

High energy and radio complements to the VVV

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Overview

- Motivations for going to much longer and much shorter wavelengths
- What data we've lined up and when, and how sure we are to get it
- What people are already planning to do
- What I think can be done which no one is planning to do yet
- Maybe some new ideas from the audience?

Galactic X-ray surveys

- Mostly aimed at compact objects
 - Binaries with black holes and neutron stars generally dominated by X-rays
 - Cataclysmic variables show substantial X-ray emission as well
- Some other classes will appear – W UMa stars, T Tauri stars, colliding wind binaries, active stars, background AGN
- Two major goals
 - Binary evolution constraints
 - Finding new, rare objects to study accretion physics

Binary evolution studies

- A large fraction of the key unsolved problems in stellar evolution are binary evolution problems
 - Type Ia supernovae
 - Short GRBs
 - Long GRBs too??
 - Gravitational wave sources
 - Blue stragglers
 - Some classes of stars with unusual abundances (e.g. RCB stars, barium stars)

Rare objects

- Quiescent X-ray binaries
- Expand samples of black holes and neutron stars for mass measurements
- More black holes in general are welcome
 - Mass distribution, orbital period distribution for black hole X-ray binaries maybe heavily biased by which ones have shown outbursts
- Eclipsing neutron stars especially valuable
 - Inclination angles crucial for precise masses, precise masses needed for EoS science

X-ray variability and transient studies

- All sky monitors
- INTEGRAL scanning and monitoring programs
 - VVV INTEGRAL work led by Masetti, Rojas
- Galactic Center region
 - Much was originated by e.g. Munro et al., Wijnands et al.
 - VVV work led by Bandyopadhyay
- Chandra Galactic Bulge Survey
 - See talk by Sandra Greiss

