Sesto 2015 Workshop

Accretion Disk Spectra with Self-Irradiation

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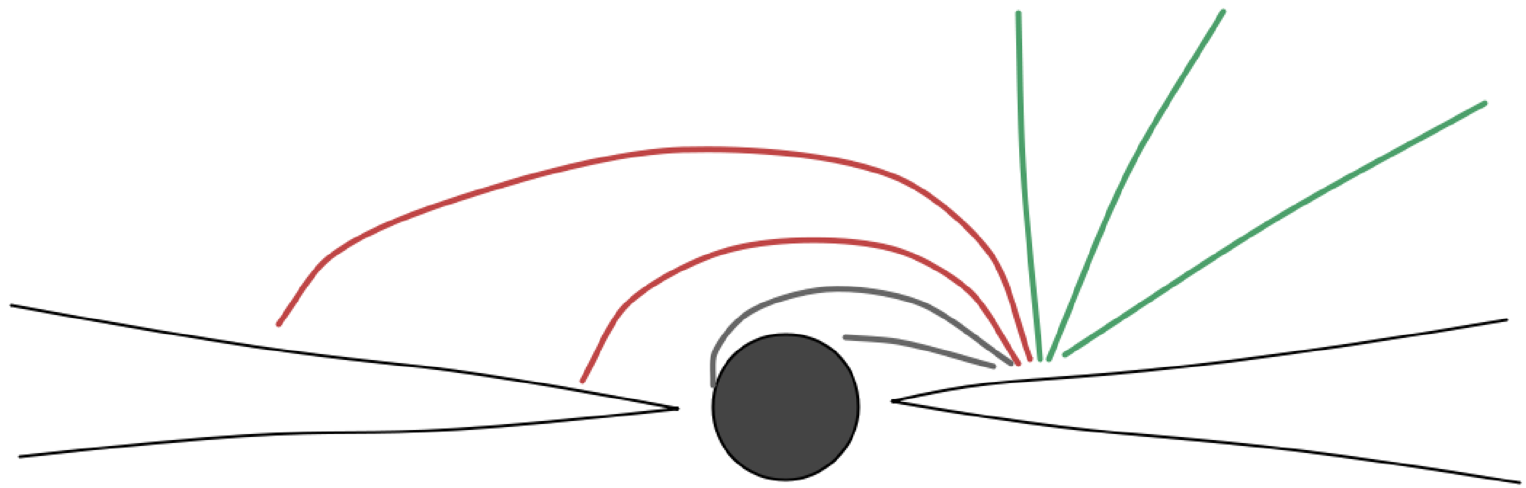
SEVENTH FRAMEWORK PROGRAMME

Motivation

- radiation escapes accretion disk in all directions
- some photons reach observer, some are captured by the black hole, some hit the disk surface (**returning radiation, self-irradiation, back-radiation**)
- how much flux comes back depends on disk shape and spacetime → spin+Mdot function
- up to now only qualitative treatment (Li+2005) by adjusting Mdot
- check Li's approach plus asses the effect on spin estimates



