PENNSTATE

1855

Effects of an Accretion Disk Wind on the Profile of AGN Emission Lines

by Mike Eracleous
Hélène Flohic and Tamara Bogdanović

Shameless plug

- Poster 2.3

  Constraining Accretion Disk Wind Theory with Intrinsic Narrow Absorption Lines
  by **Drew Clausen**

- Poster 2.4

  Probing Quasar Winds Using Narrow Intrinsic Absorption Lines
  by **Chris Culliton**

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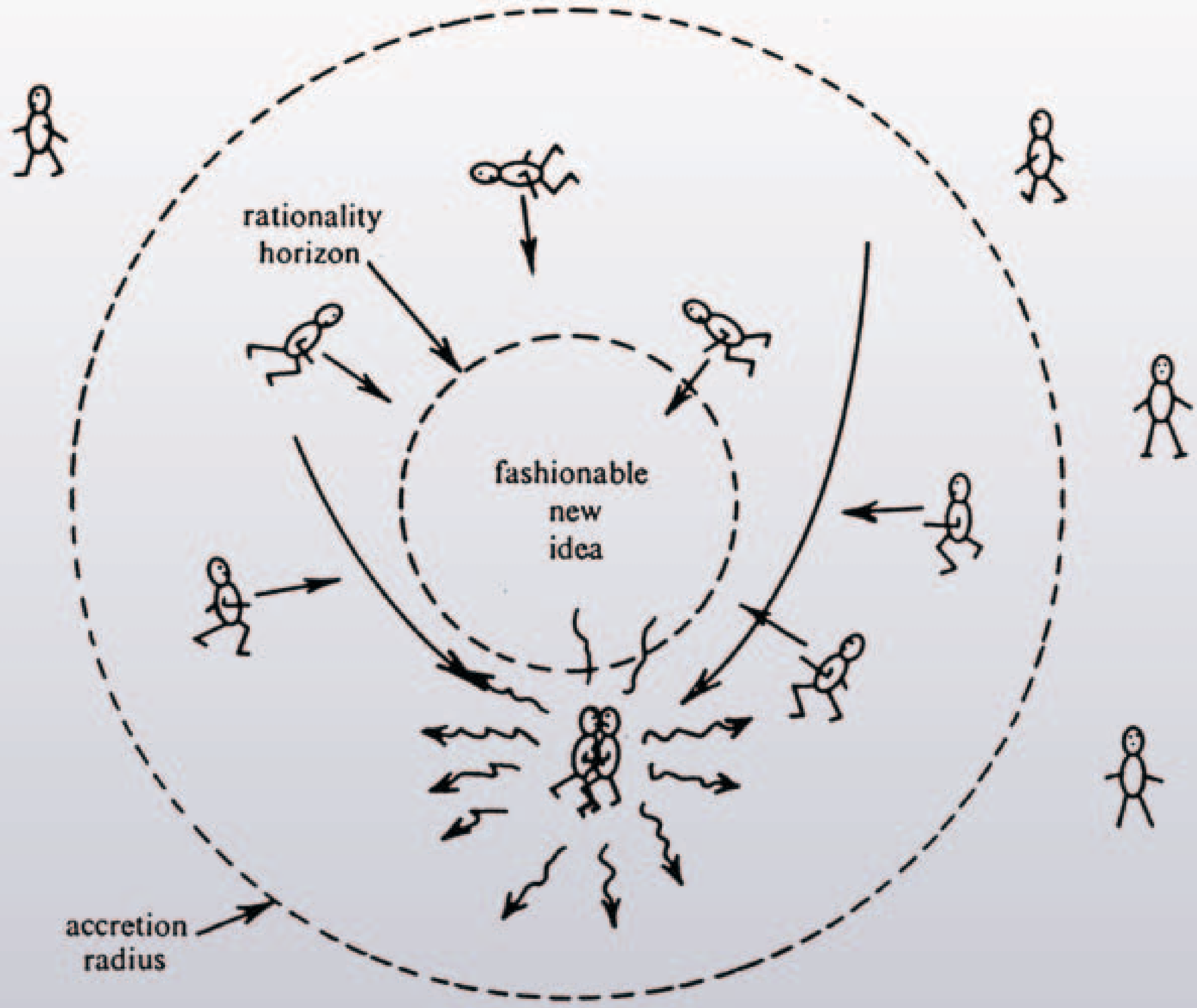

Fig. 1. Response of astronomers to a fashionable new idea.

from McCray, 1979, in “Active Galactic Nuclei,”
eds. Hazard, C. & Mitton, S. (Cambridge: Cambridge University Press), p.227

Motivation and basic picture

Understanding the BLR

- Broad lines a defining characteristic of AGNs
- **Integral part of the accretion flow and wind**
- Affects our analysis of intrinsic absorption lines
- Broad lines a tool for getting black hole mass

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Clues we can use

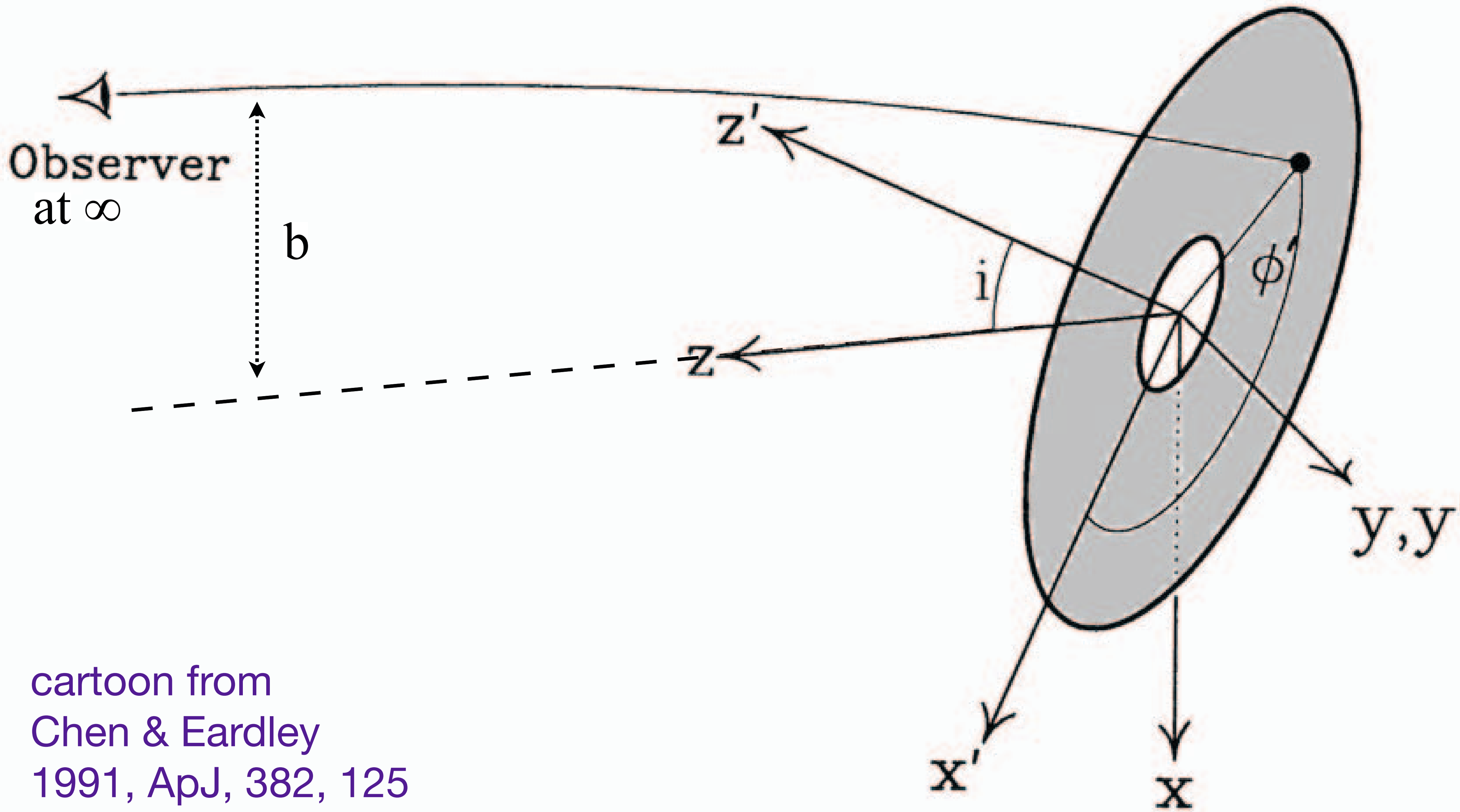
- Virialized gas motions
- Flattened geometry
- Reverberation signature of a Keplerian disk

