OUR ULTIMATE GOALS

The overarching goal is to understand the phenomenon of an active galaxy and the associated jet. We are working within the paradigm where an AGN is ultimately powered by the release of gravitational energy via flow of material onto a black hole.

We envision that our work will have broad implications for understanding of:

* formation, structure and evolution of black holes
* formation, structure and evolution of relativistic jets, and the connection between the jet and the black hole
* basic physics of particle - particle and particle - field interactions, in particular under extreme environments (ultra-high energy particles and radiation)
* particle acceleration processes
* origin of the cosmic rays
* implications for the evolution of structure in the Universe

Our approach here is akin to "peeling the onion":

- we study AGN via the "messengers" - photons – to infer first the emission mechanisms, leading to the physical setting and energization mechanisms of the particles that emit the radiation, then leading to the ultimate source of power

- We divide the study into three parts:
- (A) AGN as a population and the blazar phenomenon
- (B) Physics of the gamma-ray emission in AGN
- (C) AGN as tools for other investigations

A. AGN as a population and the blazar phenomenon

This general, top-level topic concerns several subjects – and those are listed below.

We anticipate that more points will be added, and the details will be filled in as time progresses.

* Definition of a gamma-ray emitting AGN

* Statistical properties of the class of gamma-ray emitting AGN:
    e.g. spectral and variability properties
        - probing the unification scheme (radio galaxies as mis-directed blazars);
            beaming statistics?
        - relationship to radio-quiet AGN
        - the blazar sequence
        - comparison of statistical properties to blazar properties inferred from other spectral bands

* Luminosity function & cosmological evolution, ...

* Contribution of unresolved blazars to the extragalactic gamma-ray background

B. PHYSICS OF GAMMA-RAY EMITTING AGN

This is about how gamma-ray emitting radio-loud AGN work, including the jet structure, content, and radiative processes.

We are considering the two leading candidate processes for radiation emission mechanisms. Those are (1) leptonic processes, where the low energy "peak" is produced by synchrotron mechanism by a non-thermal population of relativistic electrons/positrons, and the high energy peak is produced by inverse Compton mechanism by the same particles, where the seed photons are the internal synchrotron radiation, or on the external circum-nuclear radiation; or (2) hadronic processes, where the low energy "peak" is also produced by synchrotron radiation, and meson production (via the interaction of highly relativistic protons and photons) and subsequent cascading is involved for the production of the high energy peak. Such cascades are initiated by the photons resulting from the decay of pi^0 (produced via proton-photon interaction), or by inverse Compton/synchrotron photons from the secondary pairs, Those are then reprocessed to lower energies where they can escape the emission region. Further components may include synchrotron radiation of the photoproduced charged particles and protons and their reprocessed radiation. The target photon field for photomeson production and cascading encompasses the same internal and external photons fields as in the leptonic model.

B.1 WHAT is the structure (ingredients/content) of jets in blazars and radio galaxies?

* *B.1.(a) the content of innermost part of the jet (ionic, e+e-, Poynting flux; baryon loading?)*

*** Approach:** Is there a substantial e+/e- component to those? Are they most likely Poynting flux dominated? --> search for X-ray "precursors" to gamma-ray flares and determine the time delay; presumably if jets are particle dominated to begin with, one should see "bulk-Compton" radiation prior to dissipation events - the intensity of the "precursors" should reveal the total e+ /e- content of the jet. Note that an opposite behavior is predicted by some specific hadronic models (e.g. blast-wave model) which predict in general the X-ray flare to follow (lag) the gamma-ray flare; this is because the X-ray component in this model is produced by synchrotron radiation by the secondary pairs from charged pions that are produced in proton-proton interactions whereas the gamma-ray flare consists of the hadronically produced pi^0-decay photons.

Targets: Bright blazars in flaring states: 3C279, 1622+398, PKS 0528+134
Other data needed: Good coverage in soft X-rays during pre-flare, flare, and post-flare state; time lag information. Needed duration: 2 weeks; sampling: every 3 hours if feasible since little is known regarding the location of particle acceleration region from the central engine (although this can't be too close, or Compton drag prevents the jet to survive: the jet would then become photon dominated).

