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Radiative shock models for the NLR of AGN: Predictions up to 1000 km s^{-1}

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Abstract. High velocity shocks may provide an important source of ionizing radiation in the NLR of active galaxies. Here we present preliminary results of a new grid of MAPPINGS III shock models for shock velocities up to 1000 km s^{-1}. This grid significantly extends the parameter space covered by the previous models, and will serve as an important component in building multi-process models of the NLR.

1. Introduction

High velocity radiative shocks generate strong local UV ionizing radiation. Optical and UV emission from the shock and precursor regions is dominated by gas photoionized by this radiation. Models of such photoionizing shocks (Dopita & Sutherland 1996) have been successful at reproducing emission line ratios observed in Narrow Line Regions (NLR) of active galaxies, and have lead to a set of diagnostics (Allen, Dopita & Tsvetanov 1998) for the excitation mechanism of the gas.

Many observations of Seyfert and radio galaxy NLRs however lie near or beyond the high shock velocity limit (500 km s^{-1}) of the model grids. Here we present preliminary results of modeling radiation from shocks with velocities up to 1000 km s^{-1}.

2. New MAPPINGS III Shock Grids

The MAPPINGS III shock and photoionization modeling code provides improved calculation of the adaptive time steps required for modeling the cooling of gas from the high temperature of high velocity shocks of order 1000 km s^{-1}. Also, a higher resolution radiation field is used for the final calculations (compared to MAPPINGS II used by Dopita & Sutherland 1996). The shock velocity is the dominant parameter which controls the slope of the radiation field generated at the shock front, while the magnetic field limits the compression in a shock, and controls the effective ionization parameter in the recombination region of the shock. The new shock grid extends the region of parameter space of the previous models, we consider shock velocities in the range 100-1000 km s^{-1}, magnetic parameters of $Bn^{-1/2}$=0.5–10 μG $cm^{3/2}$, and a range of abundances from solar (depleted) to 2$\times$ solar (depleted). The global properties of the new models match the Dopita & Sutherland (1996) results, including the extrapolation of the total predicted emission line flux (which scales as the mechanical energy flux through the shock).

The figures show a standard line ratio diagram which is commonly used to compare observations to models. The left panel shows a diagram from Allen, Dopita & Tsvetanov (1998) which plots the MAPPINGS II shock and shock+precursor models of Dopita &

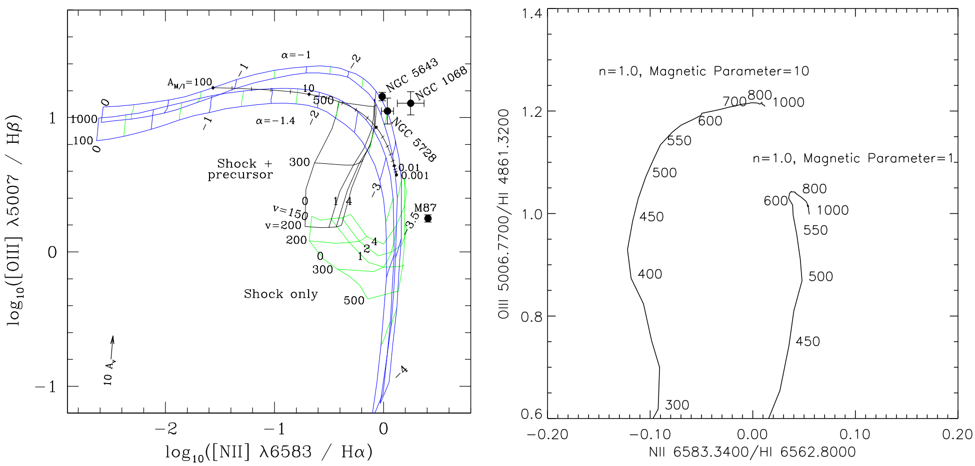

Figure 1. Line ratio diagrams.

Sutherland (1996), a set of power-law photoionization models, and the $A_{M/I}$ photoionization model sequence from Binette, Wilson & Storchi-Bergmann (1996). Also included is a small sample of observational data. The right panel shows a section of the new MAPPINGS III shock+precursor model grid. Two shock velocity sequences are shown, for solar (depleted) abundances, and for magnetic parameters of 1 and 10. The sequences are labeled with shock velocity in km s^{-1}.

The new models show that with increasing shock velocity, the [OIII]λ5007/Hβ ratio in the shock+precursor models flattens or turns over. This happens because with higher shock velocities there is a greater fraction of oxygen in higher ionization stages, with the effect that some observations falling near the 500 km s^{-1} part of the shock+precursor grid may also be consistent with higher shock velocities. Also, some observation falling outside the model grid may be reconsidered in terms of higher velocity shocks.

3. Multi-process Models for the NLR

Advances in both observations and modeling now allow a more complete multi-wavelength (X-ray, UV, optical, IR) approach to modeling emission line gas in active galaxies. Recent developments include: i) the inclusion of dust and radiation pressure in photoionization models (Dopita et al. 2002, Groves - these proceedings); ii) Modeling of shocks in 2- and 3-d (Sutherland, Bisset & Bicknell 2003); and iii) the inclusion of starburst ionization (Kewley et al. 2001). The grid of 1-d shock models presented here are designed to be used as components in multi-process (shocks, photoionization and starburst) models for the diffuse emission in active galaxies.

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