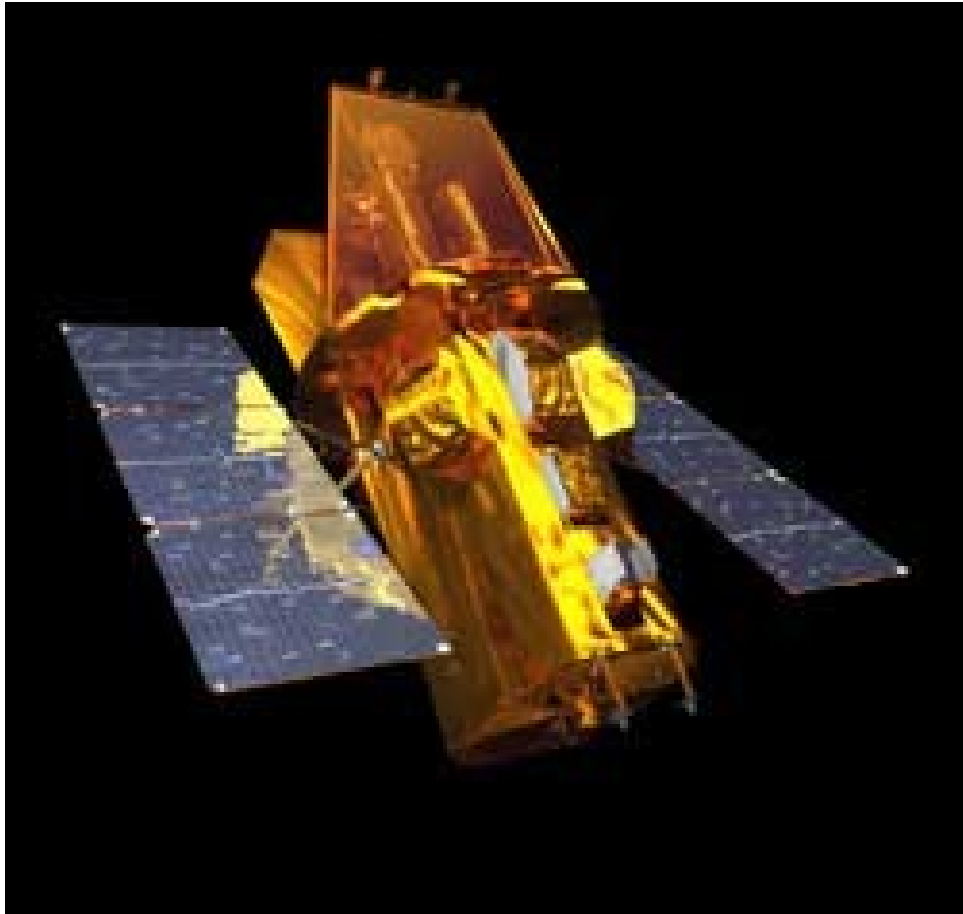
Radio transient surveys

- Largely breaking new ground
- A few attempts made so far, but surprisingly few transients discovered, and nearly all extragalactic
 - Two Galactic transients in Bannister et al. (2011) survey of entire MOST archive, but those are both known X-ray binaries
 - But nearly all these objects are unclassified, some (many?) could be nearby late-type stars, or even brown dwarfs

Radio transients: classes

- Scintillators (pulsars, BG AGN)
 - Probably not in Galactic Center because too much gas on too many lines of sight, but maybe in outer Bulge
- X-ray binaries
 - Cataclysmic variables also, but probably too faint in radio
- Flare stars
 - M dwarfs
 - Active binaries
- Unknowns?

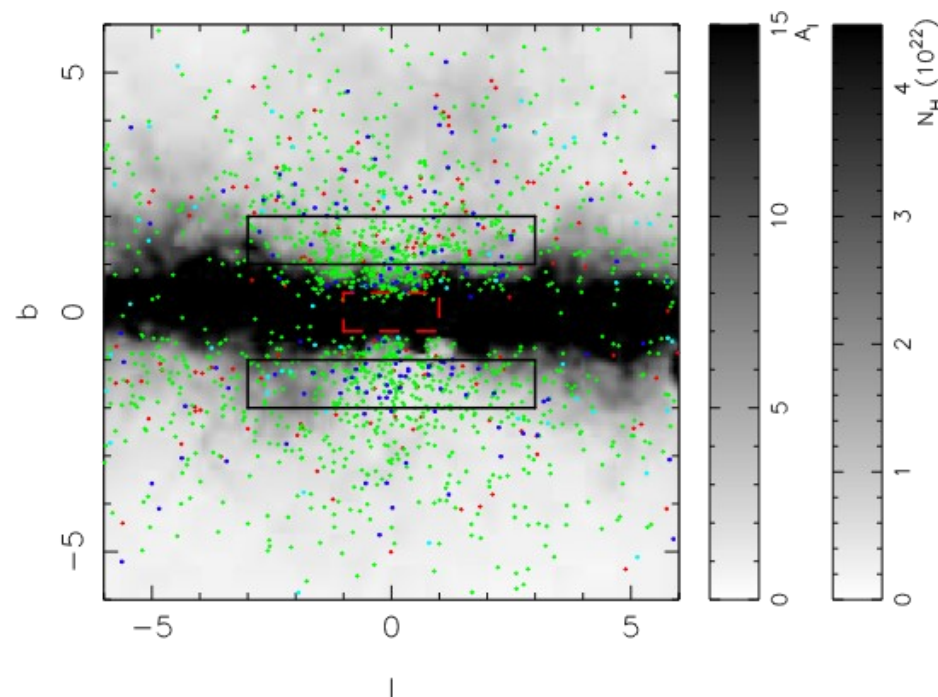
Swift: capabilities



- Gamma-ray
 - Moderately sensitive over 1-3 sr
- X-ray
 - Decent sensitivity (similar A_{eff} to Chandra), 23' diameter FOV
- UVOT
 - V,B,U, 3 space-UV filters
 - 17*17 minute FOV, 2" resolution, 30 cm aperture

The Swift/VVV Bulge survey

- Covers Chandra GBS region, plus inner 2*2 degrees of the Galaxy
 - Region chosen to cover regions already well surveyed with Chandra
- 8 epochs of 500 seconds each
- Will be done quasi-simultaneously with the VVV intensive Bulge survey next summer
- Through a deal with Leicester Swift team
 - Strongly encouraged by Julian Osborne to produce UK-led results

