temperatures to the outermost rings

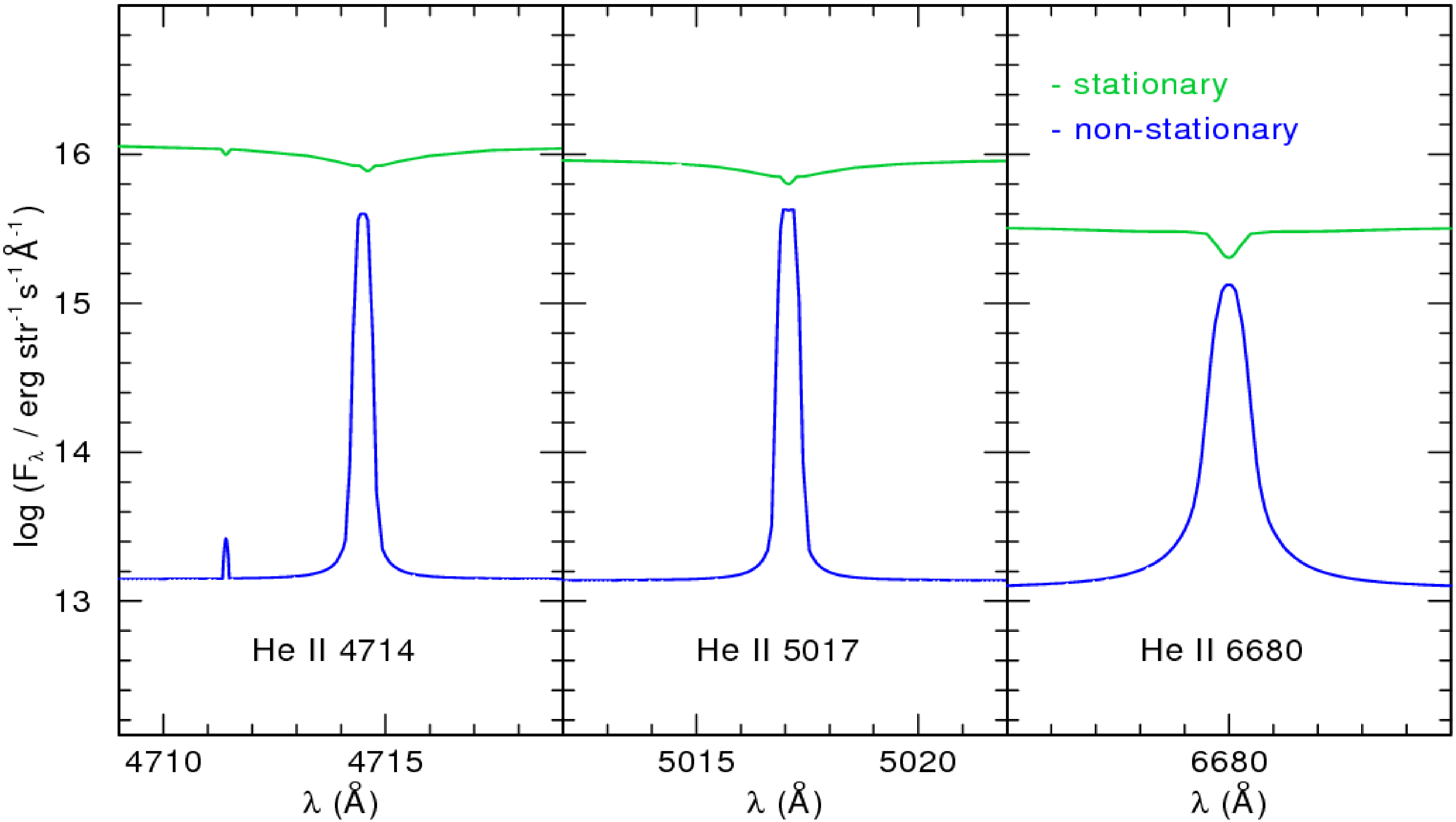
SD vs NSD: Ringspectra



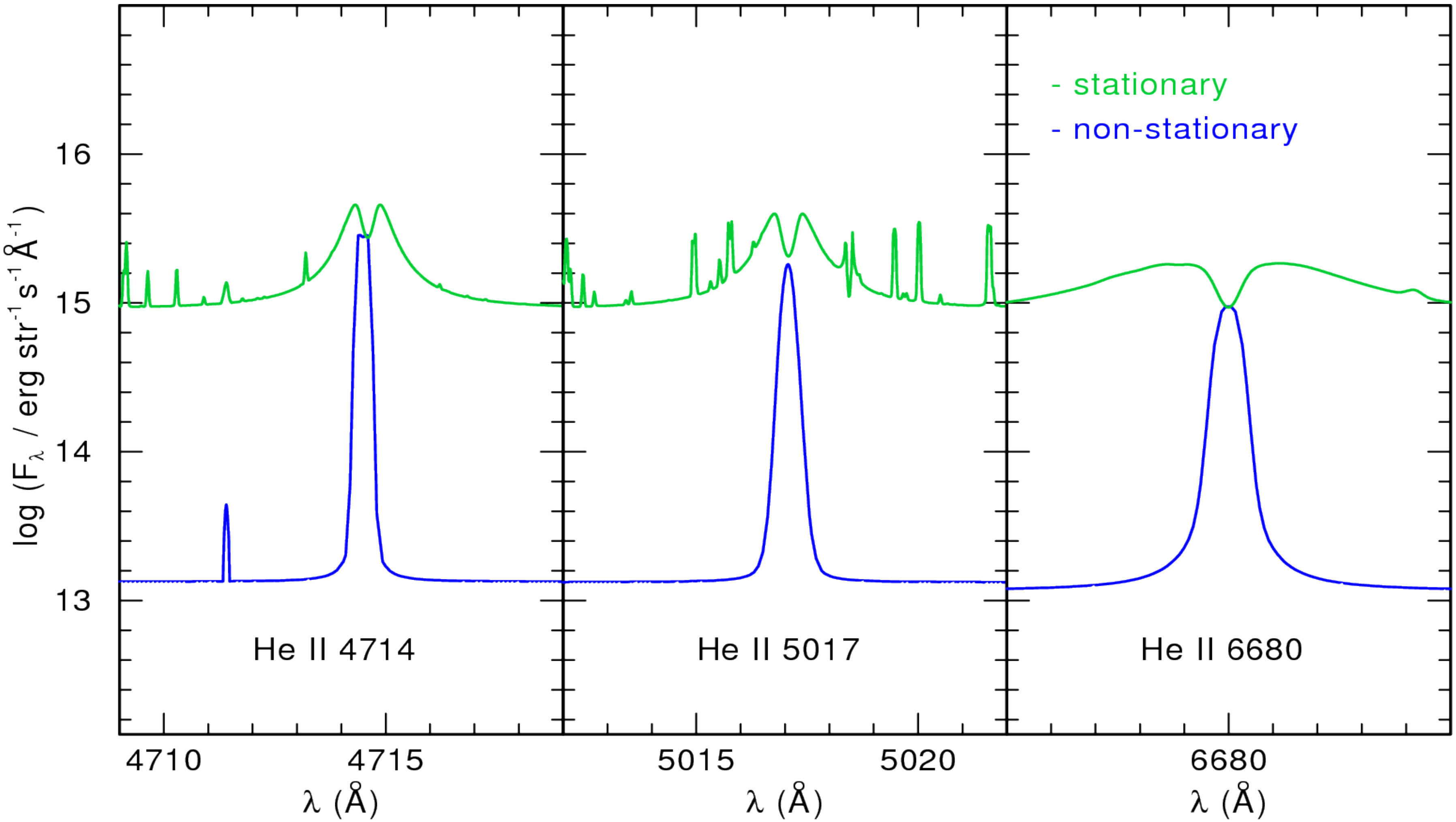
SD vs NSD: Ringspectra



SD vs NSD: Ringspectra



SD vs NSD: Ringspectra



SD vs NSD: Ringspectra

Comparison ring spectra

