OBSERVING REQUEST
University of Arizona Observatories

Year: 2015 **Term:** Jan–Jul **Proposal type:** long-term⋆ **Proposal ID:** L57

The γ-Ray/Optical Connection in Blazars During the Fermi Era

P.I.: Paul Smith (SO; *psmith@as.arizona.edu*; 520–621–2779)
CoI(s): Buell Jannuzi (SO), Gary Schmidt (NSF)

Abstract of Scientific Justification

This program provides optical linear spectropolarimetry and spectrophotometry of blazars monitored by the *Fermi Gamma-ray Space Telescope* over the final year of its current NASA funding. This telescope time request will execute the proposed observing commitment to the *Fermi* mission for 2015. *Fermi* is now in year 7 of its primary science mission of continuously observing the entire γ-ray sky every 3 hr. It has a projected 10-year mission lifetime. Given its vastly improved sensitivity over previous high-energy observatories, *Fermi* is able to monitor the 20 MeV – 300 GeV emission from the brightest 20 or so γ-ray–detected blazars on a daily basis. The optical project supports the *Fermi* mission with daily monitoring of blazars using the Bok and Kuiper telescopes and the SPOL spectropolarimeter. Observations will be obtained during $\sim$1 week per month. The optical data are combined with measurements by *Fermi* and scheduled radio campaigns to investigate connections between the γ-ray, optical, and radio emission in blazars and constrain models of the relativistic jets producing the observed variable, polarized continuum. The Steward Observatory polarimetry provides unique information on the magnetic field within the continuum emission regions of blazars and has shown that there is often a strong connection between the optical and γ-ray emission. This work builds upon our well established and highly successful six-year program during 2008–14 that has provided the *Fermi* research community with well over 7000 polarization and nearly 6000 flux measurements for the large multi-wavelength effort that are accessed from **http://james.as.arizona.edu/˜psmith/Fermi**. A proposal to NASA to continue the unprecedented ground-based support for the final 3 years of the *Fermi* mission will be submitted this January.

Summary of observing runs requested for this project

Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Scheduling Optimal	Scheduling Acceptable	Sharing Poss.	Sharing Adv.
1	90” or 61”	f/9-13	SPOL	*		7	dark	Jan	Jan–Feb	yes	no
2	90” or 61”	f/9-13	SPOL	*		7	dark	Feb	Jan–Feb	yes	no
3	90” or 61”	f/9-13	SPOL	*		7	dark	Mar	Mar–Apr	yes	no
4	90” or 61”	f/9-13	SPOL	*		7	dark	Apr	Mar–Apr	yes	no
5	90” or 61”	f/9-13	SPOL	*		7	dark	May	Apr–May	yes	no
6	90” or 61”	f/9-13	SPOL	*		7	dark	Jun	May–Jun	yes	no
7	90” or 61”	f/9-13	SPOL	*		7	dark	Jul	Jun–Jul	yes	no
8	90” or 61”	f/9-13	SPOL	*		7	dark	Sep	Sep–Oct	yes	no
9	90” or 61”	f/9-13	SPOL	*		7	dark	Oct	Sep–Oct	yes	no
10	90” or 61”	f/9-13	SPOL	*		7	dark	Nov	Nov–Dec	yes	no
11	90” or 61”	f/9-13	SPOL	*		7	dark	Dec	Nov–Dec	yes	no

Scheduling constraints and unusable dates *(up to 4 lines)*: **Either 90″ or 61″ telescopes can be used for any given observing run**, but the 90″ is much preferred to boost the productivity of the project. Allocated time *needs* to be scheduled in at least 1-week-long blocks. Other programs utilizing SPOL at these telescopes are possible this semester, but it is desirable that SPOL be scheduled in contiguous blocks of time to minimize instrument changes.

no text past this line

A ⋆ appended to the proposal type indicates a continuation proposal; a ⋆ appended to the name of a proposer indicates the proposer is a (graduate) student; a proposer whose name is underlined is certified on the proposed telescope/instrument combination; if a * appears within the PI or AO box in the observations summary table, the instrument is a PI instrument and/or Adaptive Optics are requested – signatures are required on the next page.