See poster 2.12 by Kelly Denney

Outline

- Put together two previous calculations of emission line profiles from a disk (relativity + radiative transfer).
- Produce a simple model that allows us to scan parameter space efficiently and evaluate the merits of the basic idea.
- **Explore the consequences of radiative transfer of line photons through the base of a wind.**
- **Compare the statistical properties of observed Balmer line profiles with the predictions of the model.**

Overal geometry



cartoon from
Chen & Eardley
1991, ApJ, 382, 125

Methodology

ala Chen & Halpern 1989, ApJ, 344, 115

$$F_\nu = \int_0^{2\pi} d\varphi' \int_{\xi_1}^{\xi_2} \xi d\xi \;\; I'_{\nu_\mathrm{e}}(\xi, \varphi', \nu_\mathrm{e}) \; D^3(\xi, \varphi', \nu_\mathrm{e}) \; \Psi(\xi, \varphi')$$

$\xi = rc^2/GM$

- I'_{ν_e}: disk emission properties (local)
- D^3: potential and phase space distribution of emitting particles (velocity field + metric + geometry)
- Ψ: photon trajectories (metric + geometry)

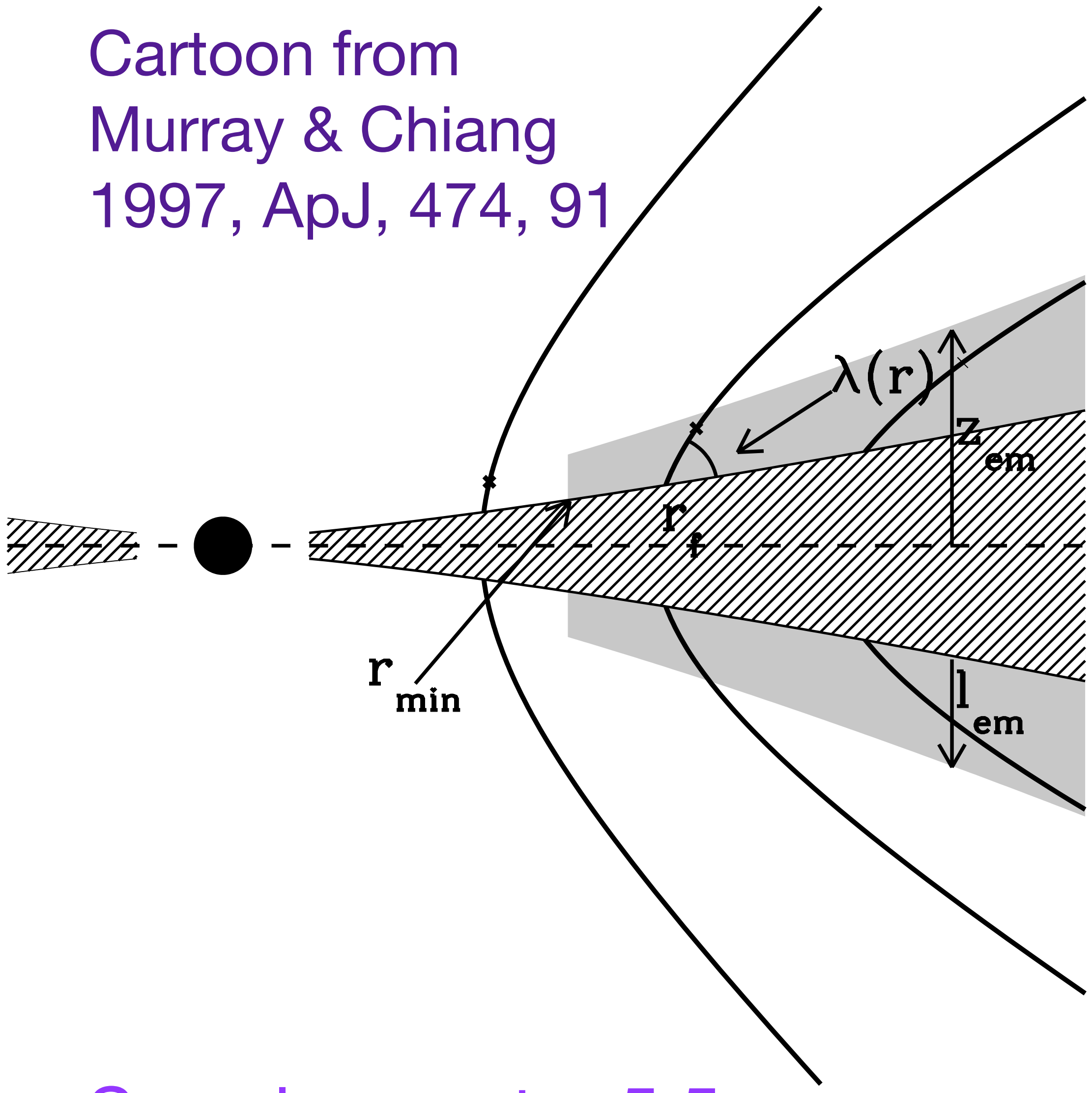
$$I_{\nu_e}(\xi, \phi', \nu) \propto \beta(\tau_{\nu_e}) \epsilon(\xi, \phi') \exp\left[-\frac{(\nu_e - \nu_0)^2}{2\sigma^2}\right]$$

Structure of line-emitting skin

Approximations for Balmer lines only

- Emission from base of wind (highest *n*, lowest *U*)
- Keplerian rotation
- No net outflow but high acceleration
- No electron scattering or resonance scattering.

