The Many Faces of Centaurus A

Sydney, June 28 - July 3, 2009

Scientific Program and Abstract Booklet

Scientific Organising Committee:

Ilana Feain (chair, CSIRO/ATNF)
Phil Edwards (CSIRO/ATNF)
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Bill Harris (McMaster University)
Frank Israel (Leiden University)
Jun Kataoka (Tokyo Institute of Technology)
Ken Kellermann (NRAO)
Raffaella Morganti (ASTRON)
Marina Rejkuba (ESO)
Rob Sharp (AAO)
Diana Worrall (University of Bristol)

Local Organising Committee:

Ilana Feain (chair, CSIRO/ATNF)
Björn Emonts (CSIRO/ATNF)
Bärbel Koribalski (CSIRO/ATNF)
Vicki Fraser (CSIRO/ATNF)
Ángel R. López-Sánchez (CSIRO/ATNF)
and Tobias Westmeier (CSIRO/ATNF)

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Sir Stamford Hotel at Circular Quay
Sydney Observatory
International Year of Astronomy 2009 (IYA09)

The Many Faces of

Centaurus A

Sydney, June 28 - July 3, 2009

Conference Delegates

Name	Institution	Country	email
Abraham, Zulema	University of São Paulo	Brazil	*zulema@astro.iag.usp.br*
Aharonian, Felix	DIAS/Dublin and MPIK/Heidelberg	Ireland	*felix.aharonian@mpi-hd.mpg.de*
Bicknell, Geoffrey	Australian National University	Australia	*geoff@mso.anu.edu.au*
Birkinshaw, Mark	University of Bristol	UK	*Mark.Birkinshaw@Bristol.ac.uk*
Bland-Hawthorn, Joss	SIfA, University of Sydney	Australia	*jbh@physics.usyd.edu.au*
Bray, Justin	University of Adelaide	Australia	*justin.bray@gmail.com*
Burtscher, Leonard	Max-Planck-Institut fr Astronomie	Germany	*burtscher@mpia-hd.mpg.de*
Cannon, Russell	Anglo-Australian Observatory	Australia	*rdc@aao.gov.au*
Cheung, Teddy	NASA Goddard Space Flight Center	USA	*ccheung@milkyway.gsfc.nasa.gov*
Ching, John	SIfA, University of Sydney	Australia	*jhyc@physics.usyd.edu.au*
Clay, Roger	University Of Adelaide	Australia	*roger.clay@adelaide.edu.au*
Cornwell, Tim	CSIRO - ATNF	Australia	*tim.cornwell@csiro.au*
Croom, Scott	SIfA, University of Sydney	Australia	*scroom@physics.usyd.edu.au*
Croston, Judith	University of Hertfordshire	UK	*j.h.croston@herts.ac.uk*
Edwards, Philip	CSIRO - ATNF	Australia	*philip.edwards@csiro.au*
Ekers, Ronald	CSIRO - ATNF	Australia	*ron.ekers@csiro.au*
Ellis, Simon	SIfA, University of Sydney	Australia	*sce@physics.usyd.edu.au*
Espada, Daniel	Harvard-Smithsonian Center for Astrophysics	USA	*despada@cfa.harvard.edu*
Evans, Robert	Linden Observatory	Australia	*bobevans@exemail.com.au*
Feain, Ilana	CSIRO - ATNF	Australia	*ilana.feain@csiro.au*
Gaensler, Bryan	SIfA, University of Sydney	Australia	*bgaensler@usyd.edu.au*
Hancock, Paul	SIfA, University of Sydney	Australia	*hancock@physics.usyd.edu.au*
Hardcastle, Martin	University of Hertfordshire	UK	*m.j.hardcastle@herts.ac.uk*
Harris, Gretchen	University of Waterloo	Canada	*glharris@astro.uwaterloo.ca*
Hopkins, Andrew	Anglo-Australian Observatory	Australia	*ahopkins@aao.gov.au*
Hudson, Christopher	Adelaide University	Australia	*christopher.hudson@adelaide.edu.au*
Israel, Frank	Sterrewacht Leiden	Netherlands	*israel@strw.leidenuniv.nl*
Jelliffe, Ben	SIfA, University of Sydney	Australia	*jelliff@physics.usyd.edu.au*
Jiraskova, Sarka	Radboud University Nijmegen	Netherlands	*sarka@astro.ru.nl*
Johnston, Simon	CSIRO - ATNF	Australia	*Simon.Johnston@csiro.au*
Kafle, Prajwal	Tribhuvan University	Nepal	*prrajkafle@gmail.com*
Kainulainen, Jouni	University of Helsinki Observatory	Finland	*jouni.kainulainen@helsinki.fi*
Koribalski, Bärbel	CSIRO - ATNF	Australia	*Baerbel.Koribalski@csiro.au*
Kraft, Ralph	Smithsonian Astrophysical Observatory	USA	*rkraft@cfa.harvard.edu*

Name	Institution	Country	email
Lenc, Emil	CSIRO - ATNF	Australia	*emil.lenc@csiro.au*
López-Sánchez, Ángel R.	CSIRO - ATNF	Australia	*Angel.Lopez-Sanchez@csiro.au*
Mahony, Elizabeth	SIfA, University of Sydney	Australia	*emahony@physics.usyd.edu.au*
Mao, Minnie	University of Tasmania & CSIRO - ATNF	Australia	*minnie.mao@csiro.au*
McAdam, Bruce	SIfA, University of Sydney	Australia	*mcadam@physics.usyd.edu.au*
McFadden, Rebecca	University of Melbourne	Australia	*r.mcfadden@pgrad.unimelb.edu.au*
Morganti, Raffaella	ASTRON - Netherlands Institute for Radio Astronomy	Netherlands	*morganti@astron.nl*
Neff, Susan	NASA Goddard Space Flight Center	USA	*susan.g.neff@nasa.gov*
Neumayer, Nadine	ESO	Germany	*nneumaye@eso.org*
Norris, Ray	CSIRO - ATNF	Australia	*Ray.Norris@csiro.au*
Nulsen, Paul	Harvard-Smithsonian Center for Astrophysics	USA	*pnulsen@cfa.harvard.edu*
Okuda, Takeshi	Nagoya Univesity	Japan	*okuda@a.phys.nagoya-u.ac.jp*
Oosterloo, Tom	ASTRON - Netherlands Institute for Radio Astronomy	Netherlands	*oosterloo@astron.nl*
Ostapchenko, Sergey	Norwegian University for Science and Technology	Norway	*sergey.ostapchenko@ntnu.no*
Ott, Jürgen	NRAO	USA	*jott@nrao.edu*
Priddle, Laurence	*Not affiliated*	Australia	*lpriddle@matra.com.au*
Quillen, Alice	University of Rochester	USA	*alice.quillen@gmail.com*
Randall, Kate	SIfA, University of Sydney & CSIRO - ATNF	Australia	*randall.kate@gmail.com*
Rejkuba, Marina	ESO	Germany	*mrejkuba@eso.org*
Robertson, Peter	James Cook University	Australia	*peter.robertson@rmit.edu.au*
Rowell, Gavin	University of Adelaide	Australia	*growell@physics.adelaide.edu.au*
Sadler, Elaine	SIfA, University of Sydney	Australia	*ems@physics.usyd.edu.au*
Saikia, D.J.	NCfRA	India	*djs@ncra.tifr.res.in*
Sharp, Rob	Anglo-Australian Observatory	Australia	*rgs@aao.gov.au*
Sivakoff, Gregory	University of Virginia	USA	*grs8g@virginia.edu*
Slee, Bruce	CSIRO - ATNF	Australia	*bruce.slee@csiro.au*
Steinle, Helmut	Max-Planck-Institut fuer extraterrestrische Physik	Germany	*hcs@mpe.mpg.de*
Struve, Christian	ASTRON - Netherlands Institute for Radio Astronomy	Netherlands	*struve@astron.nl*
Tingay , Steven	International Centre for Radio Astronomy Research	Australia	*s.tingay@curtin.edu.au*
Tzioumis, Anastasios	CSIRO - ATNF	Australia	*tasso.Tzioumis@csiro.au*
Wagner, Alexander	Australian National University	Australia	*ayw@mso.anu.edu.au*
Walsh, Jeremy	European Southern Observatory	Germany	*jwalsh@eso.org*
Westmeier, Tobias	CSIRO - ATNF	Australia	*tobias.westmeier@csiro.au*
Woodley, Kristin	McMaster University	Canada	*woodleka@mcmaster.ca*
Worrall, Diana	University of Bristol	UK	*d.worrall@bristol.ac.uk*

