# X−ray Spectral Modeling for Low−Mass X−ray Binaries

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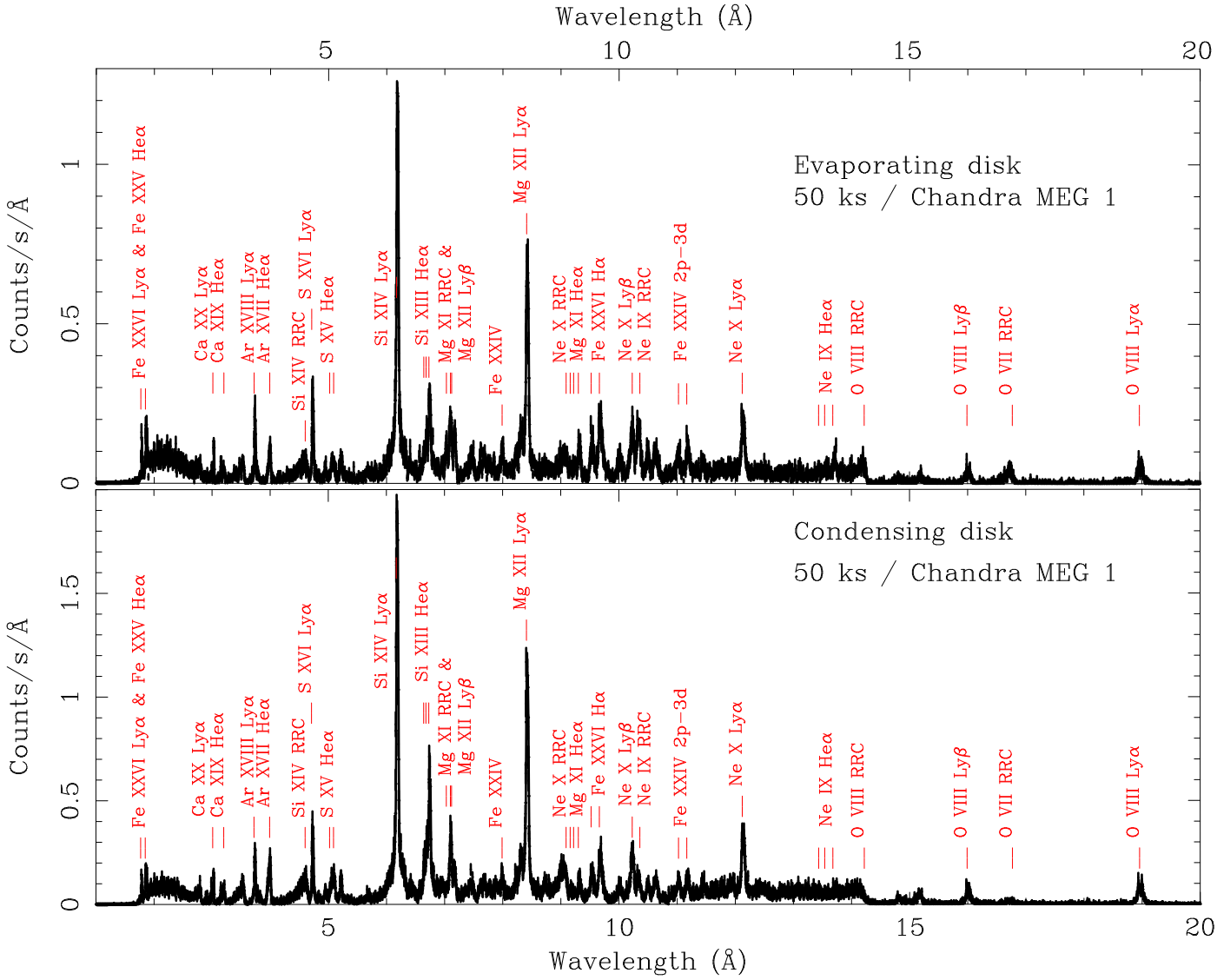
Duane Liedahl (LLNL)

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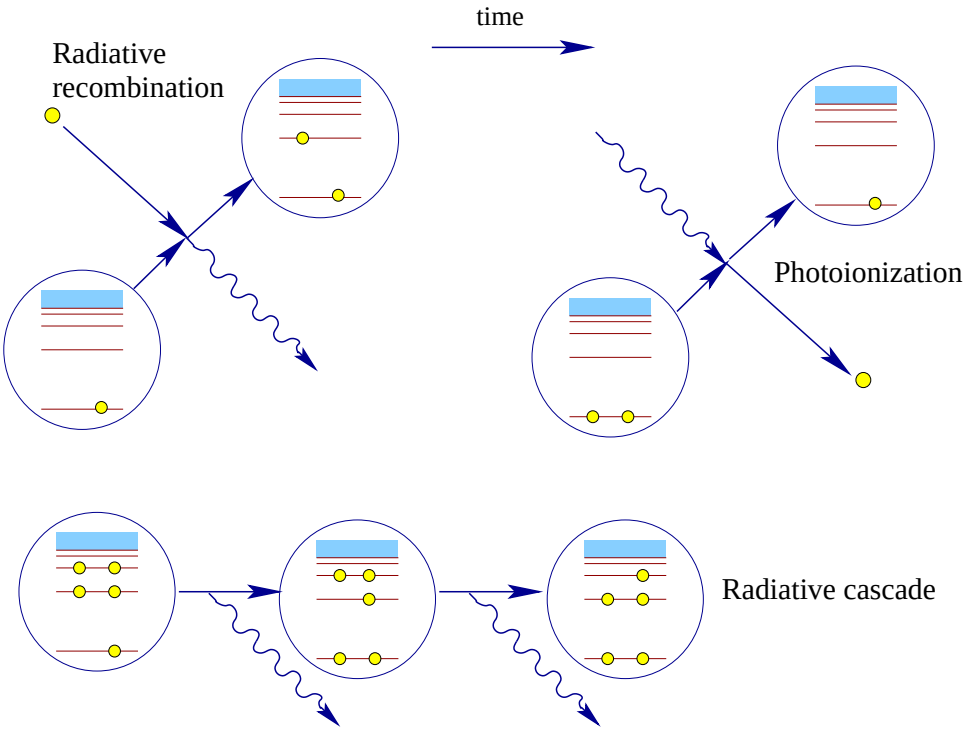
# Photoionized Plasma Models