Target list (attach list if longer than 26 objects)

#	Object	RA	Dec	mag / color / type / redshift / comment / etc.
1	MG1 J021114+1051	02:11:13.18	+10:51:34.8	V=16.5
2	3C 66A	02:22:39.60	+43:02:08.0	V=15.5, z=0.444, TeV source
3	4C 28.07	02:37:52.41	+28:48:09.0	V=18.5, z=1.207
4	PKS 0235+164	02:38:38.93	+16:36:59.3	V=19.0, z=0.940
5	PKS 0454−234	04:57:03.18	−23:24:52.0	V=18.5, z=1.003
6	S5 0716+71	07:21:53.45	+71:20:36.4	V=14.2, z=0.300, TeV source
7	BZU J0742+5444	07:42:39.80	+54:44:24.7	V=16.9, z=0.723
8	OJ 248	08:30:52.09	+24:10:59.8	V=17.4, z=0.940
9	OJ 287	08:54:48.87	+20:06:30.6	V=14.0, z=0.306
10	S4 1030+61	10:33:51.42	+60:51:07.4	V=19.0, z=1.401
11	Mrk 421	11:04:27.31	+38:12:31.8	V=13.3, z=0.030, TeV source
12	W Com	12:21:31.69	+28:13:58.5	V=16.5, z=0.102, TeV source
13	PKS 1222+216	12:24:54.46	+21:22:26.4	V=17.5, z=0.435, TeV source
14	3C 273	12:29:06.70	+02:03:08.6	V=12.9, z=0.158
15	3C 279	12:56:11.17	−05:47:21.5	V=17.8, z=0.536, TeV source
16	H 1426+428	14:28:32.66	+42:40:20.6	V=16.8, z=0.129, TeV source
17	PKS 1502+106	15:04:24.98	+10:29:39.2	V=15.5, z=1.839
18	PKS 1510−08	15:12:50.53	−09:05:59.8	V=16.5, z=0.360
19	3EG J1635+3813	16:35:15.49	+38:08:04.5	V=17.7, z=1.814
20	Mrk 501	16:53:52.22	+39:45:36.6	V=14.2, z=0.034, TeV source
21	1ES 1959+650	19:59:59.85	+65:08:54.7	V=12.8, z=0.048, TeV source
22	PKS 2155−304	21:58:52.07	−30:13:32.1	V=14.0, z=0.116, TeV source
23	BL Lac	22:02:43.29	+42:16:40.0	V=14.5, z=0.069, TeV source
24	3C 454.3	22:53:57.75	+16:08:53.6	V=16.1, z=0.859
25	PMN J2345−1555	23:45:12.46	−15:55:07.8	V=18.0, z=0.621
26	1ES 2344+514	23:47:04.84	+51:42:17.9	V=12.9, z=0.044, TeV source

Approval for Instrument Use from PI: ____________________

*(have instrument PI signature appear on, or attach PI e-mail to, **all** copies)*

Graduate students *(provide the following information for **each** student named as PI or CoI on the cover page. Have the advisor's signature(s) appear on **all** submitted copies)*

Student's Name	Advisor's Name	Advisor's Signature	2nd-yr	Thesis

Scientific Justification

Fundamental advances in understanding the extreme physics and structure of the emission regions in active galactic nuclei (AGNs) have come through coordinated observations made in various spectral regions. In no other class of AGNs has this approach been found to be more important than with the blazars, which are highly variable in both flux and linear polarization at all observed wavelengths. During the past decade, evidence has been found in several blazars for connections between the high-frequency radio VLBI cores and the small regions within the relativistic jet that give rise to the optical synchrotron continuum. Simultaneous optical and VLBI polarization measurements provide a strong case for the polarized emission in both spectral regimes to originate from the same volume, often identified with the core component in high spatial-resolution radio maps (Marscher et al. 2008; Gabuzda et al. 2006). The evidence even includes cases where the optical and radio core polarization track each other over time scales of 1–2 weeks (D'Arcangelo et al. 2007) and systematic rotations in the optical polarization position angle associated with superluminal VLBI components (Marscher et al. 2008).

The continuous survey of the γ-ray sky by the Large Area Telescope (LAT; Atwood et al. 2009) aboard the Fermi Gamma-ray Space Telescope (*Fermi*) presents an unprecedented opportunity to extend the multi-wavelength approach in the study of blazars to GeV energies. In particular, the ability of the LAT to sample the flux variability of the brightest γ-ray blazars on daily time scales has focused multi-wavelength observing programs during the *Fermi* mission. For the first time, the variability of the high-energy emission, presumably produced by inverse-Compton scattering of photons by relativistic particles within the jet, can be followed in relation to the flux and polarization variations of the synchrotron continuum that dominates the spectrum from ultraviolet to radio wavelengths.

