Galactic Center: Prospects for Fermi/Gamma-ray Astronomy

Frederick K. Baganoff

MIT Kavli Institute for Astrophysics
and Space Research

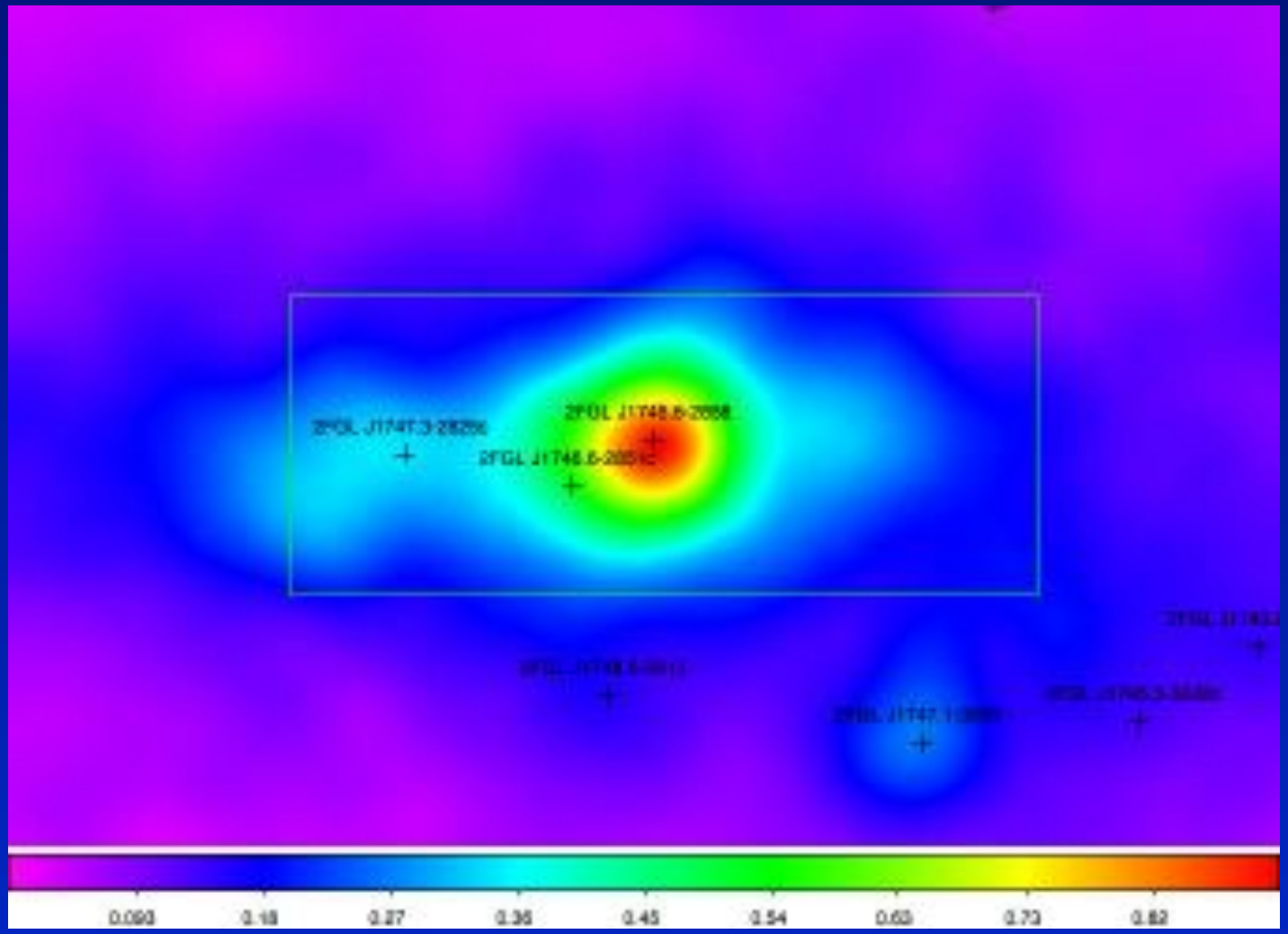
2012 October 30

Overview

- X-ray & Gamma-ray views of our dynamic Galactic Center
- SNRs, NTFs/Shocks, PWNe & SFRs
- Sgr A* flares above Chandra passband?
- Tidal disruption of gas cloud by Sgr A*
- Summary

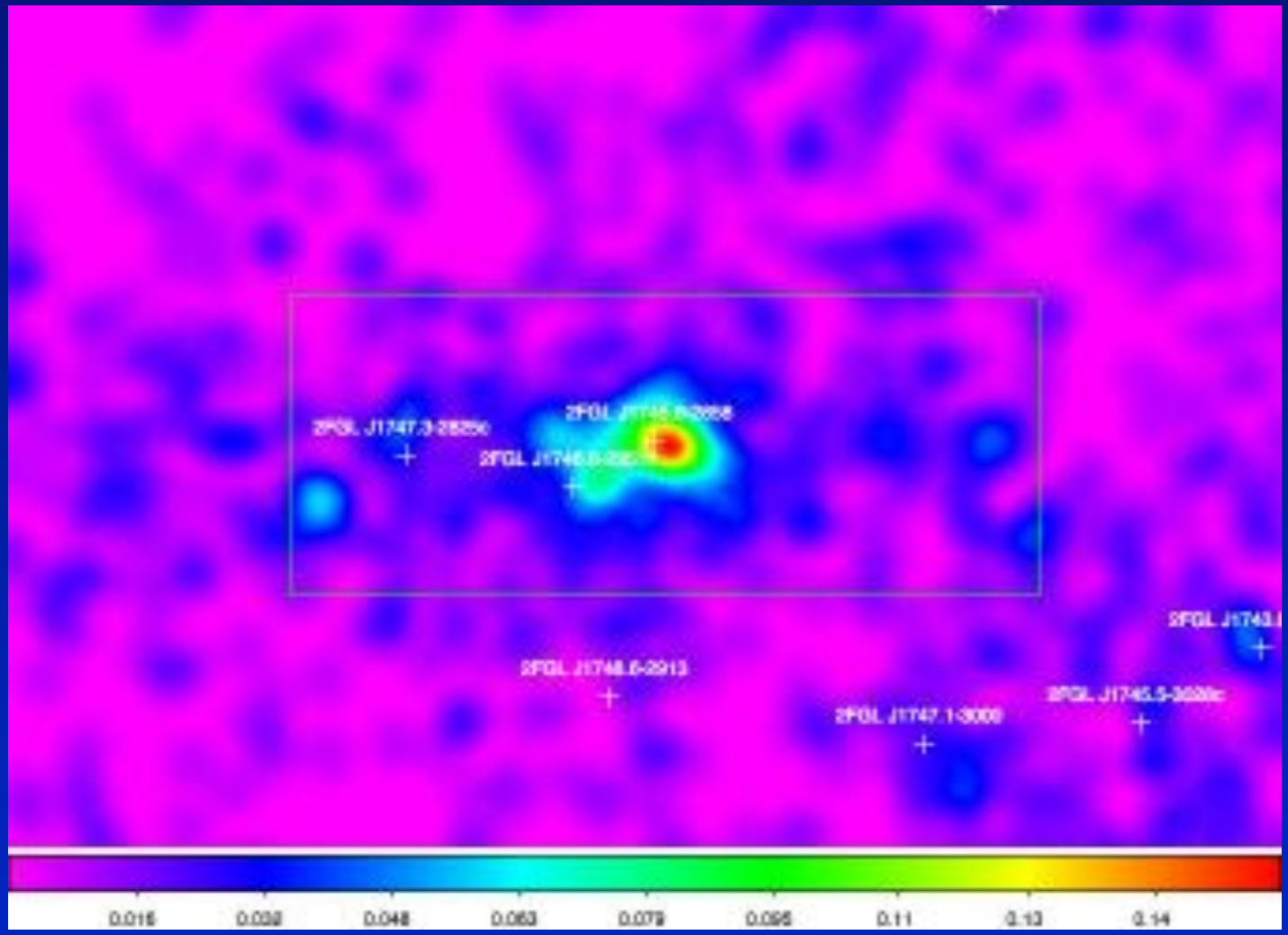
X-ray & Gamma-ray views of our dynamic Galactic Center

Fermi 2-200 GeV Galactic Center View
(aka Fermi Galactic Zone of Avoidance)



