MEGACAM: A WIDE-FIELD IMAGER FOR THE MMT OBSERVATORY

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1. INTRODUCTION

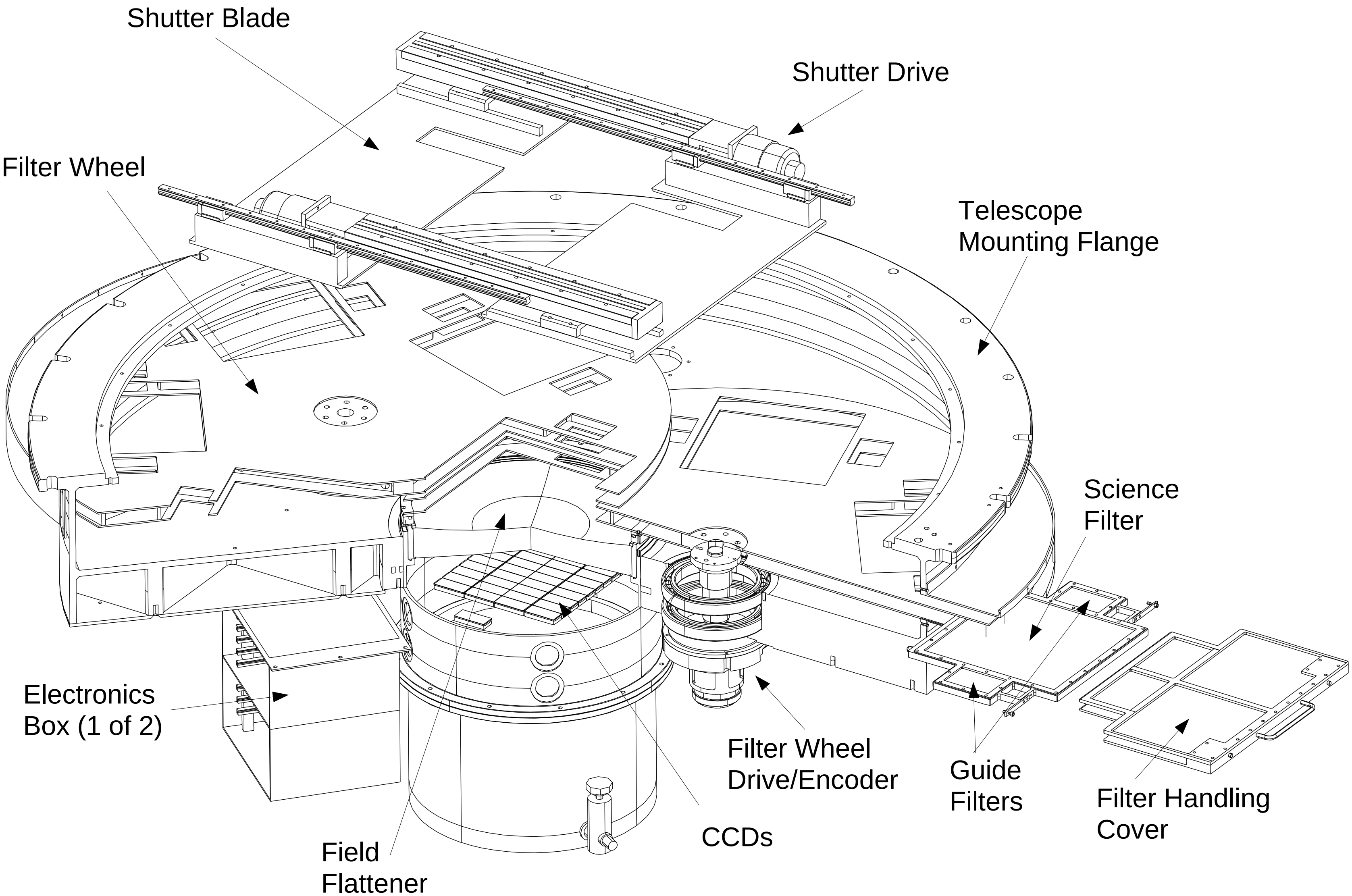
The Multiple Mirror Telescope on Mt. Hopkins, Arizona, is currently being converted from six 1.8 m telescopes to a single 6.5 m diameter mirror. The imaging configuration of the f/5 wide-field corrected Cassegrain focus will provide a 35′ diameter field, which is flat and has 0.″1 RMS image quality from 0.35 to 1.0μm. Megacam will populate this focal plane with state-of-the-art CCD detectors. The mosaic will consist of 18432 × 18432 0.″08 pixels. We have previously described a design for this camera.[1,2] In this paper we provide an updated description of the planned hardware.