The results from large multi-wavelength campaigns involving γ-ray–bright blazars have been impressive and largely confirm a general association between activity levels at GeV and lower energies for several objects [e.g., PKS1510$-$089 (Marscher et al. 2010); 3C 279 (Abdo et al. 2010); OJ 287 (Agudo et al. 2011a); AO 0235+164 (Agudo et al. 2011b; Ackermann et al. 2012); PKS0528+134 (Palma et al. 2011); 4C 38.41 (Raiteri et al. 2012); 3C 454.3 (León-Tavares et al. 2013; Jorstad et al. 2013; Isler et al. 2013); BL Lacertae (Arlen et al. 2013; Raiteri et al. 2013)]. In general, these studies have often been able to connect γ-ray, X-ray, optical, and/or radio activity with events seen at milli-arcsecond scales, like the emergence of new superluminal components from the VLBI core. In some cases, the results of the variability analyzes has led to estimates that the γ-ray emission region may be many parsecs downstream from the base of the jet (e.g., Agudo et al. 2011a), effectively ruling out the emission sources close to the central engine, such as the accretion disk and broad emission-line region, from supplying the photons that are up-scattered to GeV energies. Of special note is that the observed behavior of the optical polarization during these programs has often provided the basis of the physical interpretation presented. For example, systematic rotations in the optical polarization position angle have been interpreted as being the result of emission from regions where a helical magnetic field is collimating and accelerating the jet (Marscher et al 2008; 2010; Abdo et al. 2010).

Evidence that the γ-ray and optical emission may originate from the same region within the relativistic jet is shown in **Figure 1** (see Smith et al. 2009). Here, the LAT 0.1–300 GeV measurements (blue open circles) of 3C 454.3 are shown along with the optical observations (solid points) made using the Steward Observatory (SO) Bok 2.3 m telescope and SPOL spectropolarimeter (Schmidt et al. 1992). The top panel of the figure shows the γ-ray flux tripling in a span of 5 days, reaching a peak that is coincident with the maximum of a sharp optical flare to within the temporal binning of the *Fermi* data. Further, both the γ-ray and optical flux levels decline quickly and reach their pre-flare levels in just a few days. The tight correlation observed between γ-ray and optical fluxes is even more pronounced in polarized flux. The degree of optical polarization (P) generally increases to $\sim$ 12% at the peak of the outburst and then drops to $\sim$3% within a day (Fig. 1, middle panel). This suggests that the bulk of the γ-ray and optical flux emitted during the flare originated in a region having a fairly well ordered magnetic field. The polarization position angle (θ) is relatively stable at around 150° throughout the outburst.

Although the systematic behavior seen in Fig. 1 for 3C 454.3 is highly suggestive of a common region producing the optical and γ-ray photons, even this relatively short series of observations reveals complications. On MJD = 55098, $P > 10\%$, but this is not accompanied by an increase in either γ-ray or optical

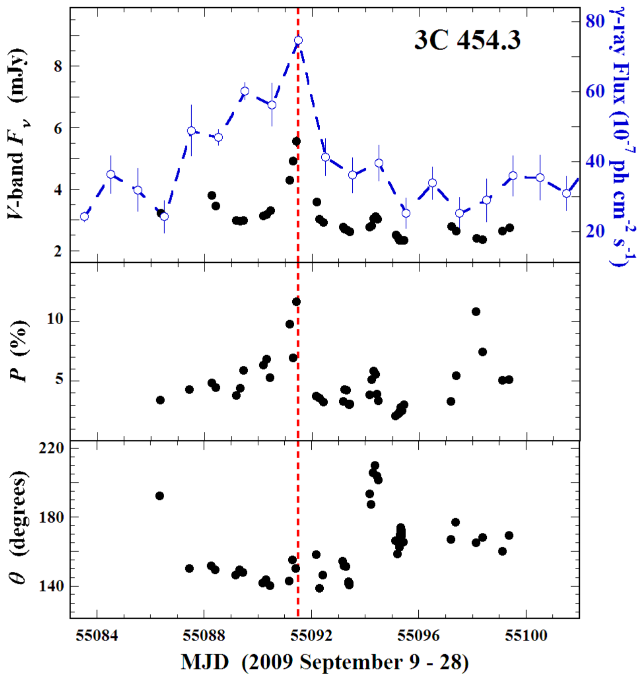

Figure 1: 3C 454.3 during 2009 September. LAT 0.1-300 GeV measurments are displayed in the upper panel as open circles, while the optical data are shown as solid points. The peak of the γ-ray flare is identified by the vertical dashed line.