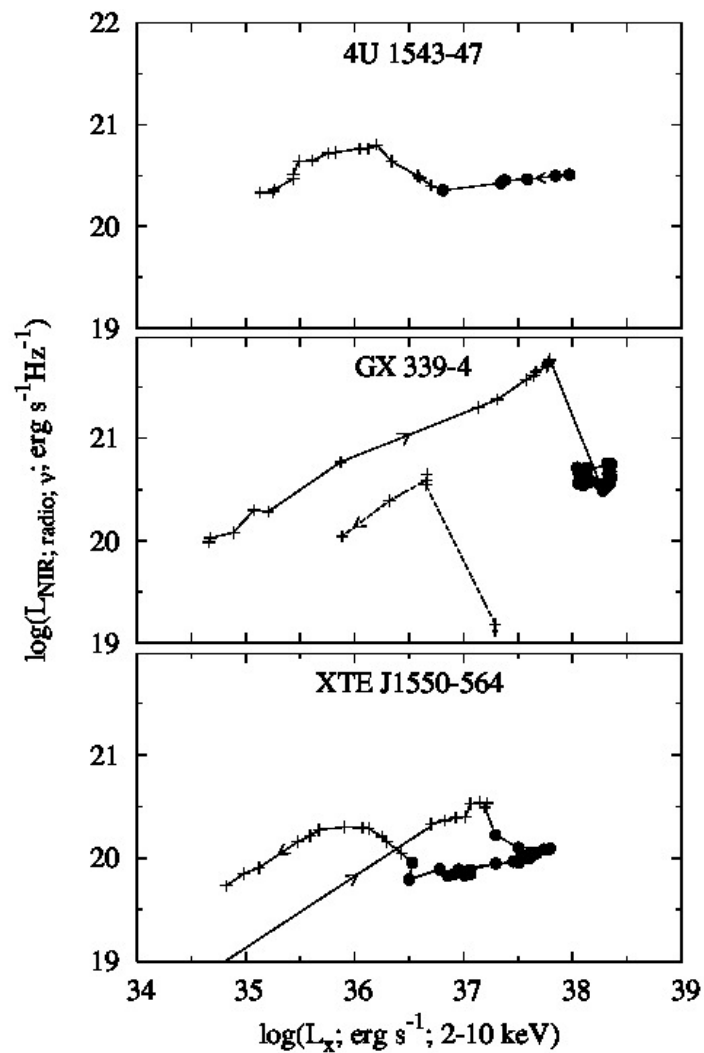


Areas of inner Galaxy X-ray surveys –
black: GBS (only half of Southern part covered so far); red: Muno survey of inner Bulge