Cartoon from
Murray & Chiang
1997, ApJ, 474, 91



See also poster 5.5
by Laura Chajet

Directional escape probability & optical depth

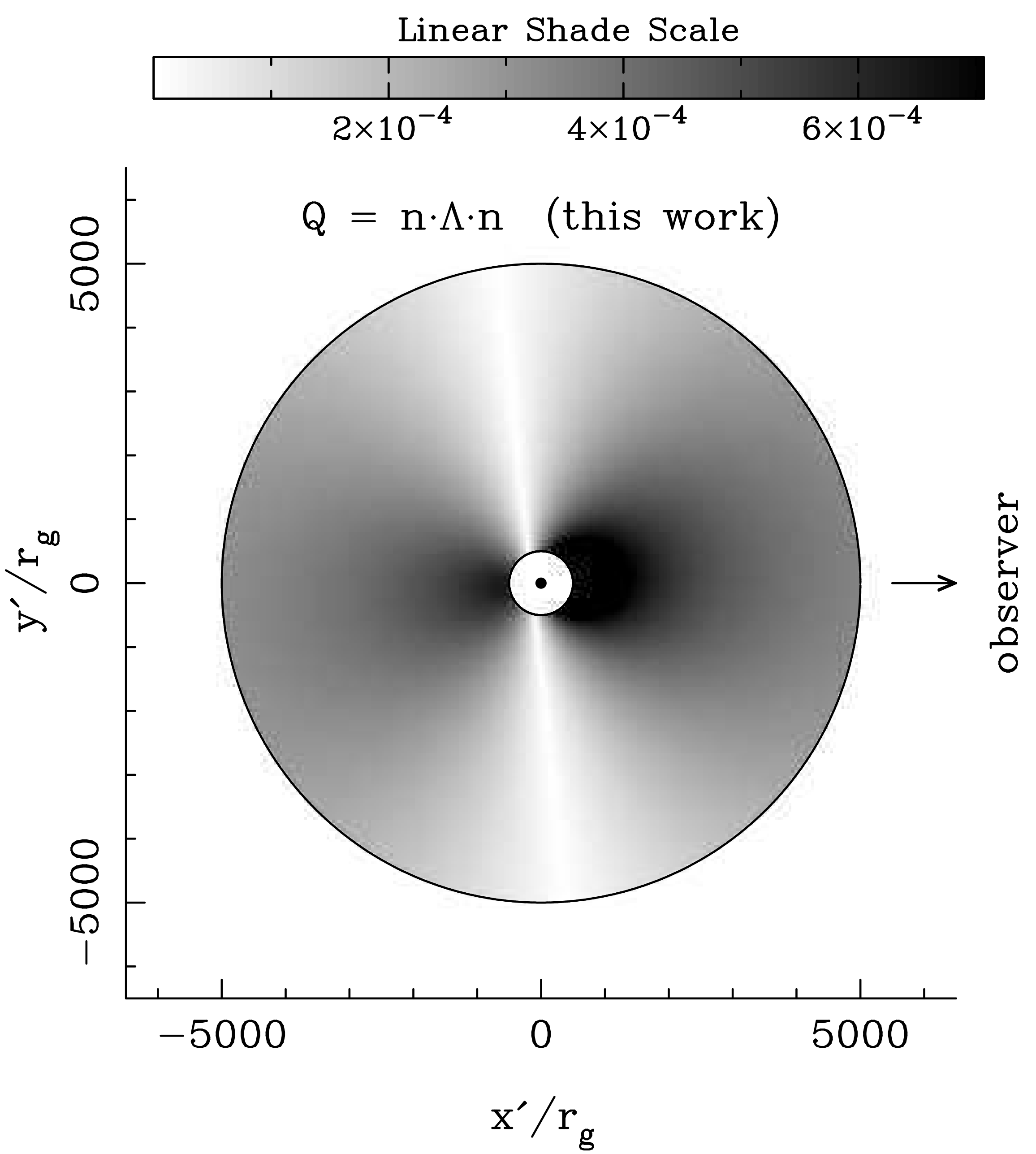
$$\beta(\tau_{\nu_e}) = \frac{1 - e^{-\tau_{\nu_e}}}{\tau_{\nu_e}}$$

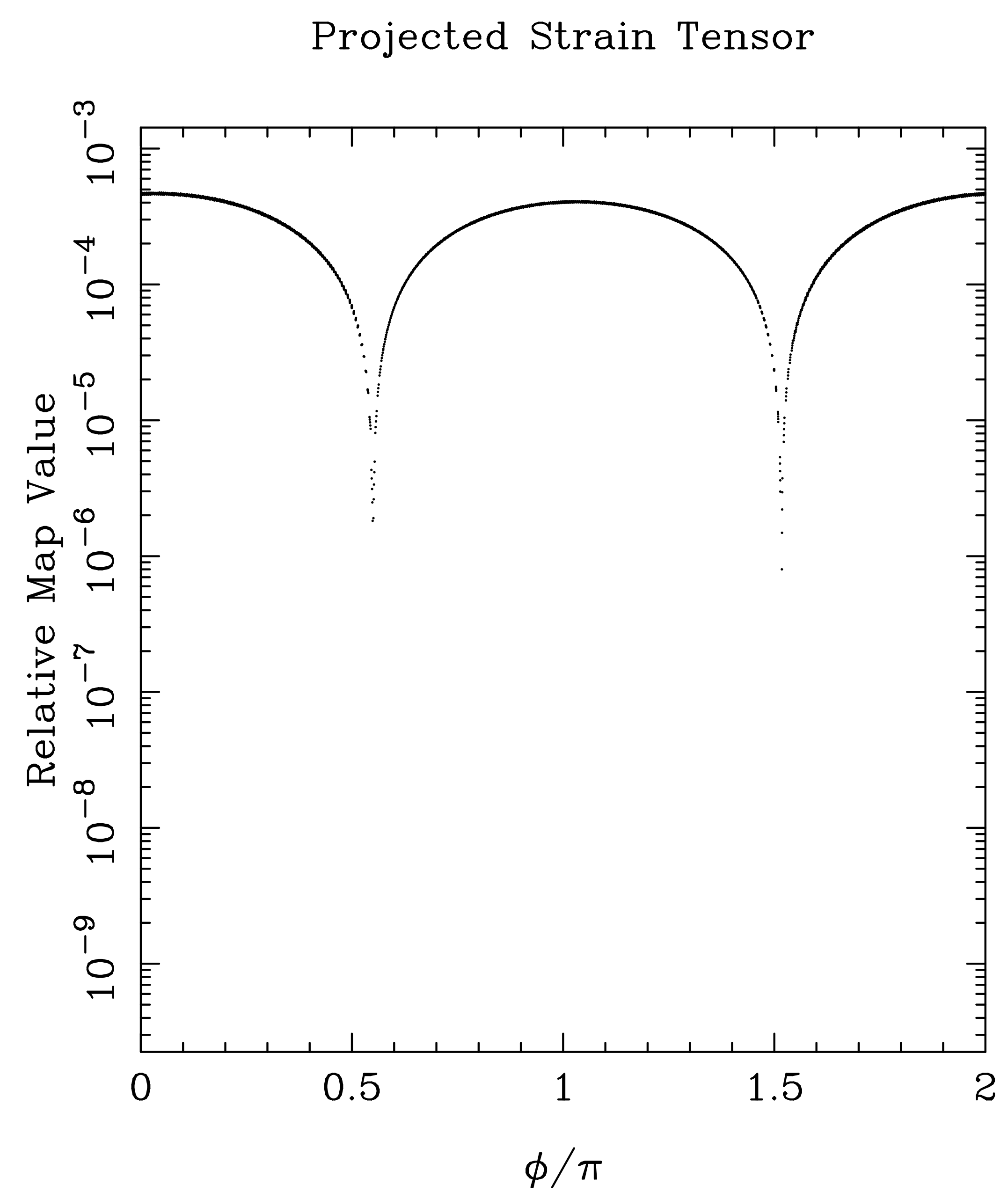
Following Murray & Chiang 1997, ApJ, 474, 91

$$\tau_{\nu_e}(\xi, \phi') = \frac{\kappa\rho\sigma}{|\hat{\mathbf{n}} \cdot \mathbf{\Lambda} \cdot \hat{\mathbf{n}}|} = \frac{\tau_0 \xi^{3/2-\eta}}{Q_0}$$

