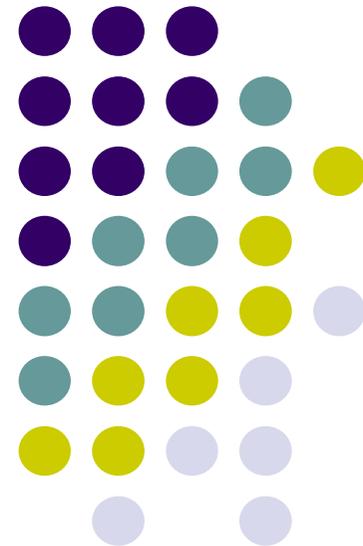


Development of Theoretical Databases for TITAN



Anabela C. Gonçalves

LUTH, Observatoire de Paris

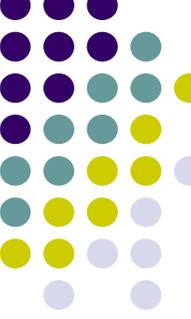


Theoretical databases with TITAN



Photo-ionization models for dense, warm, and optically thick/thin media irradiated by an X-ray continuum

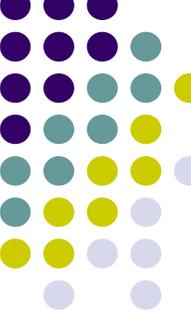
- Provides: ionization and temperature structures for media in constant density, constant gas pressure, or **constant total pressure**
- Also: outward, transmitted and reflected **spectra** in multiple directions
- Scientific applications: the central regions of Active Galactic Nuclei (AGN), X-ray binaries, Ultra-soft Luminous X-ray sources (ULXs) ...
- Observational applications: interpretation of high-quality X-ray data from *Chandra*, *XMM-Newton*, *Suzaku*
- Coupled with the code NOAR, covers the Energy range 10 - 10^5 eV: preparation of future X-ray missions (*Con-X*, *Simbol-X*, ...)



The need for model databases

TITAN modeling capabilities required by a growing community working on X-ray spectra of AGN, ULXs, ...

- TITAN models compute the transfer for ~ 1000 lines and the continuum \Rightarrow longer computation times (~ 30 h for constant P_{tot})
- TITAN allows for the modeling of regions in total pressure equilibrium \Rightarrow hand-check for convergence, possible instabilities
- Several domains of applicability: physical parameters can vary over a large range \Rightarrow quick, first-order estimation of the physical parameters needed prior to complete modeling
- Compare TITAN physical modeling with phenomenological tools and model X-ray data in XSPEC \Rightarrow need **atable** FITS models



Grids of models benchmark

Focused on a TITAN particularity: constant P_{tot} models

- Started by a small number of varying parameters characterizing the ionized medium: ξ , N_{H} , and Γ
- Parameters covered by the test grids:
 - Ionization parameter $1000 \leq \xi \leq 4000 \text{ erg cm s}^{-1}$
 - Incident continuum (a power-law) photon index: $2.1 \leq \Gamma \leq 3.3$
 - Ionised medium column density: $10^{22} \leq N_{\text{H}} \leq 10^{23} \text{ cm}^{-2}$
- Computed multiple sets of grids (45 models each), for different R
 - Absorption grid
 - Emission grids in multiple directions ($\sim 0-37.5^\circ$, $37.5-60^\circ$, $60-83.5^\circ$)
 - Reflection grids in multiple directions (same angles)

Interface with XSPEC

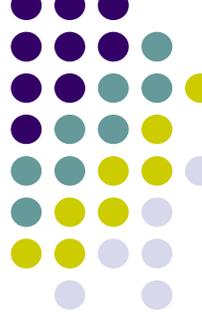
TITAN ascii tables converted into FITS table models

- Header and body format, specific to XSPEC

```
anabela@bob75-2-82-67-146-115.fbx.proxad.net: /home/anabela/OPM/titan-noar - Terminal - Konsole
Session  Édition  Affichage  Signets  Configuration  Aide
XSPEC>model atable{Tabs.fits}
Model: TITAN_ab<1>
Input parameter value, delta, min, bot, top, and max values for ...
      1.4      0.3      1.4      1.4      2.3      2.3
1:TITAN_ab:alpha>1.8
      1000    1.5E+03    1E+03    1E+03    4E+03    4E+03
2:TITAN_ab:xi>2200
      1E+22    4.5E+22    1E+22    1E+22    1E+23    1E+23
3:TITAN_ab:NH>3e22
      0      -0.001      0      0      5      5
4:TITAN_ab:Redshift>0
      1      0.01      0      0      1E+24    1E+24
5:TITAN_ab:norm>1e-3
-----
Model: TITAN_ab<1>
Model Fit Model Component Parameter Unit Value
par par comp
  1  1  1  TITAN_ab  alpha      1.80000 +/- 0.00000
  2  2  1  TITAN_ab  xi      2200.00 +/- 0.00000
  3  3  1  TITAN_ab  NH      3.000000E+22 +/- 0.00000
  4  4  1  TITAN_ab  Redshift 0.00000 frozen
  5  5  1  TITAN_ab  norm     1.000000E-03 +/- 0.00000

Files being used for table models:
Model comp File
  1          Tabs.fits
-----
```