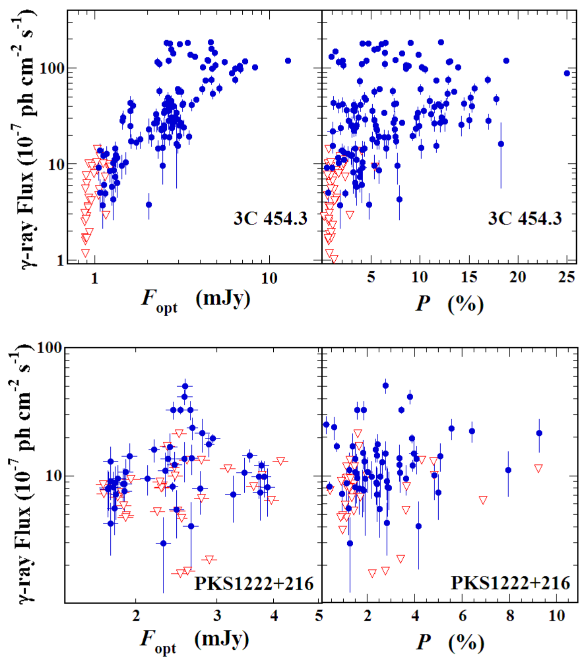

Figure 2: The 0.1-300 GeV flux plotted against optical brightness and polarization for 3C 454.3 (upper panels) and PKS1222+216 (lower panels). All optical data shown are from the SO program. Upper limits on the γ-ray flux are shown as open triangles.

flux. Also, large rotations in θ are seen during periods of relatively stable optical and γ-ray emission, after the decline of the flare (Fig. 1, bottom panel).

Taking a more global view of the behavior of 3C 454.3, **Figure 2** (top panels) shows the γ-ray flux plotted against the SO measurements of the optical brightness and P obtained between the launch of *Fermi* and 2011 October (178 nights). The correlation seen in the fluxes measured in the two bandpasses during the 2009 outburst is present throughout the entire 3-yr period. The long-term correlation between γ-ray flux and P is more muted, as expected, given that the polarization can be observed over a large range of values in most blazars regardless of brightness (see e.g., Smith et al. 1987). Even so, it is clear from Fig. 2 that high levels of optical polarization in 3C 454.3 do not occur when the γ-ray flux is weak. For instance, P is $< 3\%$ during periods when the high-energy emission falls below the threshold for detection by the LAT within a 24-hr period (red triangles). In contrast, the relatively direct relationship between the γ-ray and optical emission in 3C 454.3 is not apparent in the long-term behavior of the $z = 0.435$ blazar PKS1222+216 (lower panels in Fig. 2). There is no indication that the γ-ray flux is related to either optical flux or polarization. Outbursts in both wavebands last only a few days and although this similarity indicates that the emission regions have similar sizes, outbursts can occur in either band with little or no variability in the other (Smith et al. 2011).

The benefits of long-term optical monitoring and spectropolarimetry are seen in **Figures 3** and **4**. Spectropolarimetry is able to distinguish the highly variable polarized jet emmision from unpolarized, less variable thermal sources of flux common to AGNs, such as emitted from the broad-line region and presumably from the accretion disk itself (i.e., the “Big Blue Bump”). In this way, the optical non-thermal radiation can be more accurately tracked and compared to the high-energy and radio emission from the jet. In addition, the thermal emission components are tracked on useful time scales. For example, the Balmer-line emission is found to be constant over a nearly two-year period in PKS 1222+216 (**Figure 4**).