Venue Location

The Mint is in Sydney's central business district. This historic building, originally built to host a hospital in the early 19th century, later became the first branch of the Royal Mint in Australia. Today, it serves as a conference venue under the administration of the Historic Houses Trust.

The Mint
10 Macquarie Street
Sydney NSW 2000
Australia

Directions:

By Train: Get on any train stopping at St James station. At St James Station, cross Hyde Park into Macquarie St. The Mint is 100-metres along Macquarie Street. Please see *http://www.cityrail.info/* (the City Rail website) for more information on trains, timetables and ticket fares.

By Bus: In addition, there are numerous bus lines serving the CBD. Please have a look at the website (*http://www.sydneybuses.info/*) of Sydney Buses for an overview of lines and options. The website also provides a useful overview map of the area around St James station and Macquarie Street.

By Car: The conference venue does not provide on-site parking. Since traffic in the CBD is very heavy and parking tickets very expensive, we strongly encourage participants to use public transport instead.

Walking: The Sir Stamford Circular Quay conference hotel is also located on Macquarie St, only 800m from the conference venue.

Out and About in Sydney

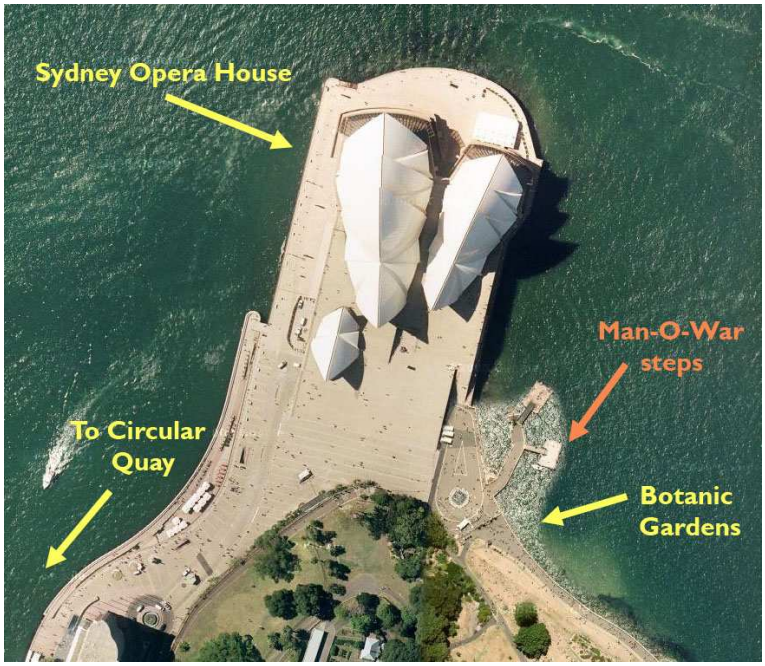
Sydney is a fantastic place to visit and very safe and friendly. Enclosed in your conference folder are some information guides to the Sydney Harbour foreshore area. Please ask the LOC or other locals if you have any questions or want information about visiting other parts of Sydney. Your folder should include:

1. Sydney Visitor Pass - discount vouchers to attractions!
2. Maps of the Sydney Foreshore area.
3. The official tourist guide to Sydney.

Please ask at the information booth if you have not received any of these.

Conference Dinner Details

The conference dinner will be held onboard **The Magistic Cruise** vessel on Sydney Harbour. The Man-O-War steps are located on the eastern (Botanic Gardens) side of the Opera House. Embarkation and departure details are given below. Please take some warm clothes if you want to enjoy the view from the deck!



Embark/Boarding Time: 17:00 *sharp*, Man-O-War steps
Disembark Time: 21:00, Man-O-War steps

Internet Access at Conference Venue

A wireless system has been set up for conference delegates. Please refrain from large downloads etc as this will slow down internet access for everyone else. Unfortunately wireless is the only way to access the internet at the conference venue: there is no possibility for internet access through an Ethernet cable. To connect to the conference wireless system:

SSID (Wireless Connection Name):	Mint
Password:	Mint Wireless Access
Encryption Type:	WPA-PSK
Standard:	802.11b/g

Please note the password is case sensitive. Take note of capital letters and white spaces.

Sunday, 28 June 2009

17:00-19:00 Opening Reception

The Mint, 10 Macquarie St. Sydney.

The Many Faces of
Centaurus A

Sydney, June 28 - July 3, 2009

Monday, 29 June 2009 - Setting the Scene

08:00-09:00 *Registration*

Chair: Ilana Feain

09:00-09:15 *Conference welcome*

09:15-10:00 Peter Robertson **(I)** — Early Australian optical and radio observations of Centaurus A / NGC 5128

10:00-10:45 Ron Ekers **(I)** — The radio continuum view of Centaurus A

10:45-11:15 *Morning tea*

Chair: Diana Worrall

11:15-12:00 Mark Birkinshaw **(I)** — The physics of active galaxies as revealed by Centaurus A

12:00-12:45 Ralph Kraft **(I)** — The X-ray view of Centaurus A

12:45-14:00 *Lunch*

Chair: Marina Rejkuba

14:00-14:45 Gretchen Harris **(I)** — NGC 5128 the giant beneath

14:45-15:15 Raffaella Morganti **(R)** — The many faces of the gas of Centaurus A

15:15-15:45 *Afternoon tea*

Chair: Ralph Kraft

15:45-16:15 Helmut Steinle **(R)** — Centaurus A at hard X-rays and γ-rays

16:15-14:45 Phillip Edwards **(R)** — Centaurus A at ultra-high energies

(I) = Invited talk.
(R) = Review talk.