- Stationary Disks

→ strong emission lines to the radial outside

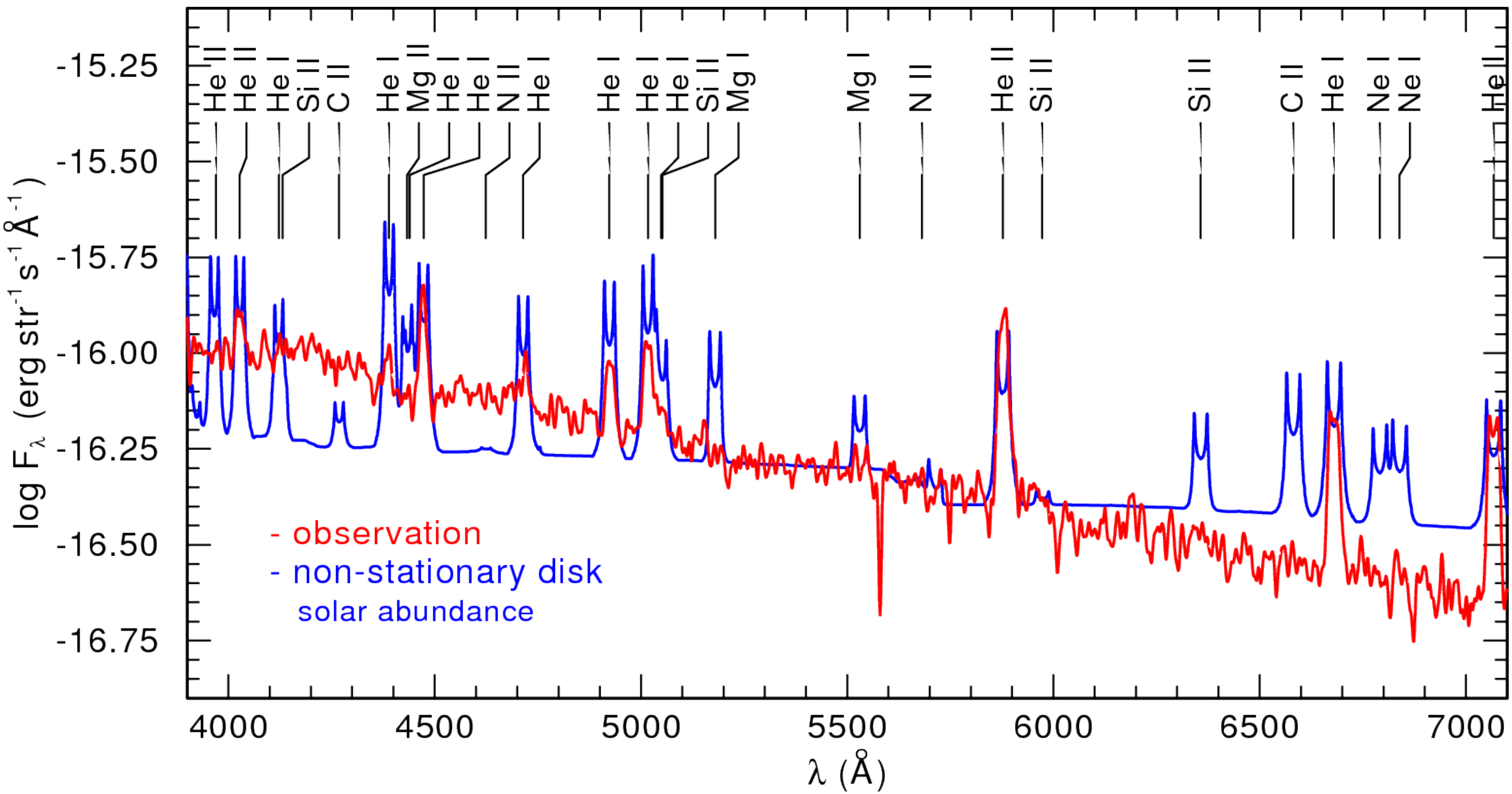
→ weak absorption lines to the radial inside

- Non-stationary Disks

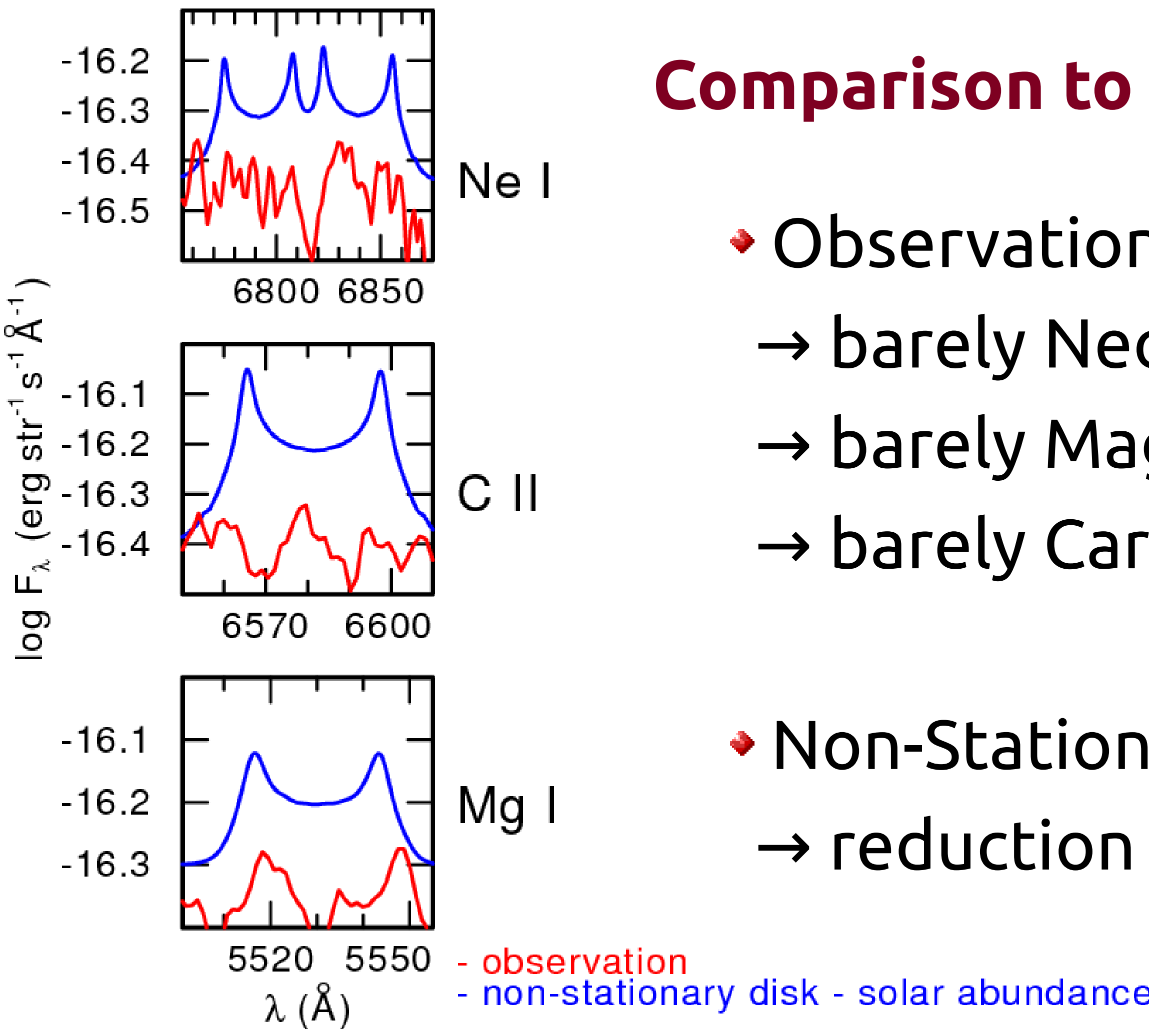
→ strong emission lines all over the disk