The comparison between the properties of 3C 454.3 and PKS1222+216 give just a taste of the wealth of behavior being revealed by *Fermi* and its associated multi-wavelength programs. Optical observations, particularly polarimetry, which provides direct information of the magnetic field within the emission regions,

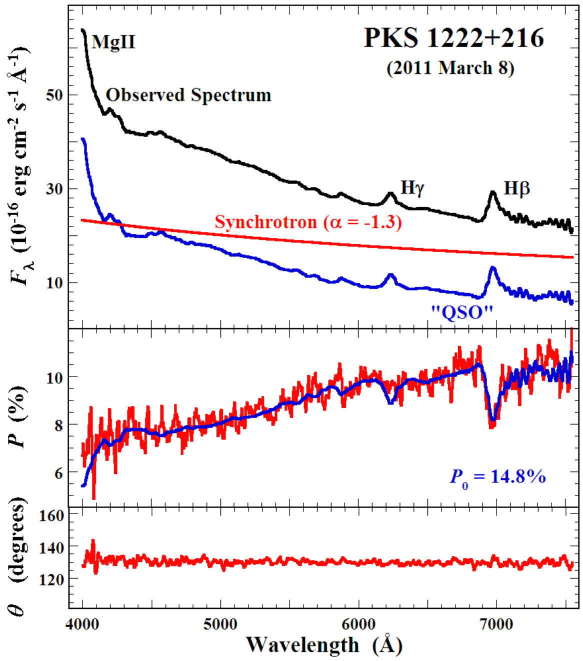

Figure 3: PKS1222+216 during an optical outburst. The flux and polarization spectra can be reproduced by a non-thermal continuum (with P = 14.8% and a spectral index of -1.3) plus an unpolarized optically-selected QSO. The dilution of P by the QSO component is seen the middle panel (see text for details).

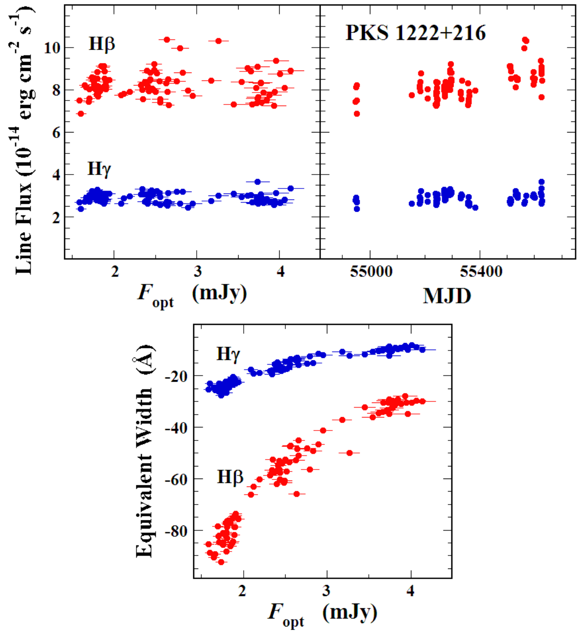

Figure 4: The behavior of the broad Balmer emission lines in PKS1222+216 monitored at SO over the past 2 years. Despite numerous optical and γ-ray outbursts, the line fluxes (upper panels) have remained constant within the measurement uncertainties. The dependence of the EWs (lower panel) on optical brightness is as expected for a variable continuum and constant line flux.

are an important bridge between the high-energy measurements and VLBI observations where the source structure begins to be resolved. The complex nature of blazars argues for a concerted effort across the electromagnetic spectrum to leverage the unique and temporary opportunity that *Fermi* presents into increased understanding of relativistic jets in AGNs. In this vein, NASA accepted our Cycle 5 proposal to the *Fermi* Guest Investigator (GI) program for full funding to continue the SO blazar optical monitoring until at least 2015 November. A proposal to extend the program until the expected end of the *Fermi* mission will be submitted to the Cycle 8 *Fermi* GI program in 2015 January.