The Many Faces of
Centaurus A

Sydney, June 28 - July 3, 2009

Tuesday, 30 June 2009 - Nuclear Region ⟶ Dust Lane

08:15-09:15 *Registration*

Chair: Raffaella Morganti

09:15-10:00 Nadine Neumayer **(I)** — Centaurus A's black hole mass - from gas and stars

10:00-10:45 Steven Tingay **(R)** — The sub-parsec-scale structure and evolution of Centaurus A

10:45-11:15 Zulema Abraham — 43 GHz light curve of the nucleus of Centaurus A

11:15-11:45 *Morning tea*

Chair: Sergey Ostapchenko

11:45-12:30 Teddy Cheung **(I)** — First year Fermi Gamma-ray Space Telescope observations of Centaurus A

12:30-12:45 *Poster Sparkler Session*

12:45-14:00 *Lunch*

Chair: Helmut Steinle

14:00-14:30 Felix Aharonian — Discovery of very high energy γ-rays from Centaurus A

14:30-15:15 Roger Clay **(I)** — Centaurus A and the Pierre Auger Observatory

15:15-15:45 *Afternoon tea*

Chair: Roger Clay

15:45-16:15 Sergey Ostapchenko — Multi-Messenger studies of Centaurus A with PAO, HESS and FERMI: does everything fit together?

16:15-16:40 Justin Bray — Limit on the UHE neutrino flux from Centaurus A with the Parkes radio telescope?

16:40-17:00 Bärbel Koribalski — Latest results from the *Compact Array Broad-Band* (CABB)

(I) = Invited talk.
(R) = Review talk.

Wednesday, 1 July 2009 - Dust Lane ⟶ Inner Jets

Chair: Rob Sharp

09:00-09:45 Alice Quillen **(I)** — Infrared views of Centaurus A

09:45-10:15 Joss Bland-Hawthorn — Ionisation cone in Centaurus A

10:15-10:45 Leonard Burtscher — Resolving the nuclear dust structure in Centaurus A

10:45-11:15 *Morning tea*

Chair: Alice Quillen

11:15-11:45 Jouni Kainulainen — Uncovering the kpc-scale stellar ring of the Centaurus A galaxy

11:45-12:15 Rob Sharp — Integral field spectroscopy of the central arcminute of Centaurus A

12:15-13:00 Tom Oosterloo **(R)** — The latest on the HI in Centaurus A

13:00-14:00 *Lunch*

Chair: Bärbel Koribalski

14:00-14:25 Christian Struve — From the kinematics of the large-scale HI disk to the nuclear absorption

14:25-14:50 Frank Israel — Emission and Absorption of Circumnuclear Molecular Gas in Centaurus A

14:50-15:15 Daniel Espada — Molecular gas imaging of the circumnuclear environs of Centaurus A

15:15-15:35 Takeshi Okuda — CO(32) observations toward the dust lane in Centaurus A

17:00-19:00 *Visit to the Sydney Observatory*

(I) = Invited talk.
(R) = Review talk.

Thursday, 2 July 2009 - Inner Jets ⟶ Stellar Halo

Chair: Geoff Bicknell

09:00-09:45 Judith Croston **(I)** — The radio-lobe shock of Centaurus A: particle acceleration and environmental impact

09:45-10:15 Diana Worrall — X-ray spectral structure

10:15-10:45 Paul Nulsen — Dissipation in the jet of Centaurus A

10:45-11:15 *Morning tea*

Chair: Paul Nulsen

11:15-11:45 Susan Neff — Radio & ultraviolet emission from the northern middle lobe of Centaurus A

11:45-12:15 Simon Ellis — Shock induced star formation in the outer filament of Centaurus A

12:15-12:35 Geoffrey Bicknell — Centaurus A: Some Core Physics

12:35-12:55 Alexander Wagner — 3D simulations of a supersonic jet interacting with an inhomogeneous medium

12:55-14:00 *Lunch*

Chair: Gretchen Harris

14:00-14:30 Marina Rejkuba **(R)** — The stellar halo of NGC 5128

14:30-15:15 Kristin Woodley **(I)** — The globular cluster system of NGC 5128: ages, metallicities, kinematics and structural properties

14:15-15:40 Jeremy Walsh — Light element abundances in NGC 5128 from planetary nebulae

15:40-16:05 Gregory Sivakoff — A deep study of X-ray binaries in Centaurus A

17:00-21:00 *Harbour cruise and conference dinner*

(I) = Invited talk.
(R) = Review talk.

Friday, 3 July 2009 - Outer Lobes

Chair: Tom Oosterloo

10:00-10:45 Martin Hardcastle **(I)** — The radio continuum properties of Centaurus A

10:45-11:15 Ilana Feain — The first aperture synthesis radio continuum image of the outer lobes of Centaurus A

11:15-11:30 Tim Cornwell — ATCA imaging techniques of Centaurus A

11:30-12:00 Bryan Gaensler **(I)** — Polarimetry and Faraday Rotation of radio galaxies behind the lobes of Centaurus A

12:00-12:20 Joss Bland-Hawthorn — *Conference summary*

12:20-14:00 *Lunch*

(I) = Invited talk.

Talk abstracts

Monday 28 June, 09:15-10:00

Early Australian Optical and Radio Observations of Centaurus A

Peter Robertson, James Cook University, Australia, *peter.robertson@rmit.edu.au*
***Co-authors*: Bruce Slee & Wayne Orchiston**

The discoveries of the radio source Centaurus A and its optical counterpart NGC 5128 are closely connected to the history of astronomy in Australia. NGC 5128 was first observed in August 1826 by James Dunlop during a survey of southern objects at the Parramatta Observatory, west of the settlement at Sydney Cove. The observatory had been founded a few years earlier by Thomas Brisbane, the new governor-general of the British colony. Just over 120 years later, John Bolton, Gordon Stanley and Bruce Slee discovered the radio source Centaurus A at the Dover Heights field station in Sydney, operated by CSIROs Radiophysics Lab (the forerunner of the Australia Telescope National Facility). This paper will describe this early historical work and briefly summarise further studies of Cen A by other Radiophysics groups up to 1960.