2 x 0.8 Degree Box

Fermi 10-200 GeV Galactic Center View



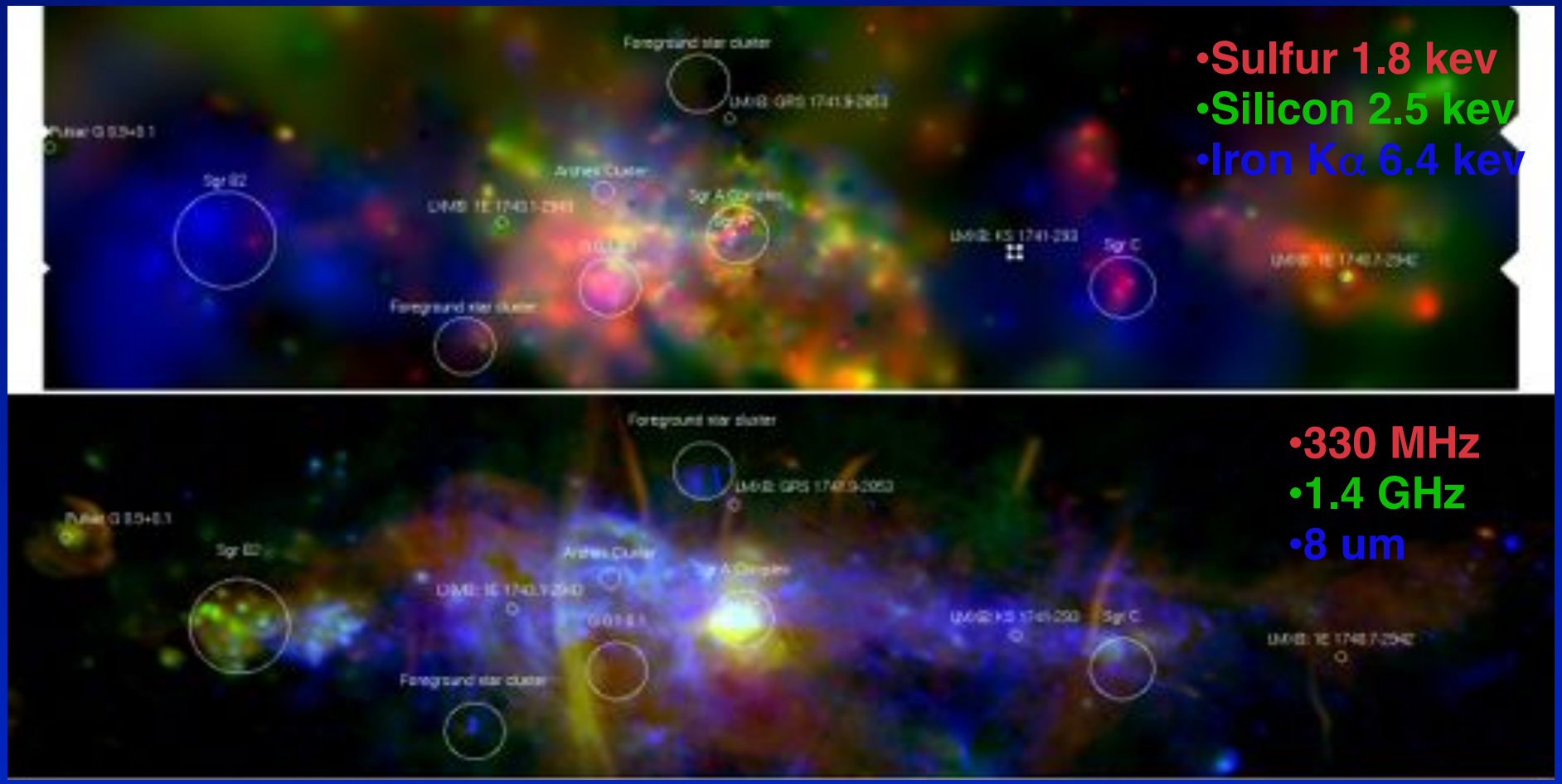
2 x 0.8 Degree Box

Chandra 2-8 KeV Survey

2 x 0.8 Degree

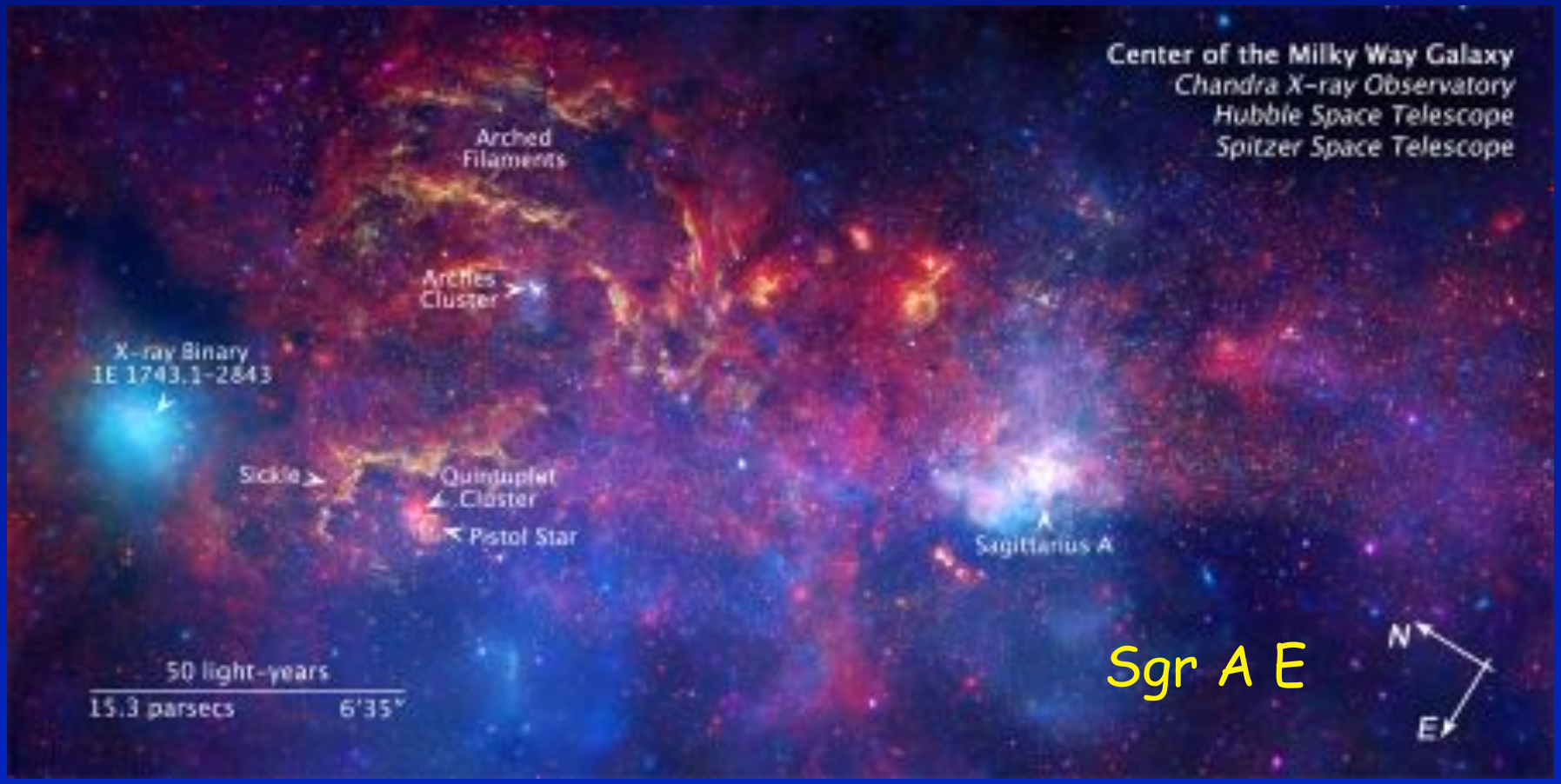
SNRs, NTFs/Shocks, PWNe & SFRs

X-ray Line Map vs Radio/8 um Maps



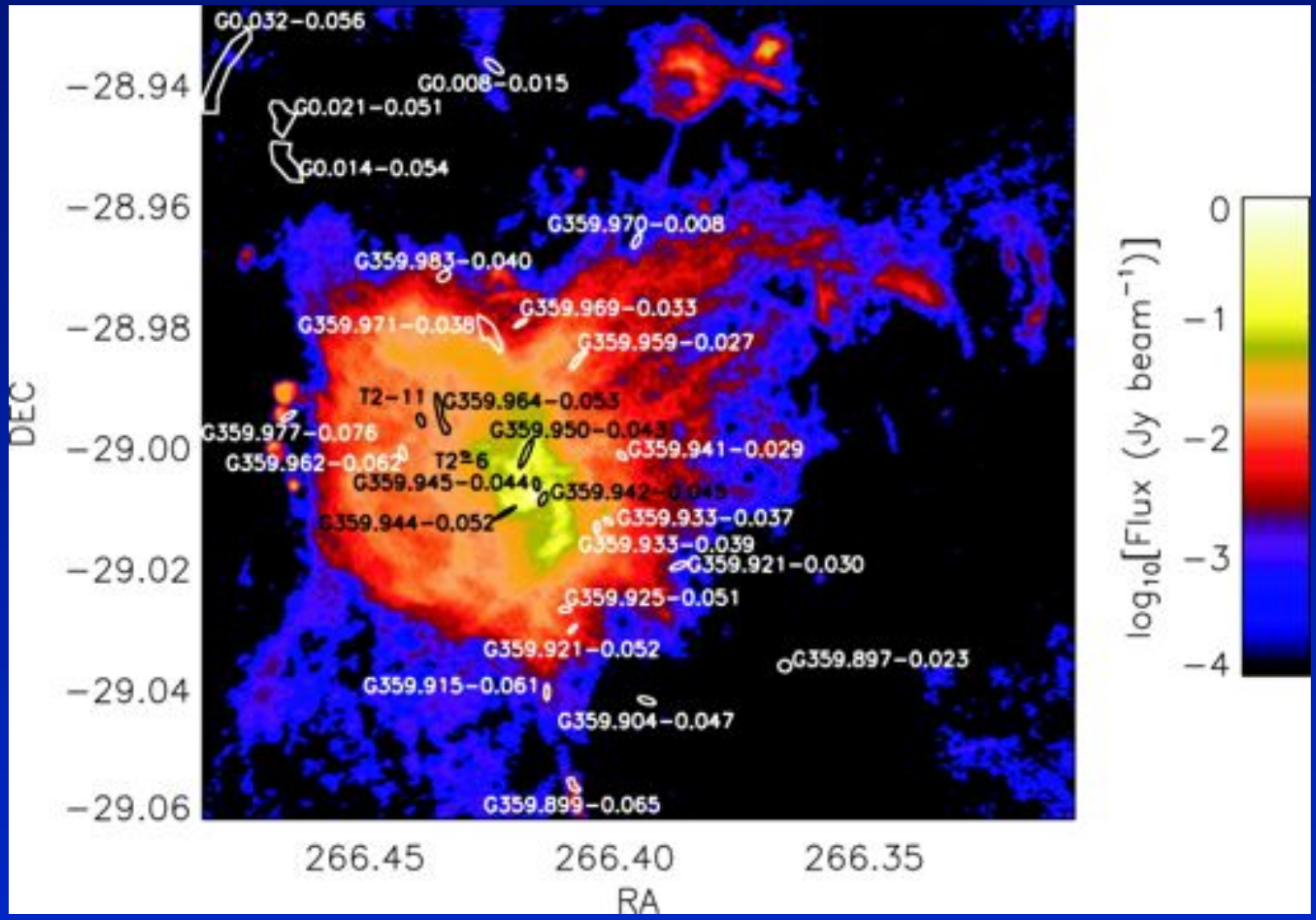
Composite maps created by Franz Bauer

Chandra, Hubble & Spitzer Views of the Galactic Center