References

Abdo, A.A., et al. 2010, Nature , 463, 919
Ackermann, M., et al. 2012, ApJ , 751, 159
Agudo, I., et al. 2011a, ApJ , 726, L13
Agudo, I., et al. 2011b, ApJ , 735, L10
Arlen, T., et al. 2013, ApJ , 762, 92
Atwood, W.B., et al. 2009, ApJ , 697, 1071
D'Arcangelo, F.D., et al. 2007, ApJ , 659, L107
Gabuzda, D.C., et al. 2006, MNRAS , 369, 1596
Isler, J.C., et al. 2013, ApJ , 779, 100
Jorstad, S.G., et al. 2010, ApJ , 715, 362
Jorstad, S.G., et al. 2013, ApJ , 773, 143
León-Tavares, J., et al. 2013, ApJ , 763, L36
Longo, F., Giroletti, M., & Iafrate, G. 2009, ATEL#2021
Marscher, A.P., et al. 2008, Nature , 452, 966
Marscher, A.P., et al. 2010, ApJ , 710, L126
Palma, N.I., et al. 2011, ApJ , 735, 60
Raiteri, C.M., et al. 2012, A&A , 545, 48
Raiteri, C.M., et al. 2013, MNRAS , 435, 1530
Schmidt, G.D., et al. 1992 ApJ , 398, L57
Smith, P.S. 2010, ATEL#2831
Smith, P.S., & Bechetti, G.J. 2010, ATEL#2623
Smith, P.S., et al. 1986 ApJ , 305, 484
Smith, P.S., et al. 1987 ApJS , 64, 459
Smith, P.S., et al. 2009, arXiv:0912.3621v1 (*Fermi* Symposium; Washington, DC)
Smith, P.S., et al. 2011, arXiv:1110.6040v1 (*Fermi* Symposium; Rome, Italy)

Experimental Design & Technical Description *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science.* ***(up to one page)***

Very successful observing strategies have been developed during the *Fermi* mission for using SPOL at both the Bok and Kuiper telescopes to maximize the information obtained from each observation. SPOL is a highly efficient dual-beam polarimeter, designed and built by one of the co-investigators (Schmidt), with a measured total throughput (telescope + instrument) of ∼30%. Its design enables simultaneous measurement of both senses of polarization and the associated background. As a result, polarization measurements are insensitive to atmospheric transparency and seeing variations during an observation. Not having a requirement that the sky be strictly photometric to obtain accurate polarimetry greatly increases the amount of useful telescope time for the monitoring program. The SO program routinely produces some of the highest quality polarization and spectral information available for blazars and provides uniform data products to the research community. These data are accessed through the program website (**http://james.as.arizona.edu/˜psmith/Fermi**) and are suitable for both purely optical studies of sample objects and, as intended, for combination with data obtained at other wavelengths.

An example of an individual observation is displayed in **Figure 3**, which shows $\lambda\lambda$4000–7550 spectropolarimetry of PKS1222+216 in 2011 March. The full range of the data products collected for the public archive are apparent. The high signal-to-noise-ratio (*S/N*) measurements of the polarization reported in the data archive are derived by averaging the spectra of the linear Stokes parameters over $\lambda\lambda$5000–7000 (see Figs. 1&2). However, the spectra are typically good enough for most of the blazar sample to examine how P and θ vary as a function of wavelength with a minimal amount of spectral binning. For the example of PKS1222+216, the polarization decreases into the blue, yet θ is stable with wavelength. Many blazars with strong broad emission lines (including 3C 454.3) show this trend, suggesting for these objects that two continuum sources contribute to the observed optical spectrum (Smith et al. 1986). In addition to the polarized, variable synchrotron power-law associated with the relativistic jet, an unpolarized spectrum very similar to an optically-selected QSO is present. The optical spectrum of PKS1222+216 shown in Fig. 3 is successfully separated into these two components, with $P \sim 15\%$ for the power law. The dilution of P by the unpolarized QSO-like spectrum explains the observed polarization spectrum (middle panel of Fig. 3).

Since the SO spectropolarimetry yields a high-*S/N* spectrum with a resolution of 15–20 Å, the strength of broad emission lines can also be monitored over long periods of time, as is shown for PKS1222+216 in **Figure 4**. Both Hβ and Hγ show little variation in flux over a period of nearly 2 yr. The bottom panel of Fig. 4 shows the expected relationship between the equivalent width of the emission-lines and optical continuum brightness if the line fluxes are constant with time as the continuum varies. Analysis of the entire SO data set for PKS1222+216 indicates that both the emission lines and the unpolarized continuum that dilutes the synchrotron polarization have remained unchanged since *Fermi* found this quasar to be active in γ-rays (Longo et al. 2009).

Typically, SPOL is configured in its spectropolarimetric mode so that flux-calibrated spectra of targets can be obtained. Our work during the past 6 years reveals that adequate polarimetry and photometry of targets as faint as $V \sim 19$ can be obtained in this observing mode within 1–2 hr in dark skies. The instrument can be reconfigured within minutes for imaging polarimetry if broad-band polarimetry is desired for even fainter targets. Both Bok and Kuiper telescopes have demonstrated the capability to provide very high-S/N measurements.