The Radio Continuum Properties of Centaurus A

Ron Ekers, CSIRO / ATNF, Australia, *Ron.Ekers@csiro.au*

Centaurus A is a very special for radio astronomers: it heralded the discovery of the extragalactic radio source population. It is the brightest radio source in the southern sky, the closest radio galaxy, the closest AGN and probably the closest super massive blackhole. For a long time it was also the largest radio galaxy known. I will give an overview of the radio continuum morphology from the megaparsec scale of the outer lobes down through the middle lobe and the inner double straddling the galaxy and its dust lane to the sub pc scale structure of the AGN core and jet. Centaurus A was one of the first radio galaxies to be studied in detail but it is still full of surprises and its alternating symmetric and asymmetric structures confound our theories.

The physics of active galaxies as revealed by Centaurus A

Mark Birkinshaw, University of Bristol, UK, *Mark.Birkinshaw@Bristol.ac.uk*
***Co-author*: Diana M. Worrall**

Centaurus A provides us with our best chance of interpreting many of the phenomena that we see in active galaxies. This review will summarize the key processes that we believe are active in Centaurus A, and discuss the extent to which the observed properties of Centaurus A can be related to underlying microphysics and large-scale astrophysics. The talk will concentrate on the nature of the non-thermal emission and the interactions between the non-thermal and thermal plasmas on kpc scales, and attempt to generalize from Cen A to other radio galaxies at greater distances.

The X-ray View of Centaurus A

Ralph Kraft, SAO, USA, *rkraft@cfa.harvard.edu*
***Co-authors*: Cen A VLP collaboration**

Centaurus A is both the nearest radio galaxy and the nearest massive early-type galaxy, making it a unique astrophysical laboratory in which we can study the processes of these two classes of objects at a sensitivity unattainable in any other object. Cen A has been well studied by the current generation of high-energy observatories including Chandra, XMM-Newton, Suzaku, Galex, Swift, and Fermi. In this talk, we will summarize the most recent observational results on Cen A from a high-energy perspective. Emphasis will be placed on synergies with other observing programs at lower frequencies, and possible theoretical investigations. We will also present preliminary results from on-going, unpublished work by the Cen A VLP collaboration, outline additional future investigations with the current generation of high-energy observatories, and describe the potential of studies of Cen A with future high-energy missions.

NGC 5128: The Giant Beneath

Gretchen Harris, University of Waterloo, Canada, *glharris@astro.uwaterloo.ca*

When most people think of NGC 5128 (also known as Centaurus A) they see radio jets, central black holes, a very visible accretion disk and more. But these are "icing on the cake" of the underlying giant E galaxy. We now know the it has a fairly normal old halo system as seen in its globular clusters, planetary nebulae, and red giant stars. Its proximity makes NGC 5128 an ideal template for understanding the properties of large E galaxies in general.

Monday 28 June, 14:45-15:15

The many faces of the gas in Centaurus A

Raffaella Morganti, ASTRON - Netherlands Institute for Radio Astronomy, The Netherlands, *morganti@astron.nl*

I will review the observational picture of the various gaseous components in Centaurus A. In addition, I will discuss the relation (if any) of these components and the presence of the radio source and, in particular, the presence of the radio jet.

Centaurus A at hard X- and γ-rays

Helmut Steinle, Max-Planck-Institut fuer extraterrestrische Physik, Germany, *hcs@mpe.mpg.de*

Cen A, at a distance of less than 4 Mpc, is the closest radio-loud AGN and considered a prototype FR I radio galaxy. Its emission is detected from radio to gamma-rays. Despite the fact that Cen A is one of the best studied extragalactic objects the origin of its hard X-ray and soft Gamma-ray emission is still poorly understood. Observations with high spatial resolution in the X-ray and gamma-ray regimes that have been made in recent years suggest that several distinct components such as a Seyfert-like nucleus, a relativistic jet, and even luminous X-ray binaries within Cen A may contribute to the total emission at these energies that had been detected in the past with low spatial resolution. A review of hard X-ray and gamma-ray emission will be given (keV up to GeV) and the contribution of this observations to models of the Cen A emission wil be discssed. (If no other talk addresses the newly reported emission >250 GeV, this will be included.)

Centaurus A at ultra-high energies

Philip Edwards, CSIRO/ATNF, Australia, *philip.edwards@csiro.au*

As it is the closest active galaxy, Centaurus A has been a natural target for searches for very high energy and ultra high energy photons and particles. In this presentation, the searches made and techniques used to detect emission from Centaurus A will be reviewed, setting the stage for contributed talks later in the programme.

Cen A's black hole mass - from gas and stars

Nadine Neumayer, ESO, Germany, *nneumaye@eso.org*
***Co-authors*: Michele Cappellari, Juha Reunanen, Hans-Walter Rix, Paul van der Werf and Tim de Zeeuw**

I will present the determination of the mass of the supermassive black hole of Centaurus A using high-resolution integral-field observations of both the gas and the stellar kinematics. The observations were obtained with SINFONI at the ESO Very Large Telescope in the near-infrared (K-band), using adaptive optics to correct for the blurring effect of the earth atmosphere. The data have a spatial resolution of 0.12" FWHM and high S/N>80 per spectral pixel. The black hole mass measurements of both tracers, gas and stars, are in excellent agreement and provide one of the cleanest gas versus stars comparisons of a BH mass determination. Moreover, they bring CenA in agreement with the M-sigma relation.

Tuesday 29 June, 10:00-10:45

The sub-parsec-scale structure and evolution of Centaurus A

Steven Tingay, International Centre for Radio Astronomy Research, Australia,
s.tingay@curtin.edu.au
***Co-authors*: The Australian VLBI team**

I will review the history of high angular resolution observations of Centaurus A, concentrating on the structure and evolution of the sub-parsec-scale radio source, its nuclear environment, and recent results revealing parsec-scale structure in the kiloparsec-scale jet.

43 GHz light curve of the nucleus of Centaurus A

Zulema Abraham, University of São Paulo, Brazil, *zulema@astro.iag.usp.br*
***Co-authors*: Anderson Caproni, Pedro Paulo Beaklini and Tânia P. Dominici**

The spectral energy distribution of the nucleus of Centaurus A, extending from radio to gamma-rays, is similar to that of blazars, although the position of the low energy maximum is not well defined because of the uncertainty in the optical absorption. The recent detection of TeV emission from this object strengthens this supposition, which requires the synchrotron origin of both radio and X-rays. In this work we report the 43 GHz light curve of the core of Centaurus A during the last six years, with timescales of days, and months. The observations were made with the Itapetinga radiotelescope that has a resolution of about 2 arc min at this frequency. The observing technique consisted of scans with 24 arc min amplitude, centered at the core and passing through the two inner lobes, which were used for instantaneous calibration. The core of Centaurus A seem to have entered a phase of high activity during the last two years, with fast and high amplitude variability, well correlated with the 2-10 keV patterns observed by the ASM of the RXTE observatory. The delay between the two light curves favor the interpretation of a common synchrotron origin of both emissions, with the delay at radio frequencies due to variation of the optical depth, probably produced in an expanding source.

