Current research interests:

My current research has two main branches. The first branch is observational, aimed at understanding the accretion structure of Galactic black hole transients (GBHT) during outburst decays using data from mainly Rossi X-ray Timing Explorer (RXTE), and from other instruments. The second branch is related to the scientific and technical studies using the INTEGRAL Gamma-ray observatory. In this branch, I work on the analysis of JEM-X, IBIS and SPI data of SN1006, and on the search for the red-shifted 2.2 MeV line from certain neutron stars using SPI. I also work on several SPI detector related projects, such as understanding radiation damage using PSD information, polarization, background distribution in coincidence events, etc. as part of the SPI Science Team.

Observations of GBHTs:

My dissertation (University of California, at San Diego, 2002) is on the temporal properties of GBHTs during outburst decays. Using the PCA instrument on RXTE, I uniformly analyzed the energy spectra, power-density spectra (PDS) and cross-spectra (lag and coherence) of all GBHTs observed between 1996 and 2001, and characterized the evolution of several spectral and temporal parameters during the state transitions and the hard state (Kalemci et al. 2004). I showed that the sharpest change during a state transition occurs in the temporal properties, mainly a jump in the rms amplitude of variability, often accompanied by a jump in the power-law flux. Interestingly, the evolution of the spectral index is quite smooth during the transition. We interpreted these results as a requirement of a threshold size of a corona for appearance of variability. I also showed correlations between several spectral and temporal parameters (in preparation). The most notable correlations are between the spectral index and the QPO frequency valid for many sources in different states, and between the spectral index and the integrated time lag between 3—6 keV and 6—15 keV in 1—10 Hz band. The two previous projects that led to this thesis were temporal analysis of XTE J1550-564 during its outburst decay in 2000 (Kalemci et al. 2001), and temporal analysis of XTE J1650-500 during its decay in 2002 (Kalemci et al. 2003). These publications utilized the RXTE observing program to monitor GBHTs during outburst decays (PI Tomsick) in AO5 and AO6. In Kalemci et al. 2001, we discovered a 65 Hz high frequency quasi-periodic oscillation (QPO), first time in the low/hard state of GBHTs. We discussed several models that can explain this QPO. In Kalemci et al. 2003, the emphasis was on lag and coherence during the state transition. Observation of higher lags and lower coherence during the transition, along with other temporal information resulted in a hypothetical model of state transitions involving a large, optically thin outflow with a radially decreasing temperature structure. For RXTE AO7, a new proposal in addition to our usual black hole monitoring proposal was accepted. This new proposal (PI Kalemci) consisted of three longer observations (20 ks), for two TOO triggers to search for high-frequency QPOs, and to have good statistics to be able to utilize HEXTE energy spectrum as well as to do cross spectral temporal analysis by the PCA instrument. We have triggered two TOOs with this proposal, 4U 1543-47 (submitted to ApJ), and GX 339-4 (in preparation).

For 4U 1543-47, our first long observation took place right during the transition to the low/hard state from an intermediate state. This allowed us to analyze the state transition hour by hour. Later, we also found out that there was coverage of this source with radio, and also with the optical and infrared (Buxton, 2004). By combining the multi-wavelength observations, we were able to place constraints on several black hole accretion models in Kalemci et al, 2004b. By comparing the rising-time of the infrared light curve, and the evolution of the HEXTE light curve and the energy spectral index, we showed that the jet synchrotron emission could not be contributing significantly to the overall X-ray emission for this source. We also showed a very tight correlation between the spectral index and the QPO frequency that holds in hours timescale! Another interesting result from this work was the presence of high-energy cut-off in the HEXTE spectrum only during the transition to the low/hard state, but not before in the intermediate state, nor after, in the low/hard state. We interpreted this as presence of non-thermal electrons during the IS, thermal, cool, thermal electrons during the transition as part of an enlarging corona, and very hot, thermal (or non-thermal) electrons in the low/hard state. We have analyzed GX 339-4 observations, and waiting for the optical and infrared data to be analyzed to combine with the X-ray data.

