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Conference Summary

Galaxy Evolution, AGN and Gravitational Waves

Ron Ekers

Southern Cross Astrophysics Conference #1

Hydro Majestic

15-20 June 2008



Quotes

- Sterl Phinney
 - *“Black holes are the most beautiful objects in the Universe”*
- Dick Manchester
 - *“The best timing on any pulsar on any telescope at any time”*
 - *“pulsar timing is immune from the effects of global warming”*
 - *“why does it have to be Eddington anyway, it accretes from plane and ejects along axis”*
 - *answer - so we can calculate black hole mass*
- Michael Brown
 - *“both models are likely to be incorrect but they are still very popular”*
- Matt Jarvis
 - *“this is now a very famous correlation based on limited data”*
- Bill Coles
 - *“this a well understood problem that doesn’t need Bayesian techniques”*



some topics linking disciplines

- Mark Lacy - high z radio galaxies and SMBH
 - radio galaxies contain really big BH (10^{8-9}) this is just the mass range which is detected by pulsar timing
- models the SMBH merger rate (Wen)
- what is measured (George Hobbs)
 - MBH mass function and merger rate
 - problem is how to separate these effects
- black hole merger recoil kicks (Joan Centrella)



some topics linking disciplines (2)

- any em counterpart gives a standard candle at cosmological distances (Benz Kocsis)
- gravity waves for radio astronomers (Sterl Phinney)
 - just replace strain by amplitude
- ISS phenomena first recognised by pulsars (Barney Rickett)
 - Interpretation initially strongly opposed by AGN astronomers
 - an example of innovation through cross fertilization
- another perspective from an electrical engineer (Bill Coles)
- impact of the Parkes multibeam receiver (Marta Burgay)



Archeoastronomy

- Warren Brown 2006, found a main sequence star moving at 850km/s
 - distribution of hyper velocity stars supports continuous ejection for the last 250Myr
- Chiaki Kobayashi - chemiodynamical evolution
 - many stars form in dwarf galaxies before massive galaxies form
 - That's where the old stars come from
- Use pulsar separation to build a time machine



Galaxy Evolution

- In mid 1990 a few non AGN objects beyond $z=3$,
now 1000's
- some process truncates star formation in massive
halo's
 - AGN feedback?



AGN

- all methods to investigate SMBH at higher redshift need an AGN on at least one SMBH component as tracers visible at high z
- jets can give both positive and negative feedback
- SMBH and galaxy growth are linked so need feedback
- Laura Blecha notes that recoil requires a paradigm shift
 - feedback is dramatically effected by recoil
 - notes that young people adapt faster to a paradigm shift
 - this is expected because older scientists loose the advantage of accumulated knowledge
- AGN as evidence for mergers?



SMBH mass

- Great review by Sterl Phinney
- $M_{\text{bh}} \propto M_{\text{bulge}}$ relation
 - Its this relation that requires a link between the SMBH mass and the whole galaxy, hence need for feedback
- only AGN can be used to explore the redshift dependence
 - line width + virialized + reverberation mapping
 - the many problems where outlined by Matt Jarvis
 - Peng $z=2$ sample with careful modelling of AGN
 - » SMBH relatively more massive than bulge
 - » hence SMBH first and galaxy assembly later
 - sub mm galaxies are a problem - opposite dependence with redshift
- Do AGN follow the $M_{\text{bh}} \propto M_{\text{bulge}}$ relation?
 - looks OK (Matt Jarvis)