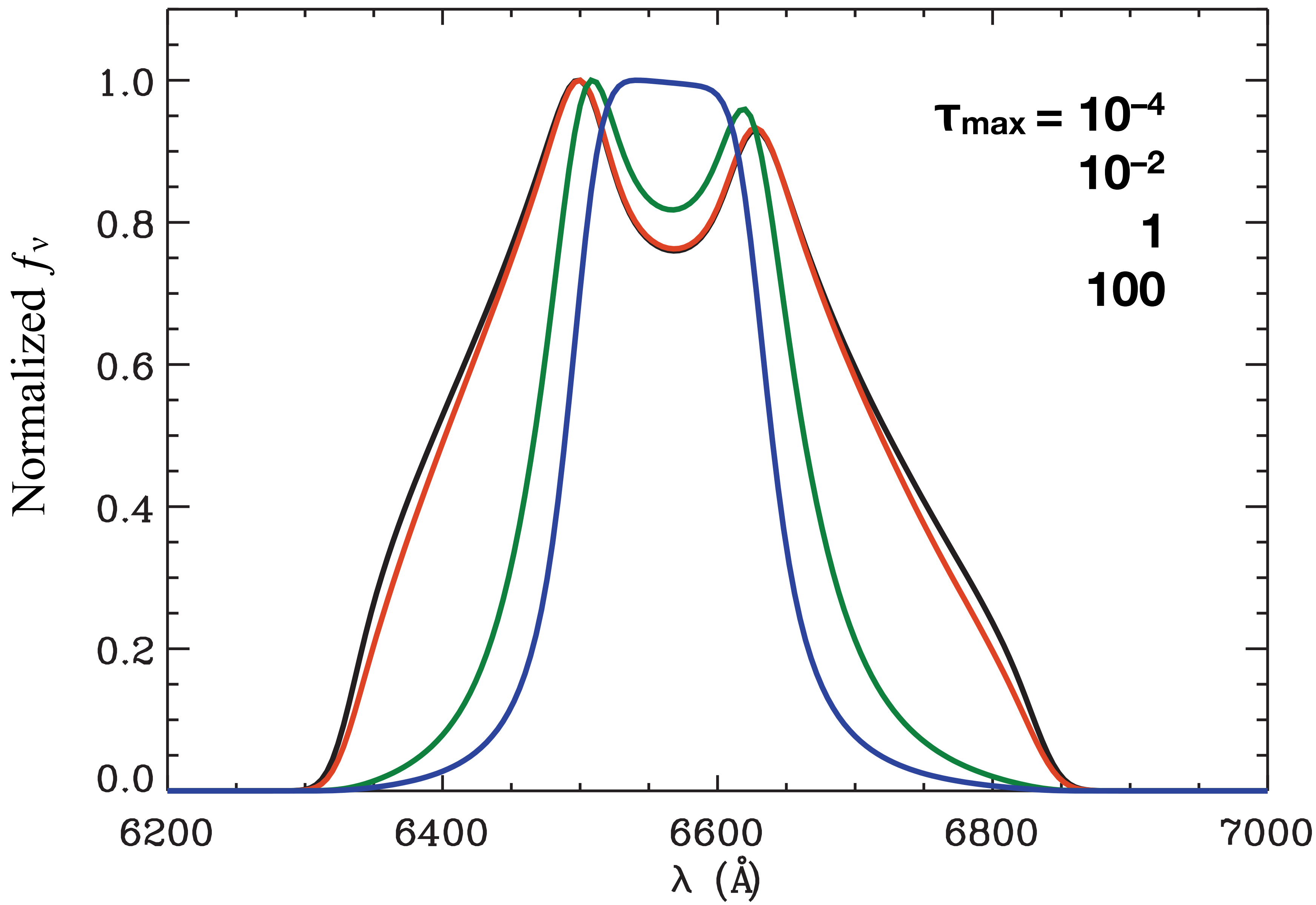
$$\begin{aligned} Q_0 \quad &= \quad \sin^2 i \left(4.7 \cos^2 \phi' + \frac{3}{2} \sin \phi' \cos \phi' \right) \\ &+ \cos i \left(\frac{4.7 \sin i \cos \phi'}{\sin \lambda} + 4.7 \cos i + \frac{\sin i \sin \phi}{2 \sin \lambda} \right) \end{aligned}$$

Bottom line: surface brightness of the disk





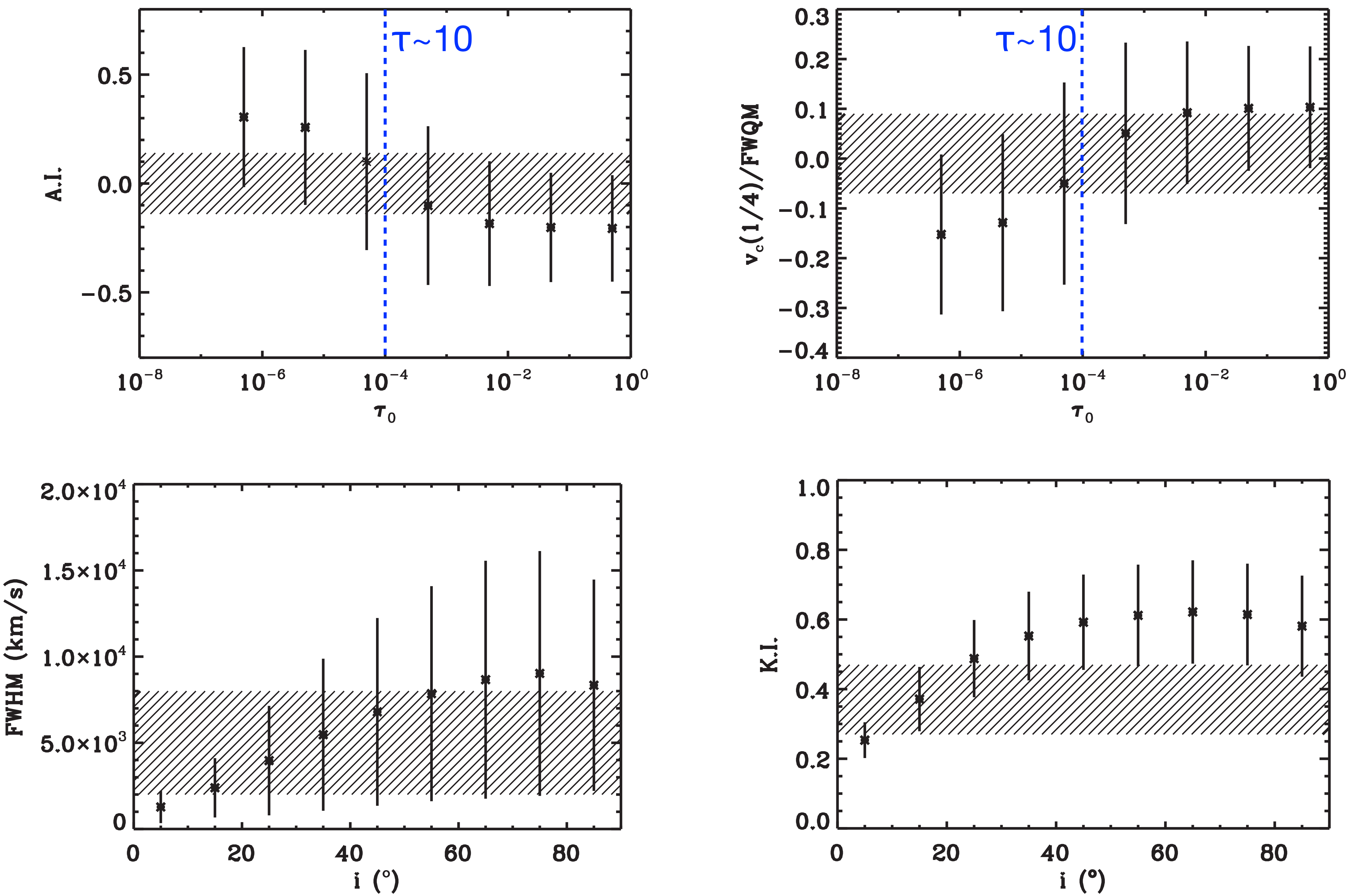
Effect of optical depth on line profiles