→ all rings look alike

Non-Stationary: Spectra



Non-Stationary: Abundances

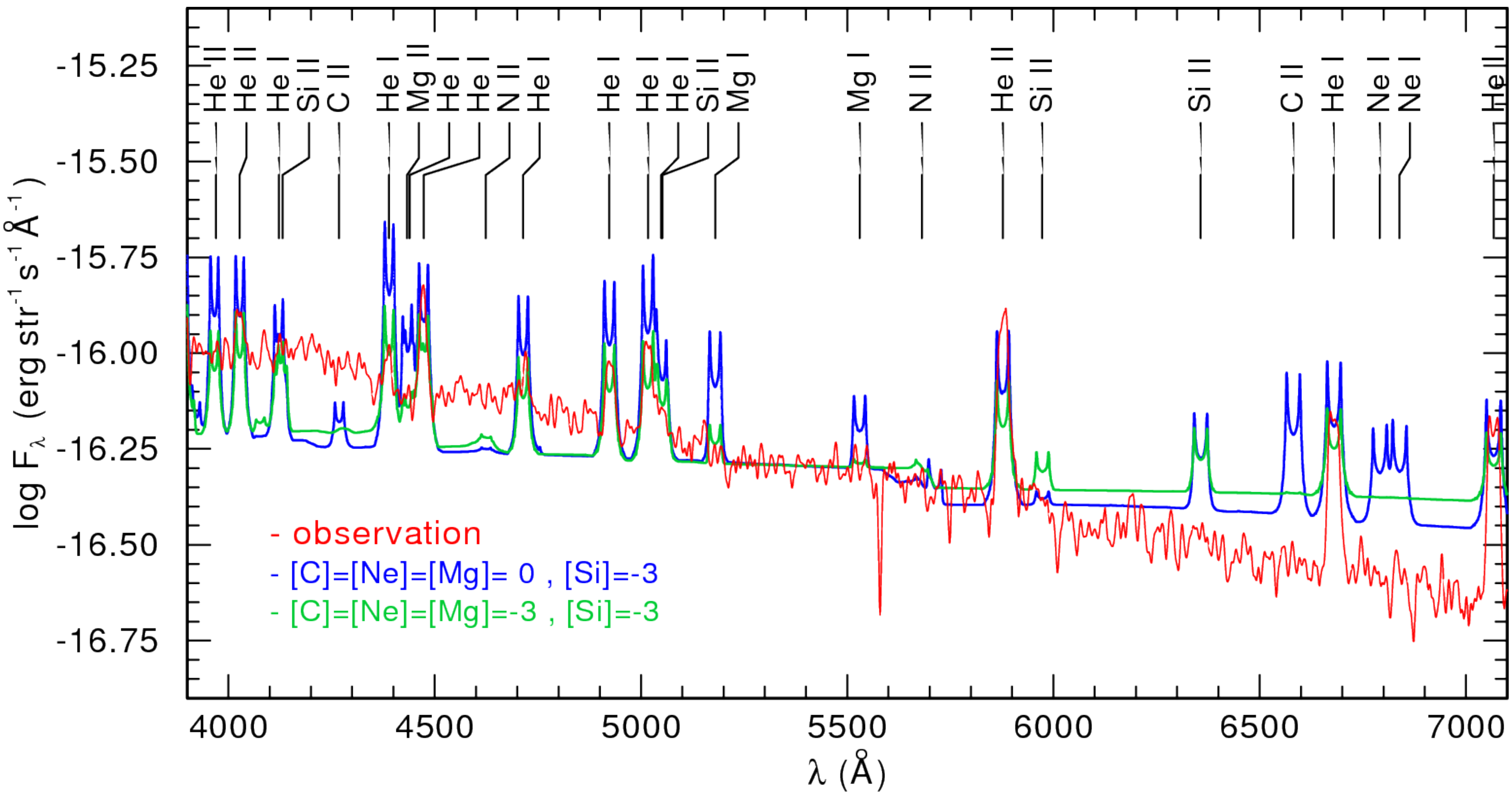


Comparison to Observation

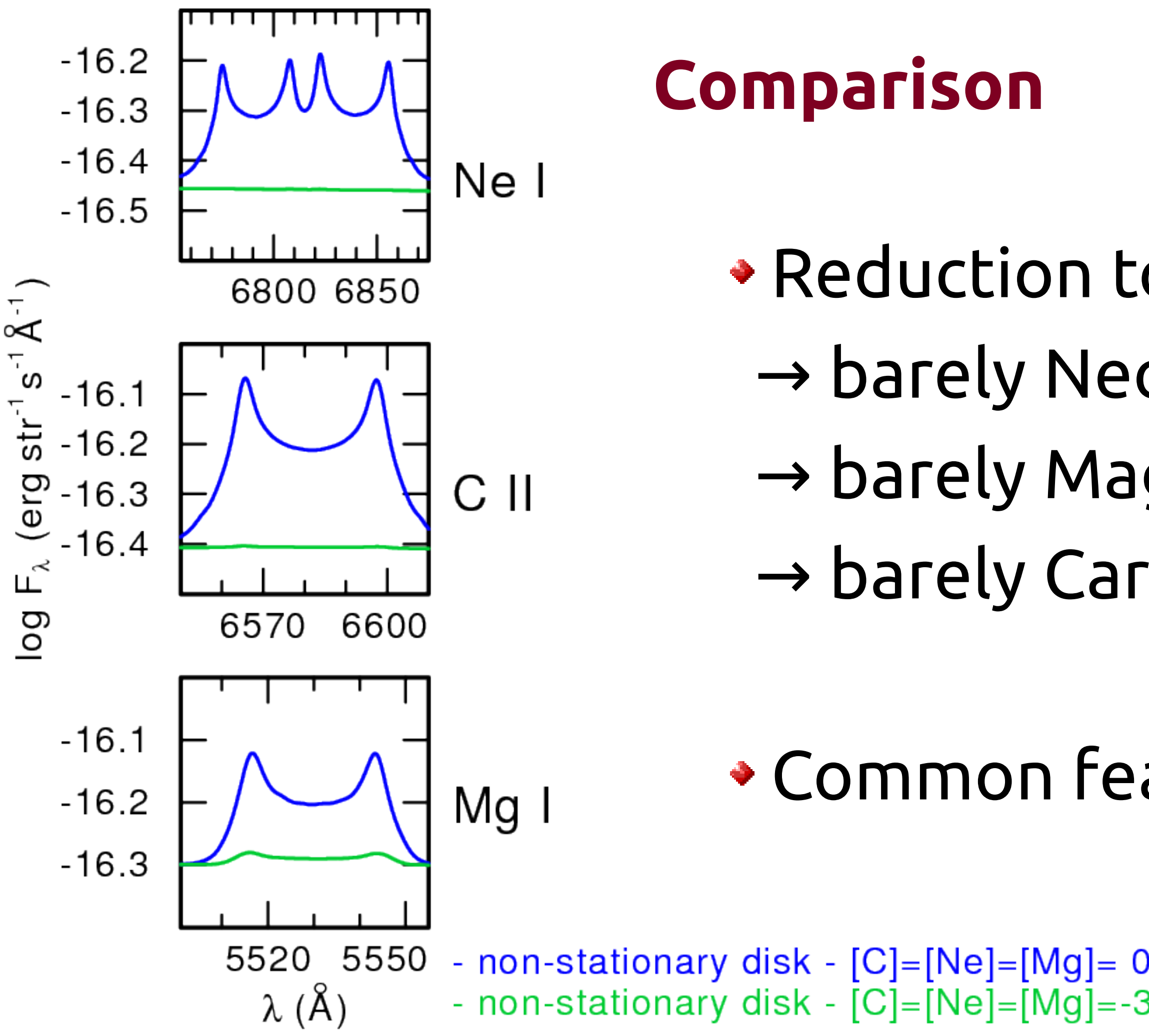
- Observation:
  → barely Neon
  → barely Magnesium
  → barely Carbon