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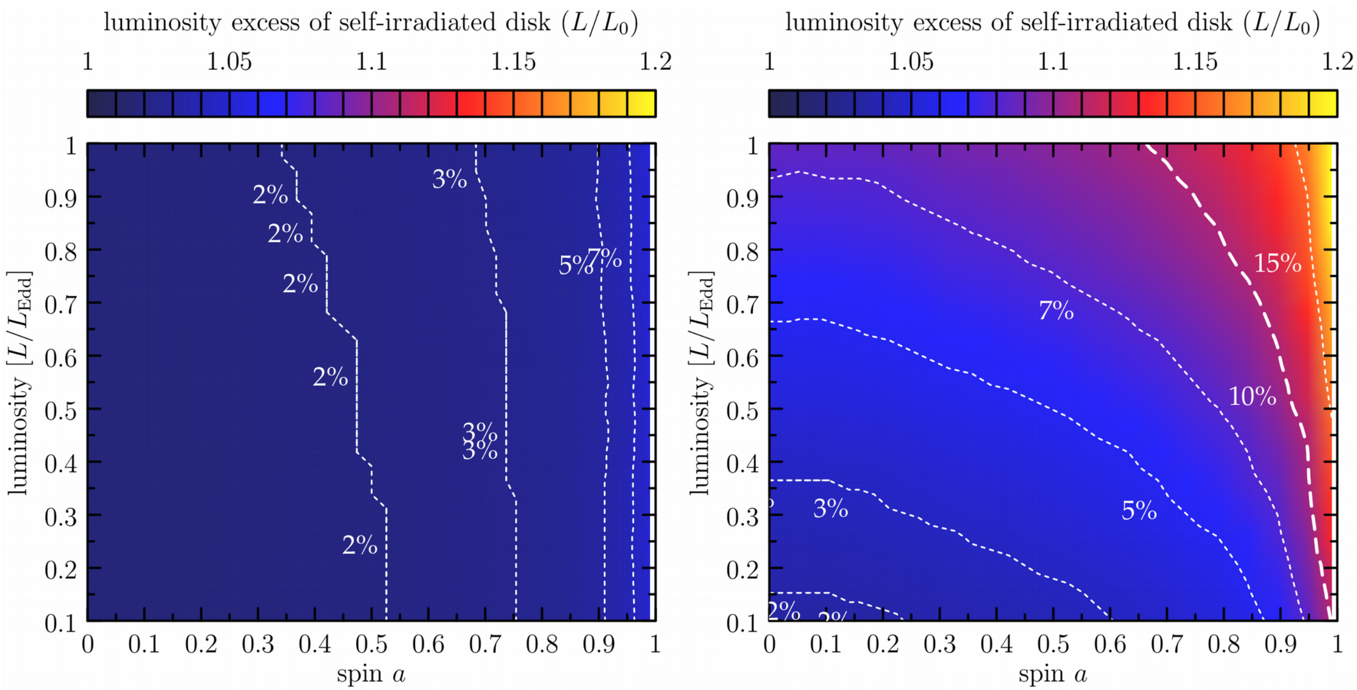

Objectives

WP10 tries to improve on:

- detailedness of the underlying physical models of thermal emission of stellar-mass black-hole accretion disks
- accuracy of the modelling with respect to observational evidence.

trying to assess how much difference there is in assumptions that existing thermal emission models makes in comparison with newly developed or improved models in which some of those simplifying assumptions are relaxed.

Codes used:

- SIM5 (ASU) for ray-tracing
- TLUSTY (UoA) for radiative transfer + improvements
- C/Python/Bash bindings

Numerical Procedure (1)

1. set up disk radial structure

- disk model (thin/slim)
- BH spin, mass accretion rate (luminosity), alpha
- divide disk into set of rings (by increments of F(r)*r*dr); ~150 rings
- each ring has: eff. temperature, column density, vertical gravity, spec. ang. momentum, radial velocity
- each ring is treated as infinite plane-parallel layer (no communication between rings => constrain on some parameters)

Numerical Procedure (1)

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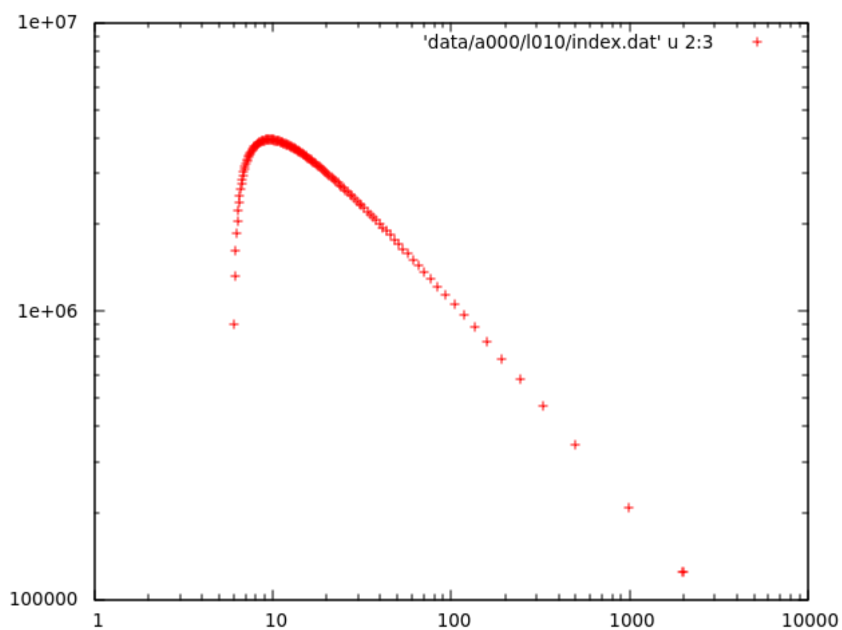