** B.1.(b) composition/structure of <u>gamma ray emitting part</u> of jet (e+/e-, p/e or UHECRs, B field)*

*** Approach 1:** Test simple, 1-zone leptonic models: To first order, no lags (or at most, small lags) between the synchrotron and Compton components are expected. Non-expected behavior calls for alternative model solutions which may be linked with the need for hadronic jet components (see ``orphan flares``, low-E component lagging high-E component, etc.)

Examples: are SSC models already in trouble for the HBL-type blazars? SSC model precludes flares that are seen only in one, but not in the other component: "orphan" flares pose substantial problem to SSC models; a few were reported in previous data, but no clear consensus

Targets: HBL blazars Mkn 421, Mkn 501, 1ES1959+65
Other data needed: good coverage in soft X-rays and in the TeV band

** B.1.(b) composition/structure of <u>gamma ray emitting part</u> of jet (e+/e-, p/e or UHECRs, B field) (continued)*

*** Approach 2:** Identify dominant general scenario: (a) leptonic, (b) hadronic (protons interacting with protons, photons or fields) at gamma-ray energies. Apart from (non-available) polarization data at these energies, this goal can be approached through detailed broad-band modeling (including simultaneous broadband data and variability information) using competing blazar emission models. E.g., leptonic models predict significantly sharper cutoff at high energies for the LBL objects than the hadronic models which predict more gradual spectral decline in the (sub-) TeV range. This is because in blazars with denser target photon fields (such as LBLs) components from charged muon/pion synchrotron radiation may produce additional flux in the sub-TeV range.

Targets: nearby strong emission line LBLs (BL Lacertae, W Comae), but potentially also FSRQs (3C273, 3C279, 3C454.3, PKS 0528+134)- there, one must consider complications of the gamma-UV pair production.

Other data needed: For unambiguous model fits both simultaneous broad-band SEDs plus variability information (light curves, hysteresis...) are required in energetically equally distributed energy bands.

** B.1.(b) continued: composition/structure of gamma ray emitting part of jet*

*** Approach 3:** Derive a measurement or UPPER limit on B field strength in the gamma-ray emitting region; useful tools may be: equipartition arguments using low-E peak flux, width of ACF, multi-lambda leads/lags including optical + X-ray + GLAST data, information on the total kinetic luminosity of the jet (radio lobes?) - (apart from (non-available) polarization data at GeVs)

Targets: nearby, bright blazars (both HBL, TeV – emitting objects, and LBL objects)
Other data needed: broadband long continuous data trains, very short sampling time scale

*** Approach 4:** Determine the relative importance of adiabatic vs. radiative losses, via study of the flare profiles (symmetric vs. not symmetric); non-symmetric flare profiles are a tell-tale of radiative processes dominating. Time-dependent hadronic models?

Targets: same as above

*** Approach 5:** Derive an unbiased estimate for the total jet luminosity / total charged particle content / kinetic energy of the blazar jet. Need to do this in the HE component since the LE component might be contaminated by much larger volume and/or affected by synchrotron self-absorption

Targets: should yield inferences about the particle content from modeling of the Compton component - presumably the "low end" of the distribution is due to less energetic but much more numerous particles -> bright sources with hard X-ray spectra are best, such as BL Lacertae, PKS 1510-089

Other data needed: Hard X-ray / soft gamma-ray band regimes are most important, besides GLAST

*** Approach 6:** Search for gamma-ray emission from blazars and radio galaxies that display spectra consistent with neutron-decay and hadronic cascade origins for synchrotron and Compton components (cf. Atoyan & Dermer 2003 etc...).

Targets: 3C 279, PKS 0528+135, Mrk 421, Cygnus A, Pictor A, others
Other data needed: Multi-wavelength coverage of blazars at energies of most highly variable synchrotron flares.