- Non-Stationary Disk:
  → reduction to 0.001 times solar

Non-Stationary: Abundances



Non-Stationary: Abundances

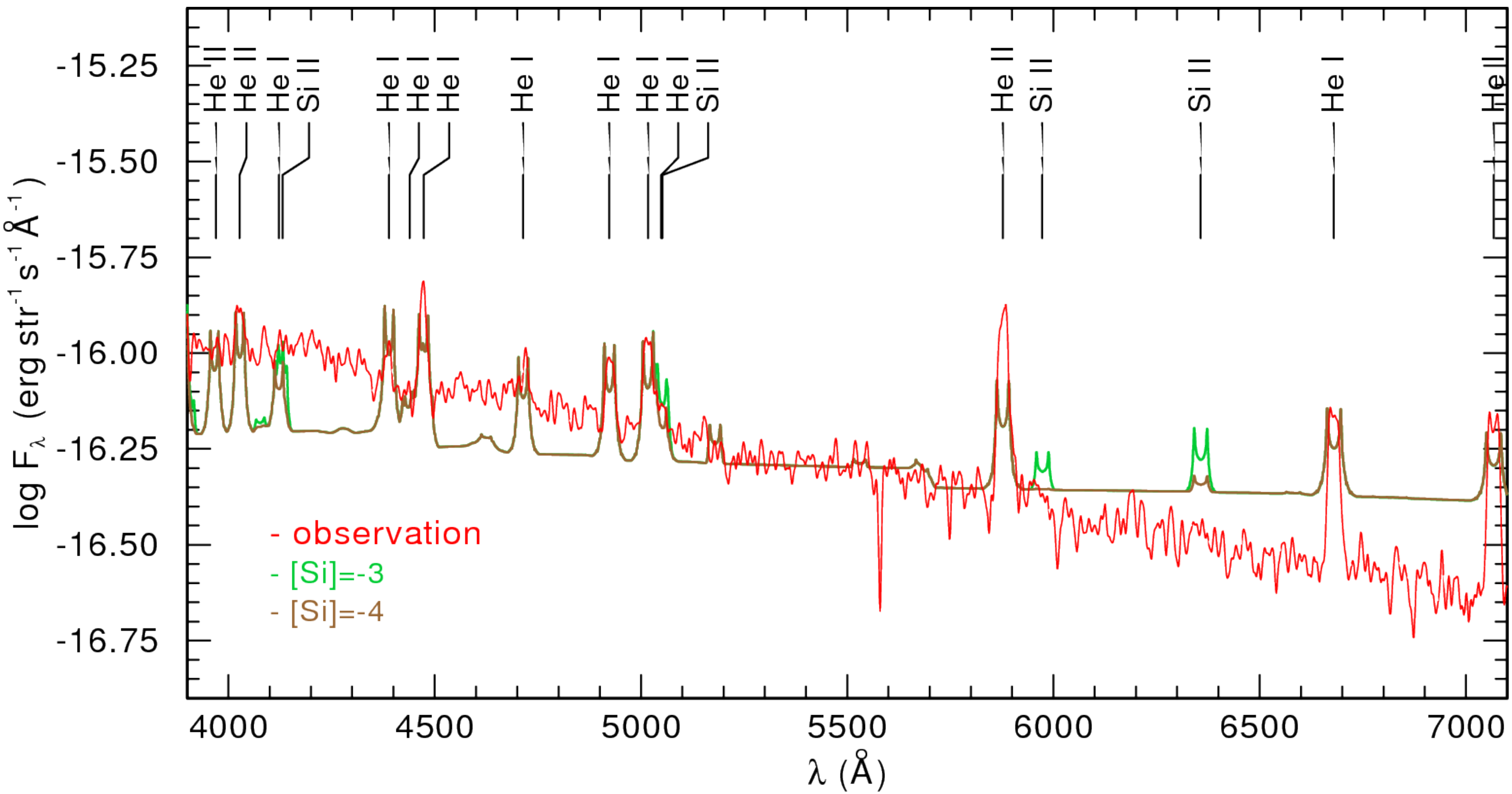


Comparison

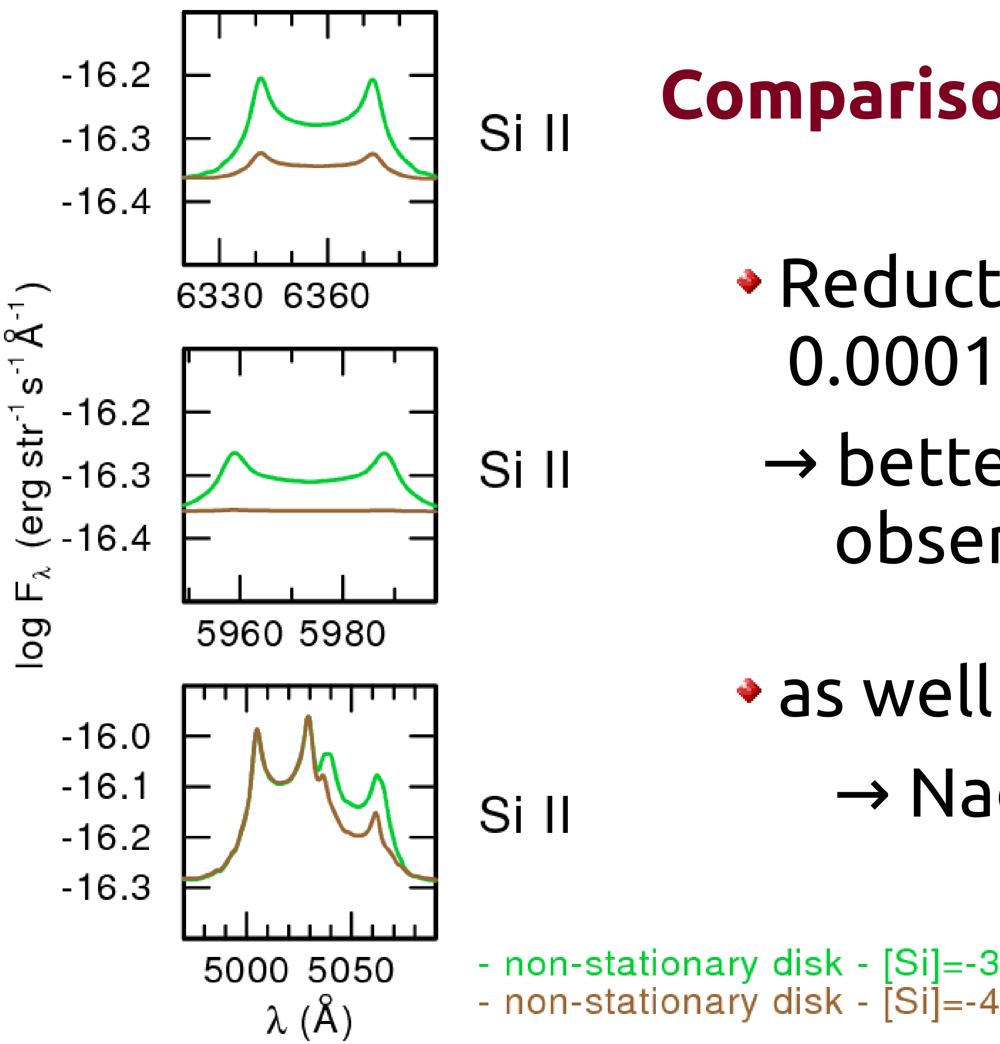
- Reduction to 0.001 times solar
  - → barely Neon
  - → barely Magnesium
  - → barely Carbon

- Common feature in AM CVn?