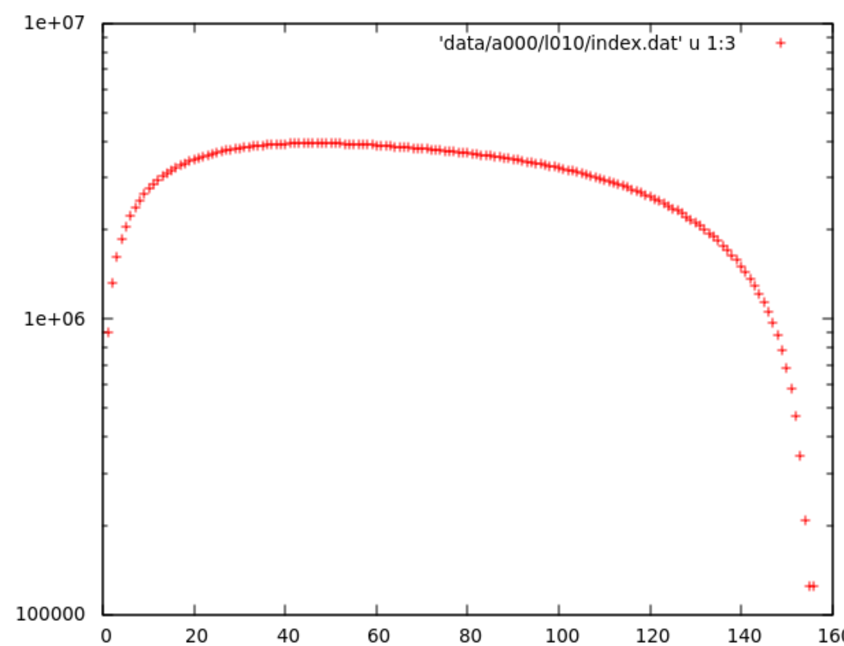

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ı rings

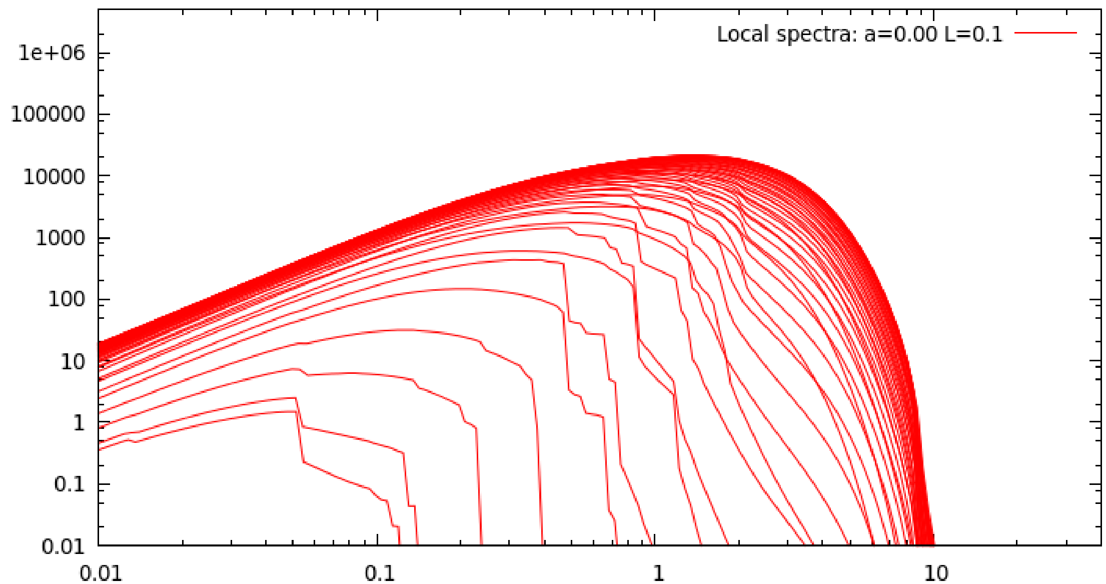
Numerical Procedure (2)