** B.2 WHERE are the X-rays/gamma-rays produced ?*

** B.2.(a) photon production sites of low & high energy (HE) component*

* **Approach:** Is an one-zone model sufficient? If the flares are indeed produced by the same co-spatial electron population, the light curves for the synchrotron and Compton component flares should be strictly simultaneous, meaning no measurable leads or lags of the IR/opt/UV and gamma-ray flares

Targets: HBL blazars Mkn 421, Mkn 501, 1ES1959+65
Other data needed: Simultaneous monitoring in the IR/opt/UV bands, at a cadence allowing to temporally resolve the flares (implied by the GLAST data)

** B.2.(b) energization sites*

* **Approach:** Use the "gamma-gamma attenuation within a jet" arguments to place a minimum limit on the bulk relativistic Lorentz factor of blazar jets, and to set minimum distances of the location of the emitting jets from the central supermassive black holes. Correlate Lorentz factors with blazar types.

Targets: 3C 279, CTA 102, PKS 1622+398, others
Other data needed: Correlated X-ray observations

** B.3 HOW are the X-/gamma-ray flares produced in blazars and radio galaxies?*

** B.3.(a) Importance of external photon fields (BLR, accretion disk, CMB, ...) for X- & gamma-ray production*

**** Blazars:***

*** Approach 1:** Is Self-Compton or External Compton more applicable for objects with strong emission lines? Gamma-ray flares (presumably Compton) should obey the simple quadratic (for SSC) or linear (for ERC) relationship against the amplitudes of the IR/Opt/UV flares (presumably synchrotron component) IF the low and HE component are co-spatially produced (which is in doubt considering the most recent MWL results). In this case correlated variability between optical and 100 MeV - GeV emission, and X-ray and >>GeV – TeV emission should be examined as evidence for SSC and EC processes by comparing with model expectations.

* **Approach 2:** via direct verification of the strength of the putative external target photon fields (e.g. BLR, accretion disk through emission line measurements, etc.)

Target(s): Bright blazars in flaring states: 3C279, 1622+398, PKS 0528+134

Other data needed: Simultaneous monitoring in the IR/opt/UV/X-ray bands, at a cadence allowing to temporally resolve the flares (implied by the GLAST data); BLR emission line strengths around times of gamma-ray activity

** B.3.(a) continued: Importance of external photon fields (BLR, accretion disk, CMB, ...) for X- & gamma-ray production*

<u>* Radiogalaxies/large scale jet structures</u>:

*** Approach:** Tests of the Compton-scattered CMBR interpretation of extended X-ray (Chandra) jets; Highly relativistic motions on hundred kpc scale is required to explain X-ray knot emission in Chandra jets through Compton-scattering of the CMBR, with definite predictions for GLAST.

Targets: PKS 0637-752, Cen A?
Other data needed: Measurements of the minimum non-variable flux of PKS 0627-752 will test this model.

** B.3.(b) Relation between flares and dissipation of magnetic energy*

* **Approach:** Are gamma-ray flares related to dissipation of magnetic energy? This can be accomplished via monitoring of the IR/optical polarization near the peak of the synchrotron component, and correlation of polarization direction changes with gamma-ray flares

Targets: BL Lacertae, AO 0235+164, 3C454.3, others; preferred sources are those with the peak in the optical / IR band
Other data needed: good optical polarization coverage, at good (< hour) temporal resolution

B.4 Testing of predicted features of various hadronic models

* **Approach:** Assess various classes of hadronic models, and evaluate the consequences that might be potentially observable via multi-wavelength data

Targets:
Other data needed:

C. AGN as a tool

- This includes two main topics, related to the host galaxy, and the intervening medium.

* Study of the matter content of the circum-nuclear region at intermediate – to large distances from the black hole: probing the baryonic Compton-thick material in the AGN's vicinity, host galaxy, and in the intergalactic space

* Study of the cosmic background radiation (presumably in the intergalactic space); this is the infrared, optical, UV radiation, presumably due to star formation, ... via γ–γ pair production