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Background-Limited Imaging in the Near-Infrared with Warm InGaAs Sensors: Applications for Time-Domain Astronomy

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We describe test observations made with a customized 640 × 512 pixel Indium Gallium Arsenide (InGaAs) prototype astronomical camera on the 100″ DuPont telescope. This is the first test of InGaAs as a cost-effective alternative to HgCdTe for research-grade astronomical observations. The camera exhibits an instrument background of 113 e-/sec/pixel (dark + thermal) at an operating temperature of -40C for the sensor, maintained by a simple thermo-electric cooler. The optical train and mechanical structure float at ambient temperature with no cold stop, in contrast to most IR instruments which must be cooled to mitigate thermal backgrounds. Measurements of the night sky using a reimager with plate scale of 0.4″/pixel show that the sky flux in Y is comparable to the dark current. At J the sky brightness exceeds dark current by a factor of four, and hence dominates the noise budget. The sensor read noise of $\sim 43e^-$ falls below sky+dark noise for exposures of $t > 7$ seconds in Y and 3.5 seconds in J. We present test observations of several selected science targets, including high-significance detections of a lensed Type Ia supernova, a type IIb supernova, and a $z = 6.3$ quasar. Deeper images are obtained for two local galaxies monitored for IR transients, and a galaxy cluster at $z = 0.87$. Finally, we observe a partial transit of the hot Jupiter HATS34b, demonstrating the photometric stability required over several hours to detect a 1.2% transit depth at high significance. A tiling of available larger-format sensors would produce an IR survey instrument with significant cost savings relative to HgCdTe-based cameras, if one is willing to forego the K band. Such a camera would be sensitive for a week or more to isotropic emission from r-process kilonova ejecta similar to that observed in GW170817, over the full 190 Mpc horizon of Advanced LIGO's design sensitivity for neutron star mergers.

DuPont 100" 望遠鏡に取り付けられた試験機

- 近赤外線広視野変動天体サーベイの重要性が高まっているが検出器 (HgCdTe) が高すぎて気軽に広視野にできない
- **K-band を捨てて InGaAs 検出器を使おう**: FLIR で買える検出器にあわせて FPGA 回路を開発して天文用の駆動ができるようにした
- センサにペルチェ素子をくっつけて -45 ℃ に冷却 ⇉ ダークカレントはおおよそ 110$e^-s^{-1}pix^{-1}$ を達成 (同条件の HgCdTe より圧倒的に低い)
- 再結合光学系の筒を望遠鏡に取り付けて試験観測 on the 100" DuPont telescope を実施
- Y-band では dark ~ sky, J-band では sky-background limit での観測を実現 (limiting magnitude ~ 21.5 ABmag for 10 min integration)
- 線形性もそこそこ & 検出器の安定性も十分で 1% 級の hot Jupiter transient event の検出にも成功
- 安価に赤外線モザイクカメラを作成できる ⇉ NS-merger や SPRITEs などの赤外で明るい transient の探査で活きる
- SPIE の Ground-based and Airborne Instrumentation for Astronomy VII でポスターを出しているようです (#10702-133)

観測空気を流して結露を防止するらしい

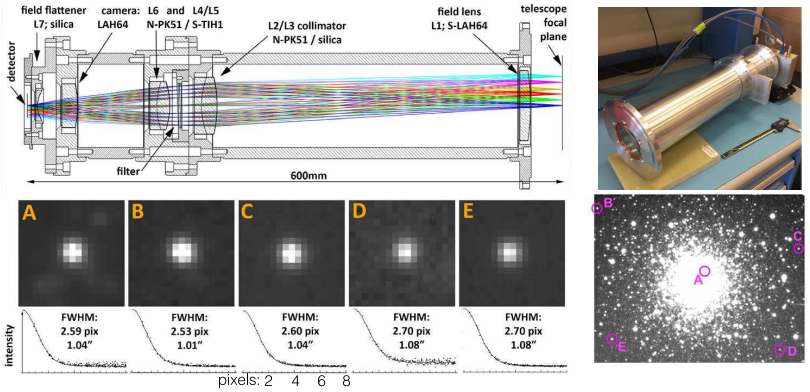

Figure 1. Photograph of the InGaAs reimaging camera assembly (upper right) and cross-sectional view of the lens configuration (upper left). The DuPont telescope focal plane is to the right of the field lens, and the sensor is located at left. The camera requires only boas voltages, separate power for the backing TEC, and USB3 (which is converted and transmitted over fiberoptic lines to the control room). Bottom row indicates PSF image quality across the field, measured using the globular cluster shown at bottom right for indicated field positions.