After AO7, taking into account the RXTE peer review panel's recommendation, we merged the proposal to observe GBHTs with longer observations and the usual monitoring program (PI, Tomsick). In AO8 and AO9, our proposal has been accepted. We observe one source, H1743-322, in AO8. We observed the disappearance of variability with a sudden drop in power-law flux, very similar to what has been observed in XTE J 1859+226 (in preparation). So far, we have not triggered on AO9.

SPI / INTEGRAL Related Studies

As part of the SPI Scientific Team, I have been working on several scientific and technical studies related to SPI detector and the INTEGRAL observatory in general. It is hard to disentangle scientific and technical studies, as, any scientific result coming from a relatively new Gamma-ray observatory with novel detector implementations requires a genuine understanding of the capabilities and properties of the instrument itself. Here I list the projects that I work on, starting with more scientifically oriented ones:

A. INTEGRAL observations of SN 1006

I inherited the data analysis part of this project, although the AO1 proposal (PI, S. Reynolds) was submitted before I joined Steve Boggs's group at SSL. The aim of this project is to resolve the limbs and center of SN 1006 in soft to hard X-rays, and differentiate between synchrotron and bremsstrahlung as the origin of X-rays from different regions. Although JEM-X should be able to detect and resolve the source easily, with the first 250 ks of the data, I was not able to detect the source neither with JEM-X nor with IBIS. We believe that, both the early problems with JEM-X and the dithering pattern of INTEGRAL observations resulted in non-detection in JEM-X. We have just received the remaining of the data (750 ks more), and are more optimistic about detecting and interpreting results from this source.

B. Search for red-shifted 2.2 MeV line

Neutrons that are liberated during the accretion process onto a neutron star surface may form D with H(n,γ)D reaction while emitting a 2.2 MeV photon. Since this line originates very close to the neutron star surface, its properties (change in line energy due to gravitational red-shift, and broadening due to neutron star spin and other relativistic effects) could be used to constrain the nuclear equation state of neutron stars. 4U 1820-30 is a neutron star that accretes matter from a helium white dwarf, and therefore has a lot of neutrons in its atmosphere. I accumulated all the Galactic Center Deep Exposure (GCDE) and Galactic Plane Scan (GPS) data from SPI and started analyzing the data to image and do spectral studies of 4U 1820-30. The source was easily detected with SPI in hard X-rays, however initial analysis has not yielded a detection of a line at the expected energies. Searching for lines in the SPI data is a delicate business and several different approaches need to be applied before the existence or the non-existence of the line could be shown. Currently I have been trying different parameters for spectral analysis as well as background estimation methods in pursue of this line.

C. Polarization measurements of a gamma-ray burst with SPI

Gamma-ray polarization is a hot topic, especially after the discovery of high amplitude polarization from a gamma-ray burst (GRB) by the RHESSI instrument. The detector material and the geometry of RHESSI and SPI are not that different; both use hexagonal Ge detectors, SPI has a more compact geometry and larger effective area than RHESSI. However, SPI does not rotate, which gives RHESSI an advantage on eliminating systematic effects in background. Nevertheless, my Monte Carlo simulations using MGEANT shows that the modulation factor for SPI and RHESSI are similar, but SPI is more sensitive to polarization (for sources in its field of view) than RHESSI due its larger effective area. However, the GRB that RHESSI observed was an extraordinary event, and it may be years before such a bright, hard, and long GRB is observed in the field of view of SPI. An approved INTEGRAL proposal (both in AO1 and AO2, PI Kouvelitou) is in place for a bright GRB in the field of view of both INTEGRAL instruments. I have worked on obtaining the modulation factors as a function of energy, and wrote software to determine and bin the azimuthal scattering angles obtained from the coincident multiple events (ME) in SPI.