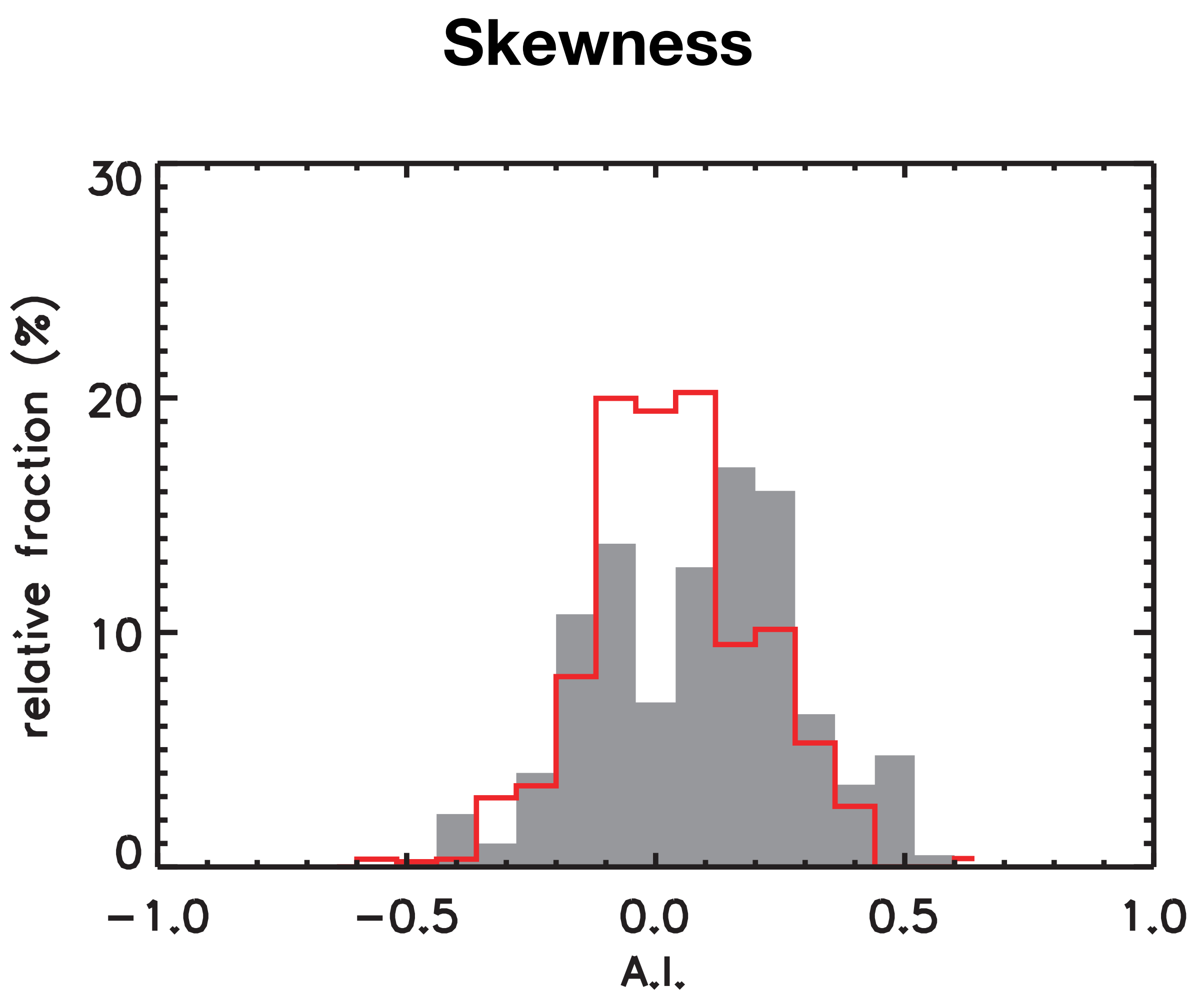
i = 60°
ξ = 500 – 10000
λ = 10°
q = 2.5
η = 2

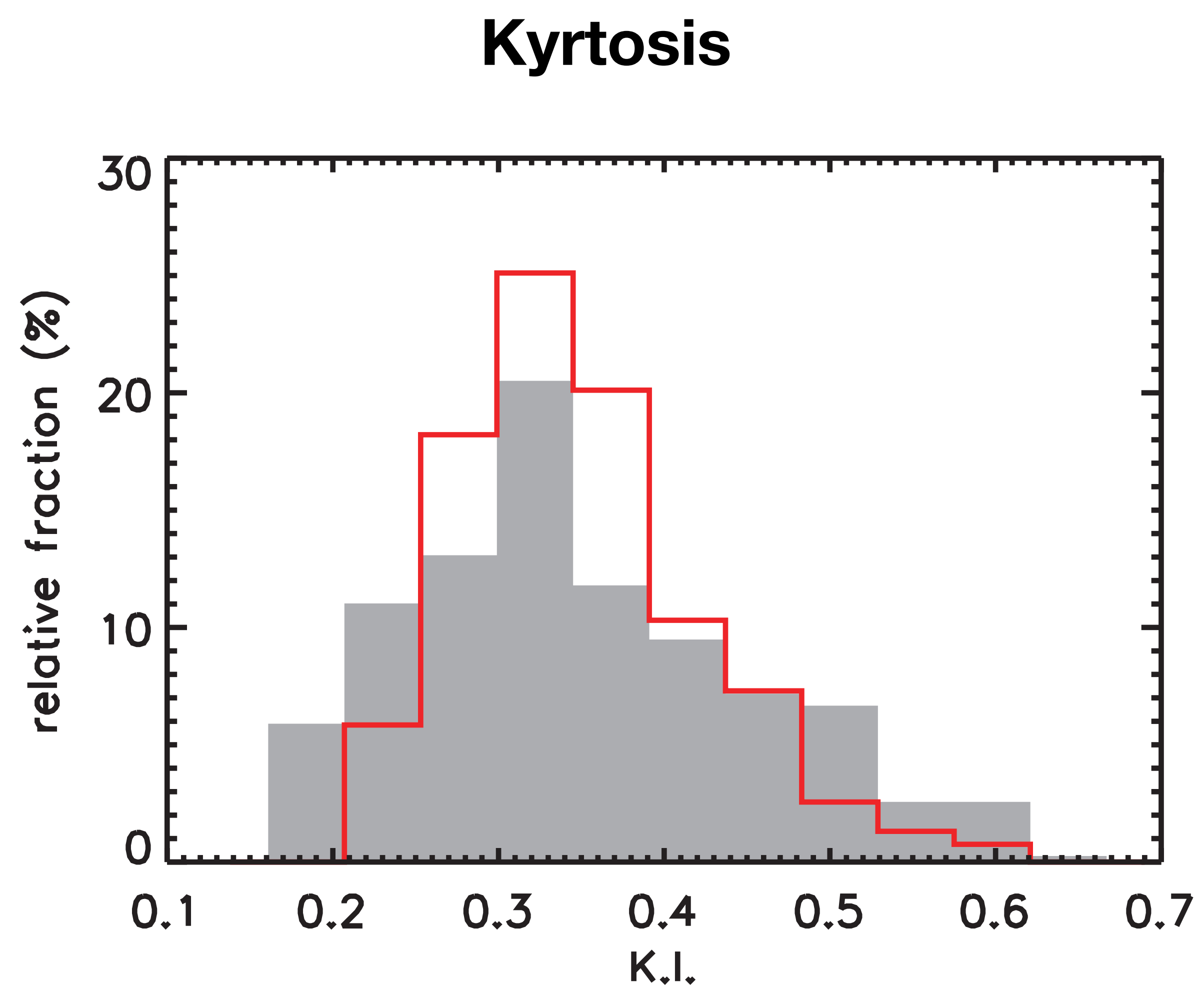
Comparison with data

from Zamfir et al. 2010,
MNRAS, 403, 1759


τ~10
A.I.
τ_0
τ~10
$v_c(1/4)$/FWQM
τ_0
FWHM (km/s)
i (°)
K.I.
i (°)