Non-Stationary: Silicon Abundance



Non-Stationary: Silicon Abundance



Comparison

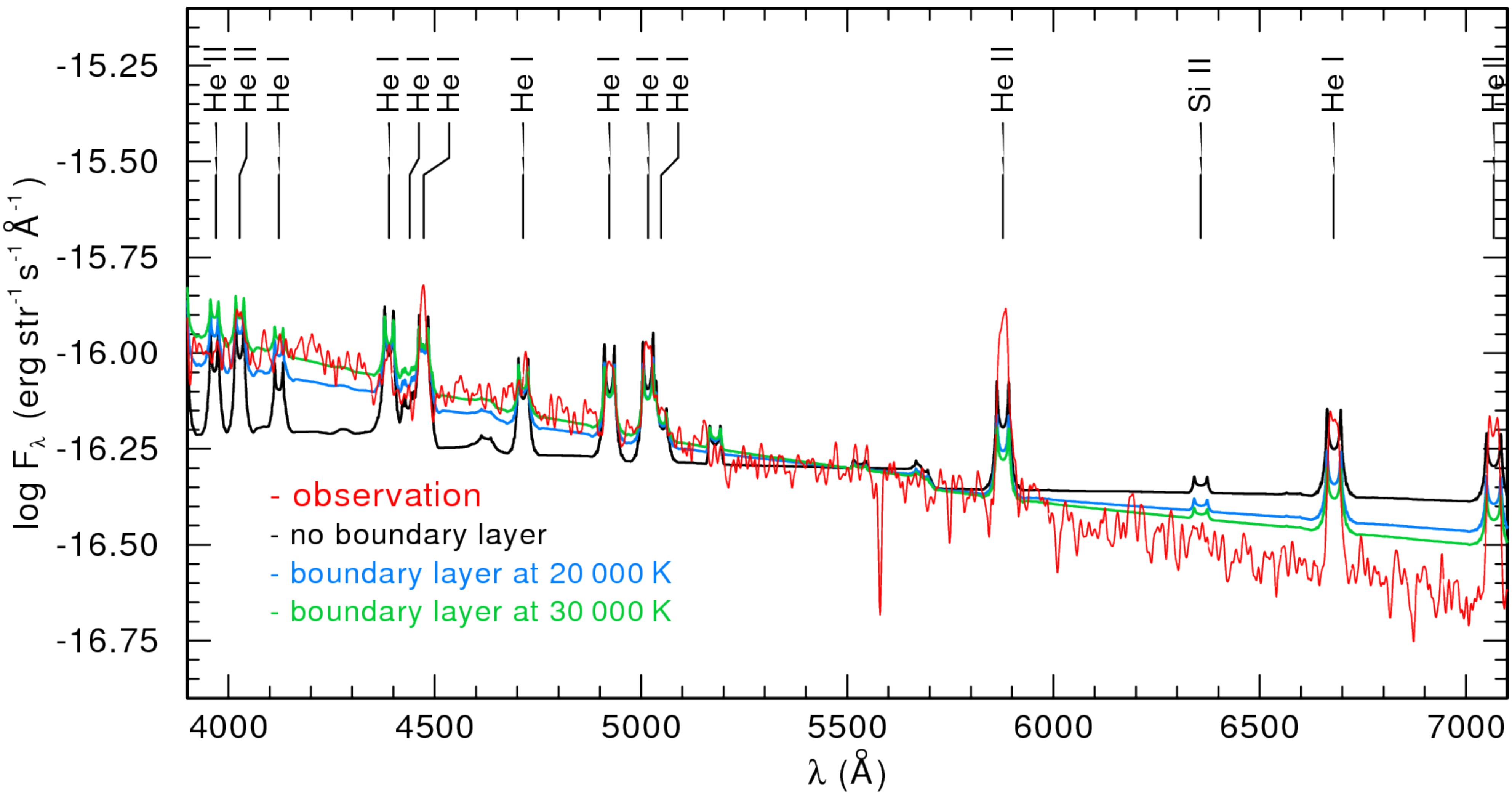
- Reduction silicon abundance to 0.0001 times solar

  → better agreement with observation

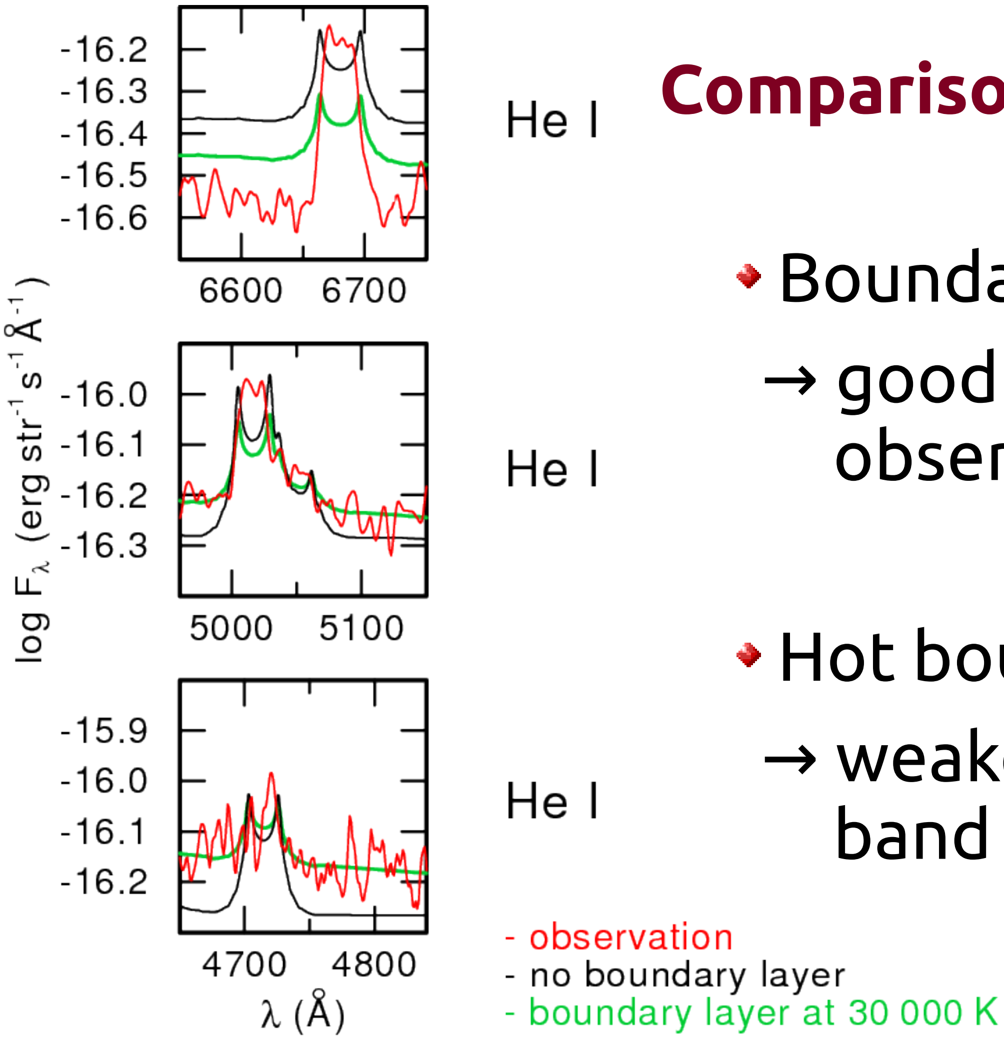
- as well as CE 315

  → Nagel et al. (2009)