First Year Fermi Gamma-ray Space Telescope Observations of Centaurus A

C.C. Teddy Cheung, NASA GSFC, USA, *ccheung@milkyway.gsfc.nasa.gov*
***Co-authors*: On behalf of the Fermi-LAT collaboration**

Results from the first year of Fermi Large Area Telescope (LAT) observations of the gamma-ray emitting radio galaxy Centaurus A will be presented. This will include a comparison to other known gamma-ray (MeV, TeV) emitting radio galaxies, focusing on the unique insight into emission models of relativistic jets provided by these systems. Additionally, results from a search for extended gamma-rays from the giant radio lobes will be presented.

Tuesday 29 June, 14:00-14:30

Discovery of Very-High-Energy (VHE) gamma-rays from Cen A

Felix Aharonian, DIAS/Dublin and MPIK/Heidelberg, Ireland and Germany,
felix.aharonian@mpi-hd.mpg.de
***Co-authors*: HESS collaboration**

Recently the HESS collaboration announced the discovery of very high energy gamma-rays from the nearby radiogalaxy Cen A. I will describe the results obtained with the HESS array of imaging atmospheric Cherenkov telescopes located in Namibia, and discuss different possible scenarios and sites of gamma-ray production.

Centaurus A and the Pierre Auger Observatory

Roger Clay, University Of Adelaide, Australia, *roger.clay@adelaide.edu.au*

The Pierre Auger Observatory will consist of two high energy astrophysics observatories with all-sky coverage at energies above 10^{19} eV. The southern site is now complete in Argentina and is already producing major astrophysical results. At a latitude of 35 degrees south, the observatory is ideally placed to observe the direction of Cen A and has published sky maps which, subjectively, show a clustering of directions close to Cen A. This paper will discuss the significance and interpretation of results such as this.

Multi-messenger studies of Cen A with PAO, HESS and FERMI: does everything fit together?

Sergey Ostapchenko, Norwegian University for Science and Technology (NTNU), Institutt for fysikk, Norway, *sergey.ostapchenko@ntnu.no*

Gamma-ray signatures of hadronic acceleration in Centaurus A are investigated. Using two different models for the generation of ultra-high energy cosmic rays (UHECR) in active galactic nuclei and normalizing the UHECR flux of Cen A to the observations of the Pierre Auger Observatory, we calculate the accompanying high energy gamma-ray flux in the GeV-TeV range. The predictions are then compared to recent Cen A observations by HESS and FERMI and implications of these measurements for the high energy neutrino flux of the source are discussed.

Tuesday 29 June, 16:15-16:40

Limit on Ultra-High-Energy (UHE) neutrino flux from Centaurus A with the Parkes radio telescope

Justin Bray, University of Adelaide, Australia, *justin.bray@gmail.com*
***Co-authors*: C.W. James, R.D. Ekers, R.J. Protheroe, C.J. Phillips, J. Reynolds, P. Roberts and R.A. Robinson**

Active galactic nuclei such as Centaurus A have been proposed as sources of ultra-high energy (UHE) cosmic rays and neutrinos. When these neutrinos interact in the lunar regolith, they will generate electromagnetic cascades of relativistic particles, which produce Cherenkov radiation at radio frequencies. Radio telescopes may therefore be used to observe UHE neutrinos indirectly, by searching for the nanosecond-scale pulses that these cascades produce.

The most recent such experiment was with the Parkes radio telescope in March 2009, and employed a new scheme to discriminate against impulsive radio-frequency interference. It was optimised for sensitivity to any UHE neutrino flux from Centaurus A. The non-detection from this experiment allows us to place an upper limit on this flux.

Tuesday 29 June, 16:40-17:00

Latest news from the *Compact Array Broad-band* (CABB)

Bärbel Koribalski, CSIRO/ATNF, Australia, *Baerbel.Koribalski@csiro.au*

I hope to show new molecular line measurements of Centaurus A obtained with the new *Compact Array Broad-band* (CABB) system at the *Australia Telescope Compact Array* (ATCA). We should be able to obtain spectra and images of HCO+, HNC, HNC, etc.

Infrared Views of Centaurus A

Alice Quillen, University of Rochester, USA, *alice.quillen@gmail.com*
***Co-authors*: Joss Bland-Hawthorn and the Spitzer team**

Spitzer Space Telescope spectroscopy and imaging of Centaurus A have revealed in exquisite detail the dusty warped disk as well as some new surprises. I will report on the discovery of a 500 pc bipolar warm dust shell. A resolved ionization cone is seen for the first time in infrared high ionization emission lines near the jet axis.

Ionization cone in Centaurus A

Joss Bland-Hawthorn, University of Sydney, Australia, *jbh@physics.usyd.edu.au*
***Co-authors*: R.G. Sharp, A. Quillen, S.C. Ellis and G.V. Bicknell**

We have known for more than twenty years that the dust band around Cen A is a severely warped, thin gaseous disk seen in projection. Recent observations with the Taurus Tunable Filter and the SPIRAL IFU have identified high excitation gas above and below the thin disk. This gas is evidence for a large-scale wind from the nucleus. We discuss the extent to which the wind is associated with the formation mechanism of the optical/radio/x-ray jet.

Resolving the nuclear dust structure in Centaurus A

Leonard Burtscher, Max-Planck-Institut für Astronomie, Germany, *burtscher@mpia-hd.mpg.de*
***Co-authors*: K. Meisenheimer, K. R. W. Tristram, W. Jaffe**

Interferometric observations in the mid-infrared made studies of the central dusty tori of Active Galactic Nuclei (AGNs) possible and proved their existence in a number of nearby AGNs. Our first results on Centaurus A (NGC 5128) showed that nuclear dust also exists in the innermost parsec of this galaxy (Meisenheimer et al., 2007). From new observations with an improved (u,v)-coverage and resolution, it is now possible to determine the size, orientation and the physical nature of the mid-infrared emitters in the nucleus more precisely: We find that the extended component that accounts for about half of the mid-IR emission has a size of 0.6 by 0.2 pc (FWHM) and is consistent with an inclined, disk-like dust structure. Its minor axis is oriented almost perfectly parallel to the radio jet. With a bolometric luminosity of $L_{dust} \sim 3 \times 10^{34}$ W the disk is much less luminous than the nuclear dust emission from other nearby AGNs, e.g. the torus in the Seyfert 2 galaxy Circinus with $L_{dust} \sim 2 \times 10^{36}$ W. The rest of the mid-IR emission of Cen A stems from an unresolved core, the radio-to-mid-infrared spectrum of which can be explained by synchrotron emission from the base of the jet.

