Balmer Wing Formation in Active Galactic Nuclei.

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1. Abstract

Powered by a supermassive black hole, active galactic nuclei (AGNs) are characterized by prominent emission lines including Blamer lines. The unification scheme of AGNs requires the existence of a thick molecular torus that may hide the broad emission line region. In this configuration, it is expected that the far UV radiation from the central engine can be Raman scattered by neutral hydrogen to reappear around Balmer lines which can be identified observationally with broad Balmer wings. Another mechanism that can form Balmer wings is considered by invoking a fast moving medium around the central engine. In this presentation, we produce Balmer wings that are formed through Raman scattering and also those expected from a fast moving emission flow. It is noted that Raman Balmer wings exhibit stronger red part whereas the opposite behavior is seen in the Balmer wings obtained from a fast moving emission flow.

2. Introduction

① Active Galactic Nuclei

AGNs are classified by the widths of emission lines.

I. **Type I AGNs exhibit broad E-1 permitted emission lines with width ~ 5000 km/s. The forbidden lines are narrow with width ~ 500 km/s.**

II. **Type 2 AGNs exhibit only narrow lines that are both E-1 permitted and forbidden.**

III. **Unification models of AGN invoke a geometrically and optically thick torus that may hide the broad emission line region from those observers with low latitude.**

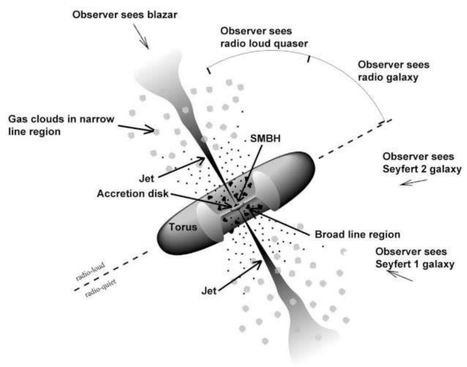


Figure 1 Unification Model

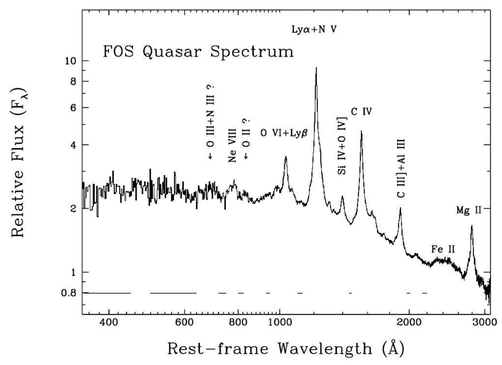


Figure 2 AGN Spectrum (Zheng et al. 1997)

② AGN Unification and Balmer Wings

The presence of a geometrically and optically thick torus invoked in the unification model of AGNs implies a theoretical possibility that far UV radiation from the AGN central engine may be scattered inelastically by atomic hydrogen to form broad features around Balmer emission lines.
However, we may also consider the possibility that Balmer wings can be formed from fast outflows coming from the central engine. Therefore, it is interesting to compare the Balmer wings that can be formed via various physical processes.

3. Balmer Wings Models

- **Model I : Spherical Shell Model**
  Study the basic properties of Balmer wing formed from Raman scattering.
- **Model II : Cylindrical Shell Model**
  Apply to Raman Scattering to Unification Model.
- **Model III : Emission Wing Model**
  In very fast moving emission material, special relativistic beaming is important.