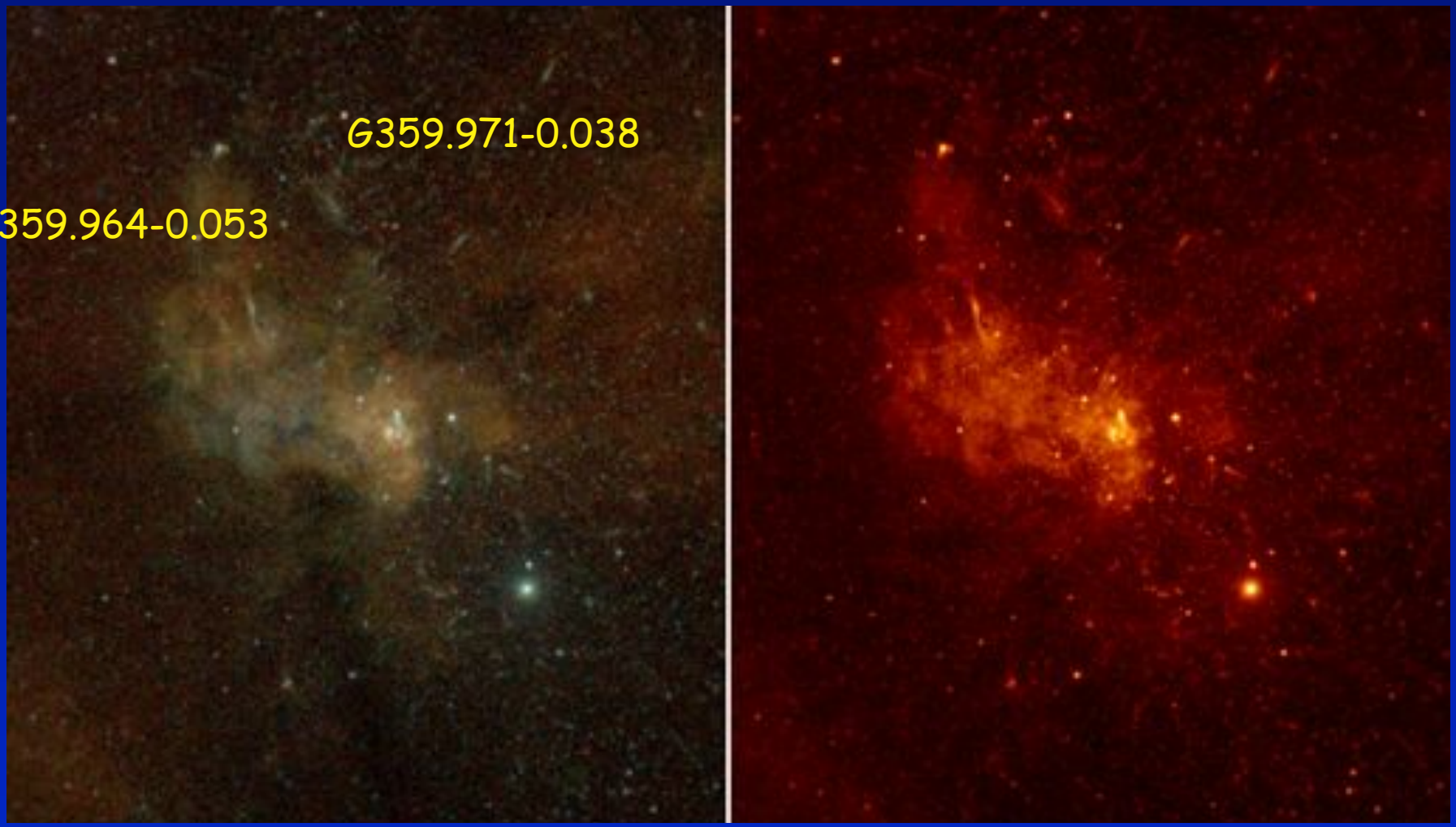
NASA, ESA, CXC, SSC, & STScI

Radio Image of Sgr A Complex Overlaid with Extended X-ray Features

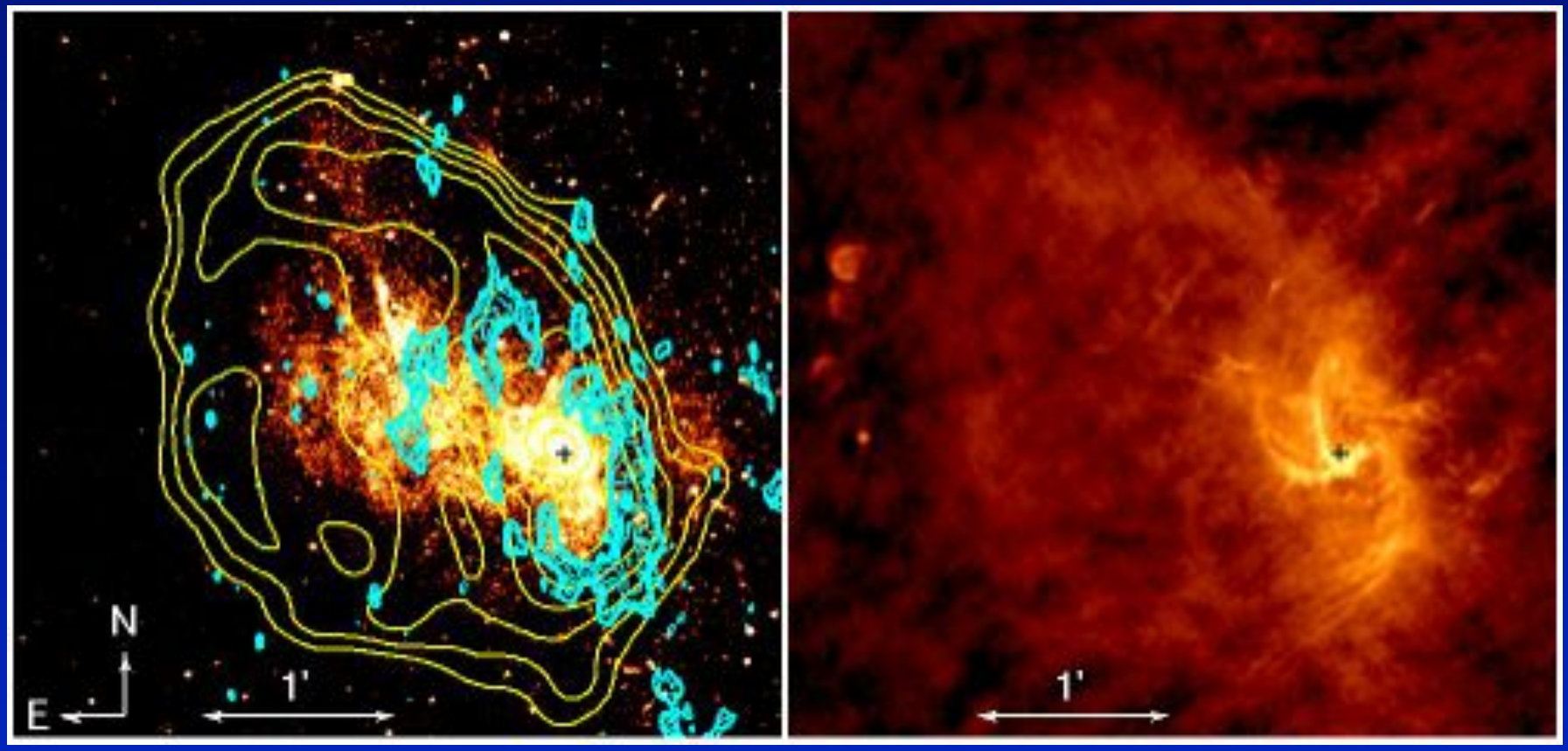


Muno et al. 2008, ApJ, 673..251

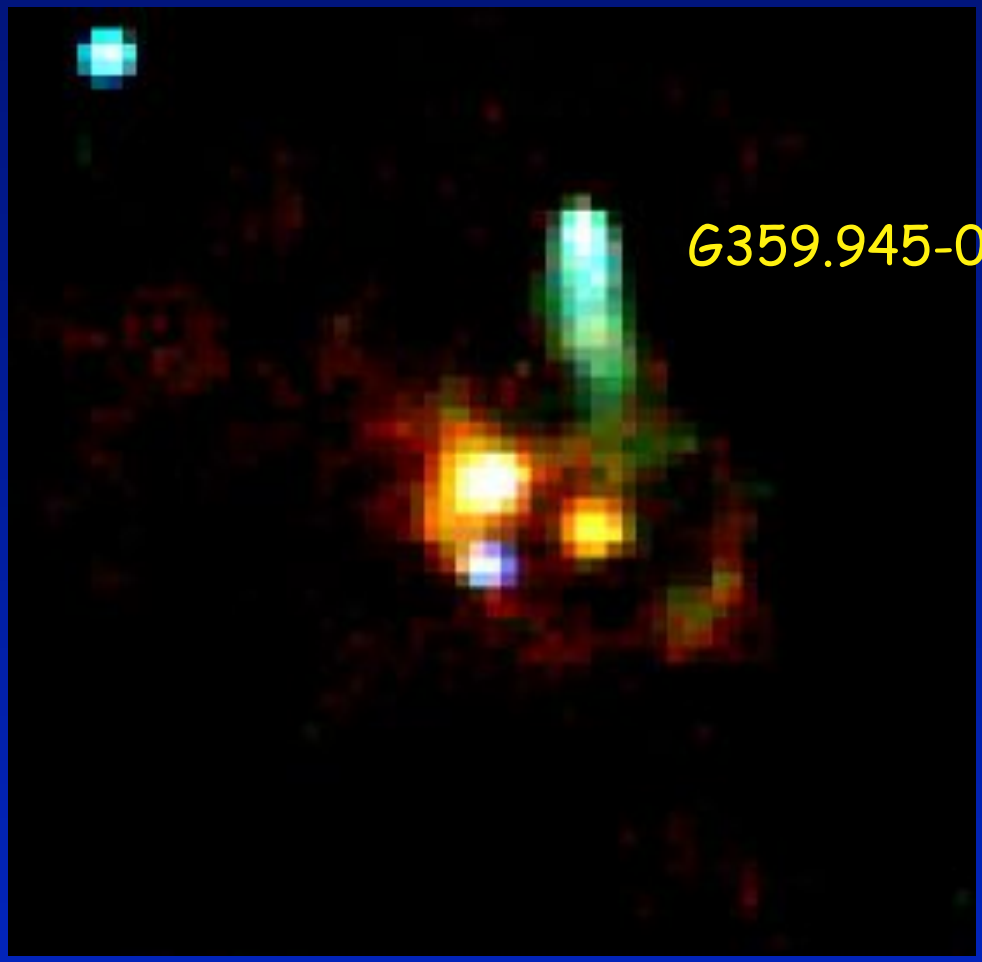
NTFs/Shocks & PWNe Candidates Near Sgr A Complex



NTFs/Shocks in Sgr A East SNR



PWN in the Central Parsec?



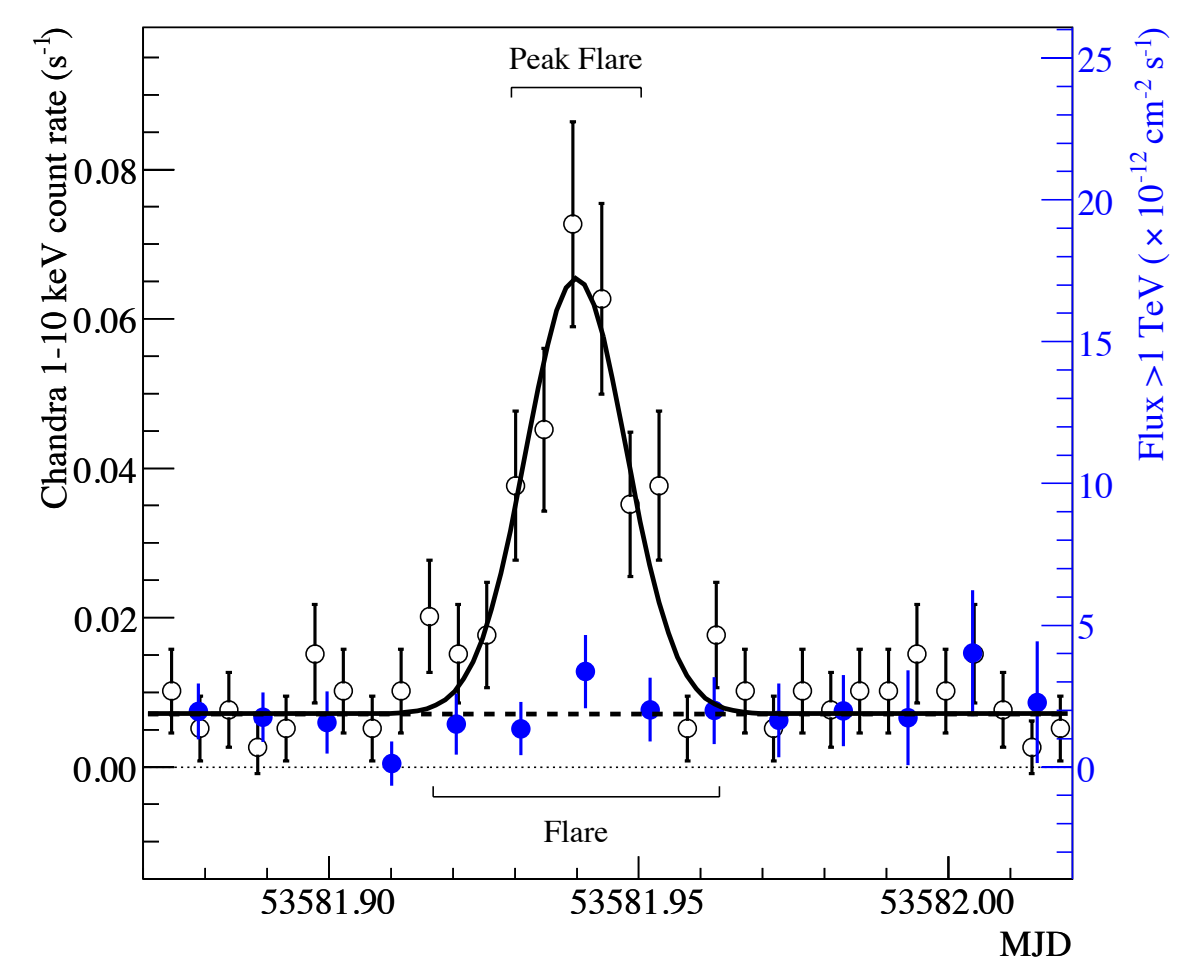
2-3.5, 3.5-5, 5-8 keV

SNRs, NTFs/Shocks, PWNe & SFRs

- Chandra sees ~20 PWNe candidates in central 20pc (Muno et al. 2008 & references therein)
- ~7 NTFs/SN Shocks; esp. Sgr A East and Sgr A E & F (Ho et al. 1985)
- Several dozen high-mass stars => potential sites for transient young HMXBs and young PSRs (e.g., Mauerhan et al. 2008, 2009)
- Higher Frequency GBT Project may detect PSRs and provide ephemerides for gamma-ray pulsation searches