The structure of the observing program will remain unchanged at roughly one week-long campaign each month. This observing cadence enables a period of intensive, nightly monitoring of the sample each month that can be compared to the daily γ-ray measurements from the LAT (see Fig. 1). Continued monitoring over monthly time scales allows for the optical data to be compared with the results of the long-term VLBI monitoring programs associated with the *Fermi* mission.

The SO program is kept flexible to rapidly respond to high-energy events announced by the *Fermi* Collaboration and from the Cherenkov telescopes. For example, responding to announcements of new γ-ray activity detected by the LAT from ambiguous sources, we were able to identify the likely optical counterparts within 24 hr (Smith & Bechetti 2010; Smith 2010). In both cases, the initial observations with SPOL identified the counterparts as blazars undergoing optical outbursts and showing high polarization.

Summary of Time Requested and Awarded *The TAC needs to understand the scope of this project — (1) tell us how many UAO nights you've already had for this project, how many you request this time, and (a good guess of) how many you need to complete the project; (2) if a substantial amount of observing for this project comes from non-UAO telescopes, tell us about that observing, and how the UAO part fits in; (3) if you are collaborating with people who have telescopes, especially if you are part of a large collaboration, tell us who is leading the project, and how UAO time and your participation fit in. (**up to one page**)*

The SO monitoring program has made impressive progress using SPOL at the Bok and Kuiper telescopes since the launch of *Fermi* and has played its intended role in the large multi-wavelength variability studies cited in the Scientific Justification. The SO telescope assignment committee has allocated 469 nights from the beginning of the *Fermi* mission through 2014 December. A NASA review of the Steward Observatory program in spring 2012 resulted in the approval for a 3-year extension of the optical monitoring of the blazar sample. The NASA funding will fully support the program until the end of 2015 November.

The favorable institutional support for the program over the past six years can be gauged by the fact that 56% of the nights assigned have been for the larger Bok Telescope and that almost all of the time granted has been for periods when the moon does not hamper observations. Data have been collected on 487 nights through 2014 October 1, with the inevitable losses due to weather more than made up for by utilizing open nights at the telescopes and sharing nights with other TAC-approved programs utilizing SPOL. This huge investment in resources has resulted in a fully public archive (**http://james.as.arizona.edu/˜psmith/Fermi**) of over 7300 linear polarization and flux spectra, along with $\sim$5800 differential photometric measurements of $\sim$60 γ-ray–bright blazars by the end of 2014 September. By delivering well over 1000 observations per year, the SO program is achieving its stated goal of providing to the research community a comprehensive data set for a large number of γ-ray–bright blazars that augments both the LAT and VLBI monitoring.

Generally, dark sky conditions are requested for each observing campaign, especially for the campaigns when the 61$''$ telescope must be used. Not having a bright moon in the sky greatly improves the effectiveness of the program, as more targets can be observed per night without the presence of a bright, highly polarized background. Importantly, fainter sources ($V \sim$ 18–20) can still be successfully observed. Because of the capability to reach faint flux levels, the program is not overly biased by observing sources only when they are optically bright. For example, 3C 454.3 has been observed at least once on 347 nights from 2008 October to 2014 September, yielding accurate polarization information spanning a range in flux of $\gtrsim$10 optically and $>$200 at GeV energies (Fig. 2).

The factor of 2 increase in sensitivity offered by the Bok Telescope and its ability to point at targets north of +61° make it the preferred choice for the monitoring program. However, we realize that this project demands a large fraction of available dark time on general-use telescopes to provide the maximum level of support for the *Fermi* mission given manpower constraints. Therefore, the Kuiper Telescope is an acceptable alternative when scheduling pressures from equivalently (or higher) ranked science programs that require the 90-inch telescope are encountered. By using both telescopes, we have been able to avoid undesired gaps in the optical monitoring and create a truly unique and comprehensive record of the optical behavior of γ-ray–bright blazars during the *Fermi* era.