Heating = Cooling
Recombination rate = Photoionization rate

## Particle−photon interactions




Ionization parameter $\xi = \frac{L}{n_e r^2}$

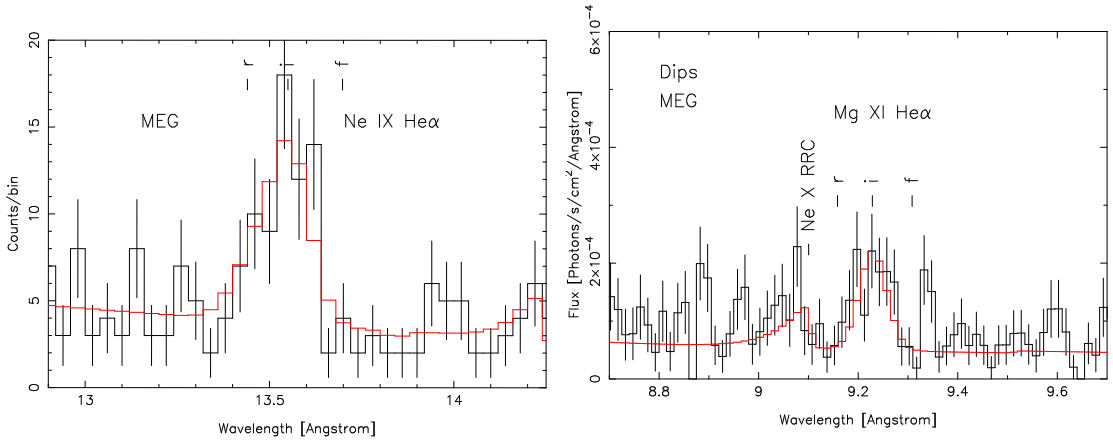
# Low−Mass X−ray Binaries with Broad X−ray Line Emission

Hypothesis: Kepler−velocity broadened lines from the accretion disk

HETG

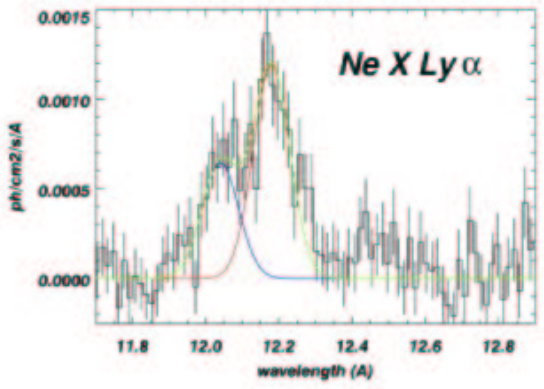
EXO 0748−676: eclipses, bursts, dips

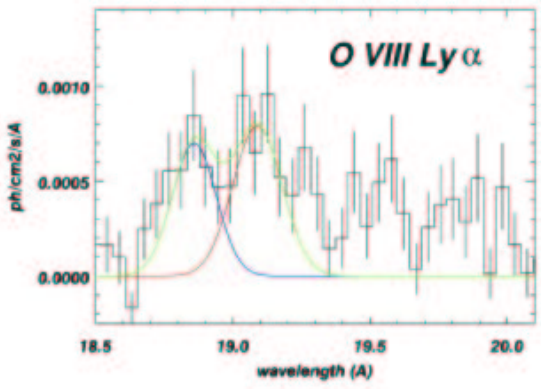
$P_{orb}$= 3.8 hr, $M_2$ ~ 0.4−0.8 $M_{sun}$




4U1626: X−ray pulsar

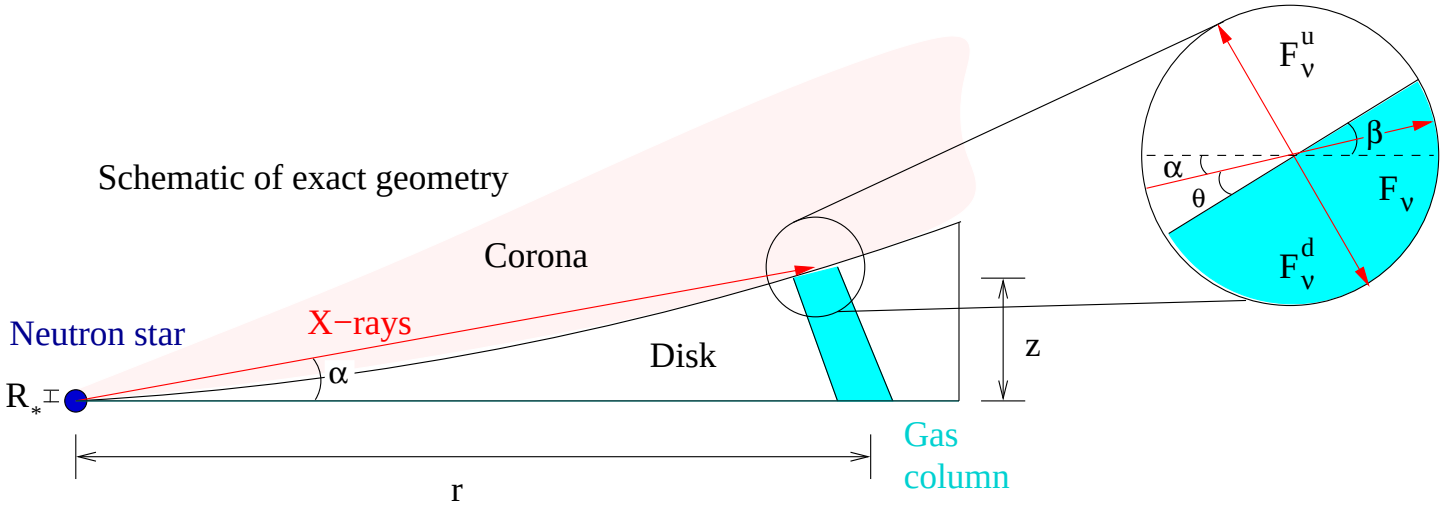
$P_{orb}$= 42 min, $M_2$ < 0.1 $M_{sun}$