Distribution of line profile asymmetries



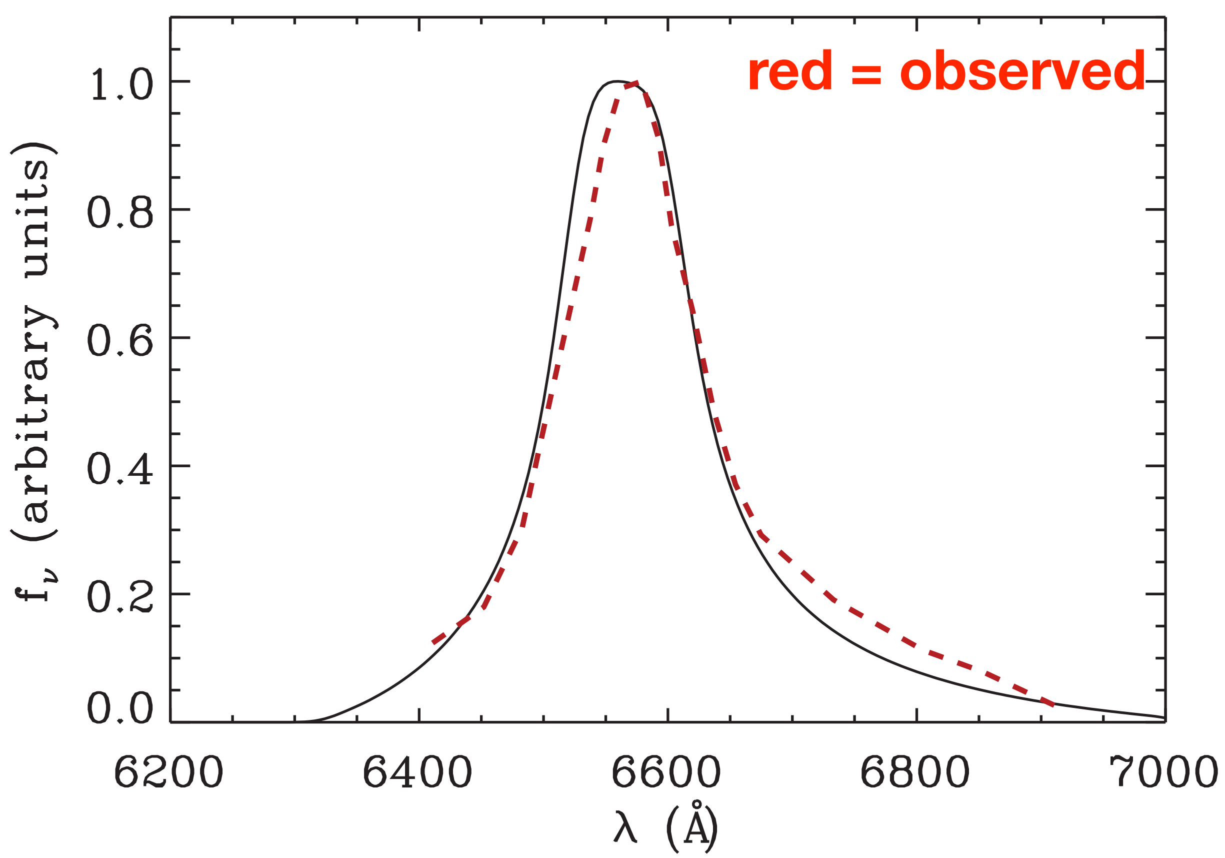


red = observations

grey = simulations

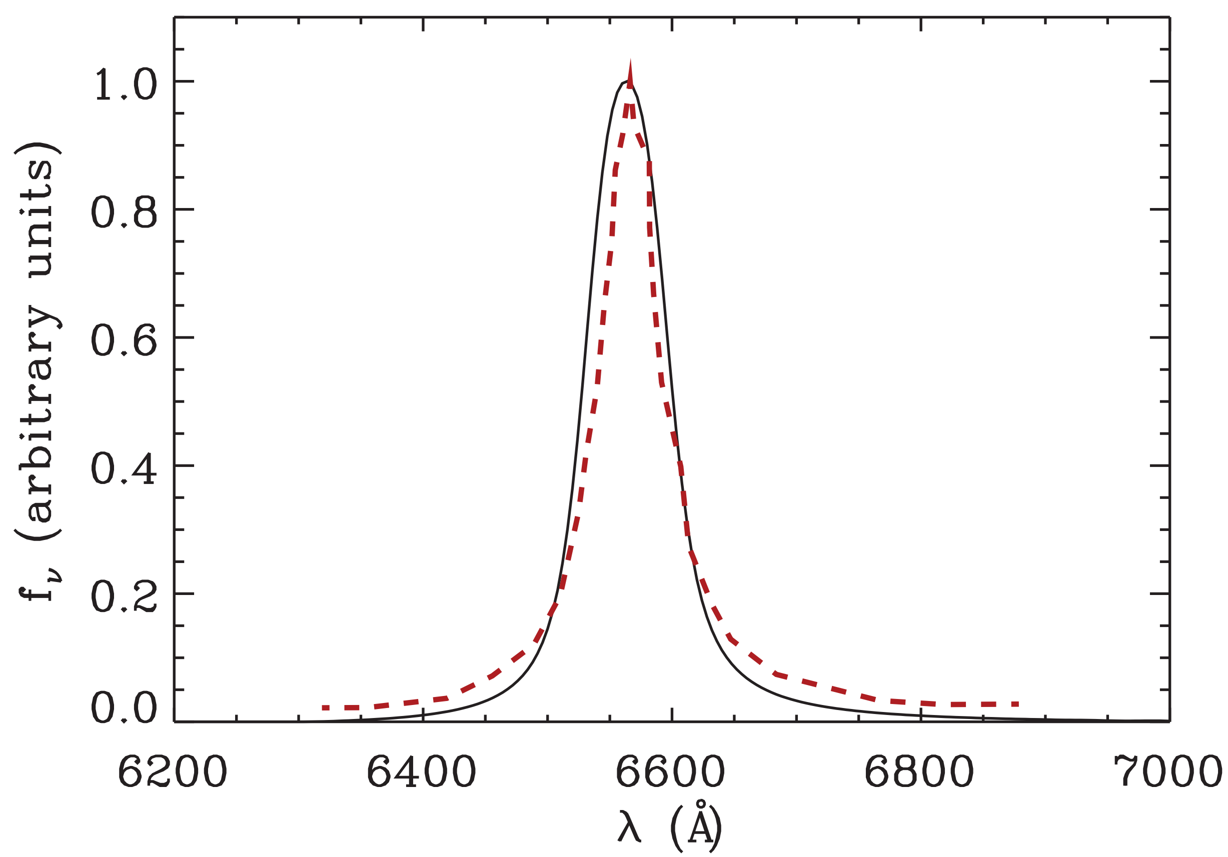
Comparison with observed average line profiles