2. ring spectra with TLUSTY

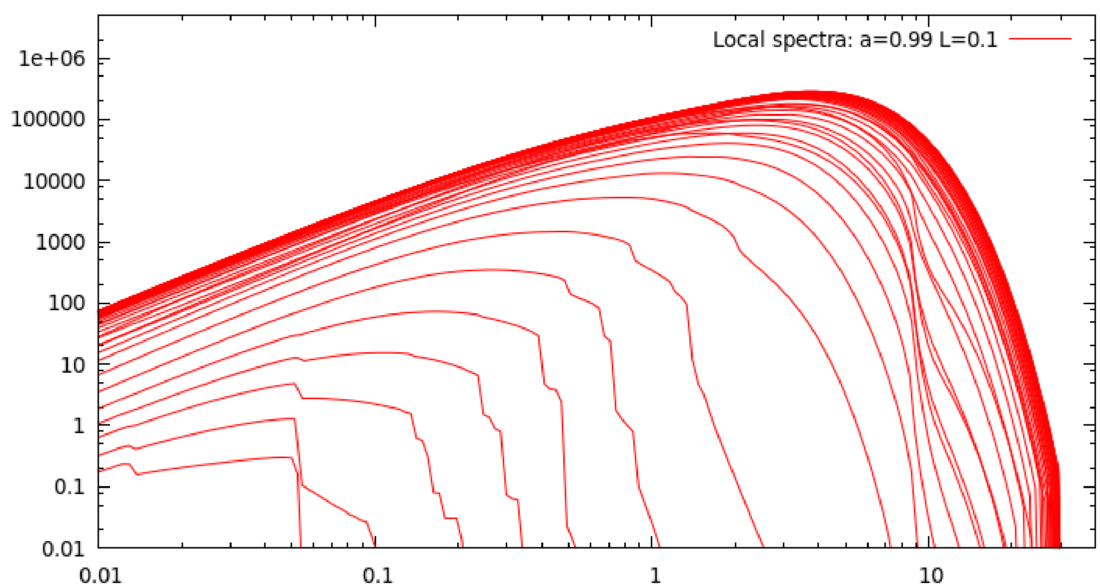
- find solution for vertical disk structure and radiation field simultaneously
- initial anzatz = grey atmosphere model
- result from anzatz is used for refinement
- TLUSTY not always converges (problems with ion transitions, optical depth, radiation pressure, low vertical gravity) => iterations from suitable anzatz (neighbouring ring) or isothermal atmosphere (low tau) or approximation (black body)

Numerical Procedure (2)

2. ring spectr



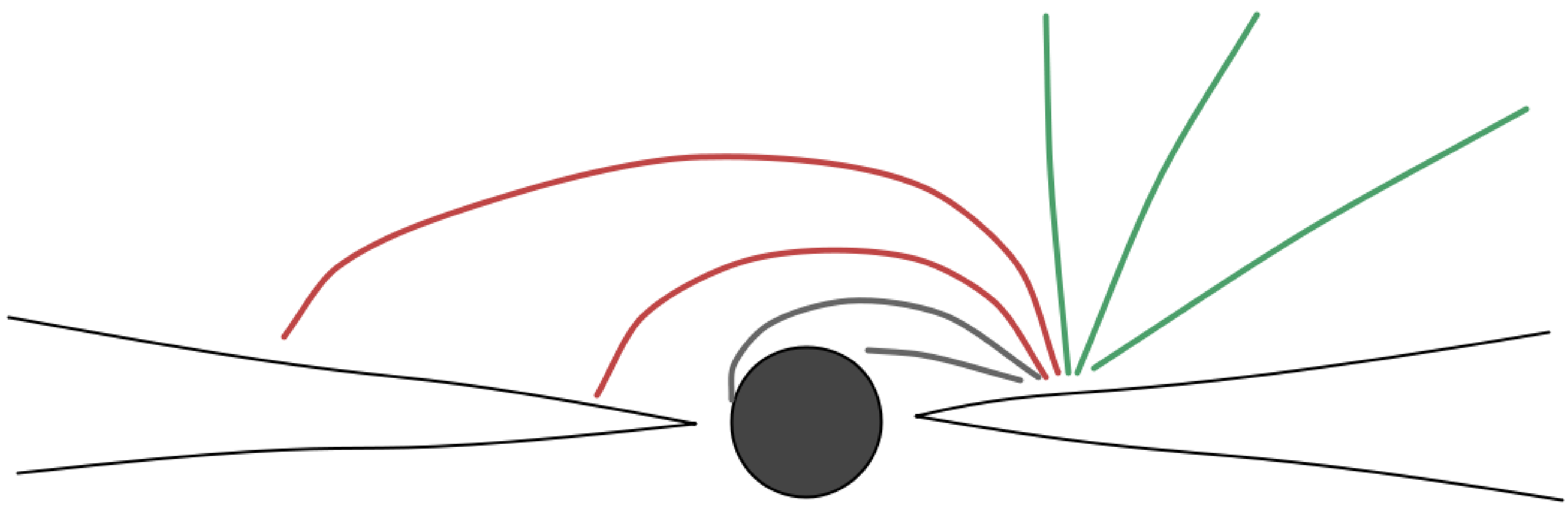
- find solu ... aneously
- initial an
- result frc
- TLUSTY ... tical depth, radiation ... ing ring) or isotherm