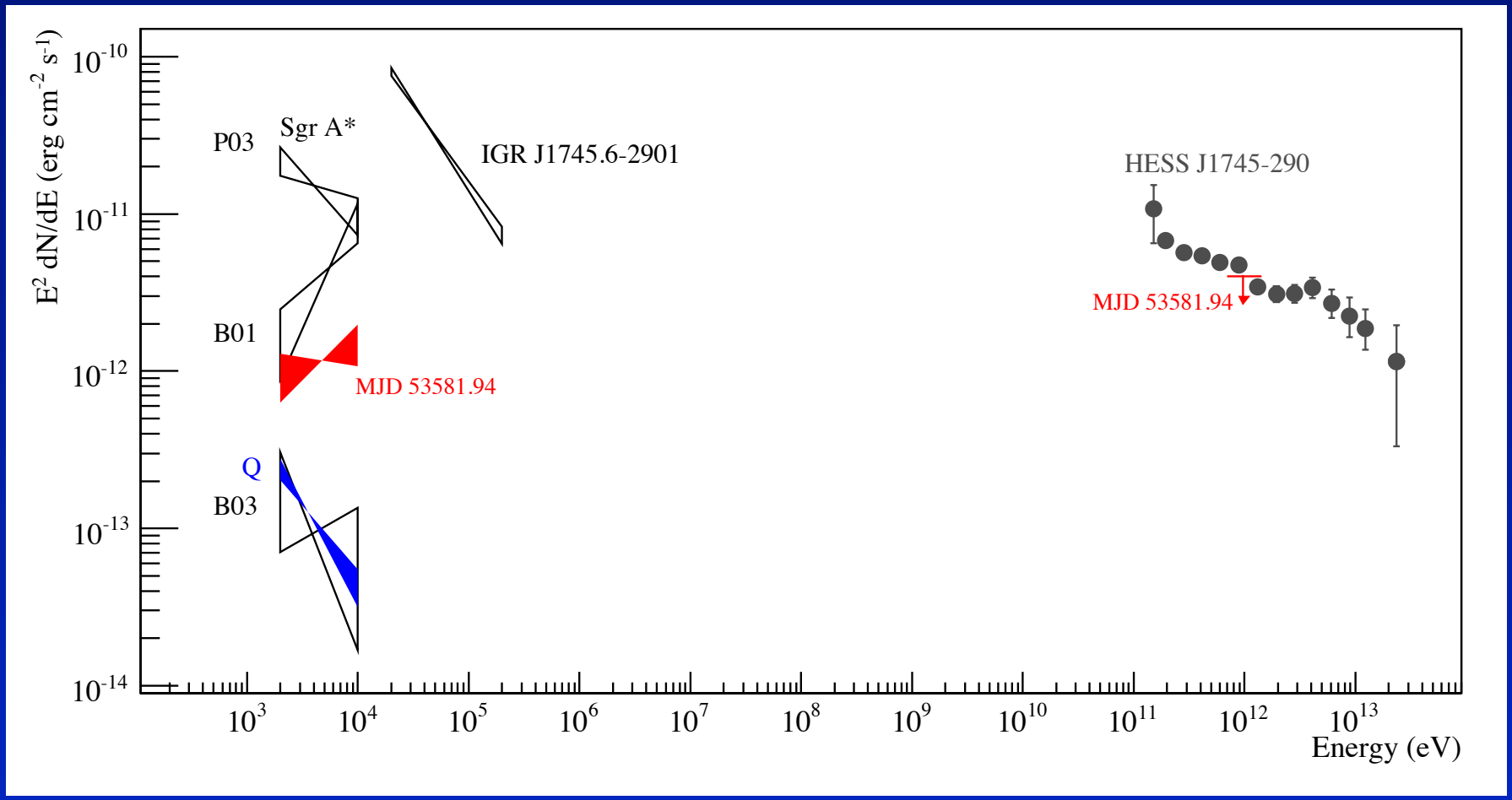
Sgr A* flares above Chandra passband?

Chandra/HESS Campaign: 3-sigma HESS Variation



Aharonian et al. 2008, AA, 492, L25

Chandra & HESS Flare Spectra

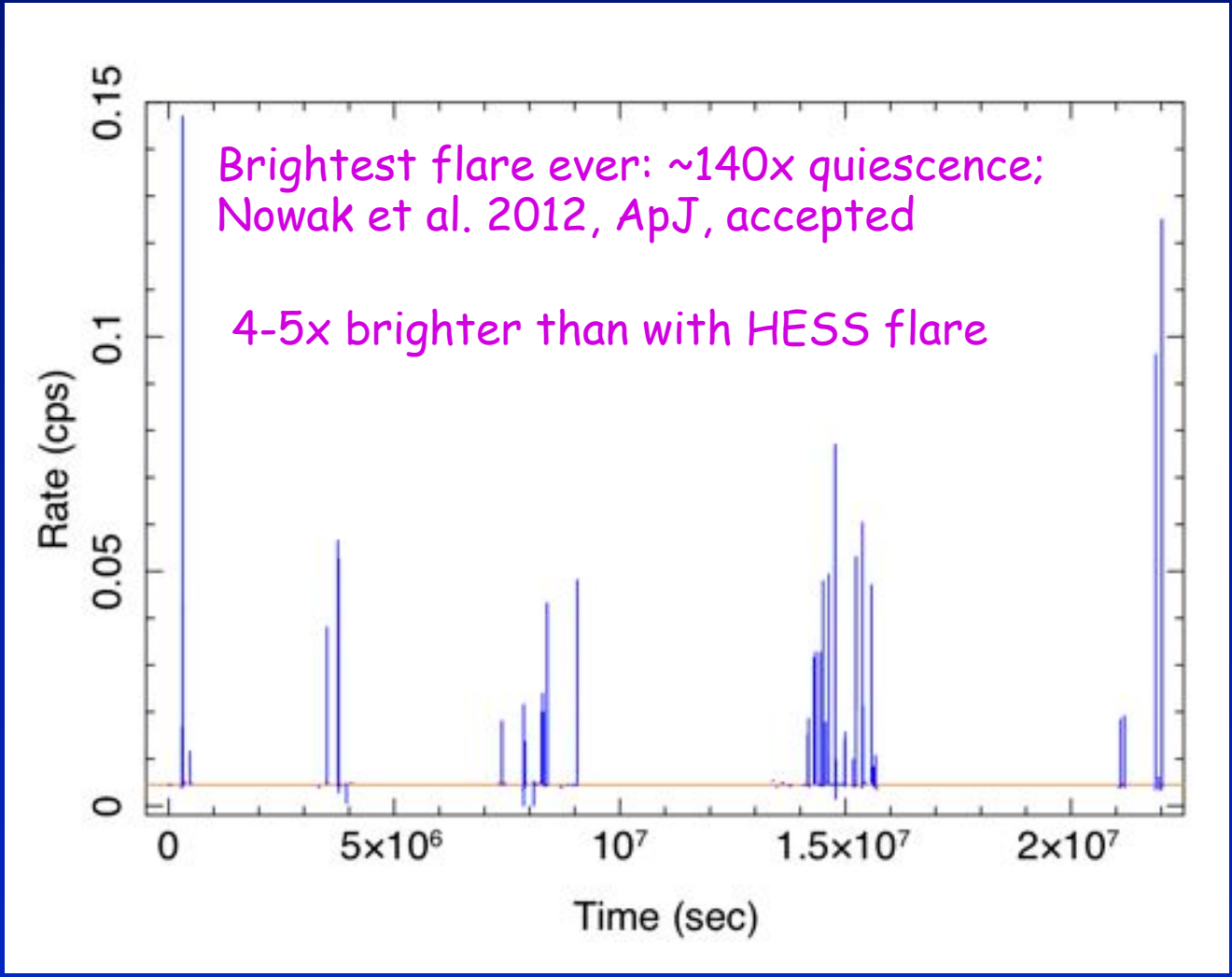


Chandra flare ~30x quiescence

Guess Where the Galactic Center Is?