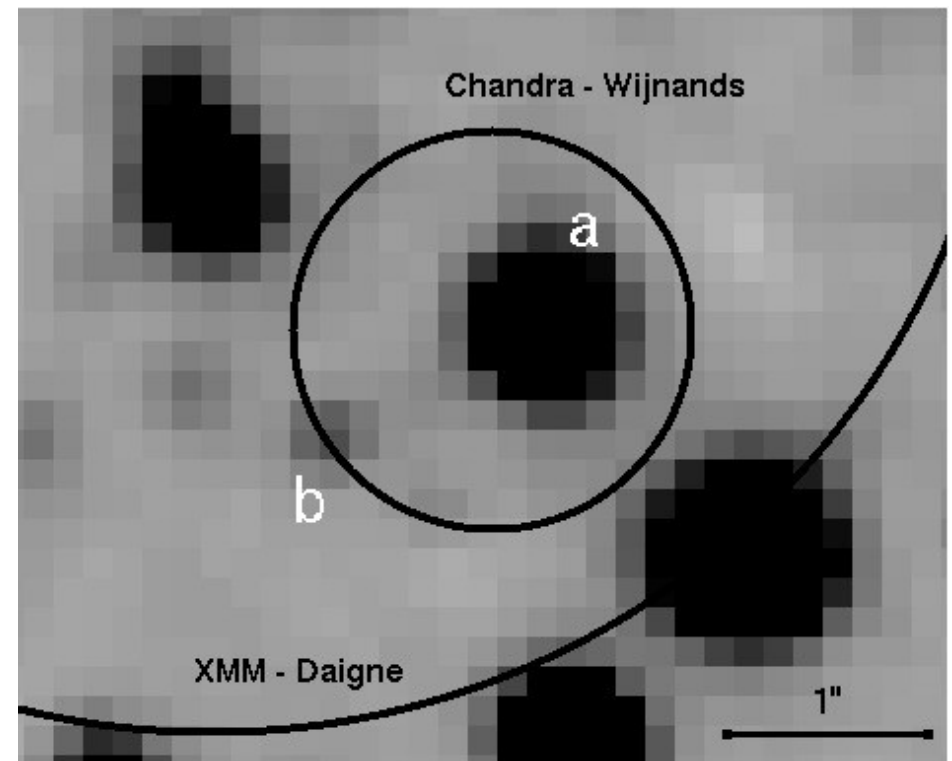
Sensitivity of these data

- X-rays: reach $L_x = 3 \times 10^{-14}$ in the full survey
 - Effectively a second epoch for GBS (but not nearly as deep as Galactic Plane observations)
- About 10^{-13} ergs/sec/cm² in each epoch
 - About 10^{33} ergs/sec in each epoch at $d=8$ kpc
 - Enough to see the enigmatic **very faint X-ray transients**, get eclipses for some of the quiescent neutron star systems
- UVOT – will all be in uvm2 (~2300 Ang)
 - Avoids bright star problems
 - Goes to 20.6 (Vega mags) for full survey, 19.5 in each epoch
 - Will be very effective in sorting out CVs from LMXBs