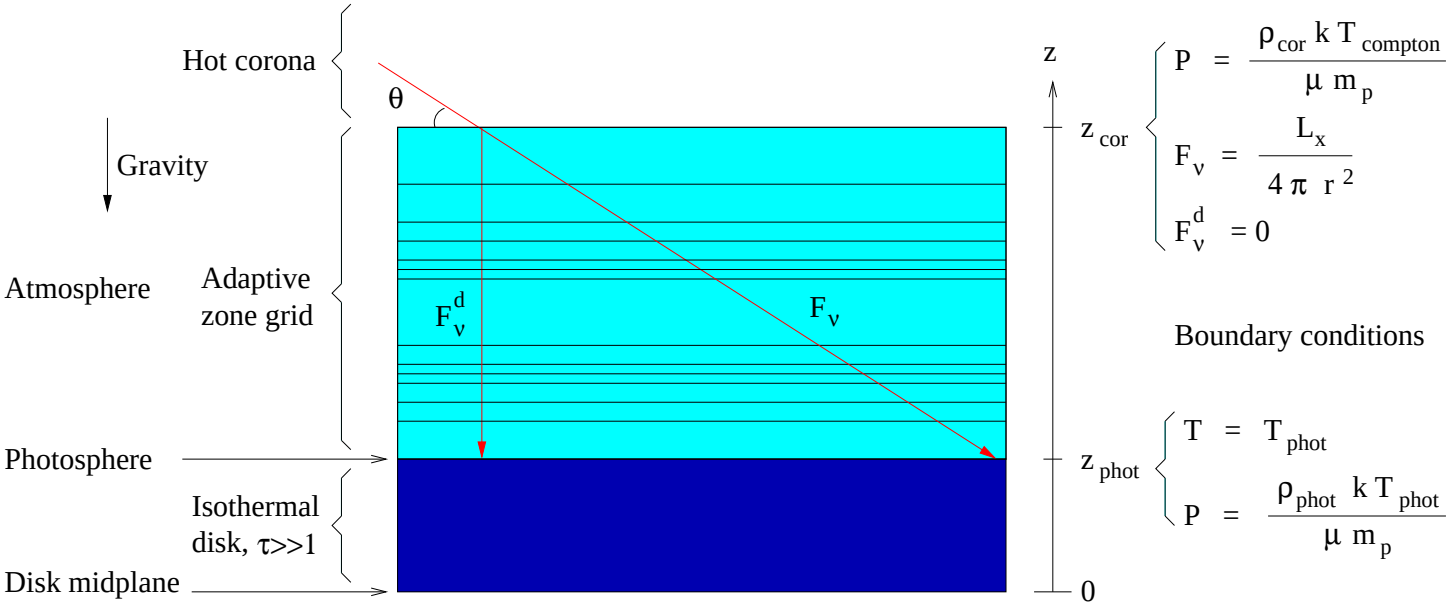

HETG Schulz et al.(2001)

# Centrally Illuminated Accretion Disk Atmosphere and Corona



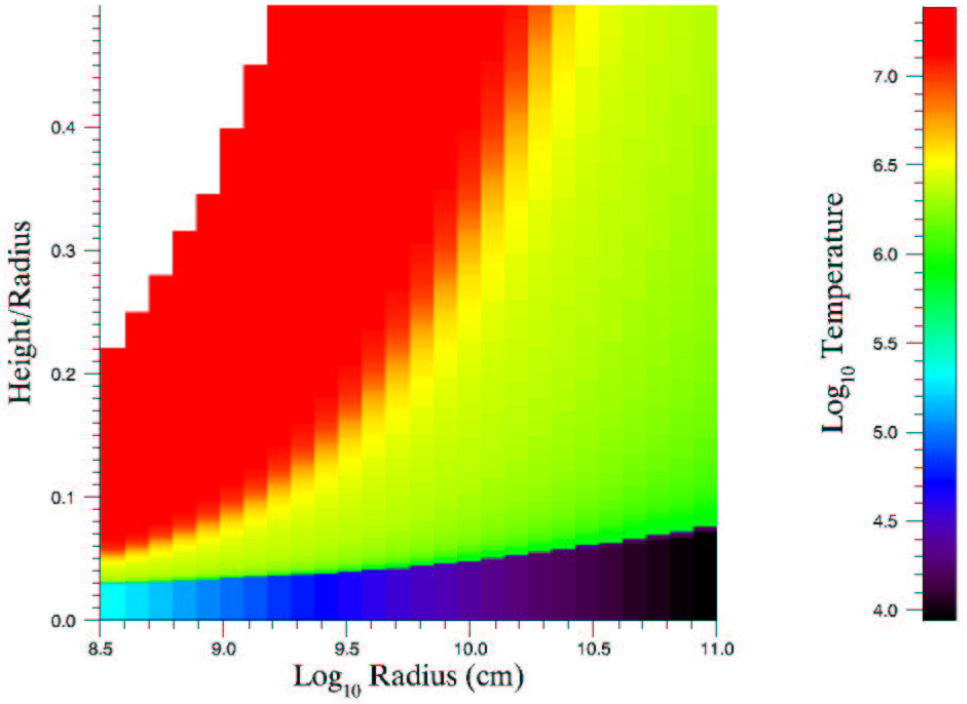

Radiation Transfer
Gravity
Hydrostatic Equilibrium
Thermal Balance
Ionization Equilibrium

