THE IRCAM REVOLUTION

Ian McLean
Beginnings of modern infrared astronomy

INFRARED OBSERVATIONS OF THE GALACTIC CENTER*

E. E. Becklin and G. Neugebauer
California Institute of Technology, Pasadena
Received June 13, 1967

Eric and Gerry discover the Galactic Center

The Two Micron Sky Survey; PbS detectors and Ge bolometers lead the way

Strip charts, raster scans and contour plots ...
The advent of Digital Imaging
Visible light astronomy gets the Charge-Coupled Device

Willard Boyle and George Smith – inventors of the CCD

CCDs change everything! What about IR?

“PIXELS”

An early CCD

C. 1979
Infrared “pictures” made 1 pixel at a time were fuzzy.

M17: fuzzy pictures obtained by “scanning” a single pixel across the sky.
IR astronomy grows

Becklin
Kuiper Airborne Observatory
1975

1979: Specials IR telescopes on Mauna Kea (UKIRT and IRTF)

IRAS launched in 1983

BUT, STILL USING SINGLE PIXEL DETECTORS … NO CAMERAS!
1981: Royal Observatory Edinburgh wants imaging devices for UKIRT

I was building a CCD imaging spectropolarimeter, so ... this becomes my job

1982: My survey reveals best vendors are in USA

But the technology is classified!

Small IR arrays that have “slipped out” to the US astronomical community are designed for high-background, real-time imaging – not what we want

Prospects seem very bleak at first

1983: An astronomer working for Hughes-SBRC called Alan Hoffman to think about my visit in October 1982. He convinces his management to start a commercial array development program for astronomy!

1984: We select SBRC (now Raytheon) to develop an InSb array specifically for near-IR astronomy (1-5 μm)
Infrared Array Detectors

- **Silicon** CCDs can’t work beyond 1.1 μm
- Need lower band-gap semiconductors e.g. Ge, InSb or HgCdTe
- Can’t make good CCDs with these materials
- **HYBRID**: Use the IR-sensitive material to make the detector array and attach this array with *indium* bumps to a silicon readout integrated circuit (ROIC).

Sensor Chip Assembly or SCA
Negotiating with SBRC

- March 28, 1984
- Mauna Loa is erupting
- SBRC leaders visit UKIRT
- Terry Lee and I take them up
- Spectacular!
- VP says “yes”
- I follow up with visit to Santa Barbara, CA in May with Tim Chuter
The IRCAM Project Begins

Viewgraph from first IRCAM Project Meeting July 1984

Optical and mechanical layout follows
Construction starts
The first IR array for astronomy

Al Fowler at KPNO buys in to this project; we get devices 001 and 002 at same time.

58x62 = 3,596 pixels ... small

But 3,595 more than we had before!
IRCAM comes together

Detector and double filter wheel; removable module
The team celebrates shipping out

September 1986

12 crates shipped to Hawaii
In Hawaii

Colin Aspin and I transfer to Hilo. Later we are joined by my two PhD students Mark McCaughrean and John Rayner.
First Light on the sky
October 23, 1986

We are given only “morning” observing time after night program ends — confidence in IR arrays was not yet high!

At the telescope was Colin Aspin, Gillian Wright, Dolores Walther and me.

Trapezium

BN
The flood gate opens
Outside the Galaxy

Yes, we can detect objects outside the galaxy!
Wow!

NGC3690

IRCAM image at K
Infrared images sharpen up

M17

DR21

Narrow band filter (1%)
H₂ S(1) v=1-0 line
The Orion Nebula – MOSAIC
Mark McCaughrean’s PhD thesis
Did we know that the world of infrared astronomy had just changed?

1987: “Turning point” meeting (Hilo, Mar 1987)

Wayne van Citters (NSF): “I don’t think there’s any doubt that we are on the verge of a promised land in optical and infrared astronomy.”

Don Hall (UH): “Things that seemed in the future and beyond my grasp for so long are clearly here.”
The “I like it” image from the Hilo Meeting

OMC-2 IRS1 nebula: K filter
UKIRT 24 Jan 87: 0.6"/pixel

From John Rayner’s thesis
The Galactic Center

IRCAM obtains high-speed snapshots during a lunar occultation in April 1987.

IRCAM creates velocity maps in the Brackett gamma line at 2.17 μm using the Fabry-Perot mode,
The added impact of AO

In the years that follow IR astronomy gets the added bonus of adaptive optics

From 1987 to 2007
From 4,000 to 4 million pixels

- In 1984 we had 58 x 62 pixels each 60 μm
- Today, 2Kx2K arrays are common
  - e.g. H2-RG HgCdTe 2Kx2K array with 18 μm pixels from Teledyne shown below
- Controlled by a single Application Specific Integrated Circuit (ASIC)
  - λ = 0.9-2.5 μm or even 5 μm
  - QE >80%
  - RN ~5 e- rms
  - Dark <0.01 e/s
That is the full impact of the IRCAM revolution.
Modern astronomy relies heavily on technological advances to detect and interpret the faint signals from distant parts of the Universe and is therefore as exciting and challenging for the professional engineer and applied physicist as it is for the astronomer.

This book describes the remarkable developments that have taken place in astronomical detectors and instrumentation in recent years, from the invention of the charge-coupled device (CCD) in 1970 to the current era of very large telescopes. It includes all the key methods used to obtain astronomical images across the entire spectrum, and uses the story of the charge-coupled device to link many of them together. The book’s unique approach blends scientific motivation, a focus on specific instrumentation, and a thorough description of electronic imaging technology across a range of wavelengths.

Electronic Imaging in Astronomy:
- collects all the fundamental astronomical observing techniques and methods into a single reference work;
- is ideal for advanced undergraduate and graduate students interested in the significant role of modern observational astronomy;
- illustrates a wide range of principles and techniques using detailed case studies;
- provides invaluable guidance for anyone interested in the design, development and characterisation of astronomical instrumentation;
- presents the underlying principles behind the cameras, spectrometers and telescopes used to make important astronomical discoveries.

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