Value of simultaneous data

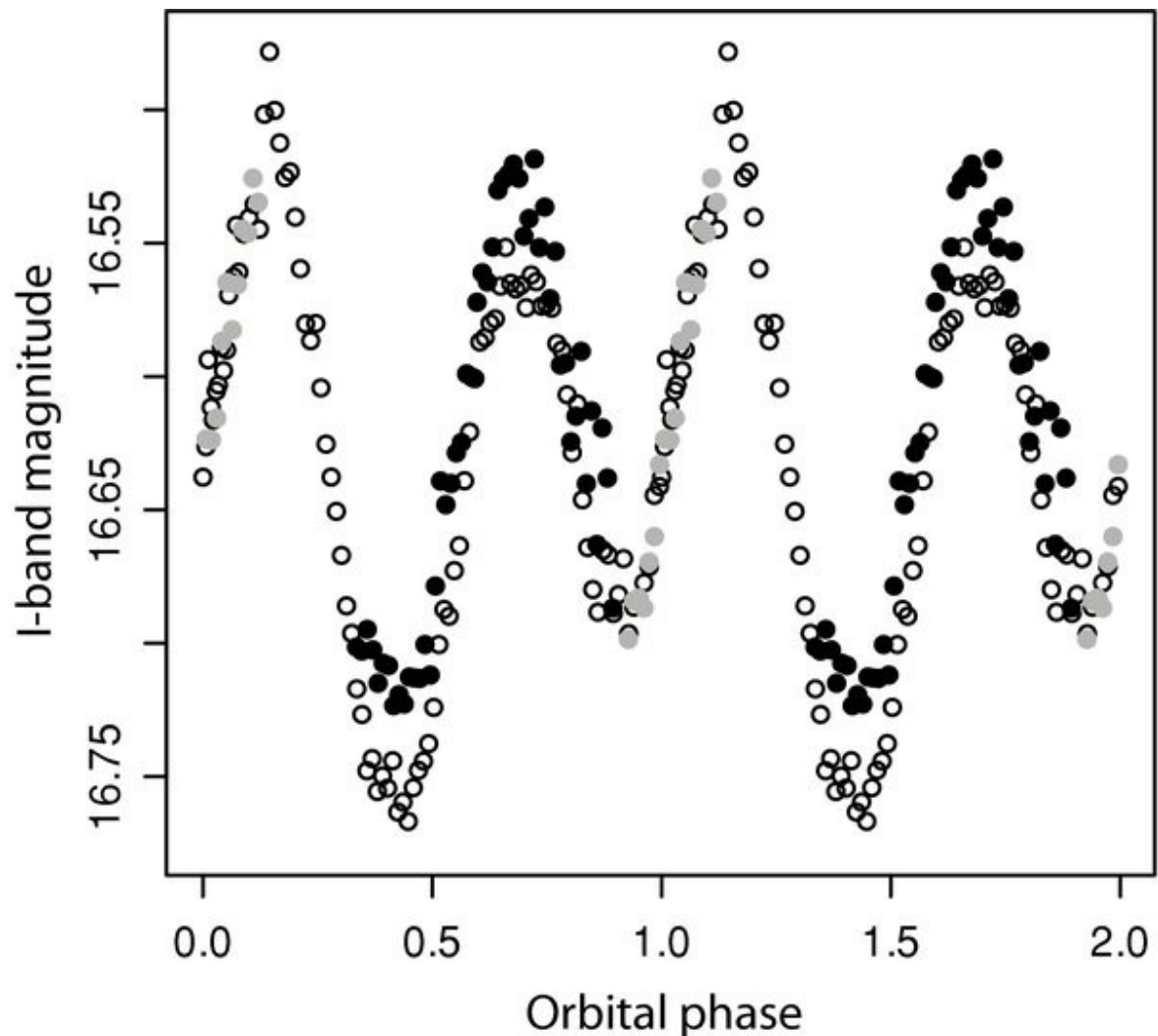


From Russell et al. 2007



From Gosling et al. 2007

Ellipsoidal modulations



Three ellipsoidal light curves in one week, same source (A0620-00), from Cantrell et al. 2010; Even in “quiescence”, good X-ray coverage is helpful

Opportunities

- Star clusters in UV
- X-ray emission from T Tauri stars, active binaries, active cool dwarfs
- Variability amplitudes in UV versus IR for RR Lyrae stars
- Other ideas?

Radio surveys: KAT-7 and MeerKAT

- KAT – Karoo Array Telescope
- Variability a key goal of early science
- Commissioning going on now, should be fully rolling in 2012



KAT-7 – first seven dishes. Will eventually expand to 64 dishes, with much longer baselines

Small dishes mean ~ 1.5 degree FOV

What's lined up...

- Early stages of planning right now – informal agreement with Fender, Woudt
- Likely to get KAT-7 to observe the previous night's VVV Bulge fields
- Probably will get almost every night, albeit on best effort basis
- Sensitivity level to be ~ 0.1 mJy (roughly the confusion limit for KAT-7, so no going deeper than that...)

Radio transients: value of simultaneity

- Two big surveys have detected radio transients
 - Bannister et al. 2011
 - Entire MOST archive
 - Most sources unidentified, or already known
 - Retrospective optical follow-up of essentially no value
 - Bower et al. 2007
 - One VLA test field, 944 epochs
 - 10 transients, a few associated with galaxies, and possibly supernovae, but none clearly identified
- Nearly coincident radio, OIR measurements may be essential. Late optical follow-up clearly not very useful

Improvements to pipeline, scheduling?

- Pipeline

- Get the data off the mountain nightly?
 - Problems with ESO policies?
 - Can we do this, or maybe have some workstations on the mountain for quick and dirty transient detection?
- Even better, but understandably harder would be to have pipeline alerts of new transients

- Scheduling

- Can we respond to new X-ray transients quickly?
 - Might require doing bad airmass pointings
 - Might disrupt sampling for other classes of objects
 - Worth discussing the trade-offs

Some additional high energy projects

- Sgr A* 2 Msec with Chandra transmission gratings
- Has zero order, which is an image, but with lower efficiency
- Will necessarily involve some monitoring, may be useful for VVV, too
- INTEGRAL Bulge Scans
- INTEGRAL Galactic Center deep observations
- Probably good chance to coordinate one or both programs

Summary

- There will be an X-ray/UV variability survey overlapping in time with the VVV intensive bulge survey
- Also a radio one, covering a larger field of view
- Opportunities to get involved still exist, especially for the non-compact object science
- Taking full advantage of this project may require some adjustments to VVV operations
 - We understand there may be reasons not to do this, but think it's worth discussing