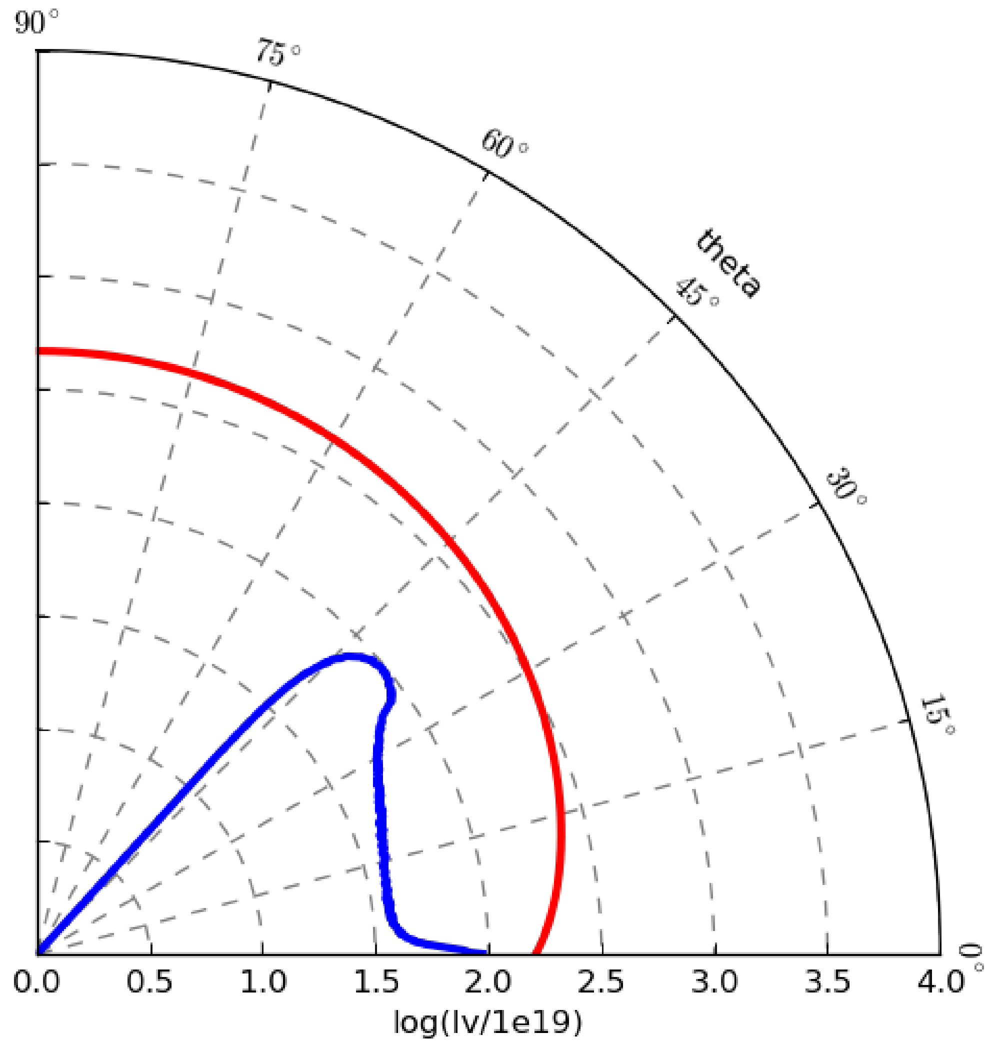
Numerical Procedure (3)

3. irradiation field

- compute angularly resolved field of returning radiation
- at each ring ray-trace over local observer's sky (half-sphere on top of disk photosphere) and collect photons that come from different places at the disk surface (fully relativistic, surface-to-surface)



Numerical Procedure (3)