2. CAMERA HOUSING

The camera housing, or "topbox", is a 2 m diameter, 0.3 m deep steel structure that contains the shutter and filter wheels, and provides a rigid interface between the CCD Dewar and the telescope. A cut-away view of the assembly is shown in Figure 1. When not on the telescope, the housing is mounted on a custom cart with a trunnion to allow easy rotation. For storage and handling the instrument is rotated 90° to take up minimum floor-space.

2.1. Filter Wheels

The housing contains two overlapping filter wheels, each with five slots. Normally one of these slots will be left blank in each filter wheel, allowing a choice of eight filters at any given time. The filter wheels are driven from their centers with a DC-servo motor, harmonic drive gear reduction, and a rotary encoder, which provides a lateral repeatability of 10μm at the radius of the filters. This high repeatability allows us the option to use segmented filters with masks between the segments. Without high positioning repeatability, flat-fielding errors would occur as the mask shadow shifts on the detector. Each filter wheel is composed of two steel facesheets separated by a web of reinforcements. Filters are mounted in a steel frame that is inserted between the two facesheets of the filter wheel from access ports on each side of the housing. During insertion and removal, the filter is completely enclosed by an aluminum handling cover to minimize risk.



Shutter Blade
Shutter Drive
Filter Wheel
Telescope
Mounting Flange
Science
Filter
Electronics
Box (1 of 2)
Filter Wheel
Drive/Encoder
Guide
Filters
Filter Handling
Cover
Field
Flattener
CCDs

2.2. Shutter

The shutter consists of two aluminum plates mounted on pairs of THK rails. Notches are cut in the shutter blades so that light reaches the guide chips when the shutter is closed. It is also possible to close the shutter completely so that no light hits the guide chips. The exposure is taken by opening one blade and ended by closing the other blade. This ensures an even exposure time over the full focal plane. A shutter blade traverses the focal plane in less than 5 sec; however, shorter exposures can be achieved by having the closing blade follow the leading blade closely, effectively scanning a slit across the focal plane. This style of shutter is used in the Big Thoughput Camera.[3] The shutter is driven from one edge with a DC servo motor and a lead-screw with a rotary encoder. The blade is attached to the other rail with a flexure to allow for differential expansion between the steel structure and the aluminum shutter blade without binding.

3. MEGACAM DEWAR

3.1. CCD Package

We plan to use EEV CCD42-90 model thinned back-illuminated CCDs with 2048$\times$4608 13.5μm pixels. We have taken delivery of an initial order of six devices. Two of these devices are being used in a prototype camera called Minicam. The other four will be used in the Hectospec and Hectochelle fiber spectrographs at the converted MMT.[4,5] These CCDs have a custom designed package to allow four-edge butting (see Figure 2). Signals from the silicon are wire-bonded onto a ceramic header, which wraps around to the bottom of the Invar package, where the signals are accessed from a pin grid array. A thermistor potted into the Invar is also connected to the pin grid array. Electrical connections to the CCDs are made via a custom zero-insertion-force (ZIF) socket.

The CCDs will be mounted on a 6 mm thick Invar plate, which is ground flat. This plate is thermally isolated from the Dewar case with a set of six titanium flexures mounted around the edge of the plate. The flexures allow for the 125° C temperature differential without bending the plate, which is critical for keeping all parts of the large focal plane in focus. When mounted in the mosaic, the gaps between the imaging areas will be 1 mm (corresponding to 6″) on 3 sides, and 6 mm (36″) on the fourth side.