Row	Col 1	Col 2	Col 3
1	1.400000E+00	1.000000E+03	1.000000E+22
2	1.400000E+00	1.000000E+03	5.500000E+22
3	1.400000E+00	1.000000E+03	1.000000E+23
4	1.400000E+00	2.500000E+03	1.000000E+22
5	1.400000E+00	2.500000E+03	5.500000E+22
6	1.400000E+00	2.500000E+03	1.000000E+23
7	1.400000E+00	4.000000E+03	1.000000E+22
8	1.400000E+00	4.000000E+03	5.500000E+22
9	1.400000E+00	4.000000E+03	1.000000E+23
10	1.700000E+00	1.000000E+03	1.000000E+22
11	1.700000E+00	1.000000E+03	5.500000E+22
12	1.700000E+00	1.000000E+03	1.000000E+23
13	1.700000E+00	2.500000E+03	1.000000E+22
14	1.700000E+00	2.500000E+03	5.500000E+22
15	1.700000E+00	2.500000E+03	1.000000E+23
16	1.700000E+00	4.000000E+03	1.000000E+22
17	1.700000E+00	4.000000E+03	5.500000E+22
18	1.700000E+00	4.000000E+03	1.000000E+23
19	2.000000E+00	1.000000E+03	1.000000E+22
20	2.000000E+00	1.000000E+03	5.500000E+22
21	2.000000E+00	1.000000E+03	1.000000E+23
22	2.000000E+00	2.500000E+03	1.000000E+22
23	2.000000E+00	2.500000E+03	5.500000E+22
24	2.000000E+00	2.500000E+03	1.000000E+23
25	2.000000E+00	4.000000E+03	1.000000E+22

