Keck observations of G2 and SgrA*

for the
UCLA Galactic Center Group
Leo Meyer

Andrea Ghez, Tuan Do, Gunther Witzel, Breann Sitarski, Mark Morris, Anna Boehle, Jessica Lu, Sylvana Yelda, Kim Phifer, Eric Becklin

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The story so far…

G2 is an intriguing source:

- Very red
- Line emission with an evolving FWHM
- Shows gas that seems to be tidally interacting with the BH
- Is on a highly eccentric orbit and passing the BH in early 2014

Many things are uncertain and under intense discussion:

- How much gas is there?
- Is this a compact gas cloud (how could it have survived?) or is it stellar in nature (which seems more natural)?
- Will it have any observable impact on SgrA*’s emission?
And now come the 2013 data …

… and it changes …

… nothing!
Kinematics
Constructing a self-consistent orbit

Two important points:

• Use the Br-Gamma emission for BOTH radial velocities and proper motions

• Use consistently our well-calibrated K’ reference frame, in which we derive the parameters of the gravitational potential \((M_{\text{BH}}, R_0, X_0, Y_0, \text{Vel}_X, \text{Vel}_Y, \text{Vel}_Z)\)
Updated Br-Gamma based orbit

Purely Keplerian orbit!
Updated Br-Gamma based orbit
Comparison of Br-Gamma orbits

<table>
<thead>
<tr>
<th></th>
<th>UCLA 2012</th>
<th>MPE 2013</th>
<th>UCLA 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>ecc</td>
<td>$0.981 \pm 0.006$</td>
<td>$0.970 \pm 0.003$</td>
<td>$0.965 \pm 0.011$</td>
</tr>
<tr>
<td>Incl [deg]</td>
<td>$121 \pm 3$</td>
<td>$118 \pm 2$</td>
<td>$113 \pm 3$</td>
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<tr>
<td>$\Omega$ [deg]</td>
<td>$56 \pm 11$</td>
<td>$82 \pm 4$</td>
<td>$77 \pm 10$</td>
</tr>
<tr>
<td>$\omega$ [deg]</td>
<td>$88 \pm 6$</td>
<td>$97 \pm 2$</td>
<td>$92 \pm 4$</td>
</tr>
<tr>
<td>$T_0$ [yr]</td>
<td>$2014.21 \pm 0.14$</td>
<td>$2014.25 \pm 0.06$</td>
<td>$2014.21 \pm 0.13$</td>
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<tr>
<td>P [yrs]</td>
<td>$276 \pm 111$</td>
<td>$391 \pm 66$</td>
<td>$264 \pm 139$</td>
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Phifer et al. 2013  Gillessen et al. 2013b
G2 and gas features
A tail of G2?
(is not on the orbit)
A tail of G2?
(is not on the orbit)

Phifer et al. 2013
A blue-shifted head?
(is not on the orbit)

Preliminary!

~ -2,500 km/s

July+August 2013
G2 is not unique!
Red emission-line sources in the GC

SgrA* G1 G2 2 3

Gunther Witzel
Red emission-line sources in the GC

Tuan Do & Breann Sitarski
Assessing possible changes in SgrA*’s variability
## Sgr A* in 2013

<table>
<thead>
<tr>
<th>Date</th>
<th>Sgr A* Kp Magnitude</th>
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<tbody>
<tr>
<td>2011 May</td>
<td>16.1</td>
</tr>
<tr>
<td>2012 July</td>
<td>16.5</td>
</tr>
<tr>
<td>2013 April</td>
<td>16.8</td>
</tr>
<tr>
<td>2013 July</td>
<td>&gt; 17</td>
</tr>
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</table>
Important to infer IF and WHEN SgrA*'s variability characteristics changed

Will G2 trigger a distinct new variability state of SgrA* and if so when did the transition occur?

Statistical methodology needed!

Idea of state changed for SgrA* brought forward by Dodds-Eden et al. 2010 (but see Witzel et al. 2012), however no timing information was used.

We have developed a methodology that fully incorporates timing information! -> Hidden Markov Model

Meyer et al., basically done 😊
In the past SgrA* itself had only one state

However, our algorithm finds a noise-dominated and a source-dominated state in the measurements

We are ready and excited to see if G2 causes a change in behavior intrinsic to SgrA*
Conclusions

- G2’s motion is sufficiently described by a Keplerian orbit
- The “tail” and blue-shifted “head” might be independent gas structures
- There are plenty of G2-like sources around
- The impact on SgrA*’s emission might be very subtle and advanced statistics is needed and has been developed
There is no K' counterpart to G2 down to $K_{\text{mag}} = 20$. 

K' image, t=2010
New K’ limit of 20 mag
Gas structures are abundant at the Galactic center

OSIRIS data cube near Br gamma (2.1661 μm)