Without special tools there is no easy way to pick up four-edge buttable CCDs for installation. Thus we handle it only via a rod which screws into the back. The handling rod, along with another temporary guide rod and two permanently attached locating pins, prevent the CCD from touching its neighbors as it is inserted into the focal plane. With practice, handling these CCDs is quite straightforward. We are making no attempt to align the CCDs to each other to better than a few pixels since the camera will not be used for drift-scanning. The relative orientations will be determined by observing star clusters with known astrometry. The coplanarity of the CCDs in the mosaic is achieved by a set of precision shims attached to the Invar package by the manufacturer. These shims also provide the thermal contact between the CCD and the cold mounting plate.

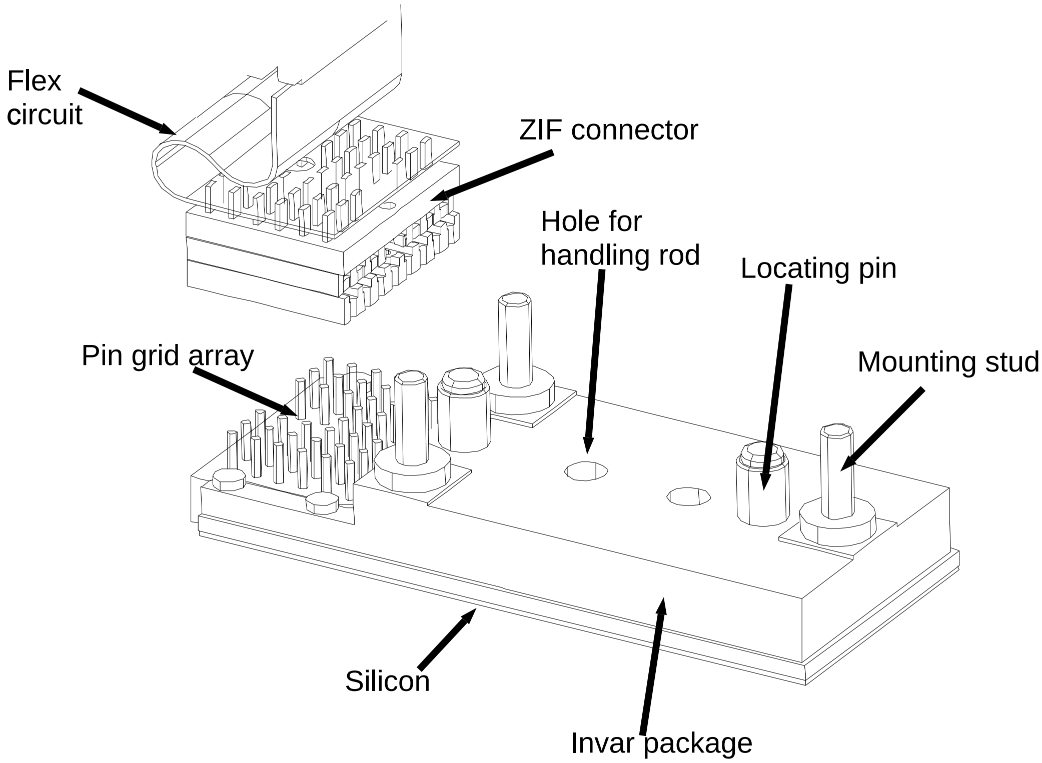


Figure 2. *CCD42-90 connected to flex circuit.*

3.2. Cooling

Cooling a large CCD mosaic provides a number of challenges. The focal plane must be kept a uniform temperature, electrical cables must pass to the middle of the mosaic, and at the same time easy access to the CCDs must be preserved for maintenance and upgrades. Because Invar is a relatively poor thermal conductor, the cooling path must be distributed evenly over the Invar plate. Initially we considered using a radiative cooling mechanism,[2] but have concluded that such a system would be only marginally adequate. Instead we are adopting a conductive system. As seen in Figure 3 a copper cold distribution plate is mounted above the Invar plate, and the two are connected by a set of straps, one for each CCD. Flexible electrical cables going to each CCD pass through the distribution plate. The distribution plate will be cooled with four Cryotiger closed cycle coolers. Alternatively, a pair of liquid nitrogen dewars could be used instead. This geometry allows one to adjust the cooling straps without disconnecting the CCDs, and allow CCD changes to be made without disconnecting the cooling straps or the Cryotigers. Access to the back of the focal plane is gained by removing a single panel from the dewar.