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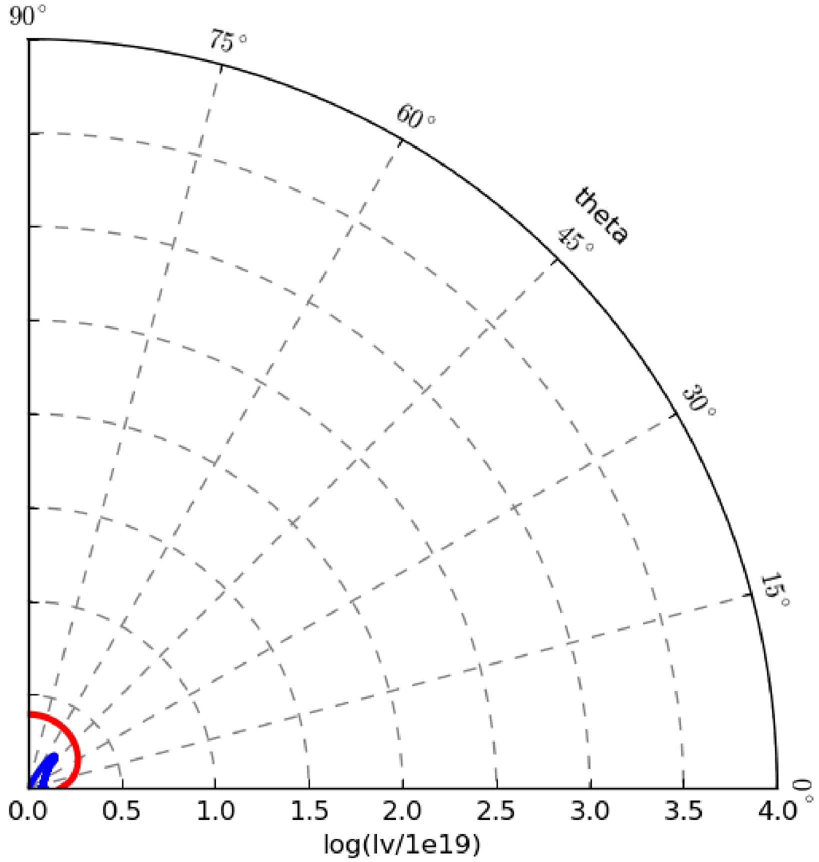
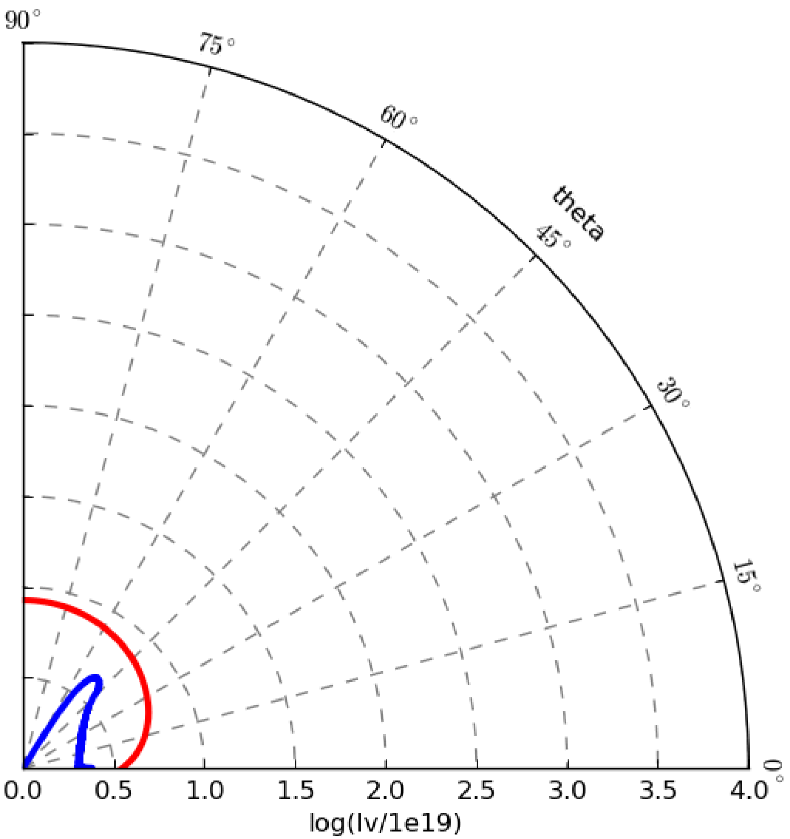


a=0.0, L=0.1



a=0.0, L=0.5

Numerical Procedure (4)