Keck I & II during XVP MW Campaigns

Chandra Sgr A* X-ray Visionary Project



30+ flares seen in 3Ms exposure: ~1.3 +/- 0.2 flars/day

NuSTAR Sees Hard X-ray Flare

NuSTAR PI: Fiona Harrison

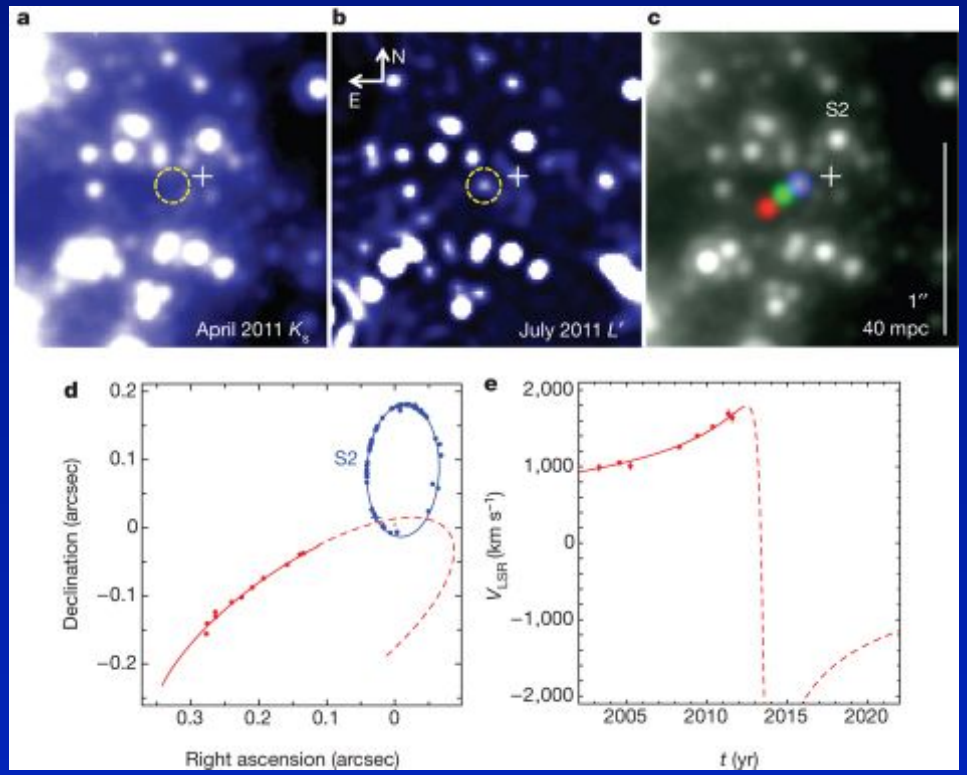
Tidal disruption of gas cloud by Sgr A*

Gillessen et al. 2012, Nature, 481, 51

Tidal Disruption Summary

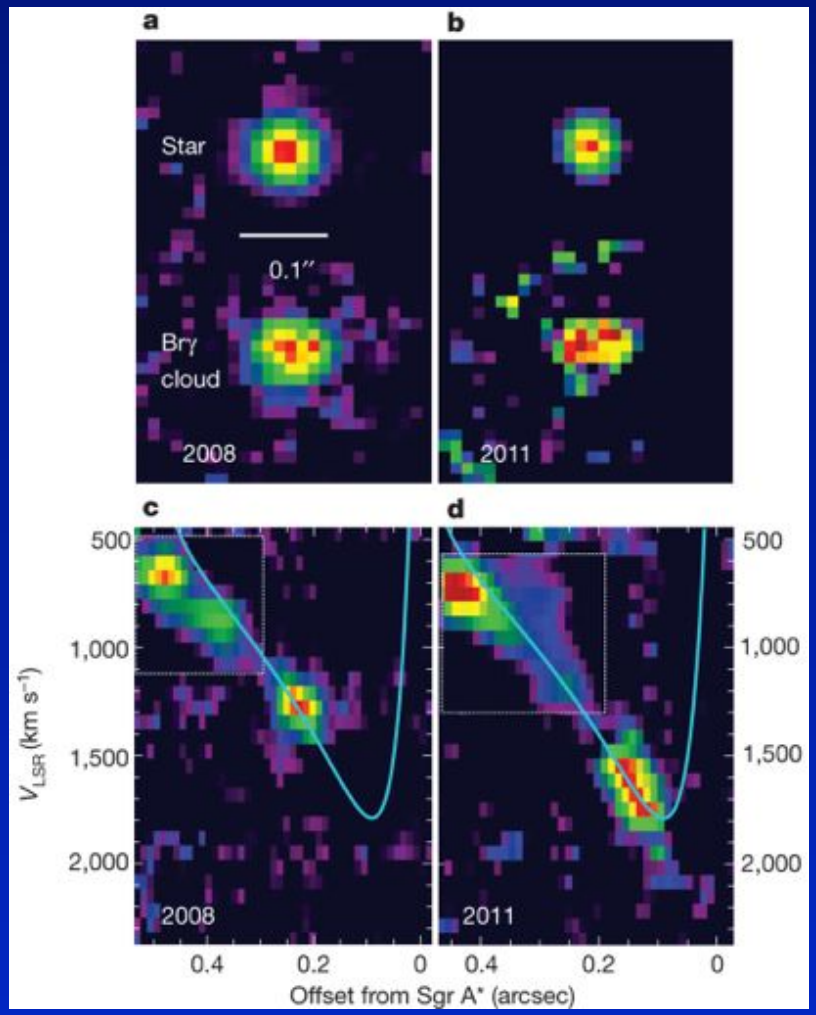
- ~3 earth-mass gas cloud approaching Sgr A* on nearly radial orbit
- Peribothron ~2000 R_S, ~0.02" or ~24 light hr at 2013 Sep 10 +/- 15d
- Cloud has begun to disrupt over past 3 yr, probably due to tidal shearing
- Dynamical evolution and radiation of cloud will probe properties of accretion flow and feeding processes of Sgr A*
- keV emission of Sgr A* may brighten significantly at closest approach
- Hydrodynamic simulation predicts increased feeding of Sgr A* in a few years

Infalling Dusty Gas Cloud in Galactic Center



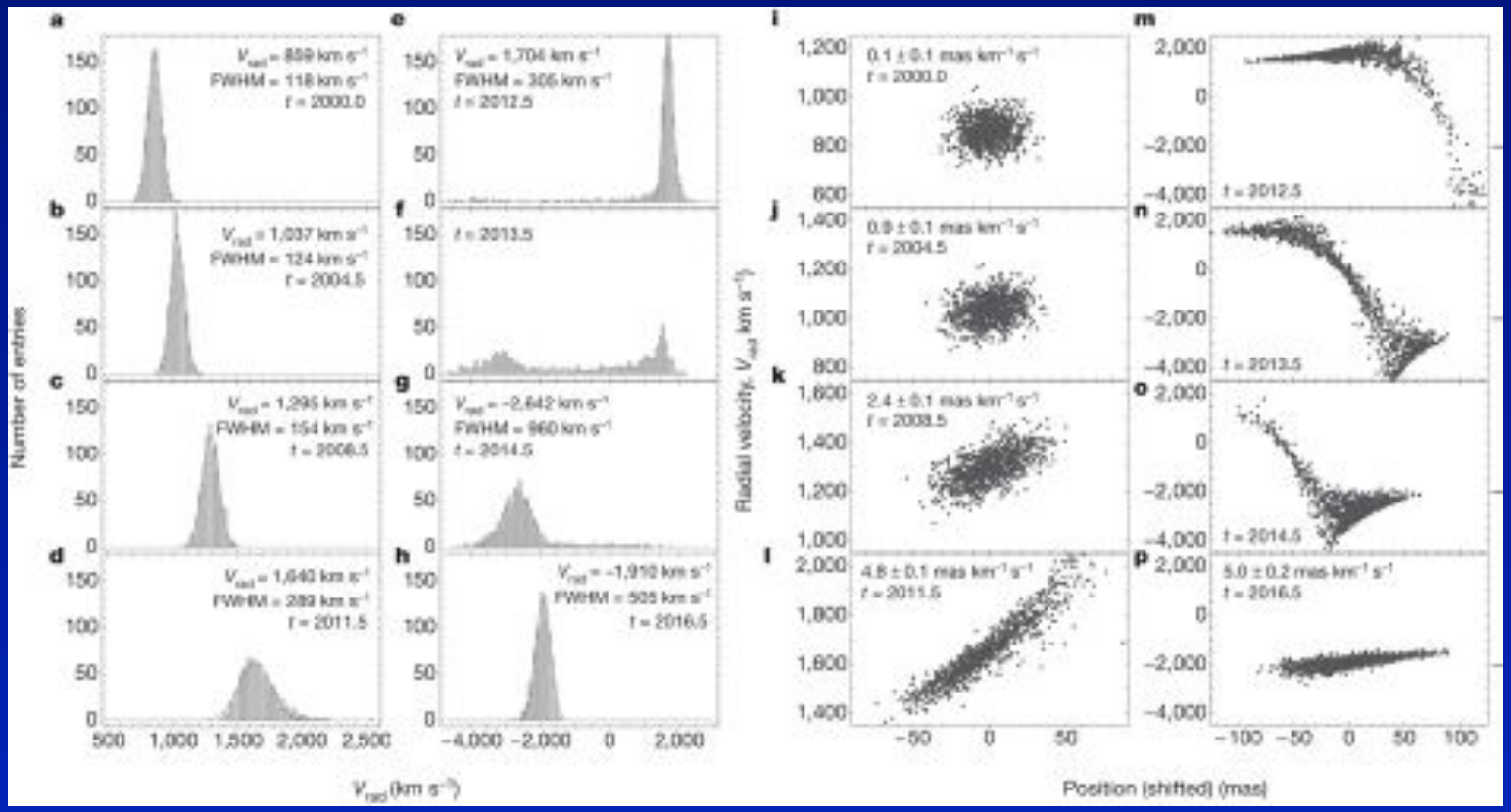
- Cloud detected at M and L', not K_s or H
- Dusty cloud T_d ~ 550 K
- Proper motion ~42 mas/yr or 1670 km/s
- Br g radial velocity ~1650 km/s
- e ~ 0.94 bound orbit
- Orbital period ~137 (11) yr
- Panel d shows orbits of cloud and star S2