a. Understanding background distribution in multiple events in SPI

It is very important to understand the systematic background in the azimuthal angle distribution of ME events in SPI in order to have reliable polarization measurements. This requires quantifying background distribution in ME in SPI, which I work on as part of the SPI science team. For this study, I have accumulated all the SPI data with no strong source in the field of view (SPI, as many other gamma-ray instruments, is a background dominated system for which days or weeks of continuous observations are required to detect a weak sources), and analyzed the distribution in different energy bands. I separated continuum and the lines in the background as their distribution show different characteristics. I found that for continuum, at lower energies, the outer detectors have a higher ME count rate than the inner detectors. The most likely reason is the higher probability of a part of a nuclear line escaping from the outer detectors than the inner detectors. I also showed that there is an inhomogeneity towards the IBIS and JEMX detectors, possibly indicating higher flux of secondary background photons from the spacecraft (caused by cosmic rays interacting in the spacecraft). I worked on the temporal variation of the distribution of the background ME events and showed that it could be modeled by using "tracers" such as the lower level anti-coincidence shield count rates of SPI. It is absolutely essential that this background variation be stable over the course of days to be able to detect polarization from a compact object (like a neutron star or a black hole).

b. Coincidence lines

A natural consequence of working on the background in ME is study of coincidence lines, background lines observed in only one of the detectors that makes up the pair. There are several ways these lines could occur: non-localized beta decays, emission of an internal conversion electron, escape of a part of the 511 keV annihilation line (leaving 511 keV in one detector), nuclear lines with more than one decay path, etc. I first identified all such lines in the background ME spectrum, and then quantified their contribution to the continuum background distribution. Only the 511 keV annihilation line, and the 25 keV internal conversion electron – 173 keV photon pair that makes the very strong 198 keV line in Ge detectors have significant effects on the continuum background. The non-localized beta decays have very small contribution. During this study I have found two lines that were not identified earlier using the single detector events.

B. Understanding the effects of radiation damage using the PSD on SPI

The pulse shape discriminator (PSD) on SPI is an electronic box that was originally designed to reduce the background by differentiating between the potentially real events that Compton scatter inside the detector and the beta decays that cause background by differentiating the expected pulse shapes (a double peaked event is expected from a Compton scattering event whereas a single peak will be present in a beta decay). It turned out that the sensitivity gain by making this discrimination is minimal, and the PSD is no longer used for background reduction. However, it is still useful in quantifying the effects of radiation damage in Ge detectors. The PSD events save "time to peak" tags in the data structure that could be used to infer the depth of interaction of the photons. Radiation damage is an important problem for semiconductor detectors, especially if the orbit of the spacecraft is above the radiation belts of the earth as the SPI on INTEGRAL. The cosmic rays create impurities in the crystal structure of the detector, which in turn become trap sites for holes causing incomplete charge collection. This in turn causes problems with calibration, and affects the energy resolution of the detector. In the case of hole trapping, charge collection strongly depends on the depth of interaction, as for interactions close to the cathode, the holes traverse less distance, hence they are less likely to be trapped. For certain strong background lines, we investigated the change in the line centroid energy as a function o depth of interaction using the PSD tags. In time, the centroid energy shifts more and more to lower energies. To be able to maintain the energy resolution and the energy calibration, the Ge detectors need to go through a delicate annealing process. I characterized the effects of radiation damage before and after the annealing and showed how much much improvement is made by annealing. In principle, the PSD information could be used to optimize annealing times for SPI.

Future research interest

Black hole transients:

Our RXTE monitoring program of GBHTs in the low hard state is a well-established program, and we expect it to continue until RXTE is out of commission. This means that I will continue to characterize the state transitions of new black hole transient systems. There is propriety and archival data from previous observations that needs to be converted into papers. I hope to continue to collaborate with M. Buxton and C. Bailyn to obtain optical and infrared light curves, and with S. Corbel to obtain radio information to have multi-wavelength coverage for new observations. There is plenty to do with the archival data. While working on my dissertation, I realized that there is a relation between the rms amplitude of variability and the hydrogen absorption column density, such that for sources with high N_H the rms amplitude of variability always increases with energy. I found two more sources that are not in my thesis that obey this relation. My fist interpretation is that the rms amplitude of variability decreases at low energies due to additional scatterings of modulated photons in a scattering halo. I am planning to test this argument by using the XMM timing analysis of those sources in a scattering halo if appropriate archival data exist.