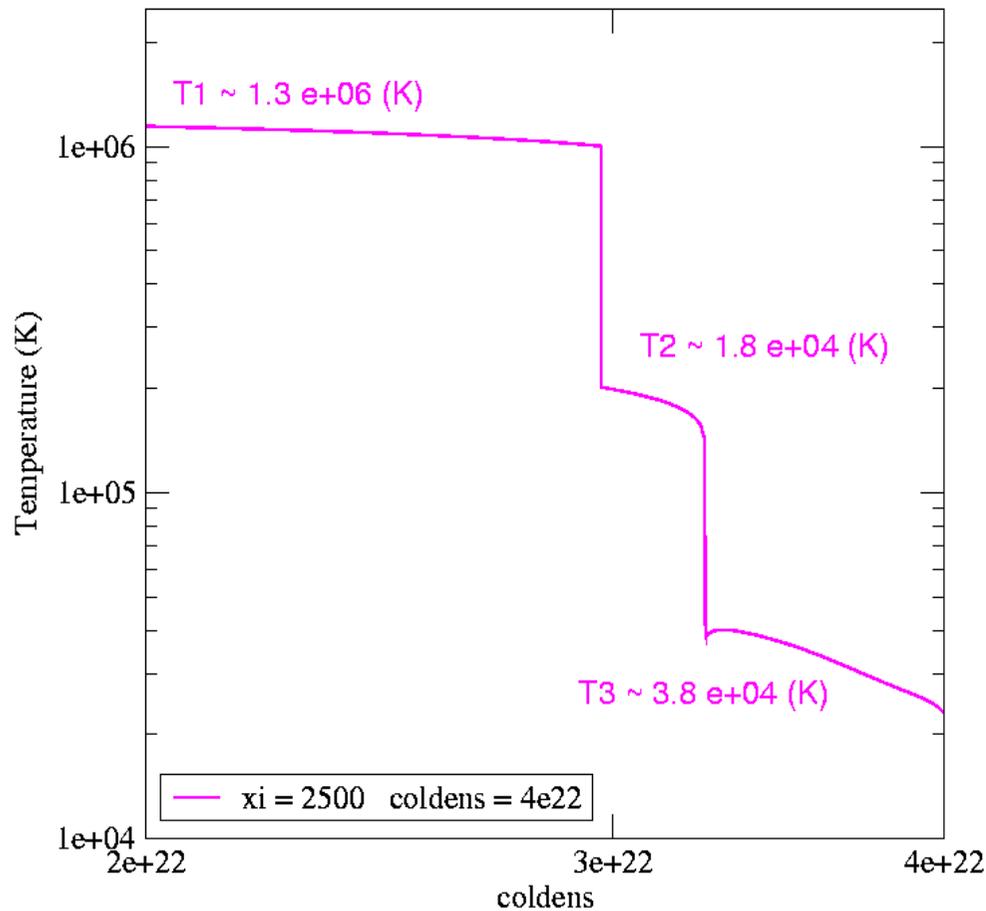


Application to *Chandra* data

Modeling the Warm Absorber (WA) in NGC 3783

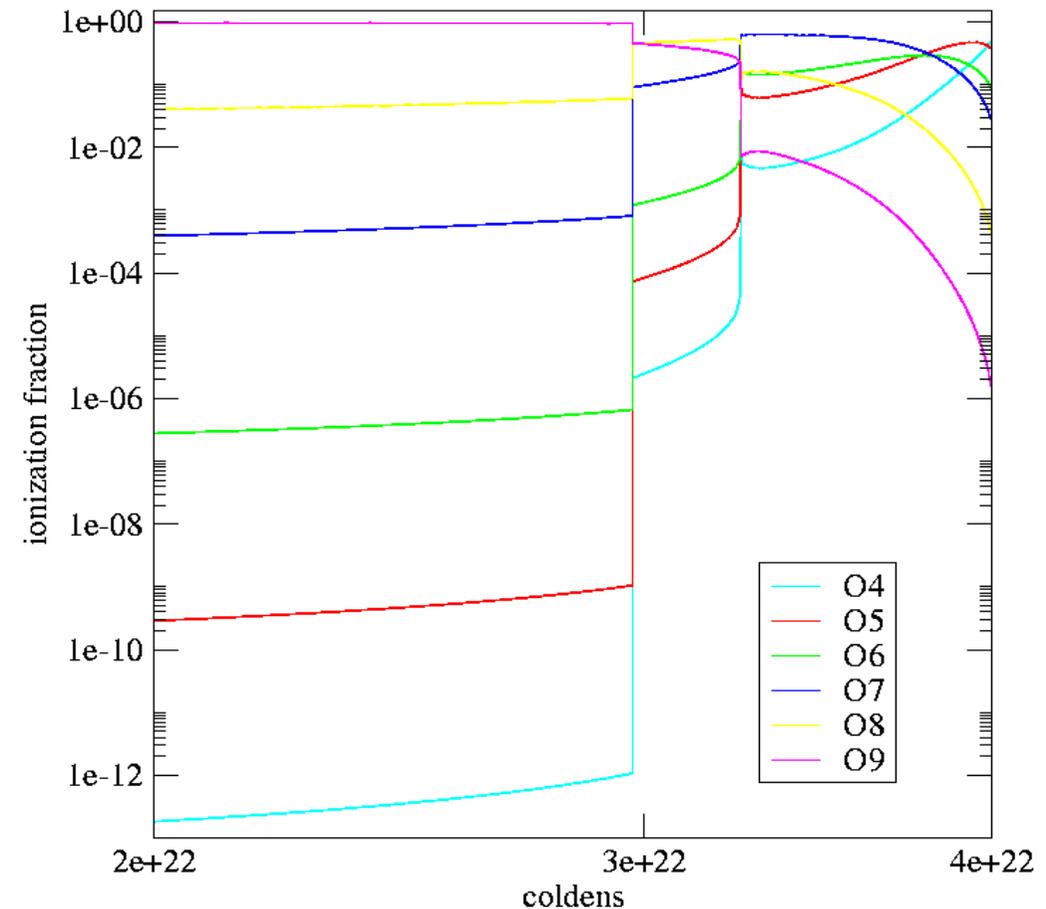
Temperature profile

1 constant pressure cloud



Oxygen ionization fraction

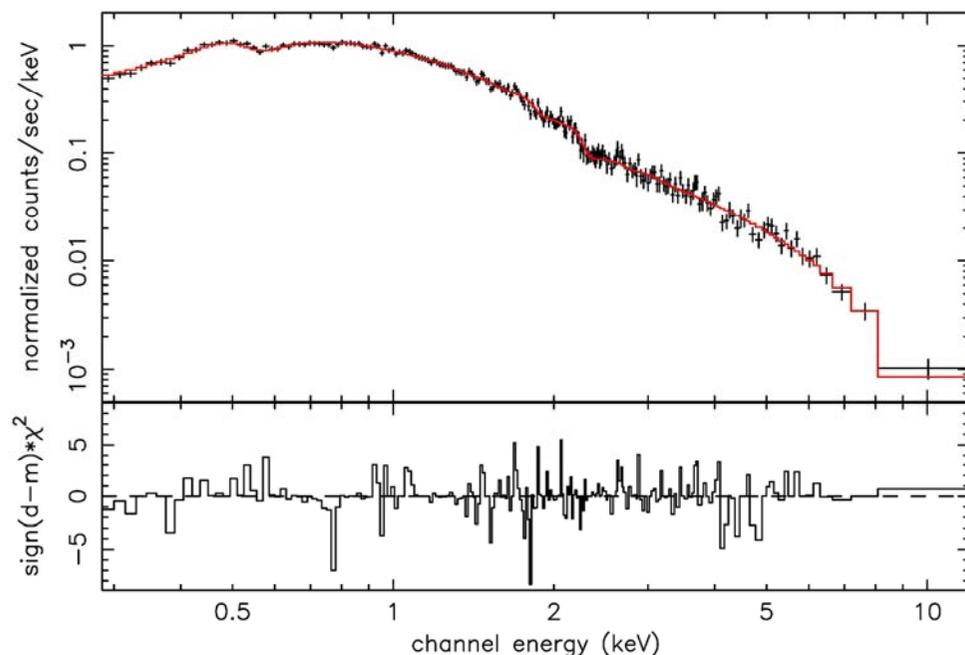
Ptotx2500c4e22v150nh5



Application to *XMM-Newton* data

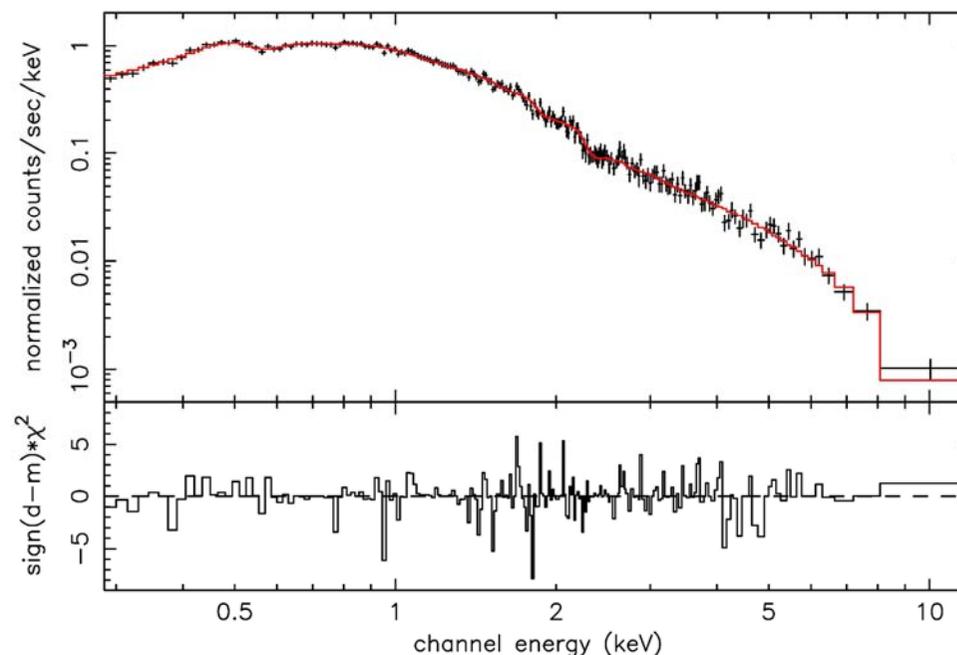


Modeling the X-ray spectra of ULXs



wabs x tbvarabs x (diskbb + po)

$$\chi^2 = 221.1/214 (1.04)$$



wabs x tbvarabs x (Temi + Tabs)

$$\chi^2 = 213.5/213 (1.00)$$



Perspectives and future work

TITAN photo-ionization models available to all

- Extend varying parameter's range (Titanic cluster, IDRIS):
 - Ionization parameter $10 \leq \xi \leq 10^5$
 - Incident continuum (power-law) photon index: $1.2 \leq \Gamma \leq 3.6$
 - Ionised medium column density: $10^{20} \leq N_{\text{H}} \leq 10^{24.5}$
- Extend energy range (and resolutions):
 - TITAN as stand-alone code: $E < 25$ keV
 - TITAN + NOAR (Compton heating/cooling): $25 < E < 100$ keV
- Automation and documentation effort:
 - Interface tools to convert TITAN models into XSPEC FITS table models
 - Databases for other information produced by the code (T, ions, ...)