$L_X = 10^{37}, 10^{38}$ erg $s^{-1}$

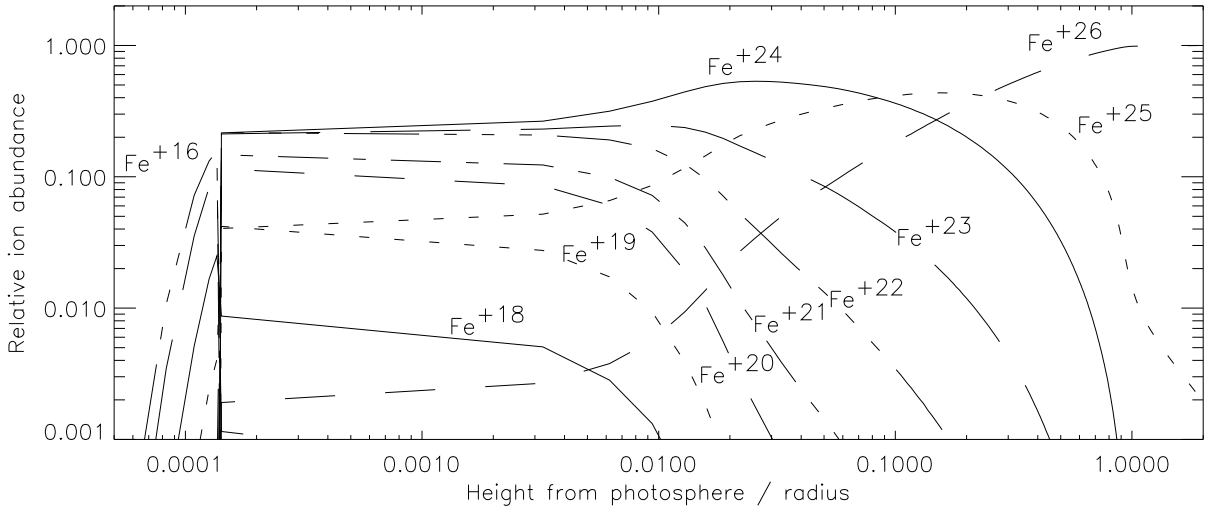


# Centrally Illuminated Accretion Disk Atmosphere and Corona

## Atmosphere thickened by Irradiation




## Vertical Ionization Structure

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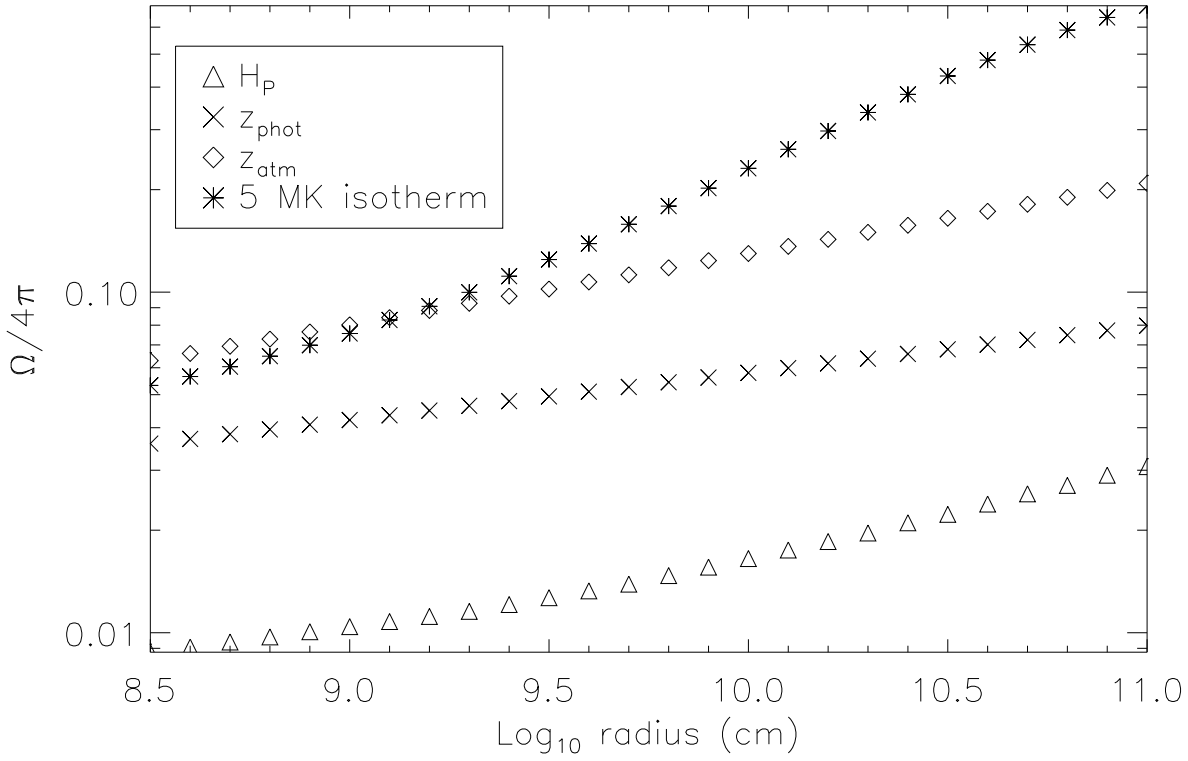
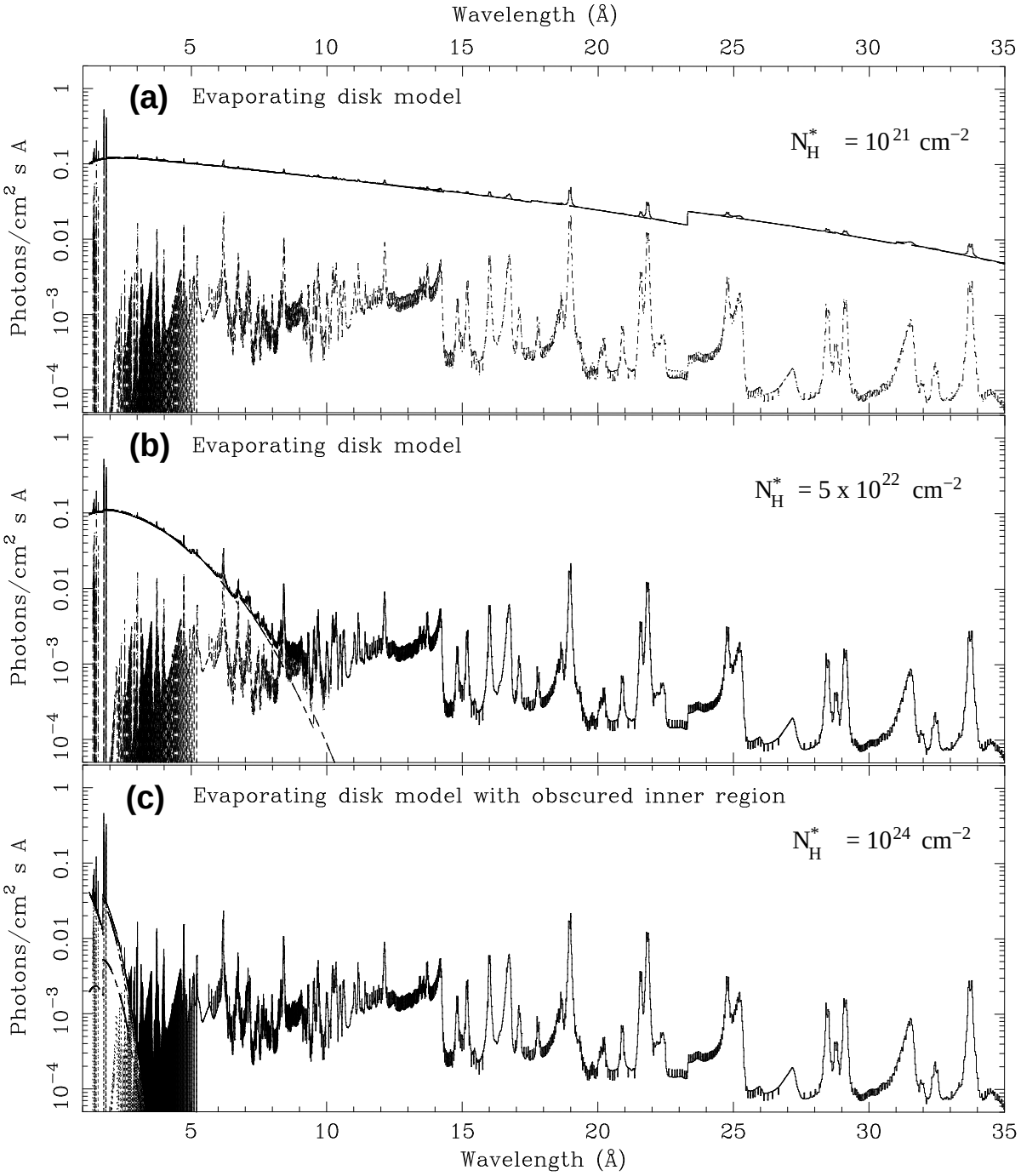
# Centrally Illuminated Accretion Disk