We have also obtained observing time with the SPITZER observatory (PI Tomsick) to observe GBHTs in the near-infrared. These observations could potentially yield very important information on jets as their emission turns from optically thick to optically thin in the observing band of SPITZER. I will be responsible for analyzing RXTE data to determine the best time for the SPITZER observation to take place, and assist in the data analysis in general.

The only high frequency QPO detection in the low/hard state is the 65 Hz QPO of XTE J1550-564 during the decay of the 2000 outburst. Our monitoring observations, long observations, and observations from other proposals resulted in a large amount of data perfect for high frequency QPO search in the low/hard state. Some high frequency QPO models invoke general relativistic effects on the accretion disk, which are effective only when the accretion disk is close to the black hole. Detection, or non-detection of high frequency QPOs in the low hard state may help us determine if the inner edge of the accretion disk changes position in the low hard state as suggested by some accretion models.

There is now enough data to characterize the evolution of GBHTs in the low/hard state during the rising phase of the outbursts. A comparison between the rise and the decay data may give us a clue on the possible reasons of the hysteresis effects that is seen in these sources.

Neutron Stars

Scientists at the Sabanci University and I have initiated a research project to search for high energy (>30 keV) emission from anomalous X-ray pulsars (AXP) with HEXTE on RXTE and the INTEGRAL observatory. We started with the AXP 4U0142+61. The RXTE observations of this source show HEXTE flux up to 100 keV. However, a background accreting pulsar 24’ away is the main source of emission in the field of view of RXTE. We therefore searched for pulsed emission with HEXTE with the known pulse period of the AXP for the entire RXTE public data (96 ks of good data with one cluster). The search yielded only an upper limit to the pulsed emission. The results will be presented in the NATO summer school in Marmaris, Turkey. We plan to continue to work on this project and search for pulsed and non-pulsed emission from AXPs using HEXTE. If high energy emission would be detected, follow up INTEGRAL proposals will be written to better characterize this emission. We also plan to write a proposal to observe 4U0142+61 and the background source RXJ0142+6191 with INTEGRAL. Since IBIS and JEM-X on INTEGRAL can resolve these sources, the presence (or non-presence) of high energy emission from 4U0142+61 can be shown with less complications.

SPI / INTEGRAL related studies

I will continue to work on the projects that have been progressing for the last year, analysis of SN1006 and the search for red-shifted 2.2 MEV lines from neutron star binaries. The whole SN1006 data have been downloaded and will be analyzed by using both JEM-X and IBIS. Analysis of 4U1820-30 with SPI will continue, and I will also analyze the data of Sco X-1 in pursue of this line using the GCDE and the GPS data.

Although the GRBs offer the best chance for detection of gamma-ray polarization with SPI, bright compact objects are also candidates. There is a huge data set for the Crab nebula that I will use to test my polarization routines. Eventually there will be enough accumulation of data to detect, or place meaningful upper limits for gamma-ray polarization for this source. Of course, in the case of a bright GRB in the field of view of SPI, I will search for polarization using my routines.

I will continue to study the coincidence lines with SPI. Although the events in these lines are a very small ratio of the total events, the study has potential applications for next generation observing satellites, especially the Advanced Compton Telescope (ACT) concept. Likewise, the radiation damage studies with the PSD will continue to quantify its effects on SPI, and also for future gamma-ray instruments for which annealings are required.