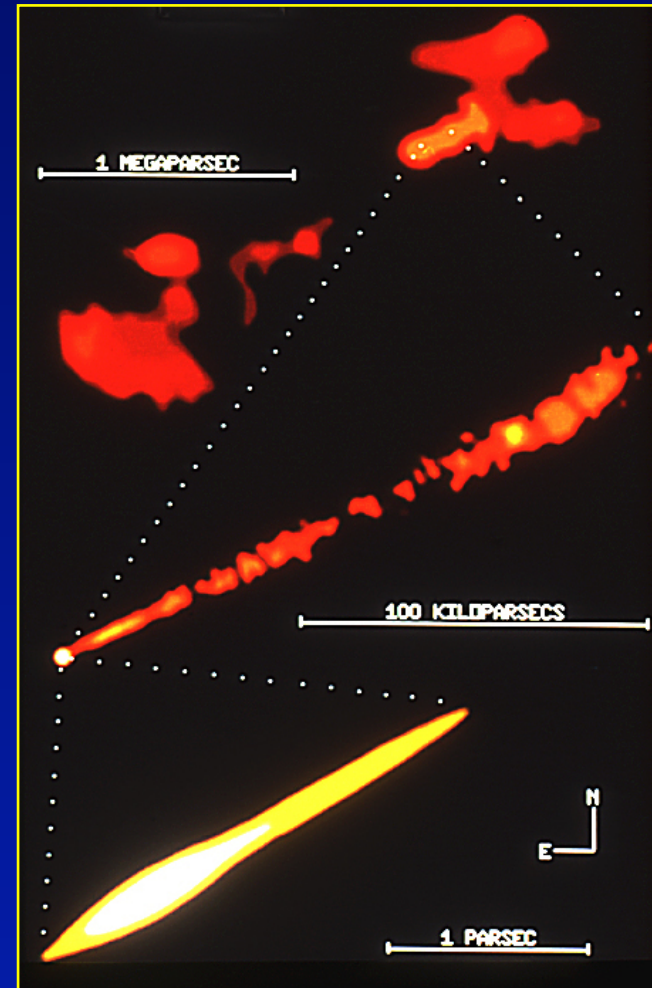
Radio Galaxies

- pc scale radio jets probe close to the SMBH
 - mildly relativistic in vol limited sample
 - highly relativistic in flux limited samples due to boosting
 - some show re-orientation
 - some show plasma running corners
 - **what about Occam's Razor?**
- M87 jet asymmetry needs 0.5 to 1c but observe 0.02c
 - intrinsically one sided!
 - is all asymmetry in AGN jets due to Doppler boosting?
- X sources – two models
 - Proposes a combined model for X sources with backflow filling the old cavity caused by previous ejection before axis re-orientation
- all radio galaxies with large HI envelopes are small (few kpc) radio galaxies
- population of double radio sources associated with spirals at high z
- 50 objects not seen in deep Spitzer fields



Radio Galaxies

- Most radio galaxies have impressive alignment!
- Maybe they are the single SMBH and the binary SMBH are not radio galaxies!





Galaxy mergers

- special session



Do galaxy mergers trigger the AGN

- examples are very rare
- color mag plot also shows no merger effect
- QSO host colours need ages 2-3 Gyrs so not very consistent with mergers
- FRI's don't need mergers but the FRII's do
- No clear indication from HI of a major merger in radio galaxy sample



SMBH mergers

- numerical GR is an exciting and expanding field
 - first attempt in 1964 - failed then and for another 40years
- Need for coincident GW and EM observations
 - identification
 - Eddington ratio
 - cosmology
 - Black hole physics
- possible electromagnetic effects
 - periodic accretion
 - huge energy in gravity wave so any coupling to plasma will give effects
 - sudden mass loss gives shocks
 - X-ray after glow when gas falls back in
 - recoil flares
- need to start coordination for search plans



Binary SMBH tracers

- many tantalising examples but generally the binary explanation is not unique
- NGC6240 double Xray source
- double profile QSO
 - very large samples available for searching
- 0402+379 double AGN (VLBI)
- periodic flux variability
 - claims made summarised by Stephanie Komossa
 - eg OJ287 modelled by Valtonen but the predicted peak did not occur
 - » modified model to fit data
- VLBI astrometry to see the orbit
- Double rotation measures
- New at this conference: use of scintillations to find double AGN
 - sub pc scale is easily accessible, peak in structure function at sub day time scales



Recoiling SMBH

- distribution of kicks for interesting parameter space
 - mass ratio effects tricky and relations not yet known
 - early days but work in progress
 - we already know that astrophysically significant velocities will occur
- need an em signature to see the recoiling SMBH
 - hence it needs an accretion disk:
 - recoiling SMBH carries the disk with it
 - bound SMBH oscillating through disk
- recoiling SMBH signatures
 - off nuclear QSO can be spatial or kinematics
 - velocity offsets between QSO and host galaxy
 - » search in Sloan SDSS found one good source with 2650km/s
- Laura Blecha discussed oscillating bound SMBH
 - carries disk for the first Gyr then get burst every plane crossing
- recoil flares



Binary SMBH & gravity waves

- backgrounds or sources
- Sterl Phinney
 - 10^9 solar mass SMBH dominates GW background
 - mass ratio cancels in total merger
 - at $z < 2$ (in Sesana model)
- Joris and George almost set a new limit
 - sensitivity curves as a function of GW frequency
 - » peak sensitivity is at $1/\text{obs time}$
 - includes jumps, red noise and does statistics better
 - right at "predicted" level
- Need to analyse detection probability v source distance and mass
 - now 10^{10} Mo at modest z
 - future 10^9 Mo at any z



Instruments

- Huge advances in survey instruments
- 10^{14} flux sensitivity improvement in 40 years of GW astronomy
 - radio 10^7 in similar time scale
- LISA
 - revolutionary for SMBH research
 - complimentary to pulsar GW detection
- New pulsar searches and timing essential for gravity wave research
 - FAST 500m spherical dish
 - Arecibo 305m



Ideas

interpreting pks0637-752

- a bound re-coiling SMBH
- periodic plunges through the disk of the galaxy
 - will maintain its spin axis so gets a new accretion disk each plunge
- maybe the bend is the merging event with re-orientation

PKS0637-752 – Quasar with Xray/radio jet