Uncovering the kiloparsec-scale stellar ring of the Centaurus A galaxy

Jouni Kainulainen, University of Helsinki, Observatory, Finland, *jouni.kainulainen@helsinki.fi*
***Co-authors*: J. Alves, Y. Beletsky, J. Ascenso et al.**

We reveal the stellar light originating from the kiloparsec-scale, ring-like structure of the Centaurus A galaxy in unprecedented detail. In particular, we use sub-arcsecond resolution near infrared images to create a "dust-free" view of this structure that is heavily obscured by the central dust lane at visual wavelengths. We then use such data to examine the shape and the total luminosity of the structure. With diffraction limited (resolution of ∼0.1" or 1.6 pc) near infrared data taken with the NACO instrument on VLT, we show that the structure contains several thousand point-like sources with the most luminous ones being M(K) = -11 mag. We discuss the implications of these observations for the star-forming activity of the structure. Finally, we discuss the large-scale geometry implied by the reddening signatures of dust in our near infrared images.

Integral Field Spectroscopy of the central arc minute of Cen A

Rob Sharp, Anglo-Australian Observatory, Australia, *rgs@aao.gov.au*
***Co-author*: J. Bland-Hawthorn.**

I report broad band optical Integral Field Spectroscopy of the central arcminute of the Cen A system. These intermediate resolution AAOmega-SPIRAL observations reveal an ionization cone and outflow structure in the emission line gas which I will discuss in the broader context of galaxy winds.

The latest on the HI in Centaurus A

Tom Oosterloo, Astron - Netherlands Institute for Radio Astronomy, The Netherlands, *oosterloo@astron.nl*

I will summarise recent high resolution observations performed with *Australia Telescope Compact Array* (ATCA) give a much improved picture of the distribution and kinematics of the HI near the centre. The data show that there are no indications for unsettled gas near the centre and that there is no obvious connection between the merger event that shaped Cen A and its current nuclear activity

From the kinematics of the large-scale HI disk to the nuclear absorption

Christian Struve, Astron - Netherlands Institute for Radio Astronomy, The Netherlands, *struve@astron.nl*
***Co-authors*: R. Morganti and T. Oosterloo**

We present new - high resolution and high sensitivity - neutral hydrogen emission and absorption ATCA data of Centaurus A. Detailed tilted-ring modeling shows that most of the gas is confined to a fairly regular, warped, rotating disk. In addition to the known warped disk structure, the HI shows a complex structure with unsettled gas and tail/arm like structures, especially in the region below the dust lane. We will show that the relatively broad absorption (Δv=400 km/s) - and in particular the blueshifted component - detected for the first time against the nucleus by our observations is not the result of gas at large radii projected onto the radio core. The absorption must, therefore, be due to gas close to the nucleus. The kinematics of the HI in the inner regions of Cen A appears very similar to that observed in emission for the molecular circumnuclear disk. We conclude that the central HI absorption is not, as was previously claimed, evidence of gas infall into the AGN, but instead is more likely due to a cold, circumnuclear disk.

Emission and Absorption of Circumnuclear Molecular Gas in Centaurus A

Frank Israel, Sterrewacht Leiden, The Netherlands, *israel@strw.leidenuniv.nl*

The nearest AGN Centaurus A is so close that its structures can be studied in detail. Its nucleus is a strong continuum source at millimeter wavelengths, and is surrounded by dense molecular gas precisely in the line-of-sight towards it. Nuclear spectroscopy at millimeter and submillimeter wavelengths reveals many molecular species in absorption and emission. The absorption spectra show a large number of velocity components, some distinct and very narrow, others blended together into a veritable forest of lines. There are strong absorption lines near the systemic velocity, flanked by weak blueshifted absorption and much stronger redshifted absorption covering a much larger velocity range. The unique combination of widely spread-out molecular line emission and absorption rather complicates interpretation of the spectra but also holds great promise for a determination of the physical properties of molecular gas very close to a supermassive black hole in an active galaxy nucleus.

Molecular gas imaging of the circumnuclear environs of Centaurus A

Daniel Espada, Harvard-Smithsonian Center for Astrophysics, USA, *despada@cfa.harvard.edu*
***Co-authors*: S. Matsushita, A. Peck, C. Henkel, D. Iono, F.P. Israel, S. Muller, G. Petitpas, Y. Pihlstroem, G.B. Taylor and Dinh-V-Trung**

We have imaged with unprecedented resolution (6 × 2 arcsec, 100 × 30 pc) the molecular gas along the dust lane of Centaurus A, as traced by the CO(2-1) line observed using the Submillimeter Array (SMA). We spatially resolve the circumnuclear molecular gas in the inner r < 200 pc, elongated along a P.A. = 155 deg, just perpendicular to the X-ray/radio jet, as well as a more extended component coextensive with the parallelogram structure observed in dust emission at P.A. = 120 deg. Towards the nuclear 1.3mm continuum emission arising from the AGN, CO(2-1) absorption features are also detected with minimized contamination by emission, which allow us to have a further insight into the bulk of molecular gas in the line of sight. We use this information in order to constrain a physical model that successfully reproduces the main observed features, including a physical connection between the circumnuclear gas and that at larger radii, brighter SE and NW sides on the parallelogram-shaped feature, and an outer curvature of its long sides. We discuss about a possible contribution of a weak bi-symmetric potential which would explain these peculiarities.

CO(J=3-2) observation toward the dust lane in Centaurus A

Takeshi Okuda,Nagoya Univesity, Japan, *okuda@a.phys.nagoya-u.ac.jp*
***Co-authors*: Kotaro Kohno, Satoru Iguchi and Kouichiro Nakanishi**

We successfully resolved the dust lane of Centaurus A (NGC 5128), that is the nearest radio galaxy (D = 3.4 Mpc), at an angular resolution of 24" (400 pc) by observing the CO (J = 3-2) emission with the sub-mm telescope ASTE. Our wide-field map of this emission in the 7' × 3' (or 7 kpc × 3kpc) region is well coincident with that of dust emissions obtained by Spitzer telescope. Since our results showed kinematics of the dust warped disk, we will discuss kinematics and physical properties in the dust lane of Centaurus A.

The radio-lobe shock of Centaurus A: particle acceleration and environmental impact

Judith Croston, University of Hertfordshire, UK, *j.h.croston@herts.ac.uk*

Cen A is the first system in which direct evidence for a strong shock associated with radio-lobe expansion has been found, and is the nearest and most dramatic example of a jet/environment interaction. Our new, very deep Chandra observations have revealed that the X-ray emission from the shock front is dominated by synchrotron radiation, with properties similar to those seen in some supernova remnants. I will discuss the implications of these results for particle acceleration at the shock, for Cen A as a source of TeV radiation and UHECRs, and for shock heating in nearby and more distant galaxies.