Past research interests

Charge transport in CdZnTe detectors:

Between 1998 and 2000, I have worked on modeling the charge transport and charge collection in CdZnTe (CZT) detectors. The ability to perform with low noise at room temperatures makes this material very valuable for space instrumentation. It is been well known that incomplete hole collection is a problem in achieving good performance from these detectors, and novel electrode configurations involving strips or pixels can eliminate this problem by virtue of the small pixel effect. At UCSD, we have developed and tested position-sensitive cross-strip CZT detectors, and I developed a computer simulation of these detectors that predicts induced charge on each electrode for various electrode geometries and various interaction positions. The modeling resulted in a deeper understanding of the processes within the detector and more efficient detector electrode design that enhances the small pixel effect. I also investigated the problem of charge diffusion in the detector and its effects on charge sharing among electrodes, and quantified the effects with a series of laboratory experiments and modeling. I used a 30 micron aperture X-ray collimator on a computer controlled X – Y stage with 10 micron precision for the experimental part of this study. I showed that when the depth of interaction is taken into account, charge sharing among the electrodes could be understood by a simple diffusion model of the electron cloud.

Monte-Carlo modeling of accretion disk – Compton corona systems:

I have also worked on Monte Carlo simulations (mainly developed at AIT by Joern Wilms) of accretion disk – Compton corona systems to interpret spectral and temporal data from Galactic black hole transients. In these simulations, the photons are created with a disk-blackbody energy distribution and undergo repeated Compton scatterings until they escape from the corona or are absorbed in the disk. The reflection from the disk and thermalization of absorbed photons in the disk are taken into account. The simulations not only reveal X-ray spectral information, but also can be used for temporal studies. I created parameter grids for these simulations, and obtained time to run the simulations at the Linux cluster at Albuquerque High Performance Computing Center. This project is on hold for a while, but I am planning to return and continue to work on it at my earliest possible time.

Modeling of dead-time effects in HEXTE power spectrum

Cosmic rays leaving more than 20 MeV in the HEXTE detectors cause them to be non-operational for at least 2.5 ms. Including the contribution from lower energy particles, the cumulative dead-time in HEXTE can be as high as 35%. This has a dramatic effect on the power spectrum. I first modeled the spectrum of cosmic rays in the HEXTE detectors, and then devised a dead-time correction formula based on this spectrum for the HEXTE power spectrum. This resulted in a good agreement between the PCA and the HEXTE power spectrum in the common energy range, and allowed me to analyze QPOs up to 120 keV.

I have worked on these scientific topics (in historical order):

- Charge transport and collection in CdZnTe detectors
  - Modeling of pulse shapes
  - Charge sharing and diffusion in CdZnTe detectors (modeling + experiment)
- Modeling of dead-time effects on HEXTE power spectrum
  - Cosmic ray spectrum for HEXTE, their effects on dead-time
  - Comparison of PCA and HEXTE power spectrum after dead-time correction
- Timing analysis of Galactic black hole transients with PCA
  - Fourier analysis, power spectrum, QPOs, continuum
  - Other Fourier analysis tools, lag and coherence
- Spectral analysis of Galactic black hole transients with PCA and HEXTE
- Monte-Carlo modeling of photon transport in accretion disk – Compton corona systems
- Multi-wavelength observations of Galactic black hole transients
- Radiation damage studies on SPI on INTEGRAL
- Polarization studies with SPI
  - Monte-Carlo simulations with MGEANT
  - Background distribution in multiple events
- Polarization studies with IBIS on INTEGRAL (using Compton mode)
  - Monte-Carlo simulations with MGEANT
  - Concept study to observe a bright black hole transient to measure polarization
- Background in SPI
  - Detector to detector distribution of lines and continuum in SPI
  - Characterization of coincidence lines in multiple events in SPI
- Imaging with IBIS and JEM-X of SN1006
- Search for red-shifted 2.2 MeV line with SPI
- Timing and pulse-folding analysis of neutron stars with PCA and HEXTE

Data analysis and programming experience:

Highly experienced with:

- IDL (Interactive Data Language)
- C
- Fortran
- FTOOLS
- OSA (Offline Scientific Analysis software to analyze INTEGRAL data)
- MGEANT (Interactive version of GEANT created especially for INTEGRAL)

Some experience with:

- Shell programming (chs, ksh)
- C++
- Monte Carlo simulations