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# A DATABASE OF PRESSURE EQUILIBRIUM MODELS WITH THE TITAN CODE

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**Abstract.** Although extremely useful in different astronomical contexts, models in total pressure equilibrium are seldom applied to the highly ionized gas in the vicinity of strong X-ray sources. This is mainly due to the lack of such an option in the main codes available to the community, as well as to the fact such models require very sensitive and time-consuming computations. The photoionization code TITAN, developed by our team, fulfills this gap allowing for the treatment of the ionized gas in constant total pressure, or in constant gas pressure. It gives as output the ionization, density, and temperature structures, as well as the reflected, emitted outward, and absorbed spectra. In an effort to provide the community with a ready-to-use set of constant total pressure models, TITAN is being used to compute a grid of results covering a wide range in ionization parameter, column density and shape of the incident ionizing continuum; the computed models correspond thus to different gas conditions and may be applied to various research subjects. Such grids of models can be easily imported into the X-ray data analysis package XSPEC and used to fit spectra of different resolutions. In addition, they can be used to simulate satellite data, an extremely useful feature in the preparation of future X-ray missions, such as *Simbol-X* or *Constellation-X*. The models will be stored in the Simulation Data Center at Paris Observatory and granted access through Virtual Observatory facilities.

## 1 The photoionization code TITAN: what is it and what is it for?

TITAN is a stationary photoionization-transfer code optimized for the study of dense, warm, and optically thick media (e.g. Dumont et al. 2000). It assumes a 1D plane-parallel geometry, with a slab of gas illuminated on one side (eventually on the two sides) by an incident X-ray continuum. TITAN computes the gas structure in ionization and thermal equilibrium and provides, in addition, the reflected, emitted outward, and absorbed spectra. When coupled with the Monte-Carlo code NOAR, which accounts for Compton heating/cooling, it can be used over a large energy range ($10^{-2}$ – $4\,10^5$ eV).

TITAN's scientific applications include the the modeling of ionized gas in the central regions of Active Galactic Nuclei (AGNs), X-ray binaries, or Ultra-soft Luminous X-ray sources (ULXs). In addition to the interpretation of high-quality X-ray data from second generation satellites such as *Chandra* or *XMM-Newton*, TITAN could be used in the preparation of future X-ray missions (e.g. *Constellation-X*, *XEUS*, or *Simbol-X*).

## 2 The need for a database of theoretical models

Thanks to its particularities — like the possibility of modeling gas in total pressure equilibrium, or addressing the thermal instabilities in thick media (e.g. Gonçalves et al. 2006, these proceedings) — the TITAN code has found its niche, and its modeling capabilities are required by a growing astrophysical community. Presently used by a restricted group of astronomers in France, Poland and the U.K., we plan to make the code available to other users through Virtual Observatory (VO) facilities; this project is under way.

A parallel approach, aimed at reaching a larger community, passes through the construction and release of a database of theoretical models computed with the TITAN code. This project presents several advantages, specially in what concerns pressure equilibrium models, for instance: *(i)* TITAN computes the exact transfer for ~1000 lines and the continuum; this implies longer computation times than other approximate methods, which may represent a drawback; *(ii)* Models in total pressure equilibrium require a certain expertise and, eventually,

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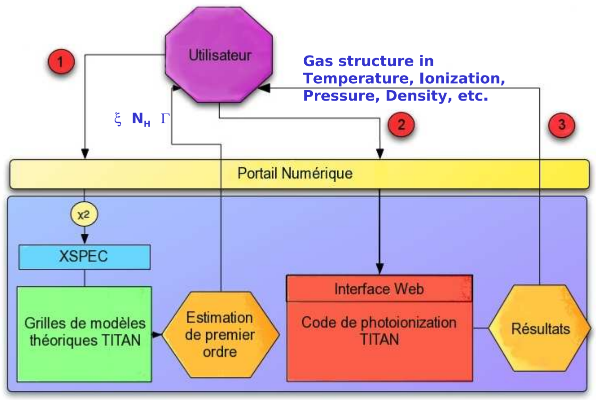


**Fig. 1.** Our grid of results permits a first order estimation of the main fitting parameters (step 1). These parameters can, in a second step, be used for a full model computation (model launch through the web, via the Paris Observatory Numerical Simulations Data Center). On-line support will be provided to registered users, at all steps.

a hand-check for convergence; the same is true when addressing the thermal instabilities in thick media; *(iii)* TITAN has very different domains of applicability and, in consequence, the input parameters can vary over a very wide range; a quick, first-order estimation of the parameters prior to the final modeling could be useful; *(iv)* TITAN's theoretical models should be easily confronted with observational data, as well as with other models and/or tools available in the principal X-ray packages for data reduction and modeling (e.g. XSPEC).

## 3 Grid of results feasibility and interoperability with XSPEC

Our feasibility tests were based on a set of models in total pressure equilibrium, covering a small number of varying parameters characterizing the ionized gas: the ionization parameter ($1000 < \xi < 4000$ erg cm s$^{-1}$), the ionized medium column density ($10^{22} < N_{\rm H} < 10^{23}$ cm$^{-2}$), and the incident continuum (a power-law) photon index ($2.1 < \Gamma < 3.3$). We have computed several grids of 45 models each: a grid of absorption spectra, plus multiple grids of spectra in emission and in reflection, covering different directions.

The interoperability with XSPEC has been carefully studied. We have developed the tools necessary to transform our grids of results into fitting table models, usable by this X-ray data reduction and analysis package. These table models allow for an easy fitting of observational data and for the comparison of different models; in addition, they can be used to simulate satellite data, in view of preparing future X-ray missions.

## 4 TITAN models in the Paris Observatory Numerical Simulations Data Center

The models will be stored in the Simulation Data Center at Paris Observatory and granted access through VO facilities. Our project contemplates a database for all theoretical results produced by the code — not only the spectra, but also the temperature, pressure, ionization structures, etc. Our long-term goal is to compute a set of grids of ∼1000 models each; we will enlarge the input parameters range and extend the resolution and energy domain encompassed by the models. Automation and workflowing issues related to the interface tools between TITAN, XSPEC, and the user, and to the coupling of TITAN with the NOAR code, are now being addressed.

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## References

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