HYPERVELOCITY STARS (HVSs)

SOME HVSs HAVE PLANETS, TOO

A MASSIVE BLACK HOLE CAN DISRUPT A BINARY STAR SYSTEM AND CREATE A HVS FROM ONE OF THE BINARY STARS; CAPTURE THE OTHER COMPANION STAR

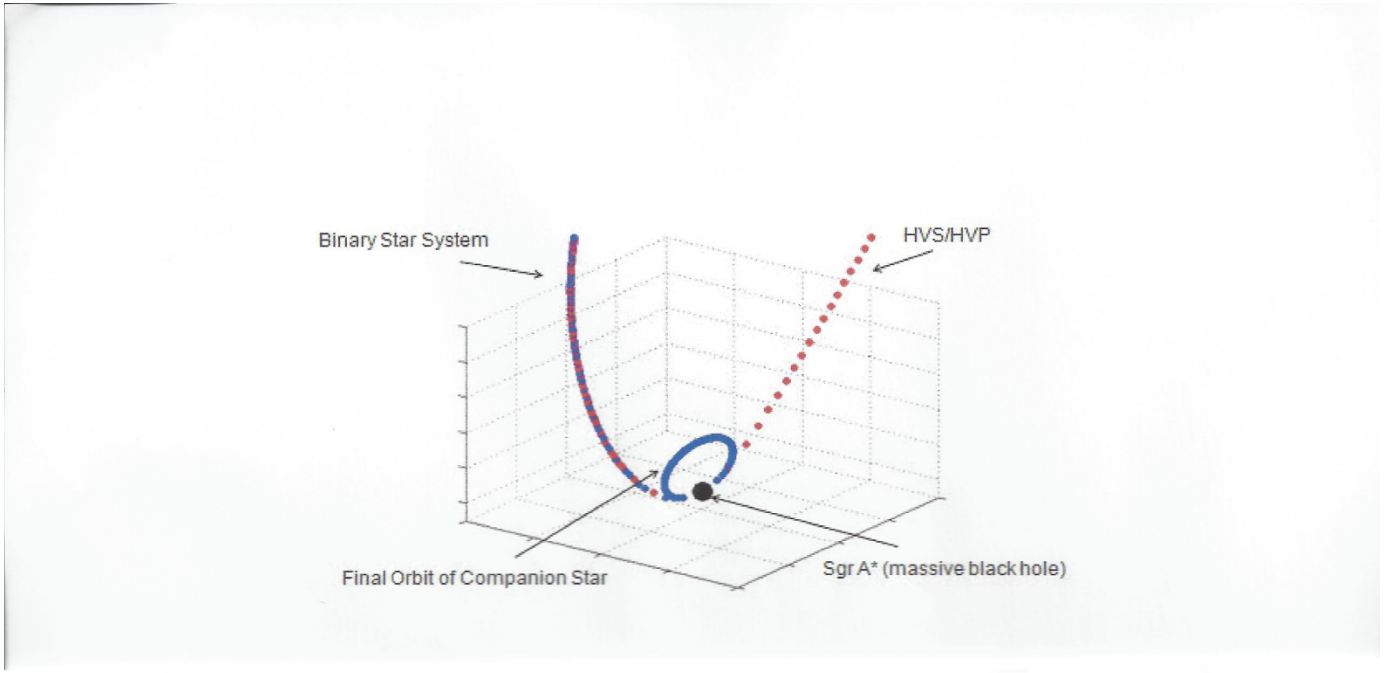
OUTLINE OF TALK

- **BACKGROUND**
- **BASIC THEORY OF THE ORIGIN OF HVSs**
- **SIMULATION RESULTS**
- **SOME SIMPLE CALCULATIONS**
- **WHAT IS THE FATE OF HVSs WITH PLANETS?**
- **WHY I CAN'T PROVE CONSERVATION OF ENERGY**