Previous Use of Steward Facilities *List **all** allocations of telescope time for the present project and allocations for other projects on facilities available through UAO during the past 2 years, together with the current status of the data (cite publications where appropriate). Mark those allocations related to the present proposal (i.e, precede text with* `\related` *command). (**up to one page**)*

Smith, Schmidt, and Jannuzi continued to make extensive and effective use of SO facilities, especially the Bok and Kuiper Telescopes, over the past two years. During this period, the Steward/*Fermi* blazar monitoring program has dominated our use of Steward Observatory facilities. In addition, over the past decade, we have made a concerted effort to use both the SO 90″ and 61″ telescopes, in conjunction with VLBI monitoring of blazars, to directly connect the optical polarized flux with resolved structures within the radio jets. This work has resulted in several papers, including a letter to *Nature* (Marscher et al. 2008), that have been able to infer the location of much of the unresolved optical emission from the jet and document events where the optical polarization variations are tracked closely by the high-frequency radio core polarization. Our work at the SO Bok and Kuiper telescopes over the past five years has resulted in the largest publicly available archive of spectropolarimetric data.

Papers appearing in **refereed** journals within the last ∼2–3 years that make use of data acquired at SO telescopes are listed below.

⋆ "The First Fermi Multifrequency Campaign on BL Lacertae: Characterizing the Low-activity State of the Eponymous Blazar", Abdo A.A., et al. 2011, ApJ , 730, 101

⋆ "On the Location of the γ-ray Outburst Emission in the BL Lacertae Object AO 0235+164 Through Observations Across the Electromagnetic Spectrum", Agudo, I., et al. (Smith; Jannuzi; Schmidt) 2011, ApJ , 735, L10

"A Spectacular Outflow in an Obscured Quasar", Greene, J.E., Zakamska, N.L, & Smith, P.S. 2012, ApJ , 746, 86

⋆ "Search for Correlations Between the Optical and Radio Polarization of Active Galactic Nuclei - II. VLBA Polarization Data at 12+15+22+24+43 GHz", Algaba, J.C., Gabuzda, D.C., & Smith, P.S. 2012, MNRAS , 420, 542

⋆ "Multi-wavelength Observations of Blazar AO 0235+164 in the 2008–2009 Flaring State", Ackermann, M., et al. 2012, ApJ , 751, 159

⋆ "Variability of the Blazar 4C 38.41 (B3 1633+382) from GHz frequencies to GeV Energies", Raiteri, C.M., Villata, M., Smith, P.S., et al. (Carleton) 2012, A&A , 545, 48

"Time-resolved Spectroscopy of the Polar EU Cnc in the Open Cluster Messier 67", Williams, K.A., Howell, S.B., Liebert, J., Smith, P., Bellinni, A., Rubin, K.H.R., & Bolte, M. 2012, AJ , 145, 129

⋆ "Rapid TeV Gamma-Ray Flaring of BL Lacertae", Arlen, T., et al. (Smith), 2013, ApJ , 762, 92

⋆ "Flare-like Variability of the Mg II λ2800 Emission Line in the γ-Ray Blazar 3C 454.3", León-Tavares, J., et al. 2013, ApJ , 763, L36

⋆ "A Tight Connection between Gamma-Ray Outbursts and Parsec-Scale Jet Activity in the Quasar 3C 454.3", Jorstad, S.G., Marscher, A.P., Smith, P.S., et al. (Schmidt) 2013, ApJ , 773, 147

⋆ "The Awakening of BL Lacertae: Observations by Fermi, Swift, and the GASP-WEBT", Raiteri, C.M., et al. (Smith) 2013, MNRAS , 435, 1530

"Candidate Type II Quasars at $2 < z < 4.3$ in the Sloan Digital Sky Survey III", Alexandroff, R., et al. (Smith) 2013, MNRAS , 435, 3306

⋆ "Rapid TeV Gamma-Ray Flaring of BL Lacertae", Arlen, T., et al. (Smith) 2013, ApJ , 762, 92

⋆ "Discovery of a New TeV Gamma-Ray Source: VER J0521+211", Archambault, S., et al. (Smith) 2013, ApJ , 776, 69

⋆ "A Time-resolved Study of the Broad-line Region in Blazar 3C 454.3", Isler, J.C., et al. 2013, ApJ , 779, 100

⋆ "MAGIC Gamma-Ray and Multifrequency Observations of Flat Spectrum radio Quasar PKS 1510−089 in Early 2012", Aleksić, J., et al. 2014, A&A , 569, 46

"Multi-epoch Spectropolarimetry of SN 2009ip: Direct Evidence for Aspherical Circumstellar Material", Mauerhan, J., et al. (Smith) 2014, MNRAS , 442 1166