4. ELECTRONICS

Here we provide an overview of the signal chain from the CCD to the computer. Details of the electronics are described in an accompanying paper in this volume.[6] Interconnections between the various elements rely heavily on custom flexible printed circuits to facilitate assembly and increase reliability.

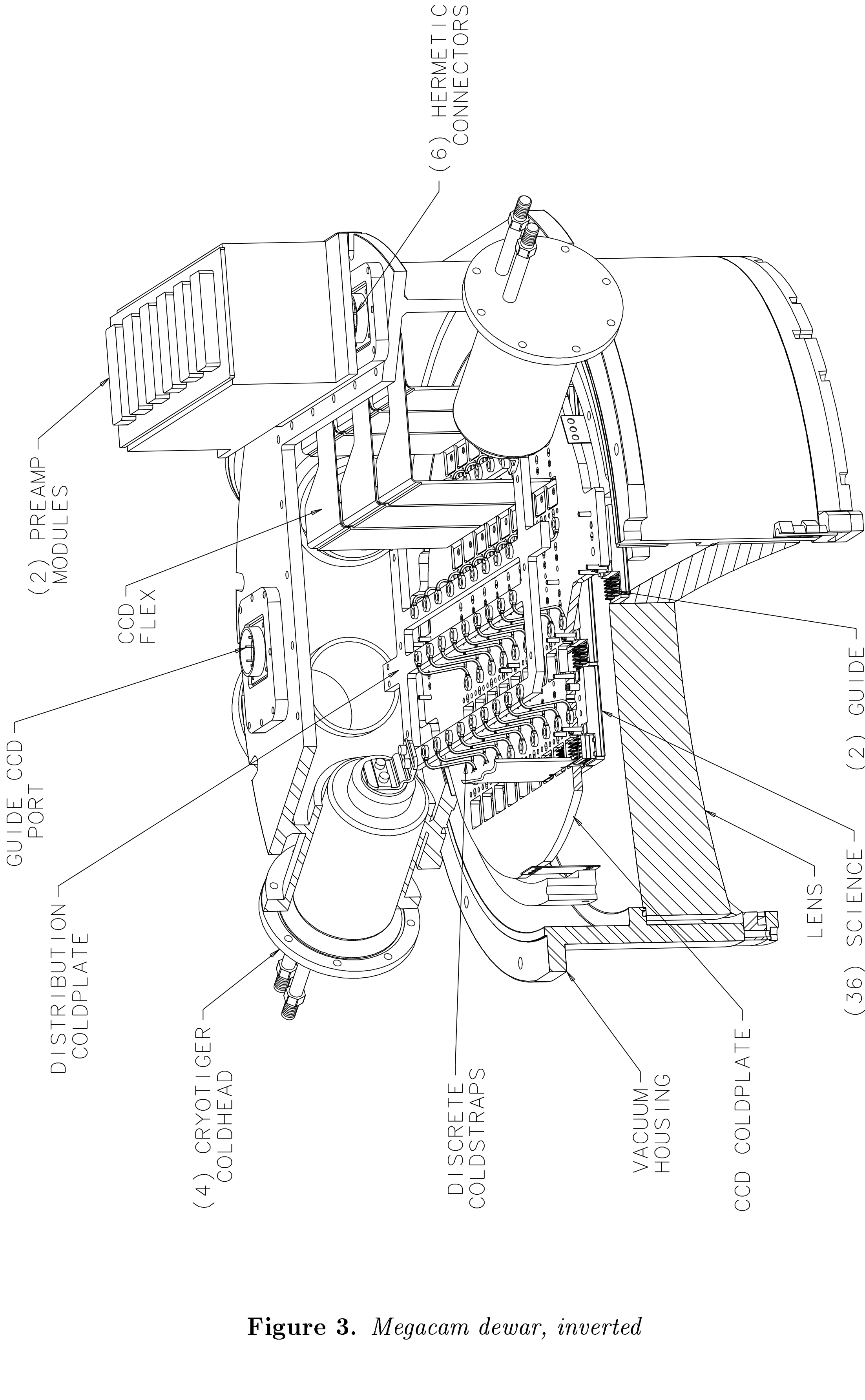


Figure 3. *Megacam dewar, inverted*

Sets of three CCDs are connected via the custom ZIF connectors to a flexible circuit which is soldered to a hermetic connector on the wall of the dewar. We will solder a small amount of passive components to the warm end of the flex cable to provide filtering and overvoltage protection.