Type B1



λ = 15°, i = 30°
q = 3
ξ = 100 – 10000
η = 1.5

Type A1



λ = 15°, i = 30°
q = 3
ξ = 100 – 20000
η = 2

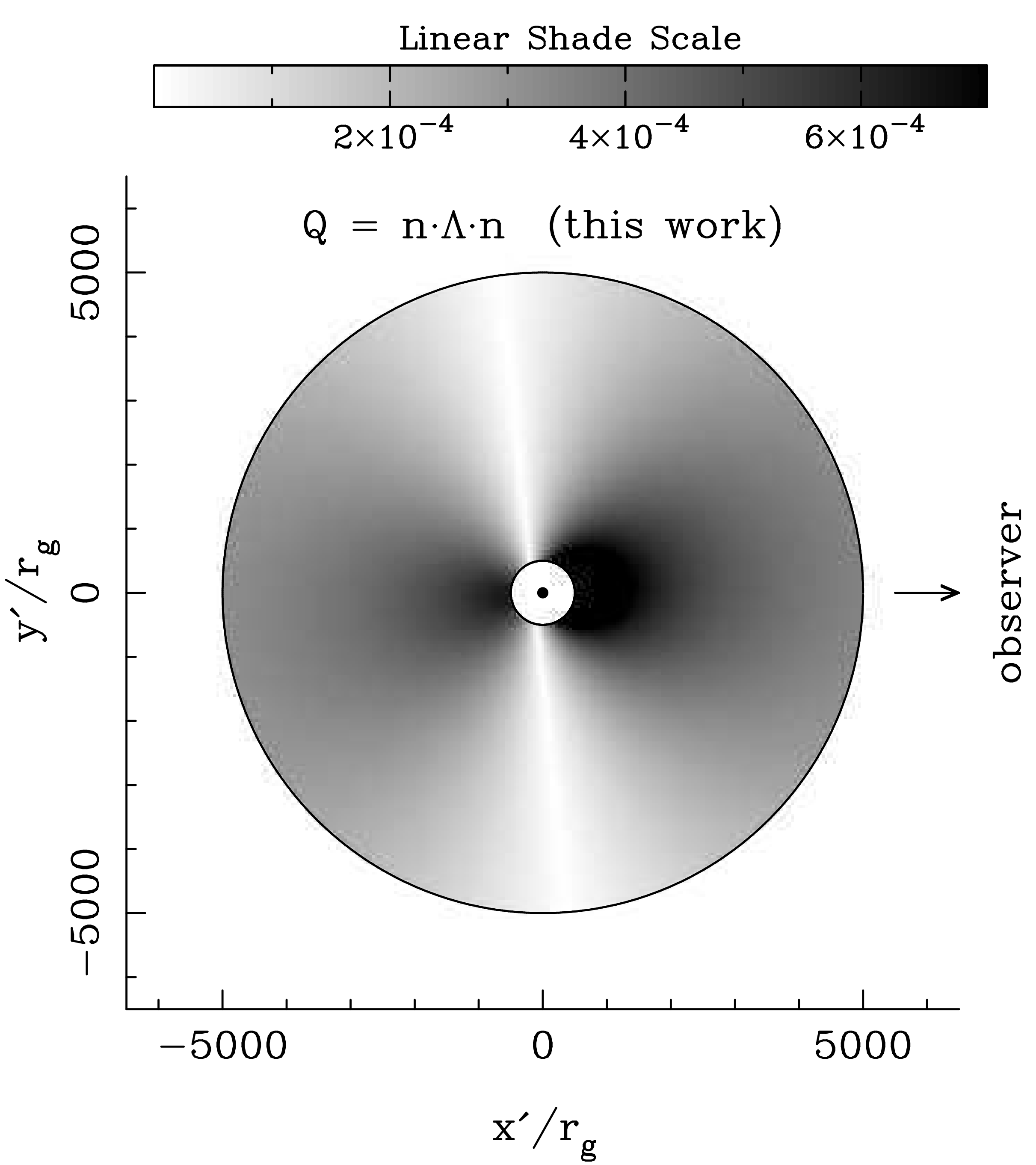
So far, so good, so what?

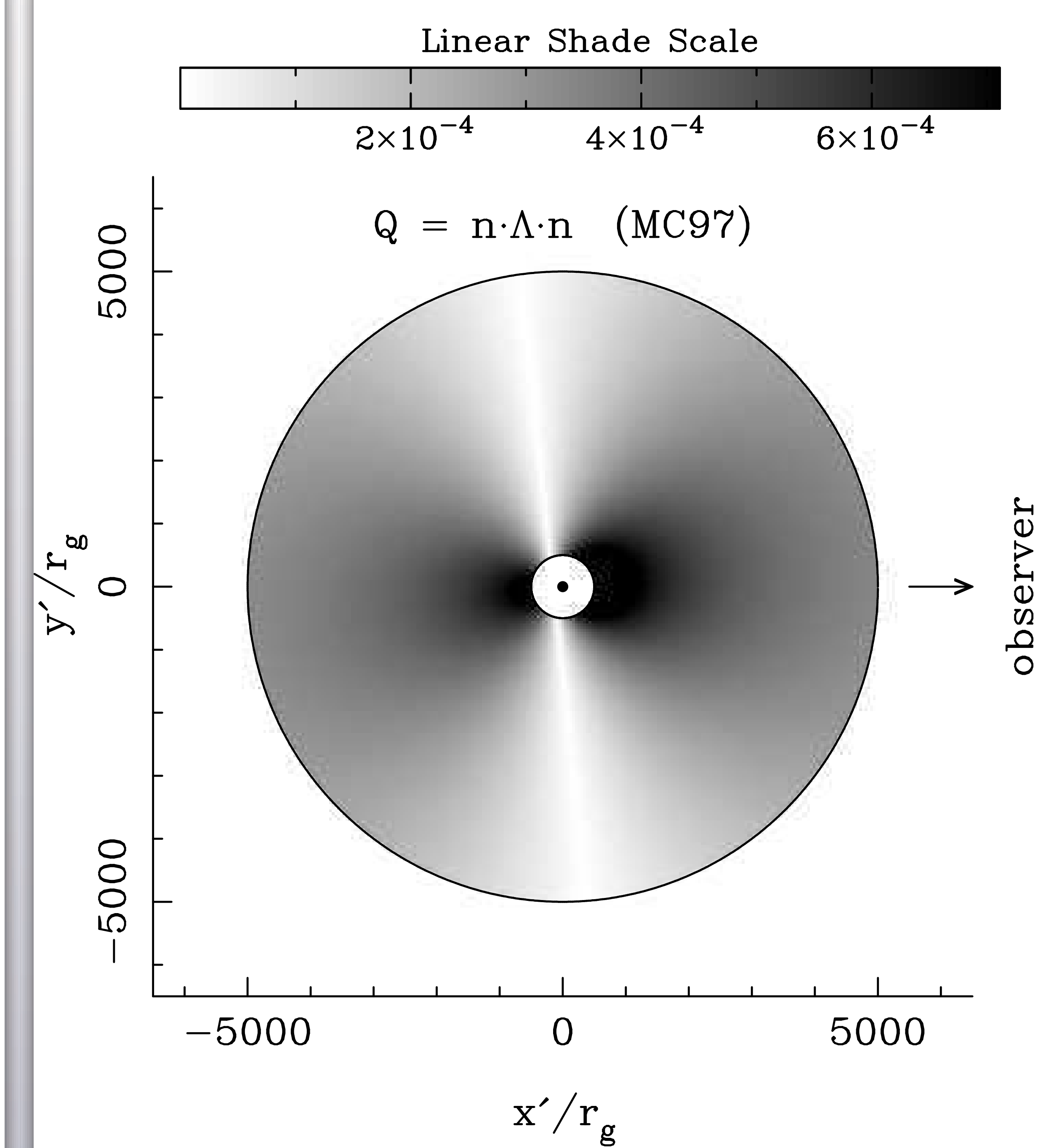
- Ultimately would like to explain **all** observed trends, (e.g., talk by G. Richards)

  Will have to couple profile calculations with photoionization models and SED shapes

- Eventually should use sophisticated models for the disk and its wind.
- Clumpiness and time variability...