## A Thick Atmosphere and Corona



# Centrally Illuminated Accretion Disk Atmosphere and Corona

## Synthetic X−ray Spectrum vs. Absorption $N_H$ of Neutron Star Flux

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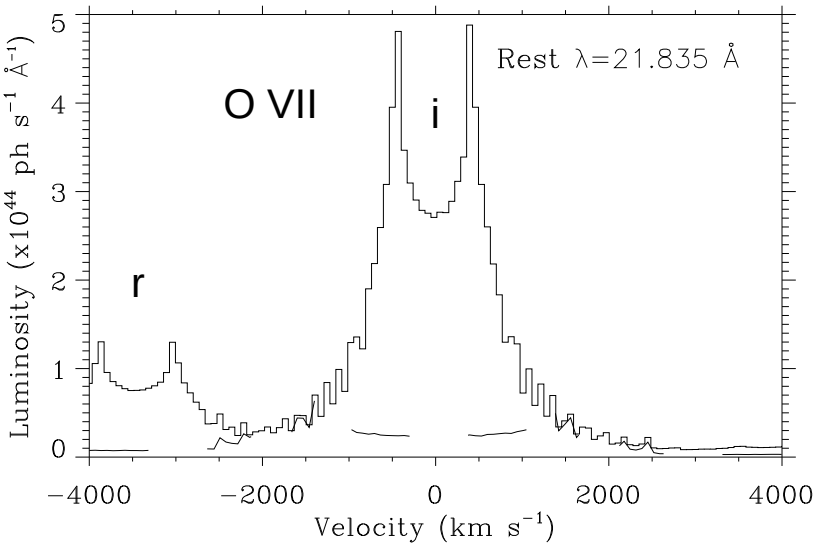
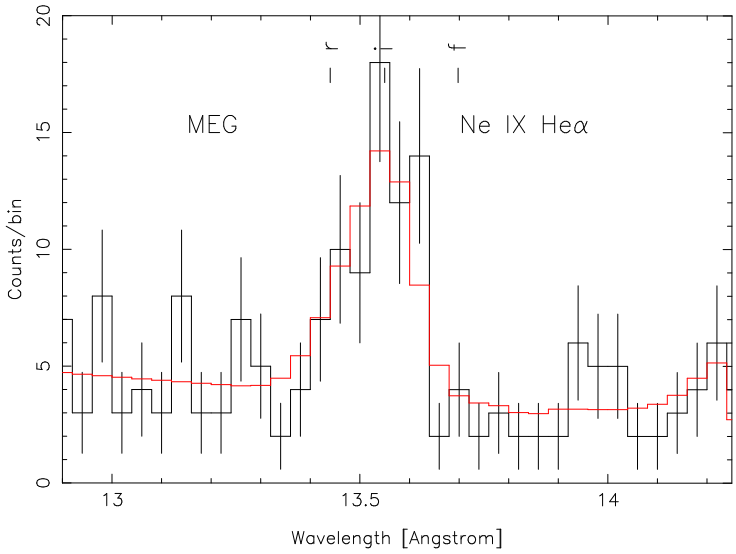
# Centrally Illuminated Accretion Disk Atmosphere and Corona