Non-Stationary: Boundary Layer



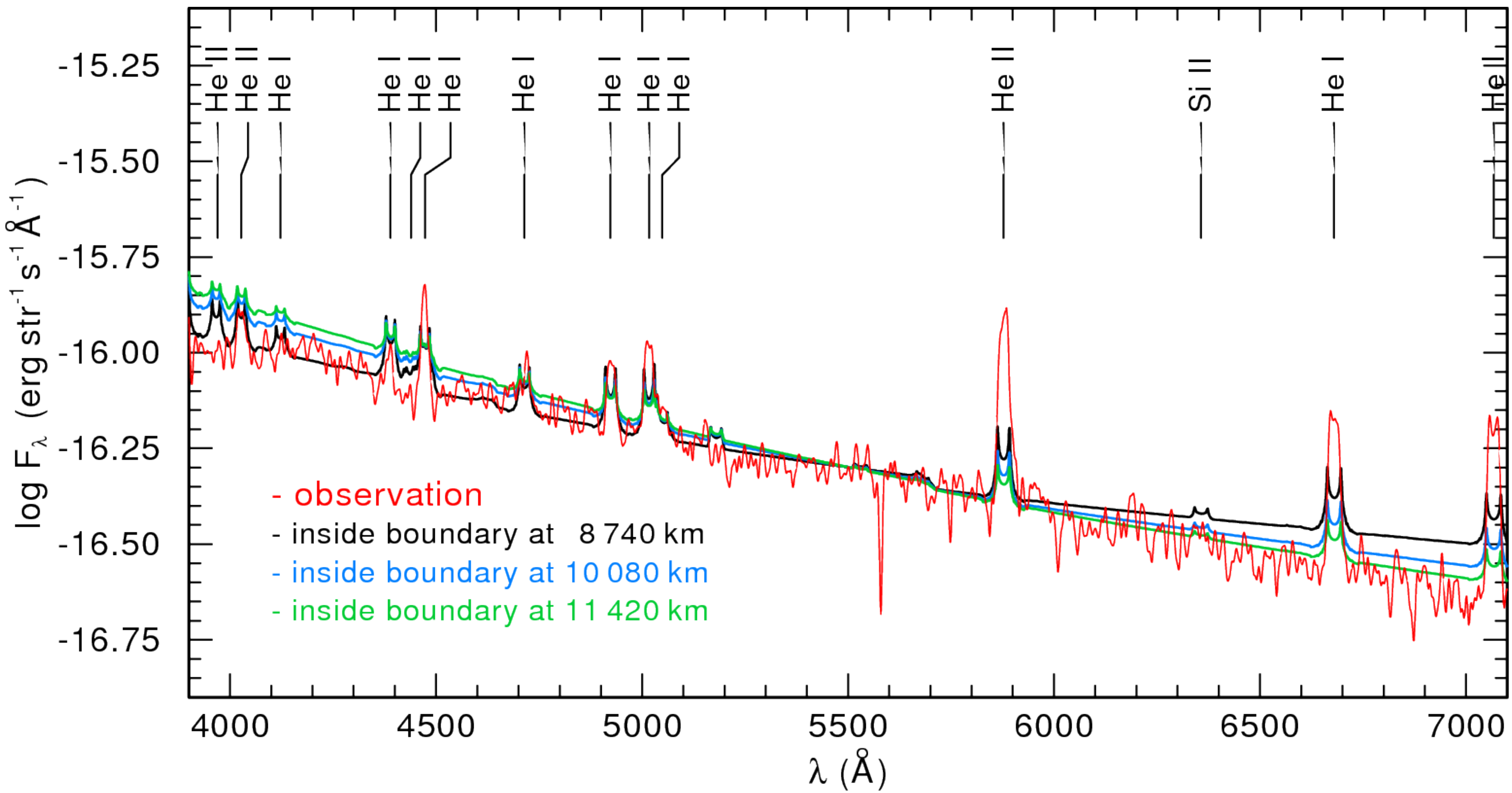
Non-Stationary: Boundary Layer



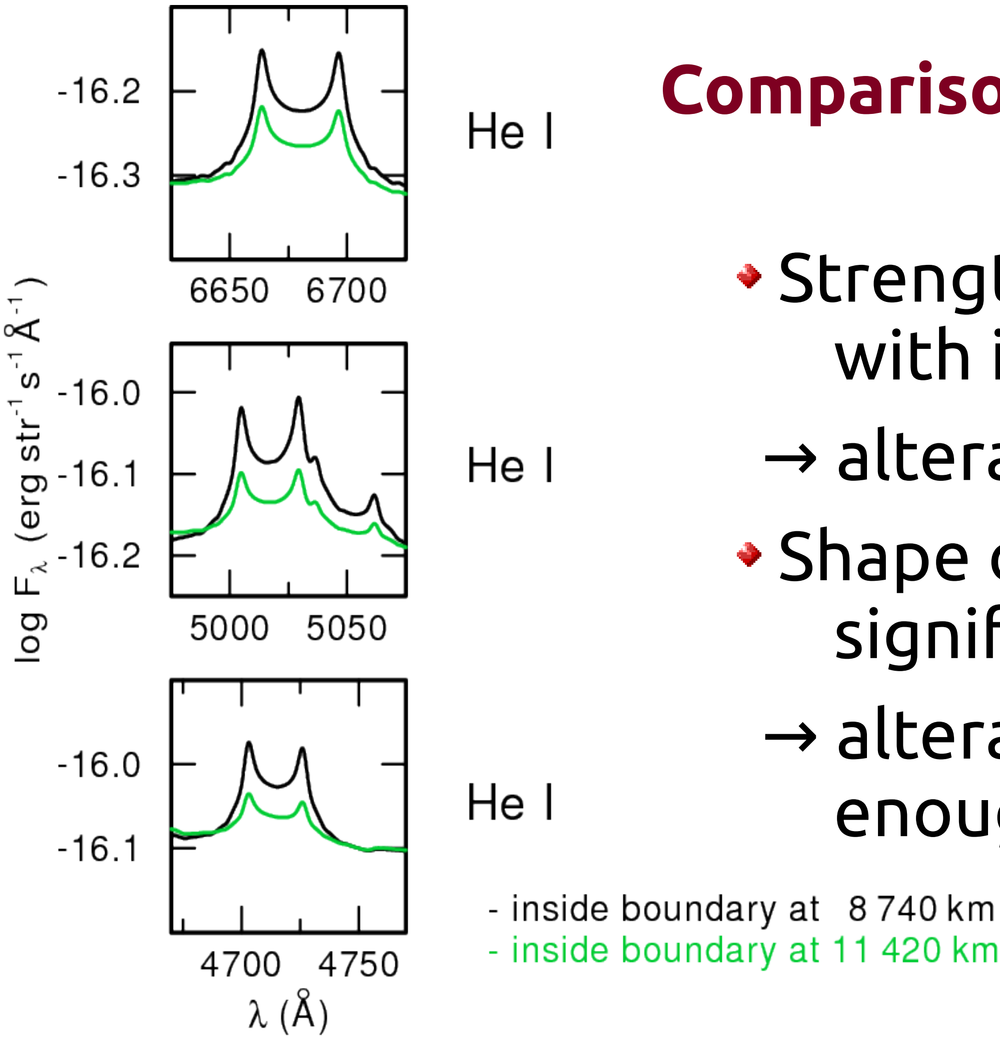
Comparison to Observation

- Boundary layer at 30 000 K
  → good agreement with observation
- Hot boundary layer
  → weaker emission lines to red band of spectrum