BACKGROUND

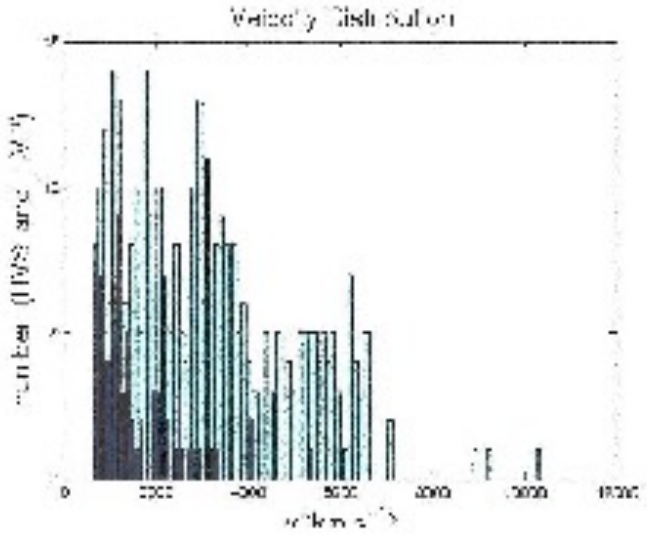
- **WHEN A BINARY STAR SYSTEM APPROACHES A MBH, THE SYSTEM CAN BE TIDALLY DISRUPTED**
- **THINK: *THE ROCHE LIMIT* *and* *TIDAL FORCES***
- **ONE OF THE STARS PICKS UP KINETIC ENERGY+ TO BECOME UNBOUND; SECOND STAR ORBITS MBH**
- **EJECTION SPEEDS OF HVSs CALCULATED TO EXCEED THE ESCAPE VELOCITY OF THE MILKY WAY GALAXY**
- **HVSs SPEEDS CONFIRMED WITH SPECTROSCOPY**

PRODUCTION OF A HYPERVELOCITY STAR



SIMULATION RESULTS

(SAMPLE = 1000)



SIMPLE CALCULATIONS

$V_{esc} = \sqrt{2GM/r}$ ➔ *G = 6.674E-11 m^3/kg/sec^2*

M = 5E11 (2E30),mass MW halo

r = 50 kpc = 50(3.1E19)

Vesc = 292.88 E3 = 293 km/sec

V(HVS1) = spectroscopy ➔ radial velocity = 853 km/sec

V(HVS1) = calculated ➔ v = $\sqrt{V\delta V}$; δv = $\sqrt{Gm*/a}$;

v ~ $\sqrt{GM(bh)/r}$; $\sqrt{v\delta v}$ = 1,000 km/sec

THE FATE OF COMPANIONS TO HVSs?

- **IF A HVS HAS PLANETS, CAN A PLANET STILL ORBIT A HVS?** **SIMULATIONS SHOW UP TO 10% OF PLANETS TIGHTLY ORBITING A HVS COULD STAY BOUND AS THE STAR IS FLUNG OUTWARD.**
- **WHAT HAPPENS TO THE STAR CAPTURED BY THE BLACK HOLE?** **THE FORMER COMPANION STAR TO A HVS IS TYPICALLY KICKED INTO A HIGHLY ECCENTRIC ORBIT AROUND THE BH; WITH SHORT PERIODS OF 36 – 100+ YEARS.**
- **CAN PLANETS BECOME HYPER-V PLANETS?** **YES: EITHER FLUNG OFF THE HVS; OR RIPPED FROM THE COMPANION, CAPTURED STAR (ORBITING THE BLACK HOLE).**

WHY I CAN'T CONCLUSIVELY PROVE CONSERVATION OF ENERGY

- I CAN ROUGHLY ESTIMATE THE CHANGE IN VELOCITY OF THE EJECTED STAR AND THE ASSOCIATED DELTA ENERGY OF THE HVS.
- HOWEVER, THERE IS INSUFFICIENT INFORMATION ON THE RESULTING ORBIT OF THE STAR CAPTURED BY THE BLACK HOLE, FOR GIVEN HVS.
- BOTH THE EJECTION SPEED OF THE HVS AND THE SIZE/ PERIOD OF THE CAPTURED STAR ARE HIGHLY DEPENDENT ON ORIENTATION OF THE BINARY WHEN IT GETS DISRUPTED, AS WELL BINARY SEPARATION.
- SIMULATION IS REALLY A BETTER TOOL!