Immediately outside the dewar will be a preamp module which mates to the hermetic connectors on one side, and has a set of second custom flexible circuits on the other. These flex cables lead to the backplane of the main electronics chassis. The flex circuits will be made with several layers to allow for shielding of the video lines.

The electronics are divided into two boxes mounted on either side of the dewar. Each of the two boxes will be responsible for driving signals for eighteen CCDs and digitizing the data from their 36 output amplifiers, before bussing the data back to the master box for transmission to the host computer. Analog levels on the driver boards are set with D/A converters individually for each CCD. Each driver board can control three CCDs. Each signal processing board can service four channels, i.e., two CCDs.

In addition to the driver and video boards, one of the two boxes, the master, contains two additional boards for timing generation and communications. On the timing board clock signals are generated in digital form and transmitted via the back plane to the analog clock driver boards. The clock signals are generated from waveforms and sequences stored in RAM chips on the timing board which are loaded from the host computer.The CCDs will be clocked at 200 kilopixels s^{-1}, yielding a readout time of 24 s at full resolution, or 3 s if the pixels are binned 3×3 to $0\farcs24$. The logic circuitry on all boards is largely consolidated into Altera programmable gate arrays. There is no microprocessor in the CCD electronics.

Communications with the host computer for programming the controller and receiving data is done with the EDT PCI-RCI interface system. The camera module of the interface is mounted on a board in the master box. Programming commands to the electronics are transmitted over an optical fiber on a 110 Kbaud channel. The data channel will support the full 29 Mbyte s^{-1} rate of Megacam over a single optical fiber link. The computer end of the PCI-RCI system resides in a Sun Sparc Ultra-60 running Solaris 2.6. This system is adequate for the Minicam and spectrograph applications, but we will upgrade to a faster machiine before the full Megacam focal plane is complete.

For housekeeping, all analog voltages and CCD thermistors are multiplexed onto a Keithley Smartlink multimeter for monitoring. Data from the Smartlink is read over the local ethernet. With this configuration, the CCD electronics on the telescope are connected to the control room with only a network connection and the EDT link.

REFERENCES

1. B. A. McLeod, D. G. Fabricant, J. C. Geary, and A. H. Szentgyorgyi, "Wide-field CCD imager for the 6.5-m MMT telescope," in *Solid State Sensor Arrays and CCD Cameras*, C. N. Anagnostopoulos, M. M. Blouke, and M. P. Lesser, eds., *Proc. SPIE* **2654**, pp. 233–238, 1996.
2. B. A. McLeod, M. Conroy, T. M. Gauron, J. C. Geary, and M. P. Ordway, "Megacam: paving the focal plane of the mmt with silicon," in *Optical Astronomical Instrumentation*, S. D'Odorico, ed., *Proc. SPIE* **3355**, pp. 477–486, 1998.

3. D. Wittman, J. A. Tyson, G. M. Bernstein, D. R. Smith, R. W. Lee, M. M. Blouke, I. P. Dell'Antonio, and P. Fischer, "Big throughput camera: The first year," in *Optical Astronomical Instrumentation*, S. D'Odorico, ed., *Proc. SPIE* **3355**, pp. 626–634, 1998.
4. D. G. Fabricant, E. H. Hertz, A. H. Szentgyorgyi, R. G. Fata, J. B. Roll, and J. Zajac, "Construction of the Hectospec: a 300 optical fiber-fed spectrograph for the converted MMT," in *Optical Astronomical Instrumentation*, S. D'Odorico, ed., *Proc. SPIE* **3355**, pp. 285–296, 1998.
5. A. H. Szentgyorgyi, L. W. Hartmann, P. N. Cheimets, D. G. Fabricant, M. R. Pieri, and Y. Zhou, "Hectochelle: a multi-object echelle spectrograph for the converted MMT," in *Optical Astronomical Instrumentation*, S. D'Odorico, ed., *Proc. SPIE* **3355**, pp. 242–249, 1998.
6. J. C. Geary in *ICSOI4*, M. B. Denton, ed., pp. ?–?, 1999.