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PROMPT: Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes^(*)

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Summary. — Funded by \$1.2M in grants and donations, we are now building PROMPT at CTIO. When completed in late 2005, PROMPT will consist of six 0.41-meter diameter Ritchey-Chrétien telescopes on rapidly slewing mounts that respond to GRB alerts within seconds, when the afterglow is potentially extremely bright. Each mirror and camera coating is being optimized for a different wavelength range and function, including a NIR imager, two red-optimized imagers, a blue-optimized imager, an UV-optimized imager, and an optical polarimeter. PROMPT will be able to identify high-redshift events by dropout and distinguish these events from the similar signatures of extinction. In this way, PROMPT will act as a distance-finder scope for spectroscopic follow up on the larger 4.1-meter diameter SOAR telescope, which is also located at CTIO. When not chasing GRBs, PROMPT serves broader educational objectives across the state of North Carolina. Enclosure construction and the first two telescopes are now complete and functioning: PROMPT observed Swift's first GRB in December 2004. We upgrade from two to four telescope in February 2005 and from four to six telescopes in mid-2005.

PACS 95.55.Cs – Ground-based ultraviolet, optical and infrared telescopes.

PACS 95.75.Hi – Polarimetry.

PACS 95.75.Rs – Remote observing techniques.

PACS 98.70.Rz – γ -ray sources; γ -ray bursts.

PACS 98.80.Es – Observational cosmology (including Hubble constant, distance scale, cosmological constant, early Universe, etc.).

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1. – PROMPT

PROMPT (Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes 1; figs. 1 and 2) is a robotic telescope system that will provide well sampled multiwavelength light curves and polarization histories of GRB afterglows beginning only seconds after spacecraft notification. When completed in late 2005, PROMPT will consist of six 0.41-meter Ritchey-Chrétien telescopes by RC Optical Systems on rapidly slewing Paramount ME mounts by Software Bisque. Each mirror and camera coating is being optimized for a different wavelength range and function, including a NIR imager, two red-optimized imagers, a blue-optimized imager, an UV-optimized imager, and an optical polarimeter. The NIR imager is a LN₂-cooled MicroCam by Rockwell Scientific, which uses a PICNIC 256×256 HgCdTe FPA (same as NICMOS3) and will have a $5'$ field of view and $1.2''$ pixels. The optical imagers are Alta U47+s by Apogee, which use back-illuminated E2V 1024×1024 CCDs with ≈ 1 -second readout times and will have $10'$ fields of view and $0.6''$ pixels. The optical polarimeter consists of a Fresnel rhomb + Wollaston prism assembly that we are designing and building at the Abraham Goodman Laboratory for Astronomical Instrumentation at the University of North Carolina at Chapel Hill. It will produce two orthogonally polarized $5'$ fields of view on another Alta U47+. Stokes parameters for linear polarization are measured from the ratio of the images for different rotation angles of the Fresnel rhomb.

PROMPT's six imager design (counting the polarimeter) will allow the u'g'r'R_ci'z'JH SFD of the afterglow to be reconstructed, modulo a small, calibration-induced slope when non-photometric, after only two, mostly redundant exposure sets—regardless of potentially great variations in the early-time light curve—simply by repeating (preferably long-wavelength) filters across consecutive exposure sets: With only two cameras at least seven exposure sets would be needed, and with only one camera this would not be possible until after the afterglow settled into an easy-to-model behavior. From the reconstructed SFD the redshift of the GRB can be estimated from dropout, and because of the eight-band coverage the dropout signature can be distinguished from the similar but broader signatures of extinction by dust, both in our galaxy and in the host galaxy, using the



Fig. 1. – The six PROMPT enclosures at CTIO as of January 15, 2005. Photo by Enrique Figueroa.



Fig. 2. – PROMPT’s first science image, of Swift’s first GRB (041217). No obvious transients were found to a 3-sigma limiting magnitude of $R_c = 21.5$ mag at a mean time of 23.8 hours after the burst [8].

extinction-curve, Ly α -forest, and Lyman-limit models of [1]. Since the possibility of an early-time color transition might cause confusion, the technique will be repeated to confirm the result.