## Line profiles probe radial Atmosperic Changes

Synthetic Profiles and Plasma Diagnostics

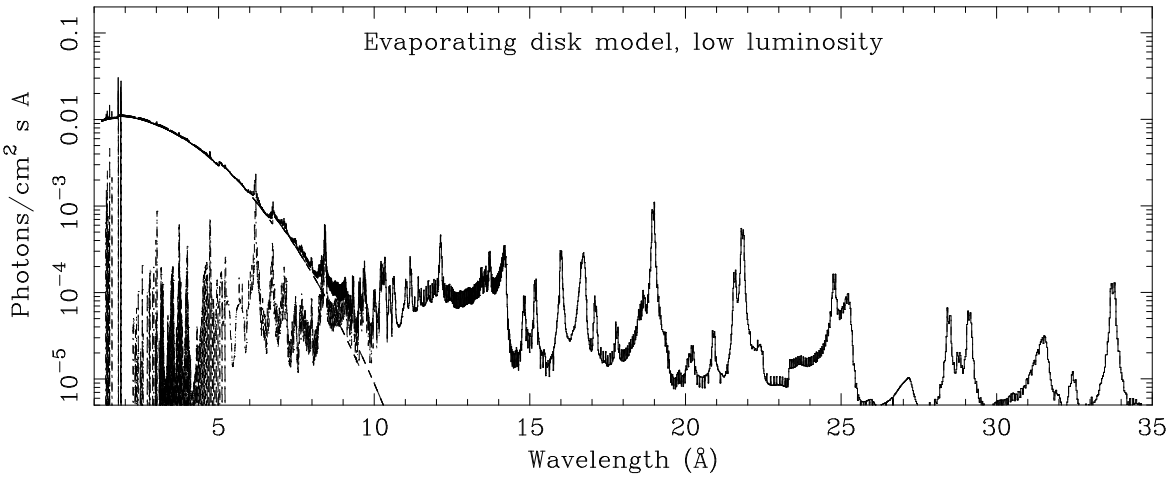



## HETG Data (EXO 0748−676)

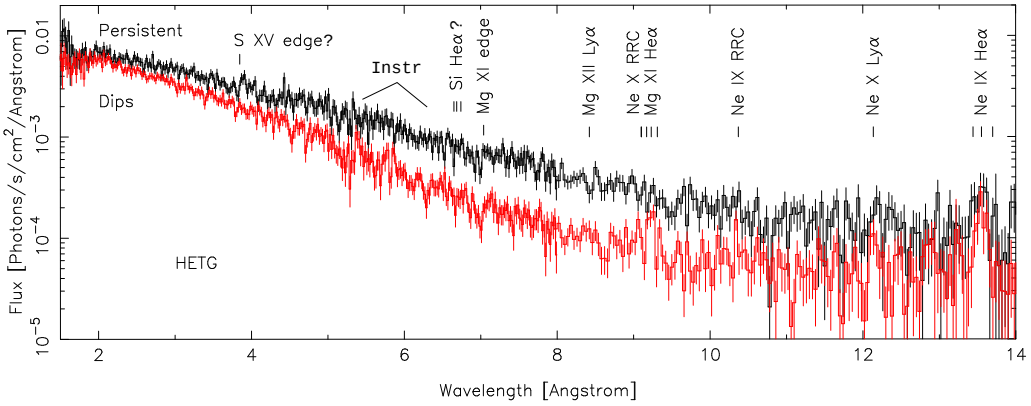


# Centrally Illuminated Accretion Disk Atmosphere and Corona

## Comparison with Spectral Data

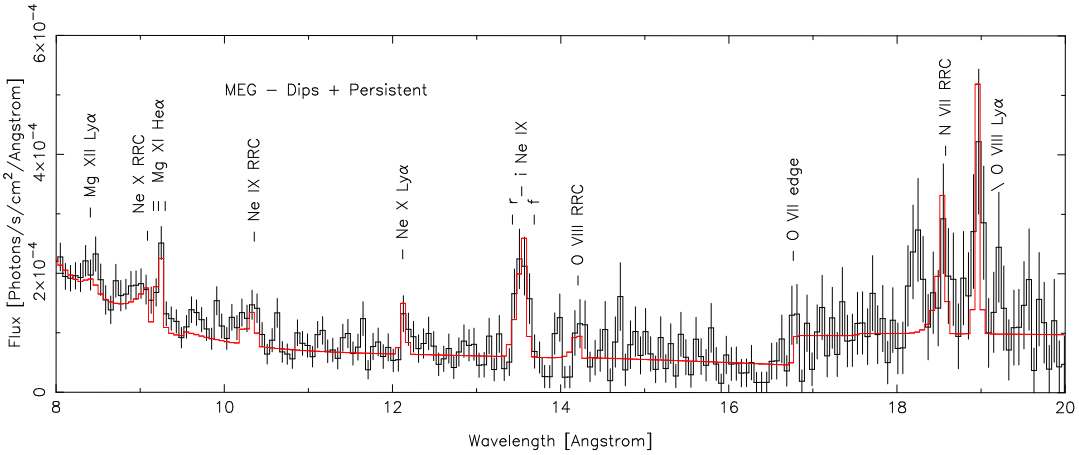



Model




HETG Data (EXO 0748−676)