Transverse X-ray spectral structure in Cen A's inner jet, and the implications for particle acceleration

Diana Worrall, University of Bristol, UK, *d.worrall@bristol.ac.uk*
***Co-authors*: M. Birkinshaw and the Chandra Cen A-VLP consortium**

Chandra data taken as part of the Very Large Program (VLP) show that the X-ray spectrum in Cen A's jet steepens with increasing distance from the jet axis. This transverse spectral steepening predominantly arises from a change in the average spectrum of the most knotty emission. Electrons with sufficient energy to emit synchrotron X-rays must be accelerated locally to the knots, since their energy loss timescale is short compared with any dynamical timescale associated with fluid motion. Thus the observed X-ray spectral changes imply that the conditions for particle acceleration differ across the jet. If the knots are predominantly a surface feature residing in a shear layer between faster and slower flows we would have expected a harder spectrum towards the edge of the jet, the opposite to what is found. Thus we conclude that the knots reside throughout the jet and that particle acceleration is more efficient near the jet axis, presumably because the kinetic energy density of the flow is higher here. The knots themselves may result from internal flow irregularities, or from gas clouds or high-mass stars intruding into the jet, with different and potentially testable predictions for the speed of knot migration across the jet.

Dissipation in the Jet of Centaurus A

Paul Nulsen, Harvard-Smithsonian Center for Astrophysics, USA, *pnulsen@cfa.harvard.edu*
***Co-authors*: David Stark, Ralph Kraft and the Cen A Chandra VLP Collaboration**

The eastern jet of Cen A is well resolved in Chandra X-ray images, which have been used to measure its bounding pressure and width. Combining the results with estimates of jet power and initial speed permit the construction of a 1-dimensional model for flow through the jet. The flow is inconsistent with Bernoulli's theorem, implying that there is substantial internal dissipation. The most likely cause is mass entrainment by the jet. Since the flow is over-constrained, the rate of entrainment can be determined and it is found to be consistent with the rate of stellar mass loss within the body of the jet. Some implications will be discussed. If dissipation is dominated by stellar mass injection, jet width becomes highly sensitive to the bounding pressure, so that small changes in the environment can determine whether the jet remains confined or expands rapidly in width, so inflating a radio lobe. The may account for the asymmetry in the radio morphology of Cen A.

Radio and Ultraviolet Emission from the Northern Middle Lobe of Centaurus A

Susan Neff, NASA / Goddard Space Flight Center, USA, *susan.g.neff@nasa.gov*

We present new 90cm images of the Northern Middle Lobe (NML) of Centaurus A. The radio morphology at this wavelength is indicative of a more complex system than either a straightforward flaring jet (Morganti et al. 1999) or a bubble with trailing stem (Saxton et al. 2001). New limits are placed on the lack of radio emission from any corresponding southern counterpart to the NML.

Shock Induced Star-formation in the Outer Filament of Cen A

Simon Ellis, University of Sydney, Australia, *sce@physics.usyd.edu.au*
***Co-authors*: Joss Bland-Hawthorn, Sylvain Veilleux, Michael McDonald, Ed Cackett, Ilana Feain and Alice Quillen**

I will present new deep narrow band [NII] and Hα imaging of the NE region of Cen A obtained with the Maryland-Magellan Tunable Filter. I will show evidence for a gradient in the [NII]/Hα ratio along the filament, with the ratio increasing with distance away from the galaxy. We interpret this result in the context of jet-driven shock induced star-formation. The distant regions, show signs of an ongoing shock; the nearer regions show evidence of young stars formed by the passing shock in the recent past.

Centaurus A: Some Core Physics

Geoffrey Bicknell, Australian National University, Australia, *geoff@mso.anu.edu.au*
***Co-authors*: Stefan Wagner, Landessternwarte, University of Heidelberg**

In recent years our observational knowledge of several important components of the central region of Centaurus A has increased dramatically: High resolution X-ray observations have revealed unprecedented detail in the jet and surrounding atmosphere; a kpc sized bipolar shell has been detected in the Mid IR; gamma rays have been detected in the GeV domain by Fermi and in the TeV domain by HESS. In this talk I shall attempt to relate the relevant physics for these observations through consideration of the gravitational power released by the black hole, the likely flux of ionising radiation from the black hole accretion disk, the location of the gamma ray emission and the implications of a power-law spectrum extending from MeV to TeV energies. The inference of extended particle acceleration regions in the jet will also be considered together with the implications of these observations for the modelling of jet high energy emission in general.

3D simulations of a supersonic jet interacting with an inhomogeneous ISM

Alexander Wagner, Australian National University, Australia, *ayw@mso.anu.edu.au*
***Co-authors*: Geoffrey V. Bicknell and Ralph S. Sutherland**

Recent X-ray images of Centaurus A (Hardcastle et al. 2008) show compact knots in the region where the jet flares. It is feasible that interaction of the jet with clouds along its trajectory causes a transition to turbulent flow causing the jet to flare. We shall present simulations of a supersonic jet interacting with a cloudy, inhomogeneous interstellar medium, which enable us to understand this type of interaction in detail. We examine the velocities and emission line properties of radiative shocks driven into the clouds in order to ascertain whether any of the optical and infrared emission in the region of the jet may be associated with jet-cloud interactions.

The stellar halo of NGC 5128

Marina Rejkuba, ESO, Germany, *mrejkuba@eso.org*

NGC 5128 (Centaurus A) is the nearest easily observable giant elliptical galaxy and as such an ideal laboratory for studies of star formation history and halo assembly in giant ellipticals. I wll present the results of the reconstruction of the star formation history of the halo of Cen A based on deep HST and ground based imaging observations.

The Globular Cluster System of NGC 5128: Ages, Metallicities, Kinematics, and Structural Properties

Kristin Woodley, McMaster University, Canada, *woodleka@mcmaster.ca*
***Co-authors*: William Harris, Thomas Puzia,**
Matias Gomez, Mario Mateo, Gretchen Harris and Doug Geisler

Globular clusters can probe the formation history of galaxies by providing evidence for the chemical evolution and major episodes of star formation in their host galaxies, by examining their kinematic signatures, as well as their structural parameters. Elliptical galaxies are particularly important as they can form from a variety of channels, including formation at early times, major mergers, and accretion of smaller galaxies. The giant elliptical NGC 5128 (Centaurus A), at a mere 4 Mpc away, gives us the only opportunity to study in extensive detail the globular cluster system of a recent merger galaxy.