Non-Stationary: Inside Boundary



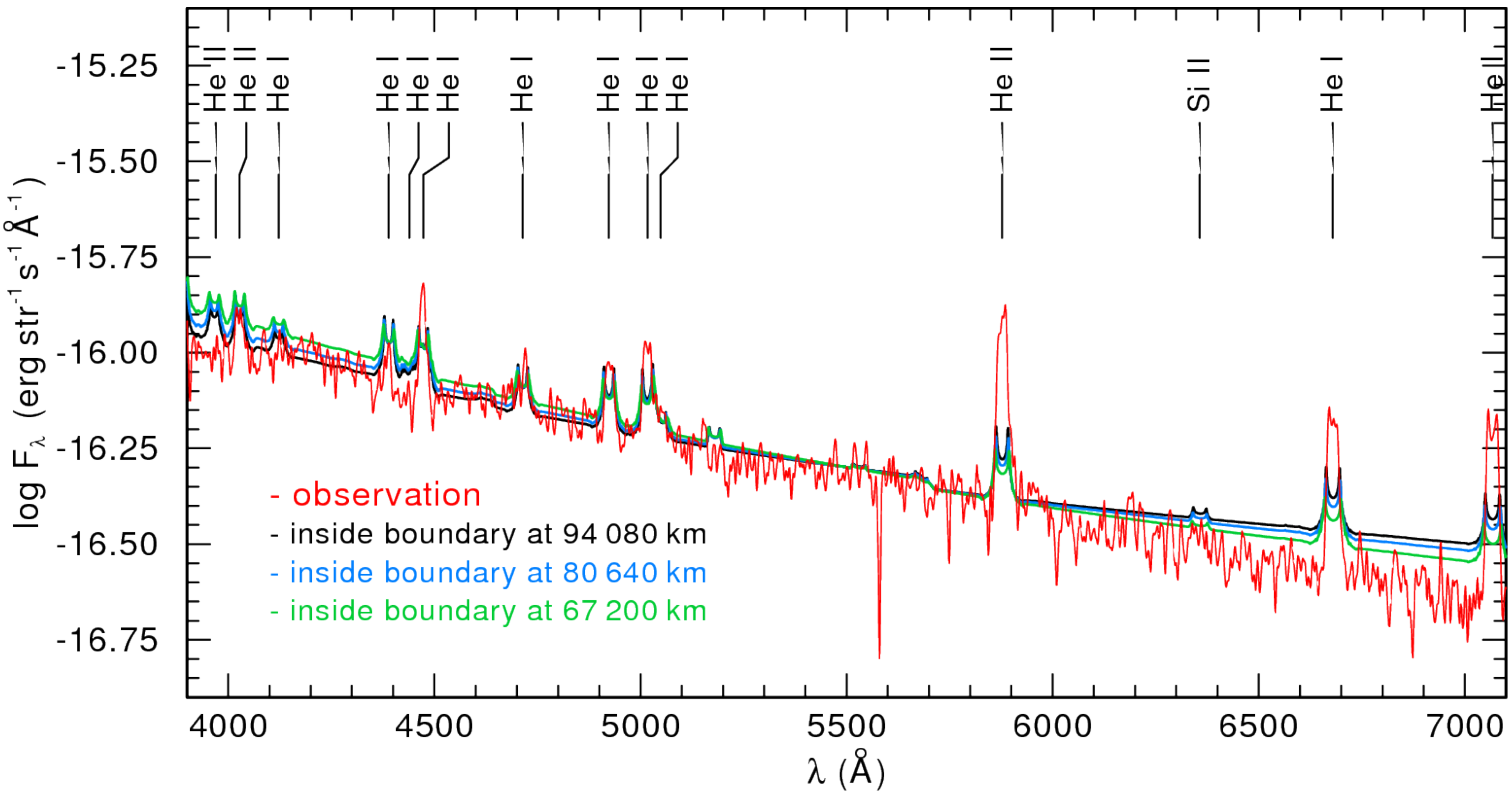
Non-Stationary: Inside Boundary



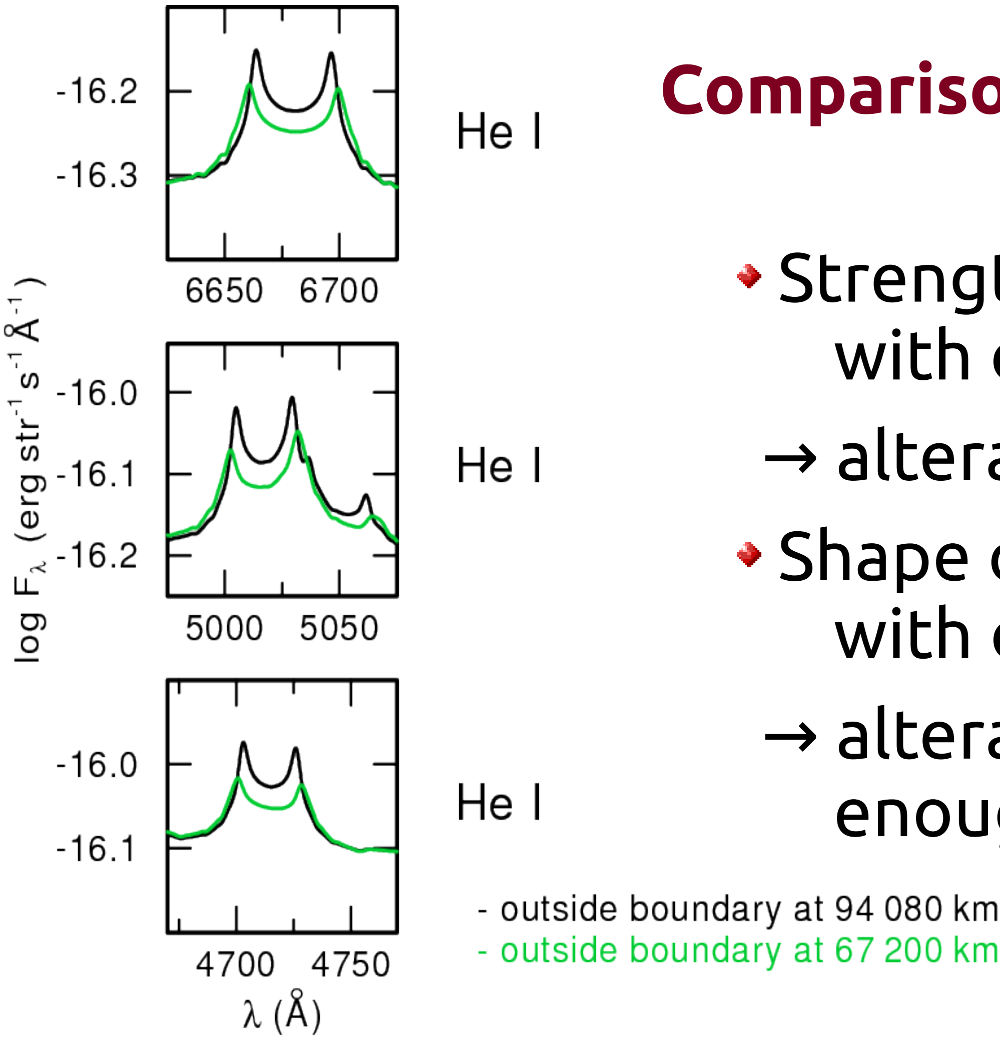
Comparison

- Strength of emission lines alters with inside boundary
  → alteration of radiating area
- Shape of emission lines does not significantly alter
  → alteration of velocity is not big enough