Velocity Shear in Gas Cloud



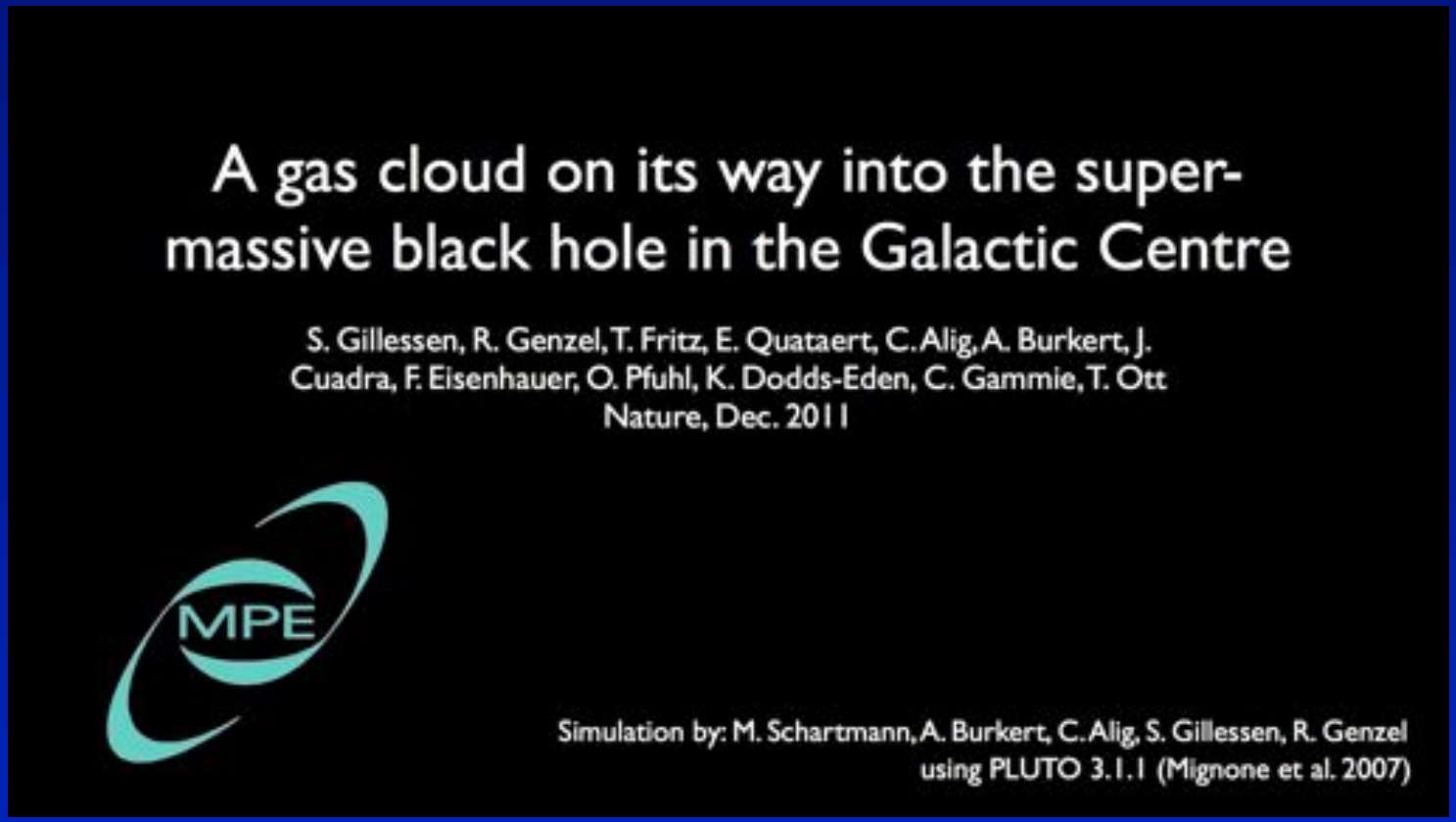
- Integrated Br g maps vs stellar PSF ~21 mas E-W
- Position-velocity maps of Br g emission show head-tail structure; ~62 mas for head
- Tail spread ~200 mas downstream of head
- Velocity gradient ~2 km/s/mas
- 89 (30) km/s in 2003 increased to 350 (40) km/s in 2011

Test Particle Simulation of Tidal Disruption



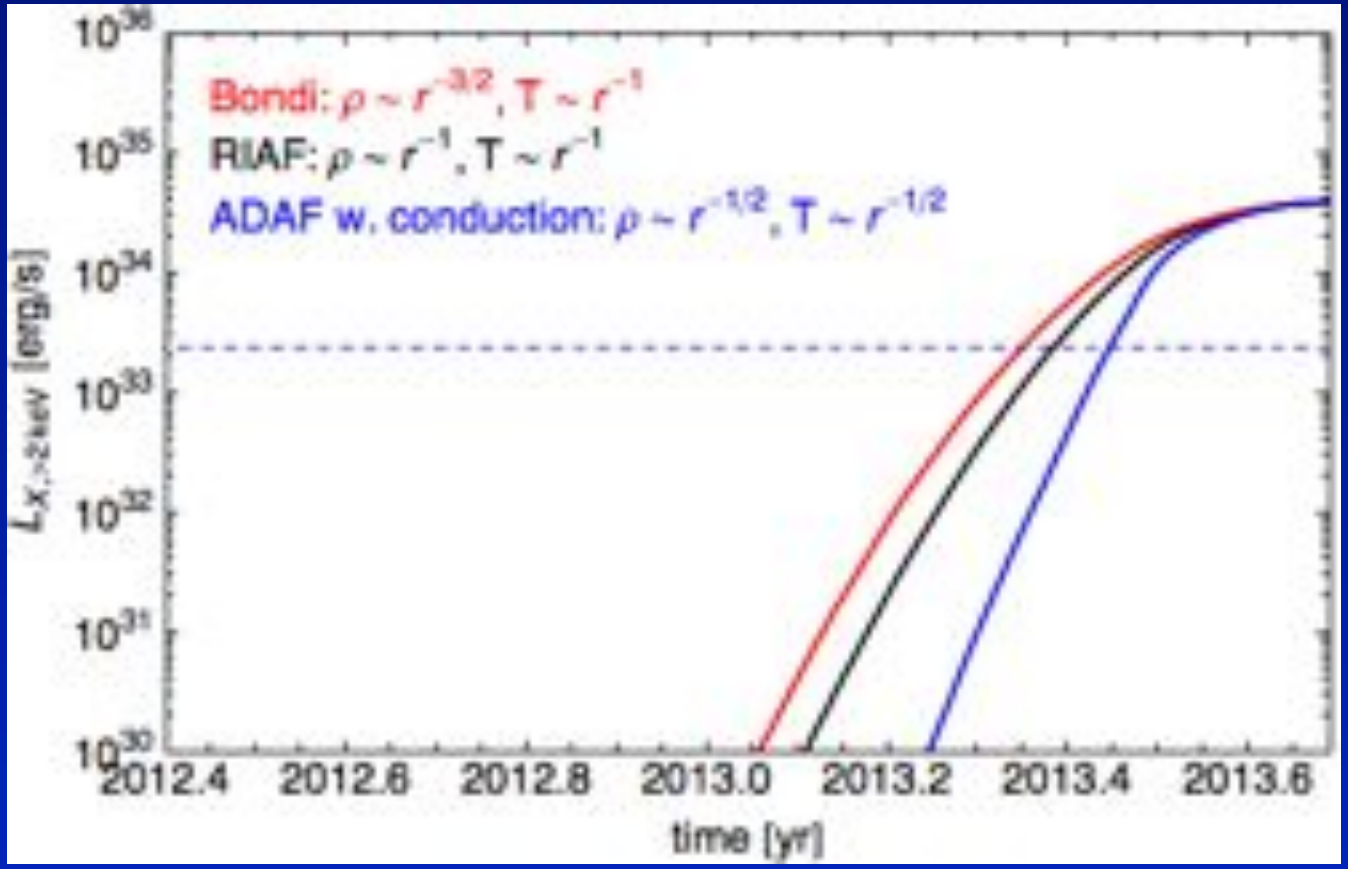
- Panels a-h: evolution of radial velocity and FWHM
- Panels i-p: evolution of velocity change vs position

Close-up on Gas Cloud



R-T & K-H instabilities fragment cloud

X-ray Evolution of Cloud Ploughing through Several Hot Accretion Flow Models



Gas cloud may exceed Sgr A* quiescent luminosity starting Spring 2013

Origin of Cloud?