PROMPT’s polarimeter will also forge new ground. When we first proposed to build a robotic polarimeter, polarizations of only a few percent had been measured, and then only at intermediate and late times. However, since then the solar gamma-ray spacecraft RHESSI’s serendipitous detection of GRB 021206 resulted in a polarization measurement for the GRB of $(80 \pm 20)\%$ ([2]; however, see [3]), which suggests that the jet that produces the GRB, at least initially, might not be completely hydrodynamically driven, but rather might have a magnetically driven component through an almost completely ordered field. If this is indeed the case, the reverse shock, which is most likely responsible for the prompt optical emission, would propagate back through this highly ordered field and consequently the prompt emission would be similarly polarized (*e.g.*, [4]). Hence, the optical polarization might actually be highest, and potentially extremely so, right when the afterglow is brightest, and potentially extremely so—and consequently almost trivial to measure if one has a robotic polarimeter. When completed, PROMPT will be able to measure optical polarizations beginning only ≈ 20 seconds after the burst, while many of the long-duration GRBs are still bursting.

The construction of PROMPT’s first four telescopes is well timed with the beginning of operations for Swift. Swift will revolutionize the GRB field for the second time in eight years: Swift is expected to localize ~ 100 GRBs per year with localizations accurate to $1'–4'$ relayed to observers on the ground within ≈ 15 seconds of the burst and localizations accurate to many arcseconds relayed within minutes of the burst. Swift will also localize relatively unextinguished, $z < 3–4$ GRBs (probably about half of their long-duration/soft-spectrum GRBs) to a few tenths of an arcsecond on a longer timescale with UVOT. The expected rate of GRBs that will be observable from the PROMPT site

(*i.e.* that occur sufficiently above the horizon when the sun is below the horizon and the weather is acceptable) during the Swift era (including HETE-2, Integral, IPN, etc.) is ~ 15 per year that will be observable within minutes of the burst and another ~ 30 per year that will be observable on longer timescales as the earth rotates the GRB field above the horizon and/or the sun below the horizon. Of the ~ 15 GRBs per year that PROMPT will observe on the rapid timescale, ~ 2 or 3 are expected to be at redshifts greater than 5 and ~ 1 is expected to be more distant than the most distant object in the universe yet identified, based on various best guesses about the star-formation rate at high redshifts (*e.g.*, [5-7]). Over an extended mission, we expect to detect and identify GRBs with redshifts as high as ~ 10 – 15 , reaching back to when some of the first stars in the universe formed.

2. – SOAR

By locating PROMPT on Cerro Tololo near the 4.1-meter diameter SOAR telescope (which is less expensive and more convenient than locating PROMPT on Cerro Pachon next to SOAR), we ensure that every GRB that is observable to PROMPT is also observable to SOAR. Given SOAR’s rapid response capabilities—rapid slewing and instrument changing, an interrupt policy that was designed with GRBs in mind and spans partner institutions, and remote observing centers—this ensures that a spectroscopic redshift will also be measured for nearly every GRB that PROMPT detects, even if faint or rapidly fading. Although we do not plan to use PROMPT for target selection for SOAR, PROMPT will prove useful for deciding which spectrograph to use once SOAR is in position: If PROMPT finds a GRB to be at high redshift or highly extinguished, we will stick with our default, NIR spectrograph (OSIRIS, resolution = 3000). Otherwise, we will switch to the optical spectrograph (UNC-Chapel Hill’s Goodman Spectrograph, resolution = 8000), a change that we can make in under a minute. Swift’s UVOT, although unable to distinguish between high-redshift and highly extinguished GRBs, will provide similar information, but on a longer timescale.

In addition to using SOAR to complement PROMPT’s u’g’r’R_ci’z’JH spectral coverage with NIR and optical spectroscopy, we will take a few K-band images with SOAR to extend PROMPT’s redshift range from $z \approx 13$ to $z \approx 17$. This spectral coverage synergizes nicely with Swift’s UVOT’s ultraviolet and UVB spectral coverage, not to mention PROMPT’s typically half-minute faster response time.

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