Non-Stationary: Outside Boundary



Non-Stationary: Outside Boundary



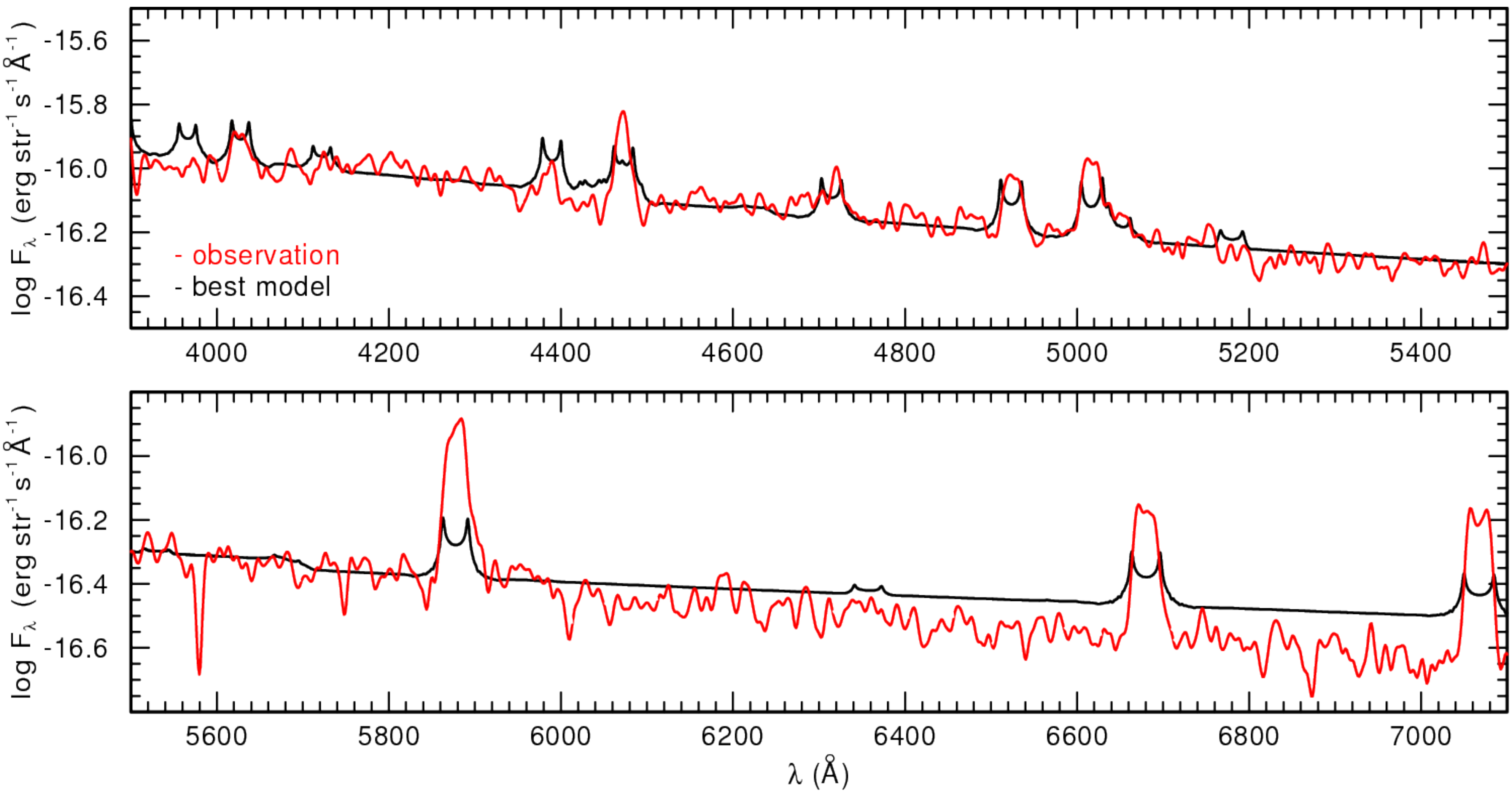
Comparison

- Strength of emission lines alters with outside boundary

  → alteration of radiating area
- Shape of emission lines alters with outside boundary

  → alteration of velocity is big enough

Non-Stationary: Preliminary Result

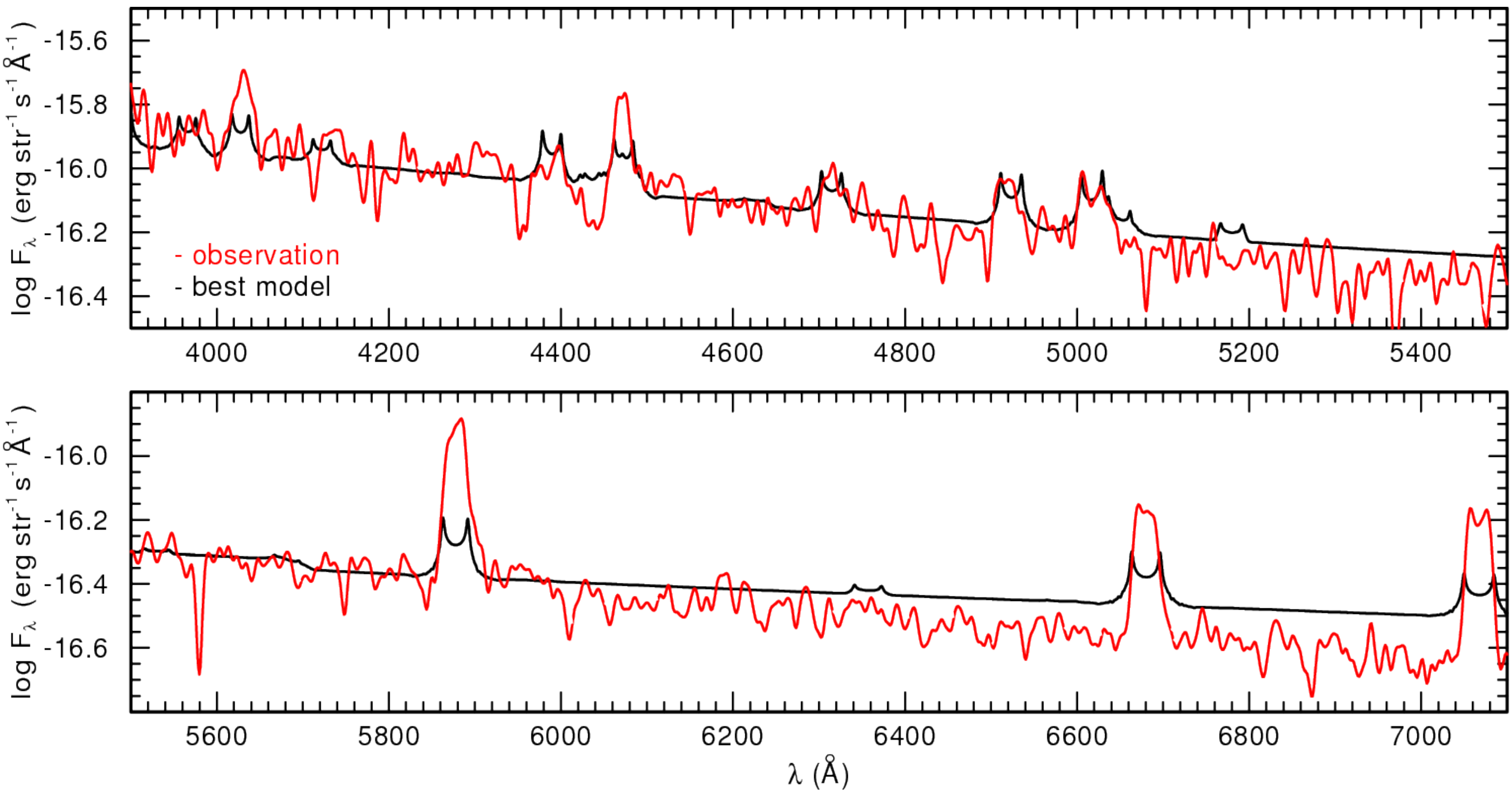


Non-Stationary: Object

SDSS J155252.48+320150.9

- Long-period AM CVn star
- Low mass-transfer rate system
- Orbital Period: 56.272 ± 0.005 minutes
  (Roelofs et al. 2007)
- Mass of central object: 1.0 solar masses
  (Roelofs et al. 2007)
- Spectral twin to J141118.31+481257.6

Non-Stationary: Preliminary Result



Future Prospects

Extension of previous work

- Application to other objects
  → low mass-transfer rate systems
  → AM CVn candidates

- Determination of abundances
  → include more elements (iron group)
  → upper limit of various abundances
  → Determination of genesis scenario

Future Prospects

Helium Dwarf Nova

- Non-stationary disk
  → application to low state
- Stationary disk
  → application to high state
- Crossover from stationary to non-stationary disk