INTENSIVE SPECTROSCOPIC MONITORING OF NGC 5548 WITH HST AND IUE

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Abstract. We present preliminary results on a combined *HST*/*IUE*/ground-based monitoring campaign on the Seyfert 1 galaxy NGC 5548 undertaken by the International AGN Watch in order to answer questions that require both high temporal resolution (one day) and high signal-to-noise ratios. Our preliminary conclusions are (1) the ultraviolet and optical continuum variations are simultaneous to within a day (2) the He II λ1640 variations lag behind the continuum by about 1.7 days, and (3) the velocity field of the C IV-emitting region is not characterized by bulk by radial motion, but the higher velocity gas seems to originate closer to the continuum source than the lower velocity gas.

Key words: Spectroscopy, variability, multiwavelength observations

1. Introduction

In 1988 – 89, a large consortium known as the International AGN Watch (Alloin et al. 1993) carried out a program of monitoring continuum and emission-line variability in the Seyfert 1 galaxy NGC 5548 with *IUE* and ground-based telescopes (Clavel et al. 1991; Peterson et al. 1991). This highly successful effort (summarized by Peterson 1993) showed (1) that the UV and optical continua vary in phase to within approximately 2 ± 2 days, (2) that the broad emission lines respond to the continuum variations on short time scales (days to weeks) and (3) that the highest ionization lines (e.g., He II λ1640) respond more rapidly than the low ionization lines (e.g., Hβ), providing clear evidence for radial ionization stratification of the broad-line region (BLR). A second campaign by the International AGN Watch on the southern hemisphere Seyfert galaxy NGC 3783, discussed in these proceedings in papers by Reichert and by Stirpe, produced results that are similar to those obtained on NGC 5548.

The surprisingly short response times for the emission lines and the apparent simultaneity of the UV/optical variations leaves some important questions unresolved, specifically:

1. Is there a phase difference between the UV and optical continuum variations? Whether or not the variations in the different wavebands are truly simultaneous can provide a fundamental constraint for models of the continuum emission.

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2. What is the response time of the most rapidly varying high-ionization lines? The rapid variability of the highest ionization lines indicates that there are ionization fronts within a few light days of the continuum source.
3. What is the velocity field of the BLR? Determination of the velocity field provides some of the strongest possible constraints on the origin of the BLR and physical conditions within a few light days of the central source, and indeed might also lead to an unambiguous determination of the mass of the central object. The results from the original campaign are ambiguous, with Clavel (1991) arguing for random cloud motions with higher velocities close to the central source, and Crenshaw & Blackwell (1990) arguing for gravitational infall.

Resolution of these important questions requires not only better temporal sampling than was achieved in the original campaign (4 days), but higher signal-to-noise ratios as well.

2. The 1993 Monitoring Campaign

In order to address these key issues, an intensive monitoring program was undertaken with *HST*, *IUE*, and ground-based telescopes. The *IUE* observations were made once every two days between 1993 March 16 and May 27. During the 39-day period from April 19 to May 27, *HST* FOS spectra of the UV spectrum between 1150 Å and 2330 Å were obtained once per day at nearly regular intervals. Ground-based observations have been obtained throughout the entire observing season and are continuing at the time of this conference.

All of the scheduled observations were made as planned. At the present time, both the *IUE* and *HST* spectra have been reduced and closely compared. Various calibration difficulties have been encountered with approximately one quarter of the FOS spectra, and the calibration is currently being refined. We have performed preliminary analysis on most of the optical data as well. The results presented here are based solely on the preliminary versions of the reduced *HST* spectra and optical spectra; only one FOS spectrum has been excluded in this first look at the results.

The light curves for the UV and optical continua and for the He II and C IV emission lines are shown in Fig. 1, along with the cross-correlation functions (CCFs) obtained by cross correlating each light curve with the UV continuum light curve. The UV/optical continuum CCF shows that to within our currently estimated uncertainties the two continuum bands vary simultaneously. The peak of the continuum/He II CCF is at about 1.7 ± 0.5 days. The peak C IV response is at a longer delay, around 7 – 10 days, which is consistent with the result of the first campaign. The C IV line can be arbitrarily divided into four velocity ranges, a blue and red line core extending from line center to $\pm 3000\,\mathrm{km\,s^{-1}}$, and wings at larger relative velocities. The red wing is probably unreliable because of contamination by He II $\lambda1640$. However, blue core/red core CCF shows that they are perfectly in phase, which argues strongly against a predominantly radial velocity field, at least

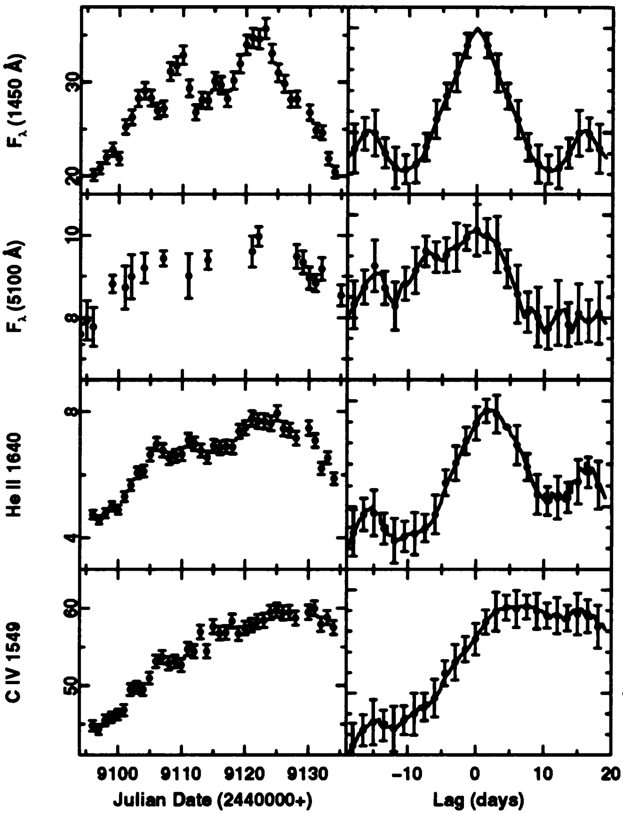

Fig. 1. The left column shows the light curves for the UV continuum, optical continuum, and two emission lines from the *HST* FOS data and contemporaneous ground-based data. The right column shows the CCFs (both interpolation and DCF methods, as described by White & Peterson 1993) produced by cross-correlating the light curve to the immediate left with the UV continuum light curve shown in the top panel (the top right panel is the continuum autocorrelation function). For the UV/optical continuum CCF, the interpolation was done *only* in the UV continuum.

out to 3000 km s^{-1}. The blue wing/blue core CCF reveals that the *wing leads the core* by about 2 days, i.e., there is evidence that the higher velocity material lies closer to the central source.

3. Conclusions

Preliminary analysis of the *HST* spectra gives us great confidence that the data will allow us to address each of the questions we posed in a definitive way. We find that the UV and optical continua vary simultaneously. The He II λ1640 emission line responds to continuum variations on a time scale of about 1.7 days. A sim-

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ple attempt to examine the C IV λ1549 emission line for radial velocity-dependent variations indicates that the higher velocity material lies closer to the continuum source than does the lower-velocity material. We find no evidence at this stage for large-scale radial motions in the BLR. The results presented here are very preliminary, and may change with (a) completion of the calibration of the FOS data, (b) integration of the *IUE* results, (c) completion of the optical data base analysis.

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