We have studied the globular cluster system of NGC 5128 in three ways: 1) using Gemini-S/GMOS low-resolution, high signal-to-noise spectroscopy of over 70 globular clusters, we have obtained ages and metallicities, as well as the level of alpha enrichment of the metal-poor and metal-rich globular cluster subpopulations, 2) with a large sample of confirmed globular clusters, we have explored the rotational signature and velocity dispersion of the galaxy's halo, as well as the dependence of these properties on galactocentric distance and globular cluster age and metallicity. We have also analyzed the dynamics, mass, and M/L ratio of the galaxy using the globular clusters as tracers, 3) lastly, we have measured the structural parameters, such as half-light radii and ellipticity, of the globular clusters from a superb 1.2 square degree Magellan/IMACS image taken in 0.5" seeing. We will present the findings of these studies and discuss the connection to the formation and evolution of NGC 5128.

Light element abundances in NGC 5128 from planetary nebulae

Jeremy Walsh, ESO, Germany, *jwalsh@eso.org*
***Co-authors*: G. H. Jacoby, N. A. Walton and R. F. Peletier**

Planetary nebulae constitute a unique source of light element abundances for individual stars in a distant stellar population. Multi-slit spectra of 50 planetary nebulae (PN) in NGC 5128 have been observed with the ESO VLT and FORS1 spectrometer. The planetary nebulae were observed in three fields covering a range of galactic radii from 2 to 19 kpc. The emission line spectra have been analysed for light element abundances (He, O, N, Ne, S, Ar). Stacked spectra were formed to determine the average conditions for O abundances of the faint nebulae. The measured range in [O/H] is 0.4 dex and is sub-solar, resembling the PN population in a Magellanic irregular. The [O/H] dependence with galactic radius is notably flat, but the PN with the highest O abundance occur in the field closest to the nucleus.

A Deep X-ray Study of X-ray Binaries in Centaurus A

Gregory Sivakoff, University of Virginia, USA, *grs8g@virginia.edu*
***Co-authors*: The Centaurus A Very-Large Project Team**

As the nearest early-type galaxy, Centaurus A contains a treasure trove of information about X-ray binaries. With over 700ks of Chandra observations spread over 10 years, the Centaurus A Very Large Project provides the deepest look at X-ray binaries in an early-type galaxy. Approximately 1000 X-ray sources are detected when the observations are merged, and half are detected individually in at least two observations. Preliminary results have already shed light on the low-mass X-ray binary connection to globular clusters and the discovery of a remarkable transient ultra-luminous X-ray source. We further dip into the trove to present new results on the entire population of sources. These include a comparison of the luminosity functions of XRBs associated with/without globular clusters, preliminary variability results, and follow-up observations on the transient ULX.

The radio continuum properties of Centaurus A

Martin Hardcastle, University of Hertfordshire, UK, *m.j.hardcastle@herts.ac.uk*

The five-year WMAP results coupled with single-dish observations at low frequencies have provided us with the first broad-band, spatially resolved observational constraints on the radio spectral properties of the giant lobes of Cen A. I will review what this tells us about the dynamics and activity history of the source and comment on the implications for inverse-Compton emission and high-energy particle acceleration in the giant lobes.

The first aperture synthesis radio continuum image of the outer lobes of Centaurus A

Ilana Feain, CSIRO/ATNF, Australia, *ilana.feain@csiro.au*
***Co-authors*: Ron Ekers, Tim Cornwell, Jürgen Ott, Melanie Johnston-Hollit and Enno Middelberg**

We have recently completed the first aperture synthesis radio image of the entire 45 deg^2 of the nearest radio galaxy, Centaurus A, using the Australia Telescope Compact Array and Parkes 64m single dish. The spectropolarimetric observations were made at 1.4 GHz and 45" resolution making this the most detailed image ever of a radio galaxy!

ATCA imaging techniques of Centaurus A

Tim Cornwell, CSIRO/ATNF, Australia, *tim.cornwell@csiro.au*
***Co-author*: I. Feain**

Imaging Cen A with the Compact Array requires over 400 separate pointings, observed in multiple configurations. Observing may have been the easiest part - there are many obstacles in data processing to be overcome if a noise limited image of this very complex source is to be made. I'll discuss these obstacles and what we did to get around them.

Polarimetry and Faraday Rotation of Radio Galaxies Behind the Lobes of Centaurus A

Bryan Gaensler, Sydney Institute for Astronomy, Australia, *bgaensler@usyd.edu.au*
***Co-authors*: I. J. Feain (ATNF), R. D. Ekers (ATNF), T. Murphy (U. Sydney), J.-P. Macquart (Curtin U.), R. P. Norris (ATNF), T. J. Cornwell (ATNF), J. Ott (NRAO), E. Middelberg (Ruhr-U. Bochum), M. Johnston-Hollitt (Victoria U.)**

The lobes of Centaurus A have a maximum angular extent of almost 10 degrees. The large projected area of these lobes has thus allowed us to carry out a unique experiment, in which we have used the Australia Telescope Compact Array to measure the polarisation and Faraday rotation of approximately 300 distant radio galaxies in the direction of Cen A. Approximately a third of these sources lie directly behind the lobes, while the remaining two-thirds have positions just outside the lobes, and allow us to account for foreground Faraday rotation in the Milky Way. I will present the first results from this *rotation measure grid* through Centaurus A – our analysis suggests enhanced fluctuations in Faraday rotation around the rim of the southern lobe, potentially demonstrating the presence of a skin of thermal gas swept up from the surrounding intra-cluster medium.

Poster abstracts

Listed Alphabetically by Author

SN 1986G

Robert Evans, Linden Observatory, Australia, *bobevans@exemail.com.au*

Photos and summary of the published research on this supernova.

Simulation of flaring in AGN

Christopher Hudson, Adelaide University, Australia, *christopher.hudson@adelaide.edu.au*
***Co-author*: R.J. Protheroe**

Flaring in blazars is seen in both the low- and high-energy components of the spectral energy distribution. We plan to conduct simulations to investigate how well this may be explained by injection of bursts of mildly energetic charged particles into a some acceleration process. By following the time-dependence of the synchrotron and inverse compton components due to electrons accelerated for different energy dependence of the acceleration rate, we hope to obtain some insight into the nature of the acceleration process.

A molecular line survey towards Centaurus A with Mopra

Jürgen Ott, NRAO, USA, *jott@nrao.edu*
***Co-author*: C. Henkel (MPIfR)**

Centaurus A is one of the most extreme galaxies in the nearby Universe. The active nucleus and the related jet structure has a large influence on the surrounding atomic and molecular gas which, in turn, regulates the star formation close to the core. We present multi molecular line observations towards Centaurus A with the Mopra telescope in the 3 and 12mm bands. A comparison of a variety of molecular species, their line shapes and strengths shows how different the conditions are compared to those near the centers of normal and starburst galaxies lacking a dominant radio-loud AGN.

The Dedicated Centaurus A Web Pages - an Update

Helmut Steinle, Max-Planck-Institut fuer extraterrestrische Physik, Germany, *hcs@mpe.mpg.de*

An updated overview of the Centaurus A devoted web pages maintained at MPE is presented that describes the pages.