The End


Linear Shade Scale
2×10⁻⁴
4×10⁻⁴
6×10⁻⁴
Q = n·Λ·n (this work)
observer
y′/r_g
x′/r_g
5000
0
−5000
−5000
0
5000


Linear Shade Scale
2×10⁻⁴
4×10⁻⁴
6×10⁻⁴
Q = n·Λ·n (MC97)
observer
y′/r_g
x′/r_g
5000
0
−5000
−5000
0
5000

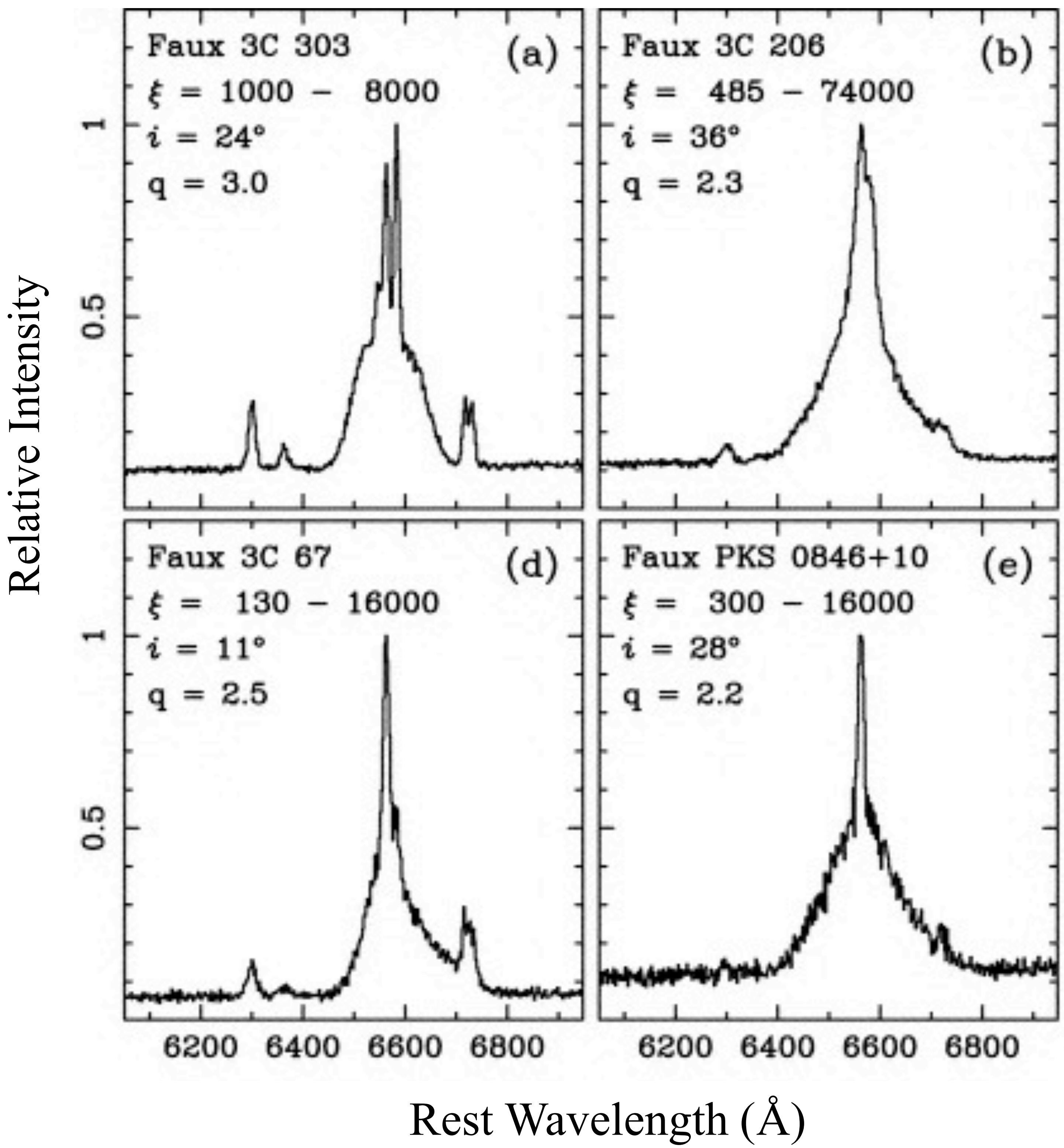
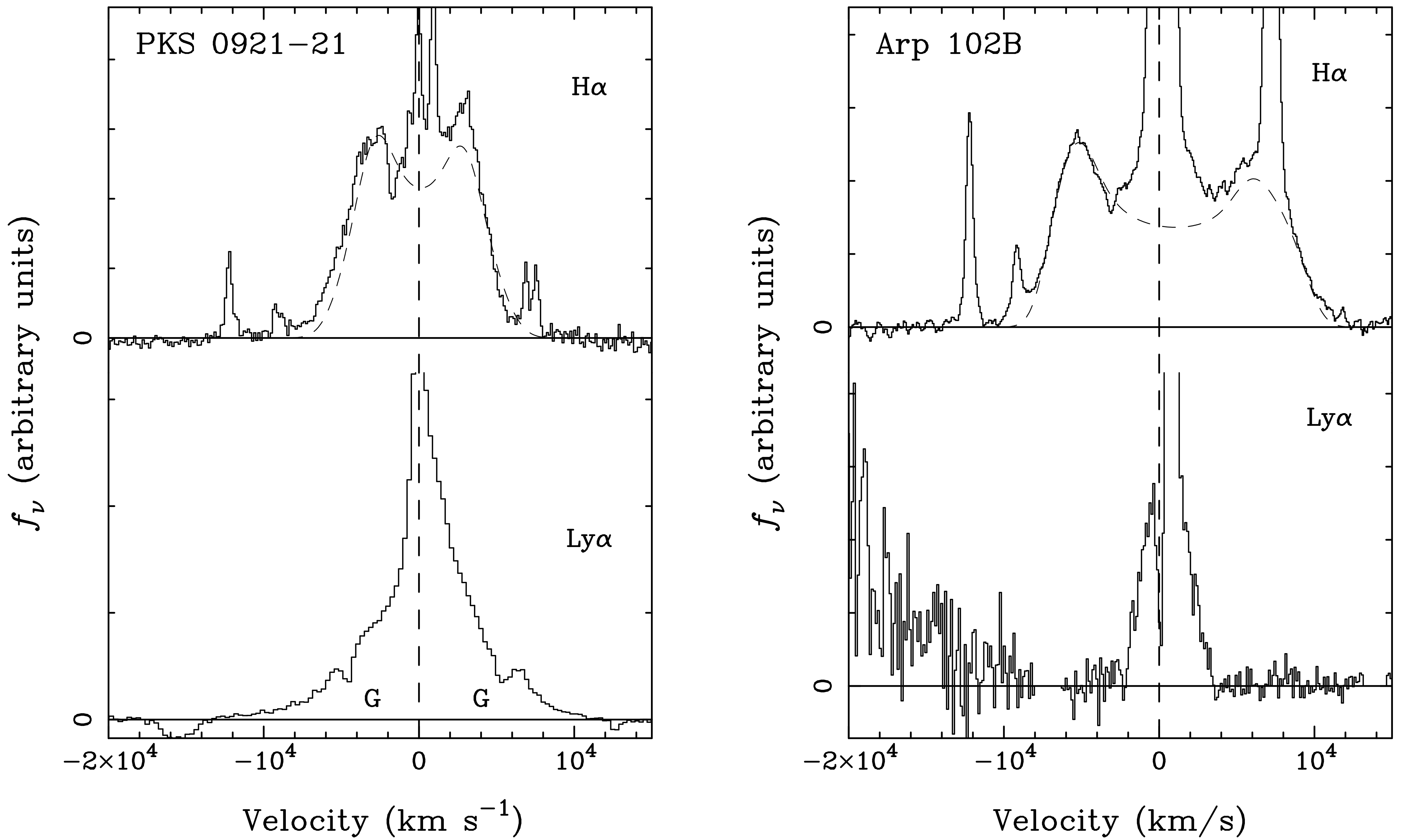


figure from
Eracleous & Halpern
2003, ApJ, 599, 886



Halpern et al. 1996, ApJ 464, 704