When Fermi met ALMA:

ALMA's role in multi-wavelength monitoring of AGN

Phil Edwards CSIRO Astronomy and Space Science



Outline

- Where is ALMA?
- What is Fermi?
- AGN at gamma-ray energies
- Spectral Energy Distributions
- What can ALMA do for us?
- What can we do for ALMA?



There's an Alma in South Australia...



About 100km north of Adelaide



...not far from the famous vineyards of the Barossa Valley



...and ALMA lends its name to a number of wines









...even some from Chile!





The Alma in South Australia is close to the towns of Balaklava, and Inkerman, and all are named after battles during the Crimean War (1853-1856)





The CASS/ATNF site in Marsfield is very close to a Crimea Rd and Balaclava Rd – could there be an Alma Rd in Marsfield? Yes there is!



The site of the next ALMA workshop photo??



AGN in cycle 0

- Searching through the highest priority cycle 0 proposals turns up a surprising number of AGN...
- ... many of them in "magnitude"
- ... many more in "diagnostic"
- But only a small number of active galactic nuclei!



What is Fermi?

- First gamma-ray satellite was Explorer XI, launched 51 years ago
- Followed by OSO-3 (1960s), SAS-2 (1970s), COS-B (1980s)
- EGRET on CGRO (1990s) detected ~100 radio-loud AGN as variable gamma-ray sources (and many unidentified sources)
- Fermi (2000s) maps the sky each day with better sensitivity and better angular resolution; now ~1000 AGN identified







Spectral energy distributions

- Low energy component due to synchrotron radiation
- For high energy component there are both leptonic and hadronic models
 - Inverse Compton scattering of the synchroton photons (SSC), or
 - Inverse Compton scattering of external photons (EC), e.g., broad line region, dust torus, CMB
 - High energy photons interact creating pions which decay into gamma-rays and neutrinos
 - High energy photons can produce high energy synchrotron radiation



Conclusions from the EGRET era

- A gamma-ray high state is accompanied by a flare at mm wavelengths and the ejection of a new, often superluminal, component on the parsec scale. Identifications with Jy-level sources
- The relative timing of these events is unclear, and the physical processes similarly uncertain
- There is some evidence the mm flare precedes the gamma-ray high state, though the limited cadence of EGRET observations made this difficult to quantify







PKS 2155-304 on the kpc scale



Laurent-Muehleisen et al. 1993



PKS 2155-304 on the pc-scale



Piner & Edwards 2004



Complementary programs

• LBA TANAMI project (V252)

- LBA observations at 8 GHz and 22 GHz to study structural and spectral evolution of Fermi sources at declinations < -30 deg
- Observations requested at both bands every two months
- •ATCA (C1730)
 - ATCA observations at 5/9, 17/19, 38/40 GHz to study temporal and spectral evolution of southern Fermi sources
 - 2007-11 to 2009-06 and 2011-05 onwards
 - Prompt release into ATCA calibrator database



PKS 2155-304 outburst in July 2006





PKS 2155-304 – ATCA monitoring

PKS 2155-304





PKS 0402-362 Fermi light curve



Courtesy Faith Hungwe





CSIRO

PKS 0521-365 SED



Self-consistent radiation code of Weidinger et al. 2010



PKS 2142-758 at gamma-ray energies



PKS 2142-758 SED



Dutka et al. 2012 based on Dermer et al. 2009 modelling

CSIRO

What can ALMA do for us?

- Snapshot observations add points to the SEDs of southern AGN in a key part of the spectrum to help differentiate between models
- Snapshot observations will identify sources with structure on ALMA baselines for detailed imaging follow-up
- High spectral resolution observations could use these bright sources to probe the intervening material
- Polarisation variations also valuable
- VLBI (bands 1 and 2) challenging but important

What can we do for ALMA?

- These AGN are bright and variable at all frequencies
- These are mostly core-dominated sources are well studied with positions determined with milli-arcsecond accuracy
- Ideal sources for use as phase calibrators and pointing sources
- Most efficient use of these sources relies on knowing their current flux density, which a flux density monitoring program like this can contribute to



Conclusions

A	Lot of	Meanings for	ALMA !
Appreciate	Locally	Made	Alcohol
Always	Looking for	More	Ammunition
Advanced	Low-frequency	Modelling of	AGN
ALMA	Legacy for	Monitoring	AGN





Conclusions

A	Lot of	Meanings for	ALMA !
Appreciate	Locally	Made	Alcohol
Always	Looking for	More	Ammunition
Advanced	Low-frequency	Modelling of	AGN
ALMA	Legacy for	Monitoring	AGN
Australians	Like	Making	Acronyms

Answers to questions

- Can this monitoring use the publicly available ALMA calibrator data?
 - Yes, it could, though ideally that data would be supplemented by targeted observations of AGN during flaring phases as well as quiescent phases to contribute to separate SEDs
- What causes these flares?
 - Something (Infall to accretion disk? Material crossing the jet flow? Material in the jet traversing a standing shock?) results in the acceleration of particles to high energy, producing increases across the multi-wavelength spectrum and often resulting in the emergence of a new jet component on the parsec-scales probed with VLBI.



CSIRO/ATNF

Philip Edwards CSIRO ATNF Head of Science Operations

Email: <u>Philip.Edwards@csiro.au</u> Web: www.atnf.csiro.au

Thank you

Contact Us

Phone: 1300 363 400 or +61 3 9545 2176 Email: Enquiries@csiro.au Web: www.csiro.au