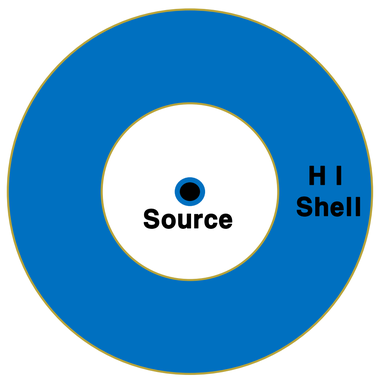


Figure 3 Shell Model

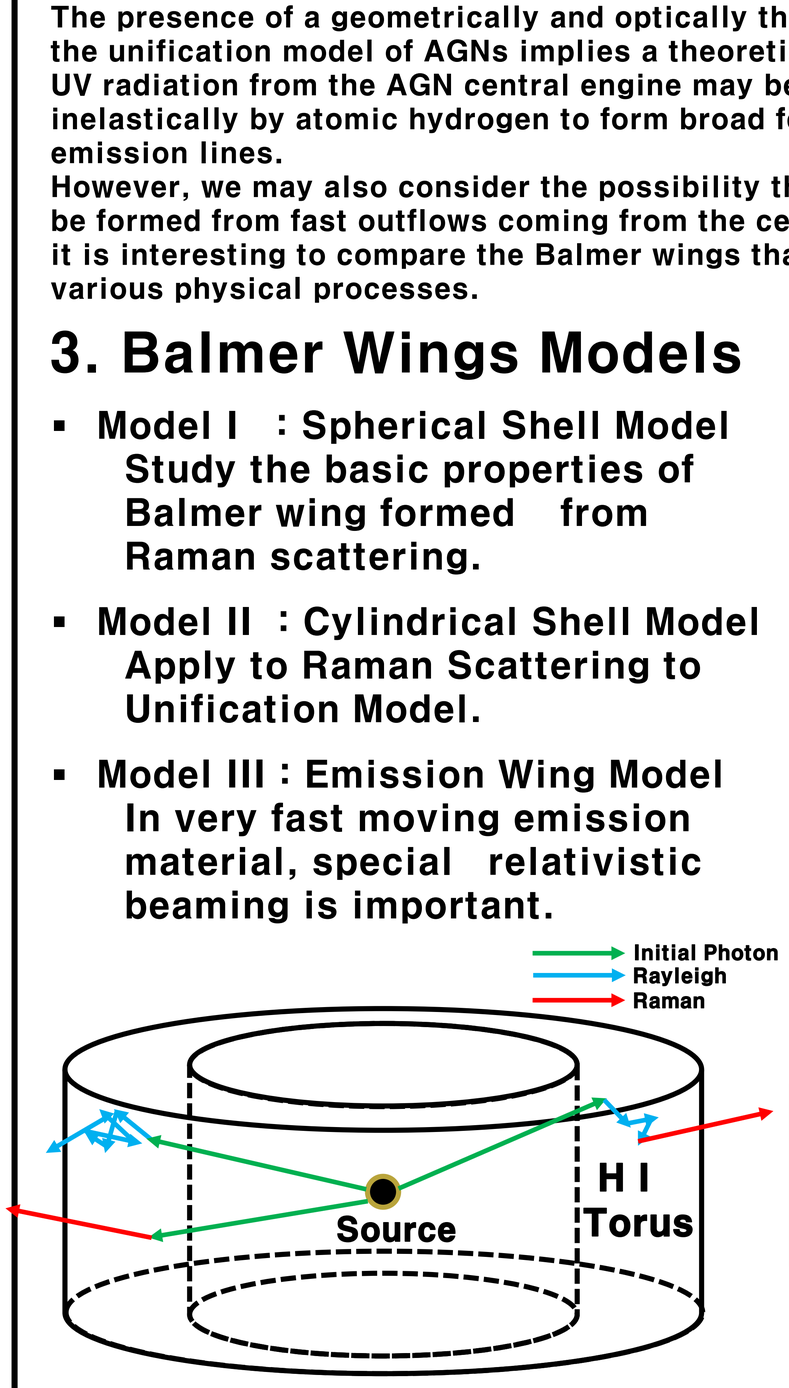


Figure 4 Cylindrical shell(Torus) Model Geometry

Figure 5 Emission Wing Model

① Spherical Shell Model

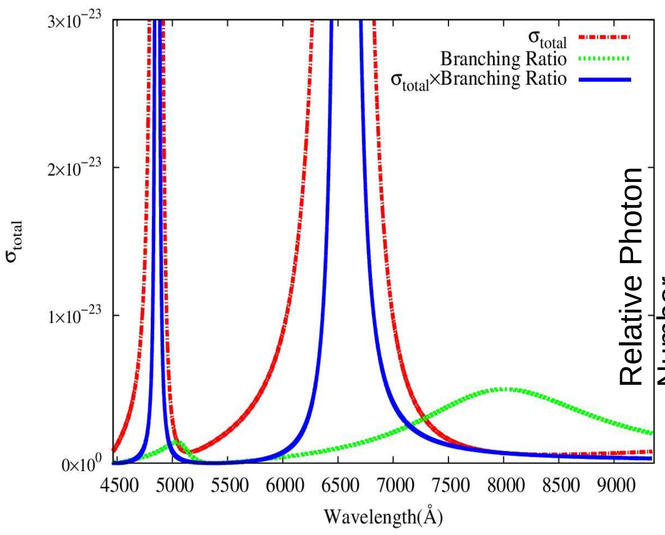


Figure 6 Raman-Scattering Cross Section & Branching Ratio

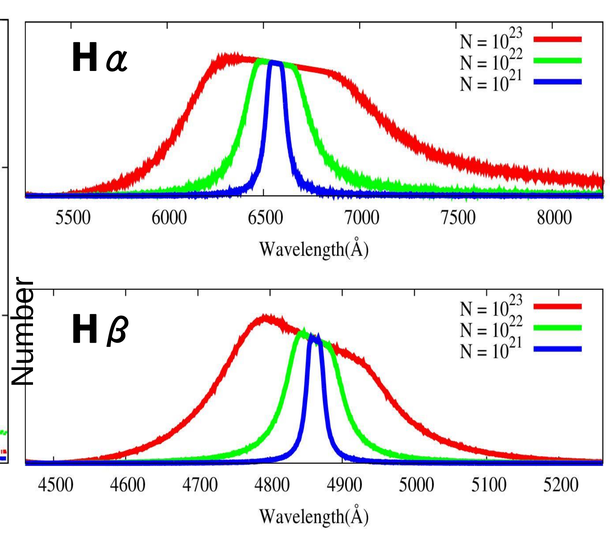
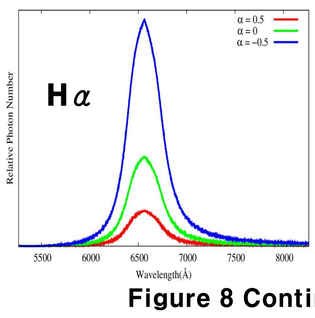


Figure 7 Balmer Line Spectrum

Column Density N ↑ → Reveals feature of atomic physics

② Raman-scattering in Torus Model

The product of the branching ratio and the total cross section is higher in the red part for Raman scattering around Hα, it is apparent that H alpha wings show red asymmetry.
However, the opposite behavior is seen for Raman scattering around Hβ.



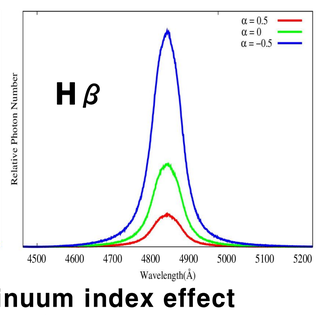
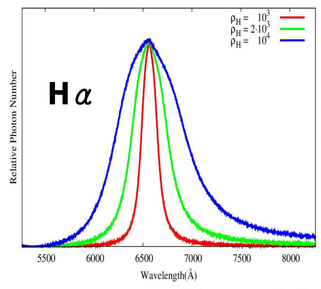


Figure 8 Continuum index effect



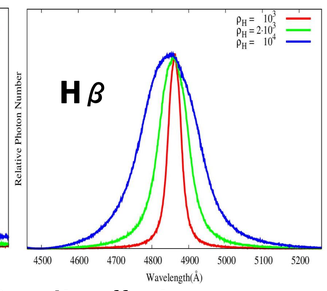


Figure 9 Density effect