Dips vs. No Dip




Dips

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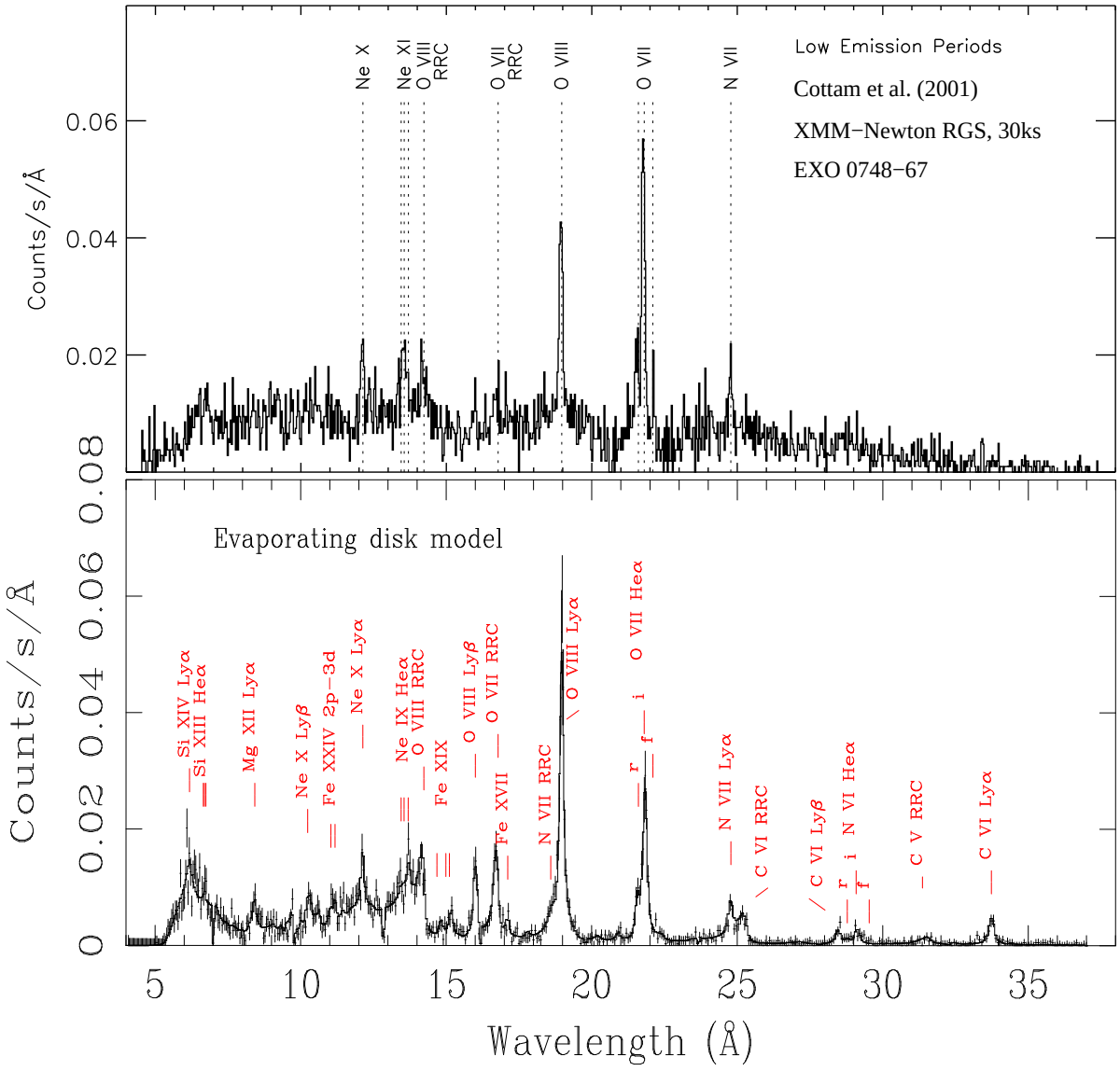
# Centrally Illuminated Accretion Disk Atmosphere and Corona

## Comparison with Spectral Data




Data

Model

EXO 0748−676: eclipses, bursts, dips

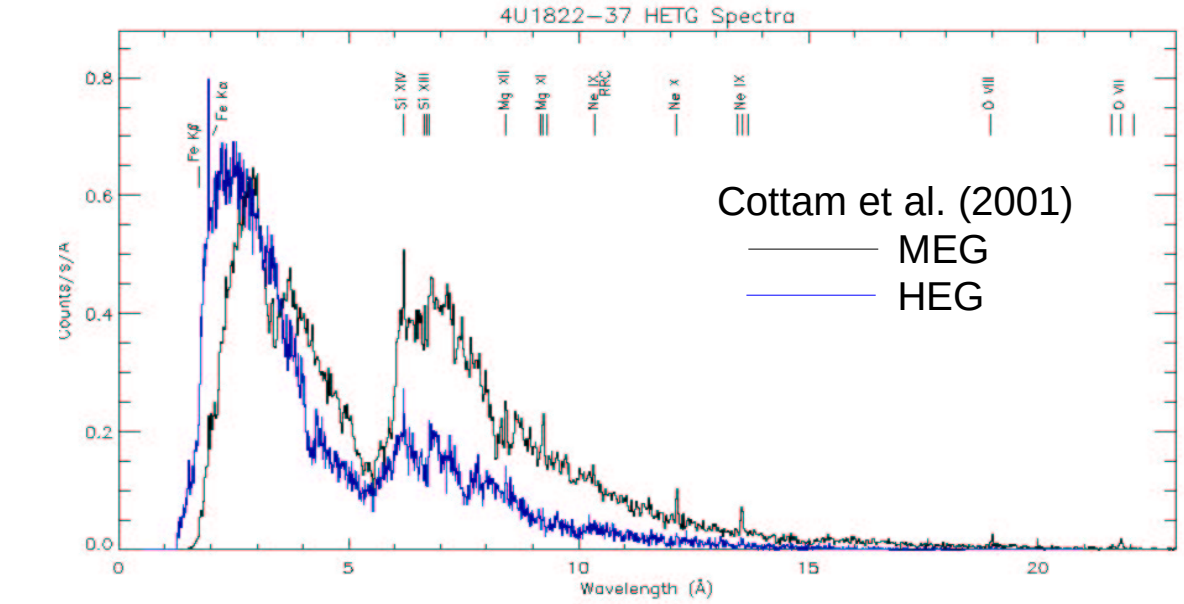
$P_{orb}$= 3.8 hr, $M_2$ ~ 0.4−0.8 $M_{sun}$

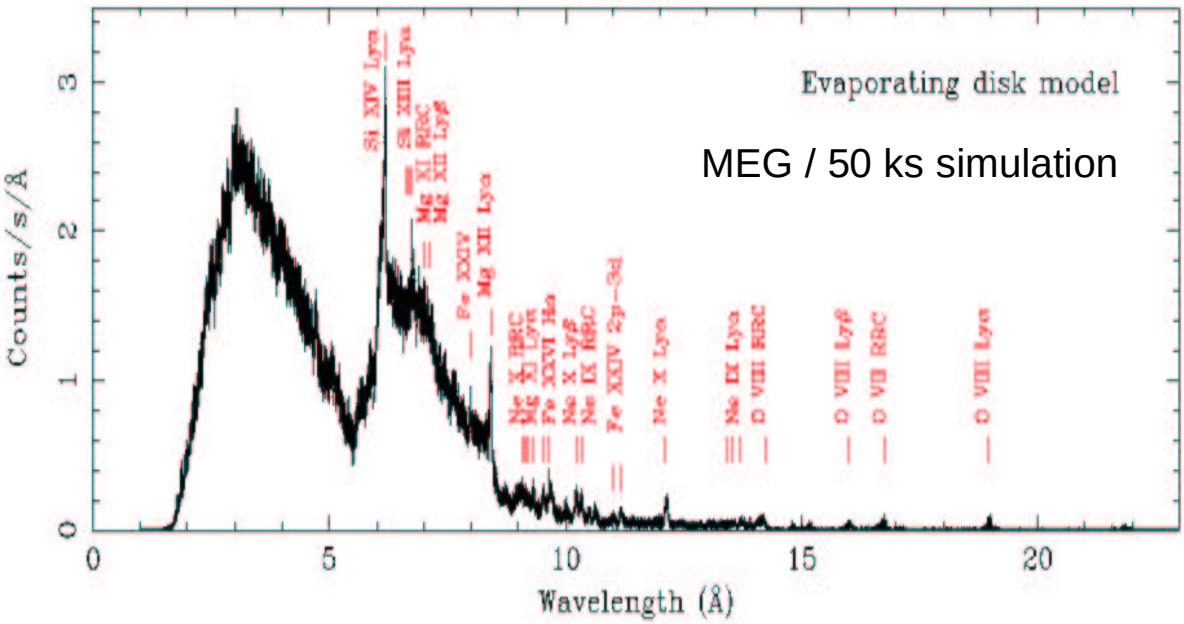
# Centrally Illuminated Accretion Disk Atmosphere and Corona