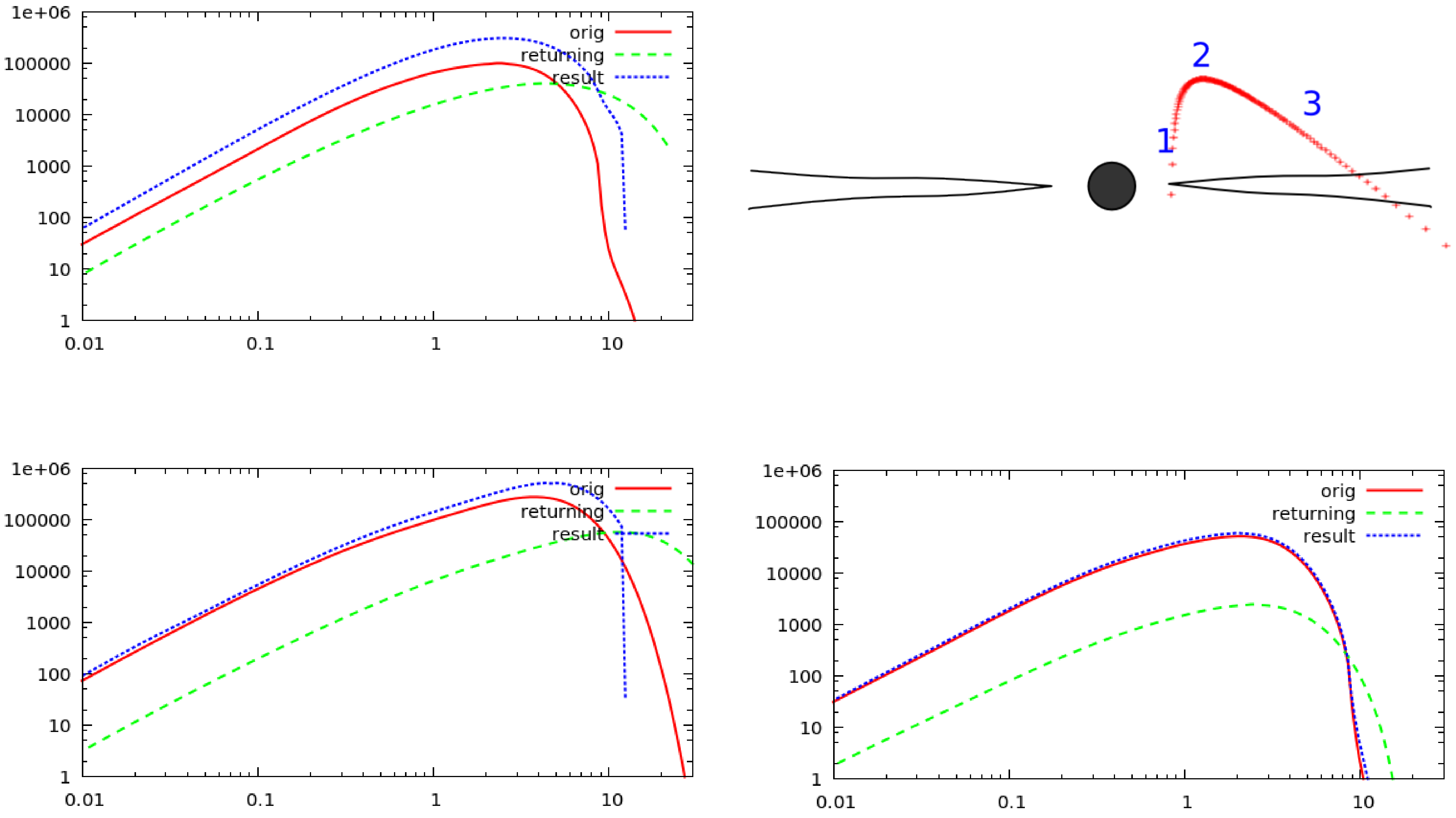
4. spectrum with external radiation

- run TLUSTY again and obtain new solution for vertical disk structure providing disk radiation field from step 3 as an external radiation source on the top-most vertical zone
- even more problems with convergence because of the discontinuity in the first and second top-most zones → mostly solved by a 'dilution factor' that controls the fraction of returning radiation considered
(e.g. for a=0.98 and L=0.5 we have to aproximate 17 out of 157 rings)