$$n_\lambda(\lambda) = \left(\frac{\lambda}{\lambda_{H\alpha}}\right)^{\alpha}$$

③ Relativistic Emission Wing

I. **When the emission material moves very fast, special relativistic beaming is important, which enhances the blue part.**
II. **This behavior is in contrast with the Balmer α wing formed through Raman scattering, in which case red part is stronger.**

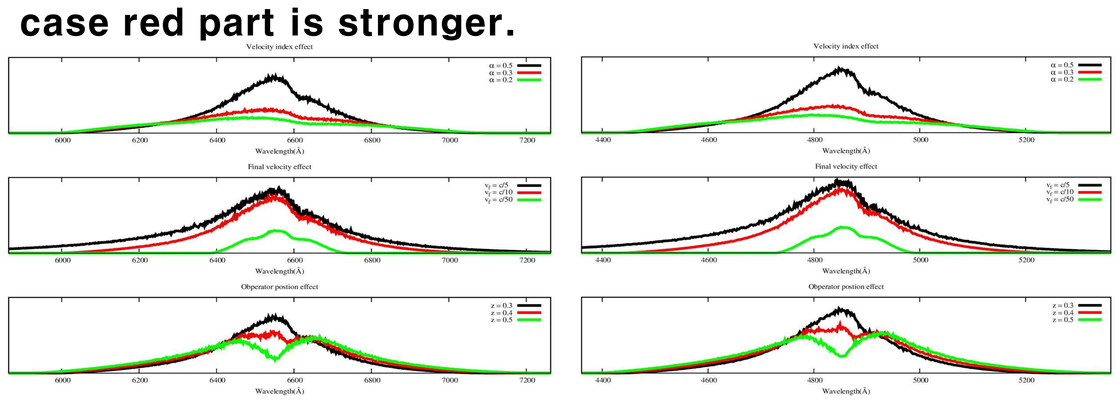


Figure 10 Relativistic Balmer Emission Wing

5. Summary and Discussion

- **Balmer wings can be formed either through Raman scattering or from fast outflows.**
- **In the case of fast outflows, blue asymmetry is expected due to relativistic beaming.**
- **In the case of Raman scattering, red asymmetry is expected around H alpha and blue asymmetry around H beta.**
- **Careful observations of Balmer wings may reveal important information around the AGN central engine.**

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