## Comparison with Spectral Data

## Narrow Line Emission from a Disk Bulge in

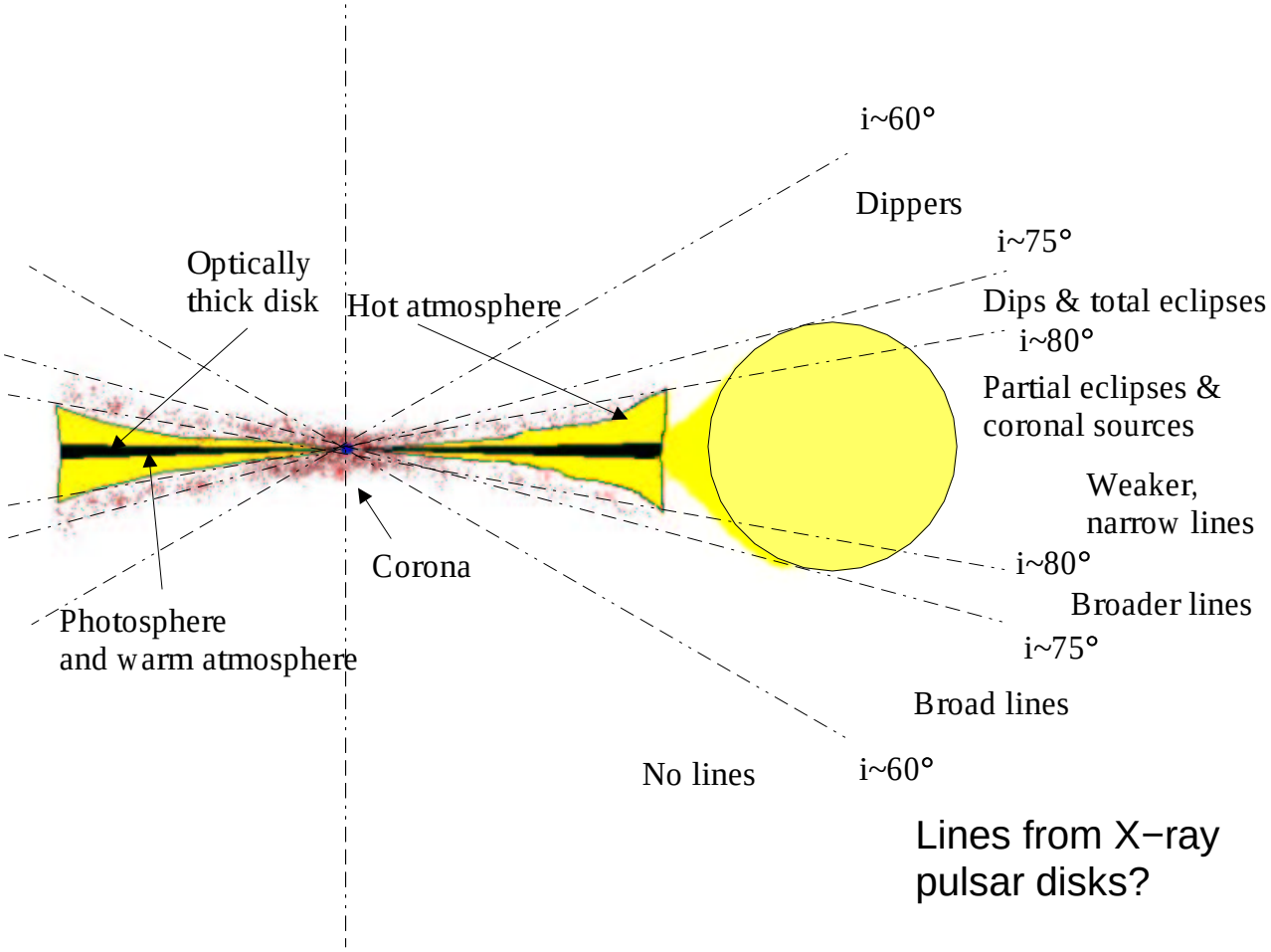
## 4U 1822−37: X−ray pulsar, ADC, $P_{orb}$= 5.6 hr



# Centrally Illuminated Accretion Disk Atmosphere and Corona

## Inclination Dependence of X−ray Recombination Emission




Lines from X−ray pulsar disks?

# Conclusions

Strong Observational Evidence for ’Thick’ Disk
in neutron star LMXB

*Strong Theoretical Evidence for Accretion Disk Atmosphere and Corona present in 0.1−1$L_{edd}$ neutron star LMXB*

Atmosphere thickened by irradiation (feedback)

Plasma Diagnostics probe Atmosphere $T_e$,$n_e$

Line profiles probe radial Atmosperic Structure

Strong Inclination Dependence of
X−ray Recombination Emission

Weak Coupling between Atmosphere and Disk!

# Future Work

Observations:

LMXB dipper 4U1254−690 (Disk Emission search)

Eclipsing Dippers EXO 0748−676, Hercules X−1
(Emission & Transmission Spectroscopy)

Theory:

Line Transfer and Relativistic Compton Scattering
(Monte Carlo)

Black Hole Accretion Disks

Collaborators: Duane Liedahl, Chris Mauche (LLNL),
John Raymond (CfA)