- Orbital angular momentum vector within 15 deg of clockwise disk of O & WR stars at 1" – 10" from Sgr A*
- Gillessen et al. propose cloud may be a blob from colliding stellar winds in this disk
- Murray-Clay & Loeb (2012) suggest disruption of proto-planetary disk by Sgr A*
- Ghez et al. stuggest dust-enshrouded Be star

Cloud Properties

- $L_{IR} \sim 5\ L_{sun}$; $L_{Br\ g} \sim 2 \times 10^{-3}\ L_{sun}$
- Case B recombination: $n_e \sim 2.6 \times 10^5\ f_v^{-\frac{1}{2}} cm^{-3}$
- Specific angular momentum ~50x less than other clouds
- Current density ~$300 f_v^{-\frac{1}{2}}$x greater than surrounding hot accretion flow; decrease to ~$60 f_v^{-\frac{1}{2}}$x at peribothron

X-ray Emission as Probe of Accretion Flow Profile & BH Feeding

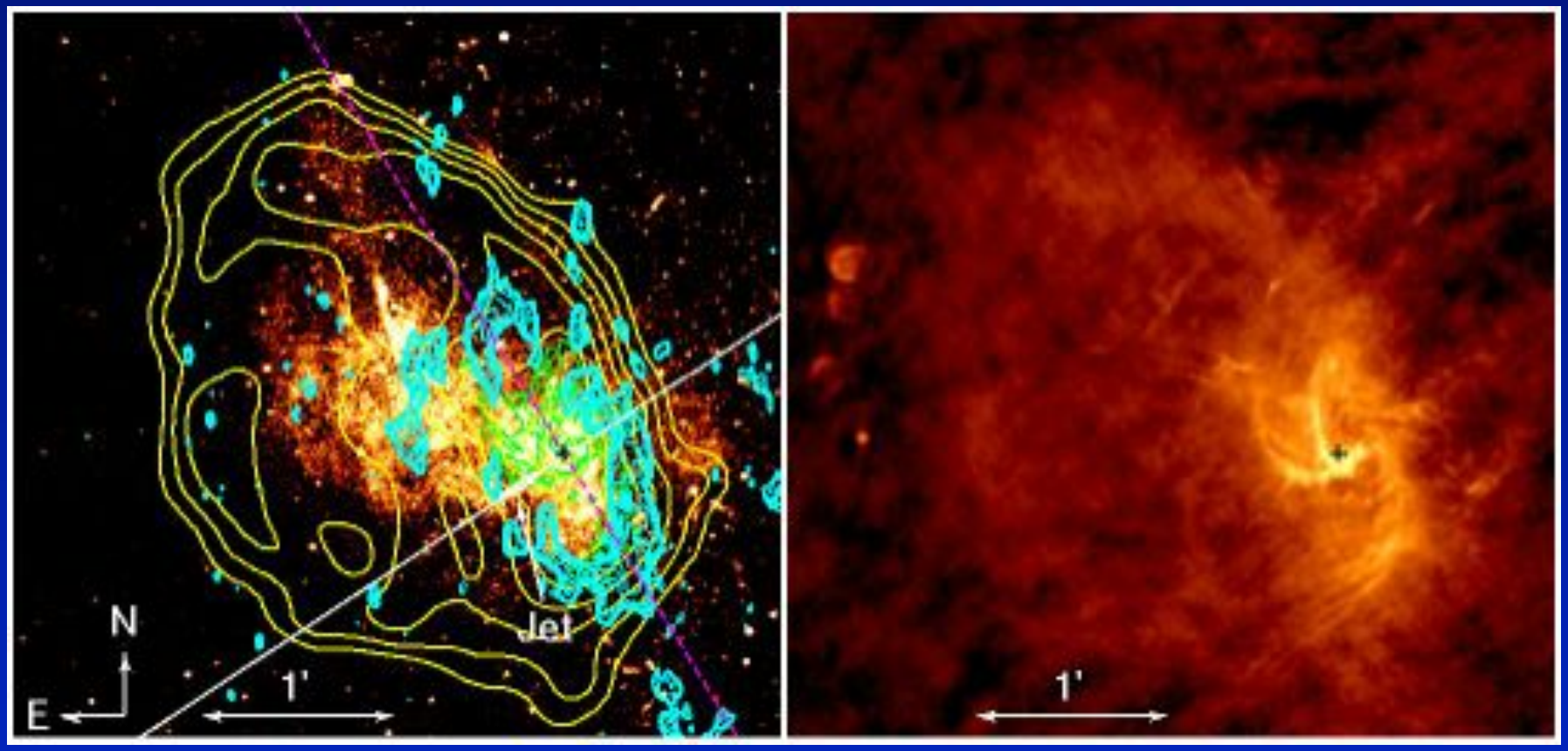
- Cloud remains cold until just before peribothron
- Post-shock T_c ~ 6-10 x 10^6 K
- L_x <~ 10^{34} erg/s (2-8 keV); possibly variable
- Stronger X-ray emission for steeper radial profiles of accretion flow density & temperature and higher f_v
- May release up to 10^{48} erg over decade => <Lx> ~10^{39-40} erg/s
- Sufficient to produce Fe Ka reflection features seen in Galactic Center (e.g., Sgr B2) => possible light echoes from previous clouds accreting onto Sgr A*?

Summary

- X-ray evidence for potential gamma-ray sources in Galactic Center: SNRs, NTFs/Shocks, PWNe & SFRs
- Sgr A* flares now seen by NuSTAR and potentially HESS

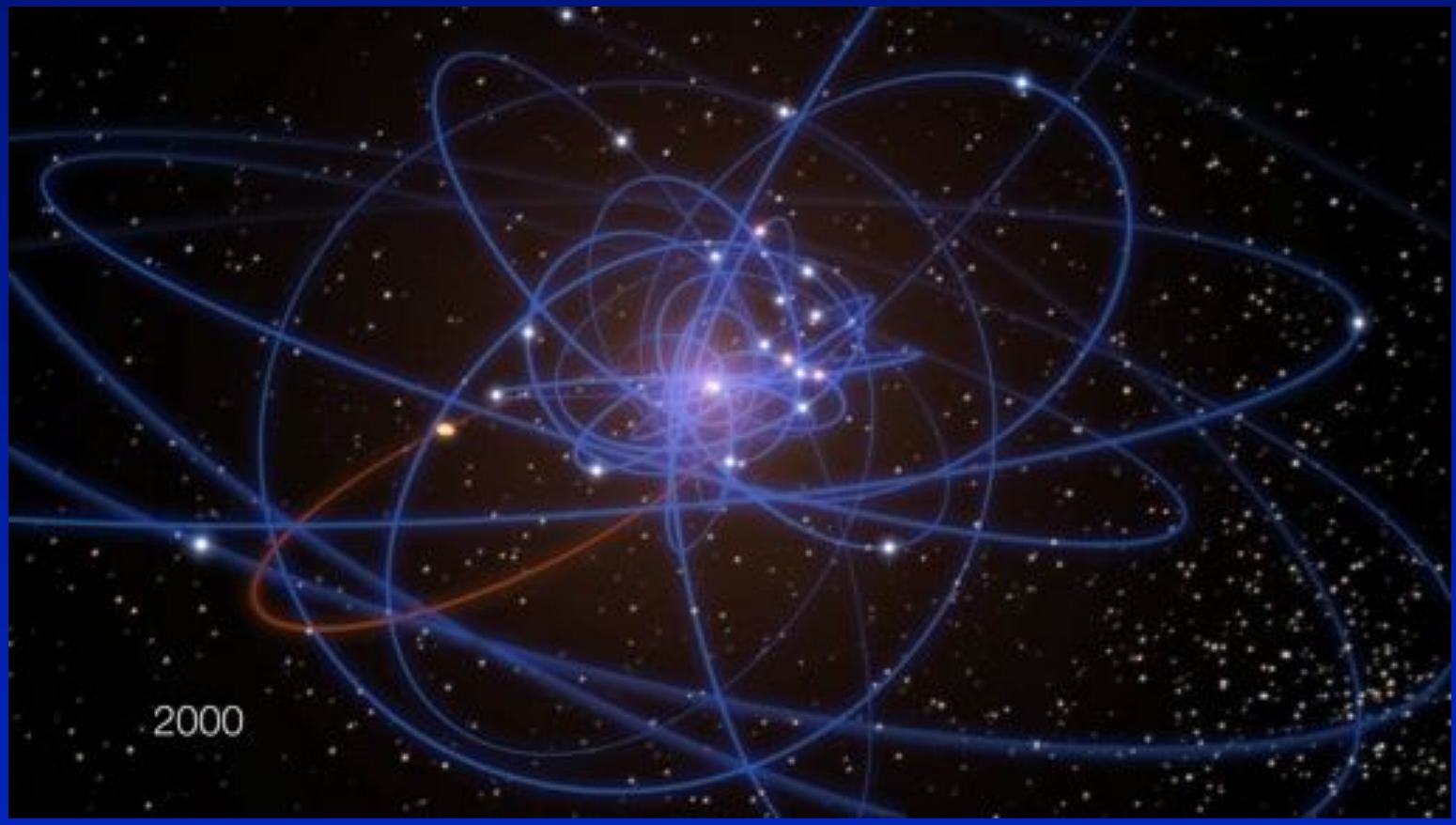
Summary

- Gas cloud approaching Sgr A* on nearly radial orbit
- Shock driven into cloud by passage through accretion flow may produce X-ray emission that can be used to probe the properties of the accretion flow
- Tidal disruption may feed Sgr A*, producing temporary increase in activity for several decades
- Possible gamma-ray source only if jet forms or other exotic mechanism
- Timescale likely years to decades not months as with stars!


N
E
1'
Jet
1'

Galactic Center Pan

Hydrodynamic Simulation of Tidal Disruption



~half of cloud mass accretes onto Sgr A*