5. iterations

- steps 3 and 4 should be repeated few times because new solutions from step 4 change the returning radiation field a bit so we go back to step 3 and re-calculate it

Numerical Procedure (4)



Results

Ring spectra

- for each setup (spin/luminosity) we have ~150 individual ring spectra
- spin from 0.0 to 0.99
- luminosity from 0.1 to 0.5 (but not for all spins)
- higher spins converge less often → can only use in combinatoin with low L

Spectral table

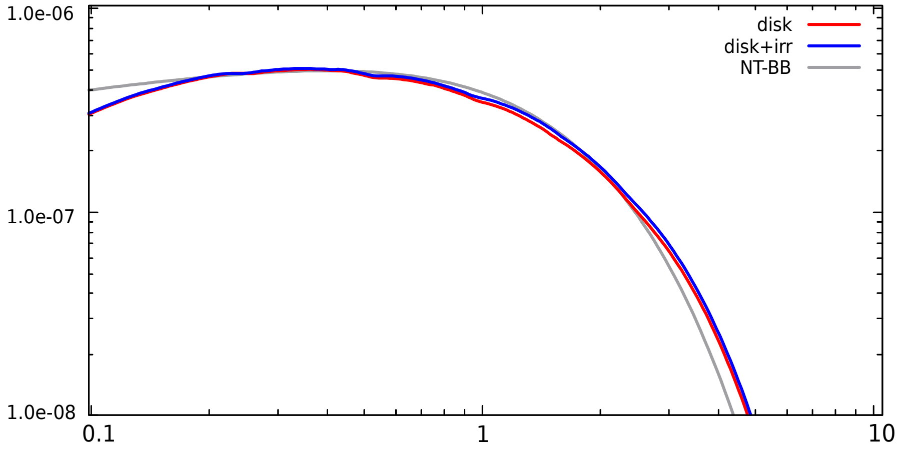
- spectra for individual rings are ray-traced into a single 'observed' spectrum
- a FITS table is compiled from the final spectra to be used as an XSPEC model

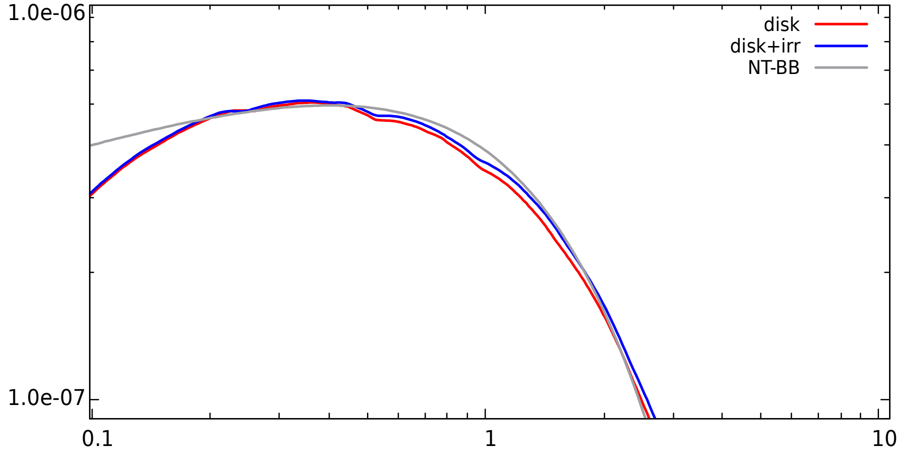
  parameters of the FITS table:
  - BH spin
  - disk luminosity (mass accretion rate)
  - inclination

  (BH mass and distance are included in normalization)

Results

a=0.0   L=0.1





Results

Applications to data

- spectra are harder with returning radiation (additional contribution, harder spectrum) → gives higher spin estimates as function of L
- observations indicate the opposite: spectra are softer than modelled
- still, for $L<0.3$ the effect on spin estimates can be ~10%

Summary

D10.1

- numerical calculation of dozens of accretion disk annuli spectra performed for each individual model setup
- limited only to low luminosities (L<~0.5 L_Edd), higher L without TLUSTY

D10.2

- spectra for rings are ray-traced into a single 'observed' spectrum
- those are put into a FITS file table to be used in XSPEC
- model in on GitLab and will be published on project web page too